

# *Use Cases in Big Data Software and Analytics*

Vol. 1, Fall 2017

---

*Bloomington, Indiana*

Tuesday 12<sup>th</sup> December, 2017, 20:04

Editor:  
Gregor von Laszewski  
Department of Intelligent Systems  
Engineering  
Indiana University  
laszewski@gmail.com

# Contents

<b>1 Preface</b>	<b>7</b>
1.1 Disclaimer . . . . .	7
1.2 Citation . . . . .	7
1.3 List of Papers . . . . .	8
<b>2 Biology</b>	<b>11</b>
<b>3 Business</b>	<b>11</b>
4 hid202	Status: Dec 04 17 100%
Big Data Analysis in E-Commerce	
Himani Bhatt, Mrunal Chaudhary . . . . .	11
5 hid229	Status: 100%; 12/4/2017
Big Data Analytics in Product Development Management	
ZhiCheng Zhu . . . . .	46
6 hid233	Status: Dec 11 17 100%
Big Data in Safe Driver Prediction	
Wang, Jiaan, Chaturvedi, Dhawal . . . . .	66
7 hid234	Status: 100% Dec 07 17
Big Data Analytics and Applications in the Travel Industry and its Potential in Improving Travel Accessibility	
Weixuan Wang . . . . .	80
8 hid235	Status: unkown
Big Data analytics in predict house price	
Yujie Wu . . . . .	96
9 hid301	Status: 100% 12/2/2017
Importance of Big data in predicting stock price	
Gagan Arora . . . . .	107
10 hid306	Status: 98%; 12/10/2017
Predicting Housing Prices	
Murali Cheruvu, Anand Sriramulu . . . . .	120
11 hid320	Status: 100% Dec 03 2017
Big Data Applications in Real Estate Analysis	
Elena Kirzhner . . . . .	159
12 hid324	Status: Dec 04 17 100%
Big Data Analytics in factors affecting Bitcoin	
Ashok Kuppuraj . . . . .	185

13 hid328	Status: Dec 4 17 100%	
Predicting Profitable Customers in Banking Industry		
Dhanya Mathew . . . . .	213	
14 hid329	Status: 100% Dec 4	
Big Data and The Customer Experience Journey		
Ashley Miller . . . . .	234	
<b>4 Edge Computing</b>	<b>256</b>	
15 hid201	Status: 100%	
IoT Application Using MQTT and Raspberry Pi Robot Car		
Arnav, Arnav . . . . .	256	
16 hid316	Status: 100%	
Big Data and Edge Analytics in Weather Monitoring and Forecasting		
Robert Gasiewicz . . . . .	269	
17 hid319	Status: 100%	
Face Detection and Recognition Using Raspberry Pi Robot Car		
Mani Kumar Kagita . . . . .	286	
18 hid334	Status: Dec 04 17 100%	
The Intersection of Big Data and IoT		
Peter Russell . . . . .	307	
<b>5 Education</b>	<b>319</b>	
19 hid236	Status: Dec 4 17 - 100%	
Big Data and Its Application in Education		
Weipeng Yang, Geng Niu . . . . .	319	
<b>6 Energy</b>	<b>341</b>	
<b>7 Environment</b>	<b>341</b>	
20 hid330	Status: 100%	
Big Data Analytics in Monitoring Outdoor Air Quality		
Janaki Mudvari Khatiwada . . . . .	341	
21 hid345	Status: 100%	
Agricultural Data Science		
Ross Wood . . . . .	368	
22 hid346	Status: Dec 08 17 100%	
Big Data Analysis for Wild File Prevention and Tracking		
Zachary Meier . . . . .	387	
<b>8 Government</b>	<b>394</b>	
23 hid310	Status: Dec 04 17 100%	
Gerrymandering Detection Using Data Analysis		
Kevin Duffy . . . . .	394	
<b>9 Health</b>	<b>416</b>	

24 hid212	Status: Dec 04 17 100%
Can Blockchain Adoption Mitigate the Opioid Crisis Through More Secure Drug Distribution?	
Kumar, Saurabh; Schwartzer, Matthew; Hotz, Nicholas . . . . .	416
25 hid232	Status: 100%
Big Data and Hearing Disabilities	
Rahul Velayutham . . . . .	437
26 hid237	Status: 100%, Dec 7, 2017
Analyzing everyday challenges of people with visual impairments	
Tousif Ahmed . . . . .	466
27 hid311	Status: 100%
Big Data in Genomics and Medicine	
Matthew Durbin . . . . .	494
28 hid312	Status: 99%
Big Data Mental Health Monitoring - A Private and Independent Approach	
Neil Eliason . . . . .	508
29 hid313	Status: 100%
The Impact of Clinical Trial Results on Pharmaceutical Stock Performance	
Tiffany Fabianac . . . . .	520
30 hid327	Status: 100% 12/05/17
How Big Data Will Help Improve People's Health Worldwide	
Paul Marks . . . . .	537
31 hid331	Status: Dec 4 17 100%
Big Data Applications in Predicting Hospital Readmissions	
Tyler Peterson . . . . .	553
32 hid332	Status: 100%
Big Data Analytics to Reduce Health Care in the United States	
Judy Phillips . . . . .	570
33 hid335	Status: 100%
Using Machine Learning Classification of Opioid Addiction for Big Data Health Analytics	
Sean Shiverick . . . . .	584
34 hid337	Status: Dec 04 17 100%
IoT and Big Data Analytics for Equipment Predictive Health Management (PHM)	
Ashok Reddy Singam, Anil Ravi . . . . .	616
35 hid348	Status: 100%
Big Data Application in Precision Medicine and Pharmacogenomicsn	
Budhaditya Roy . . . . .	635
<b>10 Lifestyle</b>	<b>660</b>
36 hid109	Status: 100% Dec 4th
Diversification of Big Data	
Shiqi Shen, Qiaoyi Liu . . . . .	660
37 hid231	Status: 100% Dec 4, 2017
Big Data Analytics on Food Products Around the World	
Vegi, Karthik, Chandwani, Nisha . . . . .	685

38	hid302	Recipe Ingredients Analysis Sushant Athaley	Status: 100% 711
39	hid347	Killings by Police in the United States Jeramy Townsley	Status: Nov 29 17 100% 753
<b>11</b>	<b>Machine Learning</b>		<b>786</b>
40	hid209	Analysis of Digit Recognizer classification algorithms in big data Han, Wenxuan, Liu, Yuchen, Lu, Junjie	Status: Dec 04 17 100% 786
41	hid343	Income Prediction Using Machine Learning Techniques Borga Edionse Usifo	Status: 100 % 810
<b>12</b>	<b>Media</b>		<b>837</b>
42	hid215	Big Data Analytics on Influencers in Social Networks Mallala, Bharat, Jyothi Pranavi Devineni	Status: Dec 04 17 100% 837
43	hid340	New Approaches to Managing Metadata at Scale in Research Libraries Timothy A. Thompson	Status: Dec 7 17 66% 856
<b>13</b>	<b>Physics</b>		<b>861</b>
44	hid304	How Far have Space Walks Walked Ricky Alan Carmickle	Status: Dec 04 17 100% 861
<b>14</b>	<b>Security</b>		<b>861</b>
45	hid224	Big Data Analytics in Detection of DDoS (Distributed Denial-of-Service) attacks Rawat, Neha	Status: Dec 04 17 100% 861
<b>15</b>	<b>Sports</b>		<b>878</b>
46	hid105	Predictive Model For English Premier League Games Lipe-Melton, Josh	Status: Dec 05 17 100% 878
47	hid228	Big data applications in Indian Premier League Swargam, Prashanth	Status: Dec 04 17 100% 889
48	hid315	TBI - A Data Driven Journey Beyond Contact Sports... Putting Data In The Drivers Seat Garner, Jeffry	Status: 80% - finishing up .txt 906
<b>16</b>	<b>Technology</b>		<b>924</b>

49 hid107	Status: Dec 08 0600 100%
Big Data Analytics in Support Filtering Wrong Informations On Social Networking Sites	
Ni,Juan . . . . .	924
50 hid308	Status: 0%
TBD	
Pravin Deshmukh . . . . .	946
51 hid325	Status: 100%
The importance of data sharing and replication, but what about data archiving?	
J. Robert Langlois . . . . .	946
<b>17 Text</b>	<b>970</b>
<b>18 Theory</b>	<b>970</b>
<b>19 Transportation</b>	<b>970</b>
52 hid211	Status: Dec 5 2017 100%
Continuous motion tracking using Deep Neural Networks and Recurrent Neural Networks	
Khamkar, Ajinkya . . . . .	970
<b>20 TBD</b>	<b>989</b>
53 hid323	Status: Dec 04 17 0%
None	
Uma M Kugan . . . . .	989
54 hid326	Status: unkown
None	
Mohan Mahendrakar . . . . .	1003
55 hid341	Status: 0%
Not submitted	
Tibenkana, Jacob . . . . .	1003
56 hid342	Status: 0%
TBD	
Nsikan Udoen . . . . .	1003

# Chapter 1

## Preface

### 1.1 Disclaimer

The papers provided are contributed by students of the i523 class thought at Indiana University in Fall of 2017. The students were educated in plagiarizm and we hope that all papers meet the high standrads provided by the policies set at Indiana University in regards to plagiarizm. In case you notice any issues, please contact Gregor von Laszewski (laszewski@gmail.com) so we cn address the issue with the student.

### 1.2 Citation

The proceedings is at this time available as a draft. To cite this proceedings you can use the following citation entry:

```
@Book{las17-i523,
  editor = {Gregor von Laszewski},
  title = {Use Cases in Big Data Software and Analytics},
  publisher = {Indiana University},
  year = {2017},
  volume = {1},
  series = {i523},
  address = {Bloomington, IN},
  edition = {1},
  month = dec,
  url={https://github.com/laszewski/laszewski.github.io/raw/master/papers/vonLaszewski-i
}
```

Contributors to the volume can cite their contribution as follows. They just need to *FILLIN* the missing information

```
@InBook{las17-,
```

```

author =      {FILLIN},
editor =     {Gregor von Laszewski},
title =       {Use Cases in Big Data Software and Analytics},
chapter =    {FILLIN},
publisher =   {Indiana University},
year =        {2017},
volume =     {1},
series =     {i523},
address =    {Bloomington, IN},
edition =    {1},
month =      dec,
url={https://github.com/laszewski/laszewski.github.io/raw/master/papers/vonLaszewski-i
pages =      {FILLIN},
}

```

## 1.3 List of Papers

HID	Author	Title
101, 230	Huiyi Chen, Yuanming Huang	Big Data in Job Recommendation Systems
102	Dianprakasa, Arif	TBD
105	Lipe-Melton, Josh	Predictive Model For English Premier League Games
107	Ni,Juan	Big Data Analytics in Support Filtering Wrong Informations On Social Networking Sites
109, 106	Shiqi Shen, Qiaoyi Liu	Diversification of Big Data
201	Arnav, Arnav	IoT Application Using MQTT and Raspberry Pi Robot Car
202, 205	Himani Bhatt, Mrunal Chaudhary	Big Data Analysis in E-Commerce
209, 213, 214	Han, Wenxuan, Liu, Yuchen, Lu, Junjie	Analysis of Digit Recognizer classification algorithms in big data
211	Khamkar, Ajinkya	Continuous motion tracking using Deep Neural Networks and Recurrent Neural Networks
212, 225, 210	Kumar, Saurabh; Schwartzer, Matthew; Hotz, Nicholas	Can Blockchain Adoption Mitigate the Opioid Crisis Through More Secure Drug Distribution?
215, 208	Mallala, Bharat, Jyothi Pranavi Devineni	Big Data Analytics on Influencers in Social Networks
219	Syam Sundar Herle	Unsupervised Learning for detecting fake online reviews
224	Rawat, Neha	Big Data Analytics in Detection of DDoS (Distributed Denial-of-Service) attacks
228	Swargam, Prashanth	Big data applications in Indian Premier League
229	ZhiCheng Zhu	Big Data Analytics in Product Development Management
231, 203	Vegi, Karthik, Chandwani, Nisha	Big Data Analytics on Food Products Around the World
232	Rahul Velayutham	Big Data and Hearing Disabilities

233, 204	Wang, Jiaan, Dhawal	Chaturvedi,	Big Data in Safe Driver Prediction
234	Weixuan Wang		Big Data Analytics and Applications in the Travel Industry and its Potential in Improving Travel Accessibility
235	Yujie Wu		Big Data analytics in predict house price
236, 218	Weipeng Yang, Geng Niu		Big Data and Its Application in Education
237	Tousif Ahmed		Analyzing everyday challenges of people with visual impairments
301	Gagan Arora		Importance of Big data in predicting stock price
302	Sushant Athaley		Recipe Ingredients Analysis
304	Ricky Alan Carmickle		How Far have Space Walks Walked
hid305	error: yaml		How Far have Space Walks Walked
306, 338	Murali Cheruvu, Anand Sriramulu		Predicting Housing Prices
308	Pravin Deshmukh	TBD	
hid309	error: yaml	TBD	
310	Kevin Duffy		Gerrymandering Detection Using Data Analysis
311	Matthew Durbin		Big Data in Genomics and Medicine
312	Neil Eliason		Big Data Mental Health Monitoring - A Private and Independent Approach
313	Tiffany Fabianac		The Impact of Clinical Trial Results on Pharmaceutical Stock Performance
314	Sarang Fadnavis	TBD	
315	Garner, Jeffry		TBI - A Data Driven Journey Beyond Contact Sports... Putting Data In The Drivers Seat
316	Robert Gasiewicz		Big Data and Edge Analytics in Weather Monitoring and Forecasting
318	Irey, Ryan	None	
319	Mani Kumar Kagita		Face Detection and Recognition Using Raspberry Pi Robot Car
320	Elena Kirzhner		Big Data Applications in Real Estate Analysis
323	Uma M Kugan	None	
324	Ashok Kuppuraj		Big Data Analytics in factors affecting Bitcoin
325	J. Robert Langlois		The importance of data sharing and replication, but what about data archiving?
326	Mohan Mahendrakar	None	
327	Paul Marks		How Big Data Will Help Improve People's Health Worldwide
328	Dhanya Mathew		Predicting Profitable Customers in Banking Industry
329	Ashley Miller		Big Data and The Customer Experience Journey
330	Janaki Mudvari Khatiwada		Big Data Analytics in Monitoring Outdoor Air Quality
331	Tyler Peterson		Big Data Applications in Predicting Hospital Readmissions
332	Judy Phillips		Big Data Analytics to Reduce Health Care in the United States
334	Peter Russell		The Intersection of Big Data and IoT
335	Sean Shiverick		Using Machine Learning Classification of Opioid Addiction for Big Data Health Analytics
336	Jordan Simmons	None	
337, 333	Ashok Reddy Singam, Anil Ravi		IoT and Big Data Analytics for Equipment Predictive Health Management (PHM)
339	Hady Sylla		Diagnosis of Coronary Artery Disease Using Big Data Analysis

340	Timothy A. Thompson	New Approaches to Managing Metadata at Scale in Research Libraries
341	Tibenkana, Jacob	Not submitted
342	Nsikan Udoyen	TBD
343	Borga Edionse Usifo	Income Prediction Using Machine Learning Techniques
345	Ross Wood	Agricultural Data Science
346	Zachary Meier	Big Data Analysis for Wild File Prevention and Tracking
347	Jeramy Townsley	Killings by Police in the United States
348	Budhaditya Roy	Big Data Application in Precision Medicine and Pharmacogenomicsn

# Big Data Analytics in E-commerce

Himani Bhatt, Mrunal L Chaudhary

Indiana University

Bloomington, Indiana

himbhatt@iu.edu,mchaudh@iu.edu

## ABSTRACT

Humongous amounts of data gets generated every day in the domain of E-commerce industry. With the increasing competition and ever-changing market trends, it is a challenging task for the store owners to strategize business and marketing activities. If the companies are able to predict customer behavior, they can come up with business designs which can help them in making predictions about the customer purchasing patterns and thereby increase their revenue. In this project we have aimed to do analysis on the data of an E-commerce non-store online retail giant based in UK. The dataset, available in the UC Irvine repository by the name of 'Online Retail', consists of the goods purchased by different customers at a given time. Through this data available to us, we have done customer segmentation on the basis of the type and amount of goods purchased by a customer. We achieved this by doing a thorough exploration of the data, data pre-processing and then running different Machine Learning Classifiers to classify the customers in different categories.

## KEYWORDS

HID 202, HID 205, i523, Machine Learning, Analysis, E-commerce, retail, Customer Segmentation, Python, Regression, Boosting, KNN, Random Forest.

## 1 INTRODUCTION

The E-commerce industry is in constant shifts due to the ever-increasing changes in the technologies used to develop and maintain the E-commerce systems, the services that they are willing to offer, the market strategies which gain popularity at the time, and most importantly- the customer behavior [3]. The online store owners are the ones who are most affected by these changes. And since the competition in the field of E-commerce is fierce, the online store owners need to come up with business strategies and technologies which provide better customer services leading to their satisfaction and earning customer loyalty. To achieve this, they need to address these ever changing issues to survive and thrive in the E-commerce market and come up with better decisions faster. The key to achieving this lies in better understanding of the customer behavior and their purchasing patterns. That is where analytics comes into play. Analysis of customer behavior and purchasing patterns helps in devising better and accurate marketing strategies which can not only help in generating more profits but also in saving both time and efforts that goes into trying and testing different marketing activities [3]. This ability to capture and analyze user data, and then provide useful and in depth insights in it is what Machine Learning empowers us with. In this project, we aim to do analysis on a data set 'Online Retail' from the UC Irvine Machine Learning Repository to determine the customer purchasing pattern by using

different machine Learning algorithms like K-Means Clustering, Logistic Regression, Random Forest, Gradient Boosting, etc.

## 2 BACKGROUND

Before the advent of the World Wide Web, transactions that happened on a day to day basis meant physical presence of customers, the brick-and-mortar setting of a store which offered a limited variety of goods. With the evolution of internet and its application in retail, the field of E-commerce emerged and changed the entire facet of shopping. Since a proper set-up of a store is no longer needed, customers can buy goods at much lower prices, with a wider variety to choose from and that too without the need of physical presence. The online market is expected to grow by almost 56% from the year 2015 to 2020 [16]. In the United States alone, 56% of the population prefers to shop online. The E-commerce industry is growing at an average rate of 23% every year, with 90% of the Americans having done online shopping at some point in their lives [15]. With so many transactions happening over the internet, naturally the amount of data getting generated is humongous. Also, with the constantly changing market trends, strategies to overcome the competition and make profits need to be constantly improved. The key issues therefore are managing the data and drawing insights from them which will help in bettering the business decisions. To store and maintain the magnanimous amounts of data getting generated *everyday* is a huge hassle, because along with the volume, this data gets generated at a break neck speed and in different formats from traditional numeric databases to unstructured text documents [12]. The big data technologies like Hadoop and Spark can be used in addressing these hurdles, namely the volume, velocity and variety.

### 2.1 The Three V's of E-commerce Big Data

Like other technologies which deal with a humongous amount of data, E-commerce must also respond to the 3 Vs, namely Volume, Velocity and Variety:

**Volume** Thousand of online transactions happen every day making the data generation a real time process. The integration of Big Data involves collection of relevant data like customer behavior statistics on the basis of their searches, transactions, demography, etc. The challenge here is not only gathering the data but also in analyzing it.

**Variety** The data from online transactions comes in different varieties, right from structured databases to unstructured text documents, videos, feedback emails and comments, and others. The retailers need to understand this for making the right business decisions by keeping a leeway for possible data fluctuations such as seasonal ad peak loads like Black Friday sales.

**Velocity** Handling the huge amounts of data which is generated at unprecedented rates is another challenge that needs to be taken care of. It is therefore imperative to do rapid analysis so that timely actions can be taken to sustain in the competition and boost the profit margins

Storing and maintaining the big data is a hassle in itself, but it will provide little value if proper analysis is not done on it. That is where we will be focusing on in this project - making sense of the data. Hence for the scope of this project, we have performed analysis on a small data set of around 45 MB. Machine Learning Algorithms learn from the data. Since we will be using Machine Learning Algorithms, the accuracy of Analysis will only increase with increase in the size of the dataset. We will be discussing this in further detail in the coming sections.

We have now established the fact that the E-commerce companies have a lot of data at their fingertips. Making use of this data is where the challenge lies. Machine learning is an approach by which insights can be drawn from digital data at a rate much faster than any human is capable of doing [7]. Following are some of the biggest challenges that are faced in the field of E-commerce which Machine Learning addresses successfully:

(1) Optimization of the Prices:

Pricing, and in that, online pricing is critically important. Since prices of the competitors are only a few clicks away, it is far easier for the customers to compare prices. Setting up the optimum price, by considering many factors like the prices set by the competitors, the time of the day, the type of the customer and the product's demand therefore is a difficult task. Machine Learning technology can set the prices by considering all these factors at once.

(2) Fraud detection:

The E-commerce industry, like the other industries, is susceptible to fraudulent activities. The consequences of these activities can lead to tarnishing the name of the company forever. Machine Learning helps in detecting and preventing the frauds by processing the repetitive data at a high speed.

(3) Search Ranking:

Machine Learning is capable of pulling information from patterns of search and purchase by considering the factors like preferences, content and search items and come up with a powerful search engine that shows what the customer exactly wants.

(4) Product Recommendations:

Machine Learning is capable of effortlessly quantifying the buying patterns of the customers and developing a recommendation engine which makes relevant product suggestions to them.

(5) Customer Segmentation and Personalization:

In any business, Customer base is the most important factor and therefore providing a satisfactory customer experience is of utmost importance. The biggest challenge that E-commerce systems endeavor to overcome is the separation from their customers. In person, a salesperson can quickly take in what the customers are saying, their economic status, their body language, and behavior to help them find better or desired products. The salesperson thus is able to *segment* customers, and provide them with a *personalized* shopping experience. With online shopping, it is very difficult to make this happen since an in depth understanding is needed of the vast amount of the data to provide tailored choices to the customers,

which can result in sale loss.

Machine Learning makes the biggest impact by making it possible to give personalized customer experiences which can boost the sales and thereby increase the revenue.

The type of analysis and Machine Learning Algorithm to be chosen depends solely on the data at hand. The data set we aim to analyze is a transnational data set that has been archived in the UC Irvine Machine Learning Repository under the name 'Online Retail'.

A thorough Exploratory Data Analysis on this data lets us know what kind of Machine Learning Algorithm needs to be used. Also, several models can be applied and the one which gives the best accuracy and precision against the test data can be chosen. To add icing to the cake, we can even combine the results given by the different models to make an ensemble model which gives an accuracy that is better than that of the individual algorithms. Machine Learning Algorithms are mostly classified as supervised and unsupervised Learning algorithms.

In Supervised Learning, each example is a pair of an input object and the corresponding output value, also called the supervisory signal. A supervised learning algorithm analyzed the training data to produce an inferred function which is used to map new, unknown output-value examples [8]. Since there is the output value to *supervise* the learning algorithm, such approach is called 'Supervised Learning'. The most commonly used Supervised Learning Algorithms are Logistic and Linear Regression, Bagging and Boosting Algorithms, Decision Trees and Random Forest. The Logistic Regression algorithm determines the relationship between the input and the output variables and generates a classifier model to predict the category to which a new example belongs to. Thus Logistic Regression is a classification algorithm [2]. Decision Trees are non parametric Supervised Learning Algorithms which create a model by learning simple decision rules inferred from data attributes to predict the value of a target variable. Decision Trees can be used either for Classification or Regression [5]. Bagging is a technique used to reduce the variance in the predictions by combining the result of multiple classifiers modeled on different sub-samples of the same data set. One of the most commonly and widely used implementation of Bagging is Random Forests. In Random forest, there are multiple trees which classify a new sample based on the set of attributes and a new sample is classified to that class which received the maximum 'votes' from the individual trees. In case of doing Regression with the help of Random Forest, the average of the outputs given by different trees is taken [10].

In Unsupervised learning, only the input data is known with no knowledge of the corresponding output variable. The goal therefore of the Unsupervised Learning Algorithms is to model the underlying distribution or structure in the data to understand the data more. Since there is no output available to validate or 'supervise' the answers, such learning algorithms are called Unsupervised. The most common application of unsupervised learning is clustering. Clustering enables to differentiate the data by discovering the inherent groupings of the input. The most common implementation of Clustering is the K-means algorithm. This algorithm works iteratively to assign each data point to one of the k-groups based on the feature similarity.

### 3 EXPLORING THE DATASET

The dataset taken for the analysis is the ‘Online Retail’ data set available on the UCI Machine Learning Repository. This is a transnational dataset which contains all the transactions occurring between 01/12/2010 and 09/12/2011 for a UK-based and registered non store online retail. The company mainly sells unique all-occasion gifts. Many customers of the company are wholesalers.

Data set consists of 5,41,909 transactions and 8 features which describe each of these transactions. There are missing values present in the dataset. All the attributes are integer and real numbers. The size of the dataset is 43.4 MB.

#### 3.1 Attribute Information

**InvoiceNo** : This refers to the Invoice number. It is a Nominal, 6-digit integral number uniquely assigned to each transaction. If this code starts with letter ‘c’, it indicates a cancellation.

**StockCode** : This refers to the Product (item) code. It is a Nominal, 5-digit integral number uniquely assigned to each distinct product.

**Description** : This refers to the Product (item) name. It is of Nominal data type.

**Quantity** : This refers to the The quantities of each product (item) per transaction. It is Numeric in type.

**InvoiceDate** : This refers to the Invoice Date and time. It is Numeric, and represents the day and time when each transaction was generated.

**UnitPrice** : This refers to the Unit price. It is of Numeric type, and represent the Product price per unit in sterling.

**customerID** : This refers to the Customer number. It i a Nominal, 5-digit integral number uniquely assigned to each customer.

**Country** : This refers to the Country name. It is of Nominal type, and represents the name of the country where each customer resides.

## 4 DATA PREPARATION

### 4.1 Installation Steps

The project has been implemented in Python 2.7 version and we have used the Jupyter Notebook App for the program execution. The Jupyter Notebook Application is an application having server-client architecture which allows editing and executing notebook documents through a web browser. A notebook document is a human readable and machine executable document which can be executed for implementation of data analysis. The Jupyter Notebook Application can be executed on the local host or can be installed on a remote machine accessed via the internet [6].

The Jupyter Notebook can be installed very easily on a machine which has either Python 2 or Python 3 version. Since we have implemented our project in Python 2.7, following commands are to be run in the terminal:

```
pip install --upgrade pip
```

The above command will upgrade the Python package manager (pip). 

```
pip install jupyter
```

The above command will install Jupyter in the local machine.

Once the Jupyter Notebook has been installed, it can be run using

the following command in the terminal:

```
jupyter notebook
```

This command will run the Jupyter notebook in the default browser of the machine on the default port 8888 of the localhost.

### 4.2 Packages Installation

Before running the code the following packages were imported/installed in the Python environment.

**Pandas** Pandas provide a very fast and flexible data structures to make working with relational data easy and fairly intuitive.

**Numpy** This is a fundamental package for scientific computation with Python and can be used as an efficient multi-dimensional container of generic data.

**Sklearn** Scikit-learn makes a wide range of supervised and unsupervised machine learning algorithms available in python. We have implemented all the Machine Learning Algorithms using this library.

### 4.3 Null Value Treatment

Before going ahead with Data Exploration, a quick look through the data showed many missing values. Hence before doing any analysis, it is imperative to treat the missing values. The dataset has almost 25% of the entries that are not assigned to any of the customer i.e. customerID attribute for those entries is null.

Missing value treatment can be done by deleting the columns and/or rows which have missing values beyond a decided threshold, or replacing them with the attribute mean, median or mode. Since the missing values in our case is the customerID, the replacement method cannot be applied. Also, these entries are useless for the analysis since we aim to do Customer Segmentation and without knowing the customerID, it cannot be achieved. Hence we have deleted the rows with missing customerID. After removing these entries , the dataset left is with 4,06,829 transactions.

The content of the dataset appears as shown in the Figure 1.

[Figure 1 about here.]

We also removed the duplicate values present in the dataset. There are 5225 such entries present in the data set that are deleted.

## 5 EXPLORING THE CONTENT OF VARIABLES

The dataframe has 8 variables and we can draw some inferences by analyzing these variables.

### 5.1 Countries

From the data we can see that there are 37 different countries from which orders were placed. We can determine the number of orders per country by a ‘Chloropeth’ map. A Chloropleth map shown in Figure 2 uses different colors and shades within predefined areas to indicate quantities in those areas.

[Figure 2 about here.]

The Figure 2 shows that maximum number of orders are placed from UK.

## 5.2 Customers and products

On observing the number of users, products purchased and number of transactions made; we can see that these are not proportional. This suggests that there were many transactions made for cancelling the orders shown in Figure 3

[Figure 3 about here.]

We can also determine the number of products purchased in each transaction. It shows that some customers purchased goods in bulk whereas some purchased a single product in a transaction. Also the orders with InvoiceNo starting with C are the cancelled orders. The details are shown in Figure 4.

[Figure 4 about here.]

## 5.3 Cancelled Orders

Almost 16% (3654) of the transactions are corresponding to the cancelled orders. In the dataset, corresponding to each cancelled transaction we should have an order placed with same quantity of products requested. While checking the same in the dataset, we found the details shown in Figure 5 for some of the orders.

[Figure 5 about here.]

This hypothesis should apply to the complete dataset, but on checking the whole dataset it is found out that there are some cancelled orders without the purchase order (the history of the order) made. This is done by locating the entries that indicate a negative quantity and then checking if there is an order indicating the same quantity (but positive) with the same description and the same customerID. We still get negative quantities. Going deeper in to this suggests that the entries with description 'Discount' have negative quantities associated with that transaction. And hence, to do the verification, we eliminated the 'Discount' entries. But again the initial hypothesis do not match; we still have negative numbers appearing in the quantity.

This can be because the buy orders were performed before December 2010 (the point of entry of the database). We can delete the records where a cancel order exists without the corresponding purchase order or where there is at least one counterpart with the exact quantity (since both records are logically cancelling each other). Total 8795 such records are found and deleted from the dataset.

## 5.4 StockCode

The StockCode variable should ideally contain letters. So we have filtered out the codes with only letters. We can observe from Figure 6, different type of transactions based on these (example D is for discounted transaction).

[Figure 6 about here.]

## 5.5 Basket Price

We have added a new variable to indicate total price of the purchase (by multiplying unit price of each product with quantity purchased). Each transaction corresponds to the prices for a single product. On

grouping the records based on a single order, we can see the complete price for that order as shown in Figure 7.

[Figure 7 about here.]

We can visualize the orders distinguished on the basis of total price of the basket. It can be shown as Figure 8 using a pie-chart.

[Figure 8 about here.]

It shows that majority of the orders are the bulk purchases since 60% of the orders have amounts greater than 200 Sterling.

## 6 EXPLORING PRODUCT CATEGORIES

The dataset contains two variables- Stockcode and Description defining products. We can categorize the products based on the content of the description variable. This can be done in the following way. Firstly, the proper or the common names appearing in the products' description are extracted. Then the root of the word and combining set of names associated with this particular root is extracted. Lastly, the frequency of the word is found in the description variable of the dataframe.

Upon checking, we found that there are 1483 keywords present in the description variable of the dataset. The most common keywords can be determined based on the occurrences. The Figure 9 shows the top word occurrences.

[Figure 9 about here.]

### 6.1 Categorizing Products

We have obtained around 1400 keywords from the above occurrence list , most of which do not make sense. After discarding the keywords that are appearing less than 13 times, we are left with 193 keywords that we will consider for our analysis.

These significant keywords are used for creating categories of the products. The data has been encoded using the principle of one-hot-encoding.

**One hot encoding** - One hot encoding is a process by which categorical variables are converted into a binary format of 0's and 1's that could be provided to ML algorithms to do a better job in prediction. The words present in the descriptions of the products are encoded. Also price range column is added as it will help in balanced grouping of the products.

### 6.2 Clustering of products

In the previous step we have created a matrix with encoded version of words present in the description variable. K-means clustering is used for the cluster assignment and since the data is in binary format because of encoding, the most appropriate distance method will be Hamming's metric (other distance functions are euclidean distance, Manhattan distance, binary distance, etc). It basically measures the minimum number of substitutions required to change one string into the other. But since the k-means package available in sklearn uses Euclidean distance by default, we have used it for our analysis.

Selection of optimum K-value:

The number of clusters can be selected using silhouette analysis on K-means clustering. It is used to study the separation distance between the resulting clusters. The silhouette plot displays a measure of how close each point in one cluster is to the points in the neighboring clusters and thus provides a way to assess parameters like number of clusters visually. This measure has a range of [-1, 1]. Silhouette coefficients (as these values are referred to) near +1 indicate that the sample is far away from the neighboring clusters. A value of 0 indicates that the sample is on or very close to the decision boundary between two neighboring clusters and negative values indicate that those samples might have been assigned to the wrong cluster.

The Figure 10 shows silhouette score for different values of k. These scores do not have significant differences, but since for k value greater than 5, the resulting clusters have very few elements in them, we have taken k as 5.

[Figure 10 about here.]

### 6.3 Validating Quality of Classification

**6.3.1 Silhouette Score.** From the silhouette plot shown in Figure 11 we can see that cluster 1 has more number of elements than the other clusters. But overall distribution of elements in the clusters is comparative. Same can be seen from the Figure 12.

[Figure 11 about here.]

[Figure 12 about here.]

**6.3.2 Principal Component Analysis.** The main idea of principal component analysis (PCA) is to reduce the dimensionality of a data set consisting of many variables correlated with each other, either heavily or lightly, while retaining the variation present in the dataset, up to the maximum extent. The initial matrix has large number of variables and hence, PCA is used for dimensionality reduction. From the Figure 13 we can say that we need more than 100 components to explain 90% of the variance in the data.

[Figure 13 about here.]

Another application of PCA is that it sets the indication of flicterfi membership. Biplot is the best example that can be provided here to support this idea. Using biplot, we get the indication of number of clusters in a dataset. Below Figure 14 shows these on limited number of components (since it is only for visualizing cluster distribution). We can observe the groupings of points or clusters as expected.

[Figure 14 about here.]

## 7 EXPLORING CUSTOMER CATEGORIES

In the previous section, we have divided products in 5 clusters. We have added a dummy variable categ\_product to indicate the cluster to which that customer belongs. Based on the clustering done on products we have created variables categ\_0..4 which stores amount spent on each of the product category. And the categ\_product variable which we have just created will have initial cluster assignment

based on these variables. These can be further grouped on the basis of InvoiceNo as shown in Figure 15.

[Figure 15 about here.]

### 7.1 Subsetting dataframe based on Time

We have taken 12 months data for the analysis. This can be done on the basis of variable InvoiceDate present in the dataset. Using this data we have developed a model to characterize and anticipate the habits of customers using the site and this, we are doing it from the first visit.

In the previous section we have seen the basket price of each invoices. For further analysis we will combine these on the basis of customerID to analyze the number of purchases made by each customer as shown in Figure 16. A customer category of particular interest is that of customers who make only one purchase. So one objective may be, for example, to target these customers in order to retain them. In the dataset we have almost one-third of the customer base similar to this.

[Figure 16 about here.]

### 7.2 Categorizing Customers

The information transactions per user is used for characterizing different types of customers. Because of different ranges of variations of different variables we have first scaled the data set. As done in the case of product categorization, we have again used K-means algorithm for cluster assignment.

Using the silhouette score, the optimum value of k comes out to be 11. The assignment of customers into different clusters is shown in Figure 17

[Figure 17 about here.]

Now we will check validity of the cluster assignment using PCA and Silhouette plot as done in the case of product categorization.

**7.2.1 PCA.** There is a certain disparity in the sizes of different groups that have been created. So we have validated it using PCA. From the representation shown in Figure 18, it can be seen, for example, that the first principal component allow to separate the tiniest clusters from the rest. More generally, we see that there is always a representation in which two clusters will appear to be distinct.

[Figure 18 about here.]

**7.2.2 Silhouette Plot.** As with product categories, another way to look at the quality of the separation is to look at silhouette scores shown in Figure 19 within different clusters:

[Figure 19 about here.]

We can see that the different clusters are indeed disjoint.

## 8 CLASSIFICATION OF CUSTOMERS USING CLASSIFICATION ALGORITHMS

In the previous section, we have made different client categories. In this part we will adjust a classifier so that the consumers can be classified in different client categories. The main aim of this is to enable the Classification on the first visit of the customer. To do this, we have defined a class that will allow interfacing the common functionalities to the different classifiers. Since we are going to classify the client on the basis of his/her first visit, the only parameters that we take into consideration are the contents of the basket and not the frequency of visits or the variation in the basket price over a period of time. Once this is done, we have split the dataset into train and test sets. The classification algorithms which we used to do this are mentioned below.

Before we delve deeper into the Classification Algorithm, some important concepts that need to be addressed are Cross Validation, Bias, Variance, underfitting and overfitting of the model.

**Variance** Variance essentially means how much the models estimated from the different training sets differ from each other. It measures how much the predictions made for a given point vary between the different realizations of the model [4]. When the training data tries to fit all the sample points to define the model, even the outlier data points, which are nothing but the noise, affect the model. Usually, the variance increases with increase in the complexity of the model.

**Bias** Bias essentially means how much the average model over the training sets differ from the true model. Bias usually occurs if the model is over simplified or if some inaccurate assumptions are made. Thus Bias increases with increase in the over simplification of the model [4].

**Underfitting** Scientific study of mental processes and behaviour.Underfitting occurs when the model is too simple to make relevant classification of the testing data [4].Thus when a model possesses high bias and low variance, we say there is underfitting of the model.

**Overfitting** Overfitting of a model occurs when the model is too complex and tries to fit in the irrelevant/outlier datapoints from the training set which is nothing but the noise [4]. Thus when a model possesses low bias and high variance, we say there is overfitting of the model.

**Cross Validation** Cross Validation is a technique for evaluating the predictive models by partitioning the original dataset into a training set to train the model, and a testing set to evaluate the model [11]. There are different ways to implement Cross Validation, the most effective of them all is the K-fold Cross Validation. In this method the dataset is divided into k subsets, out of which one is used as the test data and the remaining  $k - 1$  are combined together to form training data. This process is done k times, ensuring that every single sample in the dataset gets to be tested exactly one time and gets trained upon exactly  $k - 1$  times. The variance therefore gets decreased as the k increases [11].

### 8.1 Logistic Regression

Logistic Regression as mentioned before is a Supervised Learning method which does analysis on a dataset containing two or more independent variables for determining the outcome. This outcome, i.e the dependent variable, is binary in nature, meaning it can have only two possible outcomes [9]. Multinomial Logistic Regression as the name suggests, generalizes the Logistic Regression to multiple classes, meaning the model can be used to predict the probabilities of the different outcomes of a categorically distributed dependent variable [17]. The goal of a Logistic Regression model is to determine a fitting model which best describes the relationship between the dependent variables (output variable) and a set of the input independent variables. Logistic Regression generates the coefficients along with the standard errors and significance levels of the below equation for predicting the logit transformation of the probability of presence of the characteristics of interest in a given sample example [9].

$$\text{logit}(p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \dots + \beta_k X_k$$

where p is the probability of the presence of a characteristic of interest. and  $\text{logit}(p) = \log(p/1-p)$  In logistic Regression, the goal is to choose the parameters  $\beta$  in such a way that the likelihood of observing the new sample values is maximized [9].

In the Python code, we have imported the module ‘linear\_model’ from the ‘sklearn’ package to perform Logistic Regression by using the function ‘logistic\_regression’. And we have taken the  $k = 5$  for k-fold cross validation. While performing Logistic Regression, we created an instance of the Class\_Fit class and then ran the model on training data and see how the predictions are made as compared to the real values. The learning curve graph is as shown in Figure 20.

[Figure 20 about here.]

As we can see from the Figure 20, when the number of training examples increases, the cross-validation and train curves almost converge towards the same limit suggesting that the model has low variance. Thus we can say that model is not suffering from overfitting. Also one point to note is that the accuracy is high, which means that the model has low bias, thus suggesting that it does not under-fit the data. The precision which we got from running the Logistic Regression model on the training data is 88.78%.

### 8.2 K Nearest Neighbours

KNN is a non parametric algorithm which means that there are no underlying assumptions that are made on the data. Also it is a lazy learning algorithm meaning that it does not do any generalization by using the training data. All the training data is needed during the testing phase [13].

KNN makes predictions using the training dataset directly. Predictions are made for a new instance (x) by searching through the entire training set for the K most similar instances (the neighbors) and summarizing the output variable for those K instances. For regression this might be the mean output variable, in classification this is be the model (or most common) class value. To elaborate on this, KNN makes predictions using the training dataset directly. These predictions are made for a new sample by going through the entire training set to find k such samples which are most similar or which are the ‘neighbors’ of the the new instance. Once these k

instances are found out, the output variable corresponding to these is summarized and in case of Classification, it gives a class value to which the new instance belongs. The k ‘neighbors’, i.e., the most similar instances from the data set are found by using the distance measure- k such instances whose distance from the new instance is the least [13]. There are many distance functions which can be used, the most popular being the Euclidian distance function, the formula for which is given by:

$$\text{EuclideanDistance}(x, x_i) = \sqrt{\sum((x_j - x_{ji})^2)}$$

where  $x$  is a new data point and  $x_i$  is an already existing point [13].

The optimum value of K can be found by algorithm tuning, i.e. running the algorithm over several values of k and finding out and then figuring out for which k the algorithm gives the best results [14].

The output, i.e the class of the new sample can be calculated as the class which has the highest frequency from the k neighbours. Thus, each of the instances votes for their own class and the class which gets the maximum votes is taken as the prediction value [14].

In Python, the ‘neighbors’ library is imported from the sklearn package which performs the KNN classification through the KNeighborsClassifier function. The parameters that are used are ‘n\_neighbors’ which represents the number of neighbors to use, in our case we have used the np.arange method to give sequence from 1 to 49. Also, we run the model using the K-fold Cross Validation with the value of  $k = 5$ . Once the model is run, we have drawn the learning curve graph which is as represented in the Figure 21.

[Figure 21 about here.]

The precision which we got from running the KNN model on the training data is 80.33%.

### 8.3 Random Forest

As the name suggests, Random Forest is an ensemble classifier which consists of many classification trees. An ensemble classifier is a multiple classifier algorithms, decision trees in the case of Random Forests, and the final output is the combined output of the all the classifier algorithms. In our case we will be using Random Forest Algorithm for classification of the clients into different categories. A Random Forest grows many trees. For classifying a new object from an input vector, each tree in the forest gives a classification and vote for a particular class. And the forest then chooses the class having maximum number of votes over the other classes [1].

The question here that needs to be addressed is, how does the growth of a tree happen?

Each tree is grown as follows:

If the training set consists of N cases, then N cases are sampled with replacement from the original data. This is the training set for growing a tree. Thereafter, a number  $m \leq M$  which is the number of input variables is taken such that the best split obtained on these m is used to split the node. The value of m is constant throughout the forest-growing. Each tree is allowed to grow to the fullest possible extension [1]. In Python, the ‘ensemble’ library is imported from the sklearn package which performs the Random Forest classification through the RandomForestClassifier function. The parameters given to this function are criterion, n\_estimators and max\_features. The criterion is used to measure the quality of the split. The Gini is

for measuring the Gini impurity and Entropy is for information gain. The max\_features are the number of the features that can be chosen when looking for the best split. For ‘sqrt’, the number of maximum features chosen are square root of the number of the features and for ‘log’, it is log of the number of the features. And the n\_estimators is the number of trees in the forest. Once the model is run, we have drawn the learning curve graph which is as represented in the Figure 22 .

[Figure 22 about here.]

The precision which we got from running the Random Forest model on the training data is 90.17%.

### 8.4 Gradient Boosting Classifier

AdaBoost Classifier, short for Adaptive Classifier is another example of ensemble classifier. It is a general ensemble method which creates a strong classifier by combining the outputs of the weaker learning algorithms into a weighted sum to finally provide the output of the *boosted* classifier. This is done by building one model from the training set and then building a second one which attempts to rectify the errors from the first model and so on until either the limit of maximum models that can be added is reached or the training set is predicted accurately. AdaBoost is an adaptive algorithm, meaning that the weak learning algorithm can be tweaked to create a stronger classifier [6].

The Adaptive Boosting algorithm was recast into a statistical framework. “Arcing is an acronym for Adaptive Re-weighting and Combining. Each step in an arcing algorithm consists of a weighted minimization followed by a re-computation of [the classifiers] and [weighted input] [6]” This framework is called as Gradient Boosting.

Gradient Boosting involves three elements namely:

**A loss function** The selection of the loss function depends on the problem at hand. For example if it is a regression algorithm, then squared loss functions are used and if it is a classification algorithm then logarithmic functions are used. The main aim of the algorithm is to optimize the loss function.

**A weak learner** Regression trees are used as the weak learners in the Gradient Boosting Algorithm since they can output real values for splits which can be added together and the residuals in the predictions can be corrected. The weak learners are used for making predictions. These trees are constructed in a greedy manner usually up to 4-8 levels.

**An additive model** The additive model is made so as to add the weak learners to minimize the loss function. The trees are added one at a time with no changes to the existing trees in the model. A gradient descent model is used to reduce the loss when adding trees first by parameterizing the tree and then by modifying the parameters of the tree and moving in the right direction by reducing the loss in residuals. This approach is called Functional Gradient descent [6].

This framework was further developed by Friedman and called Gradient Boosting Machines. Later called just gradient boosting or gradient tree boosting [6].

In Python, the ‘ensemble’ library is imported from the sklearn package which performs the Gradient Boosting classification through the GradientBoostingClassifier function. The parameter given to this function is n\_estimators which is the number of boosting stages to perform. Gradient boosting is fairly robust to over-fitting so a large number results in better performance. Learning curve is shown in the Figure 23.

[Figure 23 about here.]

The precision which we got from running the Gradient Boosting model on the training data is 90.86%.

Now that we have the results of all the models, we can combine them using VotingClassifier method that we imported from the sklearn package to improve the classification model. Since we have already found the best parameters for each of the classifiers, we have adjusted the parameters of the classifiers accordingly. So now the best parameters are taken and merged to define a classifier which we then trained on the data. When we created a prediction on this, we got the precision value as 90.44%.

## 9 TESTING THE PREDICTIONS

Until now we have done all the analysis on the data from the first 10 months. After this we test the model on the set\_test dataframe which contains the data of the last two months. The regrouping of the data is done according to the same procedure that we followed while regrouping the training data. But now we have to take into consideration the time difference in between the two datasets and the count(the total number of visits which the client made to the website) and sum(total amount that he/she spent) variables so that we have an equivalence in between the training set and testing set. The dataframe so obtained is now converted to a matrix and we retained only those variables that define the category to which the clients belonged. And just like on the training dataset the method of normalization was called, to maintain consistency, the same method is called on the test set as well.

Each row of the matrix obtained now represents the buying habits of the customers. Now all we have to do is to define the category to which the customer belongs by using these habits. The important point to note here is that this is just the test data preparation step by defining the category to which the consumer belongs for a period of two months through the variables count, min, max and sum. Thus this step *does not* correspond to the classification step itself. The classifier that we defined in the step 5 uses variables that were defined from the client’s first purchase.

So now, we have the data available for two months, and through that we can define the category to which the consumer belongs. The predictions now obtained by running the classifiers on test data can be tested against these categories. The instance of the k-means clustering method that we used in the Customer Categories section is used to define the category to which a client belongs. This contains the predict method which will calculate the distance of the consumers from the centroids of the 11 categories that we deduced, and the category which is closest to the clients’ buying habits will define his/her category. Thus all we need after this for the execution of the classifier is to select the variables on which it acts, i.e. on mean, cat\_0, cat\_1, cat\_2, cat\_3 and cat\_4. After examining the predictions of the different classifiers, we get precision scores as

shown in Table 1.

[Table 1 about here.]

And now, like we did in the Section 5, we will use the voting classifier method to merge the results obtained by these individual classifiers and see whether they combined result is better than the individual. It turns out that it is. We get the precision rate for the combined classifier to be 76.48% for the test data set. This concludes the analysis phase.

## 10 CONCLUSION

E-commerce is one of the emerging fields for Data Analysis since a lot of data gets generated every day at a break-neck speed in many different formats. To sustain in such a business, a very robust and extensive data analysis is needed to keep up with the ever changing markets by implementing different marketing strategies. And since the whole business revolves around the customers, they form the most important aspect of the analysis. We have tried to achieve Customer Segmentation on the basis of the purchasing patterns and frequency of client visits to their online portal. The dataset on which we performed analysis provided details on the purchases made by the consumers over a period of more than a year. Every entry in the dataset contained the purchase of a particular product on a given date by a particular customer. Out of the 591909 entries made in the dataset, approximately 4000 different consumers are present. From the information available for each consumer, we decided to go ahead with Customer Segmentation analysis by developing a classifier that predicts the type of purchase a consumer would make and his/her frequency of visits to the E-commerce website.

In the first step of this classification, we found out the different products sold by the company, and then classified the products into 5 categories of goods by using K-means clustering. In the second step we performed the classification of the customers on the basis of purchasing habits in the first 10 months. The customers were classified into 11 categories on the basis of the types of products they usually bought, the number of visits they made to the website and the amount for which they shopped over a period of 10 months. Once we had the categories of the consumers, we performed training of the data of the first 10 months using different classifiers namely Logistic Regression, Random forests, KNN and Gradient Boosting algorithms to classify the consumers in these 11 categories, on the basis of their first purchase. The classifiers were based on these variables: the total price of the current purchase and the percentage of the amount spent in each of the 5 product categories. Once the customers were classified in the 11 categories, the quality of the data set was tested on the remaining two months of the dataset. This was achieved in two steps. In the first step, we assigned the category to which each customer belonged to, and then the classifier predictions were compared against these categories. And then we combined the results of the various classifiers by using the Voting Classifier method. The model performed with a 76.48% of precision, that is 76.48% of the times the clients were awarded the right classes.

One bias which we did not consider while doing the analysis is the

seasonal fluctuations, like festive and seasonal sales. Since at these times the sales of products may rise and just before and after the sale duration, the sales may drop. Thus the purchasing habits of customers are dependent on the time of the year as well. Hence the seasonal effects may cause the actual sales in the last two months to be quite different from the ones which we extrapolated from the first ten months to the last two months. For overcoming such biases, it would be beneficial if the data were of a larger size and covered a larger period of time.

Knowing the type of a customer is critically important for an E-commerce business. By doing so, the store owners can provide personalized services to the customers, which will yield higher customer satisfaction. Customer satisfaction is directly proportional to the loyalty of the customers, thus Customer Segmentation and Personalization can help the company in increasing their brand name. Knowing the preferences and choices of customers also helps in catering to those needs of the customers which they may not be aware of in the first place. Thus by knowing the purchasing patterns of the customers, we can provide them with tailored suggestions, which can even increase the revenues of the company. Thus through proper implementation of the business strategies and marketing activities, which are motivated by a thorough Analysis of the data available can help the company in attracting loyal customers, increasing the revenue and establishing a better brand value.

## ACKNOWLEDGMENTS

The authors would like to thank Prof. Dr. Gregor von Laszewski for giving the opportunity to work on this project. The author would also like to thank the Associate Instructors of the class for their help and for answering questions on Piazza which helped everyone.

## REFERENCES

- [1] Jason Brownlee. 2016. <https://machinelearningmastery.com/k-nearest-neighbors-for-machine-learning/>. (2016). <https://machinelearningmastery.com/k-nearest-neighbors-for-machine-learning/>
- [2] Jason Brownlee. 2016. Supervised and Unsupervised Machine Learning Algorithms. (2016). <https://machinelearningmastery.com/supervised-and-unsupervised-machine-learning-algorithms/>
- [3] Justin Butlion. 2015. An Introduction to Analytics for Ecommerce Websites. (2015). <https://blog.kissmetrics.com/intro-to-ecommerce-analytics>
- [4] Scott Fortmann-Roe. 2012. Understanding the Bias-Variance Tradeoff. (2012). <http://scott.fortmann-roe.com/docs/BiasVariance.html>
- [5] Prashant Gupta. 2017. Decision Trees in Machine Learning. (2017). <https://towardsdatascience.com/decision-trees-in-machine-learning-641b9c4e8052>
- [6] Antonino Ingargiola. 2015. What is the Jupyter Notebook? (2015). [http://jupyter-notebook-beginner-guide.readthedocs.io/en/latest/what\\_is\\_jupyter.html](http://jupyter-notebook-beginner-guide.readthedocs.io/en/latest/what_is_jupyter.html)
- [7] Lacie Larschann. 2017. 7 Powerful Applications of Machine Learning in E-Commerce. (2017). <https://www.granify.com/blog/powerful-applications-of-machine-learning-in-e-commerce>
- [8] EILEEN MCNULTY. 2015. WHAT'S THE DIFFERENCE BETWEEN SUPERVISED AND UNSUPERVISED LEARNING? (2015). <http://dataconomy.com/2015/01/whats-the-difference-between-supervised-and-unsupervised-learning/>
- [9] Medcalc. 2017. Logistic Regression. (2017). [https://www.medcalc.org/manual/logistic\\_regression.php](https://www.medcalc.org/manual/logistic_regression.php)
- [10] Sunil Ray. 2017. Understanding Support Vector Machine algorithm from examples (along with code). (2017). <https://www.analyticsvidhya.com/blog/2017/09/understanding-support-vector-machine-example-code/>
- [11] Jeff Schneider. 1997. Cross Validation. (1997). <https://www.cs.cmu.edu/~schneide/tut5/node42.html>
- [12] Granner Smith. 2017. Big Data: Making It Big For E-Commerce Retailers. (2017). <http://www.digitalistmag.com/customer-experience/2017/04/28/big-data-making-it-big-for-e-commerce-retailers-05049637>
- [13] Saravanan Thirumuruganathan. 2010. A Detailed Introduction to K-Nearest Neighbor (KNN) Algorithm. (2010). <https://saravananthirumuruganathan.wordpress.com/2010/05/17/a-detailed-introduction-to-k-nearest-neighbor-knn-algorithm/>
- [14] Saravanan Thirumuruganathan. 2010. A Detailed Introduction to K-Nearest Neighbor (KNN) Algorithm. (2010). <https://saravananthirumuruganathan.wordpress.com/2010/05/17/a-detailed-introduction-to-k-nearest-neighbor-knn-algorithm/>
- [15] Tracey Wallace. 2017. Ecommerce Trends: 147 Stats Revealing How Modern Customers Shop in 2017. (2017). <https://www.bigcommerce.com/blog/ecommerce-trends/>
- [16] Wikipedia. 2017. E-commerce. (2017). <https://en.wikipedia.org/wiki/E-commerce>
- [17] Wikipedia. 2017. Multinomial logistic regression. (2017). [https://en.wikipedia.org/wiki/Multinomial\\_logistic\\_regression](https://en.wikipedia.org/wiki/Multinomial_logistic_regression)

## LIST OF FIGURES

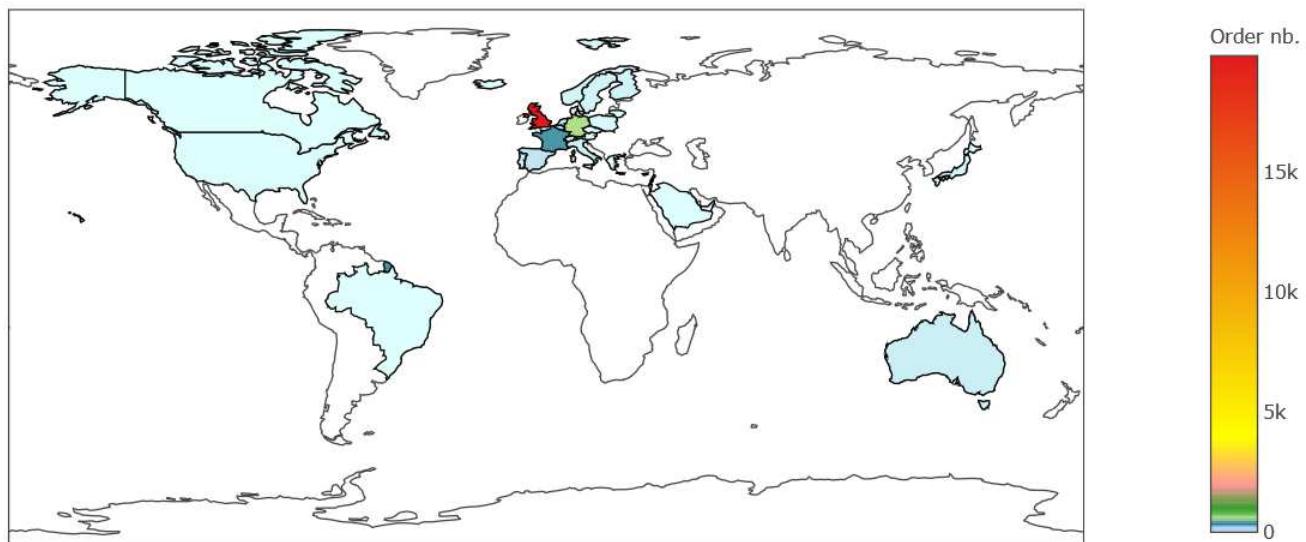
1	Data set Contents	11
2	Distribution of Orders based on Countries	11
3	Customer Products Transactions	11
4	Number of products per Customer	12
5	Transactions for Cancellation	12
6	Stock Codes	13
7	Basket Price	13
10	Silhouette Scores	13
8	Pie-Chart	14
9	Word Occurrences	15
11	Silhouette plot	16
12	Cluster Composition	17
13	PCA	18
14	Biplot	18
15	Table	18
16	Number of Purchases	19
17	Number of Purchase	19
18	PCA	19
19	Silhouette Plot	20
20	Logistic Regression Learning Curve	21
21	KNN Learning Curve	22
22	Random Forest Learning Curve	23
23	Gradient Boosting Learning Curve	24

**Figure 1: Data set Contents**

	InvoiceNo	StockCode	Description	Quantity	InvoiceDate	UnitPrice	CustomerID	Country
0	536365	85123A	WHITE HANGING HEART T-LIGHT HOLDER	6	2010-12-01 08:26:00	2.55	17850	United Kingdom
1	536365	71053	WHITE METAL LANTERN	6	2010-12-01 08:26:00	3.39	17850	United Kingdom
2	536365	84406B	CREAM CUPID HEARTS COAT HANGER	8	2010-12-01 08:26:00	2.75	17850	United Kingdom
3	536365	84029G	KNITTED UNION FLAG HOT WATER BOTTLE	6	2010-12-01 08:26:00	3.39	17850	United Kingdom
4	536365	84029E	RED WOOLLY HOTTIE WHITE HEART.	6	2010-12-01 08:26:00	3.39	17850	United Kingdom

**Figure 2: Distribution of Orders based on Countries**

Number of orders per country



**Figure 3: Customer Products Transactions**

products	transactions	customers
quantity	3684	22190

Figure 4: Number of products per Customer

<b>CustomerID</b>	<b>InvoiceNo</b>	<b>Number of products</b>
0	12346 541431	1
1	12346 C541433	1
2	12347 537626	31
3	12347 542237	29
4	12347 549222	24

Figure 5: Transactions for Cancellation

	<b>InvoiceNo</b>	<b>StockCode</b>	<b>Description</b>	<b>Quantity</b>	<b>InvoiceDate</b>	<b>UnitPrice</b>	<b>CustomerID</b>	<b>Country</b>
61619	541431	23166	MEDIUM CERAMIC TOP STORAGE JAR	74215	2011-01-18 10:01:00	1.04	12346	United Kingdom
61624	C541433	23166	MEDIUM CERAMIC TOP STORAGE JAR	-74215	2011-01-18 10:17:00	1.04	12346	United Kingdom
286623	562032	22375	AIRLINE BAG VINTAGE JET SET BROWN	4	2011-08-02 08:48:00	4.25	12347	Iceland
72260	542237	84991	60 TEATIME FAIRY CAKE CASES	24	2011-01-26 14:30:00	0.55	12347	Iceland
14943	537626	22772	PINK DRAWER KNOB ACRYLIC EDWARDIAN	12	2010-12-07 14:57:00	1.25	12347	Iceland

Figure 6: Stock Codes

POST	-> POSTAGE
D	-> Discount
C2	-> CARRIAGE
M	-> Manual
BANK CHARGES	-> Bank Charges
PADS	-> PADS TO MATCH ALL CUSHIONS
DOT	-> DOTCOM POSTAGE

Figure 7: Basket Price

CustomerID	InvoiceNo	Basket Price	InvoiceDate
1	12347	537626	711.79 2010-12-07 14:57:00.000001024
2	12347	542237	475.39 2011-01-26 14:29:59.999999744
3	12347	549222	636.25 2011-04-07 10:42:59.999999232
4	12347	556201	382.52 2011-06-09 13:01:00.000000256
5	12347	562032	584.91 2011-08-02 08:48:00.000000000
6	12347	573511	1294.32 2011-10-31 12:25:00.000001280

Figure 10: Silhouette Scores

```
('For n_clusters =', 3, 'The average silhouette_score is :', 0.10158702596012364)
('For n_clusters =', 4, 'The average silhouette_score is :', 0.12680045883937879)
('For n_clusters =', 5, 'The average silhouette_score is :', 0.14553871352885445)
('For n_clusters =', 6, 'The average silhouette_score is :', 0.15122077520906058)
('For n_clusters =', 7, 'The average silhouette_score is :', 0.1463684372259042)
('For n_clusters =', 8, 'The average silhouette_score is :', 0.14764212603720744)
('For n_clusters =', 9, 'The average silhouette_score is :', 0.13974230402472737)
```

Figure 8: Pie-Chart

## Distribution of the amounts of orders

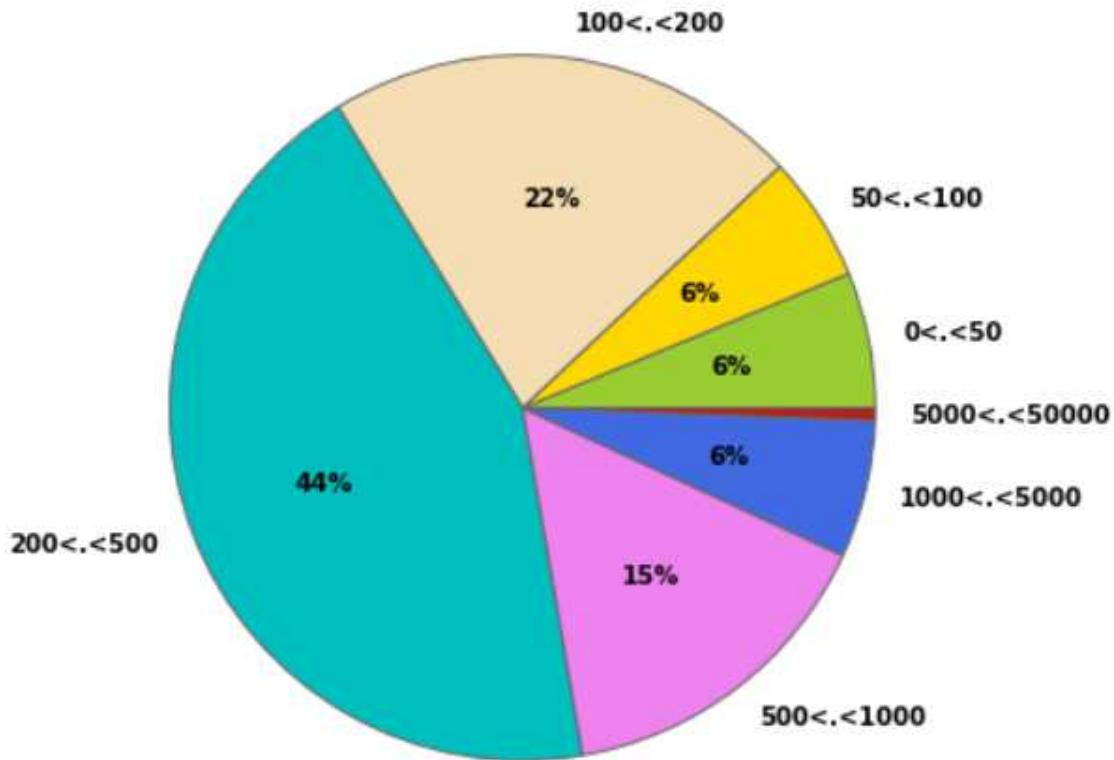


Figure 9: Word Occurrences

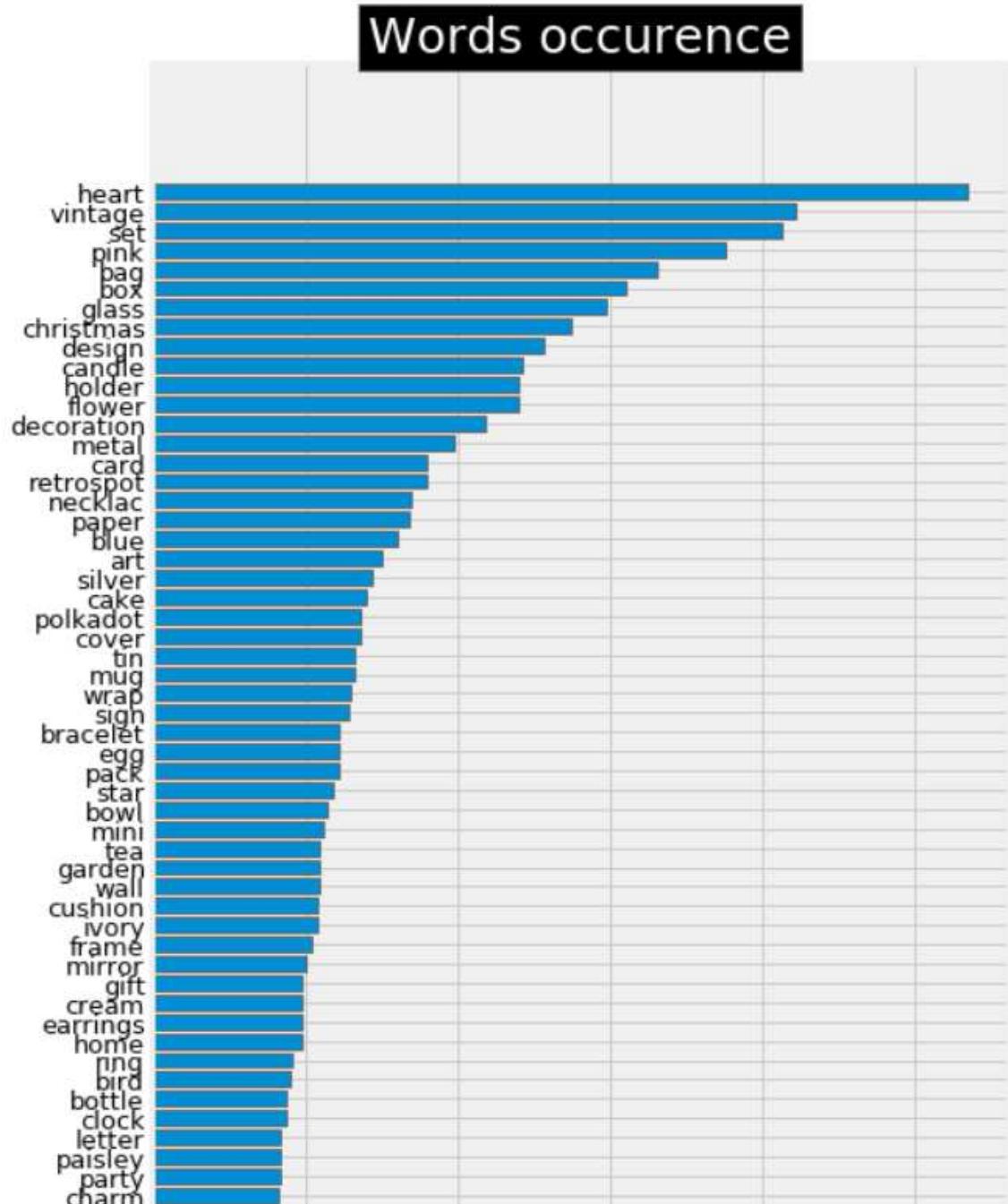


Figure 11: Silhouette plot

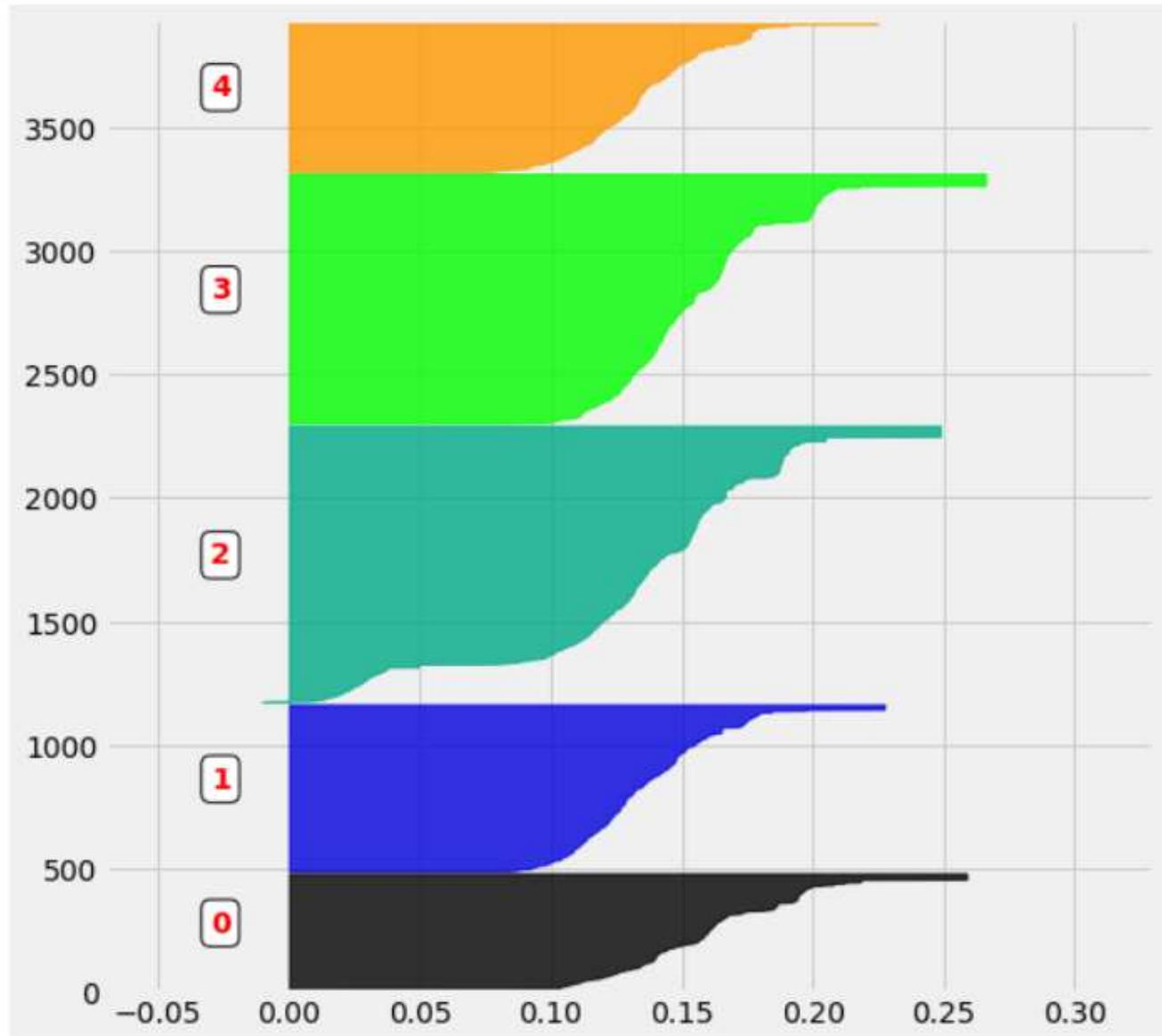


Figure 12: Cluster Composition

2	1118
3	1009
1	673
4	606
0	472

Figure 13: PCA

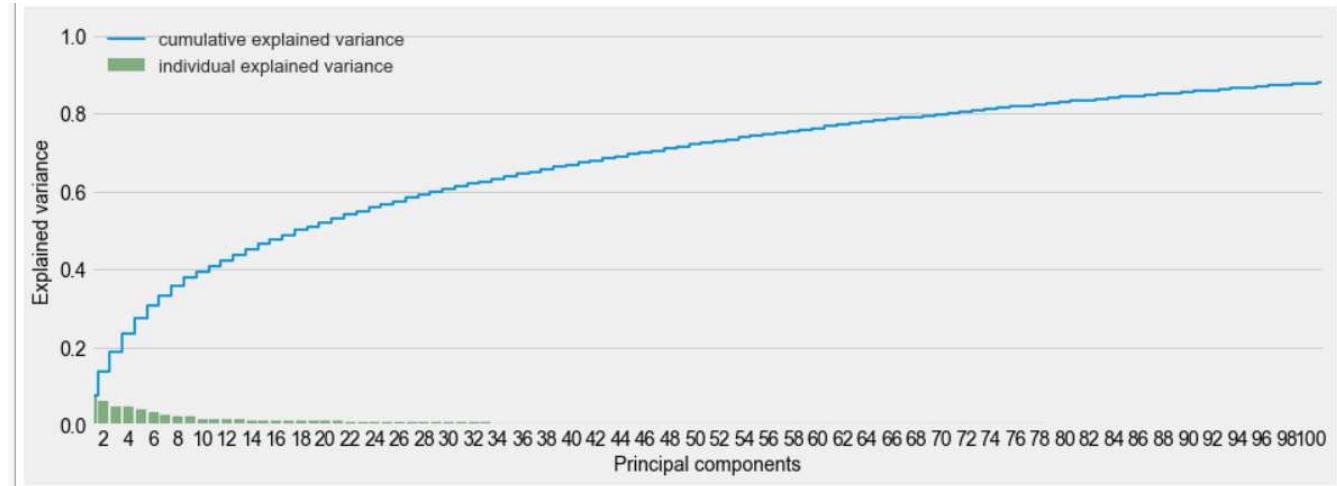


Figure 14: Biplot

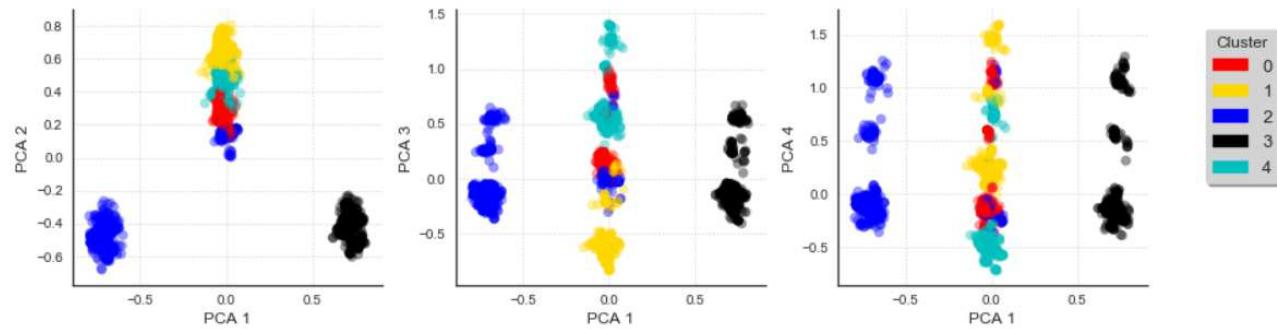


Figure 15: Table

	CustomerID	InvoiceNo	Basket Price	categ_0	categ_1	categ_2	categ_3	categ_4	InvoiceDate
1	12347	537626	711.79	124.44	83.40	23.40	187.2	293.35	2010-12-07 14:57:00.000001024
2	12347	542237	475.39	0.00	53.10	122.59	130.5	169.20	2011-01-26 14:29:59.99999744
3	12347	549222	636.25	0.00	71.10	119.25	330.9	115.00	2011-04-07 10:42:59.999999232
4	12347	556201	382.52	19.90	78.06	41.40	74.4	168.76	2011-06-09 13:01:00.000000256
5	12347	562032	584.91	97.80	119.70	99.55	109.7	158.16	2011-08-02 08:48:00.000000000

Figure 16: Number of Purchases

	CustomerID	count	min	max	mean	sum	categ_0	categ_1	categ_2	categ_3	categ_4
0	12347	5	382.52	711.79	558.172000	2790.86	8.676179	14.524555	14.554295	29.836681	32.408290
1	12348	4	227.44	892.80	449.310000	1797.24	0.000000	0.000000	58.046783	41.953217	0.000000
2	12350	1	334.40	334.40	334.400000	334.40	0.000000	27.900718	23.654306	48.444976	0.000000
3	12352	6	144.35	840.30	345.663333	2073.98	14.301006	3.370331	53.725205	12.892120	15.711338
4	12353	1	89.00	89.00	89.000000	89.00	22.359551	19.887640	44.719101	13.033708	0.000000

Figure 17: Number of Purchase

	1	0	2	6	3	9	8	7	5	4	10
<b>nb. de clients</b>	1484	451	371	344	296	284	191	161	9	9	8

Figure 18: PCA

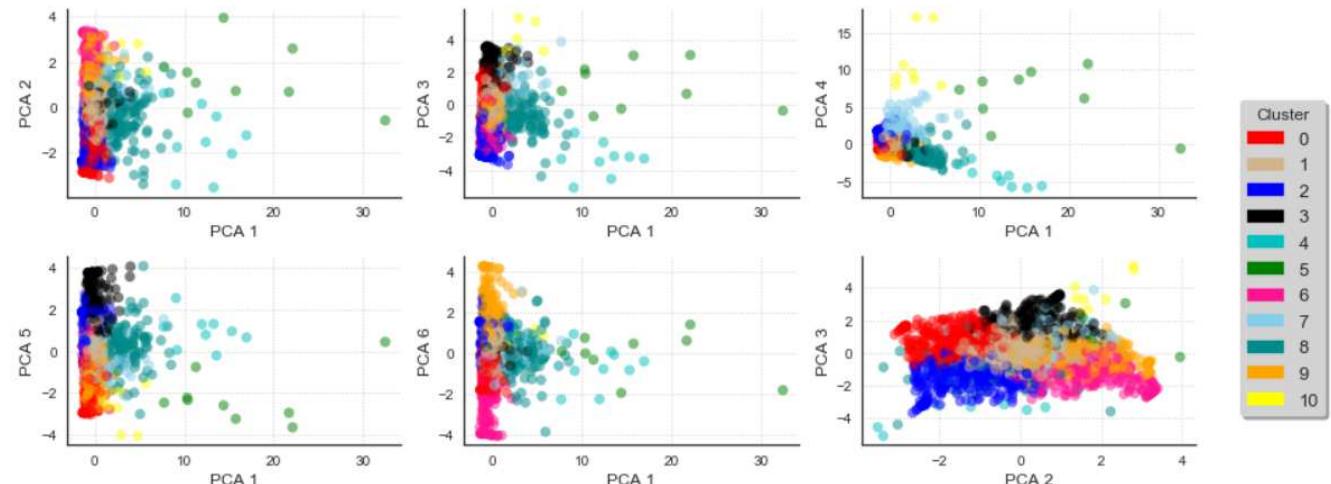


Figure 19: Silhouette Plot

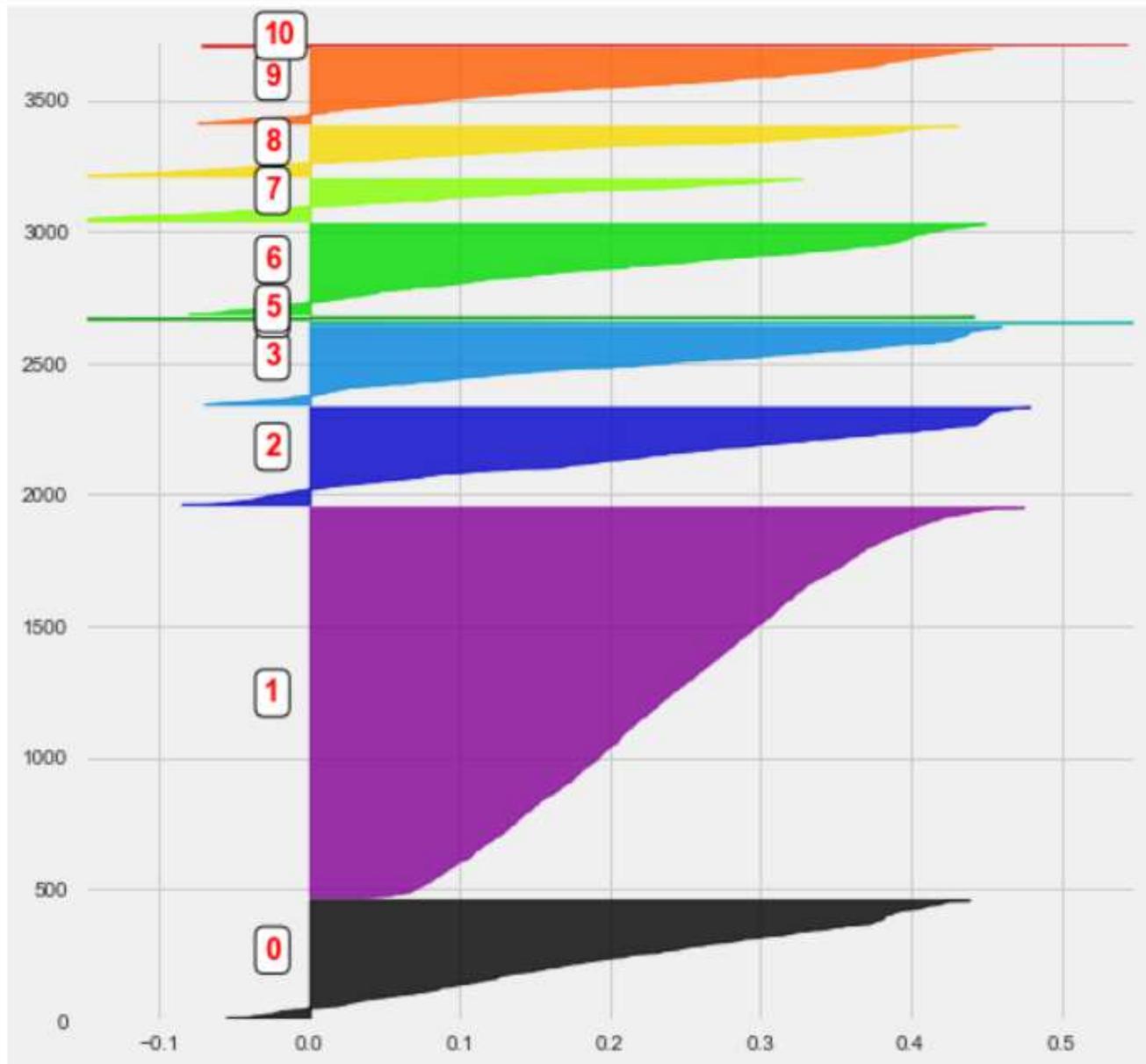


Figure 20: Logistic Regression Learning Curve

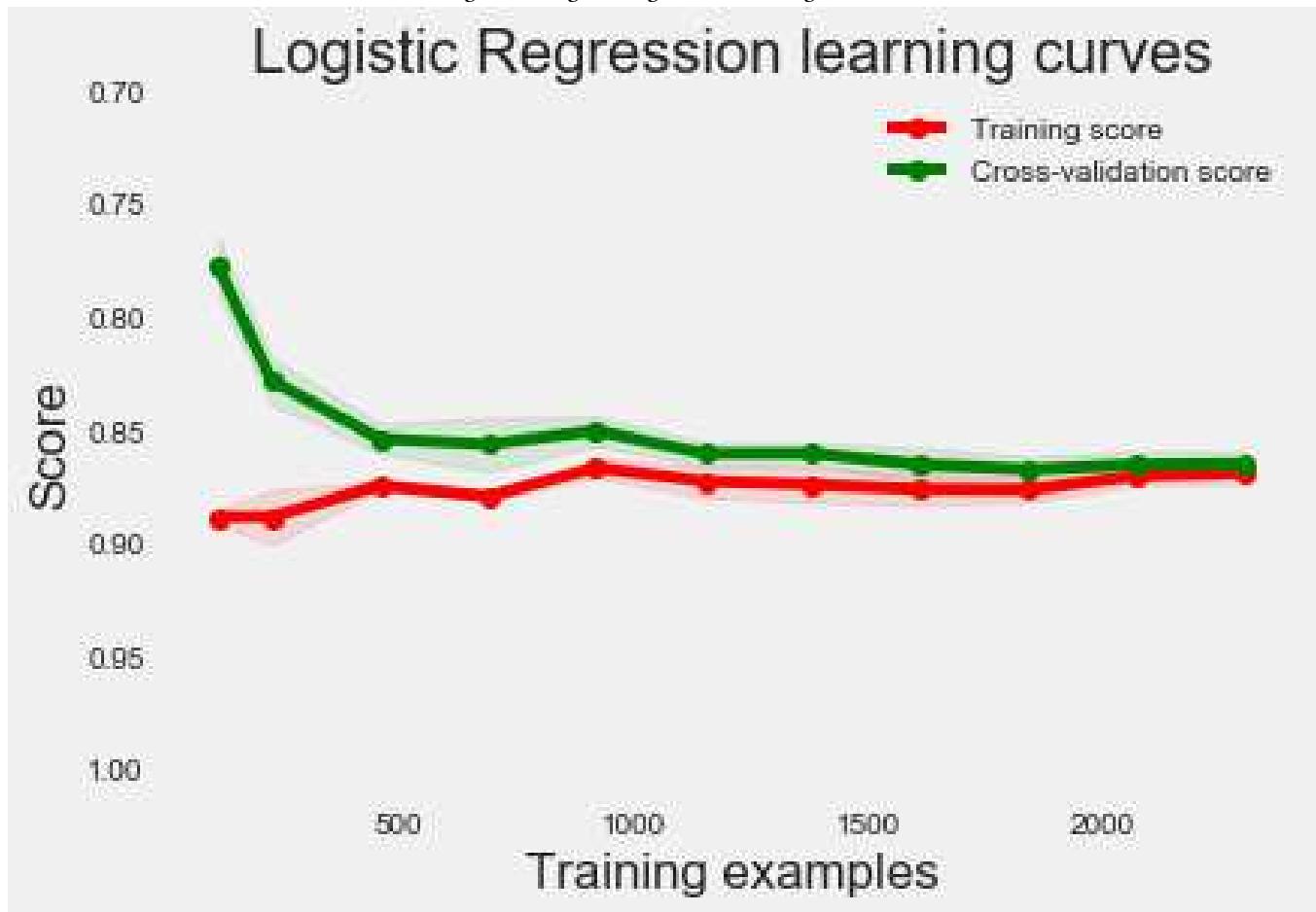


Figure 21: KNN Learning Curve

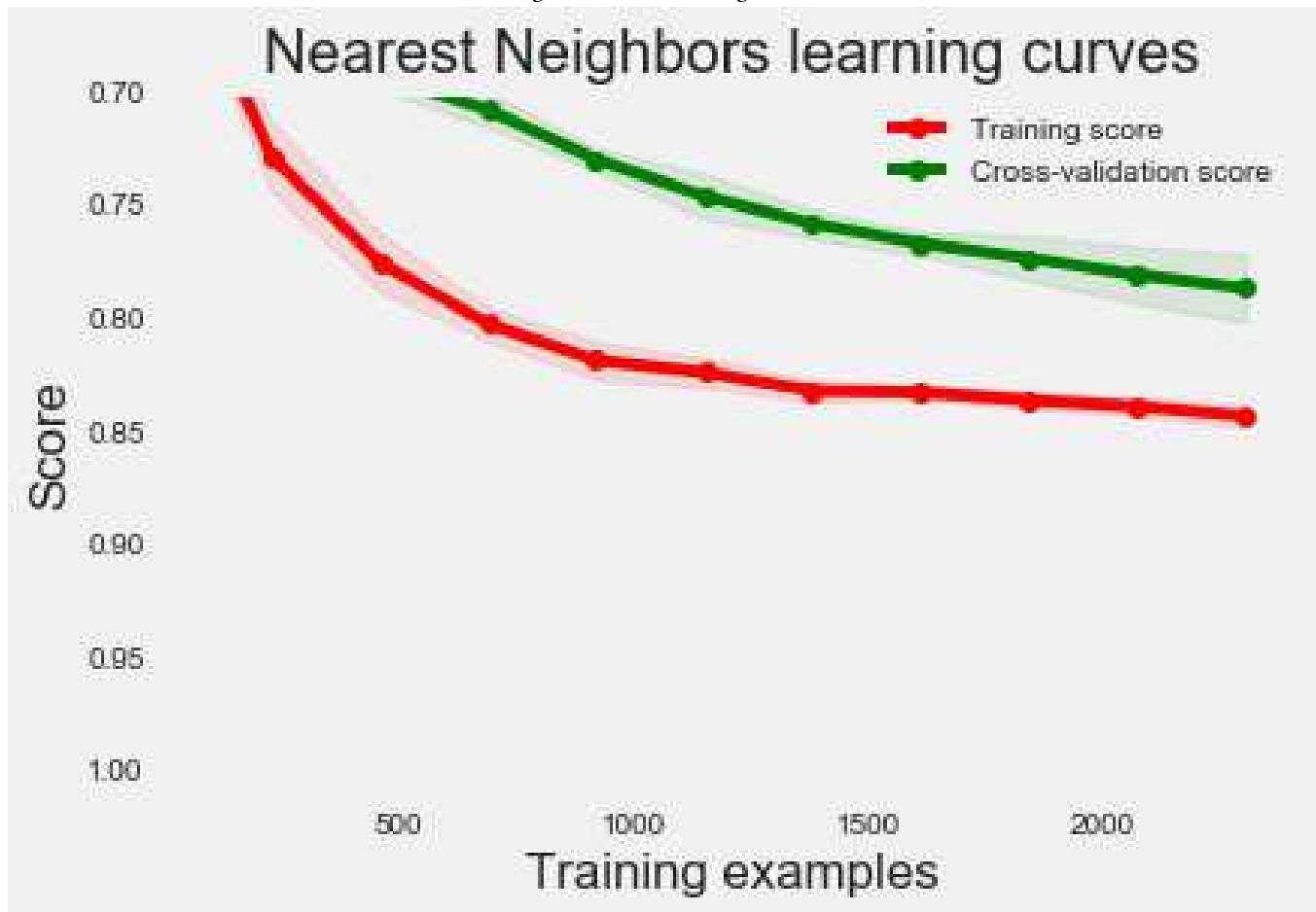


Figure 22: Random Forest Learning Curve

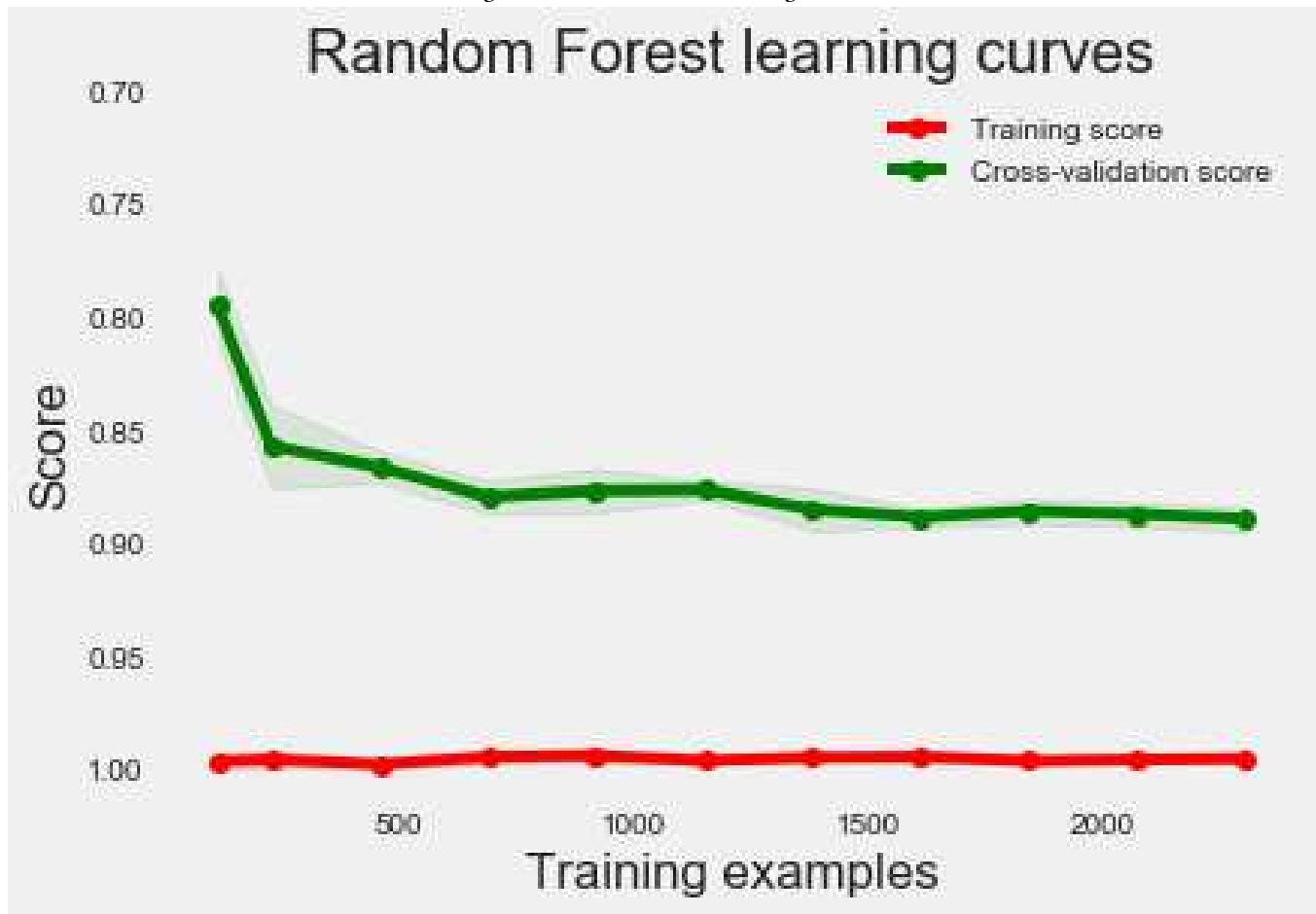
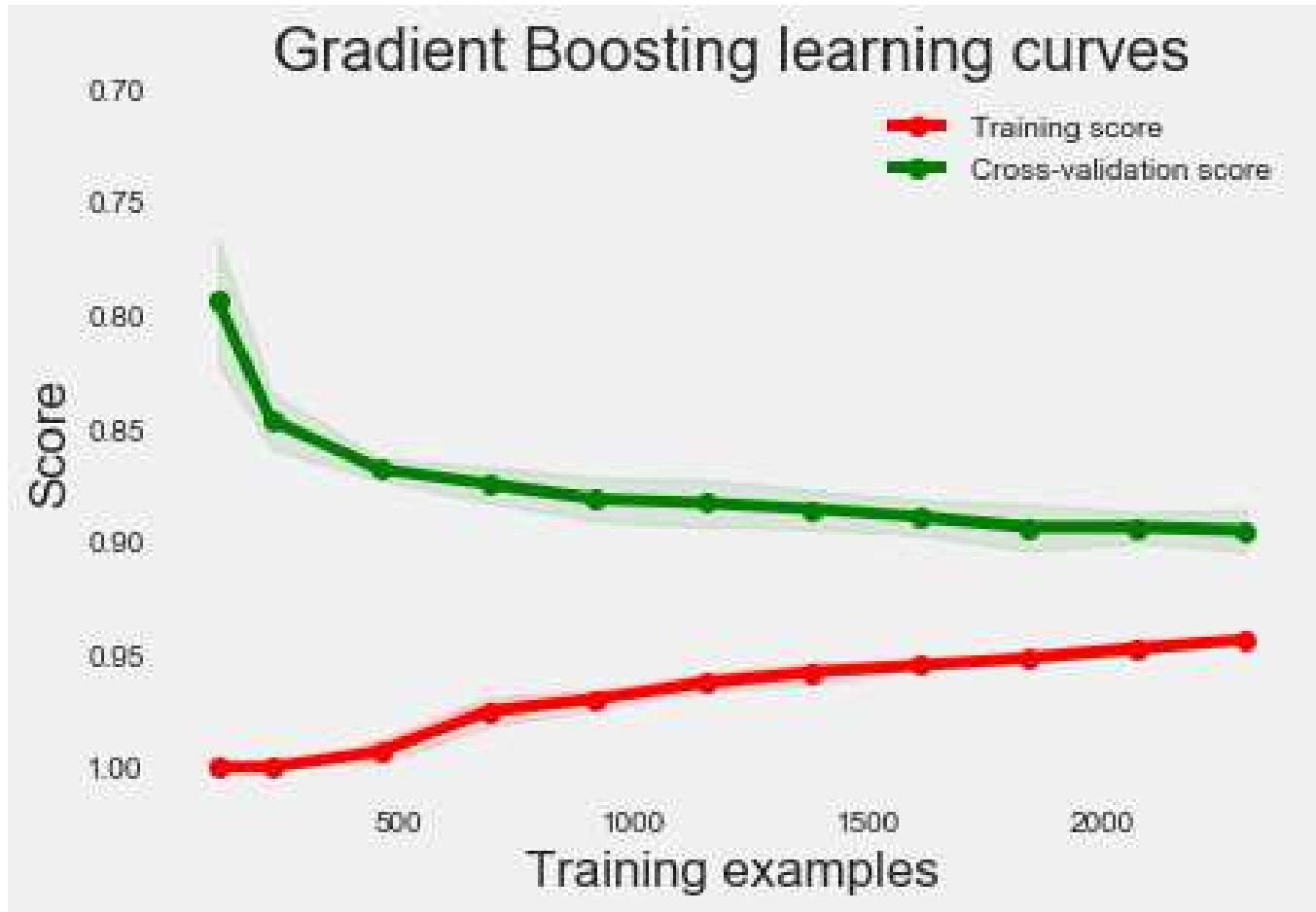


Figure 23: Gradient Boosting Learning Curve



LIST OF TABLES

1 Algorithms with their Precision Scores

26

**Table 1: Algorithms with their Precision Scores**

Algorithm	Precision(%)
Logistic Regression	72.99
KNN	68.44
Random Forest	75.93
Gradient boosting	75.74

## bibtex report

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

## bibtex \_ label error

bibtext space label error

bibtext comma label error

# latex report

[2017-12-12 19.57.23] pdflatex report.tex

```
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflate
Missing character: ""
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 1.2s.
```

..../README.yaml

```
30:14    warning  truthy value is not quoted  (truthy)
34:81    error    line too long (81 > 80 characters)  (line-length)
35:81    error    line too long (85 > 80 characters)  (line-length)
36:81    error    line too long (82 > 80 characters)  (line-length)
36:82    error    trailing spaces  (trailing-spaces)
37:81    error    line too long (82 > 80 characters)  (line-length)
38:79    error    trailing spaces  (trailing-spaces)
39:81    error    line too long (83 > 80 characters)  (line-length)
39:83    error    trailing spaces  (trailing-spaces)
```

```
40:81    error    line too long (82 > 80 characters)  (line-length)
40:82    error    trailing spaces  (trailing-spaces)
53:81    error    line too long (103 > 80 characters)  (line-length)
53:103   error    trailing spaces  (trailing-spaces)
54:81    error    line too long (104 > 80 characters)  (line-length)
54:104   error    trailing spaces  (trailing-spaces)
55:81    error    line too long (105 > 80 characters)  (line-length)
55:105   error    trailing spaces  (trailing-spaces)
56:81    error    line too long (107 > 80 characters)  (line-length)
57:81    error    line too long (110 > 80 characters)  (line-length)
58:81    error    line too long (111 > 80 characters)  (line-length)
59:81    error    line too long (116 > 80 characters)  (line-length)
59:116   error    trailing spaces  (trailing-spaces)
60:81    error    line too long (107 > 80 characters)  (line-length)
61:81    error    line too long (110 > 80 characters)  (line-length)
62:81    error    line too long (106 > 80 characters)  (line-length)
62:106   error    trailing spaces  (trailing-spaces)
63:81    error    line too long (110 > 80 characters)  (line-length)
68:27    error    trailing spaces  (trailing-spaces)
70:14    error    trailing spaces  (trailing-spaces)
```

---

## Compliance Report

---

```
name: Himani Bhatt
hid: 202
paper1: Nov 04 17 100%
paper2: Nov 27 17 100%
project: Dec 04 17 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
26
wc 202 project 26 8175 content.tex
wc 202 project 26 8196 report.pdf
wc 202 project 26 380 report.bib
```

```
find "
```

```
-----  
passed: True  
  
find footnote  
-----  
  
passed: True  
  
find input{format/i523}  
-----  
  
10: \input{format/i523}  
  
passed: True  
  
find input{format/final}  
-----  
  
passed: False  
  
floats  
-----  
  
112: The content of the dataset appears as shown in the Figure  
      \ref{data}.  
114: \begin{figure}  
116: \label{data}  
118: \includegraphics[width=\columnwidth]{images/DatasetContent.PNG}  
129: From the data we can see that there are 37 different countries  
      from which orders were placed. We can determine the number of  
      orders per country by a ‘Chloropeth’ map. A Chloropleth map  
      shown in Figure \ref{country} uses different colors and shades  
      within predefined areas to indicate quantities in those areas. \\  
131: \begin{figure}  
133: \label{country}  
135: \includegraphics[width=\columnwidth]{images/chloropleth.PNG}  
138: The Figure \ref{country} shows that maximum number of orders are  
      placed from UK.  
142: On observing the number of users, products purchased and number  
      of transactions made; we can see that these are not proportional.  
      This suggests that there were many transactions made for  
      cancelling the orders shown in Figure \ref{2.1}\\  
144: \begin{figure}  
146: \label{2.1}  
148: \includegraphics[width=\columnwidth]{images/2_1.PNG}
```

```

152: Also the orders with InvoiceNo starting with C are the cancelled
orders. The details are shown in Figure \ref{2.2}.
154: \begin{figure}
156: \label{2.2}
158: \includegraphics[width=\columnwidth]{images/2_2.PNG}
163: Almost 16\% (3654) of the transactions are corresponding to the
cancelled orders. In the dataset, corresponding to each cancelled
transaction we should have an order placed with same quantity of
products requested. While checking the same in the dataset, we
found the details shown in Figure \ref{2.3} for some of the
orders.\\
165: \begin{figure}
167: \label{2.3}
169: \includegraphics[width=\columnwidth]{images/2_3.PNG}
177: The StockCode variable should ideally contain letters. So we have
filtered out the codes with only letters. We can observe from
Figure \ref{2.4}, different type of transactions based on these
(example D is for discounted transaction).\\
179: \begin{figure}
181: \label{2.4}
183: \includegraphics[width=\columnwidth]{images/2_4.PNG}
188: We have added a new variable to indicate total price of the
purchase (by multiplying unit price of each product with quantity
purchased). Each transaction corresponds to the prices for a
single product. On grouping the records based on a single order,
we can see the complete price for that order as shown in Figure
\ref{2.5}.\\
190: \begin{figure}
192: \label{2.5}
194: \includegraphics[width=\columnwidth]{images/2_5.PNG}
197: We can visualize the orders distinguished on the basis of total
price of the basket. It can be shown as Figure \ref{2.6} using a
pie-chart.
199: \begin{figure}
201: \label{2.6}
203: \includegraphics[width=\columnwidth]{images/2_6.PNG}
211: Upon checking, we found that there are 1483 keywords present in
the description variable of the dataset. The most common keywords
can be determined based on the occurrences. The Figure \ref{3.1}
shows the top word occurrences.
213: \begin{figure}
215: \label{3.1}
217: \includegraphics[width=\columnwidth]{images/3_1.PNG}
236: The Figure \ref{3.2} shows silhouette score for different values
of k. These scores do not have significant differences, but since
for k value greater than 5, the resulting clusters have very few

```

elements in them, we have taken k as 5.  
 238: \begin{figure}[H]  
 240: \label{3.2}  
 242: \includegraphics[width=\columnwidth]{images/3\_2.PNG}  
 249: From the silhouette plot shown in Figure \ref{3.3} we can see  
 that cluster 1 has more number of elements than the other  
 clusters. But overall distribution of elements in the clusters is  
 comparative. Same can be seen from the Figure \ref{3.4}.  
 251: \begin{figure}  
 253: \label{3.3}  
 255: \includegraphics[width=\columnwidth]{images/3\_3.PNG}  
 258: \begin{figure}  
 260: \label{3.4}  
 262: \includegraphics[width=\columnwidth]{images/3\_4.PNG}  
 267: The main idea of principal component analysis (PCA) is to reduce  
 the dimensionality of a data set consisting of many variables  
 correlated with each other, either heavily or lightly, while  
 retaining the variation present in the dataset, up to the maximum  
 extent. The initial matrix has large number of variables and  
 hence, PCA is used for dimensionality reduction. From the  
 Figure\ref{3.5} we can say that we need more than 100 components  
 to explain 90\% of the variance in the data.\\  
 269: \begin{figure}  
 271: \label{3.5}  
 273: \includegraphics[width=\columnwidth]{images/3\_5.PNG}  
 276: Another application of PCA is that it sets the indication of  
 cluster membership. Biplot is the best example that can be  
 provided here to support this idea. Using biplot, we get the  
 indication of number of clusters in a dataset. Below Figure  
 \ref{3.6} shows these on limited number of components (since it  
 is only for visualizing cluster distribution). We can observe the  
 groupings of points or clusters as expected.\\  
 278: \begin{figure}  
 280: \label{3.6}  
 282: \includegraphics[width=\columnwidth]{images/3\_6.PNG}  
 288: In the previous section, we have divided products in 5 clusters.  
 We have added a dummy variable categ\\_product to indicate the  
 cluster to which that customer belongs. Based on the clustering  
 done on products we have created variables categ\\_0..4 which  
 stores amount spent on each of the product category. And the  
 categ\\_product variable which we have just created will have  
 initial cluster assignment based on these variables. These can be  
 further grouped on the basis of InvoiceNo as shown in Figure  
 \ref{4.1}.\\  
 290: \begin{figure}  
 292: \label{4.1}

```

294: \includegraphics[width=\columnwidth]{images/4_1.PNG}
303: In the previous section we have seen the basket price of each
     invoices. For further analysis we will combine these on the basis
     of customerID to analyze the number of purchases made by each
     customer as shown in Figure \ref{4.2}. A customer category of
     particular interest is that of customers who make only one
     purchase. So one objective may be, for example, to target these
     customers in order to retain them. In the dataset we have almost
     one-third of the customer base similar to this.
305: \begin{figure}
307: \label{4.2}
309: \includegraphics[width=\columnwidth]{images/4_2.PNG}
317: Using the silhouette score, the optimum value of k comes out to
     be 11. The assignment of customers into different clusters is
     shown in Figure \ref{4.3}
319: \begin{figure}
321: \label{4.3}
323: \includegraphics[width=\columnwidth]{images/4_3.PNG}
330: There is a certain disparity in the sizes of different groups
     that have been created. So we have validated it using PCA. From
     the representation shown in Figure \ref{4.4}, it can be seen, for
     example, that the first principal component allow to separate the
     tiniest clusters from the rest. More generally, we see that there
     is always a representation in which two clusters will appear to
     be distinct.\\
333: \begin{figure}
335: \label{4.4}
337: \includegraphics[width=\columnwidth]{images/4_4.PNG}
342: As with product categories, another way to look at the quality of
     the separation is to look at silhouette scores shown in Figure
     \ref{4.5} within different clusters:\\
344: \begin{figure}
346: \label{4.5}
348: \includegraphics[width=\columnwidth]{images/4_5.PNG}
374: In the Python code, we have imported the module ‘linear\_model’
     from the ‘sklearn’ package to perform Logistic Regression by
     using the function ‘logistic\_regression’. And we have taken the
     $k=5$ for k-fold cross validation. While performing Logistic
     Regression, we created an instance of the Class\_Fit class and
     then ran the model on training data and see how the predictions
     are made as compared to the real values. The learning curve graph
     is as shown in Figure \ref{5.1}.
376: \begin{figure}
378: \label{5.1}
380: \includegraphics[width=\columnwidth]{images/5_1.png}
383: As we can see from the Figure \ref{5.1}, when the number of

```

training examples increases, the cross-validation and train curves almost converge towards the same limit suggesting that the model has low variance. Thus we can say that model is not suffering from over-fitting. Also one point to note is that the accuracy is high, which means that the model has low bias, thus suggesting that it does not under-fit the data. The precision which we got from running the Logistic Regression model on the training data is 88.78\%.

394: In Python, the ‘neighbors’ library is imported from the sklearn package which performs the KNN classification through the KNeighborsClassifier function. The parameters that are used are ‘n\\_neighbors’ which represents the number of neighbors to use, in our case we have used the np.arange method to give sequence from 1 to 49. Also, we run the model using the K-fold Cross Validation with the value of \$k=5\$. Once the model is run, we have drawn the learning curve graph which is as represented in the Figure \ref{5.2}.

396: \begin{figure}

398: \label{5.2}

400: \includegraphics[width=\columnwidth]{images/5\_2.png}

410: In Python, the ‘ensemble’ library is imported from the sklearn package which performs the Random Forest classification through the RandomForestClassifier function. The parameters given to this function are criterion, n\\_estimators and max\\_features. The criterion is used to measure the quality of the split. The Gini is for measuring the Gini impurity and Entropy is for information gain. The max\\_features are the number of the features that can be chosen when looking for the best split. For ‘sqrt’, the number of maximum features chosen are square root of the number of the features and for ‘log’, it is log of the number of the features. And the n\\_estimators is the number of trees in the forest. Once the model is run, we have drawn the learning curve graph which is as represented in the Figure \ref{5.3} .

412: \begin{figure}

414: \label{5.3}

416: \includegraphics[width=\columnwidth]{images/5\_3.png}

436: In Python, the ‘ensemble’ library is imported from the sklearn package which performs the Gradient Boosting classification through the GradientBoostingClassifier function. The parameter given to this function is n\\_estimators which is the number of boosting stages to perform. Gradient boosting is fairly robust to over-fitting so a large number results in better performance. Learning curve is shown in the Figure \ref{5.4}.

438: \begin{figure}

440: \label{5.4}

442: \includegraphics[width=\columnwidth]{images/5\_4.png}

452: So now, we have the data available for two months, and through that we can define the category to which the consumer belongs. The predictions now obtained by running the classifiers on test data can be tested against these categories. The instance of the k-means clustering method that we used in the Customer Categories section is used to define the category to which a client belongs. This contains the predict method which will calculate the distance of the consumers from the centroids of the 11 categories that we deduced, and the category which is closest to the clients' buying habits will define his/her category. Thus all we need after this for the execution of the classifier is to select the variables on which it acts, i.e. on mean, cat\\_0, cat\\_1, cat\\_2, cat\\_3 and cat\\_4. After examining the predictions of the different classifiers, we get precision scores as shown in Table \ref{t:precisionscore}.\\"

454: \begin{table}[htb]  
457: \label{t:precisionscore}

figures 23

tables 1

includegraphics 23

labels 24

refs 25

floats 24

False : ref check passed: (refs >= figures + tables)

True : label check passed: (refs >= figures + tables)

True : include graphics passed: (figures >= includegraphics)

True : check if all figures are referred to: (refs >= labels)

Label/ref check

passed: True

When using figures use columnwidth

[width=1.0\columnwidth]

do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

WARNING: algorithm and below may be used improperly

355: In the previous section, we have made different client categories. In this part we will adjust a classifier so that the consumers can be classified in different client categories. The main aim of this is to enable the Classification on the first visit of the customer. To do this, we have defined a class that will allow interfacing the common functionalities to the different classifiers. Since we are going to classify the client on the basis of his/her first visit, the only parameters that we take into consideration are the contents of the basket and not the frequency of visits or the variation in the basket price over a period of time. Once this is done, we have split the dataset into train and test sets. The classification algorithms which we used to do this are mentioned below.\\

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

ascii

---

```
non ascii found 8220  
non ascii found 8221
```

```
=====  
The following tests are optional  
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

```
-----  
passed: True  
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

```
-----  
passed: True
```

# Big Data Analytics in Product development management

ZhiCheng Zhu

Indiana University Bloomington

936 S Clarizz Blvd

Bloomington, Indiana 47401

zhuzhic@iu.edu

## ABSTRACT

The success of a new product is to a large extent due to whether the producer making efficient and accurate strategies between the different stages of a product lifecycle. Big Data analytic techniques have the potential to improve the efficiency of product development, making accurate product strategy, channel strategy, pricing strategies and promotional strategies in the different period of a product lifecycle. In this project, I will try to figure out how the data affect the decision making and try to use the relation between different twitter account to describe the potential of the Big data also I will describe decision trees and PageRank and how do these tools produce a good market segmentation and market positioning for a product.

## KEYWORDS

i523, hid229, Big data, Product Development, Technology

## 1 INTRODUCTION: BIG DATA

The advent of technology has resulted in virtually all industries and organizations collecting large volumes of data. The data collected results from diverse source, which include product sales, customer information, historical industry data, and employee information just to mention a few. Computers and the internet in particular have made it easier to collect data of different kinds because they make it easy to create, store, transfer, and analyze data. As a result, data has become a critical asset for many organizations and corporations in their bid to control the markets of the products or services they offer consumers. Furthermore, According to Arora, big data also refers to large and complex dataset [13]. This means that it is virtually impossible to use traditional processing applications to organize and analyze this data. Therefore, there are various challenges associated with big data due to its large volume and complexity [1]. These problems include data capture, data storage, data analysis, sharing of the data, making searches on the data and the privacy of the information [? ]. Information increasingly becomes an important factor in determining the success of a product. A few years ago, manufacturing and the Internet have still belonged to two different separated industries, But as the mainstream consumer groups changed from old generation to Millennial generation, and the use of computers and the establishment and application of the Internet have produced a violent shock to the traditional way of product development, thus resulting in a new product development strategy. I have to say that the relation between the manufacturing and the Internet are getting closer and closer. One of the major changes might cause by using big data as a technique to develop right product and make effective promotion strategy.

[Figure 1 about here.]

## 2 EXAMPLES OF BIG DATA

For example, organizations with an online presence such as online market places collect data from their clients. This includes different types of data such as customer information, purchases, and time spent on the website. For very large organizations (such as Amazon or eBay) dealing with thousands and probably millions of customers daily, this type of data soon becomes voluminous and difficult to analyze. For effective analysis, such data needs large physical storage space and organization in ways that will make it usable and of benefit to the organization [1]. The main solution to this problem is the use of a data warehouses since traditional databases are too basic to handle the complexities involved with big data. Data warehouses provide the much-needed processing power needed in handling and analyzing big data [1]. Another issue is Outdated decisions and information are bound to create disadvantages when competing with other companies, but the traditional data processing system is obviously not suitable for the era of big data. Corporate decision-makers must adopt new technologies to face the changes of the times and customer. For example, Hadoop technology is a new and widely accepted technology.

- “Hadoop is an open-source software framework for storing data and running applications on clusters of commodity hardware. It provides massive storage for any kind of data, enormous processing power and the ability to handle virtually limitless concurrent tasks or jobs[9].”

[Figure 2 about here.]

### 2.1 Application of Big Data in Product Development

how to clean the data and find useful data more quickly in product development is even more important. Quickly identify the characteristics of the target customers and their possible needs for a variety of products. base on the analysis, we can develop some products that more suitable for marketplace needs, or we can be more accurate when we try to find our potential target customer. According to different consumer behavior, we can design different software, for example, during the financial turmoil we found that lots of users are price sensitive, we can design a kind of software that can provide local discount merchandise information in real time. If the target customer is a group which wants higher quality of life, we can push more high value-added product. One of the most vital areas where big data finds use is in product development management. The product development process allows for the design and release of new products into the market. Product development also involves processes such as forecasting, planning, and marketing of new products. The process adopted ensures that first the product developed meets a certain need in the market.

Second, the process certifies that the price set reflects the amount consumers are willing to pay. Lastly, it guarantees the organization is making the product in such a way that it will be able to reach the targeted market. Typically, an organization will collect market data from various systems.

- For instance, transaction-processing systems provide invaluable data to organizations [11]. An example of a company that uses big data is the online market place Amazon. The market place has thousands of products stocked by the company and by third party sellers using the platform to sell their products. The checkout system in such an organization will collect very important data such as the products sold, the customers buying the products, the time of purchases and such details [14]. The details of the customers will probably include the age and gender of the customer. When the company analyzes such data, it provides the management with a vital insight into the business activities and performance. Such as SEM analysis, SEM analysis is a research and analysis methods which focus on customer satisfaction. This is a good way to make a classification for our users. One of the most typical examples is some recommender systems such as Pandora use songs or artist properties to create a radio station, all of these songs and artist have similar attributes. User feedback is used to adjust the content of the radio and recommend some music which is more attractive to the listener.

### 3 ANALYSIS OF CUSTOMER NEEDS AND MARKET DEMAND

#### 3.1 Anticipating Customer Needs for New Products

For instance, using the data collected from the checkout system, the company can tell what type of products are likely to be bought and by which customers [14]. Using information about customers contained in other systems such as customer relationship management (CRM) systems, the company can get information about the people likely to purchase a certain product, at what time they are likely to make the purchases, and the other goods they are likely to purchase with the products [14]. The company can then use such information to make decisions on which products to stock, what price to sell them, which products to suggest to clients as they are making purchases and the time of day, week and even year that such products are in demand. For instance, Walker points out that big data plays an important role in helping Amazon launch new products. In particular, the data collected by the organization on books played a central part in the establishment of the Amazon Kindle product, which is highly successful in the market [14].

#### 3.2 Inventory Management

Therefore, with the help of big data, product developers and manufacturers are able to ensure that the products needed by the customers are available in the right quantities and at the right times [4]. For example, a person purchasing a large flat screen television is also likely to purchase wall brackets for mounting the television set. The company can also get information on what brand and size

of TV sets are in demand. The company can then ensure that it stocks such products when they are in demand. Because of the increased competition, profit margins can be very small. This requires the company to ensure efficiency to ensure that it avoids issues such as dead stock, which have negative impacts on profitability. Getting the right amount of products is critical as it ensures that the company meets all the demand and there are no excess items, which are a cost to the organization [11].

### 3.3 Anticipating Customer Demands

[Figure 3 about here.]

In addition, using big data, product developers able to anticipate demand for new products and it can therefore embark on developing such products and ensure that customers get the products. For example, Facebook the social media giant employs big data in making decisions on how to present its services for clients [8]. For instance, the company collects data on user activity on its platform [8]. Using this information, the company is able to present an interface customized to a specific user. Such data also finds use in targeted advertising, which is one of the key ways in which such companies make majority of their revenues. In 2013, Morabito pegs the revenue drawn by Facebook from advertising at almost 8 billion dollars [8]. The use of big data by the company has made it able to forecast the needs of the market and provide users with products and services that the customers find useful. This has resulted in the company becoming the world's most used social media site and maintain its advantage over its rivals, some of which the company has ended up buying out. What is worth to mention is that some Big Data technique can help these company decide which user are more worthy of advertising. According to what I got from my programming, some people with a high degree centrality in their tweet network has a higher value than other people with a sparse network. Because the dense network can spread the information faster with a lower cost.

### 4 MANAGEMENT OF THE PRODUCT DEVELOPMENT CYCLE

In product development management, a product passes through various stages in the lifecycle. The main stages are product research and development stage, the introduction stage, the growth stage, maturity stage and the decline stage [13]. Big data can help to ensure that a company develops a product that maximizes returns in each of the main stages. Once the product is in decline, the company also has the information needed to make decisions on the products it will introduce that will ensure that the company maintains its competitive advantage on the market.

#### 4.1 Research and Development

In the product research and development stage, an organization will collect large amounts of data from the public, from its own internal systems or data from third parties [2]. Such data will contain information on the type of products favored by the market. The company will analyze this data and come up with information that its management can use to improve the overall decision-making process [2]. Using the example of the online retailer Amazon, the company can use big data to carry out research and development

processes to determine that many customers want an easier way of making payments. The organization can obtain such information directly from customers, as well as, based on received feedback. For example, the company could notice trends in customers who browse for items but abandon the purchase when they are required to pay. This may be because the payment methods offered by the company are difficult or customers are not confident in them. Using such information, the company can decide to introduce alternative ways to make payments, which are easy to use.

## 4.2 Introduction Stage

Big data also proves to be very useful in the introduction stage. For instance, a company selling warm winter clothes would not be successful if such items in summer. The main reason for this is that at the time, customers are not in need of the products. Organizations can derive such information by analyzing data on the type of purchases made by customers in different periods of the year.

## 4.3 Growth Stage

Furthermore, the growth stage is also vital for any product in the market. During this stage, the product introduced by the company gains a foothold in the market [13]. During this stage, more and more customers learn about the product and they are likely to make a purchase. Using big data can be advantageous to a company as it can help it to organize its marketing appropriately. The purpose of this is to ensure that the products reach the widest coverage [2]. Big data can also help the company in making decisions such as which locations to introduce the product.

## 4.4 Maturity Stage

Similarly, in the maturity stage of the life cycle of a product, the product has already gained a foothold in the market and its growth slows down [13]. Big data can help the company to make decisions that will enable the product to maintain growth during this stage for the longest time.

## 4.5 Decline Stage

The decline stage occurs after a product has been in the market for a while and probably newer technologies have become available reducing the usefulness of the product to the market [3]. Big data can help the organization in this stage of the product life cycle by ensuring that the product remains available for people who still need the product. For example, smartphone use has overtaken the use of feature phones in the market. Feature phones offering simple functions have therefore reached the decline stage of the cycle. Despite the noted decline in the global environment, in many developing countries feature phones remain in demand due to factors such as battery life and cost. Using big data, a company manufacturing feature phones can understand its market and therefore be able to ensure that supply to such markets remains available. Moreover, by the decline stage of the product life cycle, the company dealing with the product is likely to have begun the research into the next product that it will offer to clients that will meet their emerging needs. Big data, which will consist of data collected from the lifecycle of the previous product, will prove to be very useful in the development of the new product. As the name

suggests, this is a lifecycle and the process should ideally continue indefinitely for the company. This ensures that the company is always ready with a new product that is able to meet the demand of clients in the market. Constant innovation is vital in the modern market where competition is very high. Nokia Corporation, once the largest manufacturer of cell phones is an example of a company that failed because of not innovating constantly. In the mid-2000s when competing firms introduced the first smartphones, Nokia was the dominant player. According to Robbins, Rolf, Ian, and Mary by 2007 Nokia controlled 40 percent of the global mobile phone market [3]. However, because of poor forecasting, the company continued to manufacture its previous phones and soon it lost its market share to other companies manufacturing smartphones such as Apple [12]. The use of big data in making decisions during the product lifecycle can help a company to avoid making such mistakes, which may prove to be catastrophic. From the analysis above, it is evident that during the different stages of the product lifecycle, there are different strategies that organizations can employ. For example, product manufacturers and sellers can utilize different marketing strategies during the different stages of a product's lifecycle. The marketing strategy that is useful in the introduction stage may not be as effective during the growth stage of the product. The production strategy employed during the introduction stage may be very effective but the same strategy when employed during the growth stage or other subsequent stages may not be very effective. Big data therefore helps an organization to make the best decisions on different strategies based on the information obtained from analyzing the data. This ensures that the strategies selected for various activities during the different stages of the product's life are the most appropriate which ensures that the company is able to gain the most benefits from its products.

# 5 BIG DATA ANALYSIS METHODS

In big data, organizations can adopt different analytic methods in order to extract useful information. Data in its raw form is not very useful to an organization. Analysis of the data ensures organizations come up with patterns emerging in the data with the aim of improving the decision making process. The analytical method chosen for analysis of big data depends on various factors such as the type of data available (e.g. qualitative or quantitative), the amount of data available and the result desired. Among the most common analysis methods in big data are Decision tree analysis, PageRank, and kNN algorithm.

## 5.1 The Decision Tree Analysis

The decision tree analysis is a method of analyzing data that uses a graph in the shape of a tree, hence the name. In this method of analysis, a decision maker considers a decision and its resulting consequences [16]. These consequences include the chance of the consequence occurring, the costs involved when the consequence occurs and how useful the consequence is for the organization. The initial decision represents a node and the possible consequences are the branches [5]. Each consequence then becomes another node and the tree represents consequences in further branches [5]. When using a decision tree to make a decision, the decision maker selects the path that is most likely to lead to the desired solution. Big

data requires the analysis of large amounts of data. A decision tree algorithm will analyze the data available and present a decision tree with all the possible paths (the connections between nodes and branches) based on the information available [5]. For example, the decision to select a particular marketing strategy will show the chance of it achieving the result, the costs involved, and the utility to the company, depending on the information obtained from the large data sets. This will therefore present different paths based on the different strategies chosen. Usually, the decision maker will make a decision by selecting the path of least resistance. Usually this path contains the best attributes needed by the organization. For instance, one path may be more costly than a different path based on the strategy chosen but they eventually lead to the same result. The path that costs less will therefore be best suited for the organization since it will allow it to achieve its objective more efficiently. Lastly, because making a decision will lead to different consequences (which in themselves require other decisions) the path that best suits the organization results from the final objective through the path of branches and nodes that best meet the needs of the organization [5].

## 5.2 PageRank

PageRank is an algorithm named after Larry Page who was a co-founder of the search giant and technology company Google. This algorithm finds use in ranking the search results on the search site [17]. This algorithm works by counting the number and quality of links to a webpage. This algorithm helps to determine the quality of the information on the different WebPages with information related to the search queries entered [7]. Based on the quality and number of links pointing to a page, the algorithm is able to determine the quality of the webpage [17]. This then results in the page receiving higher ranking in search results. PageRank is very important as it helps the search giant to present the most relevant answers to queries made on its site.

For instance, one webpage may contain very many links concerning the search query but the information contained on the webpage may not be of the highest quality. This means that another webpage with higher quality information even with fewer links can still rank higher than the other webpage [7]. This algorithm works by using data generated from previous searches with similar queries. Such an algorithm makes extensive use of big data to ensure that it presents the most appropriate results for a person making a query.

## 5.3 k-NN algorithm

The k-NN algorithm is an algorithm used in pattern recognition [15]. It finds use in both classification and regression. This is the simplest form of machine learning as it uses an approximation of values nearest to the value under analysis. For instance, in classification, the desired output is class membership. The algorithm achieves this by looking at the nearest neighbors of the value under inspection. The value receives assignment to the class to which most of its nearest neighbors belong. In regression, the desired output is typically the property value of the object under study. This is obtained by getting an average of the values of the objects that are the immediate neighbors of the object being inspected. This means that the nearest neighbors to an object contribute more

towards its value than objects that are located further away from the object inspected. This means that using these algorithms, the values of an object can be predicted accurately, which helps in making complex decisions easier based on the immediate results expected [15].

## 6 BIG DATA ANALYTICS AND DECISION MAKING

### 6.1 Big Data and Competitive Advantage

Data as previously mentioned is one of the most important assets for any business. This data needs to be analyzed so as to come up with usable information that help the management of the organization to make decisions that are likely to succeed in the market. Because of the increased competition in the modern business environment, many organizations have employed big data to help them make decisions such as how to arrange items in stores, what items to stock, the prices that are best for the market and such decisions [14]. Although these decisions might look simple, it is very important for an organization to get them correct. Miscalculations made in such decisions could lead to losses including financial and market share losses. This is because modern customers want value for their money. This means that the organization must offer the best possible services at the lowest cost. Furthermore, this makes them attract more customers for their products or services and in the process enable them to make a higher margin. Because most competitors will use some form of data to make their decisions, it is very easy for an organization or company to lose its competitive advantage to its competitors [14]. Many organizations consider making accurate decisions in an efficient way a critical aspect of their competitive advantage. For instance, a company can release a product before the competition releases their version. Customers will buy the product already in the market allowing the organization to gain a market advantage over the rivals who have not released their product. Big data has made it possible for such organizations to obtain patterns from extremely large data sets, which are more accurate and therefore likely to produce accurate decisions [14]. Another strategy can help our product to attract more customers is using the internet hub node to spread the information about our product and advertising on the network, the network hub node is a node with a number of links that greatly exceeds the average. for example, Donald Trump's Twitter is one of the most popular node in Twitter network. If someone can lobby Trump to promote the product I believe we will have increasingly more customer growth. These hubs play the same role such as what Macy's used to play. Macy's used to be a big node for people's Holiday purchase. because it attracts most of the people living in that area to enter the store. The famous Twitter account attract their follower because they have a fancy lifestyle or fulfill some value their follower admired. all of these are helpful for product promotion and the spread will have a more incredible efficiency and effectiveness.

## 7 CONCLUSION

In conclusion, despite the use of big data already being widespread in the business world, its importance will continue to grow with time. This is because of the large number of devices that are now generating data. The Internet of things has resulted in a situation

where even everyday appliances connect to the internet and they have the ability to collect large amounts of data. This results in more data that organizations can analyze to discover patterns in the market that organizations can exploit. Organizations are also overcoming the challenges facing big data with the collection of data now largely automated from different systems internal and external to the organization. Moreover, specialty companies have come up with the sole purpose of collecting and analyzing market data. Manufacturers are offering solutions to the technological challenges involved in big data by developing larger storage devices that are able to store increasing amounts of data efficiently. The security of such information has seen significant improvements with more secure communication and storage channels. The use of big data is also set to increase as current analytic methods become efficient. New analytic methods are also likely to be developed that will ensure that the data collected from independent systems and the market are analyzed better in order to develop information that can be acted upon more readily in the market. This point to a future where big data will be more important than ever in ensuring that companies come up with products and strategies that enable them to be more competitive in the market and therefore increase their chances of survival in the market.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski for his support and suggestions to write this paper as well as TAs' helpful suggestions on this paper.

## REFERENCES

- [1] Ritu Arora. 2016. Conquering Big Data with High Performance Computing. (2016).
- [2] Ron Basu. 2016. *Managing Projects in Research and Development*. Abingdon, Oxon : Routledge, 0.
- [3] Louis E Boone. 2013. *Essentials of Contemporary Business*. Hoboken. New Jersey : John Wiley & Sons, 0.
- [4] Jeanne G. Harris Robert Morison Jinho Kim Davenport, Thomas H and D J. Patil. 2014. *Analytics and Big Data*. Boston Massachusetts : Harvard Business Press, 0.
- [5] Mohammed Guller. 2015. *Big Data Analytics with Spark: A Practitioner's Guide to Using Spark for Large-Scale Data Processing, Machine Learning, and Graph Analytics, and High-Velocity Data Stream Processing*. New York: Springer, 0.
- [6] insideBIGDATA. 2017. The Exponential Growth of Data. Web page. (February 2017). <https://insidebigdata.com/2017/02/16/the-exponential-growth-of-data>
- [7] Amy N Langville and Meyer C D. 2006. *Google's Pagerank and Beyond: The Science of Search Engine Rankings*. Princeton, NJ: Princeton University Press, 0.
- [8] Vincenzo Morabito. 2015. *Big Data and Analytics: Strategic and Organizational Impacts*. 0.
- [9] The power to know. 2007. What is hadoop? (Nov. 2007). [https://www.sas.com/en\\_us/insights/big-data/hadoop.html](https://www.sas.com/en_us/insights/big-data/hadoop.html)
- [10] Media Insight Project. 2015. How Millennials Get News: Inside the habits of America's first digital generation. Web page. (March 2015). <https://www.americanpressinstitute.org/publications/reports/survey-research/millennials-news/single-page/>
- [11] Foster Provost and Tom Fawcett. 2013. *Data Science for Business: What You Need to Know About Data Mining and Data-Analytic Thinking*. Sebastopol, CA: O'Reilly Media, 0.
- [12] Rolf Bergman Ian Stagg Robbins, Stephen and Mary Coulter. 2014. *Management Vs. Sydney*: Pearson Education Australia, 0.
- [13] John Stark. 2015. *Product Lifecycle Management: Volume 1*. Cham: Springer, 0.
- [14] Russell Walker. 2015. *From Big Data to Big Profits: Success with Data and Analytics*. NY: Oxford University Press, 0.
- [15] Jia Yingmin and Du Junping. 2017. *Proceedings of 2017 Chinese Intelligent Systems Conference: Volume I*. S.l.: Springer Verlag, 0.
- [16] Jie Lu Zhang, Guangquan and Ya Gao. 2015. *Multi-level Decision Making: Models, Methods and Applications*. Heidelberg: Springer, 0.
- [17] Albert Y Zomaya and Sherif Sakr. 2017. *Handbook of Big Data Technologies*. Switzerland : Springer, 0.

#### LIST OF FIGURES

1	Difference between various generations [10]	7
2	The Exponential Growth of Data [6]	7
3	Hub Node in network	8

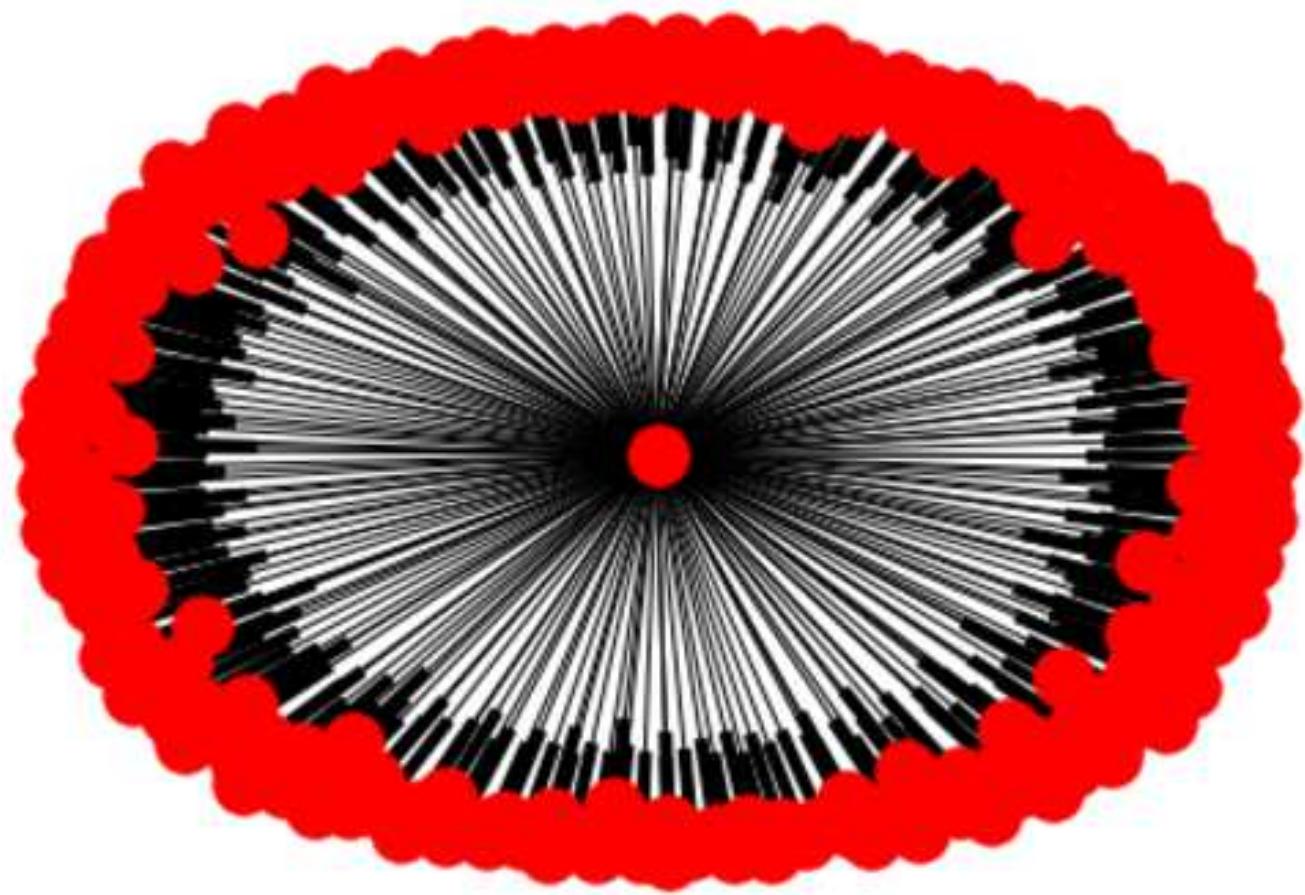
**88%**  
**of Millennials get news from Facebook** 

Figure 1: Difference between various generations [10]



Figure 2: The Exponential Growth of Data [6]

hub node with high in-degree.png



**Figure 3: Hub Node in network**

bibtext report

=====

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib  
Warning--I didn't find a database entry for "Sivarajah2017"  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2

while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, J...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t...  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte...

while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3131 of file ACM-Reference-Format.bst  
Warning--no journal in Arora2016  
Warning--no number and no volume in Arora2016  
Warning--page numbers missing in both pages and numpages fields in Arora2016  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3229 of file ACM-Reference-Format.bst  
Warning--empty publisher in Morabito2015  
Warning--no journal in sas1

```
Warning--no number and no volume in sas1
Warning--page numbers missing in both pages and numpages fields in sas1
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t
while executing---line 3229 of file ACM-Reference-Format.bst
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t
while executing---line 3229 of file ACM-Reference-Format.bst
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t
while executing---line 3229 of file ACM-Reference-Format.bst
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201
while executing---line 3229 of file ACM-Reference-Format.bst
(There were 80 error messages)
make[2]: *** [bibtex] Error 2
```

latex report

=====

[2017-12-12 19.59.13] pdflatex report.tex

This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)

```
p.1 L33 : [Sivarajah2017] undefined
Missing character: ""
There were undefined citations.
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
File 'images/gain information.png' not found.
File 'images/single hub node with high in-degree.png' not found.
Typesetting of "report.tex" completed in 1.0s.
```

```
=====
Compliance Report
=====
```

```
name: ZhiCheng Zhu
hid: 229
paper1: 100% Oct 27 2017
paper2: 100% Nov 06 2017
project: 100%; 12/4/2017
```

```
yamlcheck
-----
```

```
wordcount
-----
```

```
8
wc 229 project 8 4377 report.tex
wc 229 project 8 4537 report.pdf
wc 229 project 8 497 report.bib
```

```
find "
-----
```

```
passed: True
```

```
find footnote
-----
passed: True

find input{format/i523}
-----
4: \input{format/i523}

passed: True

find input{format/final}
-----
passed: False

floats
-----
35: \begin{figure}(!ht]
36: \centering\includegraphics[width=\columnwidth]{images/gain
    information.png}
38: \label{Figure 3}
47: \begin{figure}(!ht]
48: \centering\includegraphics[width=\columnwidth]{images/data-growth-
    rate.png}
50: \label{Figure 1}
68: \begin{figure}(!ht]
69: \centering\includegraphics[width=\columnwidth]{images/single hub
    node with high in-degree.png}
71: \label{Figure 2}

figures 3
tables 0
includegraphics 3
labels 3
refs 0
floats 3

True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
False : check if all figures are referred to: (refs >= labels)
```

Label/ref check

```
37: \label{Figure 3}
49: \label{Figure 1}
70: \label{Figure 2}
passed: False -> labels or refs used wrong
```

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find textwidth

---

passed: True

---

below\_check

---

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--I didn't find a database entry for "Sivarajah2017"
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa
while executing---line 3085 of file ACM-Reference-Format.bst
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinh
while executing---line 3085 of file ACM-Reference-Format.bst
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinh
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa
```

while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3085 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017

while executing---line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinh  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinh  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinh  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinh  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3131 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya201  
while executing---line 3131 of file ACM-Reference-Format.bst  
Warning--no journal in Arora2016  
Warning--no number and no volume in Arora2016  
Warning--page numbers missing in both pages and numpages fields in Arora2016  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3229 of file ACM-Reference-Format.bst

Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jinho Kim, and D J. Pa  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Davenport, Thomas H, Jeanne G. Harris, Robert Morison, Jim  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Langville, Amy N, and Meyer C D" has a comma at the end for entry Langville20  
while executing---line 3229 of file ACM-Reference-Format.bst  
Warning--empty publisher in Morabito2015  
Warning--no journal in sas1  
Warning--no number and no volume in sas1  
Warning--page numbers missing in both pages and numpages fields in sas1  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Provost, Foster, and Tom Fawcett" has a comma at the end for entry Provost201  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulter" has a comma at t  
while executing---line 3229 of file ACM-Reference-Format.bst  
Too many commas in name 1 of "Robbins, Stephen, Rolf Bergman, Ian Stagg, and Mary Coulte  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017  
while executing---line 3229 of file ACM-Reference-Format.bst

```
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Yingmin, Jia, and Junping, Du" has a comma at the end for entry Yingmin2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zhang, Guangquan, Jie Lu, and Ya Gao" has a comma at the end for entry Zhang2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya2017
while executing---line 3229 of file ACM-Reference-Format.bst
Name 1 in "Zomaya, Albert Y, and Sherif Sakr" has a comma at the end for entry Zomaya2017
while executing---line 3229 of file ACM-Reference-Format.bst
(There were 80 error messages)
```

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

144: note = "",

passed: False

ascii

---

non ascii found 8217  
non ascii found 8217  
non ascii found 8217  
non ascii found 8217

---

The following tests are optional

---

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Big Data in Safe Driver Prediction

Jiaan Wang

Indiana University Bloomington  
3209 E 10 St  
Bloomington, IN 47408  
jervwang@indiana.edu

Dhawal Chaturvedi

Indiana University Bloomington  
2679 E 7th St  
Bloomington, Indiana 47408  
dhchat@iu.edu

## ABSTRACT

For years, people have been trying to reduce their automobile insurance bills. Insurance companies claim that price will be reduced for good drivers and raised for bad ones. However, inaccuracies in their data predictions lead to the exact opposite. The data-set being used is released by Porto Seguro, an auto and homeowner insurance company from Brazil. It consists of information from several hundred thousands of policyholders. The goal is to predict the probability an auto insurance policyholder files a claim the next year using classification algorithms. A good prediction with decent accuracy can correctly adjust prices for policyholders.

## KEYWORDS

i523, HID233, HID204, Big data, Classification, Safe Driving, Predictive Analytics, Neural Networks

## 1 INTRODUCTION

Everyday, people die from car accidents and it should come as no surprise that automobile accidents are one of the most common causes of death in the United States [11]. As reported by the CDC, Centers for Disease Control, approximately over 40,000 people lose their lives to fatal automobile accidents each year. It should be clear that we need to enhance road safety for drivers all over the states [7]. However, as we are currently in the age of big data, these automobile accidents could be prevented by using modern technologies and methods such as artificial intelligence and predictive analytics.

Big data describes large quantities of data that are impossible to analyze using traditional data analysis methods. It includes structured and unstructured data. Structured data can be SQL database stores and unstructured data can be videos, images, social media feeds, etc. In industries, data analytics is often performed on big data in order to find specific patterns or anomalies that could prove useful for business decisions and choices. The amount of data is usually irrelevant in these cases. For example, smart cars utilize big data to improve their safety features and systems. They collect data such as driving patterns and routes as they travel from point A to B. This information is then sent to the computers onboard and gets transferred to the company servers where the data undergo analysis. The result is then collected and stored to enhance smart-car systems [13].

Big data is also helpful in providing insights for product development. It can find the causes for issues and problems in products through data analytics, which can then be used to improve the design. For example, the driver assistance feature on a Mercedes-Benz car not only has safety features but also collects data on driving habits. If large amount of drivers speed through intersections or

break hard during traffic hours, the company can obtain these information and use them properly to enhance their systems for better road safety. They could add a detector with GPS data to spot intersections or traffic jams. Furthermore, another data that are useful to collect are driving routes. Google Street View utilizes big data from driving routes to update their maps and display views of different places [13].

Aside from smart cars, we also need to master data collection in order to know how automobile accidents happen. For example, the technology behind the famous black box, which tracks planes and cockpit communications to determine the reason behind crashes, is getting used in cars as well. It is not expensive nor complicated to apply this technology onto the majority of vehicles out there. By recording the precise time, locations, speed and other variables, this technology can definitely help us collect valuable data and information in car accidents. The result from data analysis can also assist us in a deep understanding of causes behind automobile collisions in order to save more lives by preventing future accidents. The first country who thought to implement this technology on cars was South Korea. As a result, in the following year, a 14 percent decrease was saw in the number of car accidents along with a 20 percent decrease in the number of injuries and deaths of fatal automobile accidents [7].

Predictive analytics is a powerful method in big data analytics to help predict future events or outcomes based on current and historical data. It usually utilizes big data techniques such as data mining, predictive modeling and statistics. It uses a wide range of predictive models which depends on the type of event we are predicting. For example, most predictive models produce a number called a score where a higher score indicates a higher chance of that outcome happening in the future. It is a very useful tool for making business decisions and assessing potential risks in many industries such as insurance, retail, etc. Predictive analytics does not inform users about things that has happened before today. It tries to predict for a particular driver the probability that he or she may be involved in an car accident in the near future or any other chose time as accurately as possible [11].

For example, in order to find high-risk drivers, it is not enough to just have driving records, automobile incident reports or traffic tickets. We also need something called telematics. Telematics is defined as the combination of telecommunications and informatics. It collects, stores, sends and receives data and information via transmission-enabled devices. For example, the use of the car black box technology mentioned previously to collect and obtain information on driving behaviors or patterns is called vehicle telematics. With telematics data, companies can determine the possibility of a driver in a future car accident along with the expenses coupled with it. They can also take actions such as putting high-risk drivers

into training schools to correct their bad driving behaviors before an incident happens [11].

By studying the telematics data from a specific driver, we can learn his or her driving behaviors and create a report that details the potential danger this driver may inflict and use these data to correct those bad driving habits. The probability of a driver being involved in a car accident in the future can be used to categorize drivers into different groups. With these probabilities, companies can create a safety score to provide them with suggestions on which drivers to deal with first. The fundamental role for a safety score is to identify drivers with high risks before an accident happen to give the driver a chance to correct those bad driving habits and prevent incidents from happening [11].

However, just like other countless programs on risk evaluation, predictive analytics is not supposed to be flawless. In companies such as UPS, FedEx, USPS or any other services that use a large amount of drivers and vehicles called fleet vehicles, predictive analytics is just the first process and it requires the total cooperation and commitment from the company, drivers and fleet staff to achieve the highest efficiency. Companies that have numerous successful fleet operations are those who plan ahead and bring together all fleet personnel into the action. The most effective way to adjust the accuracy and precision of predictive models is to test the models every few days or few weeks or any other time that is suitable for the operations. Due to the fact that most operations have tight schedules, this leeway time will give companies enough room to call in safety personnel to step in to either train drivers to correct their driving habits or repair fleet vehicles beforehand to avoid major system failures [11].

Predictive analytics and telematics data are being used in almost all fleet companies as more of them start to see the value in predictive analytics. With the help of predictive analytics, fleet companies can be actively engaged in making better decisions about their fleets and companies by improving road safety, reducing expenses and risks or decreasing work load time [11].

## 2 BIG DATA IN THE INSURANCE INDUSTRY

For a long time, auto insurance companies have calculated insurance rates based on personal mileage through out the years [5]. Traditional auto insurance companies categorize users by demographics such as gender and other factors such as education. They then make predictions based on past statistics about their chances of getting involved in future car accidents. This means that the monthly payments insurance companies charge you are only calculated according to the information they have on you and these information has nothing to do with your driving behaviours. As a result, the premiums you pay every month is usually based on past data from people who have identical demographics as you. While a few of the factors are actually helpful in determining your risk score - for example, if you have had multiple accidents in the past, you are likely to be involved in a new one in the future - other factors such as how many cars you previously owned have little to do with your actual risk of being in an accident but yet they still matter when calculating the price. And no one ever use the most important factor in determining monthly premiums which is driving behaviors [9].

Major auto insurance companies have connection to large amount of information as well as data processing power in order to calculate risk scores and monthly premiums. It is no easy task for them to combine several different factors into one single price. Still, big data is not fully utilized. Even though these companies use a variety of different models to calculate monthly rates for drivers, not all of their methods are optimized. In a study conducted earlier this year, it was found, with the help of data mining, that there exists predictive models that have higher accuracy in categorizing drivers into high and low risk groups. Among those models was one that combined 16 factors which produced an extremely high accuracy in risk assessment [9].

Big data can help insurance companies in a big way to make better and smarter business decisions.

- Financial fraud has always been a big problem for both insurance companies and their clients ever since the invention of insurance. The expense that insurance fraud inflicts each year is more than 40 billion dollars as reported by the FBI. However, insurance companies now can put big data into good use as a brand new approach in detecting insurance fraud. Coupled with immense computing power and complex mathematical algorithms, insurance companies are now able to analyze their data to find abnormalities which might indicate possible fraud. For example, a variety of applications and computer software now have the ability to detect outliers automatically in the data. However, the anomalies detected do not always turn out to be fraud situations. There could be other reasons or explanations for them but this new approach certainly makes insurance companies a lot easier to detect potential fraud [3].
- Another benefit for insurance companies to use big data is that big data analytics applications such as Apache Hadoop are engineered to be simple to use with office software such as Excel. As a result, it is much easier to write reports in Hadoop which is intended to work with Excel. Insurance staff can now access huge amounts of data swiftly to obtain the information they need and produce a report in the form they already know how to use [3].
- Two years ago Google released a tool for residents of California to compare rates among different auto insurance companies. Since then, the competition has been increasing in the industry. However, there is no need for this useless competition because big data can help insurance companies find better ways to provide their customers with a good price while still earning profits. By collecting data and customer information from various sources such as social media, insurance companies can utilize these big data to accurately predict which customers are likely to file claims in the future and then try to bring in more of these customers [3].
- Aside from auto insurance, big data also has some interesting applications in the industry of health-care. With the accurate and effective collection of data on medical records, insurance companies can provide better health insurance plans for people so that they can have longer and better lives. As a result, people with better health insurance plans

file less claims which means insurance companies spend less money and earn higher profits. For example, insurance companies can advertise wearable technologies or devices such as apple watch to track customers well-beings in order to provide them with incentives to exercise or obtain better lifestyles [3].

- The insurance industry is continually changing. Insurance companies that can not match the pace will lose profits and resources. However, using big data, insurance companies can study and learn real time data such as social media feeds to obtain more information about customer styles and preferences. This can help insurance companies to design better marketing strategies, adapt faster to customer feedback and construct products that are more attuned with their customers' tastes [3].
- Last but not least, big data can also help insurance companies to provide insurance plans that are tailored to their customers. Every year, millions of money is lost because insurance companies do not have the means to personalize their insurance plans. However, with the help of big data analytics tools, employees in insurance companies now have the ability to gather more precision information on every one of their customers with ease so that they could create insurance plans according to each individual's needs. These tools and software can also give insights and advice based on the collected data to provide better support for employees to make decisions. This in turn will increase their customer satisfaction and lead to more customers in the future [3].

However, powered with advanced technology and big data analytics, insurance companies now-days have access to customers' driving behaviours for more personalized insurance rates. They collect specific data on how often you drive every day, how long you drive each time, how often you speed, how often you break hard and so on to determine the probability of you being in an accident in the near future. With these precise data on each individual customer, insurance companies can assess risk scores for everyone and use that information to calculate your monthly rates [5]. For example, an auto insurance company called Root is one of the first mobile auto insurance companies that are intended to help you on the go. They promise to only insure the good drivers to make sure they get the best rates. Their methods are simple. Download the app, take a test drive with the app on-board for several weeks and Root will send a personalized premium plan based on your driving behavior. Then you can just select the plan you want to purchase and buy via your phone [9].

These new and innovative mobile auto insurance plans are called UBI, short for Usage-Based Insurance and they calculate monthly premiums mostly based on driving habits. Applications on smart-phones and on-board diagnostic devices along with in-car tracking technology from manufacturer are used to record mileage and driving behaviours. These mobile insurance programs tend to give discounts for good drivers as a reward for their good driving behaviors. They are even adding new rewards such as roadside assistance on top of discounts for drivers who have maintained good driving behaviors for long periods of time. By collecting big data on driving

habits, auto insurance companies can promptly discover mistakes when accidents happen by knowing the exact positions of each car and driving habits data such as speeding or braking as well as environmental data such as weather or road conditions [10].

On the surface, these Usage-Based Insurance plans appear to be plausible and feasible. An application or a sensor is installed on your phone or car to track your driving behavior instead of estimating costs based on factors such as age, gender, education, traffic records, accident reports and so on. Several programs such as *Drivewise* from Allstate insurance and *Snapshot* from Progressive insurance have been released to the public for a couple of years in some states, completely based on customers' choices. You do not have to install them if you do not want to. However, the majority of drivers have been embracing these monitoring devices since it has no apparent downside. As long as your driving behaviors are considered to be safe, such as slow braking and accelerating or no driving around midnight, your should receive discounts like 5 to 10 percent or even up to 20 percent on your monthly premiums. On the other hand, customers are starting to worry about their privacy but we still do not know what the worst thing that might happen if we keep letting insurance companies monitor our driving behavior. According to the Wall Street Journal, these Usage-Based Insurance plans are growing exponentially. The biggest auto insurance company in United States, State Farm, announced their plans to expand their *Drive Safe and Save* program to the entire country soon. Their major advertising strategy is that by enrolling in the program, consumers can get discounts in their insurance premium by proving that they drive safely [12].

For example, one of the earliest Usage-Based Insurance programs available to the public was released about 10 years ago by Progressive and General Motors. This particular program, with the help of GPS, applied discounts based on customer mileage. Many of the Usage-Based Insurance programs these days still implement this strategy but many improvements have been made. Insurance companies nowadays know everything about the way you drive from where you drive to when you drive as well as how you drive. There are also a variety of options to choose from such as *pay as you drive* and *pay how you drive*, thanks to telematics. The advantage of having telematics in these insurance programs is to improve efficiency such as reducing response time for accidents. In addition, Usage-Based Insurance data can be analyzed using on-board diagnostic devices which are often plugged in via the on-board diagnostic 2 port on cars. These diagnostic devices do not have the ability to track car positions but they do generate more precise and meticulous data about car usage. Although telematics is the typical way to record driving habits, new creations in the future will possibly use smart-phone's location services or GPS abilities to track bad driving behaviors such as speeding and hard braking. Liberty Mutual and State Farm both tested their new tracking technology via smart-phones or other smart devices on-board cars in 2015. By 2020, the majority of auto insurance companies will be using Usage-based Insurance programs coupled with telematics data. It is no doubt that Usage-Based Insurance programs will continue to grow and achieve even higher precision and availability [4].

### 3 CURRENT APPLICATIONS

Predictive analytics are being utilized with telematics data to enhance and improve road safety. Telematics have been used for a long time in insurance industry to monitor driving behaviors such as speeding to identify high-risk drivers. Now coupled with predictive analytics, these data are being analyzed to predict the likelihood of a driver being involved in future accidents. SmartDrive Systems, a transportation safety and intelligence company, employs even more interesting ways to predict accidents. They record and gather video feeds from dashboard cameras in cars which are then integrated with telematics data. This way, they can improve their predictive analytics on driver safety and eventually leads to better predictions [1].

SmartDrive Systems uses a private cloud to provide their clients with predictive analytics solutions. All the data from their clients are collected by the company and stored on their cloud. The data includes telematics and video feeds from millions of clients with more than 4 billion mileage. SmartDrive constantly improves their predictive models because the agreements SmartDrive has with their clients permit them to study all the data they gather. The usage of both telematics data and video feeds is a great idea which enables SmartDrive researchers to better understand the data and interpret the results. By combining what they see through the video feeds and the results from telematics data analysis, the researchers can draw conclusions such as making a U-turn on a narrow road within some fixed radius is dangerous [1].

Indiana State Police came up with a different way to predict incidents and are making their predictive analytics methods open source. In their approach, they produced something called *Daily Crash Prediction Map* which finally completed in November. It contained data such as accident reports from all the police departments in Indiana going back to 2004 as well as data on daily weather, historical traffic amount and so on. This map highlights where potential accidents may happen categorized by their probabilities. It also features information about past accidents such as locations, dates, causes, fatalities and so on [2].

Liberty Mutual is the nation's third largest property and casualty insurance company. Last year, Liberty Mutual partnered up with Subaru. In doing so, customers was granted access to *Starlink*, Subaru's multimedia and navigation system, which can track and notify drivers via an app if they are speeding or braking too hard. By enrolling in the *RightTrack* program provided by Liberty Mutual, drivers can get up to 30 percent discounts for good driving behaviors [5].

### 4 DATA ANALYSIS

The data we are gonna use for our analysis is of Porto Seguro. It is one of Brazil's largest auto and homeowner insurance companies. Inaccuracies in car insurance company's claim predictions raise the cost of insurance for good drivers and reduce the price for bad ones. The task is to build a model that predicts the probability that a driver will initiate an auto insurance claim in the next year or not. An accurate prediction will allow them to further tailor their prices, and hopefully make auto insurance coverage more accessible to more drivers.

#### 4.1 Approach

We will be mainly discussing about the Exploratory data Analysis we have performed on the data until now. We will be using the help of both R and python environment and supporting packages to perform the necessary statistical analysis. Along with this, we will discuss about the Machine or Deep Learning algorithms / models that we will be using to achieve the near solution for the problem.

#### 4.2 Feature Information

Dimensions of the data [Rows x Features] : [ 595212, 59 ]

The data-set constitutes different varieties of features.

**Binomial Features** [Count : 17] : ps.ind.06.bin, ps.ind.07.bin, ps.ind.08.bin, ps.ind.09.bin, ps.ind.10.bin, ps.ind.11.bin, ps.ind.12.bin, ps.ind.13.bin, ps.ind.16.bin, ps.ind.17.bin, ps.ind.18.bin, ps.calc.15.bin, ps.calc.16.bin, ps.calc.17.bin, ps.calc.18.bin, ps.calc.19.bin, ps.calc.20.bin.

**Categorical Features** [Count : 14] : ps.ind.02.cat, ps.ind.04.cat, ps.ind.05.cat, ps.ind.01.cat, ps.ind.02.cat, ps.ind.03.cat, ps.ind.04.cat, ps.ind.05.cat, ps.ind.07.cat, ps.ind.06.cat, ps.ind.08.cat, ps.ind.09.cat, ps.ind.10.cat, ps.ind.11.cat.

**Integer Features** [Count : 16] : ps.ind.01, ps.ind.03, ps.ind.14, ps.ind.15, ps.ind.11, ps.calc.04, ps.calc.05, ps.calc.06, ps.calc.07, ps.calc.08, ps.calc.09, ps.calc.10, ps.calc.11, ps.calc.12, ps.calc.13, ps.calc.14.

**Floating Features** [Count : 10] : ps.reg.01, ps.reg.02, ps.reg.03, ps.calc.01, ps.calc.02, ps.calc.03, ps.car.12, ps.car.13, ps.car.14, ps.car.15.

The remaining two features constitutes **id** and the **output (or) target**. All the features has been clearly represented using post script, **.cat** for categorical data, **.bin** for binomial data.

The **missing values** in the features are represented by -1.

#### 4.3 Data Pre-processing

As shown in 1, missing values are found in 14 of the 58 columns. There are 6 features with more than 5000 missing row values. Owing to the shear size of the unavailable data, we have not performed any missing value treatment and removed these features from consideration. Of the remaining data, across rows, data is unavailable in almost 500 (<1%) rows and these are promptly removed.

[Figure 1 about here.]

#### 4.4 Distribution of the target variable

As shown in 2, target variable claims is a binary variable with a skewed distribution of classes. 96% of the customers didn't make any claims. We wish to consider this distribution in measuring classification accuracy. Area under the ROC curve, recall and precision would be relevant metrics in this case.

[Figure 2 about here.]

#### 4.5 Numerical Predictors (vs) Target Variable

Average value of most of the numerical predictors is higher when the claims are filed. This is a unique phenomenon and we intend to use this contrast in predicting the target variable.

## 4.6 Artificial Neural Networks

Artificial neural networks (ANNs) are computing models which are based on biological neural networks that constitute human brains. The idea of ANNs is based on the belief that working of human brain can be imitated for computers by using silicon and wires as living neurons. Such systems learn by progressively improving their performance to do tasks by considering examples, generally without task-specific programming. “The human brain can be considered as a complex network of nerve cells called neurons(about 86 billion)” [8]. They are inter-connected to other millions of cells by Axons. These neurons then react to stimulation from external environment or inputs from other organs. A neuron can then send the message to other neuron to handle the issue or does not send it forward.

ANNs also try to imitate biological neurons of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its activation. Each node is assigned with weight. ANNs are capable of learning, which takes place by altering weight values. If the network generates the desired output, there is no need to adjust the weights. However, if the network generates an undesired output or an error, then the system alters the weights in order to improve subsequent results.

## 4.7 Types of ANNs

4.7.1 *Feedback ANN.* In this type of architecture, the output goes back into the network to achieve the best-evolved results internally. The feedback network feeds information back into itself and is well suited to solve optimization problems. Feedback ANNs are used by the Internal system error corrections [6].

4.7.2 *Feed Forward ANN.* A feed-forward network is a neural network which consists of an input layer, an output layer and one or more hidden layers of neurons. By evaluating its output by changing its input, the efficiency of the network can be noticed based on group behavior of the connected neurons and the output is decided. The main advantage of this network is that it learns to evaluate and recognize input patterns [6].

4.7.3 *Radial Basis Function Neural Network.* The RBF neural network is the first choice when interpolating in a multidimensional space. The RBF neural network is a highly intuitive neural network. Each neuron in the RBF neural network stores an example from the training set as a “prototype”. Linearity involved in the functioning of this neural network offers RBF the advantage of not suffering from local minima [6].

4.7.4 *Kohonen Self-Organizing Neural Network.* “Invented by Teuvo Kohonen, the self-organizing neural network is ideal for the visualization of low-dimensional views of high-dimensional data. The self-organizing neural network is different from other neural networks and applies competitive learning to a set of input data, as opposed to error-correction learning applied by other neural networks. The Kohonen self-organizing neural network is known for performing functions on unlabeled data to describe hidden structures in it” [6].

4.7.5 *Recurrent Neural Network.* The recurrent neural network is a neural network that allows a bi-directional flow of data. The network between the connected units forms a directed cycle. Such a network allows for dynamic temporal behavior to be exhibited. The recurrent neural network is capable of using its internal memory to process arbitrary sequence of inputs. This neural network is a popular choice for tasks such as handwriting and speech recognition [6].

4.7.6 *Classification-Prediction ANN.* It is a subset of feed-forward ANN and the classification-prediction ANN is applied to data-mining scenarios. The network is trained to identify particular patterns and classify them into specific groups and then further classify them into patterns which are unique for that network [6].

4.7.7 *Physical Neural Network.* This neural network aims to emphasize the reliance on physical hardware as opposed to software alone when simulating a neural network. An electrically adjustable resistance material is used for emulating the function of a neural synapse. While the physical hardware emulates the neurons, the software emulates the neural network [6].

## 4.8 Data Analysis Using Neural Networks

Rather than beginning our inquiry into the data-set with more traditional methods like regression we straight away tried to learn Artificial Neural Networks. Logistic regression itself, can be thought of as a special case of a neural network with a single neuron (perceptron).

After studying and learning the theory behind ANNs we proceeded to learn how to implement them – by ourselves at first, and later using TensorFlow. So far we have tried quite a bit of different models and learned some lessons about the data.

- **Data Cleaning :** As pointed out by the EDA above, there were a few columns which had a lot of missing data. For columns which had > 1000 values missing (6 columns), we disregarded them altogether. For the remaining data points, we disregarded the rows which had any one particular value missing. We started with a simple data cleaning strategy so as to not complicate it too much at the initial stages, but we will probably want to look at it again as we go along.
- The first thing that we tried is using a simple **perceptron**. The input layer had 51 nodes (after removing the id, target and 6 other columns in data cleaning) and the output layer had a single perceptron with a sigmoid activation function. The best score that we got when we uploaded our code to Kaggle was 0.03 whereas the leader-board is hovering around 0.290 so this is not too impressive.
- However, now we added more hidden layers and nodes to see if we get a better job of fitting the data. To start off, we only consider the continuous variables so that we don't have to worry about handling binary/categorical data. We have 24 nodes in the input layer. The final layer has one node since it is a classification problem. We kept all activation to be logistic and experimented a bit with the number of hidden layers and nodes to get a best score of **0.211** with this simple approach.

- **Issued Encountered** Looking at the results from the neural network there is one major issue. Whenever we add too many hidden layers ( $> 3$ ) the outputs for the test data are all  $\approx 0$  and the score drops. After some trial and error, we have diagnosed the issue to be the biased nature of the training data (96% of the training data are 0's). So the ANN sees too many zeros and consequently predicts mostly zeros. We aim to explore different sampling methods to train the neural network to improve the results further (along with cross validation which we haven't implemented).

## 5 OTHER TECHNIQUES THAT CAN BE USED

Among the machine Learning algorithms that are used in practice, gradient tree boosting is one technique that shines in many applications. Tree Boosting has been shown to give many state of the art results for many standard classification problem.

The most important factor for the success of XGBoost is its ability to scale in all the scenarios. The XGBoost algorithm run ten times faster than the existing popular solutions on a single solution and scales to billions of example in distributed or memory-limited settings.

The Porto Seguro data-set is clearly an classification problem, the data will be having only two outputs either the car insurance holder is going to claim or not.

While domain dependent analysis and feature engineering plays an important role in defining or modeling the solutions, the fact that XG Boost is the consensus choice for learners shows the impact and importance of our system in tree boosting. One problem with the Porto Seguro data-set we do not have have much information about the Features and all the feature must have to under go through strict statistical treatment to build an optimal solution.

## 6 CONCLUSION

Reducing insurance rates has always been a difficult task in the past. However, armed with advanced technology, insurance companies now have the ability to track personal driving behaviours to provide better suited personalized insurance plans. We performed Neural Networks algorithm on clients data from Porto Seguro, one of Brazil's largest auto insurance companies in order to predict the probability of drivers filing claims in the next year. Our analysis proved to be a success and our model yielded a high accuracy.

## 7 APPENDIX

### 7.1 Links to iPython notebook:

[https://github.com/bigdata-i523/hid233/blob/master/project/Shallow\\_Neural\\_Nets.ipynb](https://github.com/bigdata-i523/hid233/blob/master/project/Shallow_Neural_Nets.ipynb)

### 7.2 Links to iPython notebook pdf version:

[https://github.com/bigdata-i523/hid233/blob/master/project/Shallow\\_Neural\\_Nets.pdf](https://github.com/bigdata-i523/hid233/blob/master/project/Shallow_Neural_Nets.pdf)

### 7.3 Work Contribution

Jiaan Wang - Sections: Abstract, Introduction, Big data in the insurance industry, Current application, Data analysis (10 percent) and Conclusion

Dhawal Chaturvedi - Sections: Data analysis (90 percent), Other techniques that can be used and Conclusion as well as Jupyter notebook

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski for his support and suggestions to write this paper.

## REFERENCES

- [1] Steve Banker. 2016. Using Big Data And Predictive Analytics To Predict Which Truck Drivers Will Have An Accident. Web Page. (Oct. 2016). <https://www.forbes.com/sites/stevebanker/2016/10/18/using-big-data-and-predictive-analytics-to-predict-which-truck-drivers-will-have-an-accident/#fd6888b1cb0> HID: 233, Accessed: 2017-11-28.
- [2] Jenni Bergal. 2017. Troopers Use fBig Data To Predict Crash Sites. Web Page. (Feb. 2017). <https://www.huffingtonpost.com/entry/troopers-use-big-data-to-predict-crash-sites.us.589c88ebe4b0985224db5e19> HID: 233, Accessed: 2017-11-28.
- [3] Robert Cordray. 2015. 6 Ways Insurance Companies Can Tap The Power Of Big Data. Web Page. (Aug. 2015). <https://www.digitalistmag.com/industries/insurance/2015/08/13/insurance-companies-can-use-big-data-advantage-03281426> HID: 233, Accessed: 2017-11-30.
- [4] Crosley Law Firm. 2016. Benefits and Concerns About Usage-Based Insurance. Web Page. (Nov. 2016). <https://crosleylaw.com/blog/big-data-behind-bad-driving-insurers-use/> HID: 233, Accessed: 2017-11-28.
- [5] Brian Fung. 2016. The big data of bad driving, and how insurers plan to track your every turn. Web Page. (Jan. 2016). <https://www.washingtonpost.com/news/the-switch/wp/2016/01/04/the-big-data-of-bad-driving-and-how-insurers-plan-to-track-your-every-turn/> HID: 233, Accessed: 2017-11-28.
- [6] Naveen Joshi. 2017. Six types of neural networks. Web Page. (April 2017). <https://www.allerin.com/blog/six-types-of-neural-networks> HID: 204, Accessed: 2017-11-28.
- [7] Mikkie Mills. 2017. 4 Ways How Big Data Will Improve Road Safety. Web Page. (May 2017). <https://datafloq.com/read/4-ways-big-data-will-improve-road-safety/3127> HID: 233, Accessed: 2017-11-28.
- [8] Tutorials Point. 2015. Artificial Intelligence-Neural Networks. Web Page. (April 2015). [https://www.tutorialspoint.com/artificial\\_intelligence/artificial\\_intelligence\\_neural\\_networks.htm](https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_neural_networks.htm) HID: 204, Accessed: 2017-11-28.
- [9] Cristol Rippe. 2017. Big Data, Better Rates: Why Current Car Insurance Rate Calculations are Unfair. Web Page. (Jan. 2017). <https://blog.joinroot.com/big-data-better-rates-why-current-car-insurance-rate-calculations-are-unfair/> HID: 233, Accessed: 2017-11-28.
- [10] Jonathan Shafer. 2016. How Big Data Analytics is Changing the Competitive Auto Industry. Web Page. (Aug. 2016). <https://pentaho.com/blog/2016/08/26/how-big-data-analytics-changing-competitive-auto-industry> HID: 233, Accessed: 2017-11-28.
- [11] Grace Suizo. 2015. Using Predictive Analytics to Improve Fleet Decisions. Web Page. (Sept. 2015). <http://www.automotive-fleet.com/channel/gps-telematics/article/story/2015/10/using-predictive-analytics.aspx> HID: 233, Accessed: 2017-11-28.
- [12] Brad Tuttle. 2013. Big Data Is My Copilot: Auto Insurers Push Devices That Track Driving Habits. Web Page. (Aug. 2013). <http://business.time.com/2013/08/06/big-data-is-my-copilot-auto-insurers-push-devices-that-track-driving-habits/> HID: 233, Accessed: 2017-11-28.
- [13] David Walker. 2017. How Will Big Data From Self-Driving Cars Influence Road Safety. Web Page. (July 2017). <https://technofaq.org/posts/2017/07/how-will-big-data-from-self-driving-cars-influence-road-safety/> HID: 233, Accessed: 2017-11-28.

#### LIST OF FIGURES

1	Missing Data	8
2	Target Variable Distribution	9

Features	Missing Values Count
ps_ind_02_cat	216
ps_ind_04_cat	83
ps_ind_05_cat	5809
ps_reg_03	107772
ps_car_01_cat	107
ps_car_02_cat	5
ps_car_03_cat	411231
ps_car_05_cat	266551
ps_car_07_cat	11489
ps_car_09_cat	569
ps_car_11	5
ps_car_12	1
ps_car_14	42620

Figure 1: Missing Data

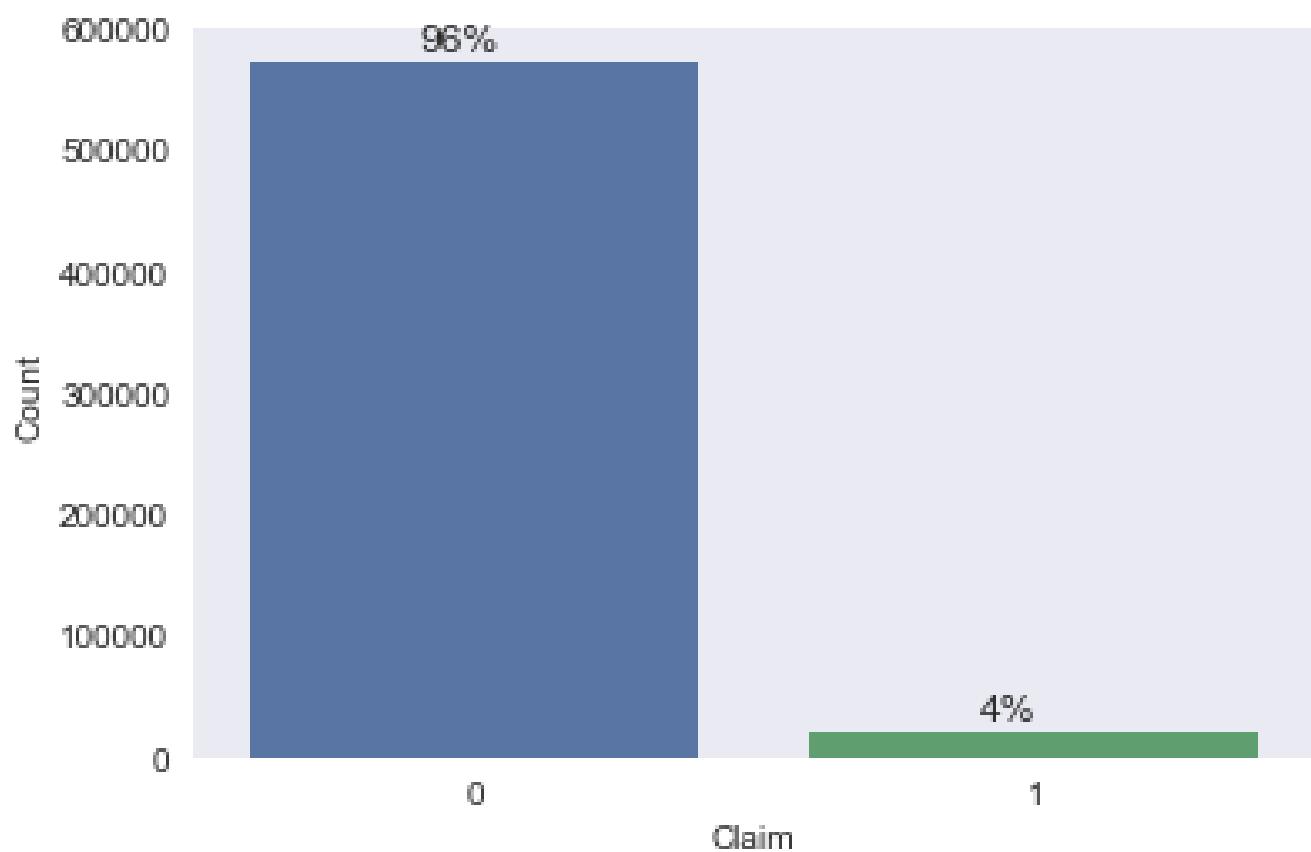


Figure 2: Target Variable Distribution

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
=====
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
=====
[2017-12-12 19.59.35] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 1.0s.
./README.yml
 32:67    error    trailing spaces  (trailing-spaces)
 33:65    error    trailing spaces  (trailing-spaces)
 34:64    error    trailing spaces  (trailing-spaces)
 35:70    error    trailing spaces  (trailing-spaces)
 36:66    error    trailing spaces  (trailing-spaces)
 37:70    error    trailing spaces  (trailing-spaces)
 38:69    error    trailing spaces  (trailing-spaces)
```

```
=====
Compliance Report
=====
```

```
name: Wang, Jiaan
hid: 233
paper1: Nov 03 17 100%
paper2: Nov 10 17 100%
project: Dec 11 17 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
9
wc 233 project 9 5504 content.tex
wc 233 project 9 5729 report.pdf
wc 233 project 9 704 report.bib
```

```
find "
```

---

```
passed: True
```

```
find footnote
```

---

```
passed: True
```

```
find input{format/i523}
```

---

```
4: \input{format/i523}
```

```
passed: True
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

```
134: As shown in \ref{f:missing}, missing values are found in 14 of
```

the 58 columns. There are 6 features with more than 5000 missing row values. Owing to the sheer size of the unavailable data, we have not performed any missing value treatment and removed these features from consideration. Of the remaining data, across rows, data is unavailable in almost 500 ( $\% < \$1\%$ ) rows and these are promptly removed.

```
137: \centering\includegraphics[width=\columnwidth]{images/missingdata}
}
138: \caption{Missing Data}\label{f:missing}
142: As shown in \ref{f:numerical}, target variable claims is a binary
variable with a skewed distribution of classes. 96\% of the
customers didn't make any claims. We wish to consider this
distribution in measuring classification accuracy. Area under the
ROC curve, recall and precision would be relevant metrics in this
case.
145: \centering\includegraphics[width=\columnwidth]{images/target}
146: \caption{Target Variable Distribution}\label{f:numerical}
```

```
figures 0
tables 0
includegraphics 2
labels 2
refs 2
floats 0
```

```
False : ref check passed: (refs >= figures + tables)
False : label check passed: (refs >= figures + tables)
False : include graphics passed: (figures >= includegraphics)
True : check if all figures are referred to: (refs >= labels)
```

```
Label/ref check
passed: True
```

```
When using figures use columnwidth
[width=1.0\columnwidth]
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

```
bibtex
```

---

```
label errors
```

```
bibtex errors
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

passed: True

# **Big Data Analytics and Applications in the Travel Industry and Its Potential in Improving Travel Accessibility**

Weixuan Wang

Indiana University Bloomington

Bloomington, Indiana 47405

wangweix@indiana.edu

## **ABSTRACT**

Big data applications and analytics have been influencing and improving tourists' experience. Travel accessibility refers to provide access for people with disabilities or limited mobility (such as seniors), who represent a growing market in the travel industry by spending billions on leisure and business trips. This report explored the implementation of big data analytics and applications in tourism, disabilities related studies and assistive technologies for people with disabilities. This report explored the potentials of big data applications and analytics in understanding the needs and travel experience of people with disabilities and improving travel accessibility and quality of life for people with disabilities.

## **KEYWORDS**

i523, HID234, Big Data Analytics, Travel Accessibility, People with Disabilities, Quality of Life

## **1 INTRODUCTION**

People with disabilities represented a large neglected tourism market. According to Amadeus annual report, 15 percent of worldwide population (around 1 billion people) lives with some forms of disability [3]. According to United Nation, people with disabilities are the largest minority group in the world [4, 16, 19]. Notably, the number of people with disabilities is expected to increase as a result of extension of human life-span, decreases in communicable diseases, the improvement of medical technology, and decrease of child mortality [42]. While some forms of disabilities might be genetic, but temporary or permanent disabilities can happen to anyone, such as spinal cord injury after car accident, or limited mobility at later stage of life [19].

Population aging trend also signifies that disability will be a more common and urgent issue in the future [22]. The World Health Organization estimates that by 2050, 21.5 per cent of the global population will be aged over 65 [3]. As a large and fast growing minority group worldwide, people with mobility limits and accessibility issues faces a large ranges of barrier when traveling, and travel and tourism demand of this group is often underestimated or completely ignored [3]. According to the Open Door Organization (ODO) market report in 2015, people with disabilities spend 17.3 billion dollars annually for their own travel [33]. Because people with disabilities usually needs a care giver or family member to accompany them when traveling, the potential economic impact could double [33].

Accessible travel or accessible tourism refers to the inclusive travel activities that enable people with access requirements, including mobility, vision, hearing and cognitive dimensions of access,

to function independently, with equity and dignity through the delivery of universally designed tourism products, services and environments [3]. However, the travel experiences for people with disabilities are more than access issues. In order to achieve travel accessibility, which means provide travel activities for people with disabilities, a variety of aspects for travel needs must be taken in consideration. An accessible destination and appropriate accommodation only lay the foundation for a particular travel experience to happen for people with disabilities [33]. More aspects that need to consider for people who are traveling with disabilities, such as accessible transportation, accessible online booking [3].

The ultimate aim for those involved in supporting accessible travel is to empower every individual to plan and travel independently, at their own will [50]. However, the task is not a easy one. Making the whole travel chain accessible, including the information and booking procedures, as well as the infrastructure and processes become a important task for travel accessibility [3].

The development of information communication technologies especially the creation and distribution of user-generated content (UGC) or consumer-generated content (CGC) has successfully changed how people travel and how people gather information for travel [12]. Big data application and analytics has become a trending topic for the tourism industry and tourism studies [12]. The fast development of information and digital technology has changed many people's lives, especially the life of people with disabilities has also been improved by technology [10]. People with poor visions can using cell phones to contact others, access information online with screen readers. People with hearing problems can text other people with their cell phone. The use of big data for disabilities related research, disability informatics and developing assistive technology has been studies to improve the quality of life for people with disabilities [22].

Although big data is becoming an important topic in both tourism studies and disability related studies. There are a gap in the literature about how big data can be used in accessible tourism practice and studies, the potential of big data analytics and applications for improving travel accessibility has not been discussed before. Travel for business and leisure, especially travel independently and with dignity, constitute an essential needs for people with disabilities, and plays a fundamental part in the quality of life for people with disabilities. This study is trying to explore the use of big data applications and big data analytics in tourism and disability related practice and research, illustrating and discovering the potential of using big data applications and analytics for accessible travel and tourism practice and studies.

## 2 TOURISM AND BIG DATA

Information Communication Technologies (ICTs) have been transforming tourism business globally and revolutionizing the world of Tourism. It transforms tourism from a labor-intensive to an information-intensive industry [45]. Tourists influence by the developments in search engines, network speed and capacity have been using use technologies for better planning and experiencing their trips [47]. In addition, ICTs enable travelers to access reliable and accurate information and make reservations faster, cheaper and more convenient than the traditional way [12]. The development of ICTs also enables Internet users to both create and distribute information (especially multimedia information), which is called user-generated content (UGC) or consumer-generated content (CGC) [12].

Big data is a new and trending topic in the tourism industry and tourism studies, however, it is not unfamiliar to tourist activities. Most activities in the tourism industry had been generating a huge amount of data for several years. Booking flight tickets, reserving a hotel room and renting a car all leaves a data trail [40]. These data could add up to more than hundred of terabytes or petabytes structured data in the conventional databases [2]. Discussions of travel planning on online travel community such as the Lonely Planet Community, status updates and posts on social media like Facebook and Twitter, compliments and compliant on review websites like TripAdvisor and Yelp, recording and sharing travel experience on travel blogs constructs more challenging and live unstructured data that arrives at a much faster pace than a conventional database [2]. Tourism practitioners and tourism scholars are trying to understand tourists' behavior by accepting and analyzing these big data [40].

Tourists in the digital age often use a variety of tools to access information that the tourism industry or other users have provided [46]. A tourist produces a high volume of data when they are searching for travel websites, reporting issues on mobile applications, sharing traffic information in the cities, searching and posting on social media, taking and sharing photos, reporting experience on travel websites and social media, documenting their trips on blogs [2, 40]. All these data that are produced constantly can demonstrate tourists' motivation, interests, and their planning patterns and so on [47].

Previous studies have demonstrated several different usage and formats of big data in the travel and tourism industry [47]. Social media is one of them that has a huge effect on the tourism industry. Social media includes social networks, review sites, blogs, media sharing, and wikis [46]. The exceptional growth of these data sources has inspired companies and institutions to come up with new strategies to understand the socio-economic phenomenon in various fields [40]. Discussions and information sharing on social media are considered as electronic word-of-mouth (eWOM) that has in some degree substituted tradition face-to-face word-of-mouth (WOM) for information exchange of tourist experience [12].

Most tourism research utilizing big data are focusing on CGC or UGC, especially online reviews for a hotel. A recent study conducted by Guo, Barnes and Jia used data mining approach and linguistic analysis to extract meaning from 266,544 online reviews for 25,670 hotels [24]. They mined their customer review data from

TripAdvisor using a web crawler [24]. Through their linguistic analysis of their data and cross-comparing with perceptual mapping of the hotels, they found 19 controllable dimensions that are important for hotels to manage their interactions with visitors (such as the price for value, check in and check out) [24].

Photo post on photographic sharing website also can also provide extensive information on the tourists. Previous studies have connected photos posted on Panoramio, Flickr, and Instagram [10, 29]. Because when a tourist post pictures on these websites, their photo is tagged with geographic locations and ordered chronologically. Therefore analyzing photos posted by tourists can provide a photo density map to better understand tourists' behaviors, and potentially provide opportunities to detect atypical tourists behavior and characterize communities behaviors [29]. However, the study also has its own limitation because of the limitation of technology to better exploit the data [10]. Another study focused on the sequence of locations in shared geotagged photos by tourist to identify and recommend travel routes which helped the travel recommender system to generate personalized recommendation according to interests and time available [29].

Overall for tourism industry and tourism research, big data has becoming more and more popular. Both tourism practitioners and tourism researcher has recognized the influence of big data and big data sources for tourism development. Big data in the tourism industry are generated by tourists directly, compared to traditional data sets that are gathered from surveys, they have argued that these direct data from tourists themselves can better represent their true travel experience [24]. Therefore, big data presented us opportunities to better understand tourist behavior, their motivations, and interests.

## 3 DISABILITY AND BIG DATA

There are many different definition of disabilities from different organizations. The most cited official definition is the 1976 definition of the World Health Organization [4]: "An impairment is any loss or abnormality of psychological, physiological or anatomical structure or function; a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being; a handicap is a disadvantage for a given individual, resulting from an impairment or a disability, that prevents the fulfillment of a role that is considered normal (depending on age, gender and social and cultural factors) for that individual". While people with disabilities are those people who have limitations in their actions or activities resulting from physical, sensory or cognitive impairments, however, there are many types and levels of disabilities and their actions and activities are affected differently by their disabilities [4]. The complexity of disabilities presents difficulties and challenges to accommodate the different needs of people with disabilities and improve their qualities of life [35].

The number of individuals living with some sensory or cognitive impairment or assisting an affected person is enormous [38]. Researchers has been using disability informatics to better understand people with disabilities. Disability informatics is a sub-specialty of health informatics that is defined as "any application that collects, manages, and distributes information that are related to people

with disabilities, as well as to caregivers (including familiar members and health care providers) and rehabilitation professionals" [4]. Disability informatics is closely related to other health informatics areas such as medical informatics, public health informatics and consumer health informatics, because people with disabilities usually have some secondary medical condition such as poor health status and increased personal health care needs.

Gather medical and health information can help to better understand and accommodate people with disabilities [38]. A study from the early 2000 has identified the potential of public health informatics for prevention at all vulnerable points in the causal chains leading to disability and proposed that applications should not be restricted to particular social, behavioral, or environmental contexts, but in a more global context [48].

Another previous research has designed and deployed an extended version of Artemis system (a cloud system designed to acquire data and store physiological data of clinical information for real-time analytics) in a hospital. They have identified that high speed physiological data produced at intensive care units as big data, and the proper use of such data can promote health, reduce mortality and disability rates of critical condition patients and create new cloud-based health analytics [26]. Research also has shown that many disabilities are genetic, therefore, bioinformatics has implications in the education of genetic screening and gen therapy treatments in the future [4].

People with disabilities usually need some assistive technology in their daily life. These technology that assist them to perform basic physical and social functions. The use information technology and assistive applications in disability informatics are categorized into three areas: virtual, personal, physical.

- Virtual environment refers to use of digital technologies like website and the Internet [4]. The digital revolution had and will continue to have a profound positive impact on the life of people with disability by empowering them with the help of digital technologies [4]. However, there are still access issues in the digital world. One of the barrier is the use of the World Wide Web (WWW or Web). Therefore, virtual environment for people with disabilities is usually discussed regarding to web accessibility.
- Personal Environment refer to having a safe personal environment for people with disabilities, which includes personal management and health monitoring [4]. Safety monitoring and health monitor devices are essential in this personal environment, which enables a safer personal environment and also provide health information for their medical care providers [4]. However the ethic of such health monitor devices are always in debate, some believe it can be an invasion of privacy and a restriction of personal freedom, others hold the ground that its main purpose is to help people with disease or disabilities, since it can alert their caregiver if the individual are exposed to harm (such as a person with mental disability and has a history of self-harming, these device can prevent unwanted behavior [15].
- Physical environment refers to the actual living space, traveling environment for people with disabilities. People with

mobility disabilities, visual impairment or cognitive limitation all need special help in their physical environment. Since the American Disabilities Act passed in the 1990s, the accessibility of physical environment has been improved in a great degree. However, people with disabilities still would meet some barrier and problem, one of them is the lack of curb cuts. Assistive information technologies has been developed in an effort to solve this problem. One of them is MAGUS, which is a project using geographical information system to inform users about wheelchair accessibility in urban areas [4]

The contribution of Big data and cloud computing have been recognized and accepted by researchers in health informatics [44]. The potential of big data and cloud computing for disability informatics and for people with disabilities has been explored by a few researchers and organizations. Data-Pop Alliance is one of the organization has recognized the big data and potential for study and help people with disabilities for disability informatics and people with disabilities [35]. Their research has categorized three type of big data source used across disability research: exhaust data (mobile-based data, financial transaction, transportation and online trace), digital content (social media and crowded-sourced/online content), and sensing data (physical and remote) [35]. They also provided the potential for some of these data sources, for example, researchers can use transaction data to compare cost, availability, and use of services that offer accessible options (such as accessible hotel listings) [35]. They also suggested that researcher can use social media data to represent people with disabilities as a network of interaction and using crow-sourcing to map the locations of accessible businesses and public places [35]. The organization has also identify four functions of big data on disability: descriptive, predictive, diagnostic and engagement. Descriptive function of big data is to describing and presenting the collected information such as using location data to map workplaces that are accessible to people with disabilities [35]. Predictive function is making inferences based on collected information such as discovering trends in the growth of number of accessible businesses in a certain urban area, while the diagnostic function means establishing and making recommendations on the basis of causal relations such as showing what can help increasing accessible business in a certain area [35]. Finally, the engagement function refer to shaping dialogue within and between communities and with key stakeholders through communication of data [35].

Cloud computing in combined with big data can also provide great opportunities for research and improvement of quality of life for people with disabilities [7]. The term cloud "refers to everything a user may reach via the Internet, including services, storage, applications, and people" [25]. Depending on the type of using, the "cloud" can be use for different purpose, such as for companies, the cloud could be used for hosting services so as to avoid the costs and difficulties associated with hosting one's own servers and software and for individuals, the could is often used as information storage [26]. Regardless of the types of usages for cloud, the end using must still access the information and services residing in the cloud through device like a smart phone or computer [25]. Cloud computing has been used to provide more accessible virtual environment,

especially Web access through project like WebAnywhere, which is a cloud based tool for blind using to access Internet [25].

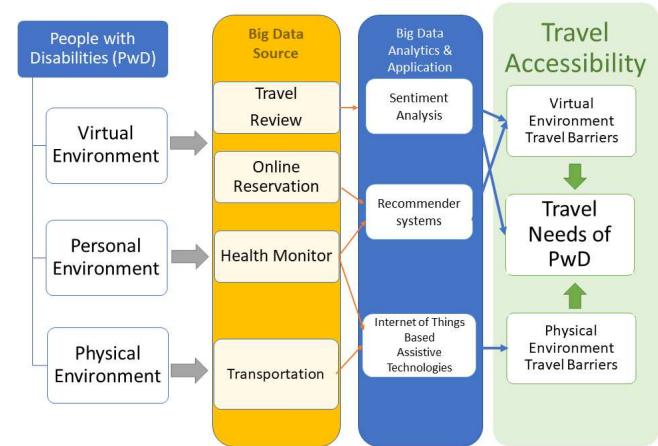
Cloud computing and big data analytics can also be helpful in health monitoring. The Artemis project mention earlier provide a example of big data analytics and cloud computing usage in health monitoring, by creating new cloud-base health analytics solutions [26]. Previous researchers have developed a mobile app to collect motion data of Parkinson's disease (PD) which is a disease resulting in mobility disorder using the smart phone 3D accelerometer and to send the data to a cloud service for storage, data processing, and PD symptoms severity estimation, which provide an user-friendly and economically affordable system to monitor and assess the condition of PD [34]. Although this system is not for people with disabilities, but it provided potentials for similar systems to be developed for different kind of disabilities.

Another application of cloud computing and big data in assistive technology is the CloudCast platform, which is a cloud-based speech recognition services that can be used for many assistive technology application for people with speech difficulties and hearing impairment, it also facilitate the collection of speech data required for the machine learning techniques [15]. Similar to Alexa Voice Service, it provide reliable speech recognition which can be used with assistive devices for people with hearing impairments, but CloudCast platform also provide customization for assistive technology applications benefiting users with speech impairment [15]. This research provided a great example of using big data and cloud computing in combine to solve a certain problem for people with disabilities (in this case it is barriers for speech impairment).

The development of information technology and assistive technology has improved the life of people with disabilities. The use disability informatics and health informatics can help researchers and service and technology providers to better understand the needs and wants for people with disabilities. Studies has discussed and proposed the great potentials to use big data source to better represent people with disability and identity and study issues and propose actions and solution to the challenges faced by people with disabilities. Using Cloud computing and big data also helps improving assistive and information technology that are now used to help people with disabilities. To improve the quality of life for people with disabilities, travel as a necessary needs and right for human cannot be ignored and the travel demands from the population with disabilities have to be addressed. Therefore, it will be beneficial and necessary to study travel accessibility with the help of big data and digital technologies, in order to improve the quality of life for people with disabilities. By reviewing previous literature, this study is exploring the potential relationship between big data and travel accessibility as shown in Figure 1.

## 4 TRAVEL ACCESSIBILITY AND BIG DATA

To explore the potential of big data applications and analytics in improving travel accessibility, the complexity of travel accessibility have to be addressed. Accessible travel includes not only the point-to-point transportation (such as air travel, flights), but also the accessibility of destination [3, 16, 30]. For people with disability to actually make the trip, they will also require booking for transportation and hotel reservation to be accessible. This study is going



**Figure 1: The Relationship Between Travel Accessibility and Big Data.**

to explore the use of big data application and analytics in different aspect of travel such as reservation, long distance transportation (in the form of airline travel), and destination transportation, the existing evidence and potentials for using these big data to improve travel accessibility..

### 4.1 Big Data and Online Reservation

Nowadays, the majority of the travel planning process happens online. Tourists would use a variety of tourism website, search engines, and reservation domains. The Internet also plays an important part at during and post travel stage, as tourists report issues on mobile applications, share traffic information in the cities, search and post on social media, take and share photos, report experience on travel websites and social media [2, 40]. These activities seems mundane and easy to complete for the general public, but for people with disabilities they can huge hassles or barriers.

Previous studies in relation to disability informatics demonstrated the profound positive impact of that the digital revolution on the life of people with disability by empowering them with the help of digital technologies [4]. However, there are still access issues in the digital world, the most urgent one is the use of the World Wide Web (WWW or Web). The Web has always had a strong awareness and been advocacy for accessibility since early on in its evolution [4]. The World Wide Web Consortium (W3C) had passed the Web Accessibility Initiative (WAI) and Web Content Accessibility Guidelines in the late 1990s [4].

A number of assistive technologies were designed to help people with disabilities to use the Web. For example BBC Education Text to Speech Internet Enhancer (BESTIE) is a CGI Perl script that can help people with disabilities who are using text-to-speech systems for Web browsing to modified the web page removing images, Java and Javascript code that may cause difficulties to understand the BBC web page content [18]. However, the limitation of BESTIE is that it is only compatible with BBC website. Other researchers also came up with Personalizable Accessible Navigation (PAN), which is a set of edge services designed to improve Web pages accessibility

which allow personalization and the opportunities to select multiple profiles, making it compatible for web as well as mobile devices [34].

The online sector of the tourism industry has quickly adopted big data applications to better understand the need of customer and to improve online experience for customers [2]. The online sector of the industry include meta-search engines (like Google), online travel agencies (like Expedia) and some information website companies that distribute tourism information (TripAdvisor)[29]. Amadeus, a tourism company known for its global distribution system, has developed a program “Amadeus Airline Cloud Availability” that can generated special result and increase search for its customers [40].

Travel domain companies like Marriott, Southwest airline, and Amtrak also developed assistive devices specially for people with disabilities to use when browsing their websites. These assistive technologies can help people with disabilities to navigate online reservation website, and help them to independently booking their travel reservations for hotels, restaurants, airplane tickets and attraction passes.

These assistive devices was design to help people with disabilities to have access to the Web. However, current web accessibility standards do not respect disability as a complex and culturally contingent interaction. The needs and demand of people with different types of disabilities are certainly not the same and this make it hard to understand and pinpoint the real needs for people with disabilities to access the Web. Researchers have proposed to use big data to better understand of the relation between disability and technology and recognized the difference of disabled people in the “Global South” where different contexts constitute different disabilities and different experiences of web access [4].

## 4.2 Accessible Transportation and Big Data

An inaccessible transport network prevents many people from going to school or studying, working, going to the doctor, meeting friends, going shopping or to the cinema and other activities that are taken for granted. However, for people with disabilities, an inaccessible transport network would left them dependent and confined in their own home [3]. More importantly an inaccessible transport network would also prevent people with disabilities to travel for business or leisure [30]. Older adults, people with disabilities, individuals in low-income households, especially those living in rural areas can face significant mobility challenges [32].

Concerns about getting into an accident, congestion, price of travel, access to transit, and lack of walkways are important issues for a large percentage of the population, but they tend to be more important for people with disabilities [32]. For today’s travel and transportation businesses, it is important to address the issue of inclusion, which is the potential to enable a broader range of people to use transportation infrastructure regardless of their individual abilities or disabilities [30]. Accessibility transportation is essential for travel accessibility, because it represent two aspect of travel accessibility: first is long distance transportation accessibility, and the second is accessible destinations. For a destination to be accessible, it have to have an accessible transport network allow people with disabilities to navigate with the destination.

**4.2.1 Airline and Big Data.** The airline industry is very familiar with big data use in their daily operations and market research. Airline companies have been using their big data which is the large volume of structured information that has been produced internally [29] to analyze prices of plane ticket. Moreover, airlines have optimized the details of planning for the crew and routing [40].

Previous studies in airline network used Big Data mined from the U.S. air transportation system over the years from 1998?2014 to characterize the network’s behavior and determine what internal and/or external drivers result in structural changes to the airline network [14]. Airline delay patents has also been studied with the help of big data by identifying by the number of late arrivals as a percent of total operations [43].

In another previous study, researchers used data from 2006 to 2008 in order to provides the result about the total flight delay for a specific period of time caused due to climate, security, carrier, National Aviation System, Arrival and Departure based on total number of flights getting delayed over in the given period of time [43]. In the study, the authors used time series analysis along with the integration of heterogeneous database to identify and achieve the Airline Seasonal Delay which is implemented and visualized in R, they were able to identify a trend line to provide the insights for the aviation industry to take future measures to avoid delays and manage them [43].

Airline studies have also used big data analytics on passenger reviews data. The advance development of social media and mobile helped the passengers to post reviews in a ubiquitous way, allow them post real time feedback over Facebook, Twitter on airports, airlines, and other travel providers [11]. However, passengers’ review can be really complex since travel activities usually involve multiple parties, therefore, the travel domain application systems are also typically managed by different stakeholders like airlines, airports, travel agencies, security and other services providers like cars, bus, trains, hotels, events. In order to provide a holistic approach to manage complex passenger reviews with data gathering, processing and disseminating, a previous study has proposed a reference architecture to manage passenger reviews where multiple stakeholders are involved by using data lakes, which can store, manage and analyze structured and unstructured data with cheaper cost, well-distributed, open sourced and powerful set of tools.

Even though previous studies on airline using big data have not address the issues of accessibility. These previous studies still show the potential for using big data source from the airline industry and passenger reviews to study the interests, motivation, needs and demands from people with disabilities.

**4.2.2 Transport Network Accessibility and Big Data.** Accessibility in the transport network studies are different defined than travel accessibility, since the urban accessibility is focus on provide access of transportation and transit to general public, not specifically people with disabilities [32]. However, since transport network accessibility usually are connected to urban transport network, which represent an important part of physical environment for people with disabilities it can provide some insight for accessible destinations especially urban destinations. Accessibility has always been a key concept in urban and regional planning for its capacity to link

the activities of people and businesses to the possibilities of reaching them effectively. The accessibility of the transport network is already challenging for general public, for people with disabilities who require special needs, it becomes a tremendous and difficult barrier, because they are required to make rapid, real-time decisions that are especially difficult for special needs populations. Therefore, previous studies using big data on urban accessibility can provide some potentials for travel accessibility studies [5].

For Urban and regional planning, accessibility represents traffic capacity to link the activities of people and business to the possibilities of reaching them effectively [32]. Accessibility is defined as "a dynamic attribute of locations that varies over time due to changes in the transport network and in the attractiveness of destinations for certain activities" [32]. Since the emergence of big data generated by social media, smart phones, satellite navigation system and other technologies, the information on transport networks has improved conclusively in recent years [5]. Navigation companies such as TomTom; websites and applications like Bing Maps, Google Map; collaborative projects like Open-Street-Map; the public availability of Transit Feed Specification and data from other transit authorities opens up a rapid growing field of research on real time and time-of-day variations in private and public transit accessibility [32]. These companies and institutions have increasingly detailed systems with information on the features of roads and public transport networks, and their databases include information on speed variations on the roads and the frequencies of passage in public transport networks, all of which contribute a more efficient and dynamic vision to urban accessibility studies [32].

Researchers have just started using these new information sources in studies on urban accessibility. Previous studies utilized data obtained from global positioning system devices to calculate speeds, congestion levels and accessibility conditions at different times of day (morning, midday, evening), other studies analyzed data from Be-Mobile system (which provided the geo-located positions of 400,000 vehicles equipped with tracking devices) to calculate car travel times [32].

Previous studies also have gathered and analyzed information from web services (such as Google map API) to calculate travel times between origins and destinations. These studies were able to use new information source and big data provided by the development of technologies to retrieve information about local locations and traffic condition for local facilities like groceries, malls, restaurants, banks, recreation centers and others, and estimate accessibility by car, walking, cycling and public transit options [32]. Previous research also used data from social media such as Twitter in combined with data from satellite navigation system (like TomTom) to provide a dynamic approach and obtain profiles that highlight the daily variations in accessibility in urban cities, identify real time influence of congestion and population location changes, by providing different accessibility profiles from different transport zone, the researchers were able to analyze the relationship between the performance of the transport network and the attractiveness of the destination [32]. Although this study is not designed to provide information for people with disability, but such dynamic approach using real time big data can also benefit people with disabilities and help them identify places to go in the city and the most accessible route to the attractions.

Another study also proposed and developed a travel assistance device for people with disabilities by using real time data from global positioning system. According to this study, recent advancements in mobile technology enabled smart phones with global positioning system provide real-time location-based services and its related data. The researchers for this study designed, implemented and tested a travel assistance device (TAD) that is designed to help transit riders with special needs using public transportation [5]. This device is a navigation software program designed to prompt individuals via a cell phone to exit the bus at a pre-set location. This travel assistance device provides the people with disabilities customized real-time audio, visual and tactile prompts for exiting the transit vehicle by announcing "Get ready" and "Pull the cord now!", based on its real-time assisted GPS data provided by the embedded GPS chip in the cell phone [5]. Once the software is downloaded and installed to the cell phone, parents, travel trainers, or other authorized individuals can access the web management page to schedule bus routes to be transmitted to the cell phone [5]. The system also provides alerts to riders, their caretakers and travel trainers when the rider with disabilities deviates from the planned route. With a website allowing easy access for the design and planning of new trip itineraries, the device allows authorized personnel (usually caregivers, family members) to monitor the rider's location in real-time from any computer [5]. The travel assistance device was catered to the needs of people with disabilities, increasing their level of independence and their care-takers security. This travel assistance device represented beneficial practice for people with disabilities [5].

However, there are still many challenges for the development of such device or services. One of the main challenges is that different needs of people with disabilities making it difficult to completely satisfy and assist people with different disabilities. Since the device proposed by this study is still at experimental stage and their test sample are limited, although through the test, the device was proved to be easy to use, it still might pose as a challenge for other people with disabilities, especially people with cognitive limitations [5].

## 5 PROMISES OF BIG DATA IN TRAVEL ACCESSIBILITY

As mentioned above, big data has some potentials in studies and research that are intended to enable and improve the ability for people with disabilities to travel independently. This section will explore different big data related technologies, applications and analytics that can help people with disabilities to travel with ease and researchers to better understand the demand and need for people with disabilities.

### 5.1 Internet of Things and Travel Assistive Technology

*5.1.1 Internet of Things Assistive Technology and Potentials for Travel use.* Assistive devices or technology (AT) for people with disabilities are not a new concept. Assistive devices refers to "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain or improve functional capabilities of individuals with disabilities", for examples, canes, crutches, walkers,

wheelchairs, and shower chairs, hearings aids, visual aids, other hardware, and software that improve ICT access or communication capacities are all assistive devices [5, 41]. People with disabilities are usually seen as depend, and in need of help from caregiver or family members [49]. However, with the technological growth that has been seen in the last 20 years, a wide array of devices have been adapted, created, and utilized with the potential to create independence for individuals with disabilities. Virtual reality, sensor monitoring devices, smart phone have all been used to assist those who require assistance in their day to day lives [32].

Older adults and individuals with physical, sensory, and mental/cognitive disabilities encounter many barriers to inclusion and accessing various opportunities and services that the society has to offer [41]. In order to overcome these barriers, people with disabilities needs some forms of assistive technologies or devices. Traditional technologies has many challenges, however, with the development of technology, the Internet of Things (IoT), smart homes, smart buildings, smart cities, and other smart environments can overcome some of these challenges due to their prevalence and diverse capabilities [9].

One of human's fundamental needs is the mobility and capability of independently traveling around, including for people with physical disabilities and even blind or visually impaired individuals [5]. In order for people with visual impairment to independently travel or moving around requires indoor and outdoor navigation capabilities, the blind and visually impaired people may rely on some type of AT to supplement their navigational abilities [41]. Previous studies has proposed using the advanced sensors of the smart phones in providing meaningful interactions with the environment for individuals with different abilities [41]. A typical modern smart phone has more than twenty sensors, which include GPS-based systems that can be useful for outdoor navigation, however in general, these sensors in smart phone still may lack the required precision and reliability for use by the blind or partially sighted individuals [41].

Previous research has proposed using Bluetooth beacons and audible instructions delivered through an interface device for navigation by the blind and partially sighted people is based on the use of such as bone conduction earphones or smart phones [5, 41]. A research team has designed and tested a system "with 16 Bluetooth beacons providing pin-point accurate indoor location mapping" for unassisted mobility in the London Underground [41]. The system is based on a mobile app, Wayfnder, which is a open platform that has the promise of promoting future development on assistive devices for people with visual limitations [41]. Microsoft, Guide Dogs, UK and several other organizations have also embarked on expanding similar concepts to respond to the challenges that people with sight loss face while navigating the cities [41]. These companies and organizations has developed technology and application that allow users to start a trip and they have a "Look Ahead" and "Find the way" mode that can help people with vision limitation to explore the city and let them stop at any point and check that they are heading the right direction [5].

**5.1.2 The Big Data Challenge of IoT Based AT.** While the growth and progress the IoT and smart environments, technologies such

as sensor technologies for comprehensive monitoring and surveillance progress and advance unbelievable fast, nevertheless, there still existed many challenges for these technologies [41]. One of the most important challenges is data availability. Because these technologies generated an enormous amount of data that surpasses the processing and use capabilities [41]. For instance, real-time localization and navigation systems that are designed to assist people with visual impairment to travel around, face two major related challenges: one is the allocation of computational resources that can process the large amounts of data coming from multiple sensors and cameras, fast enough in a real-time and synchronized manner, so that they can provide real-time guidance for people with special needs [41];the second issue relates to quick and real-time access to dynamic data sets through interfaces that are appropriate for the user [41].IoT devices typically have the issues of energy constrained, with small memory, limited processing power, and restrictive communication capabilities [41]. One positive aspect of this challenge is, these dynamic data obtained from IoT based AT device are extremely valuable and could help researchers and companies to better understand the needs of people with disabilities and analyzing such data can help researchers and companies to design better product for people with disabilities [17].

Another issues that AT adoption faces is its ability of meeting the usersfi needs and desires [41]. AT has been criticized because although AT devices "fimay have technical merit, and may solve obvious problems, but still fail to address the complex interplay of issues at work and to take the most appropriate approach to dealing with these matters. Furthermore, it is important to acknowledge that there may not even be a firightfi problem to tackle. Flexibility cannot be overvalued" [41]. Due to the complexity of the needs and wants for people with different disabilities, it can be challenging to develop an assistive device that can accommodate most people, however, a holistic understanding of the intended users is required [41]. It is important for researchers and AT device engineers to understand the wants and needs of people with disabilities, to be able to design an AT product that actually can fulfill what people with disabilities want, instead of just assuming what people with disabilities needs [5].

Some people may feel intimidated by the newer technologies such as those of the IoT-based AT [15]. First these device required some sort of learning and adapting period, and for people with disabilities, it might too longer time than for "normal" people, which can be taxing for people with disabilities and give them extra pressures [41]. For people who are used to being in control of their devices, some automate processes of IoT-based AT, which was intended to provide support for people with disabilities, ironically, may pose potential stress for operating and adapting to the devices [41]. A similar issue arises from the fast pace of the development of such advanced technologies. With the rapid advancement of technology, products and service become obsolete really quickly as the newer improved version become available. As mentioned above, people with disabilities do have a learning curve and need adapting process for IoT based assistive technologies, the constant and multiple upgrades of new version can make it harder for people with disabilities to adapt. Therefore, the elderly or people with disability or dementia may miss out on obtaining the full benefits of these devices or services [5, 15, 41]. The costs, learning curves,

or simply a lack of awareness can potentially prevent these people to use new technologies at all.

With the emergence of new technologies such as Internet of Things and large scale wireless sensor system, IoT based AT emerged as potential solution and promise for improving the quality of life for people with disabilities. They provide new opportunities and can aid people with disabilities in their travel, and help them overcome travel barriers. However, there is still manage challenges for people with disabilities, especially when it come to complex situations that they are going to encounter during their travel. There is a distinct gap in IoT based AT research: the lacking of holistic understanding of the needs and wants from people with disabilities. More studies needs to be conducted on the opinions and users experience of IoT based AT.

## 5.2 Sentiment Analysis on Online Reviews

The popularity of social media, especially review sites like TripAdvisor and blogs and wikis, leads to an enormous amount of personal reviews for travel-related information on the Web [37]. More importantly, the information in these reviews is valuable to both tourists and travel and tourism practitioners for various understanding and planning processes [49]. These UGC comes from all kinds of tourists with different demographic background, within with also has reviews from people with disabilities. Therefore, analyzing hotel reviews on various website and platform that are posted by people with disabilities can help us better understand the needs of this population group. One of the most common analytics method for large amount of review data is sentiment analysis [37].

Sentiment analysis, which is also called opinion mining, is one of the most active research areas in natural language processing [37]. The aim of sentiment analysis is to define automatic tools able to extract subjective information from text in natural language, and to create structured and actionable knowledge to be used by either a decision support system or a decision maker [23, 49]. The sentiments of reviews, online reputation or online documents are usually categorized in positive, negative and (in some studies) neutral sentiments [21]. The main goal of the sentiment classification is to extract “the global sentiment based on the subjectivity and the linguistic characteristics of the words within an unstructured text” [21]. Therefore, sentiment analysis provided a framework to transform unstructured text to structured data, which make it strongly applicable to both the academic field [8]. Because of the importance of sentiment analysis to business and society, it has spread from computer science to management science and the social sciences [36]. As a social science field and business industry, tourism and travel studies have already been using sentiment analysis in the research.

Previous studies have identified two primary approaches for sentiment analysis: methods based on the combination of lexical resources and Natural Language Processing (NLP) techniques; and machine learning approaches [21]. Since 2009, researchers have been using machine learning methods in the natural language processing (support vector machine (SVM), Nave Bayes, and the N-gram model) to do sentiment analysis on TripAdvisor reviews [49]. Their study analyzed online reviews related to travel destinations, using different supervised machine learning algorithms

The algorithms to evaluate the reviews about seven popular travel destinations in Europe and North America [49].

The etBlogAnalysis project developed a combined crawler /sentiment extraction application for the tourism industry, which used a simple and robust linguistic parsing methodology with information and terminology extraction methods in order to determine relevant utterances on expression level [37]. It will also provide a warning for tourism operator such as a hotel, if too many negative entries have been generated by their reviewers [21].

In tourism studies, sentiment analysis has been compared to traditional qualitative analytic methods. A previous study compared three alternative approaches for mining consumer sentiment (manual content coding, corpus-based semantic analysis, and stance-shift analysis) from large amounts of qualitative data found in online travel reviews [9, 13]. They applied three different approaches to study consumers' reaction to farm stays in order to demonstrate how large volumes of qualitative data can be analyzed quantitatively in a relatively efficient and reliable way [21]. Manual content coding is the same as traditional the content analysis approach involving two researchers collaborated in a manual coding process designed to extract consumer likes and dislikes from the qualitative data [20]. According to the comparison, computer generated sentiment analysis such as stance-shift analysis processing on both syntax and lexicon assures the coding maintains the statement's context identifying what is important to the informants by the way they express their comments. Most importantly, stance-shift analysis does not categorize what the researcher thinks is important in reviewer's words [9]. The study suggested by combining different approaches in sentiment analysis such as using stance-shift analysis first identifies the significant word segments then using corpus-based semantic analysis detects key themes in those segments helps uncover narrative themes of consumer experiences in large qualitative databases [9].

Sentiment analysis will help researchers to better understand people's travel experience, however, there are few studies have been done to identify demographic information of the reviewer and compare the sentiment analysis result across different demographic [23]. A recent invention present the possibility of identifying demographic characteristics while conducting sentiment analysis. The invention consist of a product or service review to determine demographic information of the reviewer [6]. A sentiment text analysis is performed on the product or service review, wherein the sentiment text analysis examines the product or service review to determine a sentiment of the product or service review. The sentiment of the product or service review is categorized based on the demographic information of the reviewer [6]. This invention presents the promise of using sentiment analysis on the travel experience of people with disabilities. However, challenges still remain for research of UGC generated by people with disabilities, such as the challenge presented by privacy concerns of personal data online [27].

## 5.3 Recommender System

Nowadays tourists faces a very challenging task of trip preparation because of the huge amount of information available on the Web about tourism and leisure activities [1]. Recommender systems

becomes essential for tourists and tourism operators. For tourists, recommender systems can be a useful tools to help them make decision for travel planning, such as the choices of destinations, attractions, accommodations and restaurants. As for tourism operators, it can be a great marketing opportunities for them to reach a variety of targeted potential consumers. Complex problems such as automated planning, semantic knowledge management, group recommendation or context-awareness have by now been heavily studied in this area [31].

There are already several tourism recommender system available for general public. TIP and Heracles systems provide recommendation service through mobile devices for tourism, through implement hybrid algorithms to calculate tourist preferences, using the defined tourist profile and location data [31]. Crumpet system provides new information delivery services for a variety of different tourist population based on location aware services, personalized user interaction, accessible multimedia mobile communication that uses Multi-Agent Technology [39]. CATIS is a Web based tourist information system using context-awareness, which include context elements such as location, time of day, speed, direction of travel and personal preferences. This system provided information to tourists relevant to his or her location and time [39]. TravelWithFriends using group recommendation service, the first step is to build a recommendation list for each user and to merge them to obtain a destinations shortlist. Afterwards, each group member rates all these options and a Borda count is used to determine the best five destinations to be recommended [31].

Classical recommender systems filter the domain items according to a particular user, using his or her demographic data, past ratings or purchasing history [28]. This approach are used to recommend specific items such as books, songs or films [28]. However, it may not be suitable for travel activities, since most of time travel is an activity that involves a group of people (such as family members, friends). Therefore, it is necessary to take into account the different preferences of all members of travel group when providing recommendations [31]. Previous studies and technology reports have identified two primary options for group recommendation: the first one is to merge the lists of items recommended to each group member, or creating a group profile with everyone's preferences and then compute a single list of group recommendations [20]. The second option's first step is the same as the previous option, by constructing of a list of recommendations for each group member. In a second step though, an automatic consensus-reaching process is applied, in which individual preferences are continuously updated until a high degree of agreement between all the group members is reached [20].

The use of semantic domain knowledge in the recommendation process has heavily increased in recent years. Previous studies have defined the semantic similarity between two concepts as "the ratio between the number of different ancestors and the total number of ancestors of both concepts" [31]. The items to be recommended are clustered according to this semantic similarity and the recommendation procedure selects the best item from random clusters [39]. Previous study has shown that this procedure keeps the accuracy and increases the diversity of the results [31]. Semantic information can also be used to determine the items to be recommended in a personalized visit to a museum or destinations,

by using a shortest-path semantic distance to determine which museum objects or attractions should be recommended to the user [31].

Previous study also proposed a hybrid tourism recommendation system for persons suffering from physical or intellectual limitation. This proposed recommendation system is not simply trying to improve experience, but to create and increase the confidence of users that despite of their limitations they can visit and experience certain places without being afraid, and to help them to truly live a touristic experience. As shown in Figure 2, the system models a user stereotype profile, by identifying the user's functionality and point of interest (POI) accessibility level, which represent user's related knowledge which is layered with several knowledge representation structures and models and produce an accurate touristic recommendation plan [39]. The study represent itself as an opportunity to provide needed information to people with disabilities through a hybrid tourism recommendation system.

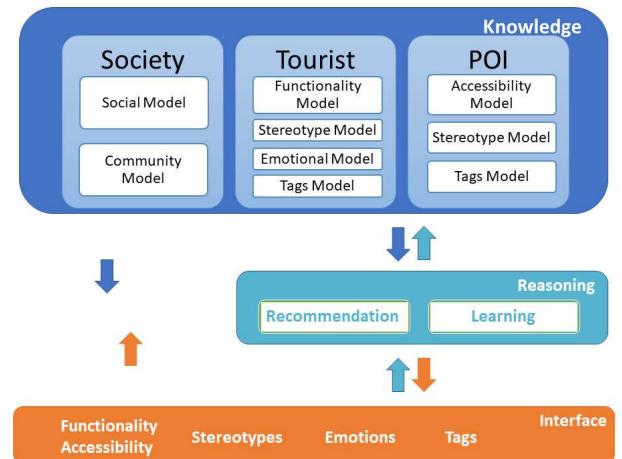


Figure 2: Hybrid Tourism Recommendation System[39].

## 6 CONCLUSION

This study has explored the big data applications and analytics in tourism industry and research, and disability related research. This study illustrated the importance of improving travel accessibility by recognizing the underestimated market for travel of people with disabilities. The lack of research on big data application and analytics in travel accessibility was identified. By recognizing the complexity of travel accessibility, this study present the potential of using big data analytics and application to better understand the need of people with disability in two travel accessibility aspects: online reservation, and accessible transportation. Although there are few studies on big data and accessible online reservations and accessible transportation directly, this study illustrate big data utilization in web accessibility, airline studies and urban accessibility. These previous studies show promises of using big data analytics and application to address accessibility issues and the needs of people with disabilities in these aspects. This study also explored the promise of big data in travel accessible by exploring:

- Potentials of Internet of Things (IoT) based assistive technology (AT): help people with disabilities overcome travel challenge presented by physical environment.
- Recommender systems: help people with disabilities to get more needed information online, and make it easier for them to navigate the virtual environment.
- Sentiment analysis on online reviews: help researchers and practitioners to better understand the needs and behaviors of people with disabilities.

However, there are still a lot challenge faced by researchers and organizations interested in improving the quality of life for people with disabilities. The most dominated challenge is the different needs for people with different disabilities types and function levels. Future studies could use sentiment analysis of reviews online generated by people with disabilities to better understand their needs and identify the differences between different disabilities groups. Future studies should also analyze dynamic data generated by the sensors on the assistive devices for people with disabilities to better understand their travel patterns and to provide more appropriate products for people with disabilities.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski and TAs for i523 for his support and suggestions to write this paper.

## REFERENCES

- [1] Gediminas Adomavicius and Alexander Tuzhilin. 2015. *Context-Aware Recommender Systems*. Springer US, Boston, MA, 191–226. [https://doi.org/10.1007/978-1-4899-7637-6\\_6](https://doi.org/10.1007/978-1-4899-7637-6_6)
- [2] Rajendra Akerkar. 2012. *Big Data and Tourism*. Technical Report. Technomathematics Research Foundation.
- [3] Amadeus. 2017. *Voyage of discovery*. techreport. Amadeus, Madrid Spain. <http://www.amadeus.com> Accessed 2017.
- [4] Richard Appleyard. 2005. *Disability Informatics*. Springer New York, New York, NY, Chapter chapter 11, 129–142. <https://doi.org/10.1007/0-387-27652-1-11>
- [5] S. J. Barbeau, P. L. Winters, N. L. Georggi, and M. A. Labrador. 2010. Travel assistance device: utilising global positioning system-enabled mobile phones to aid transit riders with special needs. *IET Intelligent Transport Systems* 4, 1 (March 2010), 12–23. <https://doi.org/10.1049/iet-its.2009.0028>
- [6] D.A. Bhatt. 2014. Sentiment analysis based on demographic analysis. (May 15 2014). <https://www.google.com/patents/US20140136185> US Patent App. 13/675,653.
- [7] Ann Cameron Caldwell. 2011. *Untapped Markets in Cloud Computing: Perspectives and Profiles of Individuals with Intellectual and Developmental Disabilities and Their Families*. Springer Berlin Heidelberg, Berlin, Heidelberg, Chapter Chapter 30, 281–290. [https://doi.org/10.1007/978-3-642-21663-3\\_30](https://doi.org/10.1007/978-3-642-21663-3_30)
- [8] E. Cambria, B. Schuller, Y. Xia, and C. Havasi. 2013. New Avenues in Opinion Mining and Sentiment Analysis. *IEEE Intelligent Systems* 28, 2 (March 2013), 15–21. <https://doi.org/10.1109/MIS.2013.30>
- [9] Antonella Capriello, Peyton R. Mason, Boyd Davis, and John C. Croots. 2013. Farm tourism experiences in travel reviews: A cross-comparison of three alternative methods for data analysis. *Journal of Business Research* 66, 6 (2013), 778 – 785. <https://doi.org/10.1016/j.jbusres.2011.09.018> International Tourism Behavior in Turbulent Times.
- [10] G. Chareyron, J. Da-Rugna, and T. Raimbault. 2014. Big data: A new challenge for tourism. In *2014 IEEE International Conference on Big Data (Big Data)*. IEEE, Washington, DC, USA, 5–7. <https://doi.org/10.1109/BigData.2014.7004475>
- [11] Cynthia Chen, Jingtao Ma, Yusak Susilo, Yu Liu, and Menglin Wang. 2016. The promises of big data and small data for travel behavior (aka human mobility) analysis. *Transportation Research Part C: Emerging Technologies* 68, Supplement C (2016), 285 – 299. <https://doi.org/10.1016/j.trc.2016.04.005>
- [12] Jin Chung and Dimitrios Buhalis. 2009. *Virtual travel community: bridging travellers and locals*. IGI Global, USA. 130–144 pages.
- [13] W. B. Claster, M. Cooper, and P. Sallis. 2010. Thailand – Tourism and Conflict: Modeling Sentiment from Twitter Tweets Using Naïve Bayes and Unsupervised Artificial Neural Nets. In *2010 Second International Conference on Computational Intelligence, Modelling and Simulation*. 89–94. <https://doi.org/10.1109/CIMSiM.2010.98>
- [14] E. Clemons, R. Jordan, and T. Reynolds. 2016. Airline network and competition characterization using big data approaches. In *2016 IEEE/AIAA 35th Digital Avionics Systems Conference (DASC)*. IEEE, Sacramento, CA, USA, 1–10. <https://doi.org/10.1109/DASC.2016.7777957>
- [15] Stuart Cunningham, Phil Green, Heidi Christensen, JJ Atria, A Coy, M Malavasi, L Desideri, and F Rudzicz. 2017. Cloud-Based Speech Technology for Assistive Technology Applications (CloudCAST). *Harnessing the Power of Technology to Improve Lives* 242 (2017), 322.
- [16] Simon Darcy. 2010. Inherent complexity: Disability, accessible tourism and accommodation information preferences. *Tourism Management* 31, 6 (2010), 816 – 826. <https://doi.org/10.1016/j.tourman.2009.08.010>
- [17] G Dewsbury, K Clarke, M Rouncefield, I Sommerville, B Taylor, and M Edge. 2003. Designing acceptable 'smart' home technology to support people in the home. *Technology and Disability* 15, 3 (2003), 191 – 199. <http://proxylib.uits.iu.edu/login?url=https://search-ebscohost.com.proxylib.uits.iu.edu/login.aspx?direct=true-db=ccm-AN=106746102-site=ehost-live-scope=site>
- [18] Ugo Erra, Gennaro Iaccarino, Delfina Malandrino, and Vittorio Scarano. 2007. Personalizable edge services for Web accessibility. In *Universal Access in the Information Society (W4A)*, Vol. 6. WWW2006, ACM, Edinburgh, UKfif, 285–306.
- [19] Lex Frieden. 2015. Why Disability Informatics? (02 2015). <https://sbmi.uth.edu/blog/feb-15/021115.htm>
- [20] Irma Garcia, Laura Sebastia, Eva Onaindia, and Cesar Guzman. 2009. *A Group Recommender System for Tourist Activities*. Springer Berlin Heidelberg, Berlin, Heidelberg, 26–37. [https://doi.org/10.1007/978-3-642-03964-5\\_4](https://doi.org/10.1007/978-3-642-03964-5_4)
- [21] Aitor Garca, Sean Gaines, and Maria Teresa Linaza. 2012. A Lexicon Based Sentiment Analysis Retrieval System for Tourism Domain. *E-review of Tourism Research* 10, 2 (2012), 35 – 38. <http://proxylib.uits.iu.edu/login?url=https://search-ebscohost.com.proxylib.uits.iu.edu/login.aspx?direct=true-db=hjh-AN=84339713-site=ehost-live-scope=site>
- [22] Jan Grue. 2016. The social meaning of disability: a reflection on categorisation, stigma and identity. *Sociology of Health and Illness* 38, 6 (2016), 957–964. <https://doi.org/10.1111/1467-9566.12417>
- [23] Dietmar Grbner, Markus Zanker, Gnther Fliedl, and Matthias Fuchs. 2012. Classification of Customer Reviews based on Sentiment Analysis. In *19th Conference on Information and Communication Technologies in Tourism (ENTER)*. Springer, Helsingborg, Sweden, 460–470.
- [24] Yue Guo, Stuart J. Barnes, and Qiong Jia. 2017. Mining meaning from online ratings and reviews: Tourist satisfaction analysis using latent dirichlet allocation. *Tourism Management* 59, Supplement C (2017), 467 – 483. <https://doi.org/10.1016/j.tourman.2016.09.009>
- [25] Jeffery Hoehl and Kaleb August Sieh. 2010. *Cloud Computing and Disability Communities: How Can Cloud Computing Support a More Accessible Information Age and Society?* Technical Report. Silicon Flatirons Center, Colorado, US. <https://doi.org/10.2139/ssrn.228526>
- [26] H. Khazaei, C. McGregor, M. Eklund, K. El-Khatib, and A. Thommandram. 2014. Toward a Big Data Healthcare Analytics System: A Mathematical Modeling Perspective. In *2014 IEEE World Congress on Services*. IEEE, Anchorage, AK, USA, 208–215. <https://doi.org/10.1109/SERVICES.2014.45>
- [27] Jonathan Lazar, Michael Ashley Stein, and Judy Brewer. 2017. *Disability, human rights, and information technology*. Philadelphia : University of Pennsylvania Press, [2017], Pennsylvania, USA. <http://proxylib.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true-db=cat0001ea-AN=inun.16424800-site=eds-live-scope=site>
- [28] Jie Lu, Dianshuang Wu, Mingsong Mao, Wei Wang, and Guangquan Zhang. 2015. Recommender system application developments: A survey. *Decision Support Systems* 74, Supplement C (2015), 12 – 32. <https://doi.org/10.1016/j.dss.2015.03.008>
- [29] Shah Jahan Miah, Huy Quan Vu, John Gammack, and Michael McGrath. 2017. A Big Data Analytics Method for Tourist Behaviour Analysis. *Information and Management* 54, 6 (2017), 771 – 785. <https://doi.org/10.1016/j.im.2016.11.011> Smart Tourism: Traveler, Business, and Organizational Perspectives.
- [30] Milo N. Mladenovif. 2017. Transport justice: designing fair transportation systems. *Transport Reviews* 37, 2 (2017), 245–246. <https://doi.org/10.1080/01441647.2016.1258599>
- [31] A Moreno, L Sebastian, and P Vansteenwegen. 2015. Recommender Systems in Tourism. *IEEE Intelligent Informatics Bulletin* 16, 1 (Dec. 2015), 1–2. <http://www.comp.hkbu.edu.hk/~iib/>
- [32] Borja Moya-Gómez, María Henar Salas-Olmedo, Juan Carlos García-Palomares, and Javier Gutiérrez. 2016. Dynamic accessibility using Big Data: The role of the changing conditions of network congestion and destination attractiveness. *Networks and Spatial Economics* 1, 7 (2016), 1–18.
- [33] Open Door Organization. 2015. Open Doors Organization Market Study Press Report. (2015). <http://opendoorsnfp.org/market-studies/2015-market-study/> accessed 2017.
- [34] Di Pan, Rohit Dhall, Abraham Lieberman, and B. Diana Petitti. 2015. A Mobile Cloud-Based Parkinson's Disease Assessment System for Home-Based Monitoring. *JMIR mHealth uHealth* 3, 1 (26 Mar 2015), e29. <https://doi.org/10.2196/2196>

- mhealth.3956
- [35] Gabriel Pestre. 2016. Big Data and Disability, Part 1. Data Pop Alliance. (March 2016). <http://datapopalliance.org/big-data-and-disability-part-1/> Accessed 2017.
  - [36] Federico Pozzi, Elisabetta Fersini, Enza Messina, and Bing Liu. 2016. *Sentiment Analysis in Social Networks*. Elsevier LTD, Oxford, Cambridge, MA.
  - [37] V. B. Raut and D. D. Londhe. 2014. Opinion Mining and Summarization of Hotel Reviews. In *2014 International Conference on Computational Intelligence and Communication Networks*. IEEE, Bhopal, India, 556–559. <https://doi.org/10.1109/CICN.2014.126>
  - [38] Paraskewi Riga and Georgios Kouroupetroglou. 2013. Indoor Navigation and Location-Based Services for Persons with Motor Limitations. In *Disability Informatics and Web Accessibility for Motor Limitations*. IGI Global, Greece, 202–233. <https://doi.org/10.4018/978-1-4666-4442-7.ch006>
  - [39] Filipe Santos, Ana Almeida, Constantino Martins, Paulo Moura de Oliveira, and Ramiro Gonçalves. 2018. Hybrid Tourism Recommendation System Based on Functionality/Accessibility Levels. In *Trends in Cyber-Physical Multi-Agent Systems. The PAAMS Collection - 15th International Conference, PAAMS 2017*, Fernando De la Prieta, Zita Vale, Luis Antunes, Tiago Pinto, Andrew T. Campbell, Vicente Julián, Antonio J.R. Neves, and María N. Moreno (Eds.). Springer International Publishing, Cham, 221–228. [https://doi.org/10.1007/978-3-319-61578-3\\_23](https://doi.org/10.1007/978-3-319-61578-3_23)
  - [40] S. Shafiei and A. R. Ghatari. 2016. Big data in tourism industry. In *2016 10th International Conference on e-Commerce in Developing Countries: with focus on e-Tourism (ECDC)*. IEEE, Isfahan, Iran, 1–7. <https://doi.org/10.1109/ECDC.2016.7492979>
  - [41] Seyed Shahrestani. 2017. *Internet of Things and Smart Environments*. Springer-Verlag GmbH, Cham, Switzerland.
  - [42] Ralph W. Smith. 1987. Leisure of disable tourists: Barriers to participation. *Annals of Tourism Research* 14, 3 (1987), 376 – 389. [https://doi.org/10.1016/0160-7383\(87\)90109-5](https://doi.org/10.1016/0160-7383(87)90109-5)
  - [43] M. Sornam, M. Meharunnisa, and Parthiban Nagendren. 2017. Big Data Analytics on Aviation data for the prediction of Airline Trends in Seasonal Delay. *International Journal of Advanced Research in Computer Science* 8, 5 (2017), 2248. <http://proxyiub.uits.iu.edu/login?url=https://search-ebscohost-com.proxyiub.uits.iu.edu/login.aspx?direct=true&db=edb&AN=124636583&site=eds-live&scope=site>
  - [44] M. Viceconti, P. Hunter, and R. Hose. 2015. Big Data, Big Knowledge: Big Data for Personalized Healthcare. *IEEE Journal of Biomedical and Health Informatics* 19, 4 (July 2015), 1209–1215. <https://doi.org/10.1109/JBHI.2015.2406883>
  - [45] N.L. Williams, A. Inversini, N. Ferdinand, and D. Buhalis. 2017. Destination eWOM: A macro and meso network approach? *Annals of Tourism Research* 64 (2017), 87–101. <https://doi.org/10.1016/j.annals.2017.02.007> cited By 0.
  - [46] Zheng Xiang, Zvi Schwartz, John H. Gerdes, and Muzaffer Uysal. 2015. What can big data and text analytics tell us about hotel guest experience and satisfaction? *International Journal of Hospitality Management* 44, Supplement C (2015), 120 – 130. <https://doi.org/10.1016/j.ijhm.2014.10.013>
  - [47] Karen L. Xie, Kevin Kam Fung So, and Wei Wang. 2017. Joint effects of management responses and online reviews on hotel financial performance: A data-analytics approach. *International Journal of Hospitality Management* 62, Supplement C (2017), 101 – 110. <https://doi.org/10.1016/j.ijhm.2016.12.004>
  - [48] WA Yasnoff. 2000. Public health informatics: improving and transforming public health in the information age. *Journal of public health management and practice* 6, 6 (11 2000), 67–75.
  - [49] Qiang Ye, Ziqiong Zhang, and Rob Law. 2009. Sentiment classification of online reviews to travel destinations by supervised machine learning approaches. *Expert Systems with Applications* 36, 3, Part 2 (2009), 6527 – 6535. <https://doi.org/10.1016/j.eswa.2008.07.035>
  - [50] Ye Zhang and Shu Tian Cole. 2016. Dimensions of lodging guest satisfaction among guests with mobility challenges: A mixed-method analysis of web-based texts. *Tourism Management* 53 (2016), 13–27.

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--empty publisher in claster
Warning--empty address in claster
(There were 2 warnings)
```

```
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
[2017-12-12 19.59.41] pdflatex report.tex
```

```
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
```

```
Missing character: ""
Typesetting of "report.tex" completed in 1.2s.
```

---

## Compliance Report

---

```
name: Weixuan Wang
hid: 234
paper1: Oct 22 2017 100%
paper2: Nov 9 2017 100%
project: 100% Dec 07 17
```

```
yamlcheck
```

---

```
wordcount
```

---

```
11
wc 234 project 11 9039 content.tex
wc 234 project 11 10088 report.pdf
wc 234 project 11 4940 report.bib
```

```
find "
```

-----  
passed: True

find footnote  
-----

passed: True

find input{format/i523}  
-----

passed: False

find input{format/final}  
-----

4: \input{format/final}

passed: True

floats  
-----

320: the potential relationship between big data and travel accessibility  
as shown in Figure \ref{F:present}.

322: \begin{figure}[htb]

323: \centering\includegraphics[width=\columnwidth]{images/present.png}  
}

324: \caption{The Relationship Between Travel Accessibility and Big  
Data.}\label{F:present}

846: As shown in Figure \ref{F:rec}, the system models a user  
stereotype profile, by

853: \begin{figure}[htb]

854: \centering\includegraphics[width=\columnwidth]{images/rec.png}

855: \caption{Hybrid Tourism Recommendation  
System}\cite{Santos2018}\label{F:rec}

figures 2

tables 0

includegraphics 2

labels 2

refs 2

floats 2

True : ref check passed: (refs >= figures + tables)

```
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includographics)
True : check if all figures are referred to: (refs >= labels)
```

```
Label/ref check
passed: True
```

```
When using figures use columnwidth
[width=1.0\columnwidth]
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

---

```
bibtex
```

---

```
label errors
```

```
bibtex errors
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--empty publisher in cluster
Warning--empty address in cluster
(There were 2 warnings)
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

```
-----  
passed: True
```

```
ascii  
-----
```

```
non ascii found 8217  
non ascii found 8211  
non ascii found 8217  
non ascii found 8217  
non ascii found 8230  
non ascii found 8216  
non ascii found 8217  
non ascii found 239  
non ascii found 8217  
non ascii found 8217
```

```
=====  
The following tests are optional  
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline  
-----
```

```
passed: True  
cites should have a space before \cite{} but not before the {
```

```
find cite {  
-----
```

```
passed: True
```

# Big Data analytics in predict house price

Yujie Wu

Indiana University Bloomington

Bloomington, Indiana 47401

yujiwu@iu.edu

## ABSTRACT

House price changes dynamically and it costs human power to evaluate the price. This project uses a large data set obtained from house dealings and algorithms to predict if house price is reasonable.

## KEYWORDS

i523, HID235, House Price, Logistic Regression, linear Regression

## 1 INTRODUCTION

Asking a home buyer to describe their dream house, and they probably won't begin with the height of the basement ceiling or the proximity to an east-west railroad. But this playground competition's dataset proves that much more influences price negotiations than the number of bedrooms or a white-picket fence. With 79 explanatory variables describing (almost) every aspect of residential homes in Ames, Iowa, this project is aimed to overcome the challenges of predicting the final price of each home.

## 2 LINEAR REGRESSION

In statistics, linear regression is a linear approach for modeling the relationship between a scalar dependent variable  $y$  and one or more explanatory variables (or independent variables) denoted  $X$ . The case of one explanatory variable is called simple linear regression. For more than one explanatory variable, the process is called multiple linear regression[2].

In linear regression, the relationships are modeled using linear predictor functions whose unknown model parameters are estimated from the data. Such models are called linear models. Most commonly, the conditional mean of  $y$  given the value of  $X$  is assumed to be an affine function of  $X$ ; less commonly, the median or some other quantile of the conditional distribution of  $y$  given  $X$  is expressed as a linear function of  $X$ . Like all forms of regression analysis, linear regression focuses on the conditional probability distribution of  $y$  given  $X$ , rather than on the joint probability distribution of  $y$  and  $X$ , which is the domain of multivariate analysis[2].

Linear regression was the first type of regression analysis to be studied rigorously, and to be used extensively in practical applications. This is because models which depend linearly on their unknown parameters are easier to fit than

models which are non-linearly related to their parameters and because the statistical properties of the resulting estimators are easier to determine[2].

## 3 LOGISTIC REGRESSION

In statistics, logistic regression, or logit regression, or logit model is a regression model where the dependent variable (DV) is categorical. This article covers the case of a binary dependent variable that is, where the output can take only two values, "0" and "1", which represent outcomes such as pass/fail, win/lose, alive/dead or healthy/sick. Cases where the dependent variable has more than two outcome categories may be analyzed in multinomial logistic regression, or, if the multiple categories are ordered, in ordinal logistic regression. In the terminology of economics, logistic regression is an example of a qualitative response/discrete choice model[3].

Logistic regression was developed by statistician David Cox in 1958. The binary logistic model is used to estimate the probability of a binary response based on one or more predictor (or independent) variables (features). It allows one to say that the presence of a risk factor increases the odds of a given outcome by a specific factor[3].

Logistic regression is used in various fields, including machine learning, most medical fields, and social sciences. For example, the Trauma and Injury Severity Score (TRISS), which is widely used to predict mortality in injured patients, was originally developed by Boyd et al. using logistic regression. Many other medical scales used to assess severity of a patient have been developed using logistic regression. Logistic regression may be used to predict whether a patient has a given disease (e.g. diabetes; coronary heart disease), based on observed characteristics of the patient. Another example might be to predict whether an American voter will vote Democratic or Republican, based on age, income, sex, race, state of residence, votes in previous elections, etc. The technique can also be used in engineering, especially for predicting the probability of failure of a given process, system or product. It is also used in marketing applications such as prediction of a customer's propensity to purchase a product or halt a subscription, etc. In economics it can be used to predict the likelihood of a person's choosing to be in the labor force, and a business application would be to predict the likelihood of a homeowner defaulting on a mortgage. Conditional random fields, an extension of logistic

regression to sequential data, are used in natural language processing[3].

## 4 EXPERIMENT

```
In [1]: import matplotlib.pyplot as plt
%matplotlib inline
from sklearn.metrics import accuracy_score
In [2]: from sklearn.ensemble import RandomForestClassifier
import pandas as pd
from sklearn.preprocessing import LabelEncoder
import numpy as np
df=pd.read_csv('C:\\\\Users\\\\Yujie\\\\s
VMware\\\\Desktop\\\\training_data.csv')
df.head()
```

	Id	MSSubClass	LotArea	OverallQual	OverallCond	YearBuilt	YearRemodAdd	MasVnrArea	BsmtFinSF1	BsmtFinSF2
0	1	60	8450	7	5	2003	2003	196	706	0
1	2	20	9600	6	8	1976	1976	0	978	0
2	3	60	11250	7	5	2001	2002	162	486	0
3	4	70	9550	7	5	1915	1970	0	216	0
4	5	60	14260	8	5	2000	2000	350	655	0

	WoodDeckSF	OpenPorchSF	EnclosedPorch	3SsnPorch	ScreenPorch	PoolArea	MiscVal	MoSold	YrsSold	SalePrice
0	61	0	0	0	0	0	0	2	2008	208500
298	0	0	0	0	0	0	0	5	2007	181500
0	42	0	0	0	0	0	0	9	2008	223500
0	35	272	0	0	0	0	0	2	2006	140000
192	84	0	0	0	0	0	0	12	2008	250000

```
# clean data and show del df['error']
Out[26]:
df.head()
```

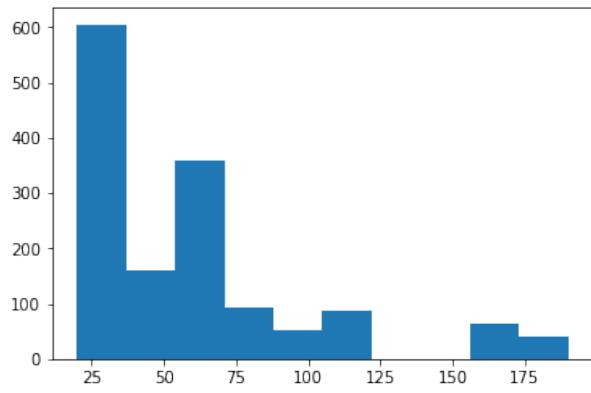
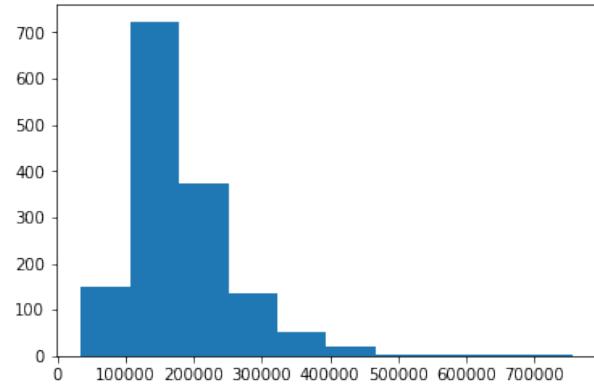
```
# clean data and show del df['error']
Out[26]:
df.head()
```

	MSSubClass	MSZoning	LotFrontage	LotArea	Street	Alley	LotShape	LandContour	Utilities	LotConfig
0	50	RM	L70	L10517	Pave	None	Reg	Lvl	AllPub	Inside
1	20	RL	L70	L10517	Pave	None	IR1	Lvl	AllPub	Inside
2	20	RL	L70	L10517	Pave	None	Reg	Lvl	AllPub	Corner
3	20	RL	G70	L10517	Pave	None	Reg	Lvl	AllPub	Inside
4	20	RL	G70	L10517	Pave	None	IR1	Lvl	AllPub	Inside

	GarageCars	GarageQual	GarageCond	PavedDrive	PoolArea	PoolQC	Fence	SaleType	SaleCondition	binSalePrice
2	Fa	TA	Y	N	None	None	WD	Abnorml	N	
1	TA	TA	Y	N	None	MnPrv	WD	Normal	N	
2	TA	TA	Y	N	None	None	WD	Normal	N	
2	TA	TA	Y	N	None	GdWo	WD	Abnorml	N	
2	TA	TA	Y	N	None	None	WD	Normal	Y	

```
In [50]: # show the distribution of a column col =
list(df['SalePrice'])
plt.hist(col)
plt.show()
# show the distribution of another column
col = list(df['MSSubClass'])
plt.hist(col)
plt.show()
```



### 0.0.1 Splitting into train and test

```
In [6]: X =
df[['MSSubClass','LotArea','OverallQual','OverallCond','YearBuilt',
'YearRemodAdd','
y = df['SalePrice']

3
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test =
train_test_split(X, y, test_size=0.2,
random_state=3)

In [7]: print("X_train: ")
print(X_train.shape)
print("y_train: ")
print(y_train.shape)
print("X_test: ")
print(X_test.shape)
print("y_test: ")
print(y_test.shape)
```

X\_train:

(1168, 18)

y\_train:

(1168,)

X\_test:

(292, 18)

y\_test:

(292,)

```

0.0.2 Using Linear Regression
In [53]: # import model
from sklearn.linear_model import LinearRegression
# instantiate
linreg = LinearRegression()
# fit the model to the training data (learn the
# coefficients)
linreg.fit(X_train, y_train)
Out[53]: LinearRegression(copy_X=True, fit_intercept=True,
n_jobs=1, normalize=False)

```

---

```

0.0.3 show the coefficients of the linear regression model
In [54]: # print the intercept and coefficients
print(linreg.intercept_)
print(linreg.coef_)
1624810.78299
[-1.32598253e+02
 7.42385752e+01
 4.81195345e+00
1.17264859e+00
3.87166477e+02
3.94460800e+01
3.27974313e+04
6.87797648e+01
8.24586253e+01
3.52017131e+02
3.05508150e+01
2.55083195e+01
3.67581004e+01
6.78306474e+01
1.90173648e+02
-2.30935682e+00
-7.58643734e+02
-1.29045399e+03]

```

---

```

In [57]: # pair the feature names with the coefficients
list(zip(X, linreg.coef_))
Out[57]: [('MSSubClass', -132.59825288297418),
('LotArea', 1.1726485927894912),
('OverallQual', 32797.431340275551),
('OverallCond', 352.01713092259615),
('YearBuilt', 74.238575183515508),
('YearRemodAdd', 387.16647668821042),
('MasVnrArea', 68.779764836201025),
('BsmtFinSF1', 30.550814975040396),
('BsmtFinSF2', 4.811953445828749),
('WoodDeckSF', 39.446080031209931),
('OpenPorchSF', 82.458625258585016),
('EnclosedPorch', 25.508319545409904),
('3SsnPorch', 36.758100373945126),
('ScreenPorch', 67.830647415049953),
('PoolArea', 190.17364768682),
('MiscVal', -2.309356818373999),
('MoSold', -758.64373443570901),
('YrSold', -1290.4539903809468)]

```

---

```

0.0.4 Make Prediction
In [58]: y_pred = linreg.predict(X_test)
print(y_pred)

```

```

[ 93201.65287675 142554.76960023 207127.40186274
 129212.10104713
284603.13460876 65916.12615103 200722.35383783
169593.14341713
138022.19789723 138387.20437863 143561.19507458
150824.4043784
141397.06769187 242451.92943507 294242.12637714
155754.66681213
137312.71913462 129724.80248527 114876.63835247
150591.3640421
123366.39990094 150807.12337525 243530.22799299
80763.41783606
197680.6442071 103336.1791911 164351.0638006
90905.30200621
168564.67988019 115830.7939216 155494.23908365
100141.70869163
129753.99108892 156909.62744952 198024.33401226
127554.26516619
202396.44876193 110389.71894826 176051.07333227
145661.99691863
220408.37444225 116538.72044784 244706.34275193
195197.31242857
278775.03276079 152402.88891841 144044.1694957
99239.71058997
131931.4514502 110682.0707577 286158.2247229
135834.2312254
97216.99608222 143430.65499509 119919.1222882
142851.58478543
204412.40936722 153442.22728046 132396.82935032
257628.30990488
169933.91094914 120347.46703607 105703.73721332
334713.28117372
114893.96280934 234743.60884166 183600.27577235
258490.04570492
375690.10951031 111056.04841375 172340.59505253
136413.8949467
144985.53609179 223770.11250678 153958.15058402
118182.70605492
231712.95504903 102900.49898239 154389.2668046
127207.38840213
145004.55720471 176843.72114247 169051.0221719
148482.89114126
5
313474.32652747 152493.90863482 173352.98469532
126431.410949
706997.59838104 273836.15113809 408289.15199464
184268.88377474
176636.23715661 275235.88756875 209025.79856597
301622.54866502
153471.41164935 210322.3456924 140373.14967059
147240.88073756
179983.14477495 236775.79874229 144459.66092891
253623.49760802
176613.8745506 229147.89622806 185611.33497853
184942.64455848
68523.77301979 111428.57621911 95690.85464389
210924.92842256
236920.78986689 179625.99265486 146998.08010809
218710.14496723
128961.12389426 144822.81021683 180904.35339614
126176.27283423

```

```

99200.6426002 257960.86042887 200015.00187306
189350.38765334
161309.58475033 188509.81215872 207842.304773
133745.60572444
146175.12018952 311506.70403465 123810.46022005
178891.00062911
161368.3460505 141225.57119693 247990.6084084
134197.93148368
105114.81700542 66238.30229136 178481.22924629
169327.77885027
115722.77661632 163980.78329632 259041.24033003
263441.73011914
283269.97449944 291907.40480834 197028.67375584
253486.2658659
104257.64311109 332402.81936497 235123.35447297
117530.28281743
331867.34936129 166007.48240655 203642.02685762
366937.27511738
254191.87188157 124456.0621068 91276.03127415
115556.73782587
135405.78846278 218110.30607514 214268.7945742
140032.81401882
182040.72686091 176083.82849172 189209.9335995
116292.72416312
156432.52235127 204191.85524977 243977.32691289
217247.92836948
285376.77266393 246843.94978091 222100.61618257
167537.81203899
173903.04681628 161022.49525822 142938.09421832
236955.86271045
118908.1141022 191184.99717802 264889.79476426
125154.14702448
227251.47377346 237911.61180972 161841.30235331
191446.14163809
116625.79736531 145735.12537565 105372.79335894
316582.43267848
122028.63732317 290593.52200424 185714.04747969
190352.49050499
231514.01368592 230079.79348368 127676.13717555
211300.51925447
195483.82714307 192652.60353829 165237.26624796
120930.29413027
246160.5957099 281456.29298689 246797.10864379
119311.41048692
125885.59543623 237312.78172775 80648.88617473
121685.26043487
114935.23554672 161184.27138098 148054.27442727
131650.06362918
201165.65733849 296531.91858395 130462.5135931
249027.70239568
177623.04403208 166277.96320103 94660.31809216
72766.55532673
120114.744019 102331.03622172 132734.52163217
195045.15386957
206238.5262443 254559.77871816 103180.37264793
217595.03298126
200740.09709761 309978.95599912 120679.0962053
105614.64472826
246644.91857921 132884.29067159 333136.91588735
167381.82062275
160037.46133837 280268.75854488 166764.14578859
163691.73116515

```

```

172120.87702276 86744.64311271 159726.64897898
152045.32160112
148376.7717957 261196.38354104 190853.69410498
147271.05605036
126117.61348537 122639.71249082 227607.46595295
170013.76929953
136917.40993332 157131.07140997 127090.52733891
135446.00011116
271380.56027395 138338.59566889 233995.26083728
141733.47586868
138265.15523182 200673.53942787 186815.23291077
226030.65231941
197560.45885543 392086.99980809 199746.97825355
194749.30417935
122346.88308178 170839.72571199 37264.46454778
153581.22281016
6
183230.11599231 143418.12876415 170655.31440413
60936.55821163
279635.84539619 141986.8959917 163848.54119987
130962.64226048
194210.12078339 222988.18563234 252212.98444331
371404.24966183
219031.5941132 63288.51714085 112594.85348706
139413.4862122 ]

```

0.0.5 Finally Check Error 0.0.6 Here, we use Root Mean Squared Error (RMSE) which is the square root of the mean of the squared errors for error checking:

$$\sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2}$$

```
In [59]: from sklearn import metrics
        import numpy as np
        print(np.sqrt(metrics.mean_squared_error(y_test,
                                                y_pred)))
46554.0967726
```

```
0.0.7 Using logistic Regression
In [8]: from sklearn.linear_model import LogisticRegression
        logreg = LogisticRegression()
        logreg.fit(X_train, y_train)
        y_pred = logreg.predict(X_test)
        print(y_pred)
```

```
[135000 139400 215000 85000 259500 108480 161750 93000
103600 129500
80000 112000 115000 194000 171000 145000 130250 130500
151000 395192
135000 266500 335000 135000 197000 110000 116000 135000
139000 98000
181000 52500 110000 161000 248328 149000 215000 112500
143000 138000
224900 86000 215000 162900 190000 165500 79000 87000
135000 112000
223000 85400 90000 145000 143000 129500 204900 145000
127500 275000]
```

```

194000 114500 157900 260400 143500 254900 180000 190000
223000 150000
215000 89500 145000 276000 111250 220000 172500 118964
130500 127000
137000 146000 196000 123600 380000 266500 229000 129900
324000 181000
260400 144152 202500 279500 319000 190000 130500 167000
171000 140000
142000 250000 98000 275000 79900 215000 193000 199900
139600 143000
137450 185900 328900 215000 259500 205950 87000 143900
167240 127000
101800 224900 196500 167000 108959 180000 162000 129900
176000 319000
124500 155900 266000 106000 215000 147000 121600 110000
165000 176000
79900 181000 195400 290000 315750 260400 153900 325624
112500 293077
181000 141000 342643 139000 135000 325000 174000 82500
78000 131500
120500 446261 378500 135000 191000 177500 79000 80000
258000 155900
263000 220000 378500 165000 184900 214000 128500 165500
159000 185900
160000 146000 240000 131500 328900 239000 166000 191000
80000 118000
7
81000 325000 117500 222000 136905 202665 220000 266000
109500 244600
181000 159500 140000 98000 195400 184900 378500 110000
200000 278000
161500 135000 180500 144152 190000 114500 181134 297000
147000 143750
155900 142000 107500 99500 117500 116050 115000 181000
215000 203000
122000 138800 104900 315000 136905 169000 250000 149000
305900 149000
164900 229000 181000 158000 144000 125500 145000 243000
130500 250000
179900 158000 145000 117500 187500 145000 117000 130000
135000 99500
215000 89000 143000 189950 154000 145000 163000 200000
181000 264132
150000 289000 167000 137900 67000 145000 127500 141500
214000 151000
209500 118000 161500 127500 143250 230000 290000 485000
191000 85000
110000 173000]

```

---

Classification accuracy:

Proportion of correct predictions

Common evaluation metric `for` classification problems

In [10]: `from sklearn import metrics`

`import numpy as np`

`print(metrics.accuracy_score(y_test, y_pred))`

0.0

---

## 5 ALGORITHM COMPARISON AND ANALYTICS

Linear Regression is used to establish a relationship between Dependent and Independent variables, which is useful in estimating the resultant dependent variable in case independent variable change. For example, using a Linear Regression, the relationship between Rain (R) and Umbrella Sales (U) is found to be -  $U = 2R + 5000$ [1]. This equation says that for every 1mm of Rain, there is a demand for 5002 umbrellas. So, using Simple Regression, you can estimate the value of your variable.

Logistic Regression on the other hand is used to ascertain the probability of an event. And this event is captured in binary format, i.e. 0 or 1. For example, I want to ascertain if a customer will buy my product or not. For this, I would run a Logistic Regression on the (relevant) data and my dependent variable would be a binary variable (1=Yes; 0=No).

In terms of graphical representation, Linear Regression gives a linear line as an output, once the values are plotted on the graph. Whereas, the logistic regression gives an S-shaped line

The logistic model is unavoidable if it fits the data much better than the linear model. And sometimes it does. But in many situations the linear model fits just as well, or almost as well, as the logistic model. In fact, in many situations, the linear and logistic model give results that are practically indistinguishable except that the logistic estimates are harder to interpret[1].

For the logistic model to fit better than the linear model, it must be the case that the log odds are a linear function of X, but the probability is not. And for that to be true, the relationship between the probability and the log odds must itself be nonlinear. But how nonlinear is the relationship between probability and log odds? If the probability is between 0.20 and 0.80, then the log odds are almost a linear function of the probability[1].

Interpretability is not the only advantage of the linear probability model. Another advantage is computing speed. Fitting a logistic model is inherently slower because the model is fit by an iterative process of maximum likelihood[1]. The slowness of logistic regression isn't noticeable if you are fitting a simple model to a small or moderate-sized dataset. But if you are fitting a very complicated model or a very large data set, logistic regression can be frustratingly slow.

The linear probability model is fast by comparison because it can be estimated noniteratively using ordinary least squares (OLS). OLS ignores the fact that the linear probability model is heteroskedastic with residual variance  $p(1-p)$ , but the heteroscedasticity is minor if p is between 0.20 and 0.80, which is the situation where I recommend using the linear probability model at all. OLS estimates can be improved by using heteroscedasticity-consistent standard

errors or weighted least squares[1]. In my experience these improvements make little difference, but they are quick and reassuring.

## REFERENCES

- [1] Donald W. Schaffner Lihui Zhao, Yuhuan Chen. 2001. Comparison of Logistic Regression and Linear Regression in Modeling Percentage Data. Online. (2001). <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC92846/>
- [2] Wikipedia. 2016. Linear regression. Online. (7 2016). [https://en.wikipedia.org/wiki/Linear\\_regression](https://en.wikipedia.org/wiki/Linear_regression)
- [3] Wikipedia. 2017. Logistic regression. Online. (2017). [https://en.wikipedia.org/wiki/Logistic\\_regression](https://en.wikipedia.org/wiki/Logistic_regression)

```
bibtext report
```

```
=====
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtext _ label error
```

```
=====
```

```
bibtext space label error
```

```
=====
```

```
bibtext comma label error
```

```
=====
```

```
latex report
```

```
=====
```

```
[2017-12-12 19.59.48] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
Missing character: ""
Typesetting of "report.tex" completed in 1.3s.
./README.yml
9:81      error    line too long (86 > 80 characters)  (line-length)
19:1       error    trailing spaces   (trailing-spaces)
23:81      error    line too long (89 > 80 characters)  (line-length)
23:89      error    trailing spaces   (trailing-spaces)
24:77      error    trailing spaces   (trailing-spaces)
25:81      error    line too long (106 > 80 characters) (line-length)
25:106     error    trailing spaces   (trailing-spaces)
26:81      error    line too long (109 > 80 characters) (line-length)
26:109     error    trailing spaces   (trailing-spaces)
38:81      error    line too long (88 > 80 characters)  (line-length)
38:88      error    trailing spaces   (trailing-spaces)
39:81      error    line too long (87 > 80 characters)  (line-length)
39:87      error    trailing spaces   (trailing-spaces)
40:49      error    trailing spaces   (trailing-spaces)
```

```
=====
Compliance Report
=====
```

```
name: Wu, Yujie
hid: 235
paper1: 100%, 10/27/2017
paper2: 100%, 11/06/2017
```

```
yamlcheck
-----
```

```
wordcount
-----
```

```
6
wc 235 project 6 2296 report.tex
wc 235 project 6 2215 report.pdf
wc 235 project 6 72 report.bib
```

```
find "
-----
```

```
84: \par In statistics, logistic regression, or logit regression, or  
logit model is a regression model where the dependent variable  
(DV) is categorical. This article covers the case of a binary  
dependent variable that is, where the output can take only two  
values, "0" and "1", which represent outcomes such as pass/fail,  
win/lose, alive/dead or healthy/sick. Cases where the dependent  
variable has more than two outcome categories may be analyzed in  
multinomial logistic regression, or, if the multiple categories  
are ordered, in ordinal logistic regression. In the terminology of  
economics, logistic regression is an example of a qualitative  
response/discrete choice model\cite{C2}.
```

```
142: In [7]: print("X_train: ")
```

```
144: print("y_train: ")
```

```
146: print("X_test: ")
```

```
148: print("y_test: ")
```

```
passed: False
```

```
find footnote
```

---

```
42: \renewcommand\footnotetextcopyrightpermission[1]{} % removes  
footnote with conference information in first column
```

```
passed: False
```

```
find input{format/i523}
```

---

```
passed: False
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

```
104: \includegraphics[width=0.95\columnwidth]{3}  
106: \includegraphics[width=0.95\columnwidth]{4}  
117: \includegraphics[width=0.95\columnwidth]{1}  
119: \includegraphics[width=0.95\columnwidth]{2}  
131: \includegraphics[width=0.95\columnwidth]{output_3_0.png}  
133: \includegraphics[width=0.95\columnwidth]{output_3_1.png}
```

```
figures 0
```

```
tables 0
```

```
includegraphics 6
```

```
labels 0
```

```
refs 0
```

```
floats 0
```

```
True : ref check passed: (refs >= figures + tables)
```

```
True : label check passed: (refs >= figures + tables)
```

```
False : include graphics passed: (figures >= includegraphics)
```

```
True : check if all figures are refered to: (refs >= labels)
```

```
Label/ref check
```

```
passed: True
```

```
When using figures use columnwidth  
[width=1.0\columnwidth]
```

do not change the number to a smaller fraction

find textwidth

---

passed: True

---

below\_check

---

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

---

ascii

---

non ascii found 8217

---

=====

The following tests are optional

---

=====

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Importance of Big data in predicting stock returns and price

Gagan Arora  
Indiana University  
2709 E 10th St  
Bloomington, Indiana 47401  
gkarora@iu.edu

## ABSTRACT

In this project, we will discuss the importance of big data in finance industry in predicting financial stock values. We will be using python libraries to fetch financial data from yahoo finance and will further predict the stock price returns of few selected technology companies such as Amazon, Yahoo depending on the historical data of x[16] years. Similarly, we will predict the returns based on y[10] years of data. The prediction will be based on SP 500 market return and market risk volatility. Here y is greater than x and then we will compare the predicted returns with the current returns. For the comparison we will be using the testing time frame as mentioned in the project later. This project will help us understand if more historic data helps in predicting the stock price returns or it adds noise. We will be using statistical approach and CAPM [capital asset pricing model ] to predict stock price. Analysis will be done on the jupyter notebook

## KEYWORDS

HID-301, Stock Price prediction, stock returns, SP500, risk free market, CAPM model, root mean square analysis, stock beta, Finance, Statistics, mean, variance, market premium, python, yahoo finance, i523

## 1 INTRODUCTION

By its nature of the business, the finance industry is always driven and dominated by data. The existence of Big data in the finance industry has exposed the big opportunity of growth and value extraction but at the same time imposed the various new challenges, which demand new skill set. [5] suggests that finance experts believe there is a huge potential in terms of value extraction from the financial big data. They also believe that finance industry can benefit more than any other industry. Historically, data was always there in some format either non-digital or digital. However, with digitization, this data has fallen into the prevalence of high volume of information, which we call as Big Data. Dominant drivers for the actuality of big data in the finance industry are mainly customer call logs, social media, news feed, regulatory data etc. Call logs, news feed and etc. fall into the category of unstructured data which is identified as an area where we can extract vast amount of business value.

[4] talks about the three V of big data in finance industry: volume, velocity and variety. [6] clearly depicts the amount of financial data pouring in the daily basis. TechNavio's forecast (TechNavio 2016) predicts data will grow at a CAGR [compound annual growth rate] of 61 percent over the period of 2017-2021. According to the

IDC financial insight 2016, every second there is around 10,000-payment card transaction and this number is expected to double by the end of this decade. The Capgemini/RBS Global payments study for 2012 suggests there was about 260 billion transactions in 2012 and is expected to grow between 15 and 22 percent for developing countries. Main drivers contributing to the big data in the finance industry are Data growth, increasing scrutiny from regulators, digitization of financial products, changing the business model and increased customer insight platforms such as customer service. [4] shows 76 percent of banks say the business driver for embracing big data is to enhance customer engagement, retention, and loyalty and seventy one percent of banks say that to increase their revenue, they need to better understand customers and big data will help them to do so.

Thinking about the data strategy, the financial industry has taken the business-driven approach to a big data. According to the IBM report, all financial organizations are not keeping the same pace as peer industry is keeping. Today because of increased competition, customers always expect more personalized banking service and at the same time, there is increased regulatory surveillance which in result creates big pressure on finance industry to better utilize the value of Big data. To achieve better-personalized experience, many banks have started the initiative to utilize the information gained from the vast ocean of data to offer better-personalized products and gain competitive advantage. Despite the fact that financial industry is data-driven, there is a gap in the amount of initiative financial industry has taken to extract the value out of big financial data. Technavio 2016 report has shown only 26 percent of financial organizations has focused on understanding the principal notation of Big data and most of those 26 percent are still struggling to define the clear roadmap. This clearly concludes that finance industry lag behind their cross-industry peers in using more varied data types. A good example to support this fact is that there are very less research and domain knowledge in extracting value out of retail bank call logs.

Big data technologies not only help in extracting the effective business value but analysis of unstructured data in conjunction with a wide variety of data set also helps in extracting commercial value. Big data in finance industry does not necessarily decode to valuable or actionable information. The real benefit lies in developing the technologies, which can be used to extract business and commercial value. [15] talks about what all advantage we can extract from the big data in the finance industry. Few examples are: Detection of false rumors that try to manipulate the finance market, Assessment of exposure to a reputational risk connected to consulting service offered by banks to their customer and Discover

topic trends, detect events, or support the portfolio optimization or asset allocation. Big data based pattern recognition can also help in enhanced fraud detection systems and prevention capability systems. Other benefits of utilizing big data include building a machine learning based algorithm to achieve higher performance and accuracy in the trading algorithm and Enhanced market trading analysis. There has been proven research [12] which states more data increases accuracy and precision of simulations which is the backbone of financial modeling based analytic. This research [12] states modern modeling techniques are data hungry. In this project we will extract inference if more financial data can be used to have better prediction.

## 2 USE OF STRUCTURED FINANCIAL DATA

This reflects the data which has a higher degree of an organization such as a relational database where information/data is easily searchable and we can easily apply standard algorithm to extract patterns out of it. In this project we will be using Yahoo finance structured data. Examples of such data set include yahoo financial data, trading applications, enterprise finance resource planner, Retail banking systems, Credit history database systems and other financial applications that use legacy application systems. Structured data always has a big advantage of being easily entered, stored, queried and analyzed. Most of the personal banking financial statements are stored in a structured way. Structured dataset combined with the distributed systems can be leveraged to achieve structured big data set on which we can run optimized SQL queries to retrieve patterns. [9] discusses various SQL based ways to specify information quality in data which can be used to filter out the noise. In this project we will be using structured data.

## 3 VARIOUS CHALLENGES UTILIZING BIG DATA VALUE IN FINANCE INDUSTRY

There are multiple challenges and constraints in extracting value out of big financial data. The biggest challenge is old IT culture and infrastructure. The much financial organization still uses old IT infrastructure which is not compatible with the big data application thus fail to take advantage of big data. Other challenges include lack of skill set and data privacy and security. With the emergence of digitalization, customer data is saved persistently because of which there has been continued concern regarding the customer privacy. Regulatory bodies guidelines on customer data are always ill-defined because of which there is always a concern regarding the use of customer data. In this project we will use standard python libraries to fetch financial data from yahoo finance. Analysis will be done on the jupyter notebook.

## 4 STOCK RETURNS PREDICTION - LITERATURE REVIEW

Authors of [1] discuss the importance of stock price and returns prediction based on the data extraction of historic data. This research [1] also shows historic financial data has definitive predictive relationship to the future value of stocks. Stock prediction always help investors to decide perfect timing of buying or selling stocks. There are various data mining, artificial neural networks and machine learning techniques available for the stock price prediction based

on the value extraction from the historic financial data. Based on the complexity of stock price matrix, pricing mechanism is essentially a non linear complex system. Authors of [14] and [13] state many predictive algorithm is based on the fundamental analysis of macroeconomics and company fundamentals. [11] states problem with the fundamental analysis is that it is too much focused on the intrinsic and lacks the quantitative aspect of the historic financial data. On the broad category we can define stock prediction analysis is based on two types of analysis: qualitative and quantitative. Choice of analysis is mainly based on the fact if we want to have short term analysis or long term analysis. In this project we have have ten and sixteen years of training data and used close to one year of testing data. Since our analysis is based on the historic data we have chosen to do quantitative analysis. Quantitative analysis is based on the pattern extraction, fact that history repeats and future financial drivers can be extracted based on the historic data. Advantage of using quantitative analysis is that we can use statistical confidence interval to validate the analysis.

There is a huge benefit of using machine learning algorithms in predicting stock prices. These algorithms made easy to cope up with the various financial events such as mergers acquisitions, bankruptcy, fraud, political changes, market crashes, housing bubble, dot net bubble and etc. In this project we have used hybrid approach of combined CAPM [Capital asset pricing] model and machine learning algorithm to mine data of sixteen and ten years of data and used close to 1 year of testing data. These machine learning algorithms can further be used to predict various financial events. Other approaches such as neural networks algorithms, SVM, logistic regression and multiple discriminant analysis can also be used to predict financial events. Example, [2] in their research they proved neural networks algorithms performs better in predicting financial events as compared to multiple discriminant analysis. There are other applications which use these algorithm to find predicted credit rating of a company. Credit rating plays a very important role doing qualitative analysis of the financial health of a company. On the other hand, accuracy of these algorithm is a big challenge because of the amount of huge data which it uses as input. Typically, accuracy of these algorithms is validated based on square root method.

In this project we have used several years of data for analysis which involves more than hundred thousands of rows with multiple columns. Then this data is analyzed two dimensionally with the same set of market return rows. Since this analysis is calculation intense, In the end we also have performed root mean square analysis.

Over the past few years there has been drastic changes in the way stock market operates. With the emergence of advance web services, there has been powerful enhancement in the data communication between various financial application. Because of which there is ocean of real time data is available, thus machine learning algorithm, neural networks algorithms, SVM, logistic regression and multiple discriminant analysis needs to be smarter. Forecasting stocks and financial parameter is of great interest to the investors. As discussed earlier these algorithms needs to modified depending on the fact if we want to have short term profit or long term profit.

[8] has shown the very interesting analysis of comparing the prediction of stock market with the random walk hypothesis. Author

of [8] ran an experiment in which he tossed a coin and recorded the results and mapped head with the company profit and tail with the company loss. Then result of this experiment was shown to the investors pretending these are the actual market profit and loss. Looking at the result graphs, investors believed it as a actual prediction. This research has shown the altogether different outlook which states stock price prediction and forecast can be fooled and stock prices are perfectly random in nature. On this theory many researchers have classified profit based on three hypothesis:

- Weak form Efficient Market Hypothesis: The weak form of the hypothesis states one can not generate profit by just looking at patterns and trends of stock market.
- Semi Strong Efficient Market Hypothesis: The semi strong form of the hypothesis states only possible way of generating profit is via inside trading.
- Strong form Efficient Market Hypothesis: The strong form of the hypothesis states its not possible to generate profit since stock market behaves in perfect random way.

However, if we are running root mean square analysis we can surely compare the accuracy of various algorithm and arrive at conclusion which algorithm is viable for prediction.

## 5 FINANCIAL DATA EXTRACTION

In this section, we will discuss various technical requirements needed to achieve value extraction from the big data in the finance industry. There are various technical requirements such as data Acquisition, data quality, data extraction, data integration, decision support. In order to fulfill requirements, a hybrid approach combining computer science, algorithms, statistics, data mining, machine learning and pattern recognition study needs to be adopted. To explore the advantage of big data there have been initiatives like data virtualization, multi-document summarization, pattern recognition from LOGS and many start-ups have been emerged. All big companies such as Microsoft, Google, IBM and Amazon are investing heavily in this field to leverage business and commercial value out of it. There has been changed in the industry pattern where financial industry is resorting big data to strategize their business. According to [6] with a very rapid pace, the financial industry is utilizing big data advantage in investment analysis, econometrics, risk assessment, fraud detection, trading, customer interaction analysis and behavior modeling. If we look at the Big promise the Big data holds in the finance industry, progress in this field is still in nascent stage and we expect more growth in upcoming years. In this project we will discuss jupyter notebook based solution for Data extraction.

In this project we have used jupyter notebook and rich python libraries to fetch financial stock data. Later in this paper we will discuss the stock data extraction in detail. Later we will also discuss what are different ways to fetch stock data and will discuss few important functions which python libraries

## 6 FETCHING FINANCIAL STOCK DATA

Fetching structured precise data is always a challenge. There are different ways to fetch the stock market data. In this project we will be fetching data from yahoo finance via python libraries which

internally makes remote web service call to the yahoo web server. There are also other ways to fetch data such as:

- Direct download of csv files from yahoo finance or google websites.
- Make web api call to download the data in the json/XML format
- Use python libraries to download data, which internally makes remote web service call to the yahoo web server. This is preferred way of doing since it allows you to save data to system variables directly.
- Call yahoo or finance web service from the application.
- Calling VBA function in excel to fetch yahoo stock data
- Quandl best for using core financial data and this website also includes access to rich python libraries.
- Google sheet has feature to fetch real time stock prices
- Install stocks macros in excel

In this project we have exhaustively used python for data manipulation. Reasons for using python are:

- Syntax is super easy which comes with very level of readability as compared to other programming languages.
- It is free and supports cross platform as python code can be called from any version of machine.
- Python has strong community support so if any problem is encountered, support is available online.
- Python has powerful tools available such as statsmodels, matplotlib, Pandas, Numpy and SciPy for calculation intense projects

Since we have exhaustively used the `get_data_yahoo` function from the `pandas_datareader` python library we will briefly discuss the parameters it takes. Please note we utilized only those arguments which are relevant to the project requirements. From [10] parameter list as listed below:

- `symbols` : string, array-like object (list, tuple, Series), or DataFrame Single stock symbol (ticker), array-like object of symbols or DataFrame with index containing stock symbols.
- `start` : string, (defaults to '1/1/2010') Starting date, timestamp. Parses many different kind of date representations (e.g., 'JAN-01-2010', '1/1/10', 'Jan, 1, 1980')
- `end` : string, (defaults to today) Ending date, timestamp. Same format as starting date.
- `retry_count` : int, default 3 Number of times to retry query request.
- `pause` : int, default 0 Time, in seconds, to pause between consecutive queries of chunks. If single value given for symbol, represents the pause between retries.
- `session` : Session, default None requests.sessions.Session instance to be used
- `adjust_price`: bool, default False If True, adjusts all prices in hist data ('Open','High', 'Low','Close') based on 'Adj Close' price. Adds 'Adj Ratio' column and drops 'Adj Close'.
- `ret_index` : bool, default False If True, includes a simple return index 'Ret Index' in hist data.
- `chunksize` : int, default 25 Number of symbols to download consecutively before initiating pause.

- interval : string, default 'd' Time interval code, valid values are 'd' for daily, 'w' for weekly, 'm' for monthly and 'v' for dividend.

In our analysis, for the symbol parameter we are passing ticker symbol one at a time. Though, we have an option to pass multiple tickers as an array argument. We are using get\_data\_yahoo function and utilizing only first three parameters: symbols, start and end. This function returns YahooDailyReader object which can further be manipulated to get Open, High, Low, Close, Adj Close and Volume stock values. Since default number of retry count is three we will be using this default value. Default value of pause which is zero is also good with respect to our requirement so we will not pass this as argument. Session argument should be used when we are handling multiple request in parallel in the code since our project we just need one session so we will not use this argument. adjust\_price is not required in our analysis since we are interested only in returns which can be fetched using pct\_change() function. Since return index is of no use in calculating the returns, we will not use this argument. Argument chunk size is used to modify number of consecutive downloads of stocks since we are just using single ticker so this argument is of no use. This function uses interval also as a parameter since we are only interested in daily values and daily value is the default interval so we didn't pass this argument in the function call. We could also use the contemporary google function which is get\_data\_google. Arguments which goes to the get\_data\_google are symbols, start, end, retry\_count, pause, chunksize and session since we are not using get\_data\_google function in our project we will not discuss these in detail.

## 7 INTRODUCTION TO CAPM MODEL

CAPM [Capital asset pricing model] model was developed by William Sharpe and John Lintner in 1964. This model is considered so powerful that it is being used in current prediction models. There are few advantages of using CAPM model as compared to other pricing models:

- This model is a single dimensional model and easy to use, still powerful to model capital asset pricing.
- Since this model is based on the market portfolio and risk free rate, this model removes unsystematic risk.
- We can run root mean square algorithm to validate the algorithm.
- This model provides a flexibility to utilize various risk free rates and run model for various time range.
- This model can be applied to various financial objects such as stocks, put option, call option, bonds, and etc

This model can be used to evaluate the theoretical expected return on a security, security can be any financial object such as stocks, put option, call option, bonds, and etc. In CAPM model we evaluate how much financial object is sensitive to the market using statistical analysis. Then this sensitivity which is also known as beta is used to find the expected return on security. This expected return can be on daily basis, weekly basis, monthly basis or yearly. Here is the formula to evaluate expected return:

$$E(R_i) = r_f + \beta_i(E(r_m) - r_f)$$

Where

- $E(R_i)$  is expected return
- $r_f$  is risk free interest rate example: Government bond
- $E(r_m)$  is return on market example SP 500
- $\beta_i$  is sensitivity of stock with respect to market

$\beta_i$  can further be defined how much stock is sensitive to the stock market. Example if  $\beta_i$  for a particular stock is two it means if market goes up by five percent then stock will go up by ten percent and if market goes down by two percent then stock will go down by ten percent. In terms of statistics  $\beta_i$  is defined as:

$$\beta_i = \frac{Cov(R_i, r_m)}{Var(r_m)}$$

Where covariance and variance are defined as

$$\begin{aligned} cov_{x,y} &= \frac{\sum_{i=1}^N (x_i - \bar{x})(y_i - \bar{y})}{N-1} \\ &= \frac{\sum_{i=1}^n (x_i - \mu)^2}{n} \\ var^2 &= \frac{\sum_{i=1}^n (x_i - \mu)^2}{n} \end{aligned}$$

$\beta_i$  matrix can be used to illustrate  $\beta_i$  in a following way:

	$\beta_i$	MarketReturn	ExpectedReturn
Row1	+2	+5%	+10%
Row2	-2	+5%	-10%
Row3	+0.5	+4%	+2%
Row4	+0.5	-4%	-2%

Above matrix suggests how expected returns can be correlated with the the  $\beta_i$ . Example if for certain company has  $\beta_i$  of +2 and market returns is +5 % then company's expected returns can be predicted as +10 %. Please note  $\beta_i$  can be positive as well as negative.

## 8 PROPOSED ANALYSIS

In this project we will utilize structured data and use CAPM [Capital asset pricing model] to statistically find the expected daily return of selected technological stocks: Amazon and Yahoo. This daily expected return can be used to predict next day stock value given the condition we have current stock price. Following formula can be used to predict next day stock price:

---

**Next Day stock price** =: Today stock price \* (1+Daily expected return)

---

Daily expected return will be calculated using CAPM model. Daily expected return sensitivity in CAPM terminology is also known as beta. In this project beta will be calculated based on two time frames:

---

**Time frame 1:** [01/01/2000 to 12/31/2016] 16 years of data  
**Time frame 2:** [01/01/2006 to 12/31/2016] 10 years of data

---

Thus we we will have 2  $\beta_i$ :

$$\beta_1 = \frac{Cov(R_1, r_{m1})}{Var(r_{m1})}$$

$$\beta_2 = \frac{\text{Cov}(R_2, r_{m2})}{\text{Var}(r_{m2})}$$

Where

- $\beta_1$  is  $\beta$  based on time frame 1
- $\beta_2$  is  $\beta$  based on time frame 2
- $R_1$  is actual return based on time frame 1
- $r_{m1}$  is a mean market return based on time frame 1
- $R_2$  is actual return based on time frame 2
- $r_{m2}$  is a mean market return based on time frame 2

Above two time frames will be our training data set. We will run two analysis: one on training time frame 1 and other on training time frame 2 to arrive at predicted CAPM variables. Then we will use this training data set to predict stock returns for test data set which will comprise of time frame:

---

**Test data time frame:** 01/01/2017 to 11/16/2017

---

Then we will run the statistically analysis on the test data to evaluate if 16 years of training data produced more accurate result or else it added noise compared to 10 years of training data. Please note this is purely a quantitative analysis not qualitative. Actual returns can also be impacted by a qualitative factors such as mergers acquisitions, bankruptcy, fraud, political changes, market crashes, housing bubble, dot net bubble and etc.

## 9 PROPOSED ALGORITHM

Code is written purely in python language and used the powerful rich python libraries such as statsmodels, matplotlib, Pandas, Numpy and SciPyfor. We have used jupyter notebook as interpreter tool to python. Code is started by importing above mentioned rich python libraries. Since we are interested only in technological stocks: Amazon and yahoo we need to initialize they stock ticker with the python variable. In CAPM model we need to know the market return in order to know the stock sensitivity we will also initialize market ticker with SP 500 index. As discussed above we will be using get\_data\_yahoo function from the pandas\_datareader and in this project we will be only utilizing only first three parameters which is stock ticker, start date and end date. For first iteration we will be using get\_data\_yahoo to fetch stocks and market returns for time frame 1. For having better understanding of how the data looks when fetched using get\_data\_yahoo function, we will have amazon financial data matrix calculated like:

```
amazonData = dr.get_data_yahoo('AMZN', start_date, end_date)
```

Where

- dr is pandas\_datareader.data class
- amazon is stock ticker for amazon which is 'AMZN'
- start\_date is start date of time frame 1: 01/01/2000
- end\_date is end date of time frame 1: 12/31/2016

and synopsis of above amazon data looks like:

	Open	High	Low	Close	Adj	Volume
23 - Dec - 16	764.54	766.50	757.98	760.59	760.59	1976900
27 - Dec - 16	763.40	774.65	761.20	771.40	771.40	2638700
28 - Dec - 16	776.25	780.00	770.50	772.13	772.13	3301000
29 - Dec - 16	772.40	773.40	760.84	765.15	765.15	3153500
30 - Dec - 16	766.46	767.40	748.28	749.86	749.86	4139400

Similarly using get\_data\_yahoo we will fetch Yahoo and market returns. Since we are interested in daily return, we fetched the daily data from yahoo finance which is evident from the above result data set. Now lets find the percentage change on the daily Close value to get the percentage change array which in finance terminology will be daily return on stock. For finding the percentage change we are using pct\_change() function on the close column of result set. This function can be elaborated as follows:

```
return_amazon = amazonData.Close.pct_change()[1 :]
return_yahoo = yahooData.Close.pct_change()[1 :]
return_market = marketData.Close.pct_change()[1 :]
```

return\_amazon, return\_yahoo and return\_market are two dimensional arrays and we need to convert them to single dimensional array in order to run statistical analysis. We can use dot values method to extract single dimensional array out of 2 dimensional array. This operation can be elaborated as follows:

```
X_amazon_actualReturns = return_amazon_testing.values
X2_yahoo_actualReturns = return_yahoo_testing.values
Y_market_actualReturns = return_market_testing.values
```

Please note these are actual returns - fetched from yahoo finance. Now in order to evaluate expected return for the testing period based on the calculated beta we need to calculate the risk free rate  $r_f$  as mentioned above in the CAPM formula. Please note get\_data\_yahoo formula will fetch the annualized rate but here we are dealing with the daily returns so this needs to be normalized to daily rate. Here we are using Treas Yld Index-10 Yr Nts bond. Ticker symbol for Treas Yld Index-10 Yr Nts bond is 'TDX'. Please note get\_data\_yahoo will return columns: Open, High, Low, Close, Adj Close and Volume. Dot values will convert to 2 dimensional array and then used index [0][4] to fetch annual rate. Detailed code with comments is mentioned on jupyter notebook.

Conversion of annualized return to daily return can be done using following formula:

```
riskFreeDailyRate = (1 + riskFreeAnnualRate)(1/365) - 1
```

Now we need to copy the content of X\_amazon\_actualReturns to new array X\_amazon\_predictedReturns and initialized each

element in X\_amazon\_predictedReturns using CAPM model as discussed above in Introduction:

```
X_amazon_predictedReturns = list(X_amazon_actualReturns)
```

We will do the same for Yahoo stocks:

```
X2_yahoo_predictedReturns = list(X2_yahoo_actualReturns)
```

In the code we have run the while loop and each element of X\_amazon\_predictedReturns and X2\_yahoo\_predictedReturns is assigned the value based on CAPM model. Now we have two returns arrays for amazon stocks based on sixteen years of data:

- X\_amazon\_actualReturns are the actual returns
- X\_amazon\_predictedReturns are returns based on the CAPM model.

Similarly we have two returns arrays for yahoo stocks based on sixteen years of data:

- X2\_yahoo\_actualReturns are the actual returns
- X2\_yahoo\_predictedReturns are the returns based on the CAPM model.

Now we can utilize mean\_squared\_error function from the sklearn.metrics python library to find how predicted returns are deviated from the actual returns. We will run this function on both stocks, amazon and yahoo:

```
a1 = Y_market_actualReturns  
a2 = X_amazon_predictedReturns  
y1 = Y_market_actualReturns  
y2 = X2_yahoo_predictedReturns  
  
rms_amazon = sqrt(mean_squared_error(a1,a2))  
rms_yahoo = sqrt(mean_squared_error(y1,y2))
```

Here is the root mean square values for both the stocks under sixteen years of data case:

- Root mean square error for Amazon stocks analysis based on 16 years of data 0.0013770 or 0.137 percent
- Root mean square error for Yahoo stocks analysis based on 16 years of data 0.0014313 or 0.143 percent

Now we run the same analysis as discussed above for the ten years of data and will validate how much predicted stocks returns based on the ten years of data are deviated from the actual returns using root mean square method. Please note testing data set remains the same we are just using different training data set. This will let us compare if sixteen years of data is of more worth in predicting stock returns or it added noise to the analysis:

- Root mean square error for Amazon stocks analysis based on 10 years of data 0.0005310 or 0.053 percent
- Root mean square error for Yahoo stocks analysis based on 10 years of data 0.0014910 or 0.149 percent

Above analysis is purely quantitative and does not include any elements of qualitative analysis. It shows predicting yahoo stock price or its returns based on the sixteen years of data or ten years of data - both resulted in almost same results. However things are totally different for the amazon stocks, recent ten years of amazon stocks data produced more accurate results as compared

to using recent sixteen years of data. Author of [7] agrees with the fact that most recent financial data are the better predictors of the future price returns. Though, in the [7] author has used the neural networks and support vector machine for prediction. Author also stressed that neural networks algorithm produced better accuracy than other machine learning algorithms.

## 10 THREE PARADIGMS OF PREDICTION

Data prediction and analysis done in this project is purely quantitative. However there are other paradigms of predictions also which we will discuss here. Example in above analysis we totally missed the qualitative aspect of the data. This is why it explains recent data on amazon stocks produced better results. Here are the other prediction paradigms explained by the author of [3] :

- Quantitative research based prediction. This is a method where we utilize statistical tools to arrive at predictive value based on data
- Quantitative research based prediction. This is a method where we utilize conceptual knowledge to arrive at predicted value. Example of such study would be prediction of stocks based on the events such as mergers acquisitions, bankruptcy, Fraud, political changes, market crashes, housing bubble, dot net bubble and etc.
- Mixed research based prediction. This is a hybrid method where we utilize both qualitative and quantitative results to predict result.

In this project we used quantitative based approach to validate the fact if more data is good for prediction or it adds noise. Result of this project also showed there is a importance of recent data in predicting results. This is also validated by the research done under [7]

## 11 LIMITATION

In this project, analysis is based on two technological stocks: yahoo and amazon. We can extend our study to more diverse portfolio by including more stocks from various industries. Technological stocks tend to be more volatile than other stocks. Since this project is purely quantitative based prediction we deliberately chosen the technological stocks to leverage their volatility. More accurate prediction could also be made by encapsulating qualitative based prediction in the analysis which is more like a hybrid approach. Such hybrid approaches includes assigning weight to each predictions and taking cumulative result. As the part of future work we can also compare results across industry and arrive at conclusion which industry is more stable in prediction. Comparison can based on the root mean square analysis which is discussed in this project report.

## 12 CONCLUSION

Main objective of doing this project is to know the importance of big data in predicting financial variables. Analysis of this project is based on two stocks: amazon and yahoo. We started this project report with the discussion of importance of big data in financial industry. In the introduction we discussed how various industries are investing in the Big Data to attain higher standards in terms of quality and customer satisfaction. Then we discussed what are

the various types of data available: structured and unstructured. Since in this project we utilized only structured data so it was discussed deeply. This project report also touch base with various challenges financial industry takes in utilizing the value of big data. As the part of literature review we reviewed various researches done in the field of stock returns prediction. In the financial data extraction section we reviewed various technical requirements need for financial data extraction. As the part of data analysis for this project we discussed what are the various ways to fetch live stock data from yahoo or google server. In this project we used the rich financial python libraries for the analysis so we discussed them in details in this report. Financial model which we chose for the prediction is the CAPM model which is explained theoretically in this report. There are two different section where we discussed the proposed analysis and proposed algorithm. We finally concluded the report by discussing three paradigms of prediction. In the end we also mentioned what further can be done under future work section.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski and TAs for their support and suggestions to write this paper. TAs and professor are very good in terms of providing valuable guidance and suggestion in a very prompt fashion.

## REFERENCES

- [1] Qasem Al-Radaideh, Adel Abu Assaf, and Eman Alnagi. 2013. Predicting Stock Prices Using Data Mining Techniques. (12 2013). [https://www.researchgate.net/publication/281865047\\_Predicting\\_Stock\\_Prices\\_Using\\_Data\\_Mining\\_Techniques](https://www.researchgate.net/publication/281865047_Predicting_Stock_Prices_Using_Data_Mining_Techniques)
- [2] A. F. Atiya. 2001. Bankruptcy prediction for credit risk using neural networks: A survey and new results. *IEEE Transactions on Neural Networks* 12, 4 (Jul 2001), 929–935. <https://doi.org/10.1109/72.935101>
- [3] Adam Chu. 2017. Quantitative, Qualitative, and Mixed Research. (2017). <https://www.bcps.org/offices/lis/researchcourse/images/lec2.pdf>
- [4] Daniel D. Gutierrez. 2014. *Big Data for Finance*. Technical Report. Dell & Intel. [https://whitepapers.em360tech.com/wp-content/files\\_mf/1427803213insideBIGDATAGuidetoBigDataforFinance.pdf](https://whitepapers.em360tech.com/wp-content/files_mf/1427803213insideBIGDATAGuidetoBigDataforFinance.pdf)
- [5] Kazim Hussain and Elsa Prieto. 2015. *Big Data in Finance*. Chapman and Hall/CRC, <https://www.cs.helsinki.fi/u/jilu/paper/bigdataapplication04.pdf>, Chapter 17, 329–356.
- [6] Kazim Hussain and Elsa Prieto. 2016. *Big Data in the Finance and Insurance Sectors*. Springer, Cham, "<https://link.springer.com/content/pdf/10.1007/>", Chapter 12, 209–223.
- [7] Hui Lin. 2014. Stanford. (2014). <https://pdfs.semanticscholar.org/56f0/59ea400f31b60bfde4d59aea71bd7b411553.pdf>
- [8] Burton G. Malkiel. 2015. *A Random Walk Down Wall Street: The Time-Tested Strategy for Successful Investing*. Recorded Books on Brilliance Audio. <https://www.amazon.com/Random-Walk-Down-Wall-Street/dp/1501260375?SubscriptionId=0JYN1NVW651KCA56C102&tag=techkie-20&linkCode=xm2&camp=2025&creative=165953&creativeASIN=1501260375>
- [9] A. Parsian, W. Yeoh, and M. S. Ee. 2015. Quality-Based SQL: Specifying Information Quality in Relational Database Queries. *Computer* 48, 9 (Sept 2015), 69–74. <https://doi.org/10.1109/MC.2015.264>
- [10] Kevin Sheppard. 2017. daily.py daily.py. (2017). [https://github.com/pydata/pandas-datareader/blob/master/pandas\\_datareader/yahoo/daily.py](https://github.com/pydata/pandas-datareader/blob/master/pandas_datareader/yahoo/daily.py)
- [11] Philip M. Tsang, Paul Kwok, S.O. Choy, Reggie Kwan, S.C. Ng, Jacky Mak, Jonathan Tsang, Kai Koong, and Tak-Lam Wong. 2007. Design and implementation of NN5 for Hong Kong stock price forecasting. *Engineering Applications of Artificial Intelligence* 20, 4 (2007), 453 – 461. <https://doi.org/10.1016/j.engappai.2006.10.002>
- [12] Teerd van der Ploeg, Peter C. Austin, and Ewout W. Steyerberg. 2014. Modern modelling techniques are data hungry a simulation study for predicting dichotomous endpoints. *BMC Medical Research Methodology* 14, 1 (22 Dec 2014), 137. <https://doi.org/10.1186/1471-2288-14-137>
- [13] Martin Walker and Mamoun Al-Deh'e. 2000. Fundamental Information Analysis: An Extension and UK Evidence. *ACS Biomaterials Science & Engineering* 31 (02 2000).
- [14] Muh-Cherng Wu, Sheng-Yu Lin, and Chia-Hsin Lin. 2006. An effective application of decision tree to stock trading. *Science Direct* 31 (08 2006), 270–274.
- [15] Sonja Zillner, Tilman Becker, and Munn. 2016. *Big Data-Driven Innovation in Industrial Sectors*. Springer International Publishing, Cham, Chapter 4, 169–178. [https://doi.org/10.1007/978-3-319-21569-3\\_9](https://doi.org/10.1007/978-3-319-21569-3_9)

## A HID 301:GAGAN ARORA

- Identified Project topic.
- Collected the python financial libraries.
- fetched data from yahoo finance
- Studied, designed and reviewed CAPM model
- Implemented CAPM model using python libraries
- Created project report

## B CODE REFERENCE

All code, notebooks and files for this project can be found in the githup repository: <https://github.com/bigdata-i523/hid301/blob/master/project/finalProject.ipynb>

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--entry type for "Ref7" isn't style-file defined
--line 169 of file report.bib
Warning--entry type for "Ref8" isn't style-file defined
--line 187 of file report.bib
Warning--entry type for "Ref14" isn't style-file defined
--line 341 of file report.bib
Warning--entry type for "Ref15" isn't style-file defined
--line 359 of file report.bib
Warning--empty address in Ref13
Warning--page numbers missing in both pages and numpages fields in Ref10
(There were 6 warnings)
```

```
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
=====
[2017-12-12 20.00.07] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
Missing character: ""
Typesetting of "report.tex" completed in 1.1s.
./README.yml
25:24     error    trailing spaces  (trailing-spaces)
32:18     error    trailing spaces  (trailing-spaces)
38:57     error    trailing spaces  (trailing-spaces)
48:62     error    trailing spaces  (trailing-spaces)
50:26     error    trailing spaces  (trailing-spaces)
```

```
=====
Compliance Report
=====
```

```
name: Arora, Gagan
hid: 301
paper1: 100% Oct 29 17
paper2: 100% Nov 4
project: 100% 12/2/2017
```

```
yamlcheck
-----
```

```
wordcount
-----
```

```
8
wc 301 project 8 5859 content.tex
wc 301 project 8 5971 report.pdf
wc 301 project 8 866 report.bib
```

```
find "
```

```
-----
```

```
passed: True
```

```
find footnote
-----
```

```
passed: True
```

```
find input{format/i523}
-----
```

```
5: \input{format/i523}
```

```
passed: True
```

```
find input{format/final}
-----
```

```
passed: False
```

floats

---

figures 0  
tables 0  
includegraphics 0  
labels 0  
refs 0  
floats 0

True : ref check passed: (refs >= figures + tables)  
True : label check passed: (refs >= figures + tables)  
True : include graphics passed: (figures >= includegraphics)  
True : check if all figures are refered to: (refs >= labels)

Label/ref check  
passed: True

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst

```
Database file #1: report.bib
Warning--entry type for "Ref7" isn't style-file defined
--line 169 of file report.bib
Warning--entry type for "Ref8" isn't style-file defined
--line 187 of file report.bib
Warning--entry type for "Ref14" isn't style-file defined
--line 341 of file report.bib
Warning--entry type for "Ref15" isn't style-file defined
--line 359 of file report.bib
Warning--empty address in Ref13
Warning--page numbers missing in both pages and numpages fields in Ref10
(There were 6 warnings)
```

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

---

ascii

---

non ascii found 8217

=====
The following tests are optional
=====

Tip: newlines can often be replaced just by an empty line

find newline

---

312: \textbf{\textit{Next Day stock price =}}: Today stock price \*
(1+Daily expected return)\newline

320: \textbf{\textit{Time frame 1}}: [01/01/2000 to 12/31/2016] 16
years of data\newline

321: \textbf{\textit{Time frame 2}}: [01/01/2006 to 12/31/2016] 10

years of data\nline

350: \textbf{\textit{Test data time frame}}: 01/01/2017 to  
11/16/2017\nline

passed: False

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Predicting Housing Prices

Murali Cheruvu, Anand Sriramulu

Indiana University

3209 E 10th St

Bloomington, Indiana 47408

mcheruvu@iu.edu, asriram@iu.edu

## ABSTRACT

In United States, more than 6 million residential homes sold in 2017. With ever-increasing demands, real estate is challenged with complex analysis of homes to provide accurate appraisals and predicting market fluctuations to react accordingly. Big data analytics helps mining the real estate data to provide valuable business insights. In this project, we have planned to analyze housing data to predict sale prices. Using well established datasets, with lots of exploratory variables, we could apply thorough exploration of the data, feature engineering and implement various advanced supervised learning algorithms, such as XGoost, Ridge, Lasso, Random Forest and Neural Network to predict accurate sale prices.

## KEYWORDS

i523, hid306, Exploratory Data Analysis, Supervised Learning Algorithms, Ensemble Modeling

## 1 INTRODUCTION

Real estate, with \$235 million dollar yearly revenue, is a continued growing industry in United States. With more than 200,000 residential and commercial brokerage firms, there are millions houses getting sold every year [9]. In recent times, Big Data has changed the way real estate is getting operated and bringing the importance of data analysis to become major factor in the decision making process. The goal of our project is to predict the sale prices of residential homes listed in the test dataset as accurately as possible. Training dataset contains sale price of the homes, and using this training data set, how accurately we can predict sale prices of the homes in the test dataset by applying data preprocessing and thorough data analysis. In this project, we have applied various exploratory analysis techniques and engineer the features before applying a few advanced supervised learning algorithms such as SVM, XGoost, Ridge, Lasso, Random Forest and Neural Network, to create more accurately predicted models.

## 2 HOUSING DATA ANALYTICS

Traditional real estate forced buyers to have physical presence to see the homes and meet the realtors. Analyzing the sale price was challenging and require extensive understanding of the neighborhood; highly depend on knowledge of the realtor about recent homes being sold in the surroundings. Assessing the sale price is a daunting task even with a good understanding of the features of any specific home. The true value of mining the real estate data and analyzing it lies in making context-aware relevant data and converting the result to enterprise-grade, tangible and *actionable* business insights. In this project, we would like to predict *sale prices* of housing prices using two datasets - training and testing, each with 79

exploratory variables describing almost every aspect of residential homes in city of Ames, Iowa state. However, the datasets, we have got, are snapshots taken in 2010. As a result, these datasets may not reflect the latest trends in the housing sale prices but the analytical approaches taken in this project are generic and can easily be applied to newer datasets. The key to achieve this lies in getting better handle on the housing data and the trends in sale patterns. With proper housing analytics, not only the realtors get benefit in getting predicted appraisals but also help buyers analyze houses with accurate sale prices within their budget. Machine Learning is empowered with all the capabilities to analyze and provide in depth business insights. Interconnectivity between the economy and housing prices is vital motivating factor in doing this project.

Big Data is defined by *four Vs*: volume, variety, velocity and veracity [5]. (a) Volume: Millions of houses that are in the market for sales will generate high volumes of data. (b) Variety: Housing data comes in various formats: structured, semi-structured and unstructured. Structured data usually come from standard datasets collected at various sources. Video and housing pictures are examples of unstructured data. Traditional relational databases (RDBMSs) will not be suitable for scale out distributed processing to handle such volume and variety. Alternatives like *Hadoop ecosystem*, with Distributed File System, Map, Reduce, etc. aspects, allows complex data processing. (c) Velocity: Data can come in batches, near-real time and real-time. During the housing sale seasons, there will be very high velocity in getting the housing details and the sale transactional data. (d) Veracity: Housing datasets are going to have lots of noise and outlier data. Data mining will address these concerns using *data cleansing* and *normalization* techniques. Various types of analytics can be done using machine learning algorithms and data visualizations to see the classification and predicting model patterns. Typical Big Data analytics include: descriptive, diagnostic, prescriptive and predictive. We will apply predictive analytics in this project, to model the predictions of the *sale prices*.

The real estate industry is tied with Big Data in many ways. Various real estate servicing companies providing advanced insights to buyers and realtors using big data analytics. These companies collect various types of high volume data, such as geographic, census and housing data for rent and sale. Just by using zip code or neighborhood information, one can easily analyze and get the information around potential value of neighborhood properties and trends in the sale. Real estate analytics can tap into *smart cities* data to provide in depth analysis of neighborhood health conditions and energy efficiencies. Banks are using big data sources to analyze and set the prices of foreclosure or short sales in the given neighborhood than offering some lower price which may not correlate with the surrounding similar homes [6]. Big data analytics is going to drive various housing aspects including: buyer identification,

accurate pricing and geographic targets [10] along with connecting national and local real estate agents. Social networking datasets can help linking the buyers and sellers [12].

### 3 DOMAIN KNOWLEDGE

To predict accurate *sale price*, we will need to understand the domain well. We need to build the intuition around all the exploratory variables in the dataset and focus on which factors could influence the target variable: *sale price*. If we do not find all these factors, perhaps, we need to add new features to address the gaps in dataset describing the domain. Some of the factors which, we think, can directly influence house prices are:

- What is the overall Size or area of the house?
- How good is the location of the house - closer to highways?
- How good is the neighborhood?
- How old is the house?
- What is the quality of the construction?
- How many garages are there in the house?
- What are the floor plans?
- How many number of bedrooms are there in the house?
- How many number of bathrooms are there in the house?
- What is the size of living area?

## 4 EXPLORATORY DATA ANALYSIS

We can start the process with exploratory data analysis. There are 1460 rows in the training data set and 1459 rows in the test dataset. Out of the 80 variables, 23 are nominal, 23 are ordinal, 14 are discrete, and 20 are continuous. The nominal variables are related to material, garage, dwelling, and environmental conditions. All the 20 continuous variables are related to the area dimensions. The ordinal variables rate various items within the property. The home listing includes only few quantified variables like typical lot size and total dwelling square footage, but this data set has more specific variables. There are individual category variables derived from basement, main living area and porch based on quality and type. We have combined training and testing datasets for easier analysis. We excluded Id attribute as it does not add value in the modeling. We also removed Sale Price, the target variable, from the training dataset. All the variables are listed in the appendix section as a reference. We applied univariate, bivariate and multivariate analytical techniques to analyze numerical and categorical variables. Various statistical and data visualizations were applied on each type of variable. The primary goal of exploratory data analysis is to amplify the insights of analysts onto given input dataset to analyze the aspects, such as:

- Good fitting of the model
- Analyzing impact of the outliers
- Missing value analysis and imputation
- Feature engineering and ranking
- Algorithm selection and tuning for optimal predictions

### 4.1 Analyze Missing Values

First part of the analysis was to check for any missing values in the training and testing datasets as shown in Figure (1). Using the bar plot shown in Figure (2), we have identified that there are 5

variables: *pool quality*, *miscellaneous features*, *alley*, *fence* and *fire place quality*, having the most missing data.

[Figure 1 about here.]

[Figure 2 about here.]

All the missed values of numeric variables are analyzed further to decide whether we need to delete the instances of all the data with missing values or impute them with something meaningful. There are various ways to find the estimate to replace the missing value including:

- Mean: Replace missed value with the mean value of the corresponding variable
- Regression: Some predicted value by regressing missing variable on all the other variables
- Interpolation and extrapolation: An estimated value from other observations of the same variable

### 4.2 Analyze Numerical Variables

There are 37 numerical variables after excluding the *Id* variable. List of numerical variables are: MS-Sub-Class, Lot-Frontage, Lot-Area, Overall-Qual, Overall-Cond, Year-Built, Year-Remod-Add, Mas-Vnr-Area, Bsmt-Fin-SF1, Bsmt-Fin-SF2, Bsmt-Unf-SF, Total-Bsmt-SF, 1st-Flr-SF, 2nd-Flr-SF, Low-Qual-Fin-SF, Gr-Liv-Area, Bsmt-Full-Bath, Bsmt-Half-Bath, Full-Bath, Half-Bath, Bedroom-Abv-Gr, Kitchen-Abv-Gr, Tot-Rms-Abv-Grd, Fireplaces, Garage-Yr-Blt, Garage-Cars, Garage-Area, WoodDeck-SF, Open-Porch-SF, Enclosed-Porch, 3Ssn-Porch, Screen-Porch, Pool-Area, Misc-Val, Mo-Sold, Yr-Sold and Sale-Price. *Interval* and *ratio* are the two types of numerical variables we encounter in most of the data analytical applications. Statistical aspects of the numerical univariate analysis include: count, minimum, maximum, mean, median, mode, quantile, range, variance, standard deviation and skewness. Data visualization techniques, such as histogram, box plot and scatter plot are used to analyze the numerical variables. We have shown *sale price*, *overall quality*, *garage live area* and *year built*, in the Figures (4) and (5) as a few sample plots from the numerical analysis. Corresponding code snippet is shown in Figure (3).

[Figure 3 about here.]

[Figure 4 about here.]

[Figure 5 about here.]

### 4.3 Analyze Categorical Variables

There are 43 categorical variables in the combined dataset. List of categorical variables are: MS-Zoning, Street, Alley, Lot-Shape, Land-Contour, Utilities, Lot-Config, Land-Slope, Neighborhood, Condition1, Condition2, Bldg-Type, House-Style, Roof-Style, Roof-Matl, Exterior-1st, Exterior-2nd, Mas-Vnr-Type, Exter-Qual, Exter-Cond, Foundation, Bsmt-Qual, Bsmt-Cond, Bsmt-Exposure, Bsmt-Fin-Type1, Bsmt-Fin-Type2, Heating, Heating-QC, Central-Air, Electrical, Kitchen-Qual, Functional, Fireplace-Qu, Garage-Type, Garage-Finish, Garage-Qual, Garage-Cond, Paved-Drive, Pool-QC, Fence, Misc-Feature, Sale-Type and Sale-Condition. We have analyzed all categorical variables and found the ways to fill the missing values. We have also evaluated proper approaches to convert them into numerical factors. Bar and pie charts are used to visualize categorical variables. Later on in the feature engineering section, we will go

through more details on numerical factors. Categorical variable factors and the corresponding code snippet for *neighborhood* and *sale type* are shown in Figure (6) and Figures (7).

[Figure 6 about here.]

[Figure 7 about here.]

#### 4.4 Analyze Correlations

*Numpy* package offers correlations functionality to analyze the variables that are positively or negatively correlated with the *sale price* and also analyze any interdependencies among the variables. Figure (8) and (9) shows the code snippet and the correlations plot. From that we can list the top 10 features those are strongly correlated with the target variable - *sale price*. We can visualize a few pair-wise correlation graphs with sale price for further detailed analysis. Figures (10) and (11) show how *overall quality*, *ground live area*, *garage cars* and *garage area* are positively correlated with *sale price*.

[Figure 8 about here.]

[Figure 9 about here.]

[Figure 10 about here.]

[Figure 11 about here.]

- (1) OverallQual: Overall material and finish quality
- (2) GrLivArea: Above ground living area square feet
- (3) GarageCars: Size of garage in car capacity
- (4) GarageArea: Size of garage in square feet
- (5) TotalBsmtSF: Total square feet of basement area
- (6) 1stFlrSF: First Floor square feet
- (7) FullBath: Full bathrooms above grade
- (8) TotRmsAbvGrd: Total rooms above ground
- (9) YearBuilt: Original construction date
- (10) GarageYrBlt: Garage built year

#### 4.5 Skewed Data Analysis

From the numerical analysis, we have identified that there are a few numerical variables need further analysis to identify the skewed data. We did not find any key variables those have skewed more than 75%. However, we wanted to replace the *sale price* with corresponding logarithmic value for the predictive models and later convert it back to the exponential value before saving the predictions. Figure (12) shows the *sale price*, before and after applying the logarithmic value.

[Figure 12 about here.]

#### 4.6 Outlier Analysis

Continuing with exploratory analysis, we have analyzed the outliers using *Cooks distance*. *Cooks distance* is a measure calculated from a regression model to find out the influence exerted by each observation (row) on the predictions. As a practice, those observations that have a *Cooks distance* greater than 4 times the mean value may be classified as an outlier. Outlier detection can be done using univariate and multivariate analysis. In univariate model, the outliers are those observations that are present outside of  $1.5 * \text{IQR}$ , where *IQR* (*Inter Quartile Range*) is the difference between 75th and 25th quartiles. Analyzing outliers in any observations based on single variable may lead to incorrect inferences. *Cooks distance*

generalizes the outlier analysis using multivariate approach [7]. Figure (13) is the code implementing Cooks distance to find the outliers from training dataset and Figure (14) shows the scatter plot with outliers being marked as bubbles. The bigger the bubbles, the bigger outlier deviations from the mean value. We have further analyzed two key variables - *ground live area* and *garage area* that are in high correlation with the *sale price*. From the scatter plot shown in Figure (15), we can see that *garage live area* has 4 outliers with values greater than 4,000 sq ft. We can also visualize 4 outliers in *garage area* scatter plot with values greater than 1,200 sq ft. as shown in Figure (16). We have removed the 8 outlier rows related to these two variables from the training dataset, the corresponding code snippet shown in Figure (17).

[Figure 13 about here.]

[Figure 14 about here.]

[Figure 15 about here.]

[Figure 16 about here.]

[Figure 17 about here.]

#### 4.7 Feature Engineering

Feature engineering is a technique to analyze all the variables those influence target variable for better predictions. Part of feature engineering, we may need to create new features to make the data to be more expressive. One of the key intents, in analyzing categorical variables, is to convert them into numerical factors as most of the machine learning algorithms expect all the variables to be numeric for them to work more effectively. Feature engineering is a difficult task; majority of the effort is manual and requires lots of domain knowledge.

**4.7.1 Numerical Encoding.** Some of the categorical variables are ordinal. we can use T-shirt sizes: small, medium and large as an example to explain an ordinal variable. When we convert this category variable into numeric encoding, we need to retain the fact that there is an implicit order within the values. Supposing, we give ordinal encoding as - small = 1, medium = 2 and large = 3; we will satisfy the implicit order or weightage and that helps in modeling the system by elevating the importance of this implicit ordering in the values of the ordinal variable. There are a few other encoding techniques, such as one-hot, binary, polynomial and helmert to factorize categorical variables. We will use ordinal and one-hot encoding techniques for this dataset. Following are a few categorical variables converted to numerical:

- *Lot shape* is encoded as: 1 - regular, 2 - Irregular-I, 3 - Irregular-II, 4 - Irregular-III
- *Alley* is encoded as: 1 - none, 2 - gravel, 3 - paved
- All quality variables such as *garage quality* are encoded as: 0 - none, 1 - poor, 2 - fair 3 - typical 4 - good, 5 - excellent
- *Building type* is encoded as: 1 - single-family, 2 - two-family, 3 - duplex, 4 - townhouse end unit, 5 - townhouse inside unit
- *Overall quality* is encoded as: 1 to 3 - bad, 4 to 6 - average, 7 to 10 - good

**4.7.2 One-hot Encoding.** One-hot encoding converts the category variable into many binary vectors, one new numeric variable

for each value in the category. Assume that we have a categorical variable called signal-light with three possible values: green, yellow and red. We will need to convert these values into numeric - green = 1, yellow = 2 and red = 3. When we apply one-hot encoding on this variable, basically we are creating three new categorical variables - signal-light-green, signal-light-yellow and signal-light-red along with the original variable - signal-light, each is pretty much a binary vector having 1s for all the corresponding values; otherwise 0s. With hot-encoding, we are basically increasing dimensions in the model. After extensive feature engineering applied on the housing dataset, we have added 228 new features (variables). Figure (18) shows the python methods to factorize categorical variables using one-hot encoding techniques.

[Figure 18 about here.]

**4.7.3 New Features.** By adding new features that fill the gaps in domain model, we can guide the model predictions more accurately. We can, easily, create more meaningful new features from existing features, such as:

- What is the total area of the house? - This variable is sum of 18 existing variables that are contributing to the overall size of the house, such as *lot frontage*, *lot area*, *ground live area*, *pool area* and *garage area*.
- Whether house has been ever remodeled? - We can find this out using two variables: *year built* and *year remodel added*.
- House remodeled since? - We can find this out using two variables: *year sold* and *year remodel added*.
- Is it a very new house? - This can be calculated based on *year built*
- What is the age of the house? - This is a calculated value from *year build* (formula: 2010 - *year built*)
- When was it last sold? - This is a calculated value from *year build* (formula: 2010 - *year sold*)
- Which season house was last sold in? - This is a calculated value from *month build*

#### 4.7.4 Handling Null Values.

- LotFrontage: Calculated the median of the *LotFrontage* grouping by neighborhood and assigned the median value for the homes with null values.
- Street: Filled null values with *Grvl*.
- Alley: Filled null values with *NA*.
- Lot Shape: Filled null values with *Reg*.
- Land Contour: Filled null values with *lvs*.
- Land Slope: Filled null values with *Gtl*
- Neighborhood\_Good: Filled null values with 0
- YearRemodAdd: Filled null values with Year Built value.
- GarageYrBlt: Filled null values with 0
- Exterior1st: Filled null values with Mode of this variable
- Exterior2nd: Filled null values with Mode of this variable
- MasVnrArea: Filled null values with 0
- ExterQual: Filled null values with *TA* (numeric factor = 2)
- BsmtQual: Filled null values with *TA* (numeric factor = 2)
- BsmtFinType1: Filled null values with Mode of this variable
- BsmtFinType2: Filled null values with Mode of this variable

- PoolQC: There are entries with *PoolArea* > 0 and *PoolQC* as NA, so filled the values with average condition - *TA*

## 5 ALGORITHMS AND METHODOLOGY

Linear regression predicts the target variable using best possible straight line fit to the set predictor variables. The best fit is usually the one that minimizes the root mean squared error (RMSE) between the actual and predicted data points. However, with complex problem space such as the housing prices dataset, we have lots of variables relating to the target variable in a non-linear fashion. Trivial supervised learning algorithms will not be effective to provide accurate *sale price* predictions. To overcome this challenge, we have applied various advanced supervised learning algorithms, such as Support Vector Machine (SVM), Random Forest, Lasso, Ridge, XGBoost and Neural Network, to predict the test data housing prices. Following are some of the aspects that are common to all the algorithms:

### 5.1 Underfitting and Overfitting

Underfitting happens when the model is trivial and does not fit the data properly. As a result it is unable to learn the model properly hence gives incorrect predictions. Underfitting suffers from low *variance* but high *bias* from the predicted model. Variance measures the variation in learning from different training sets. Variance does not properly filter outliers that are part of the model. Bias prevents generalization beyond the training dataset. Overfitting occurs when the predicted model learns the training dataset including the noise and results negatively impacting the performance and accuracy of the model. Overfitting happens more likely with non-linear and non-parametric algorithms those offer more flexibility. Overfitting, as expected, exhibits low *bias* and high *variance*. Balancing between bias and variance is a challenge and model may have to compromise one over the other.

### 5.2 Cross Validation

Before applying the trained model onto the testing dataset, we need to validate it. Cross-validation is a technique to validate the trained model by partitioning the original training dataset into two parts - training and cross validation datasets. The cross validation dataset is basically to evaluate the trained model before applying on the actual test dataset. Usually 70% of the original training dataset is kept for training the model and 30% of it for cross validation. This type of cross validation is called *holdout method*. *K-fold cross validation* is more improved and effective cross validation method, where the dataset is divided into *k* subsets, and the *holdout* method is repeated *k* times. In each iteration, one of the *k* subsets is selected as a test dataset and the remaining *k-1* subsets will be part of the training dataset. In the end, the average error across all *k* attempts is computed.

### 5.3 Support Vector Machine (SVM) Algorithm

Support Vector Machine (SVM) algorithms can be used to solve classification and regression problems. SVM creates larger margins between categories of data so that they are linearly separable. SVM regression relies on kernel functions for modeling the data. SVM handles non-linearly separable data, mainly for regression problems,

using kernel functions, such as polynomial, radial basis function (RBF) and sigmoid, to project the data onto a hyperplane. Figure (19) shows the python implementation for *sale price* predictions of the housing test dataset.

[Figure 19 about here.]

We have used *sklearn.svm* package to implement the SVM algorithm in Python. The SVM kernel used, for the *sale price* prediction, is *radial basis function*. Cost parameter, with a value of  $1e3$ , is used to increase the margin for better linear separability. Gamma controls the trade-off between error due to bias and variance in the trained model. We have used gamma value as  $1e-8$ . Once the SVM algorithm is instantiated, we fit the model by passing the training dataset and the *sale prices* vector of the training dataset as Y-target variable. After training the model is done, we checked the *root mean squared error* (RMSE) of the trained model predictions with the actuals to make sure the desired accuracy is being met. In this case, RMSE is calculated as 0.2069. Finally we predict the *sale price* of test dataset and make sure the sale prices are meaningful.

## 5.4 Random Forest Algorithm

Random Forest is an advanced machine learning algorithm for predictive analytics. Random Forest ensembles multiple decision trees to create an additive learning model from the sequence of base models created by each decision tree that worked on a sub-sample dataset. Random Forest models are suitable to handle tabular datasets with hundreds of numeric and categorical features. Along with missing values, non-linear relations between features and the target, will be handled well by random forest algorithms. With proper tuning of hyper-parameters of the random forest algorithm, it can perform well with decent accuracy in the predictions without overfitting the model. Unlike similar regression models, it does not offer feature coefficient information but it provides *feature ranking* functionality very nicely. Figure (20) shows the random forest algorithm details for the *sale price* predictions implemented using *sklearn* package and the Figure (21) shows the top 10 important features selected by random forest to model the predictions.

[Figure 20 about here.]

[Figure 21 about here.]

We have used *sklearn.ensemble* and *sklearn.metrics* packages to implement random forest algorithm. The hyper-parameters used in this algorithm are: *n\_estimators* = 100, *oob\_score* = True and *random\_state* = 123456. Parameter: *n\_estimators* is for the number of trees in the random forest. Parameter: *oob\_score* is a boolean to indicate whether to use out-of-bag samples to estimate the generalization accuracy. Parameter: *random\_state* is used as seed for the random number generator. Training dataset and the *Sale Price* vector are used as input to fit the model and verified the predicted output of the training dataset. The RMSE is calculated as 0.0519. Finished the implementation by predicting the *sale price* of the test dataset.

## 5.5 Lasso Algorithm

Lasso is a regression model that uses shrinkage to bring data points towards the center, similar to the mean value of all the data points. Lasso stands for Least Absolute Shrinkage and Selection Operator. It

is a regularized linear model with penalty term *lambda* to minimize the error. Parameter penalization controls overfitting the input data by shrinking variable coefficients to 0. Essentially this makes the variables no effect in the model, hence reduces the dimensions. Figure (22) shows the lasso algorithm implementation for *sale price* predictions in python.

[Figure 22 about here.]

We have used *sklearn.linear\_model* package to implement lasso algorithm. *sklearn.metrics* is used for RMSE calculations. The two key hyper-parameters used in this algorithm are: *alpha* = 0.0001 and *max\_iter* = 50000. The parameter: *alpha* is used as a constant term that multiplies the L1 term. L1 is explained in the following Ridge Algorithm section. We have given *alpha* by finding the best value through cross validation. Training data and the *sale price* are sent to the *fit* method to fit the model. RMSE is calculated as 0.1015 to evaluate the accuracy of the trained model against the *sale price* of the training dataset. Finally the algorithm predicted the *sale price* of the test dataset.

## 5.6 Ridge Algorithm

Ridge algorithm is very similar to lasso algorithm with the same goal. While lasso performs *L1 regularization*, ridge applies *L2 regularization* techniques in modeling the predictions. L1 regularization adds penalty to the variables equivalent to *absolute value of the magnitude* of the coefficients, whereas L2 adds the penalty equivalent to *square of the magnitude* of the variable coefficients. Figure (23) shows the python implementation of the ridge algorithm for the *sale price* predictions. Figures (24) and (25) show the top 10 positively and top 10 negatively influencing variables with *sale price*.

[Figure 23 about here.]

[Figure 24 about here.]

[Figure 25 about here.]

We have used *sklearn.linear\_model* package to implement ridge algorithm. The two key hyper-parameters used in this algorithm are: *alpha* = 0.00099 and *normalize* = True. The parameter: *alpha* is used to denote the *regularization* strength. We have given *alpha* by finding the best value through cross validation. Parameter: *normalize* is used when the value is True to normalize the regressors *X* before regression by subtracting the mean and dividing by the L2 norm. Training data and the *sale price* are sent to the *fit* method to fit the model. RMSE is calculated as 0.09888 to evaluate the accuracy of the trained model against the *sale price* of the training dataset. We have also extracted the top 10 positive and negative features influencing the target variable - *sale price*. Finally the algorithm predicted the *sale price* of the test dataset.

## 5.7 XGB Boosting Algorithm

XGBoost (eXtreme Gradient Boosting) is one of the Gradient Boosted Machine algorithms. It ensembles (combines) optimized model by taking trained models from all the preceding iterations. XGBoost regularizes the variables (parameters) to reduce the overfit and can work well with variables having missing values. It is empowered with built-in cross validation to reduce the boosting iterations; hence offers better performance along with parallel processing on

distributed systems such as Hadoop. By tuning the XGBoost hyper parameters, we can achieve well optimized model that can make more accurate predictions. XGBoost uses *F-Score* to measure the importance of variables and also given the python code, as shown in Figure (26), implementing for *sale price* predictions. Figure (27) shows the top 10 feature selection by the XGBoost. Following list explains the hyper-parameters of XGBoost algorithm.

- Maximum Iterations - Number of trees in the final model. More the trees, more accuracy.
- Maximum Depth - Depth of each individual tree to control overfitting.
- Step Size - Shrinkage, works similar to learning rate; smaller value takes more iterations.
- Column Subsample - Subset of the columns to use in each iteration.

[Figure 26 about here.]

[Figure 27 about here.]

We have used *xgb* package to implement the XGBoost algorithm. Various hyper-parameters are used to tune the algorithm and a few of them are explained in the above list. The training dataset and the *sale price* vector are used to fit the model. XGBoost algorithm gives the list of features that are important in creating the model. We have captured the feature ranking as a graph and evaluated the accuracy of the predictions by calculating RMSE on training dataset itself. Finally, we have predicted the *sale prices* of test dataset.

## 5.8 Neural Network Algorithm

Neural Network is, a *directed graph*, organized by layers and layers are created by number of interconnected neurons (or nodes). Every neuron in a layer is connected with all the neurons from previous layer; there will be no interaction of neurons within a layer. The performance of a Neural Network is measured using *cost or error function* and the dependent input *weight* variables. *Forward-propagation* and *back-propagation* are two techniques, neural network uses repeatedly until all the input variables are adjusted or calibrated to predict accurate output. During, forward-propagation, information moves in forward direction and passes through all the layers by applying certain weights to the input parameters. *Back-propagation* method minimizes the error in the *weights* by applying an algorithm called *gradient descent* at each iteration step. We have used *TensorFlow* python library to predict the *sale price* of housing dataset using simple feed-forward neural network. TensorFlow uses *tensors*, special multi-dimensional arrays to store the datasets for easier linear algebra and vector calculus operations.

We have implemented Neural Network algorithm by creating a TensorFlow based work-flow. We have created various objects, such as input variables, loss computation, optimizer and the predictions for TensorFlow to create the model. TensorFlow tunes the hyper-parameters using number of cross-validation iterations before finally predicting the *sale prices* of test dataset.

## 5.9 Model Ensembling

We can create a robust predictive model with better accuracy by merging two or more machine learning algorithms. This technique is called *model ensembling*. Ensembled algorithms may be similar

in functionality or may entirely be different from each other. Individual algorithms may not perform great but by ensembling them, the overall system can offer much better performance and accuracy. Variations in the predicting logic in each of these individual algorithms will bring unbiasedness into the unified model. *Bagging*, *boosting* and *stacking* are popular ensembling techniques. Many of the advanced machine learning algorithms use ensembled approaches to achieve accurate classifications or predictions. Random Forest uses bagging, XGBoost uses boosting and Neural Network applies stacking ensembling techniques. To optimize the predictions, we have created an ensembled model by averaging *Sale Price* of the top 3 performing ensembled algorithms - XGBoost, Lasso and Neural Network. As predicted, ensembled model has predicted better with less RMSE (*root mean squared error*), compared to all the individual algorithms. Following list displays each algorithm and the corresponding *root mean squared error* (RMSE).

- SVM - RMSE = 0.2069
- Random Forest - RMSE = 0.0519
- XGBoost - RMSE = 0.0432
- Lasso - RMSE = 0.1015
- Ridge - RMSE = 0.0988
- Neural Network - RMSE = 0.20

## 6 DEVELOPMENT ENVIRONMENT

### 6.1 OS and Programming Language

We have used *Ubuntu 16.4* Operating System that runs in Windows 10 through Oracle Virtual Box 5.2. Python 2.7 has been used as the programming language for this project. Data visualizations are done using *seaborn* and *matplotlib* packages. Most of the algorithms implemented in this project are using *sklearn* package. For the neural network algorithm, we have used *tensorflow* package as it offers simple programming interface to the complex processing needed by the algorithm. Our code is placed in github repository at <git@github.com:bigdata-i523/hid306.git>.

### 6.2 Project Folder Structure

Project is organized in three folders - code, data and images. Code folder has all the python code files. Data folder contains the *house pricing* sample datasets that we used for the exploratory analysis and *sale price* predictions. We also stored all the *sale price* prediction output files from various algorithms in the data folder. Images folder contains all the data visualization files that we have created during the analysis and in processing the algorithms. We wanted to create interactive and sharable code files that contain not only the python code but also corresponding explanation along with data visualizations. Jupyter Notebook application is ideal for such facilitation with python code components. Using Jupyter Notebook, it would be easy to share live code with the reviewers. Such environment allows to explore the code-base easily along with the interactive code execution and visualize all the corresponding exploratory analysis results with the graphs.

### 6.3 Project Files

We have a total of 11 Jupyter Notebook driven python code files. First 4 files are focused on doing the exploratory data analysis

and the next 6 files are meant for six supervised machine learning algorithms - SVM, Random Forest, Ridge, Lasso, Neural Network and XGBoost. Last code file is dedicated for ensembling the top 3 algorithms with best predictions of housing sale prices in the test dataset. We have named them in a sequence as there is an implicit order in the execution of these files. We wanted to do the data analysis first before running the predictive algorithms.

## 6.4 List of Code Files

Following is the list of code files:

- Exploratory Analysis Numerical - To load datasets and analyze all numerical variables
- Exploratory Analysis Categorical - To analyze categorical variables in the dataset
- Outlier And Skewed Data Analysis - Handles outlier and skewed data analysis
- Feature Engineering - All the feature engineering is done in this file
- SVM Algorithm - Implementation of SVM algorithm
- Random Forest Algorithm - Implementation of Random Forest algorithm
- Ridge Algorithm - Implementation of Ridge algorithm
- Lasso Algorithm - Implementation of Lasso algorithm
- Neural Network Algorithm - Implementation of Neural Network algorithm
- XGBoost Algorithm - Implementation of XGBoost algorithm
- Ensembled Model - Implementation of Ensembled algorithm

## 6.5 List of Data Files

Following is the list of data files:

- Housing Dataset with Sale Price - Sample training dataset with housing attributes along with the sale price
- Housing Dataset without Sale Price - Sample testing dataset similar to training dataset without the sale price
- SVMs Algorithm Predictions - Predicted Housing Sale Prices from SVM algorithm
- Random Forest Algorithm Predictions - Predicted Housing Sale Prices from Random Forest algorithm
- Ridge Algorithm Predictions - Predicted Housing Sale Prices from Ridge algorithm
- XGBoost Algorithm Predictions - Predicted Housing Sale Prices from XGBoost algorithm
- Lasso Algorithm Predictions - Predicted Housing Sale Prices from Lasso algorithm
- Neural Network Predictions - Predicted Housing Sale Prices from Neural Network algorithm
- Ensembled Model Predictions - Predicted Housing Sale Prices from Ensembled algorithm

## 7 CONCLUSION

Generally, ensemble models performs better compared to individual algorithms. However, there are a few factors that influence accuracy and performance of the algorithms, such as handcrafted feature engineering, proper cost function with regularized input to address

non-linearities in the training datasets and tuning hyper-parameters of the algorithms. While Deep Learning Neural Networks are good for image processing, K-Nearest Neighbor algorithms can handle unsupervised datasets with less complexity. Domain knowledge and algorithm selection play vital role in getting accurate predictions. XGBoost, Random Forest, Lasso and Neural Networks are advanced machine learning algorithms dominating in the Big Data analytics for classification and regression related tasks. With ensembling and iterative learning techniques, they can scale well and offer better predictions for huge datasets having large number of features.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski and the Teaching Assistants for their support and great suggestions. Authors would also want to thank Kaggle Website for the sample datasets and the contributed developers for their valuable information, ideas and contributions.

## REFERENCES

- [1] AiO. 2017. House Prices: Advanced Regression Techniques. (Feb. 2017). <https://www.kaggle.com/notapple/detailed-exploratory-data-analysis-using-r>
- [2] Tanner Carbonati. 2017. Detailed Data Analysis & Ensemble Modeling. (Aug. 2017). <https://www.kaggle.com/tannercarbonati/detailed-data-analysis-ensemble-modeling/notebook>
- [3] Yeshwant Chillakuru, Michael Arango, Jack Crum, and Paul Brewster. 2017. Using Neighborhood Level Data to Predict the Residential Sale Price of Properties in Ames, Iowa. (May 2017). <https://rpubs.com/jackcrum/281471>
- [4] Aarshay Jain. 2016. Complete Guide to Parameter Tuning in XGBoost. (March 2016). <https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning-xgboost-with-codes-python/>
- [5] Charles McLellan. 2015. The internet of things and big data: Unlocking the power. (March 2015). <http://www.zdnet.com/article/the-internet-of-things-and-big-data-unlocking-the-power/>
- [6] James O'brien. 2014. 5 Ways Big Data Is Changing Real Estate. (July 2014). [http://mashable.com/2014/07/09/big-data-real-estate/#\\_dujSE2o.gq2](http://mashable.com/2014/07/09/big-data-real-estate/#_dujSE2o.gq2)
- [7] Selva Prabhakaran. 2017. Outlier Treatment. (Dec. 2017). <http://r-statistics.co/Outlier-Treatment-With-R.html>
- [8] Siddharth Raina. 2017. Regularized Regression - Housing Pricing. (Jan. 2017). <https://www.kaggle.com/sidraina89/regularized-regression-housing-pricing>
- [9] Kevin Rands. 2017. 8 companies using big data to disrupt real estate. (Aug. 2017). <https://www.cio.com/article/3211601/data-science/8-companies-using-big-data-to-disrupt-real-estate.html>
- [10] Athena Snow. 2017. Why Big Data is a Game Changer for Agents. (May 2017). <https://www.coldwellbanker.com/blog/cbx-app-game-changer-for-agents/>
- [11] Kevin Wong. 2016. Predicting Ames House Prices. (Dec. 2016). <http://kevinfo.wf.com/post/predicting-ames-house-prices/>
- [12] Charlie Young. 2017. Big data takes over real estate: The best tech for attracting buyers and satisfying sellers. (May 2017). <https://www.inman.com/2017/05/12/big-data-takes-real-estate-best-tech-attracting-buyers-satisfying-sellers/>
- [13] Ricky Yue and Jurgen De Jager. 2016. Advanced Regression Modeling on House Prices. (Sept. 2016). <https://nycdatascience.com/blog/student-works/advanced-regression-modeling-house-prices/>

## A SAMPLE DATASET FILE DETAILS

The training and testing sample datasets contain the same variables explaining the housing real estate aspects. Training dataset contains the sale price information whereas the testing dataset does not the sale price as that is the target variable we need to predict using supervised machine learning algorithm. Following are the list of variables describing the housing real estate domain. Good understanding of the domain is needed for better exploratory data analysis and to apply the matching machine learning algorithms to the problem space.

- Id: Row Id

- SalePrice: Sale price of the house in dollars. This is the target variable to predict.
- MSSubClass: The building class
- MSZoning: The general zoning classification
- LotFrontage: Linear feet of street connected to property
- LotArea: Lot size in square feet
- Street: Type of road access
- Alley: Type of alley access
- LotShape: General shape of property
- LandContour: Flatness of the property
- Utilities: Type of utilities available
- LotConfig: Lot configuration
- LandSlope: Slope of property
- Neighborhood: Physical locations within Ames city limits
- Condition1: Proximity to main road or railroad
- Condition2: Proximity to main road or railroad (if a second is present)
- BldgType: Type of dwelling
- HouseStyle: Style of dwelling
- OverallQual: Overall material and finish quality
- OverallCond: Overall condition rating
- YearBuilt: Original construction date
- YearRemodAdd: Remodel date
- RoofStyle: Type of roof
- RoofMatl: Roof material
- Exterior1st: Exterior covering on house
- Exterior2nd: Exterior covering on house (if more than one material)
- MasVnrType: Masonry veneer type
- MasVnrArea: Masonry veneer area in square feet
- ExterQual: Exterior material quality
- ExterCond: Present condition of the material on the exterior
- Foundation: Type of foundation
- BsmtQual: Height of the basement
- BsmtCond: General condition of the basement
- BsmtExposure: Walkout or garden level basement walls
- BsmtFinType1: Quality of basement finished area
- BsmtFinSF1: Type 1 finished square feet
- BsmtFinType2: Quality of second finished area (if present)
- BsmtFinSF2: Type 2 finished square feet
- BsmtUnfSF: Unfinished square feet of basement area
- TotalBsmtSF: Total square feet of basement area
- Heating: Type of heating
- HeatingQC: Heating quality and condition
- CentralAir: Central air conditioning Electrical: Electrical system
- 1stFlrSF: First Floor square feet
- 2ndFlrSF: Second floor square feet
- LowQualFinSF: Low quality finished square feet (all floors)
- GrLivArea: Above grade (ground) living area square feet
- BsmtFullBath: Basement full bathrooms
- BsmtHalfBath: Basement half bathrooms
- FullBath: Full bathrooms above grade
- HalfBath: Half baths above grade
- Bedroom: Number of bedrooms above basement level
- Kitchen: Number of kitchens
- KitchenQual: Kitchen quality
- TotRmsAbvGrd: Total rooms above grade (does not include bathrooms)
- Functional: Home functionality rating
- Fireplaces: Number of fireplaces
- FireplaceQu: Fireplace quality
- GarageType: Garage location
- GarageYrBlt: Year garage was built
- GarageFinish: Interior finish of the garage
- GarageCars: Size of garage in car capacity
- GarageArea: Size of garage in square feet
- GarageQual: Garage quality
- GarageCond: Garage condition
- PavedDrive: Paved driveway
- WoodDeckSF: Wood deck area in square feet
- OpenPorchSF: Open porch area in square feet
- EnclosedPorch: Enclosed porch area in square feet
- 3SsnPorch: Three season porch area in square feet
- ScreenPorch: Screen porch area in square feet
- PoolArea: Pool area in square feet
- PoolQC: Pool quality
- Fence: Fence quality
- MiscFeature: Miscellaneous feature not covered in other categories
- MiscVal: Dollar Value of miscellaneous feature
- MoSold: Month Sold
- YrSold: Year Sold
- SaleType: Type of sale
- SaleCondition: Condition of sale

## A.1 Factorization of categorical variables

Following are the factorized categorical variable details:

**A.1.1 Street (Nominal).** : Type of road access to property

- Grvl - Gravel
- Pave - Paved

**A.1.2 Alley (Nominal).** : Type of alley access to property

- Grvl- Gravel
- Pave - Paved
- NA - No alley access

**A.1.3 Lot Shape (Ordinal).** : General shape of property

- Reg - Regular
- IR1 - Slightly irregular
- IR2 - Moderately Irregular
- IR3 - Irregular

**A.1.4 Land Contour (Nominal).** : Flatness of the property

- Lvl - Near Flat /Level
- Bnk - Banked - Quick and significant rise from street grade to building
- HLS - Hillside - Significant slope from side to side
- Low - Depression

**A.1.5 Land Slope (Ordinal).** : Slope of property

- Gtl - Gentle slope
- Mod - Moderate Slope

- Sev - Severe Slope

A.1.6 *Utilities (Ordinal)*. : Type of utilities available

- AllPub - All public Utilities (E,G,W, and S)
- NoSewr - Electricity, Gas, and Water (Septic Tank)
- NoSeWa - Electricity and Gas Only
- ELO - Electricity only

A.1.7 *Lot Config (Nominal)*. : Lot configuration

- Inside - Inside lot
- Corner - Corner lot
- CulDSac - Cul-de-sac
- FR2 - Frontage on 2 sides of property
- FR3 - Frontage on 3 sides of property

A.1.8 *Neighborhood (Nominal)*. : Physical locations within Ames city limits (map available)

- Blmngtn - Bloomington Heights
- Blueste - Bluestem
- BrDale - Briardale
- BrkSide - Brookside
- ClearCr - Clear Creek
- CollgCr - College Creek
- Crawfor - Crawford
- Edwards - Edwards
- Gilbert - Gilbert
- Greens - Greens
- GrnHill - Green Hills
- IDOTRR - Iowa DOT and Rail Road
- Landmrk - Landmark
- MeadowV - Meadow Village
- Mitchel - Mitchell
- Names - North Ames
- NoRidge - Northridge
- NPkVill - Northpark Villa
- NridgHt - Northridge Heights
- NWAmes - Northwest Ames
- OldTown - Old Town
- SWISU - South and West of Iowa State University
- Sawyer - Sawyer
- SawyerW - Sawyer West
- Somerst - Somerset
- StoneBr - Stone Brook
- Timber - Timberland
- Veenker - Veenker

A.1.9 *Condition 1 (Nominal)*. : Proximity to various conditions

- Artery - Adjacent to arterial street
- Feedr - Adjacent to feeder street
- Norm - Normal
- RRNn - Within 200 feet of North-South Railroad
- RRAn - Adjacent to North-South Railroad
- PosN - Near positive off-site feature-park, greenbelt, etc.
- PosA - Adjacent to positive off-site feature
- RRNe - Within 200 feet of East-West Railroad
- RRAe - Adjacent to East-West Railroad

A.1.10 *Condition 2 (Nominal)*. : Proximity to various conditions (if more than one is present)

- Artery - Adjacent to arterial street
- Feedr - Adjacent to feeder street
- Norm - Normal
- RRNn - Within 200 feet of North-South Railroad
- RRAn - Adjacent to North-South Railroad
- PosN - Near positive off-site feature-park, greenbelt, etc.
- PosA - Adjacent to positive off-site feature
- RRNe - Within 200 feet of East-West Railroad
- RRAe - Adjacent to East-West Railroad

A.1.11 *Bldg Type (Nominal)*. : Type of dwelling

- 1Fam - Single-family Detached
- 2FmCon - Two-family Conversion; originally built as one-family dwelling
- Duplx - Duplex
- TwnhsE - Townhouse End Unit
- TwnhsI - Townhouse Inside Unit

A.1.12 *Variable: MS Zoning*. MS Zoning (Nominal): Identifies the general zoning classification of the sale.

- A - Agriculture
- C - Commercial
- FV - Floating Village Residential
- I - Industrial
- RH - Residential High Density
- RL - Residential Low Density
- RP - Residential Low Density Park
- RM - Residential Medium Density

A.1.13 *House Style (Nominal)*. : Style of dwelling

- 1Story - One story
- 1.5Fin - One and one-half story: 2nd level finished
- 1.5Unf - One and one-half story: 2nd level unfinished
- 2Story - Two story
- 2.5Fin - Two and one-half story: 2nd level finished
- 2.5Unf - Two and one-half story: 2nd level unfinished
- SFoyer - Split Foyer
- SLvl - Split Level

A.1.14 *Overall Qual (Ordinal)*. : Rates the overall material and finish of the house

- 10 - Very Excellent
- 9 - Excellent
- 8 - Very Good
- 7 - Good
- 6 - Above Average
- 5 - Average
- 4 - Below Average
- 3 - Fair
- 2 - Poor
- 1 - Very Poor

A.1.15 *Overall Cond (Ordinal)*. : Rates the overall condition of the house

- 10 - Very Excellent
- 9 - Excellent

- 8 - Very Good
- 7 - Good
- 6 - Above Average
- 5 - Average
- 4 - Below Average
- 3 - Fair
- 2 - Poor
- 1 - Very Poor

*A.1.16 Roof Style (Nominal).* : Type of roof

- Flat - Flat
- Gable - Gable
- Gambrel - Gabrel (Barn)
- Hip - Hip
- Mansard - Mansard
- Shed - Shed

*A.1.17 Roof Matl (Nominal).* : Roof material

- ClyTile - Clay or Tile
- CompShg - Standard (Composite) Shingle
- Membran - Membrane
- Metal - Metal
- Roll - Roll
- Tar and Grv - Gravel and Tar
- WdShake - Wood Shakes
- WdShngl - Wood Shingles

*A.1.18 Exterior 1 and 2 (Nominal).* : Exterior covering on house

- AsbShng - Asbestos Shingles
- AsphShn - Asphalt Shingles
- BrkComm - Brick Common
- BrkFace - Brick Face
- CBlock - Cinder Block
- CemntBd - Cement Board
- HdBoard - Hard Board
- ImStucc - Imitation Stucco
- MetalSd - Metal Siding
- Other - Other
- Plywood - Plywood
- PreCast - PreCast
- Stone - Stone
- Stucco - Stucco
- VinylSd - Vinyl Siding
- Wd Sdng - Wood Siding
- WdShing - Wood Shingles

*A.1.19 Mas Vnr Type (Nominal).* : Masonry veneer type

- BrkCmn - Brick Common
- BrkFace - Brick Face
- CBlock - Cinder Block
- None - None
- Stone - Stone

*A.1.20 Bsmt Cond, Exter Qual and Exter Cond (Ordinal).* : Evaluates the quality of the material on the exterior

- Ex - Excellent
- Gd - Good
- TA - Average/Typical

- Fa - Fair
- Po - Poor

*A.1.21 Foundation (Nominal).* : Type of foundation

- BrkTil - Brick and Tile
- CBlock - Cinder Block
- PConc - Poured Concrete
- Slab - Slab
- Stone - Stone
- Wood - Wood

*A.1.22 Bsmt Qual (Ordinal).* : Evaluates the height of the basement

- Ex - Excellent (100+ inches)
- Gd - Good (90-99 inches)
- TA - Typical (80-89 inches)
- Fa - Fair (70-79 inches)
- Po - Poor (<70 inches)
- NA - No Basement

*A.1.23 Bsmt Exposure (Ordinal).* : Refers to walkout or garden level walls

- Gd - Good Exposure
- Av - Average Exposure (split levels or foyers typically score average or above)
- Mn - Minimum Exposure
- No - No Exposure
- NA - No Basement

*A.1.24 BsmtFin Type 1 (Ordinal).* : Rating of basement finished area

- GLQ - Good Living Quarters
- ALQ - Average Living Quarters
- BLQ - Below Average Living Quarters
- Rec - Average Rec Room
- LwQ - Low Quality
- Unf - Unfinished
- NA - No Basement

*A.1.25 BsmtFinType 2 (Ordinal).* : Rating of basement finished area (if multiple types)

- GLQ - Good Living Quarters
- ALQ - Average Living Quarters
- BLQ - Below Average Living Quarters
- Rec - Average Rec Room
- LwQ - Low Quality
- Unf - Unfinished
- NA - No Basement

*A.1.26 Heating (Nominal).* : Type of heating

- Floor - Floor Furnace
- GasA - Gas forced warm air furnace
- GasW - Gas hot water or steam heat
- Grav - Gravity furnace
- OthW - Hot water or steam heat other than gas
- Wall - Wall furnace

*A.1.27 Electrical (Ordinal).* : Electrical system

- SBrkr - Standard Circuit Breakers and Romex

- FuseA - Fuse Box over 60 AMP and all Romex wiring (Average)
- FuseF - 60 AMP Fuse Box and mostly Romex wiring (Fair)
- FuseP - 60 AMP Fuse Box and mostly knob and tube wiring (poor)
- Mix - Mixed

A.1.28 *HeatingQC (Ordinal)* : Heating quality and condition

- Ex - Excellent
- Gd - Good
- TA - Average/Typical
- Fa - Fair
- Po - Poor

A.1.29 *Central Air (Nominal)* : Central air conditioning

- N - No
- Y - Yes

A.1.30 *KitchenQual (Ordinal)* : Kitchen quality

- Ex - Excellent
- Gd - Good
- TA - Typical/Average
- Fa - Fair
- Po - Poor

## LIST OF FIGURES

1	Code - Null Checks	13
2	Graph - Missing Values	13
3	Code - Numerical Analysis	14
4	Graph - Sale Price and Overall Quality	14
5	Graph - Ground Live Area and Year Built	15
6	Code - Categorical Analysis	15
7	Graph - Neighborhood and Sale Type	16
8	Code - Correlations	16
9	Graph - Correlations with Sale Price	17
10	Graph - Overall Quality and Ground Live Area	17
11	Graph - Garage Cars and Garage Area	18
12	Graph - Sale Price skewness	18
13	Code - Outlier Analysis	19
14	Graph - Outliers using Cooks distance	19
15	Graph - Garage Live Area Outliers	19
16	Graph - Garage Area Outliers	20
17	Code - Delete Outliers	20
18	Code - factorize and one-hot encoding	20
19	Code - SVM Algorithm	20
20	Code - Random Forest Algorithm	21
21	Graph - Random Forest Feature Ranking	22
22	Code - Lasso Algorithm	22
23	Code - Ridge Algorithm	23
24	Graph - Ridge Top 10 Positive Features	24
25	Graph - Ridge Top 10 Negative Features	25
26	Code - XGBoost Algorithm	26
27	Graph - XGBoost Feature Importance	27

```

# python code - check for null values
train = pd.read_csv('../data/train.csv')
test = pd.read_csv('../data/test.csv')

#combine the data sets
alldata = train.append(test)
na = alldata.isnull().sum()
    .sort_values(ascending=False)

```

Figure 1: Code - Null Checks

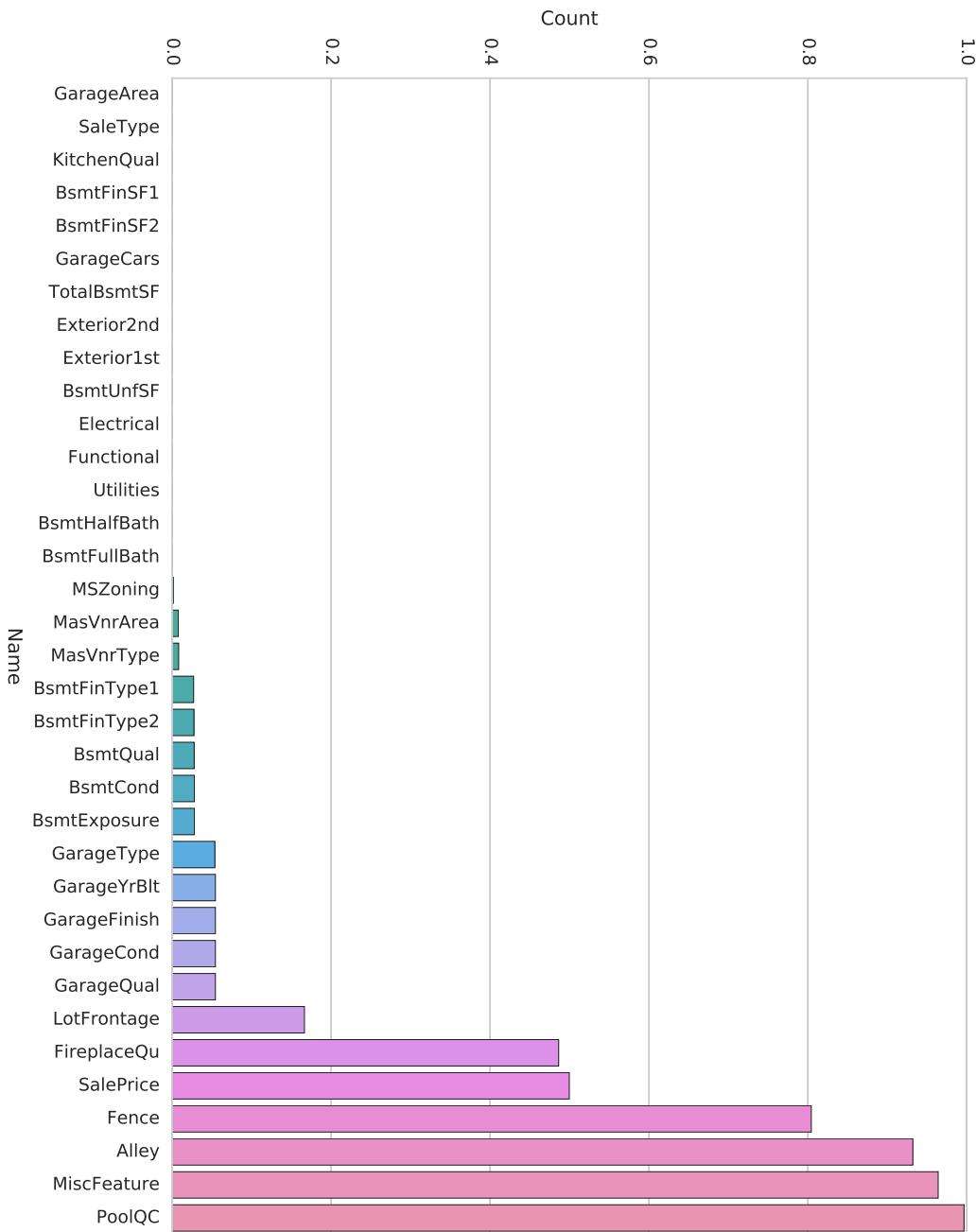


Figure 2: Graph - Missing Values

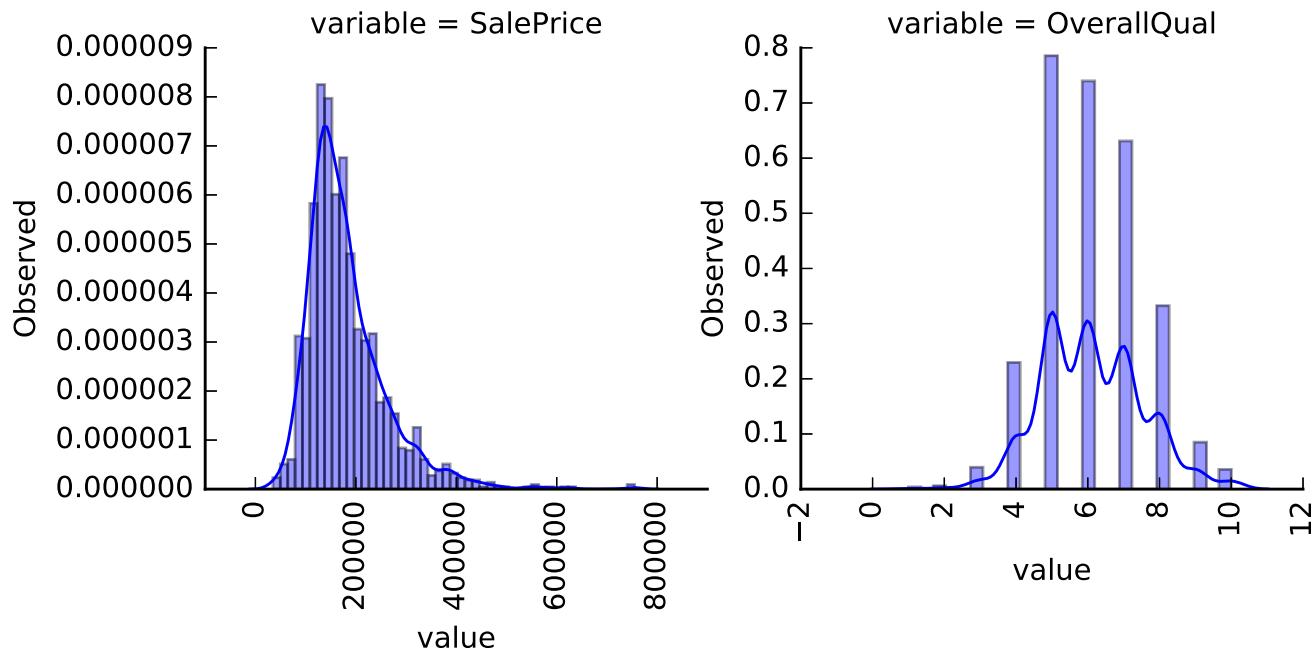
```

# python code - analyze numeric variables
numerical_features = [f for f in train.columns
if train.dtypes[f] != object]

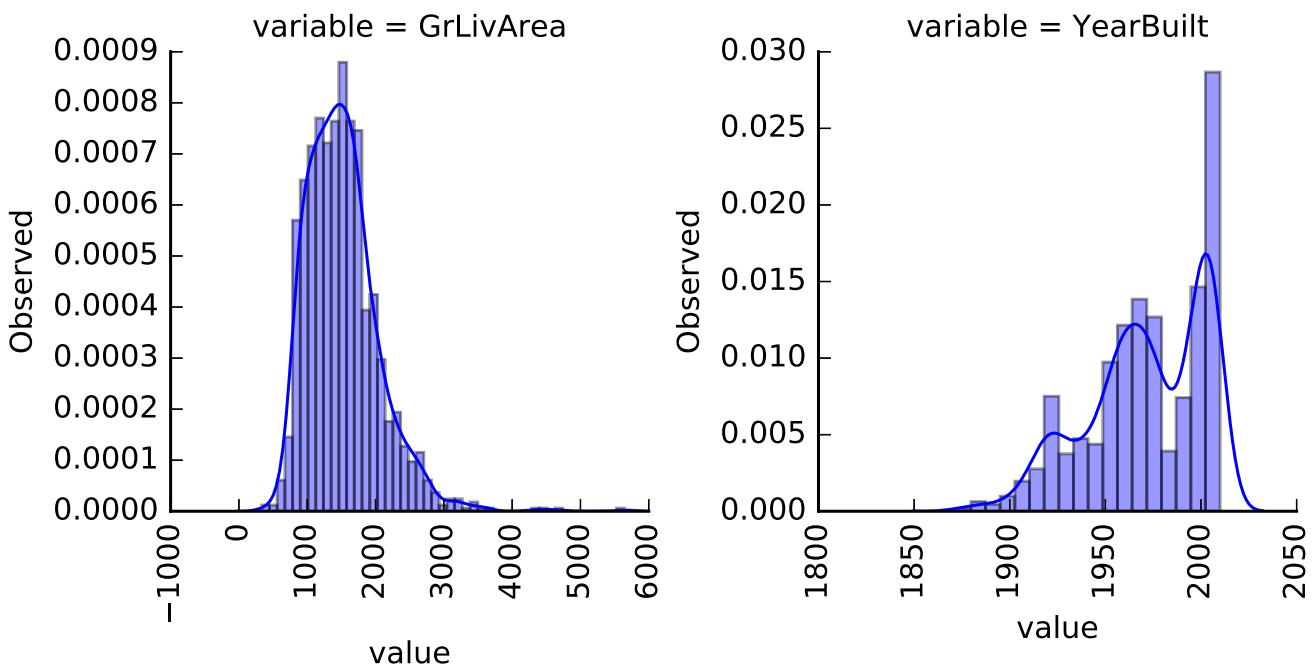
nd = pd.melt(train, value_vars = numerical_features)
plt.figure(figsize = (5,3))
plot = sns.FacetGrid (nd, col=variable, col_wrap=4,
                     sharex=False, sharey = False)
plot = plot.map(sns.distplot, value)

```

**Figure 3: Code - Numerical Analysis**



**Figure 4: Graph - Sale Price and Overall Quality**



**Figure 5: Graph - Ground Live Area and Year Built**

```
# python code - analyze numeric variables
cat_features = [f for f in train.columns
if train.dtypes[f] == object]
print(cat_features)

plt.figure(figsize = (5,3))

p = pd.melt(train, id_vars=SalePrice,
            value_vars=cat_features)

g = sns.FacetGrid (p, col=variable, col_wrap=4,
sharex=False, sharey=False, size=5)

g = g.map(barplot, value,SalePrice)
```

**Figure 6: Code - Categorical Analysis**

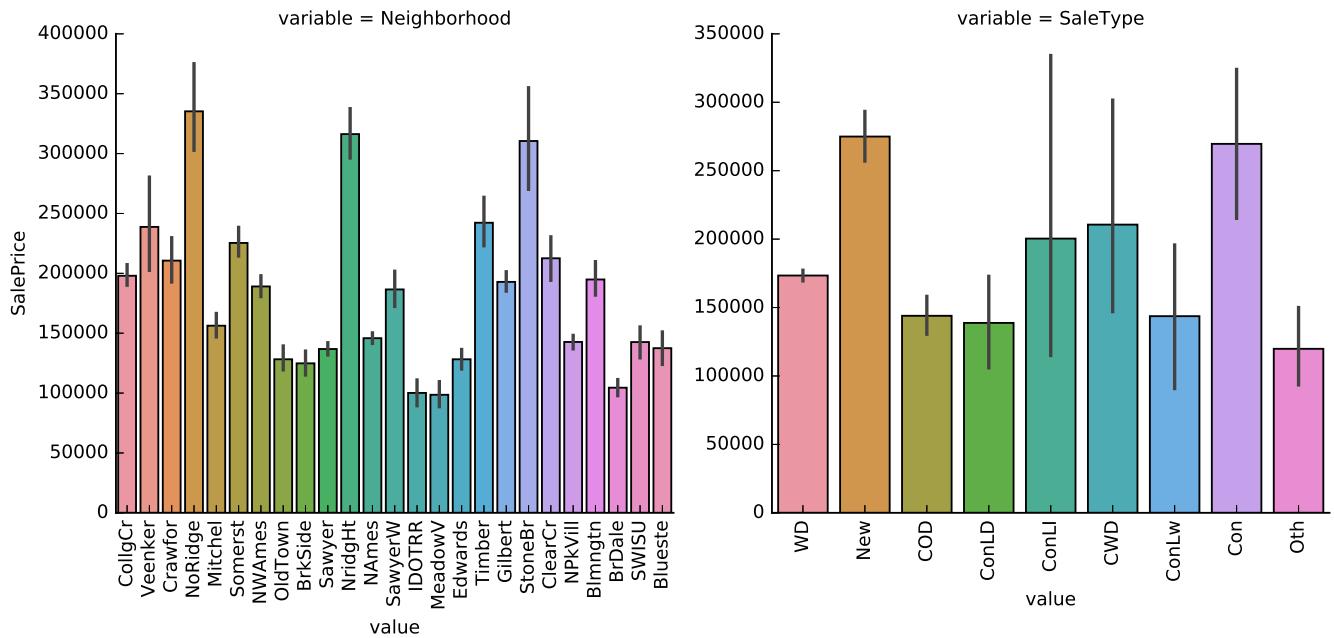


Figure 7: Graph - Neighborhood and Sale Type

```
# python code
corr = alldata[numerical_features].corr()
mask = np.zeros_like(corr)
mask[np.triu_indices_from(mask)] = True
plt.figure(figsize = (15,8))
sns_plot = sns.heatmap(corr, cmap=YlGnBu,
                      linewidths=.5, mask=mask, vmax=.3)
```

Figure 8: Code - Correlations

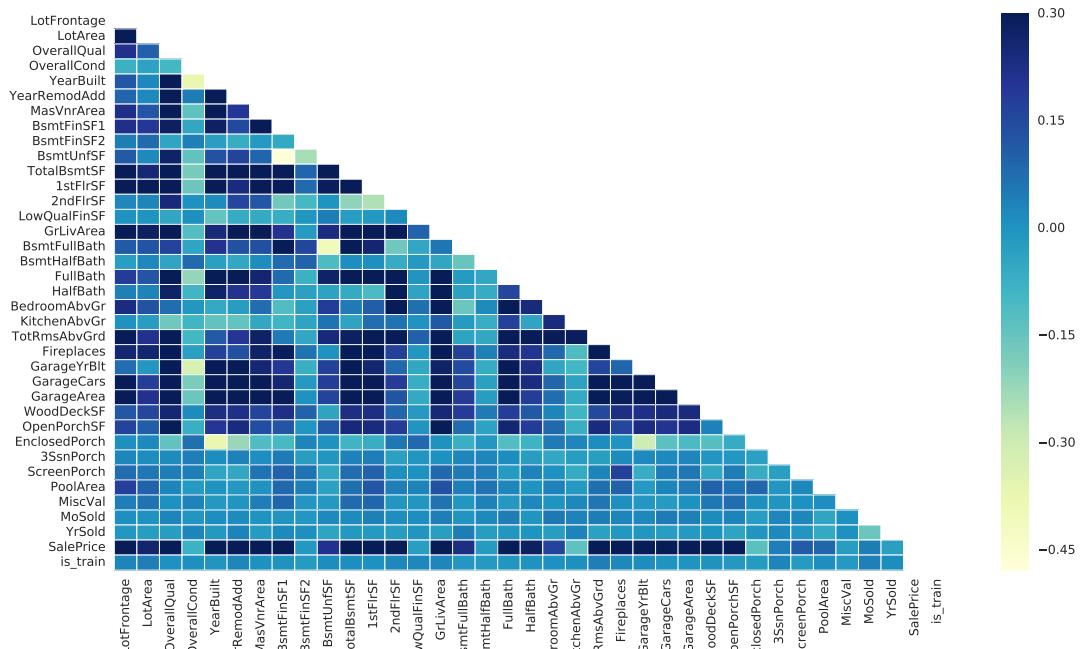


Figure 9: Graph - Correlations with Sale Price

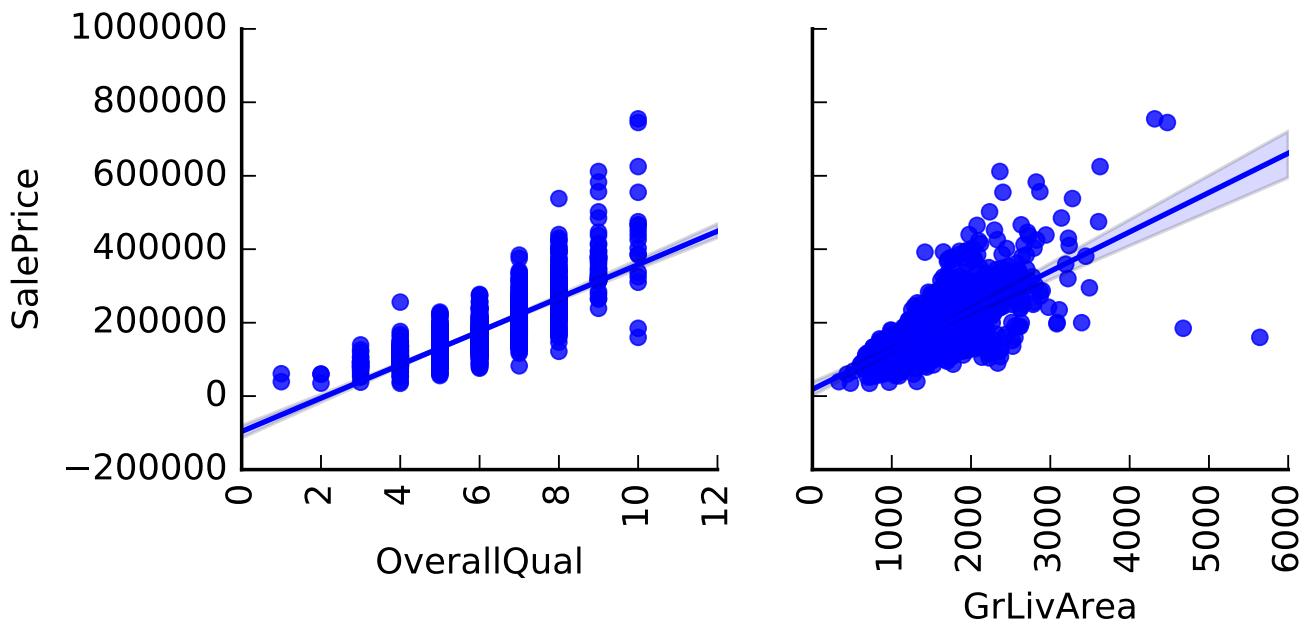
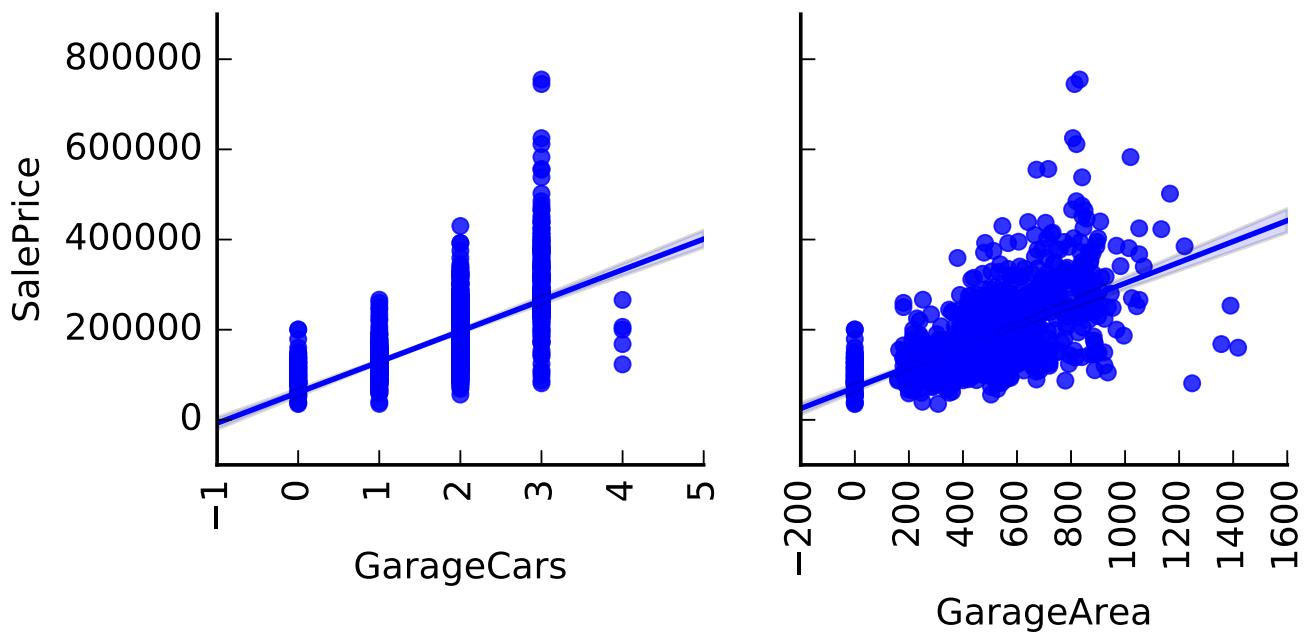
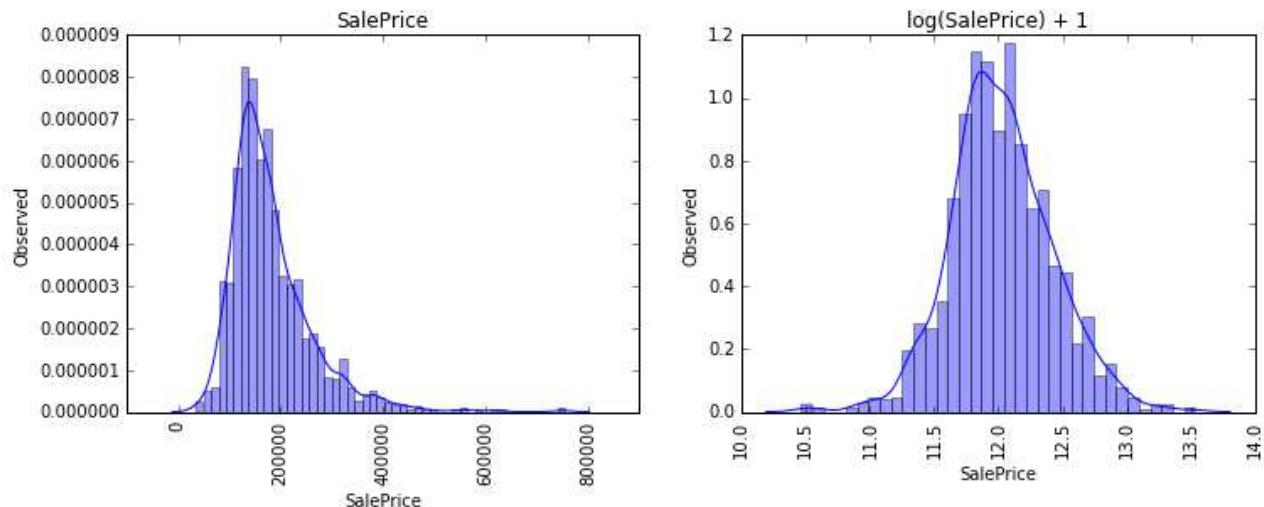


Figure 10: Graph - Overall Quality and Ground Live Area



**Figure 11: Graph - Garage Cars and Garage Area**



**Figure 12: Graph - Sale Price skewness**

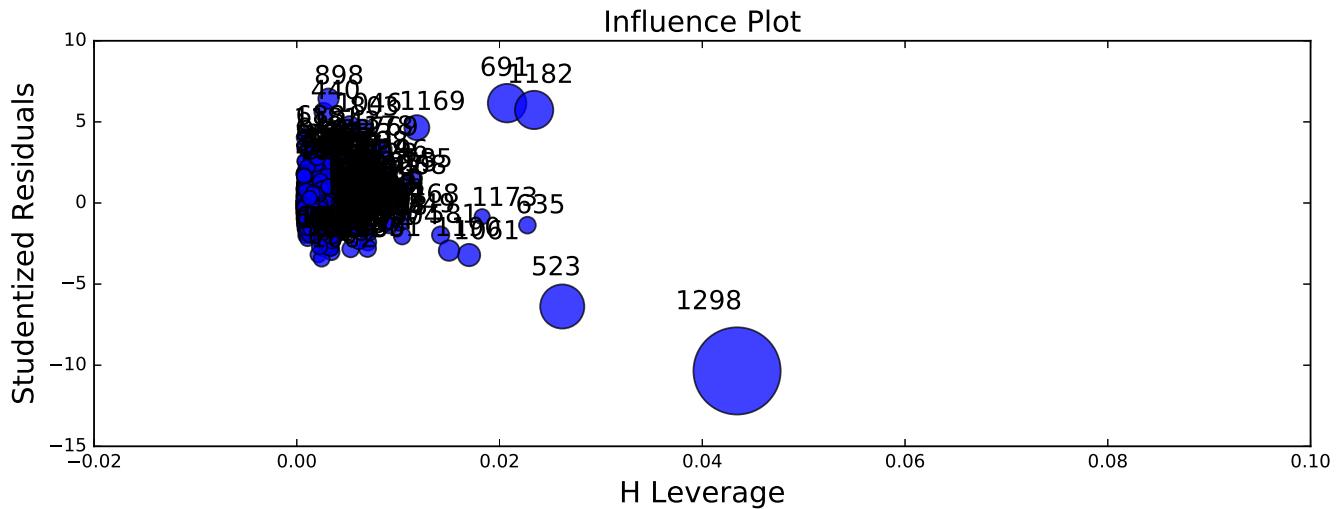
```

# python code - outlier analysis
import statsmodels.api as sm
from statsmodels.formula.api import ols

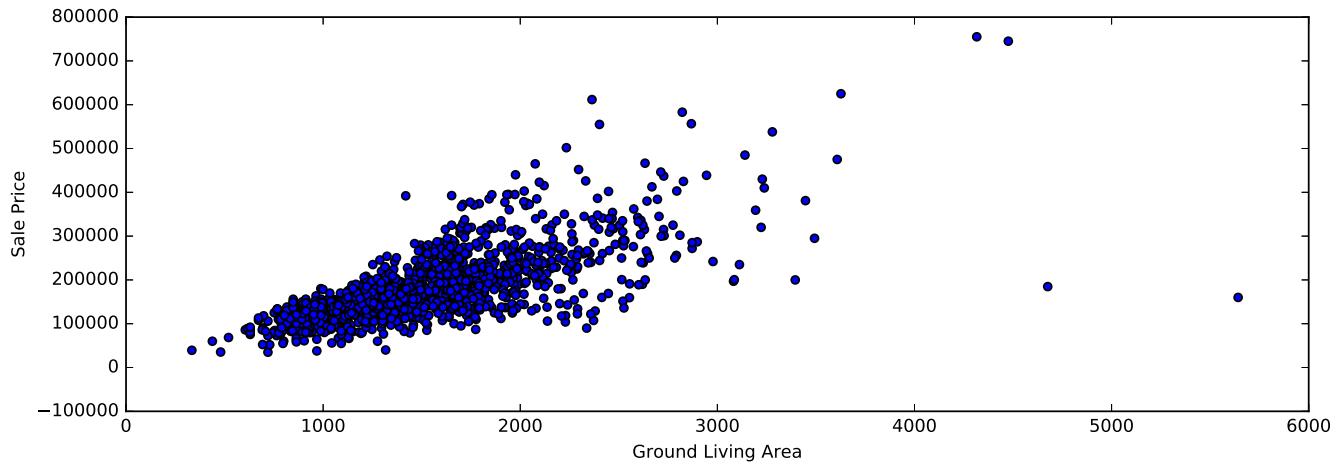
model = ols(formula = SalePrice ~
GrLivArea + GarageArea, data=train)
fitted = model.fit()
plot = sm.graphics.influence_plot(fitted,
criterion=cooks)

```

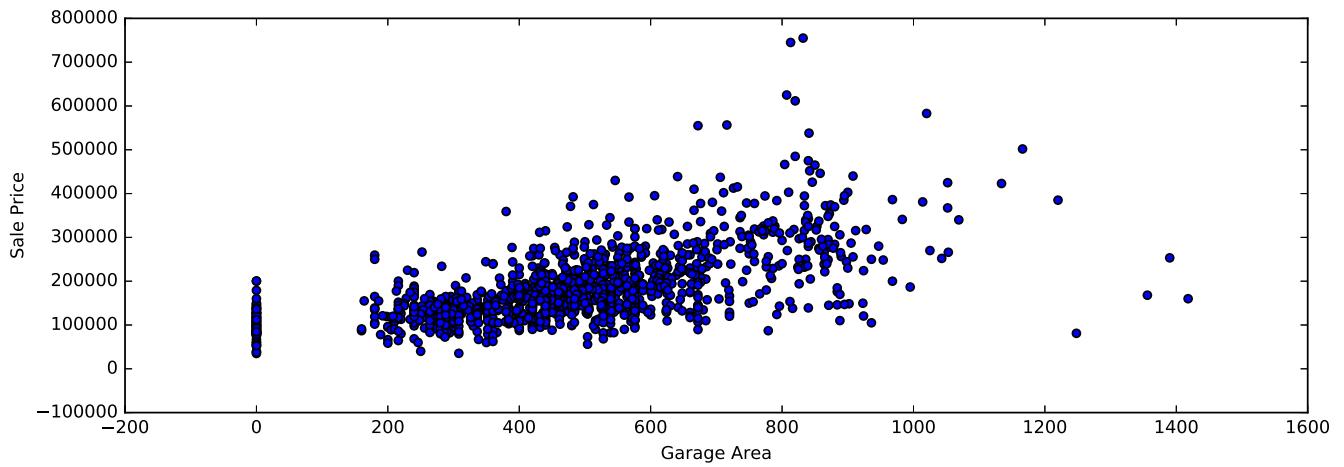
**Figure 13: Code - Outlier Analysis**



**Figure 14: Graph - Outliers using Cooks distance**



**Figure 15: Graph - Garage Live Area Outliers**



**Figure 16: Graph - Garage Area Outliers**

```
# python code - remove outlier rows
# fix all extreme outliers based on outlier analysis
# 8 rows will be deleted
train = train[train.GrLivArea <= 4000]
train = train[train.GarageArea <= 1200]
```

**Figure 17: Code - Delete Outliers**

```
# python code - factorize and one-hot
def get_one_hot(df, col_name, fill_val):
    if fill_val is not None:
        df[col_name].fillna(fill_val, inplace=True)

    dummies = pd.get_dummies(df[col_name], prefix=_ + col_name)
    df = df.join(dummies)
    df = df.drop([col_name], axis=1)
    return df
#end def
```

**Figure 18: Code - factorize and one-hot encoding**

```
# python code - SVM algorithm
from sklearn.svm import SVR

_svm_algo = SVR(kernel = rbf, C=1e3, gamma=1e-8)
_svm_algo.fit(train, target_vector)

y_train = target_vector
y_train_pred = _svm_algo.predict(train)

#root mean squared error (RMSE)
rmse_train = np.sqrt(rmse(y_train,y_train_pred))

y_test_pred = _svm_algo.predict(test)
```

**Figure 19: Code - SVM Algorithm**

```

# python code - random forest algorithm
from sklearn.ensemble import RandomForestRegressor

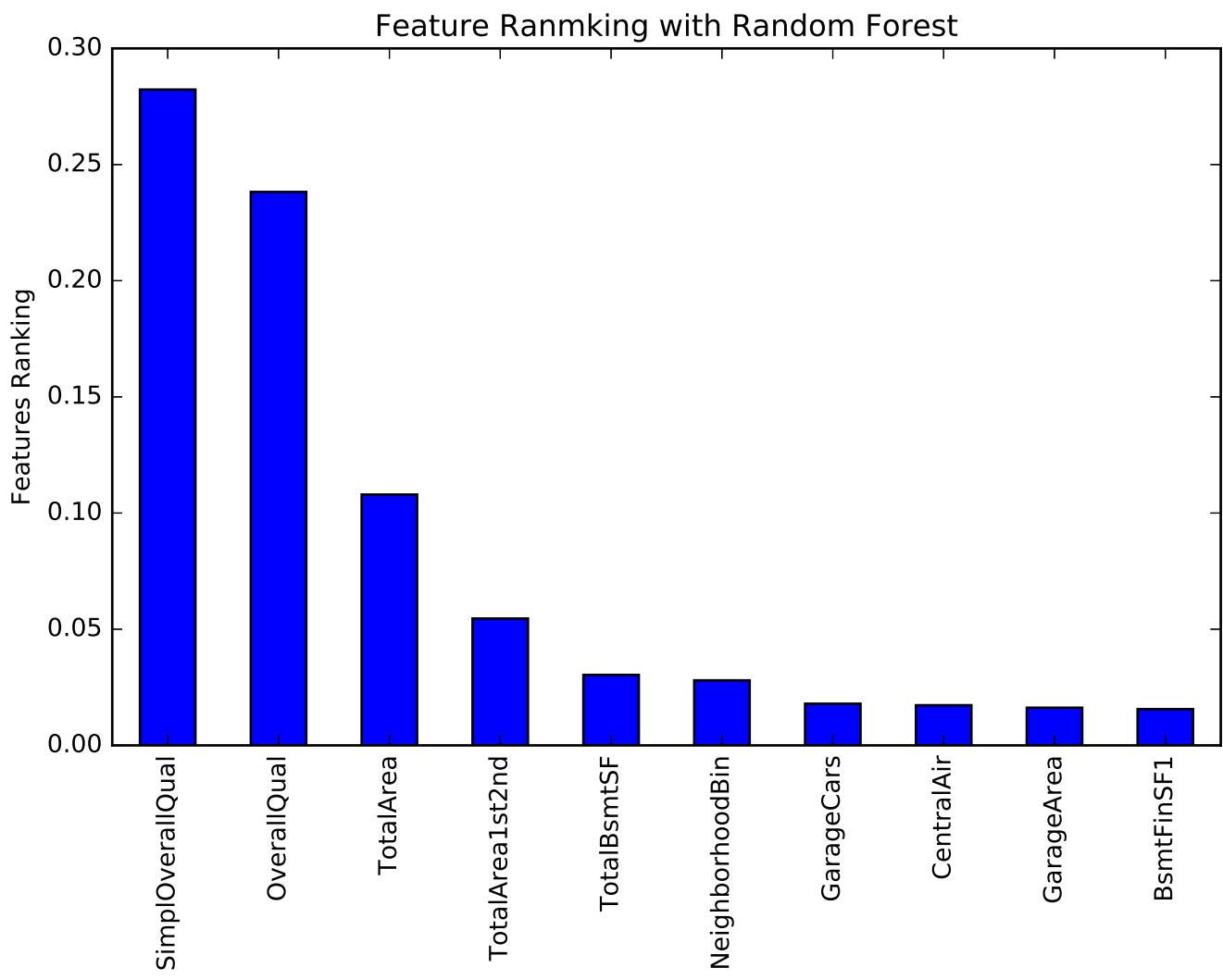
_algo = RandomForestRegressor(n_estimators=100,
oob_score=True, random_state=123456)
model = _algo.fit(train, target_vector)

feat_imp = pd.Series(_algo.feature_importances_,
train.columns).sort_values(ascending=False)
feat_imp[:10].plot(kind=bar,
title=Feature Ranmkingt)
y_train = target_vector
y_train_pred = _algo.predict(train)

#root mean squared error (RMSE)
rmse_train = np.sqrt(rmse(y_train,y_train_pred))
y_test_pred = _algo.predict(test)

```

**Figure 20: Code - Random Forest Algorithm**



**Figure 21: Graph - Random Forest Feature Ranking**

```
# python code - lasso algorithm
from sklearn.linear_model import Lasso

_best_alpha = 0.0001
_lasso_algo = Lasso(alpha = _best_alpha,
                     max_iter = 50000)
model = _lasso_algo.fit(train, target_vector)

y_train = target_vector
y_train_pred = _algo.predict(train)

#root mean squared error (RMSE)
rmse_train = np.sqrt(rmse(y_train,y_train_pred))
y_test_pred = _lasso_algo.predict(test)
```

**Figure 22: Code - Lasso Algorithm**

```
# python code - ridge algorithm
from sklearn.linear_model import Ridge
#found this best alpha value through cross-validation
_best_alpha = 0.00099
_ridge_algo = Ridge(alpha = _best_alpha,
                     normalize = True)
_ridge_algo.fit(train, target_vector)

y_train = target_vector
y_train_pred = _ridge_algo.predict(train)

#root mean squared error (RMSE)
rmse_train = np.sqrt(rmse(y_train,y_train_pred))

y_test_pred = _ridge_algo.predict(test)
```

**Figure 23: Code - Ridge Algorithm**

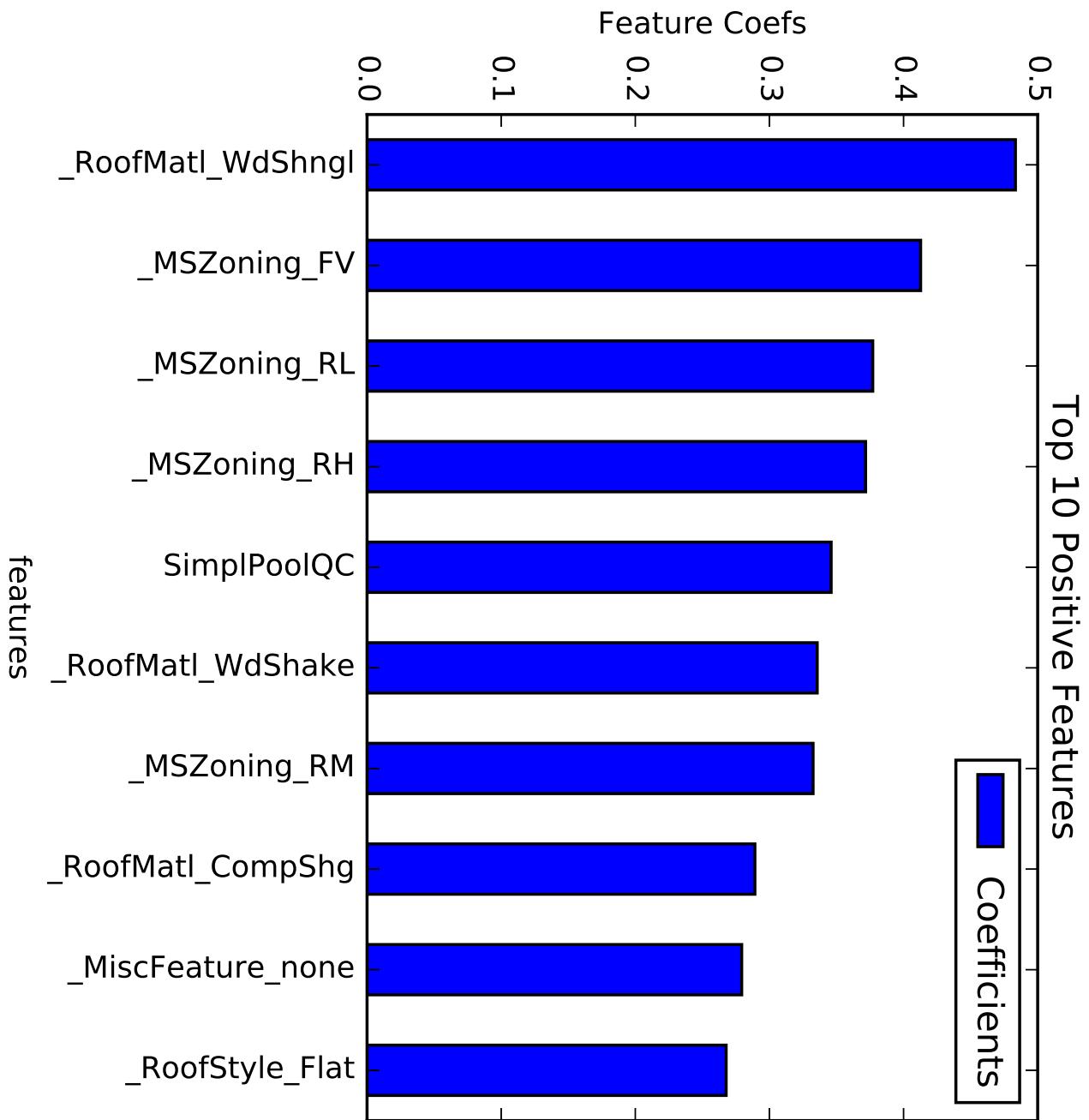


Figure 24: Graph - Ridge Top 10 Positive Features

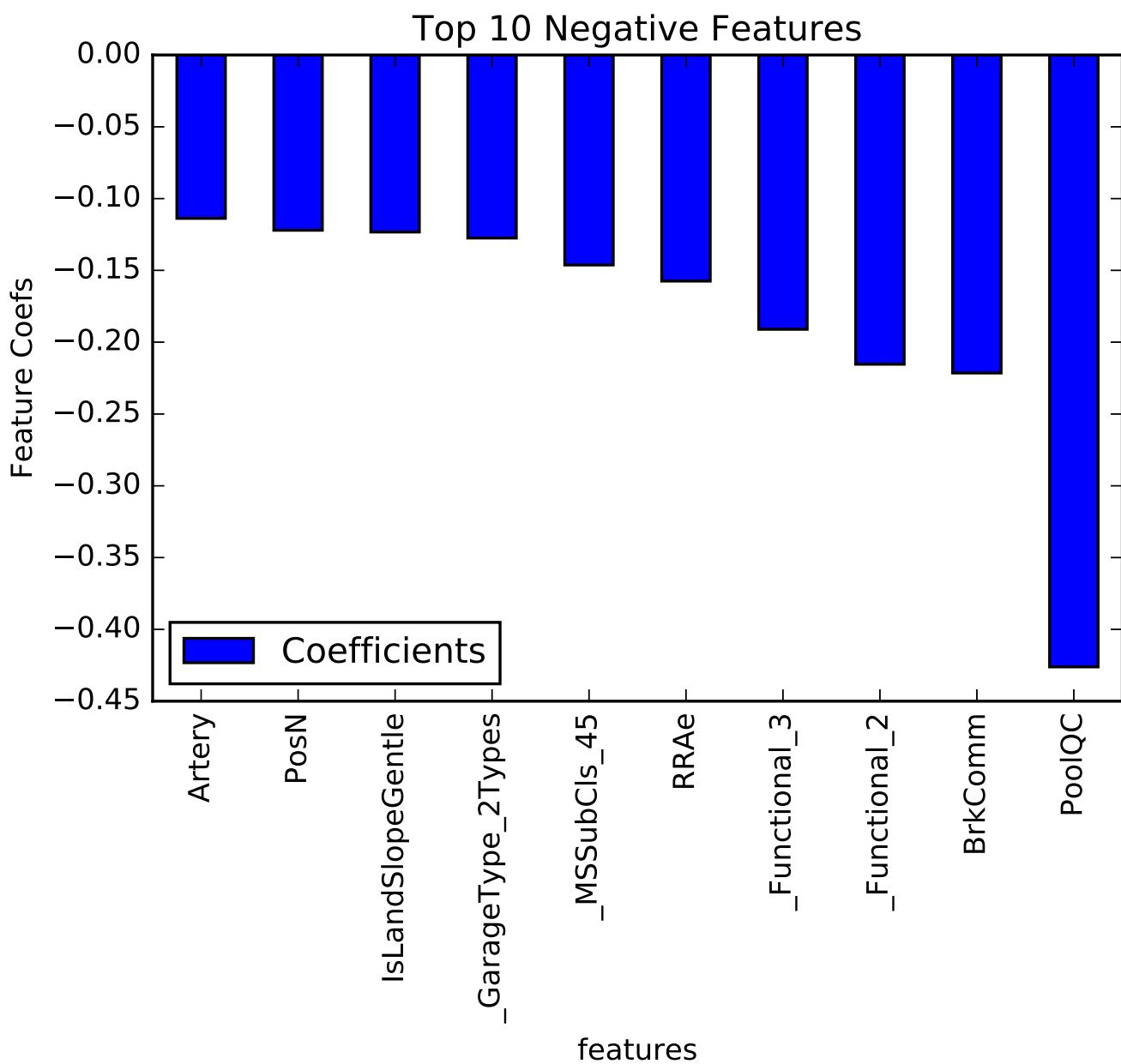


Figure 25: Graph - Ridge Top 10 Negative Features

```

# python code - XGBoost algorithm
import xgboost as xgb

_xgb_algo = xgb.XGBRegressor(
    colsample_bytree=0.8,
    colsample_bylevel = 0.8,
    gamma=0.01, learning_rate=0.05,
    max_depth=5, min_child_weight=1.5,
    n_estimators=6000, reg_alpha=0.5,
    reg_lambda=0.5, subsample=0.7,
    seed=42, silent=1)

_xgb_algo.fit(train, target_vector)

y_train = target_vector
y_train_pred = _xgb_algo.predict(train)

#root mean squared error (RMSE)
rmse_train = np.sqrt(rmse(y_train,y_train_pred))
y_test_pred = _xgb_algo.predict(test)

```

**Figure 26: Code - XGBoost Algorithm**

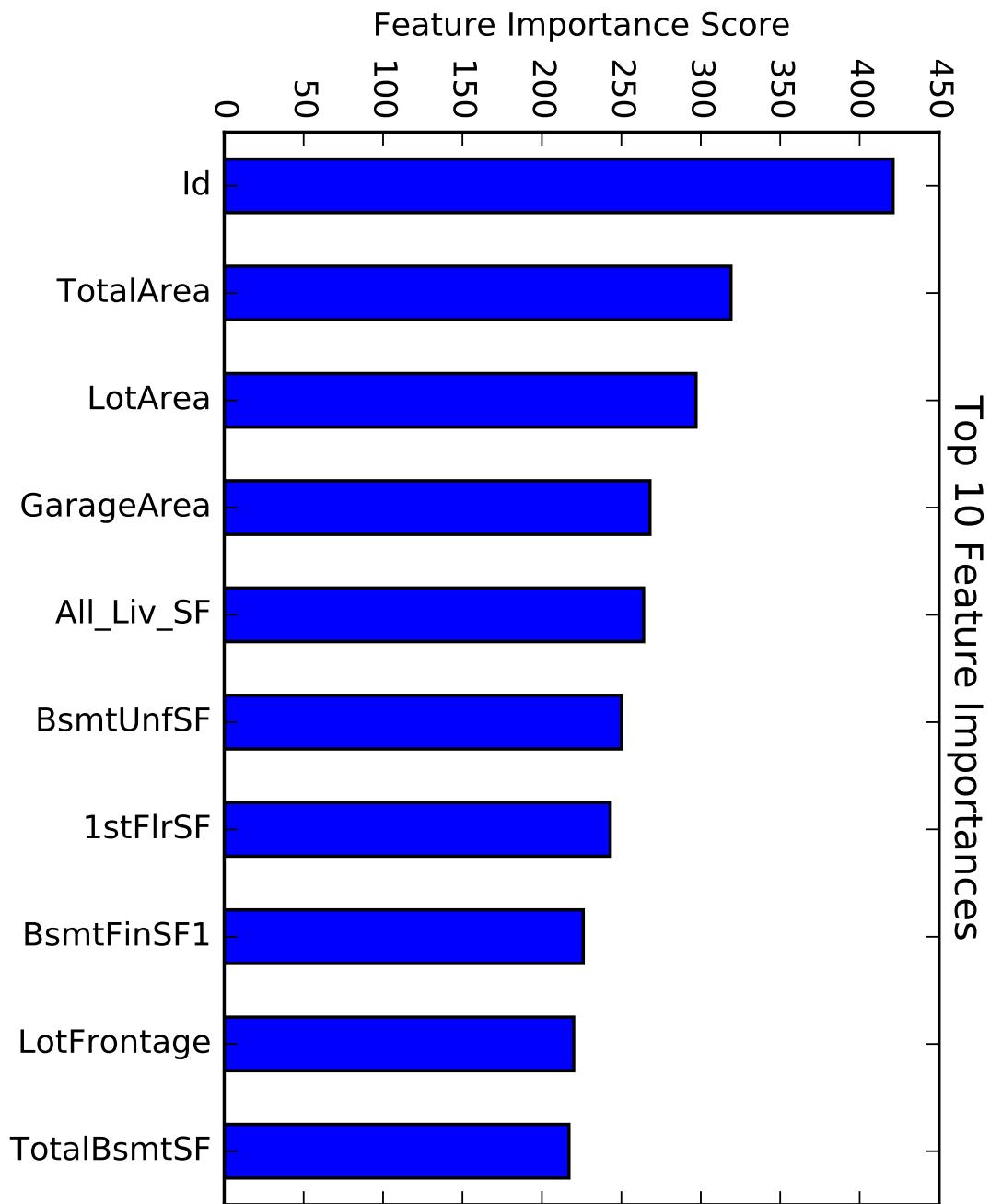


Figure 27: Graph - XGBoost Feature Importance

```
bibtext report
```

```
=====
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtext _ label error
```

```
=====
```

```
bibtext space label error
```

```
=====
```

```
bibtext comma label error
```

```
=====
```

```
latex report
```

```
[2017-12-12 20.00.28] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 1.1s.
./README.yml
44:69    error    trailing spaces  (trailing-spaces)
45:62    error    trailing spaces  (trailing-spaces)
46:53    error    trailing spaces  (trailing-spaces)
47:58    error    trailing spaces  (trailing-spaces)
48:62    error    trailing spaces  (trailing-spaces)
49:62    error    trailing spaces  (trailing-spaces)
50:63    error    trailing spaces  (trailing-spaces)
51:64    error    trailing spaces  (trailing-spaces)
52:66    error    trailing spaces  (trailing-spaces)
53:65    error    trailing spaces  (trailing-spaces)
54:62    error    trailing spaces  (trailing-spaces)
55:59    error    trailing spaces  (trailing-spaces)
56:44    error    trailing spaces  (trailing-spaces)
```

```
=====
```

## Compliance Report

---

```
name: Cheruvu, Murali
hid: 306
paper1: 100%; 10/26/2017
paper2: 100%; 11/4/2017
project: 98%; 12/10/2017
```

```
yamlcheck
```

---

```
wordcount
```

---

```
27
wc 306 project 27 8955 report.tex
wc 306 project 27 9232 report.pdf
wc 306 project 27 340 report.bib
```

```
find "
```

---

```
passed: True
```

```
find footnote
```

---

```
passed: True
```

```
find input{format/i523}
```

---

```
4: \input{format/i523}
```

```
passed: True
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

76: First part of the analysis was to check for any missing values in  
 the training and testing datasets as shown in Figure  
 $(\text{\ref{c:check-nulls}})$ . Using the bar plot shown in Figure  
 $(\text{\ref{fig:missing-values}})$ , we have identified that there are 5  
 variables: {\em pool quality}, {\em miscellaneous features}, {\em alley},  
 {\em fence} and {\em fire place quality}, having the most  
 missing data.  
 78: \begin{figure}[htb]  
 89: \caption{Code - Null Checks}\label{c:check-nulls}  
 92: \begin{figure}[htb]  
 94: \includegraphics[width=1.0\columnwidth]{images/missing\_values}  
 95: \caption{Graph - Missing Values} \label{fig:missing-values}  
 107: There are 37 numerical variables after excluding the {\em Id}  
 variable. List of numerical variables are: MS-Sub-Class, Lot-  
 Frontage, Lot-Area, Overall-Qual, Overall-Cond, Year-Built, Year-  
 Remod-Add, Mas-Vnr-Area, Bsmt-Fin-SF1, Bsmt-Fin-SF2, Bsmt-Unf-SF,  
 Total-Bsmt-SF, 1st-Flr-SF, 2nd-Flr-SF, Low-Qual-Fin-SF, Gr-Liv-  
 Area, Bsmt-Full-Bath, Bsmt-Half-Bath, Full-Bath, Half-Bath,  
 Bedroom-Abv-Gr, Kitchen-Abv-Gr, Tot-Rms-Abv-Grd, Fireplaces,  
 Garage-Yr-Blt, Garage-Cars, Garage-Area, WoodDeck-SF, Open-Porch-  
 SF, Enclosed-Porch, 3Ssn-Porch, Screen-Porch, Pool-Area, Misc-  
 Val, Mo-Sold, Yr-Sold and Sale-Price. {\em Interval} and {\em  
 ratio} are the two types of numerical variables we encounter in  
 most of the data analytical applications. Statistical aspects of  
 the numerical univariate analysis include: count, minimum,  
 maximum, mean, median, mode, quantile, range, variance, standard  
 deviation and skewness. Data visualization techniques, such as  
 histogram, box plot and scatter plot are used to analyze the  
 numerical variables. We have shown {\em sale price}, {\em overall  
 quality}, {\em garage live area} and {\em year built}, in the  
 Figures (\text{\ref{fig:num-feature-1}}) and (\text{\ref{fig:num\_features\_2}})  
 as a few sample plots from the numerical analysis. Corresponding  
 code snippet is shown in Figure (\text{\ref{c:analyze-numeric}}).  
 109: \begin{figure}[htb]  
 121: \caption{Code - Numerical Analysis}\label{c:analyze-numeric}  
 125: \begin{figure}[htb]  
 127: \includegraphics[width=1.0\columnwidth]{images/num\_features\_1}  
 128: \caption{Graph - Sale Price and Overall Quality}\label{fig:num-  
 feature-1}  
 131: \begin{figure}[htb]  
 133: \includegraphics[width=1.0\columnwidth]{images/num\_features\_2}  
 134: \caption{Graph - Ground Live Area and Year Built}  
 \label{fig:num\_features\_2}  
 138: There are 43 categorical variables in the combined dataset. List  
 of categorical variables are: MS-Zoning, Street, Alley, Lot-

Shape, Land-Contour, Utilities, Lot-Config, Land-Slope, Neighborhood, Condition1, Condition2, Bldg-Type, House-Style, Roof-Style, Roof-Matl, Exterior-1st, Exterior-2nd, Mas-Vnr-Type, Exter-Qual, Exter-Cond, Foundation, Bsmt-Qual, Bsmt-Cond, Bsmt-Exposure, Bsmt-Fin-Type1, Bsmt-Fin-Type2, Heating, Heating-QC, Central-Air, Electrical, Kitchen-Qual, Functional, Fireplace-Qu, Garage-Type, Garage-Finish, Garage-Qual, Garage-Cond, Paved-Drive, Pool-QC, Fence, Misc-Feature, Sale-Type and Sale-Condition. We have analyzed all categorical variables and found the ways to fill the missing values. We has also evaluated proper approaches to convert them into numerical factors. Bar and pie charts are used to visualize categorical variables. Later on in the feature engineering section, we will go through more details on numerical factors. Categorical variable factors and the corresponding code snippet for {\em neighborhood} and {\em sale type} are shown in Figure (\ref{c:analyze-cat}) and Figures (\ref{fig:cat\_features\_1}).

```

140: \begin{figure}[htb]
157: \caption{Code - Categorical Analysis} \label{c:analyze-cat}
160: \begin{figure}[htb]
162: \includegraphics[width=1.0\columnwidth]{images/cat_features_1}
163: \caption{Graph - Neighborhood and Sale Type}
   \label{fig:cat_features_1}
167: {\em Numpy} package offers correlations functionality to analyze the variables that are positively or negatively correlated with the {\em sale price} and also analyze any interdependencies among the variables. Figure (\ref{c:cor}) and (\ref{fig:correlations}) shows the code snippet and the correlations plot. From that we can list the top 10 features those are strongly correlated with the target variable - {\em sale price}. We can visualize a few pair-wise correlation graphs with sale price for further detailed analysis. Figures (\ref{fig:pair-wise-correlations}) and (\ref{fig:pair-wise-correlations-2}) show how {\em overall quality}, {\em ground live area}, {\em garage cars} and {\em garage area} are positively correlated with {\em sale price}.
169: \begin{figure}[htb]
179: \caption{Code - Correlations} \label{c:cor}
182: \begin{figure}[htb]
184: \includegraphics[width=1.0\columnwidth]{images/correlations}
185: \caption{Graph - Correlations with Sale Price}
   \label{fig:correlations}
188: \begin{figure}[htb]
190: \includegraphics[width=1.0\columnwidth]{images/pair_wise_correlations_1}
191: \caption{Graph - Overall Quality and Ground Live Area}
   \label{fig:pair-wise-correlations}

```

```

194: \begin{figure}[htb]
196: \includegraphics[width=1.0\columnwidth]{images/pair_wise_correlations_2}
197: \caption{Graph - Garage Cars and Garage Area} \label{fig:pair-wise-correlations-2}
214: From the numerical analysis, we have identified that there are a few numerical variables need further analysis to identify the skewed data. We did not find any key variables those have skewed more than 75\%. However, we wanted to replace the {\em sale price} with corresponding logarithmic value for the predictive models and later convert it back to the exponential value before saving the predictions. Figure (\ref{fig:sale-price-skew}) shows the {\em sale price}, before and after applying the logarithmic value.
216: \begin{figure}[htb]
218: \includegraphics[width=1.0\columnwidth]{images/sale_price_skew}
219: \caption{Graph - Sale Price skewness} \label{fig:sale-price-skew}
224: Continuing with exploratory analysis, we have analyzed the outliers using {\em Cooks distance}. Cooks distance is a measure calculated from a regression model to find out the influence exerted by each observation (row) on the predictions. As a practice, those observations that have a Cooks distance greater than 4 times the mean value may be classified as an outlier. Outlier detection can be done using univariate and multivariate analysis. In univariate model, the outliers are those observations that are present outside of  $1.5 * \text{IQR}$ , where IQR ({\em Inter Quartile Range}) is the difference between 75th and 25th quartiles. Analyzing outliers in any observations based on single variable may lead to incorrect inferences. Cooks distance generalizes the outlier analysis using multivariate approach \cite{1}. Figure (\ref{c:code-outliers}) is the code implementing Cooks distance to find the outliers from training dataset and Figure (\ref{fig:outliers}) shows the scatter plot with outliers being marked as bubbles. The bigger the bubbles, the bigger outlier deviations from the mean value. We have further analyzed two key variables - {\em ground live area} and {\em garage area} that are in high correlation with the {\em sale price}. From the scatter plot shown in Figure (\ref{fig:gr-liv-area-outlier}), we can see that {\em garage live area} has 4 outliers with values greater than 4,000 sq ft. We can also visualize 4 outliers in {\em garage area} scatter plot with values greater than 1,200 sq ft. as shown in Figure (\ref{fig:garage-area-outlier}). We have removed the 8 outlier rows related to these two variables from the training dataset, the corresponding code snippet shown in Figure (\ref{c:code-del-outliers}).
226: \begin{figure}[htb]

```

```

238: \caption{Code - Outlier Analysis} \label{c:code-outliers}
241: \begin{figure}[htb]
243: \includegraphics[width=1.0\columnwidth]{images/outliers}
244: \caption{Graph - Outliers using Cooks distance}
    \label{fig:outliers}
247: \begin{figure}[htb]
249: \includegraphics[width=1.0\columnwidth]{images/gr_liv_area_outlie
r}
250: \caption{Graph - Garage Live Area Outliers} \label{fig:gr-liv-
area-outlier}
253: \begin{figure}[htb]
255: \includegraphics[width=1.0\columnwidth]{images/garage_area_outlie
r}
256: \caption{Graph - Garage Area Outliers} \label{fig:garage-area-
outlier}
259: \begin{figure}[htb]
267: \caption{Code - Delete Outliers} \label{c:code-del-outliers}
287: One-hot encoding converts the category variable into many binary
vectors, one new numeric variable for each value in the category.
Assume that we have a categorical variable called signal-light
with three possible values: green, yellow and red. We will need
to convert these values into numeric - green = 1, yellow = 2 and
red = 3. When we apply one-hot encoding on this variable,
basically we are creating three new categorical variables -
signal-light-green, signal-light-yellow and signal-light-red
along with the original variable - signal-light, each is pretty
much a binary vector having 1s for all the corresponding values;
otherwise 0s. With hot-encoding, we are basically increasing
dimensions in the model. After extensive feature engineering
applied on the housing dataset, we have added {\em 228} new
features (variables). Figure (\ref{c:code-one-hot}) shows the
python methods to factorize categorical variables using one-hot
encoding techniques.
289: \begin{figure}[htb]
303: \caption{Code - factorize and one-hot encoding} \label{c:code-
one-hot}
353: Support Vector Machine (SVM) algorithms can be used to solve
classification and regression problems. SVM creates larger
margins between categories of data so that they are linearly
separable. SVM regression relies on kernel functions for modeling
the data. SVM handles non-linearly separable data, mainly for
regression problems, using kernel functions, such as polynomial,
radial basis function (RBF) and sigmoid, to project the data onto
a hyperplane. Figure (\ref{c:svm}) shows the python
implementation for {\em sale price} predictions of the housing
test dataset.

```

```

355: \begin{figure}[htb]
371: \caption{Code - SVM Algorithm} \label{c:svm}
378: Random Forest is an advanced machine learning algorithm for
predictive analytics. Random Forest ensembles multiple decision
trees to create an additive learning model from the sequence of
base models created by each decision tree that worked on a sub-
sample dataset. Random Forest models are suitable to handle
tabular datasets with hundreds of numeric and categorical
features. Along with missing values, non-linear relations between
features and the target, will be handled well by random forest
algorithms. With proper tuning of hyper-parameters of the random
forest algorithm, it can perform well with decent accuracy in the
predictions without overfitting the model. Unlike similar
regression models, it does not offer feature coefficient
information but it provides {\em feature ranking} functionality
very nicely. Figure (\ref{c:rf}) shows the random forest
algorithm details for the {\em sale price} predictions
implemented using {\em sklearn} package and the Figure
(\ref{fig:random-feature-ranking}) shows the top 10 important
features selected by random forest to model the predictions.
380: \begin{figure}[htb]
400: \caption{Code - Random Forest Algorithm} \label{c:rf}
404: \begin{figure}[htb]
406: \includegraphics[width=1.0\columnwidth]{images/random_forest_feat-
ure_ranking}
407: \caption{Graph - Random Forest Feature Ranking}
\label{fig:random-feature-ranking}
414: Lasso is a regression model that uses shrinkage to bring data
points towards the center, similar to the mean value of all the
data points. Lasso stands for Least Absolute Shrinkage and
Selection Operator. It is a regularized linear model with penalty
term {\em lambda} to minimize the error. Parameter penalization
controls overfitting the input data by shrinking variable
coefficients to 0. Essentially this makes the variables no effect
in the model, hence reduces the dimensions. Figure
(\ref{c:lasso}) shows the lasso algorithm implementation for {\em
sale price} predictions in python.
416: \begin{figure}[htb]
433: \caption{Code - Lasso Algorithm} \label{c:lasso}
440: Ridge algorithm is very similar to lasso algorithm with the same
goal. While lasso performs {\em L1 regularization}, ridge applies
{\em L2 regularization} techniques in modeling the predictions.
L1 regularization adds penalty to the variables equivalent to
{\em absolute value of the magnitude} of the coefficients, where
as L2 adds the penalty equivalent to {\em square of the
magnitude} of the variable coefficients. Figure (\ref{c:ridge})

```

shows the python implementation of the ridge algorithm for the `\em sale price` predictions. Figures (`\ref{fig:ridge-feature-ranking-pos}`) and (`\ref{fig:ridge-feature-ranking-neg}`) show the top 10 positively and top 10 negatively influencing variables with `\em sale price`.

```
442: \begin{figure}[htb]
461: \caption{Code - Ridge Algorithm} \label{c:ridge}
464: \begin{figure}[htb]
466: \includegraphics[width=1.0\columnwidth]{images/ridge_feature_ranking_pos}
467: \caption{Graph - Ridge Top 10 Positive Features}
        \label{fig:ridge-feature-ranking-pos}
470: \begin{figure}[htb]
472: \includegraphics[width=1.0\columnwidth]{images/ridge_feature_ranking_neg}
473: \caption{Graph - Ridge Top 10 Negative Features}
        \label{fig:ridge-feature-ranking-neg}
480: XGBoost (eXtreme Gradient Boosting) is one of the Gradient Boosted Machine algorithms. It ensembles (combines) optimized model by taking trained models from all the preceding iterations. XGBoost regularizes the variables (parameters) to reduce the overfit and can work well with variables having missing values. It is empowered with built-in cross validation to reduce the boosting iterations; hence offers better performance along with parallel processing on distributed systems such as Hadoop. By tuning the XGBoost hyper parameters, we can achieve well optimized model that can make more accurate predictions. XGBoost uses \em F-Score to measure the importance of variables and also given the python code, as shown in Figure (\ref{c:xgb}), implementing for \em sale price predictions. Figure (\ref{fig:xgb-feature-imp}) shows the top 10 feature selection by the XGBoost. Following list explains the hyper-parameters of XGBoost algorithm.
489: \begin{figure}[htb]
512: \caption{Code - XGBoost Algorithm} \label{c:xgb}
515: \begin{figure}[htb]
517: \includegraphics[width=1.0\columnwidth]{images/xgboost_feature_importance}
518: \caption{Graph - XGBoost Feature Importance} \label{fig:xgb-feature-imp}
555: \item \ href{https://github.com/bigdata-i523/hid306/blob/master/project/code/1.1_exploratory_analysis_numerical.ipynb}{Exploratory Analysis Numerical} - To load datasets and analyze all numerical variables
557: \item \ href{https://github.com/bigdata-i523/hid306/blob/master/project/code/1.2_exploratory_analysis_categorical.ipynb}{Explorator}
```

- y Analysis Categorical} - To analyze categorical variables in the dataset
- 559: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/1.3\_outlier\_and\_skewed\_data\_analysis.ipynb}{Outlier And Skewed Data Analysis} - Handles outlier and skewed data analysis
- 561: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/1.4\_feature\_engineering.ipynb}{Feature Engineering} - All the feature engineering is done in this file
- 563: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/2.1\_algorithm\_svm.ipynb}{SVM Algorithm} - Implementation of SVM algorithm
- 565: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/2.2\_algorithm\_random\_forest.ipynb}{Random Forest Algorithm} - Implementation of Random Forest algorithm
- 567: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/2.3\_algorithm\_ridge.ipynb}{Ridge Algorithm} - Implementation of Ridge algorithm
- 569: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/2.4\_algorithm\_lasso.ipynb}{Lasso Algorithm} - Implementation of Lasso algorithm
- 571: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/2.5\_algorithm\_neural\_network\_tf.ipynb}{Neural Network Algorithm} - Implementation of Neural Network algorithm
- 573: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/2.6\_algorithm\_xgboost.ipynb}{XGBoost Algorithm} - Implementation of XGBoost algorithm
- 575: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/code/3\_ensemble\_kaggle\_submission.ipynb}{Ensembled Model} - Implementation of Ensembled algorithm
- 581: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/data/train.csv}{Housing Dataset with Sale Price} - Sample training dataset with housing attributes along with the sale price
- 582: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/data/test.csv}{Housing Dataset without Sale Price} - Sample testing dataset similar to training dataset without the sale price
- 584: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/data/kaggle\_python\_svm.csv}{SVMs Algorithm Predictions} - Predicted Housing Sale Prices from SVM algorithm
- 586: \item \href{https://github.com/bigdata-i523/hid306/blob/master/project/data/kaggle\_python\_random\_forest.csv}{Random Forest Algorithm Predictions} - Predicted Housing Sale Prices from Random Forest algorithm
- 588: \item \href{https://github.com/bigdata-i523/hid306/blob/master/pr}

```
object/data/kaggle_python_ridge.csv}{Ridge Algorithm Predictions}
- Predicted Housing Sale Prices from Ridge algorithm
590: \item \href{https://github.com/bigdata-i523/hid306/blob/master/pr
object/data/kaggle_python_xgboost.csv}{XGBoost Algorithm
Predictions} - Predicted Housing Sale Prices from XGBoost
algorithm
592: \item \href{https://github.com/bigdata-i523/hid306/blob/master/pr
object/data/kaggle_python_lasso.csv}{Lasso Algorithm Predictions}
- Predicted Housing Sale Prices from Lasso algorithm
594: \item \href{https://github.com/bigdata-i523/hid306/blob/master/pr
object/data/kaggle_python_neural_network.csv}{Neural Network
Predictions} - Predicted Housing Sale Prices from Neural Network
algorithm
596: \item \href{https://github.com/bigdata-i523/hid306/blob/master/pr
object/data/kaggle_python_ensemble.csv}{Ensembled Model
Predictions} - Predicted Housing Sale Prices from Ensembled
algorithm
```

figures 27

tables 0

includegraphics 15

labels 27

refs 32

floats 27

False : ref check passed: (refs >= figures + tables)

True : label check passed: (refs >= figures + tables)

True : include graphics passed: (figures >= includegraphics)

True : check if all figures are referred to: (refs >= labels)

Label/ref check

passed: True

When using figures use columnwidth

[width=1.0\columnwidth]

do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

WARNING: algorithm and above may be used improperly

521: We have used {\em xgb} package to implement the XGBoost algorithm. Various hyper-parameters are used to tune the algorithm and a few of them are explained in the above list. The training dataset and the {\em sale price} vector are used to fit the model. XGBoost algorithm gives the list of features that are important in creating the model. We have captured the feature ranking as a graph and evaluated the accuracy of the predictions by calculating RMSE on training dataset itself. Finally, we have predicted the {\em sale prices} of test dataset.

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

ascii

---

=====

The following tests are optional

=====

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Big Data Applications in Real Estate Analysis

Elena Kirzhner

Indiana University Bloomington

3209 E 10th St

Bloomington, Indiana 47408

ekirzhne@iu.edu

## ABSTRACT

Big Data analysis reveals and comforts buyers with knowledge and facts about the neighborhood, its people and trends. Reducing risk of buying and predicting changes in home value for potential buyers.

## KEYWORDS

i523, hid320, Big Data Applications and Analytics, Real Estate

## 1 INTRODUCTION

When one mentions American dream, home ownership is first aspect that comes to mind. Another part of the American dream is financial success and wealth building. Buying your dream home to raise the family is obvious part of the real estate. For most Americans buying a home is the largest purchase they will ever make. Coupled with the fact that most conventional mortgages span 30 years research and analysis required to make educated choice should not be taken lightly as it will have implications on lifestyle for practically 40 percent of your lifetime. Successful investment in your home, potential rental property or land can lead to financially windfall. Failure to make right choices in real-estate purchases may have disastrous consequences. Financial ruin is obvious part of the equation. Majority of divorces in the united states are caused by financial duress in the households. Resulting in stress negatively affecting one's health.

The latest trend in real estate is application of Big Data. Big Data manipulation is booming and transforming the industry. We are seeing a huge move in usage of Big data and analytics. Companies build property matching online software based on customers behavior and their needs. The opportunities of Big Data are truly endless. It creates the power to change our thinking in decision making and develops efficient business approach by extracting variety of collected data points and reducing risks for consumers.

Big Data is already changing real estate industry by optimizing consumers search, offers recommendations on real estate websites to potential buyers and sellers. Utilizing Big Data in real estate could match customers with their desired home. It might include how many bedrooms they need, what neighborhood fits best, affordability, schools, crime rates, potential business property for rent, location and communities.

When using Big Data and analytics, it is possible to review patterns to understand whether the property is a good investment and a great match to potential customer. It is also possible to analyze what buyers are selecting more often and based on that data create a model.

When selecting a specific house for sale, Big Data integration within online websites made it possible to analyze local surroundings, sale patterns and neighborhood personality of each area. It created a knowledge comfort by having facts of the neighborhood, its people; and therefore reducing the risk of buying or investing in the wrong property.

## 2 BIG DATA IN REAL ESTATE BUSINESS

Risk mitigation is essential part of the way Big Data is transforming real estate. Open data across the internet and variety of Big Data tools added strong force for analysis in decision making of choosing right property or home. It equipped customers with the valuable information by extracting the data and cross analyzing it.

Big real estate agencies such as Realtor [13], Zillow [22] and Trulia [16], are pioneering those tools and provide estimated forecast of the property value from 1 to 10 years. Additionally, they provide information about the neighborhood trends, estimate mortgage payment, cost of ownership, history of the property and current value. The calculation is based on variety of public data records, market information, user data points [21] by using Big Data analysis formula developed in-house.

### 2.1 Real Estate Industry Evolution

Automated valuation methods have been used for a very long time. For decades banks utilized "Automated Valuation Model" to estimate home values. At one point banks wanted to exclusively rely on this model more than home values provided by professional appraisers. That practice led to problems with by omitting important nuances about condition resulting in overvaluation and undervaluation of properties. Big Data analysis and property estimates generated by online real estate giants are the next step in the evolution of real estate industry. This evolution diminishes importance and need for a real-estate agents as it is able to gather a lot of tribal information known only to experts in the area. That means this change can impact job market for over six hundred thousand active agents in the US.

### 2.2 Real Estate and Artificial Intelligence

Real estate businesses worry that unlocking the vast amount of data about properties could transform the business to be powered by artificial intelligence.

However, based on the GeekWire article [7] big data and artificial intelligence will not replace real estate agents. Robots are just big help and enrichment to the business. It created much better and safer decision making models. Artificial intelligence will help to deliver information about real estate transactions and trends to consumers. It says that in future Amazon voice or Siri could provide

useful information about popular housing trends and market value. Additionally, it can reveal the data on how many people were interested in the property and bids.

So far it is not a robot that is thinking and proactively making decision, it is just a voice based system that extracts the information from Big Data.

For the last twenty years, industry worries about loosing jobs in that area. However, the industry stayed the same. People still want an advice before making an important decision. Even thought, there so much more information and streamlined sales, individuals that want relationships, empathy and connecting with people are still there.

Obviously, there is some fear in real estate that robots can rock the world for real estate business. However, Big Data empowers agents with information and data, it is making them better providers with higher service.

### 2.3 Online Real Estate Agencies

Online real estate agencies calculate market value by using proprietary formulas. They are not providing expert estimation but a starting point in estimated property monetary worth. It is calculated from public data and surveys, by utilizing special features, market conditions and location. Additionally, they encourage consumers and homeowners to expand online data by doing other investigations such as comparing market prices for around areas, working with a real estate agent, getting an appraisal from an expert and visiting the house [21].

For example Zillow, developed a Zestimate prediction[21], which is Zillow's estimate of a home that currently on sale, one to ten years from now. The provided information based on current house and market condition. Other real estate agencies with online presence competing with Zillow, like Trulia and Realtor for example have developed similar proprietary formulas to assist customers.

Also, the companies provide rent estimates that would help evaluate potential monthly rental price by developed in-house algorithmic formula. Variations in rental prices can also happen because of different factors, additional investments, or length of lease.

Big Data information affects the forecasting. As an example, the amount of rental listings in a specific area affects how much we know about approximate prices in that area for condos, apartments and houses. Based on number of properties for rent, the prediction becomes more accurate. Homeowners can also update and provide information online about their needs or property, which helps even more for predicted accuracy.

The formula they use to estimate rent prices is comparing similar homes and apartments in the given area. Comparing bedrooms, square footage and other details. Then prices are being compared, and pattern to rental prices is shown.

Big data analysis provides unbiased information. Although, majority of real estate agents are esteemed professionals looking out for client's best interests they are still. There are still those that would like to manipulate client's opinion to benefit themselves. For example, if a particular house have been on the market too long and the agent might lose the listing there is a possibility that some shortcoming of the property will be omitted by the agent in order to complete the sale. Same can be said about agents trying

to achieve some sales goals or quotas. However, if the potential buyer conducts the research using Big Data all information will be available. Put simply, data does not lie.

## 3 REAL ESTATE ANALYSIS

Big Data is widely used by agents and real estate agencies to understand and improve how to target potential buyers. But the great thing about Big Data is that customers benefit from it as well. They can use free public resources with tons of data and information maps with different data analyzing tool options.

Latest tools allow to utilize Python to cross mix and match different values and data sets to analyze complex data. Prior to having these tools available such analysis would be an impossible task for individual users and required immense human and computing effort to complete. It is possible to visualize it by rendering correlations and trends. It reveals stunning insights in to chosen property for rent, business or home.

There is so much information that it is important to understand which data is relevant to consumers and improves decision making. It is useful to analyze the data-sets when considering investing [3]. The analysis can provide variety information and make the educated decision on the investment.

### 3.1 Big Data Tools

Analysis of these featured data points could be done with Python tool sets and libraries.

Python is a great programming language with variety of options. It is object oriented, semantically structured and great for scripting programs as well as connecting other programmable components. Python is considerably easy to learn and because of its high productivity and also became one of the favorite tools for programmers and data scientists. It contains libraries that are script importable and usable for a lot of use cases, such as image modification, scientific data analysis and server automation. Python world has been around for thirty years and a lot of code was written with multiple contributors. Variety of options built up on how to visualize the data [19].

The most common type of visualization is a simple bar chart and line graph [14]. It is popular and commonly used type of visualization to make comparison between values and variety of categories. It can be vertically or horizontally oriented by adjusting x and y axes, depending on what kind of information or categories the chart requires to present. Parameters need to be identified, such as axes, similarities, title and decided on what exactly the visualization supposed to show.

To make a simple bar chart, a number some of the most popular tools and libraries that have been invented for plotting the data could be utilized. These include the most used and common tools such as: Pandas, Seaborn, Bokeh, Pygal and Plotly.

Additionally, just like any other programming language issues, errors or questions with the libraries can be found on stack overflow page by Google search.

### 3.2 Data Analysis

For the purpose of this project, bar chart and graphs visualization methods with pandas modules in Python have been rendered and

explained. The simple form of this plot looks acceptable and easy to read.

The techniques were done within Jupiter notebook [9].

Jupiter notebook is great for running data sets analysis and for calculation projects. Jupiter notebook documents are readable files having the analysis description and the results in figures and tables as well as exportable files which can be executed to perform data analysis. It allows to render images and move values back and forth between different modules and coding languages.

The data-sets collected from clsearch.com [5], data.gov [17], zillow.com [22] and uploaded to the class's Google Drive to demonstrate the trends and patterns between each output.

The data includes both geographic and social data-sets evaluated by ratings in rows and titles in columns to keep it simple. The data set for both cities is being used for all examples that are demonstrated below. The point of the visualization is to understand the data in visual platform and make an informative decision based on rendered data.

A simple example of two properties in Tarzana, California versus Calabasas, were compared and exported for read.

Tarzana City is a wealthy neighborhood in the San Fernando Valley region of the city of Los Angeles, California. Tarzana was purchased in 1919 and developed on the site of local elites and named by Edgar Rice Burroughs, author of the popular Tarzan books. He established Tarzana and later sold it to local farmers [20].

Calabasas City located in the hills west of Malibu, in the San Fernando Valley region of the city of Los Angeles, California. The area established in 1991 and the name was derived from Spanish word "calabaza", meaning pumpkin. The legend has it that in 1824, a Mexican rancher spilled a wagon of pumpkin seeds and it spouted alongside the road. Therefore, the area was named Calabasas, the pumpkin land [20].

From a quick glance both areas are very similar and are located within 10 miles of each other. Both Tarzana and Calabasas are influential and desirable neighborhoods with lots of high priced homes. How does one differentiate between the two in order to find the right investment?

Big Data is the answer. Specifically in states like California. In California Big Data application benefits greatly from availability of public records such as sale price as apposed to certain "non-disclosure" states. There sale prices for homes are not disclosed in public records.

The analysis combines several main components, including property characteristics in the area, crime rate, quality of life, pollution, race and ethnicity, population growth, family household, house value, business field, employment, schools and future home value.

### 3.3 Property Characteristics

Big Data analytics can help in connecting needs of a buyer and providing neighborhood demographics. The quality of population in the neighborhood will influence who buys the house and who lives there. It is important to identify what is important to you and make sure those items are covered in the research. For example, if you are a student you will probably look for a densely populated

location around universities, closer to food locations and communities. Things like public transportation, nightlife, and bars will be very important to you and will be prioritized over other things. If you are married with kids, your best choice would be location with good schools and low crime. Parks, playgrounds and traffic and noise pollution around the house will be paramount. Most parents would love to find a nice quite cul-de-sac house. Young working professional would prefer to be right in the middle of things on a busy boulevard.

Latest Big Data collections made it all possible for real estate website to provide that information to potential buyers. Websites such as United States Zip-codes [2] collect information from public records and make it available in exportable format as well as for reviewing and analyzing local neighborhoods by states and zip codes input.

### 3.4 Crime Rate Indexes

Crime Big Data is available now and helps to see patterns and avoid areas with unfavorable statistics. The Los Angeles Police Department [1] already uses the data to show which areas in Los Angeles are hot-spots of crime.

Crime rates are being calculated by comparing the national levels of the average 100 [6]. For example, if score is 150 it means that it is 1.5 higher risk of crime than national average level. The data is coming from police department reports and public records. Additionally, the Federal Bureau of Investigation also provides factual information for ranking [18]. Furthermore, the research on crime can be extracted from United States Department of Justice via Uniform Crime Reporting Program [11].

In this example [9], running the crime data sets of Tarzana and Calabasas showed that Calabasas is in much better shape and safer place to live as compared to Tarzana, which is around the average of national rate. The total crime risk in Tarzana slightly higher than national average, it is 108, meanwhile Calabasas is almost 3 times lower, it is 24. The murder risk is 118 compared to 24 in Calabasas. Rape risk is 70 in Tarzana and 35 in Calabasas. Robbery risk in Tarzana is almost twice higher than in Calabasas, it is 125 versus 77. Assault risk three times higher in Tarzana, it is 127 versus 48 in Calabasas. Burglary risk twice higher in Tarzana as well, it is 55 versus 27. Larceny risk in Tarzana is overwhelmingly high, it is 73 versus 9 in Calabasas. Motor vehicle theft risk in Tarzana is 118 versus 39 in Calabasas. Based on these findings, it is defiantly safer to live in Calabasas [fig 1].

Based on these finding, it is defiantly safer to live in Calabasas as shown in Figure 1 [9].

[Figure 1 about here.]

### 3.5 Education Levels

Next run was done on educational level of residents. Big Data includes data of resident's education level and makes it possible to collect data about an individual resident and provides insightful information about social level interaction. The data extracted and combined from variety of sources including international school districts.

The education rating filtered by zip codes represents the percentage of people in the area who have attended colleges and received degrees. It does not represent performance and specific schools.

The rendered data showed [9] that residents in Calabasas are higher educated by 7 percent with Bachelor degrees and 6 percent higher with graduate degree, as shown in Figure 2 [9].

[Figure 2 about here.]

Based on the Economic Policy Institute study [4], there is a clear correlation between higher educated workforce and economic success within state and ability to grow. Additionally, higher educated people are good for state budgets, since workers with higher income contribute more through taxes.

### 3.6 Life Quality Standards

The next important consideration in buying a property, searching for a house and making a decision is quality of life standards in that area. Big Data and latest methods of data collection can lead to improvements in quality of life for residential areas. It can find neighborhoods that are safer, cleaner, more entertaining and a better place to live specifically tailored to potential buyer.

The data-set of life quality obtained from variety of sources, including public Google searches, social media and local study groups. The quality of life is being measured by how residents are being effected by crimes, weather, education, entertainment, religion, medical support and food supply. The positive decision variables calculated by amusement, education, culture, media, religion, weather and restaurants. The negative decision is based on the level of crime, natural disasters and mortality. The national level is being compared to 100 [5].

Rendered data showed that amusement index equal to 110 in Tarzana and 130 in Calabasas. What that means is that in Calabasas there are more community events and entertainment. Culture is 142 in Tarzana versus 129 in Calabasas. Culture refers to artistic development. Earthquake index 362 in Tarzana compared to 318 in Calabasas. this is a very interesting point considering that both neighborhoods are very close to each other. But since Tarzana's Earthquake index is higher associated insurance will likely be higher as well. Raising cost of ownership. Medical index is 137 in Tarzana and 116 in Calabasas. If you are working in the medical field this might be an important topic for you as it will help you find employment closer to home. Reduce your commute time, minimizing wasted time spent in California's infamous gridlock traffic. Mortality is much higher in Tarzana, it is 144 versus 95 in Calabasas. Religion is better in Tarzana, it is 154 compared to 96 in Calabasas. Religion refers to houses of worship and religious establishments. Restaurant index about the same, it is 144 in Tarzana and 139 in Calabasas. Weather is better in Tarzana, it is 16 versus 10 in Calabasas. That is another interesting observation considering that both neighborhoods are minutes away from each other.

Based on the data, overall quality of life is equal between two cities, as shown in Figure 3 [9].

[Figure 3 about here.]

### 3.7 Air Pollution

Big data can control and reveal pollution levels of particular area [8]. It is one of the main causes of health problems in the population and preventive cause death.

Over 80 percent of residents living in urban areas are vulnerable to poisoning from pollution. Cancer is one of the leading cause of deaths for both men and women; and exposure to pollution at early may have life-long negative consequences.

Monitored areas show that air quality levels exceed the safety levels [12]. Additionally, the World Health Organization warns that most populated states are most affected.

Government is aware of this problem, therefore collecting and monitoring the data regarding air quality has increased. The data is being shared between universities and air quality maps for further development. The data is openly shared and prepared for Big Data analysis.

Even though Big Data will not reduce the pollution by itself, it provides tools to visualize the problem which is especially helpful when choosing a place to live.

The exported data-sets showed [9] that carbon monoxide is extremely high in both cities. It is 186 in Tarzana and 183 in Calabasas. The national level is being compared to 100 [5]. Based on the data, overall air pollution index is about the same in both areas, as shown in Figure 4 [9].

[Figure 4 about here.]

### 3.8 Race and Ethnicity

Big Data can reveal a lot of information about population by using zip codes. It shows profiles of people who live there. Understanding ethnicity and identity of the community influence will help with decision.

The standard of maintaining, collecting and presenting federal data on race and ethnicity [10] were revised and improved on collecting quality about two decades ago. In accordance to best analysis practices, federal agencies conducting researches to better understand ethnic and race diversity.

The language to describe the ethnicity and race keeps changing to resonate with the category of residence and adding new meaning to not make it discriminatory. The general rule became that race and ethnicity should not be interpreted as being a science.

Based on the rendered graph, most population in Tarzana and Calabasas consist of white and non-Hispanic residents, as shown in Figure 5 [9].

[Figure 5 about here.]

That information provides insight about communities and relatedness to the buyer.

### 3.9 Population Growth

Leveraging Big Data in population growth might be helpful for economic growth prediction and future development.

For the recent centuries, population growth jumped dramatically [15]. How fast the population is growing can influence area homes and businesses development. Allowing for more business opportunities.

Educated people can contribute to the development with increased skills and knowledge. However, it is also important to look not only on the total population size, but also population growth rate.

Based on the data visualization, population size in Tarzana is higher by 3,000 residents than in Calabasas, as shown in Figure 6 [9].

[Figure 6 about here.]

Both in Calabasas and Tarzana, the rate was rapidly increasing from 1900-2000, and there was not much progress since then. Population density in Tarzana is 4,048 versus 856 in Tarzana. City area size in square miles is 7.44 and 31.67 in Calabasas. This information provides insight that Calabasas has much more opportunities for future growth and development. New housing and real estate development is achilles heel in California. State struggles to provide all existing residents with affordable housing. Compiled with population growth and migration of new residents the problem becomes even harder resolve. By having additional development space Calabasas growth potential is much higher compared to Tarzana.

### 3.10 Family Household

Big Data and internet of things are making its existence common place in each household. Only 15 years ago home computers were the only smart device in the house. Now even vacuums and thermostats are connected. Our homes are goldmines of data. Getting family household data summary instantly tells about the type of people in these areas and obtained knowledge can be used to help with buying decision.

Household definition refers to type of family and people living in a household structure. Household data is useful when consumer wants to know about the type of people living in that area and relativity.

Based on the combined data-set results [9], full family household is 64 percent in Tarzana and 76 percent in Calabasas. 48 percent are married in Tarzana, and 62 percent in Calabasas. Therefore for married families with kids it makes more sense to live in Calabasas.

### 3.11 Property Value

Big Data is being used to analyze property values. Real estate agencies, such as Zillow [22], estimate values based on Big Data collection tools and using their algorithm [21]. They combine information from variety of sources and provide insightful information to buyers, sellers or brokers.

Based on the data analysis [9], it shows that Calabasas prices are higher than in Tarzana by 23 percent. That insight shows that more financially able residence live in Calabasas.

To confirm that, the income data was calculated. Based on the rendered data as shown in Figure 7 [9], it proves that residence in Calabasas are more influential with higher income than in Tarzana.

The total income in Calabasas is higher by approximately 20 percent.

[Figure 7 about here.]

### 3.12 Employment and Occupation

The employment breakdown that derived from data, published by the Bureau of Labor Statistics showed that business field compared with employment field could help with predicting job opportunities.

Based on compared data sets, Health-care is leading employment field in Tarzana and Management in Calabasas, as shown in Figure 8 and Figure 9 [9].

[Figure 8 about here.]

[Figure 9 about here.]

### 3.13 Public Schools

Big Data in public schools are being used to fix education institutions and improve student scores and results. whereas in the past school performance was judged simply on average API scores of the students now student attributes data is further analyzed. This allows to identify subgroups of under-performing students. For example income levels of households are tracked to make sure that students from low-income families have the same opportunities to have better scores and grades as families from high-income families. It also provides tracking and comparison with schools in different districts. This helps school boards to allocate additional resources to schools that lack them. It also helps parents and home buyers identify schools and neighborhoods where their child could flourish academically.

The mined data could be used for decision making in property investment as well. Prospective buyers with kids are not only looking for good education and safe schools for their own kids, but also from stand-point of property value since homes located in good school districts are more desirable. The detailed information that can be found online made it easy to be properly informed. Compared data between two cities, showed that elementary schools have 38 percent higher rating in Calabasas, middle schools are 25 percent higher and high schools are the same. Schools in Calabasas are better based on these rating scores, as shown in Figure 10 [9].

[Figure 10 about here.]

### 3.14 Available Houses for Rent and Sale

Another shift in demographic preferences that has been observed is related to home ownership vs renting. Millennials are changing their spending habits when compared to previous generations. Food, health and entertainment take priorities over burdens expenses associated with home ownership. If that trend continues return on investment generated by buying rental properties will rise.

The best way to know if a house is a good investment is to check the rental properties near the area.

There is also a 1 percent rule of thumb to keep in mind. The rule is that a purchased home should be rented for 1 percent of the cost.

Based on the rental data, medium price in Tarzana 4,210 dollars per month, and Calabasas 4,085 dollars per month. It actually reveals that Tarzana rental properties are more expensive than Calabasas, even though the home prices in Calabasas are higher, as shown in Figure 11 [9].

[Figure 11 about here.]

Additionally, square footage was calculated. To get the price per square footage, the price of the area was divided by its square footage. The results showed that in Tarzana rent is slightly higher than in Calabasas, as shown in Figure 12 [9].

[Figure 12 about here.]

Therefore, it makes more sense to buy renting properties in Tarzana.

The lowest price of property in Tarzana is 700,000 us dollars, and in Calabasas it is 975,000 us dollars [9].

Based on the 1 percent rule, it does not make sense to buy and rent out in Tarzana or Calabasas.

### 3.15 Future Value

California housing is booming and crashing. Massive home equity destruction happened few years ago and reversed back.

When data-sets are analyzed, they can reveal insightful information and guide consumer decision making.

Based on the sales data was taken and generated, suggests that in spite of prices drops the value of houses goes up, as shown in Figure 13 and Figure 14 [9].

[Figure 13 about here.]

[Figure 14 about here.]

Calculated housing investment for the last 20 years had a growth rate of 5.46 percent [9]. By knowing a starting and ending value, it is possible to calculate the future value of an investment. Referencing the previous calculations [9], it predicts that house value will grow by 63 percent in the next 20 years.

## 4 CONCLUSION

Big Data potential to transform decision making in real-estate is immense. Home ownership is part of the American dream and Big Data will play a huge role in that process. It will allow potential buyers to have a better understanding of historic data and how it correlates to investment potential.

Big data will provide powerful insight to augment decision making process. Yet, it will not eliminate all risks associated with investment in real-estate. All risks must be evaluated and analyzed before buying and big data will provide plenty of tools for that.

Based on this analysis, it was determined that Tarzana and Calabasas properties are overpriced. Currently, renting is low compared to buying a property.

It is impossible to find properties in California that generate rents at around 1 percent of total property cost. You can not justify the prices and it is only for the privilege of living in San Fernando Valley region of the city of Los Angeles, California.

However, if you do still want to invest, Calabasas is a better choice for investing in a family home property and Tarzana for a rental property.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski, Juliette Zerick and Miao Jiang for their help, support and suggestions to write this paper.

## REFERENCES

- [1] 0 2017. *Federal Register The Daily Journal of the United States Government*. 0. <https://www.federalregister.gov>
- [2] 0 2017. *United States Zip Codes.org*. 0. <https://www.unitedstateszipcodes.org/91356/>
- [3] Andrew Beattie . 2017. *Top 10 Features of a Profitable Rental Property*. 0. <https://www.investopedia.com/articles/mortgages-real-estate/08/buy-rental-property.asp>
- [4] Noah Berger. 2013. *A Well-Educated Workforce Is Key to State Prosperity*. 0. <http://www.epi.org/publication/states-education-productivity-growth-foundations/>
- [5] CLRsearch.com. 2012. *Tarzana, CA 91356 Population Growth and Population Statistics*. 0. <https://www.clrsearch.com/Tarzana-Demographics/CA/91356/Population-Growth-and-Population-Statistics>
- [6] CLRsearch.org. 2012. *Community Demographic Information FAQ*. 0. <https://www.clrsearch.com/demographics/Demographic.Information.jsp>
- [7] John Cook. 2017. *Robots in real estate?* 0. <https://www.geekwire.com/2017/robots-real-estate-theres-nothing-see-zillow-co-founder-says-agent-jobs-safe/>
- [8] Arantxa Herranz. 2017. *Big data will control pollution in your city*. 0. <http://blog.ferrovial.com/en/2017/04/big-data-pollution-control-in-cities/>
- [9] Elena Kirzhner. 2017. *Big Data Applications in Real Estate*. 0. <https://github.com/bidata-i523/hid320/blob/master/project/project.md>
- [10] Management and Budget Office. 2016. *Standards for Maintaining, Collecting, and Presenting Federal Data on Race and Ethnicity*. 0. <https://www.federalregister.gov/documents/2016/09/30/2016-23672/standards-for-maintaining-collecting-and-presenting-federal-data-on-race-and-ethnicity>
- [11] FBIfia Crime Statistics Management. 2017. *Uniform Crime Reporting Statistics: Their Proper Use*. 0. <https://ucr.fbi.gov/ucr-statistics-their-proper-use>
- [12] World Health Organization. 2016. *Air pollution levels rising in many of the world's poorest cities*. 0. <http://www.who.int/mediacentre/news/releases/2016/air-pollution-rising/en/>
- [13] Realtor.com. 2017. *Realtor.com - resource for home buyers and sellers*. 0. <https://www.realtor.com>
- [14] Naomi B Robbins. 2012. *Creating more effective graphs*. Wiley, 0.
- [15] Max Roser and Esteban Ortiz-Ospina. 2017. *World Population Growth*. 0. [https://ourworldindata.org/world-population-growth/](https://ourworldindata.org/world-population-growth)
- [16] Trulia.com. 2017. *Trulia is a mobile and online real estate resource*. 0. <https://www.trulia.com>
- [17] U.S. General Services Administration, Technology Transformation Service. 2017. *Real Estate Sale History*. 0. <https://www.data.gov>
- [18] Mark van Rijmenam. 2017. *The Los Angeles Police Department Is Predicting and Fighting Crime With Big Data*. 0. <https://datafloq.com/read/los-angeles-police-department-predicts-fights-crim/279>
- [19] Guido Van Rossum and Fred L Drake. 2011. *The python language reference manual*. Network Theory Ltd., 0.
- [20] Wikipedia. 2017. *Tarzana, Los Angeles*. 0. [https://en.wikipedia.org/wiki/Tarzana,\\_Los\\_Angeles](https://en.wikipedia.org/wiki/Tarzana,_Los_Angeles)
- [21] Zillow.com. 2017. *The Zestimate home valuation*. 0. <https://www.zillow.com/zestimate/#what>
- [22] Zillow.com. 2017. *Zillow is the leading real estate and rental marketplace*. 0. <https://www.zillow.com>

#### LIST OF FIGURES

1	Crime rate in Tarzana, CA compared to Calabasas, CA (100 = National Average) [9].	8
2	Educational percentage of people in Tarzana, CA compared to Calabasas, CA (Population Age 25+) [9].	9
3	Life quality of people in Tarzana, CA compared to Calabasas, CA [9].	10
4	Air Pollution Indexes in Tarzana, CA compared to Calabasas, CA [9].	11
5	2012 Population by Race and Ethnicity in Tarzana, CA compared to Calabasas, CA [9].	12
6	Population change since 1990 in Tarzana, CA compared to Calabasas, CA [9].	13
7	Income in Tarzana, CA compared to Calabasas, CA [9].	14
8	Employment field in Tarzana, CA compared to Calabasas, CA [9].	14
9	Business fields in Tarzana, CA compared to Calabasas, CA [9].	15
10	Public schools in Tarzana, CA compared to Calabasas, CA [9].	15
11	Houses for rent in Tarzana, CA compared to Calabasas, CA (3bd+ House For Rent (1,500-2,500 Sqft)) [9].	16
12	Price per sqft for rent in Tarzana, CA compared to Calabasas, CA [9].	17
13	Prices Growth Index in California [9].	18
14	Prices Growth Index in California [9].	19

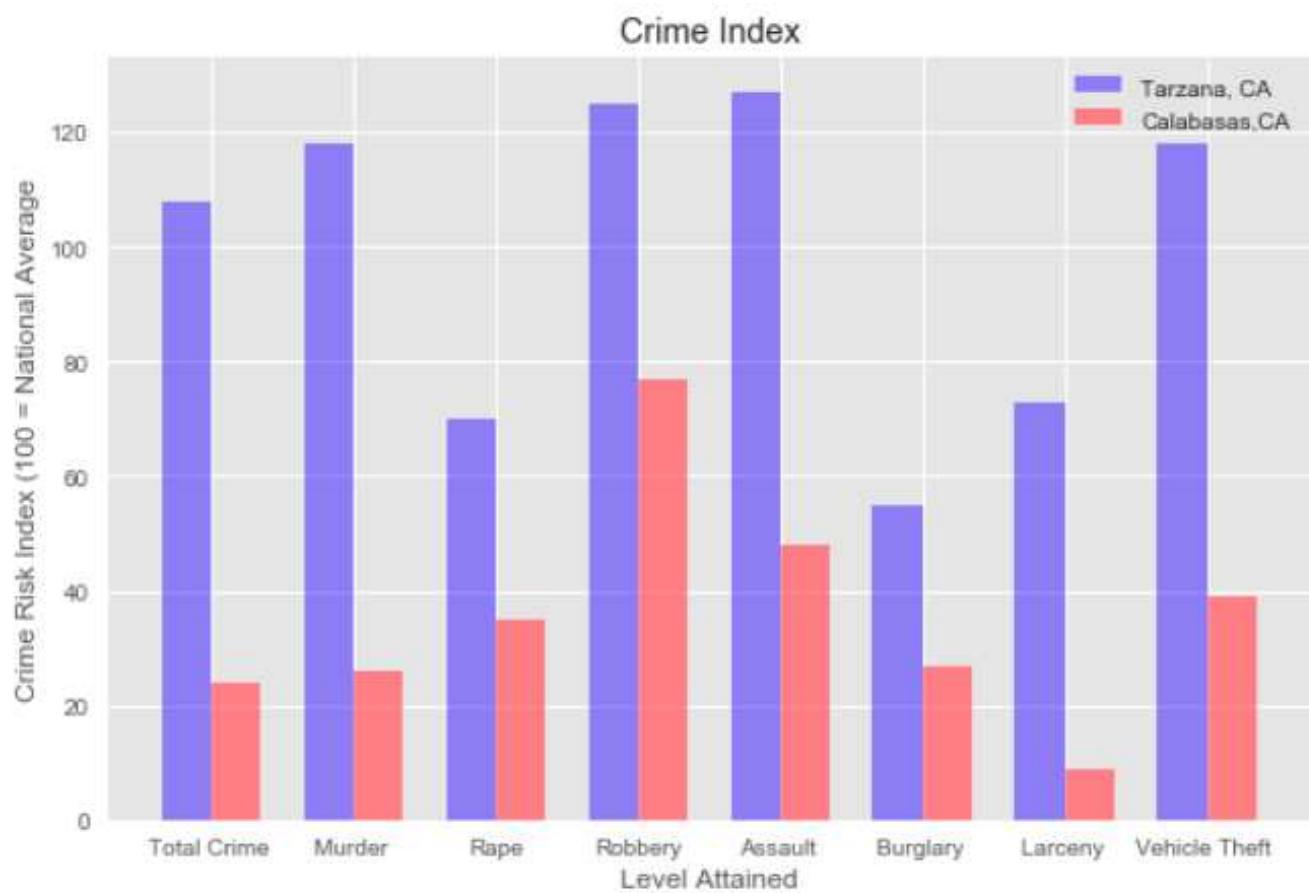


Figure 1: Crime rate in Tarzana, CA compared to Calabasas, CA (100 = National Average) [9].

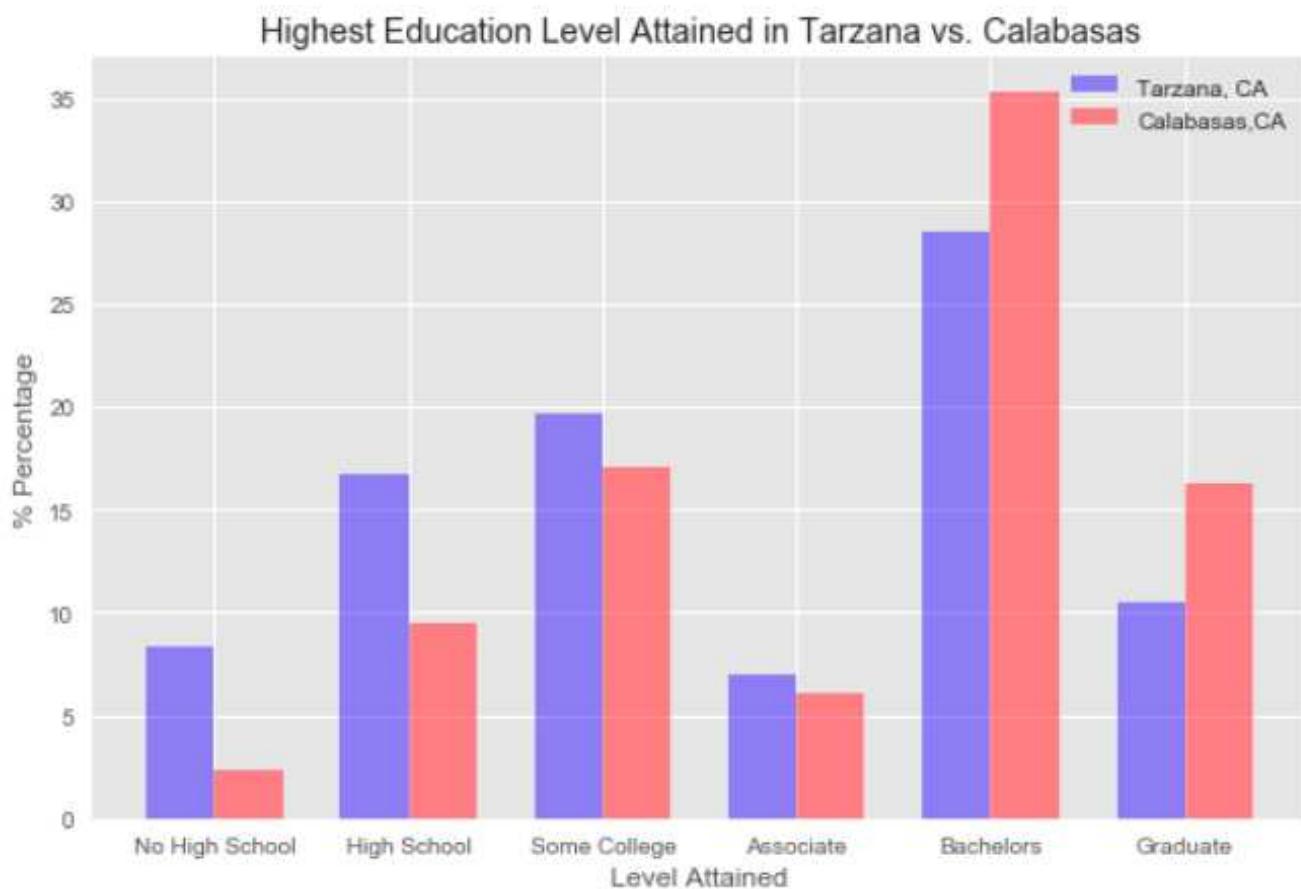


Figure 2: Educational percentage of people in Tarzana, CA compared to Calabasas, CA (Population Age 25+) [9].

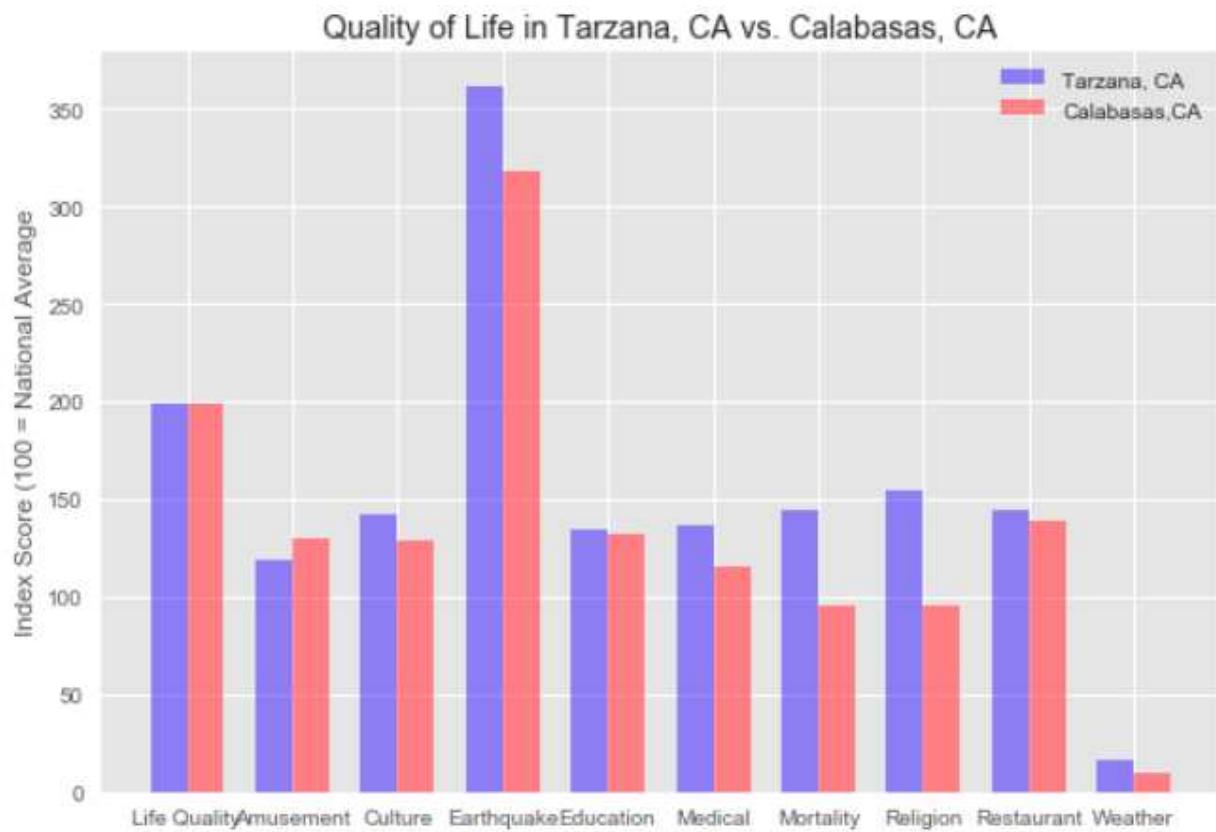


Figure 3: Life quality of people in Tarzana, CA compared to Calabasas, CA [9].

Polution Indexes in Tarzana, CA vs. Calabasas, CA

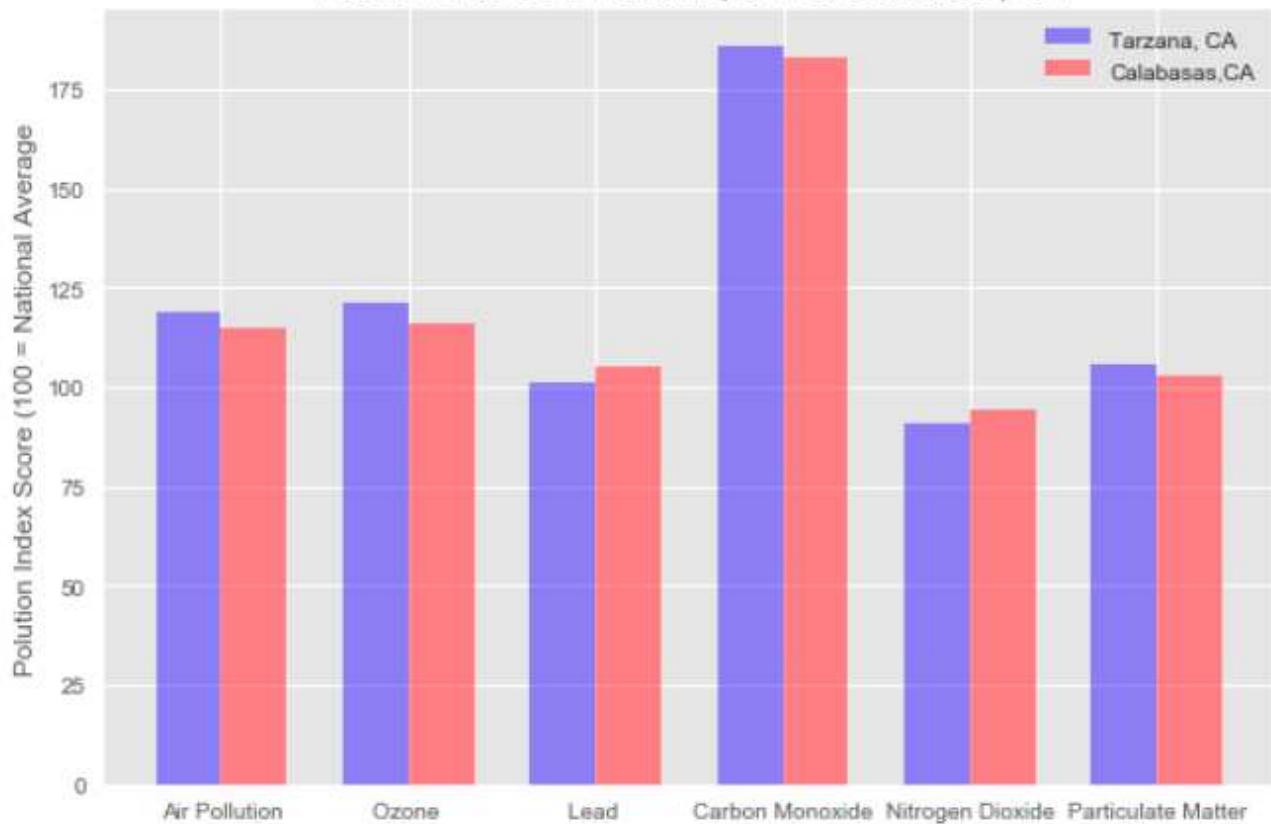


Figure 4: Air Pollution Indexes in Tarzana, CA compared to Calabasas, CA [9].

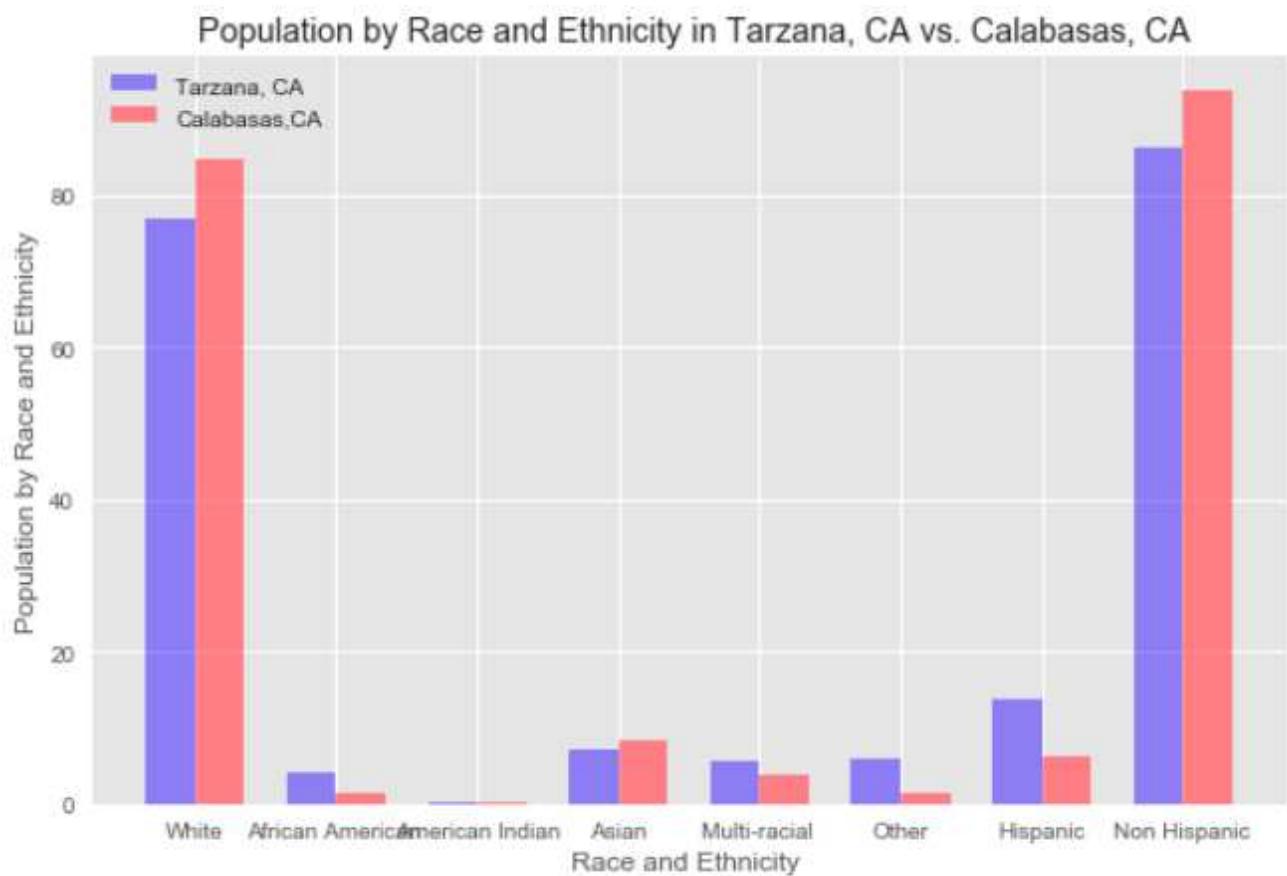


Figure 5: 2012 Population by Race and Ethnicity in Tarzana, CA compared to Calabasas, CA [9].

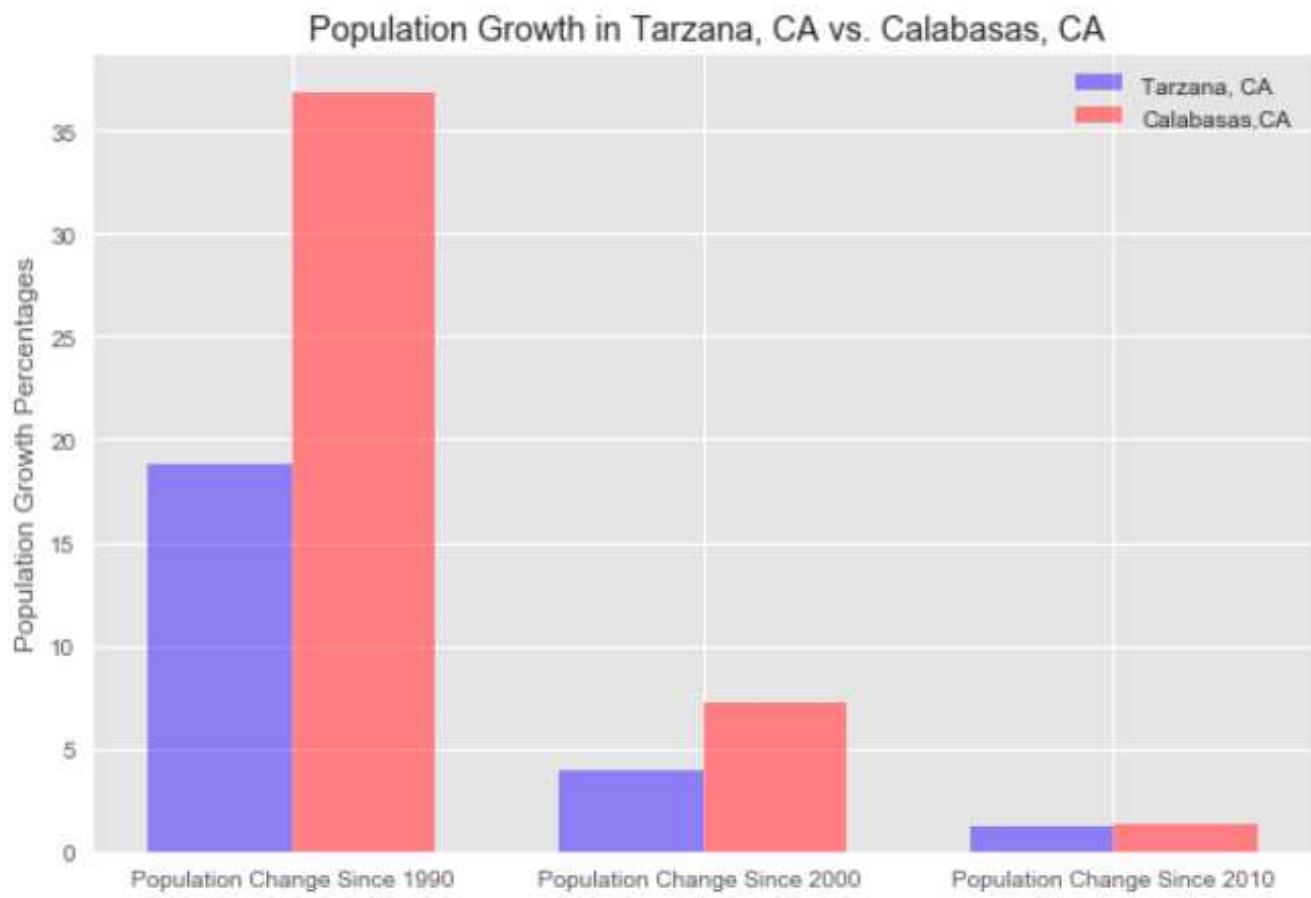
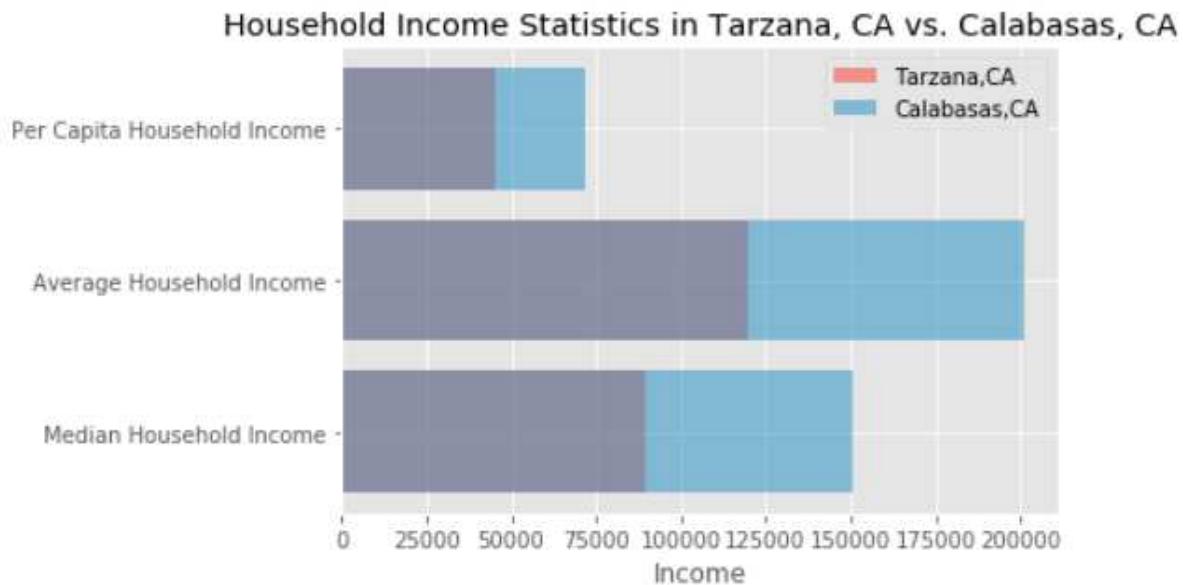
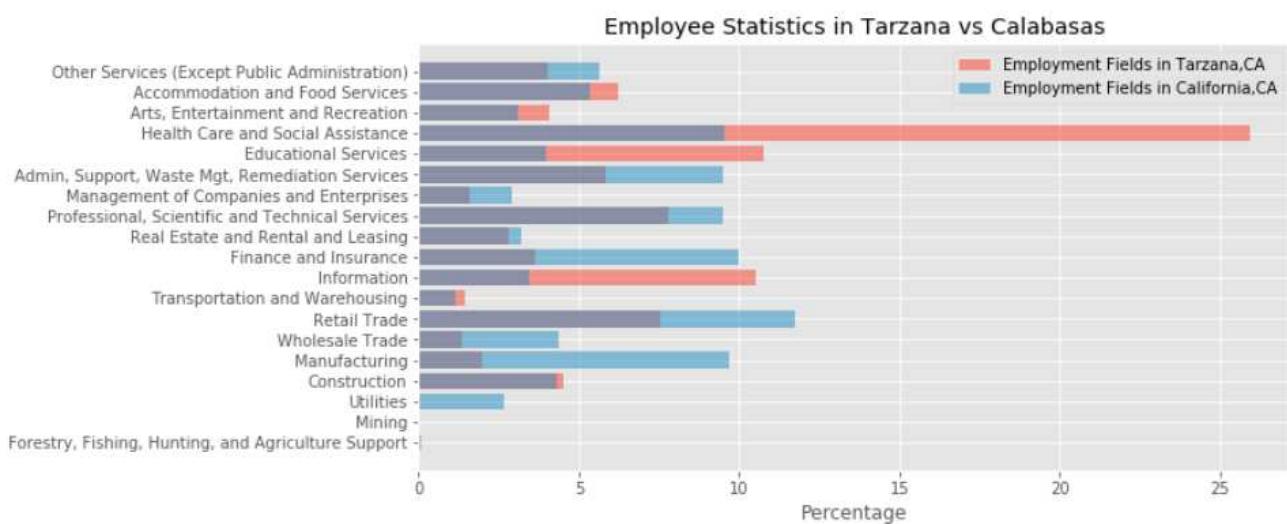


Figure 6: Population change since 1990 in Tarzana, CA compared to Calabasas, CA [9].



**Figure 7: Income in Tarzana, CA compared to Calabasas, CA [9].**



**Figure 8: Employment field in Tarzana, CA compared to Calabasas, CA [9].**

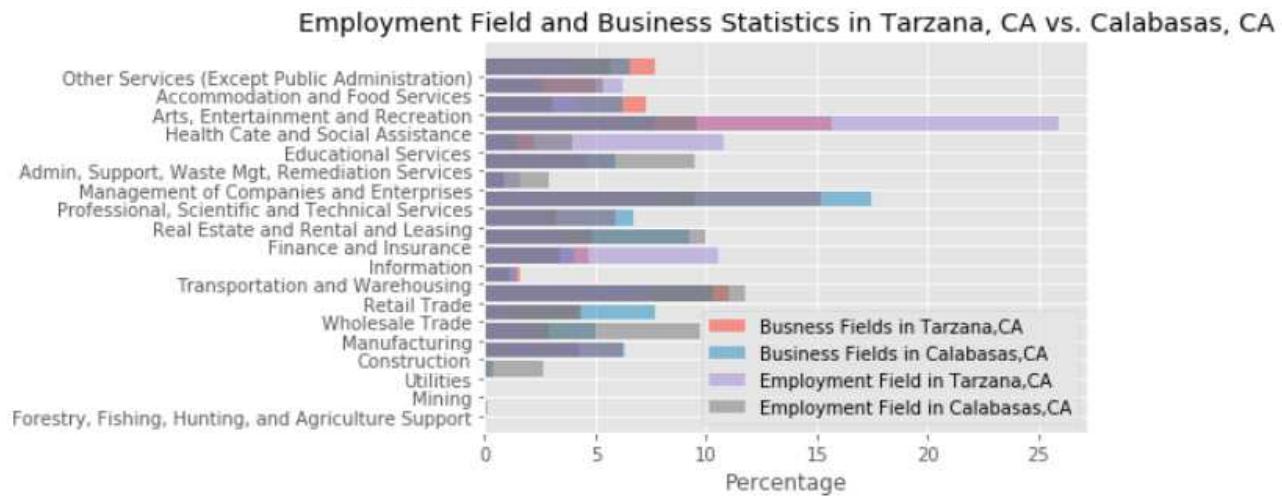


Figure 9: Business fields in Tarzana, CA compared to Calabasas, CA [9].

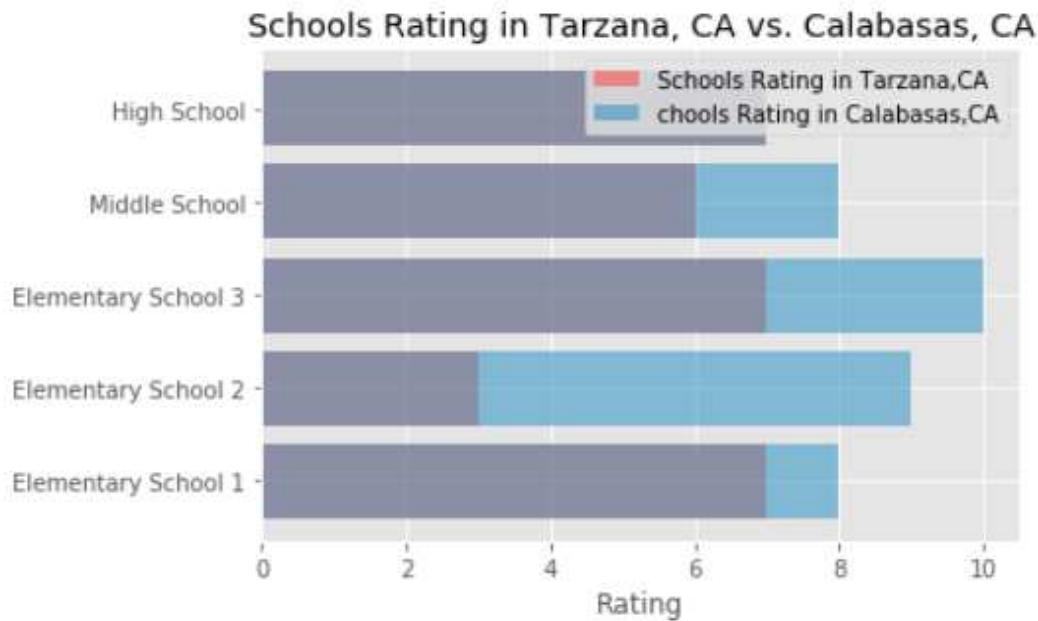


Figure 10: Public schools in Tarzana, CA compared to Calabasas, CA [9].



Figure 11: Houses for rent in Tarzana, CA compared to Calabasas, CA (3bd+ House For Rent (1,500-2,500 Sqft)) [9].

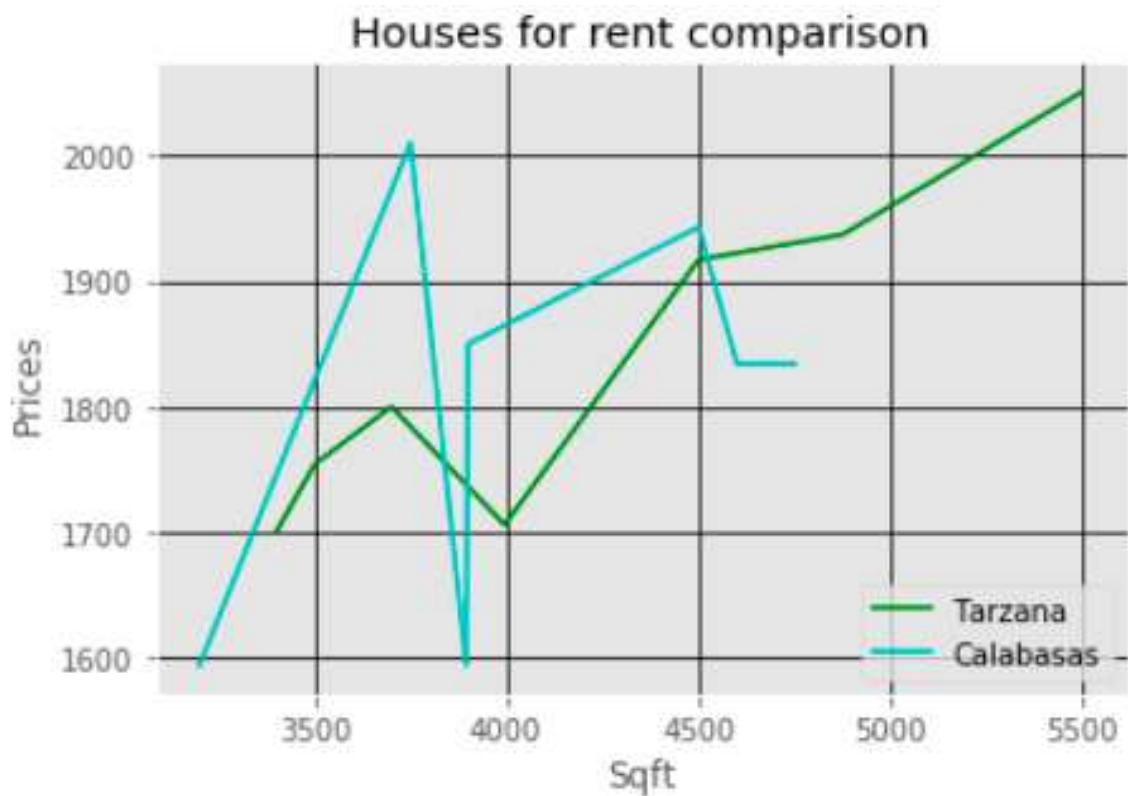


Figure 12: Price per sqft for rent in Tarzana, CA compared to Calabasas, CA [9].



Figure 13: Prices Growth Index in California [9].



Figure 14: Prices Growth Index in California [9].

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
=====
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
report.bib:105:    @manual{education,
report.bib:145:    @manual{robots,
report.bib:153:    @book{van2011python,
report.bib:169:    @book{robbins2012creating,
report.bib:57:    @manual{clr,
report.bib:65:    @manual{zipcodes,
report.bib:73:    @manual{federal,
report.bib:81:    @manual{crime,
report.bib:89:    @manual{unicrime,
report.bib:97:    @manual{crime2,
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
=====
[2017-12-12 20.01.19] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
```

```
bookmark level for unknown defaults to 0.  
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.  
Typesetting of "report.tex" completed in 1.4s.
```

```
=====  
Compliance Report  
=====
```

```
name: Elena Kirzhner  
hid: 320  
paper1: 100% Oct 31 2017  
paper2: 100% Nov 6 2017  
project: 100% Dec 03 2017
```

```
yamlcheck
```

```
-----  
wordcount
```

```
19  
wc 320 project 19 5263 report.tex  
wc 320 project 19 5567 report.pdf  
wc 320 project 19 524 report.bib
```

```
find "
```

```
-----  
passed: True
```

```
find footnote
```

```
-----  
passed: True
```

```
find input{format/i523}
```

```
4: \input{format/i523}
```

```
-----  
passed: True
```

```
find input{format/final}
```

passed: False

floats

---

141: Based on these finding, it is defiantly safer to live in  
Calabasas as shown in Figure \ref{fig:figure1} \cite{md}.  
143: \begin{figure}  
145: \includegraphics[width=1.0\columnwidth]{images/figure1.png}  
146: \caption{Crime rate in Tarzana, CA compared to Calabasas, CA (100  
= National Average) \cite{md}.} \label{fig:figure1}  
156: The rendered data showed \cite{md} that residents in Calabasas  
are higher educated by 7 percent with Bachelor degrees and 6  
percent higher with graduate degree, as shown in Figure  
\ref{fig:figure2} \cite{md}.  
158: \begin{figure}  
160: \includegraphics[width=1.0\columnwidth]{images/figure2.png}  
161: \caption{Educational percentage of people in Tarzana, CA compared  
to Calabasas, CA (Population Age 25+) \cite{md}.}  
\\ \label{fig:figure2}  
175: Based on the data, overall quality of life is equal between two  
cities, as shown in Figure \ref{fig:figure3} \cite{md}.  
177: \begin{figure}  
179: \includegraphics[width=1.0\columnwidth]{images/figure3.png}  
180: \caption{Life quality of people in Tarzana, CA compared to  
Calabasas, CA \cite{md}.} \label{fig:figure3}  
195: The exported data-sets showed \cite{md} that carbon monoxide is  
extremely high in both cities. It is 186 in Tarzana and 183 in  
Calabasas. The national level is being compared to 100  
\cite{clr}. Based on the data, overall air pollution index is  
about the same in both areas, as shown in Figure  
\ref{fig:figure4} \cite{md}.  
197: \begin{figure}  
199: \includegraphics[width=1.0\columnwidth]{images/figure4.png}  
200: \caption{Air Pollution Indexes in Tarzana, CA compared to  
Calabasas, CA \cite{md}.} \label{fig:figure4}  
212: Based on the rendered graph, most population in Tarzana and  
Calabasas consist of white and non-Hispanic residents, as shown  
in Figure \ref{fig:figure5} \cite{md}.  
214: \begin{figure}  
216: \includegraphics[width=1.0\columnwidth]{images/figure5.png}  
217: \caption{2012 Population by Race and Ethnicity in Tarzana, CA  
compared to Calabasas, CA \cite{md}.} \label{fig:figure5}  
230: Based on the data visualization, population size in Tarzana is  
higher by 3,000 residents than in Calabasas, as shown in Figure

```

    \ref{fig:figure6} \cite{md}.
232: \begin{figure}
234: \includegraphics[width=1.0\columnwidth]{images/figure6.png}
235: \caption{Population change since 1990 in Tarzana, CA compared to
Calabasas, CA \cite{md}.} \label{fig:figure6}
256: To confirm that, the income data was calculated. Based on the
rendered data as shown in Figure \ref{fig:figure7} \cite{md}, it
proves that residence in Calabasas are more influential with
higher income than in Tarzana.
260: \begin{figure}
262: \includegraphics[width=1.0\columnwidth]{images/figure7.png}
263: \caption{Income in Tarzana, CA compared to Calabasas, CA
\cite{md}.} \label{fig:figure7}
270: Based on compared data sets, Health-care is leading employment
field in Tarzana and Management in Calabasas, as shown in Figure
\ref{fig:figure8} and Figure \ref{fig:figure9} \cite{md}.
272: \begin{figure}
274: \includegraphics[width=1.0\columnwidth]{images/figure8.png}
275: \caption{Employment field in Tarzana, CA compared to Calabasas,
CA \cite{md}.} \label{fig:figure8}
278: \begin{figure}
280: \includegraphics[width=1.0\columnwidth]{images/figure9.png}
281: \caption{Business fields in Tarzana, CA compared to Calabasas, CA
\cite{md}.} \label{fig:figure9}
290: Schools in Calabasas are better based on these rating scores, as
shown in Figure \ref{fig:figure10} \cite{md}.
292: \begin{figure}
294: \includegraphics[width=1.0\columnwidth]{images/figure10.png}
295: \caption{Public schools in Tarzana, CA compared to Calabasas, CA
\cite{md}.} \label{fig:figure10}
306: Based on the rental data, medium price in Tarzana 4,210 dollars
per month, and Calabasas 4,085 dollars per month. It actually
reveals that Tarzana rental properties are more expensive than
Calabasas, even though the home prices in Calabasas are higher,
as shown in Figure \ref{fig:figure11} \cite{md}.
308: \begin{figure}
310: \includegraphics[width=1.0\columnwidth]{images/figure11.png}
311: \caption{Houses for rent in Tarzana, CA compared to Calabasas, CA
(3bd+ House For Rent (1,500-2,500 Sqft)) \cite{md}.}
\label{fig:figure11}
314: Additionally, square footage was calculated. To get the price per
square footage, the price of the area was divided by its square
footage. The results showed that in Tarzana rent is slightly
higher than in Calabasas, as shown in Figure \ref{fig:figure12}
\cite{md}.
316: \begin{figure}

```

```
318: \includegraphics[width=1.0\columnwidth]{images/figure12.png}
319: \caption{Price per sqft for rent in Tarzana, CA compared to
Calabasas, CA \cite{md}.} \label{fig:figure12}
334: Based on the sales data was taken and generated, suggests that in
spite of prices drops the value of houses goes up, as shown in
Figure \ref{fig:figure13} and Figure \ref{fig:figure14}
\cite{md}.
336: \begin{figure}
338: \includegraphics[width=1.0\columnwidth]{images/figure13.png}
339: \caption{Prices Growth Index in California \cite{md}.}
\label{fig:figure13}
342: \begin{figure}
344: \includegraphics[width=1.0\columnwidth]{images/figure14.png}
345: \caption{Prices Growth Index in California \cite{md}.}
\label{fig:figure14}
```

figures 14  
tables 0  
includegraphics 14  
labels 14  
refs 12  
floats 14

```
True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
False : check if all figures are refered to: (refs >= labels)
```

Label/ref check  
passed: True

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

bibtex

---

```
label errors
```

```
bibtex errors
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
68: author = "",
```

```
76: author = "",
```

```
passed: False
```

```
ascii
```

---

```
non ascii found 8217
```

```
non ascii found 8217
```

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
-----  
passed: True
```

# Big Data Analytics in Identifying Factors Affecting Bitcoin

Ashok Kuppuraj

Indiana University

Bloomington, Indiana 43017-6221

akuppura@iu.edu

## ABSTRACT

Pricing of Blockchain based cryptocurrencies are like a black box, as per theory the pricing compared to U.S dollar is based on a number of transactions however lot other factors like Dollar price, social media, Online threats supersede the transaction count. Big data and Analytics helps to identify the metrics impacting this variation and identify the correlation between them.

## KEYWORDS

i523, hid324, Big data, Predictive analytics, Random Forest, correlation, Blockchain, Bitcoin, Ethereum

## 1 INTRODUCTION

The start of the 21st century witnessed the evolution of various disruptive technologies, right from Big data, IoT, VR to Blockchain. When it comes to the blockchain, the sole winner is Bitcoin, with the growth rate of over 1327 percent [5], Bitcoin is disrupting the way banking system works. As the Bitcoin grows the acceptance and adoption grow along with that. Similar to any other currency in the world, Bitcoin's price deviates widely towards the positive side which created the opportunity for investment in it. Even though the same is not widely accepted everywhere, there is a grace to own Bitcoin citing its growth rate. Though the transaction counts haven't grown up, the retention of the coin has grown up making it a Digital Gold [17].

## 2 BITCOIN

Bitcoin is a progressed cryptographic cash and shared ledger that is completely decentralized, which implies it relies upon peer-to-peer trades with no bureaucratic oversight. Trades and liquidity inside the framework are somewhat based on cryptography. The concept was first introduced in 2009 [8] and is at this moment a prospering open-source gathering and portion sort out. In perspective of the uniqueness of Bitcoin's tradition and its creating choice, the Bitcoin is grabbing stacks of thought from associations, clients, and monetary experts alike. Specifically, for this technology to thrive, we need to recreate budgetary organizations and things that starting at now exist in our traditional, fiat cash world, make them available and specially fitted to Bitcoin, and other rising computerized types of cash. In technical terms, Bitcoin's is a shared ledger or a database running by a set of clusters, as the clustering is involved, a competition is set for the individual machines to acquire and update the ledger. The competition is in terms of hashing problem. The hashing needs multiple GPU's to perform validations and update the ledger. This competition eliminates the slower machines to be part of the network and improve the infrastructure's capacity, only by winning the competition a machine can be awarded some

Bitcoin as an incentive. Since one machine cannot process the competition problem, a set of peers come together to form a Mining pool and share their capacity and the incentives. We can gather useful mining statistics information from these mining pools.

## 3 PRICE PREDICTION

The Bitcoin market's cash-related basic is, clearly, a securities trade. To support money related to reward, the stock market prediction has turned out to be known ground which can be reused with the presence of high-repeat, low-dormancy trading hardware joined with solid machine learning figurings. Henceforth, it looks good that this desire is imitated in the domain of Bitcoin, as the framework expands more conspicuous liquidity and more people develop an excitement for placing profitably in the structure. To do accordingly, it is essential to utilize machine learning and Big data advancements to foresee the cost of Bitcoin [10].

### 3.1 Data Source

As Bitcoin is a decentralized and a transparent system, all the source of data can be gathered from the peer-to-peer networks. This peer-to-peer network is called as Bitcoin-mining pool [2]. The rate of block creation is adjusted every 2016 blocks to aim for a constant two week adjustment period (equivalent to 6 per hour.) The number of Bitcoins generated per block is set to decrease geometrically, with a 50 reduction every 210,000 blocks, or approximately four years. The result is that the number of bitcoins in existence is not expected to exceed 21 million [6]. The true source of data for Bitcoin analysis would be from Bitcoin mining pool. Coinbase is one of the main members of bitcoin pool from which we can gather mining statistics. In the process of identifying the features impacting Bitcoin's price fluctuations, not only the transaction volume impacts, even the popularity and people's trend towards it impact the price of the coins. Hence, data from Google is also gathered. As a currency's price also been altered by its exchange, supply, and demand, Ethereum's price data and transactional data is also acquired from Ethereum's exchange point. With all these data sources, we analyze the features impacting the Bitcoin's market price.

### 3.2 Feature Selection

Feature selection is one of the vital steps in any meaningful analysis of an expected outcome. A set of features have been selected to analyze its interdependence with Bitcoin's evaluation. The features are selected based on three wide areas, the first is Bitcoin mining data, second is social data and the last one is exchange data. The internal activities in the Bitcoin's infrastructure definitely reflect the changes or the fluctuations in the Bitcoin's network, Bitcoin's mining data is gathered from Coinbase. This is extracted from the

web service API provided by Quandl.com [9]. By making a REST call, CSV files containing the historical data is downloaded and processed. The second is the social data, which is extracted as a static data from Google trends [7], the main reason behind this data is when the popularity grows people tend to know or show interest in being part of the growth. With the impressive growth of more than 1000 percent in a year, this is considered as an important data. The last one is the exchange data, as a currencies price is directly proportional to the supply and demand, the supply of the currency can be impacted by the exchange to other currencies or commodity [18]. Ethereum is known to show a similar pattern in terms of growth and deviations [3]. Hence, there's price in US dollars and transaction volume is considered one of the features.

## 4 BIG DATA IN FEATURE ANALYSIS AND ALGORITHM'S EXECUTION

Feature extraction, transformation, and prediction can be synonymous with a conventional ETL methodology. Though few of the extraction is handled manually and the volume is comparably low, it is assumed that the data volume will be increased by modifying the extraction to real-time systems. When the extraction systems are changed, our code must be able to handle streaming data which can be related to "variety and volume " of the data. The next step is validating the data for anomalies, data miss and cleanse the data of issues which is synonymous with data cleansing. The later one is data processing, which includes data processing with multiple iterations and permutation consuming a lot of memory and other resources. These processing needs lead us in adopting Big data technologies in the entire lifecycle of the implementation. Apache Spark framework is identified as the end-to-end processing environment which is pre-loaded with redundancy, fault tolerance, in-memory processing, parallel processing, streaming, and Machine learning modules.

### 4.1 Execution with Apache Spark

"Apache Spark is a fast and general-purpose cluster computing system. It provides high-level APIs in Java, Scala, Python and R, and an optimized engine that supports general execution graphs". It also provides extensive support to Machine learning libraries(MLlib) and to streaming through Spark Streaming. The in-memory processing is implemented with the help of Resilient distributed dataset (RDD) [12].

[Figure 1 about here.]

Spark's architectures given in the figure 1 provide a glimpse of how different system in Spark is interfaced. The first level of interfacing to Spark is with high-level languages like Scala, Java, Python and R. Users implement their functionalities in these high-level languages. The primary executing components in Spark are Driver and Executor modules. The driver is the entry point for any implementation, the written programs will be executed in the main function of the Driver module, later converted to set of Directed Acyclic graph by the Spark APIs. DAGs are then executed in executors in the data nodes based on the data placement policy of the infrastructure. Four modules built on spark for serving the user's needs are SparkSQL, Spark Streaming, MLlib, and GraphX. Spark SQL and Machine Learning libraries(MLlib) are consumed in our

implementation and the future improvement would be on Spark Streaming which is used for Streaming requirements. SparkSQL and MLlib modules contain the implementation for DataFrames, SQL functionalities, and Machine learning libraries. The next level of the modules is data abstraction layer. Spark's basic data abstraction is Resilient Distributed Dataset (RDD), which is a fault tolerant partitioned data encapsulation datatype. The RDDs are lazily evaluated, hence a Directed Acyclic Graph is implemented to persist the state of the RDDs at each stage. With RDD, Spark can execute the transformation in parallel with fault tolerance. This implementation widely differentiates from conventional Python implementation which lacks this advanced logic. Apache's Spark 2.2 is used to implement all the ETL functionality. Spark is installed in the local system along with Anacondas, so Spark libraries can be consumed inside Python shell. To consume and process Pyspark libraries, sparkcontext is created which initiates the driver program. The spark context is bootstrapped with SQL and Spark session libraries so that Spark RDD and Data frames could be accessed under a single window.

As the abstract describes the necessity of the features impacting Bitcoin's price, the best metric to identify the relation between Bitcoin's price and its features is by identifying the correlation matrix provided by Charles Spearman. Spearman's function describes the relationship between two variable using a monotonic function [16]. Apart from identifying the correlation, these features can be modeled to predict the value of the dependent variable which is Bitcoin's value. The algorithm consumed for the predictions are Random forest and gradient boosted regression the Machine learning modules of Spark.

## 5 ARCHITECTURE

The architecture flow consists of three levels of components, first one is the Data extraction, second is processing and the final is visualization. The Figure 2 describes how the implementation is fitted over Spark's architecture. The logical implementation starts with extracting the data from the source and loading it over RDDs. With RDDs on the base, source data is validated for data miss and anomalies. With RDDs, all validation happens in parallel irrespective of any volume or variety of data. As RDDs are hash partitioned by default, it can consume any volume or type of data with consistent efficiency. Upon loading into RDDs, it is transformed to named columns as Dataframes which are indexed and more efficient in processing structured data. Pyspark dataframe is selected to increase the performance of the data processing even though Pyspark dataframe API is not equipped with rich functionalities similar to Pandas dataframe and Pyspark dataframe can execute the transformations in parallel whereas Pandas cannot. Machine learning algorithms are implemented over the Dataframes and generated model is executed and persisted as array objects for visualization.

[Figure 2 about here.]

### 5.1 Technologies

Technology stacks used in our implementation are,

- Python 2.7
- Pyspark 2.2
- Jupyter 5.0.0

## 5.2 Data Extraction

The data is sourced from Quandl.com, a public data service for various types of data, Bitcoin's mining data from 2015 till current date from Coinbase's mining pool. The data is in CSV format with Bitcoin's transaction details and its corresponding date associated with it.

The second set of data is from Etherscan, an open source portal for Ethereum transaction details, from which the transaction count and the price in US dollars are extracted. The third dataset is about the people's trends on Bitcoin's popularity from Google, the granularity of this data is on weekly basis, hence it has to be transformed statistically to fit into our model.

The first data set is programmatically downloaded with an API call with a private key authenticating it. `wget` is used in downloading the data within Shell script. The later ones are downloaded manually from Google and Etherscan sites manually. The volume of the dataset is low, however, the volume increases as the consumption are initiated in real-time.

[Figure 3 about here.]

Figure 3 describes the snapshot layout of one of the source data. It has 8 columns about the Bitcoin statistics segregated on per day basis. The first column is the date at which the other columns are recorded, the second is the opening price of the Bitcoin compared to USD on that day, likewise third, fourth and fifth columns pertain to high, low and closing rates of Bitcoin. The sixth column represents BTC's transaction count on that day and seventh is the volume in terms of USD value, at last is the weighted price

[Figure 4 about here.]

[Figure 5 about here.]

[Figure 6 about here.]

Figures 4, 5, 6 are the other features gathered from Google and Ethereum's mining pool.

## 5.3 Data Cleansing

The data cleansed with multiple Python and feature cleansing libraries in Python and Pyspark. Major efforts of cleansing are needed to standardize the date columns from all the data sources. The date format was in the different format in different sources. To stitch back all the data points, Date Time libraries were used and joined with a single standard format. Another important activity in the cleansing is data miss. For some instance, the values are missing resulting in incorrect predictions and correlations. To resolve these missing values, Imputer [13] functionality is used from feature library of Apache Spark. The imputer is an Imputation estimator for completing missing values, either using the mean or the median of the columns in which the missing values are located. The input to this function is dataframe columns and output are renamed dataframe columns. The processing happens in-memory with the spark.

## 5.4 Data Visualization

The visualization is provided in the form of static plots. Static plots are built-dimensional plots and scatter plots to represent correlation and projections.

## 6 SPEARMAN'S CORRELATION

Spearman's correlation function is used to identify the correlation between Bitcoin's price and the features selected. In Spark, a separate function is defined to calculate Spearman's correlation. The input is in Pyspark RDD's and the output value is returned between -1 to +1. The positive ratio indicates the feature is directly proportional and the negative values indicate indirect proportionality.

Spearman's Correlation on the selected features are :

- BTC-volume :0.348540857386
- High :0.998581861669
- Low :0.995190604708
- Open :0.997943642437
- Google-trend:0.260343238604
- ETH price :0.68683414787
- ETHTRAN :0.720031468617
- BTC-price-Label:1.0

Per Spearman's correlation algorithm, highest correlations with Bitcoin's price are with trading data like High, low and Opening values of Bitcoin. The second highest correlation is with the Ethereum's transaction data. The least ones are Google's trend and Bitcoin's own transaction volumes. These features are selected and used for the pattern analysis and prediction with regression algorithms.

[Figure 7 about here.]

The Figure7 describes the growth pattern between Bitcoin transaction count and its value. The y-axis is the count of Bitcoin's transactions and the x-axis is the date progression, it means day 0 on considered as the July 30,2015 and the next day is considered as 1. What is inferred from the correlation is that the volatility of the transactions increased as the price increases and in other perspective the transaction counts are moderately consistent even though the value is increasing which means some other feature impacting the price more than the number of transactions.

[Figure 8 about here.]

[Figure 9 about here.]

[Figure 10 about here.]

The Figures 8,9 and 10 describes the growth pattern between open, low and high prices of Bitcoin on the recorded date. The x-axis is date progression and the y-axis is the value of Bitcoin's price and Bitcoin's highest, opening and lowest price on that day. This is obvious that these prices are highly correlated with the price change.

[Figure 11 about here.]

The figure 11 describes the pattern between the Google search trend and the hike in Bitcoin's price, the x-axis in the Date progression and the y-axis defines the counts of the features.

[Figure 12 about here.]

[Figure 13 about here.]

Figure 12 and 13 describes the growth trend of Ethereum's price and its transaction volumes with Bitcoin's price in which the transaction pattern of Ethereum is more similar to Bitcoin's pattern.

As far as processing is concerned, all the RDDs are cached before feeding into Spearman's correlation function, the reason being,

when the RDDs are transformed multiple times, it has to calculate data lineage every time it is computed and lineage is the basic quality of resilience in Apache Spark. If the RDDs are cached and persisted in-memory, the iteration and other transformations happen in memory avoiding costly I/O operations, this feature cannot be easily implemented when executed in conventional python libraries.

## 7 DECISION TREE REGRESSION

With the availability of features, we can take the processing to the next level of predicting Bitcoin's price. Here, supervised learning model is used to predict the price of Bitcoin.

[Figure 14 about here.]

Figure 14 give some basic idea of how decisions are made with the supervised decision tree based model.

Ensemble method models are derived from another base model. The base model used here is Decision trees and ensemble models are Random forest and Gradient Boosted tree(GBT) Algorithms.

Though the base model for both the algorithms is same, both are different in terms of training the dataset. GBT can train only one tree at a time whereas Random forest can train multiple trees resulting in reduced overfitting caused by GBTs.

"Random forests or random decision forests operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of mean prediction (regression) of the individual trees and GBTs iteratively train decision trees in order to minimize a loss function. Like decision trees, GBTs handle categorical features, extend to the multiclass classification setting, do not require feature scaling, and are able to capture non-linearities and feature interactions" [14].

All the execution is implemented in Apache Spark, hence all the transformation and processing happens in-memory, even if the data volume is high, the processing will spawn across the clusters and will be processed with consistent redundancy.

The model is implemented by first splitting the data into two sets of different volume, i.e test data and training data. The training data will be used by the model to derive the logic and the built logic will be tested with the test data for accuracy. Here, 70:30 ratio is selected for training and test data respectively. And by altering this ratio we can adjust the performance of the model. Upon completion of the modeling, the accuracy of the models is calculated based on Metrics library in Spark. The metrics identified for the accuracy calculations are mean Squared Error, Root Mean Squared Error, r-square and mean Absolute error. Mean Squared error can be defined as an estimator to measures the average of the squares of the errors or deviations [15]. "R-squared is a statistical measure of how close the data are to the fitted regression line. It is also known as the coefficient of determination, or the coefficient of multiple determination for multiple regression" [4].

### 7.1 Random Forest

As we are predicting Bitcoin's USD value per day, Bitcoin's price is considered as a label and all other columns are marked as features, and only the features having a decent level of correlation is marked as Features. These features are loaded into the model with Labelled Points as a Spark dataframe.

Random forest requires parameters to tune the model for the highest accuracy.

The parameters used in the functions are [1] :

- Training dataset: RDDs as LabeledPoint
- NumTrees: Number of trees in the random forest
- FeatureSubsetStrategy: Number of features to consider for splits at each node
- Impurity: Criterion used for information gain calculation
- MaxDepth: Maximum depth of tree
- MaxBins: Maximum number of bins used for splitting features
- Seed: Random seed for bootstrapping and choosing feature subsets

The first parameter is the training dataset, the training datasets are constructed as LabelledPoint RDDs, the LabelledPoint RDD is a local vector associated with a label, it acts as a optimized data structure for datasets with association. The next one is the number of trees allowed to construct in the algorithm, as the decision tree is based on deriving mean of multiple decision trees, in general, more trees gives better results. However, the improvement decreases as the number of trees increase more than the threshold of the given dataset. Hence, number of trees selected is 10, which gives us better efficiency. The FeatureSubsetStrategy defines how the features are sampled at each split in a tree, we have selected *auto*, so the algorithm will take care of the split. The Impurity parameter is the criteria followed for Information gain calculation, *variance* is the default considered by Spark. The next parameter is MaxDepth, which defines the limit of the depth of the tree, beyond which decision tree will not be extended, the maximum depth allowed in Spark is 30. The next one is MaxBins, which describes the number of bins used for splitting which we have defaulted and the last one is Seed parameter, which induces randomness while multiple trees are created which is defaulted as well.

With all parameters were carefully selected and the model is tuned to give the highest accuracy, Avg.closeness index of the algorithm is closer to 0.95. After deriving the model, the closeness/correctness of the predicted results was also analyzed and it is described in the plot 15.

### 7.2 Gradient Boosted Tree

In the Gradient Boosted algorithm, the training and test data are used in similar to the Random Forest algorithm. The implementation is less complex compared with Random forest. As GBT trains the model based on iterative execution of sequence of decision trees. Upon execution of three iterations, it is clearly evident with the closeness index that the data is little bit over-fitted with the closeness index of 0.96, slightly greater than Random forest.

The parameters used in the functions are [1] :

- Training dataset: RDDs as LabeledPoint
- CategoricalFeaturesInfo: A Map of categorical features
- Loss Function: Loss function used for minimization during gradient boosting
- NumIterations: Number of iterations of boosting
- LearningRate: Learning rate for shrinking the contribution of each estimator
- MaxDepth: Maximum depth of tree

- MaxBins: Maximum number of bins used for splitting features.

Similar to Random Forest, the first parameter is LabelledPoint RDD, the second one the map of categorical features. Most important parameters used in GBT's functionality are Loss function, NumIterations and Learning rate. Loss function selected is *least-SquaresError*. Number iteration is the number of times the tree is iterated to derive the result, the default value of 100 is selected. The learning rate is optional which is defaulted to 0.1 in Spark.

By altering these parameters, the performance and the decision of the model can be optimized. The alteration includes thorough analysis of the data consists of data gap analysis and feature transformation. By selecting the default parameters, the output decision tree tend to perform better in the selected scenario.

## 8 RESULTS

From the observation of scatter plots of regression model Random forest 15 and GBT 16, it is evident that GBT's single tree iterative model has predicted the values with over-fitting. Some predicted values are consistent with some particular time scope and changes happening in steps. The prediction distribution looks like a single line and not widespread. Whereas, in the Random forest, the predicted values are widespread and closely aligned.

[Figure 15 about here.]

[Figure 16 about here.]

We have came up with a metric called *Closeness indicator*, which tells us mean ratio of test and predicted label. If it is less than 100, then the predicted value is less than the actual and if it is more than 100, then the predicted value is more than the actual value. For both algorithms, the closeness index is near 100%, hence both predictions achieved optimal results. Other important metric includes r-square values which above 95% in both the cases, hence our model fits with the expectation and the parameter selected for the algorithm holds good.

## 9 CHALLENGES FACED

Most of the challenges are with the data and casting to the required data types as the correlation and regression functions need data either in float or double data types. The other challenge faced is the data source availability, though the Bitcoin network is open to the public, gathering all the statistics data from all the mining pool available in BTC infrastructure is tedious. And, in the Bitcoin network, we do not know which user performs the transaction, we have no open option to classify the user and identify the feature inducing that transaction. Due to the void of these inducing factors, we may need to assume few features and start the analysis with the correlation. And handling all these constraints along with Big data specifics in mind adds up to the challenge, thanks to Apache Spark which handles the data lineage and persistence through RDDs.

## 10 PROJECT STRUCTURE

Three folders are created, the first one is for scripts which retain the actual code to be executed and two Korn shell scripts to install dependencies and to download the required source files. The second one is the data folder which retains the data required for the model

and correlation algorithm. The extract folder is to persist the plot figures extracted out of the python script. The versioning and multiuser synchronization is supported by Git.

## 11 IMPROVEMENT OPPORTUNITIES

There are a lot of improvement opportunities to be implemented in the project. One of them includes fetching the data in near real-time directly from the Mining-pool instead of a third party data service, the second one would be increasing the granularity of data which would increase the performance and the Spark would make more sense with that level of granularity and volume. The other improvement opportunities include gathering more features like illegal market transaction data, mining exchange data, wallet exchange data, world's inconsistency data which will increase correlation factors and result in the accurate prediction of models. Other visualization opportunity includes real-time presentation capabilities with Big Data at the back end. Matplot API has minimal options for real-time reporting which can be upgraded. Other important improvement opportunity includes implementing the prediction logic with Neural network based models like Long Short-Term Memory(LSTM) as decision tree based models sometimes fail to adapt to the changes based on their past experience. These LSTM based model keep the memory of the previous experience and improve the learning upon training.

## 12 CONCLUSION

After the analysis of the Bitcoin data, the Bitcoin transaction count does not impact the Bitcoin's value which proves that the users are not using the Bitcoin for any day to day transactions instead they are exchanging it with US Dollars and saving as an asset like Gold. By retaining it, the demand for the Bitcoin coin increases. As the new-coins can only be generated through mining and the growth is controlled, coins in circulation keep reducing, increasing its cost further. It clearly proves that Bitcoin bought are saved in the wallets are not used in the regular transaction much. Most of the Bitcoin's are retained to earn the profit over its demand and its price variation with US Dollars. Other important inference is that the exchange rate of Ethereum is changing along with Bitcoin's, the only possibility of close correlation is the exchange of both the currencies. By logically linking the findings, people are using Bitcoin as an asset and using other cryptocurrencies as the transaction medium exchanged from Bitcoin's market instead of directly from the US Dollar market.

With all prowess of Big Data and its technologies, Blockchain technologies are not only evolving, it also equips humans with the opportunity to make the world more transparent, ethical and a viable place to live. As the technology has evolved so far, it is expected to understand its growth story in terms of its microscopic level to push it to the next level of improvement. Such microscopic level of qualities was missed in legacy methods and Big Data comes to the rescue in identifying those qualities and nurture them.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski for his support and suggestions to write this paper.

## REFERENCES

- [1] Apache.org. 2017. pyspark.mllib package fi? PySpark 2.2.0 documentation. (2017). <https://spark.apache.org/docs/2.2.0/api/python/pyspark.mllib.html#pyspark.mllib.tree.RandomForestModel> (Accessed on 12/01/2017).
- [2] bitcoinmining.com. 2011. The Best Bitcoin Mining Pools For Making Money. (2011). <https://www.bitcoinmining.com/bitcoin-mining-pools/>
- [3] Etherscan.io. 2017. Ethereum Transaction Growth Chart. (2017). <https://etherscan.io/chart/tx>
- [4] Jim Frost. 2013. Regression Analysis: How Do I Interpret R-squared and Assess the Goodness-of-Fit. (May 2013). <http://blog.minitab.com/blog/adventures-in-statistics-2/regression-analysis-how-do-i-interpret-r-squared-and-assess-the-goodness-of-fit>
- [5] GDAX. 2017. Bitcoin Exchange – Ethereum Exchange – Litecoin Exchange – GDAX. (Dec 2017). <https://www.gdax.com/>
- [6] Michael Hendricks. 2011. 21 million cap. (2011). <https://bitcointalk.org/index.php?topic=3366.msg47522=msg47522>
- [7] Alphabet INC. 2017. bitcoin - Explore - Google Trends. (2017). <https://trends.google.com/trends/explore?q=bitcoin>
- [8] Satoshi Nakamoto. 2008. *Bitcoin: A Peer-to-Peer Electronic Cash System*. Technical Report. bitcoin.org. 9 pages. <https://bitcoin.org/bitcoin.pdf>
- [9] quandl. 2016. Search – Quandl. (2016). <https://www.quandl.com/search?query=>
- [10] AojiaZhao saacMadan, ShauryaSaluja. 2016. Automated Bitcoin Trading via Machine Learning Algorithms. paper. (2016).
- [11] Nimisha Sharath Sharma. 2017. Apache Spark: Scala via Python! – Nimisha Sharath Sharma – Pulse – LinkedIn. (Apr 2017). <https://www.linkedin.com/pulse/apache-spark-scala-via-python-nimisha-sharath/> (Accessed on 12/01/2017).
- [12] Spark. 2016. Overview - Spark 2.2.0 Documentation. (2016). <https://spark.apache.org/docs/latest/>
- [13] Apache Spark. 2016. pyspark.ml package fi? PySpark 2.2.0 documentation. (2016). <http://spark.apache.org/docs/2.2.0/api/python/pyspark.ml.html>
- [14] Apache Spark. 2017. Ensembles - RDD-based API - Spark 2.2.0 Documentation. (2017). <https://spark.apache.org/docs/2.2.0/mllib-ensembles.html>
- [15] Wikipedia. 2017. Mean squared error - Wikipedia. (2017). [https://en.wikipedia.org/wiki/Mean\\_squared\\_error](https://en.wikipedia.org/wiki/Mean_squared_error)
- [16] Wikipedia. 2017. Spearman's rank correlation coefficient - Wikipedia. (2017). [https://en.wikipedia.org/wiki/Spearman%27s\\_rank\\_correlation\\_coefficient](https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient)
- [17] WolfeZhao. 2017. *OSTK to HODL: Overstock to Keep 50% of All Bitcoin Payments as Investments - CoinDesk*. Technical Report. coindesk. <https://www.coindesk.com/ostk-hodl-overstock-keep-50-bitcoin-payments-investments/>
- [18] Xoom.inc. 2017. XE Money Transfer Tips: Why Do Currencies Fluctuate. (2017). <http://www.xe.com/moneytransfertips/why-do-currencies-fluctuate.php>
- [19] Xiaoyong Zhu. 2017. Running XGBoost on Azure HDInsight fi?! Azure Data Lake & Azure HDInsight Blog. (Aug 2017). <https://blogs.microsoft.com/azuredatalake/2017/08/18/running-xgboost-on-azure-hdinsight/> (Accessed on 12/01/2017).

## LIST OF FIGURES

1	Spark Architecture [11]	8
2	Project Architecture on Spark [19]	9
3	Bitcoin mining statistics data [9]	9
4	Google's trend data [7]	10
5	Ethereum's pricing on daily basis [3]	10
6	Ethereum transactions on daily basis [3]	10
7	Bitcoin Transaction and USD value	11
8	Bitcoin Highest exchange value and Closing value	12
9	Bitcoin Lowest exchange value and Closing value	13
10	Bitcoin Opening exchange value and Closing value	14
11	Bitcoin USD value and Google search trend	15
12	Ethereum price and Bitcoin price	16
13	Ethereum Transaction volume and Bitcoin transaction volume	17
14	Sample Decision tree [1]	18
15	Randomforest Scatterplot	19
16	Gradient Boosted Tree Scatterplot	20

# Spark Architecture



Figure 1: Spark Architecture [11]

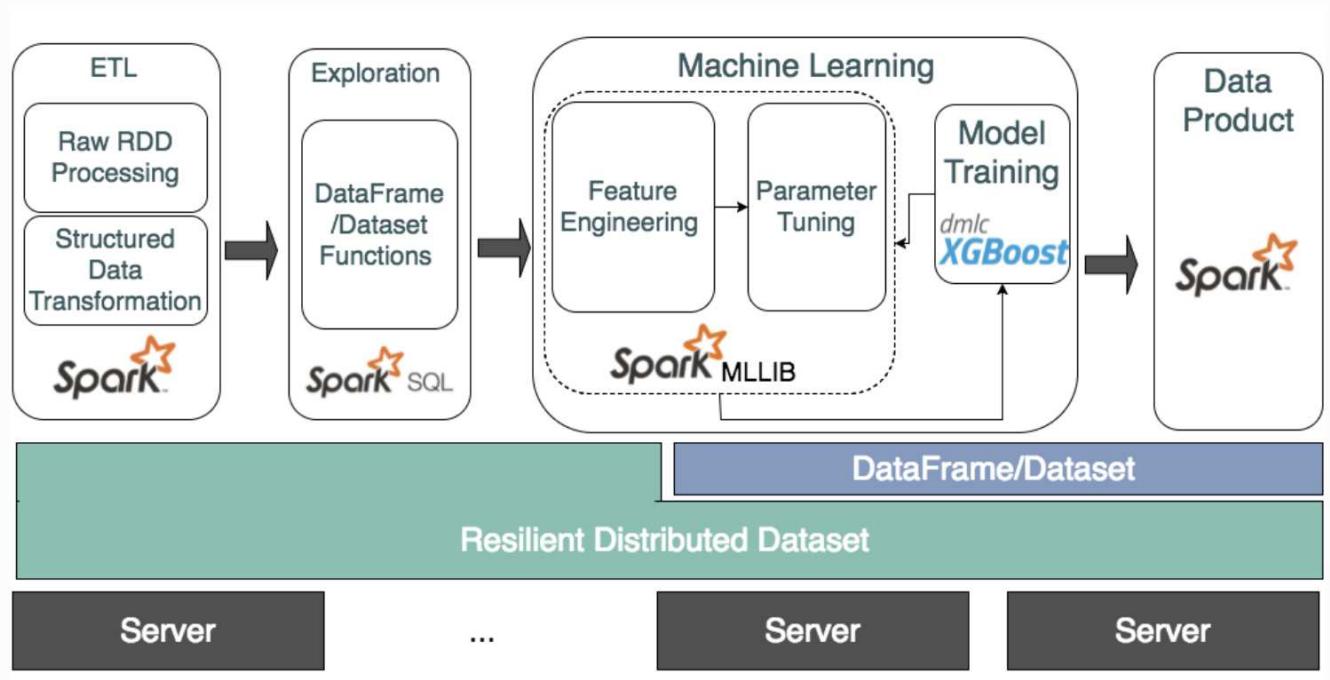


Figure 2: Project Architecture on Spark [19]

Date,Open,High,Low,Close,Volume (BTC),Volume (Currency),Weighted Price  
 2017-11-29,9949.0,9949.0,9945.96,9945.97,20.29785801,201905.011261,9947.10925468  
 2017-11-28,9768.71,9989.95,9705.99,9949.0,18393.0818191,181959821.389,9892.84031783  
 2017-11-27,9401.11,9795.0,9401.01,9768.71,24642.0982679,237829776.608,9651.36061153  
 2017-11-26,8795.5,9596.0,8795.5,9401.11,27568.0196716,253816538.997,9206.91954012  
 2017-11-25,8215.01,8795.5,8203.98,8795.5,16239.7909316,138404574.912,8522.55891071  
 2017-11-24,8031.16,8324.0,7900.0,8215.01,14213.6286885,116296487.968,8182.04066794  
 2017-11-23,8250.0,8274.98,8031.16,8031.16,11685.6896442,95602227.3138,8181.13694823  
 2017-11-22,8109.0,8298.98,8103.13,8250.0,13107.9400888,107439055.55,8196.48661974  
 2017-11-21,8256.01,8375.0,7802.99,8109.0,29504.8066982,239617882.069,8121.31679154  
 2017-11-20,8031.83,8293.25,7969.0,8256.01,15479.8961619,126479984.708,8170.59645525  
 2017-11-19,7777.01,8098.62,7700.0,8031.82,14085.4833982,111595386.42,7922.72322253  
 2017-11-18,7714.7,7847.98,7502.0,7777.01,14531.7006631,111676672.782,7685.03806756  
 2017-11-17,7838.54,7988.5,7536.0,7714.71,23950.8477411,187290409.41,7819.78205677  
 2017-11-16,7294.0,7985.37,7130.0,7838.53,28404.999214,214993745.259,7568.8699598  
 2017-11-15,6605.0,7349.0,6605.0,7294.0,27327.1284653,193024708.734,7063.48305052  
 2017-11-14,6535.87,6748.0,6464.64,6605.0,19505.257774,128729345.115,6599.72539747  
 2017-11-13,5886.35,6841.45,5850.0,6535.87,35150.8905255,224596217.133,6389.4886808  
 2017-11-12,6216.64,6106.0,5511.11,5806.25,10610.2257667,200525162.810,6017.41672071

Figure 3: Bitcoin mining statistics data [9]

```

2012-12-02,1
2012-12-09,1
2012-12-16,1
2012-12-23,1
2012-12-30,1
2013-01-06,1
2013-01-13,1
2013-01-20,1
2013-01-27,1
2013-02-03,1
2013-02-10,2
2013-02-17,2
----- -- - -

```

Figure 4: Google's trend data [7]

```

Date(UTC),UnixTimeStamp,Value
7/30/2015,1438214400,0.00
7/31/2015,1438300800,0.00
8/1/2015,1438387200,0.00
8/2/2015,1438473600,0.00
8/3/2015,1438560000,0.00
8/4/2015,1438646400,0.00
8/5/2015,1438732800,0.00
8/6/2015,1438819200,0.00
8/7/2015,1438905600,3.00
8/8/2015,1438992000,1.20
8/9/2015,1439078400,1.20
8/10/2015,1439164800,0.00
8/11/2015,1439251200,0.99
8/12/2015,1439337600,1.29
8/13/2015,1439424000,1.88

```

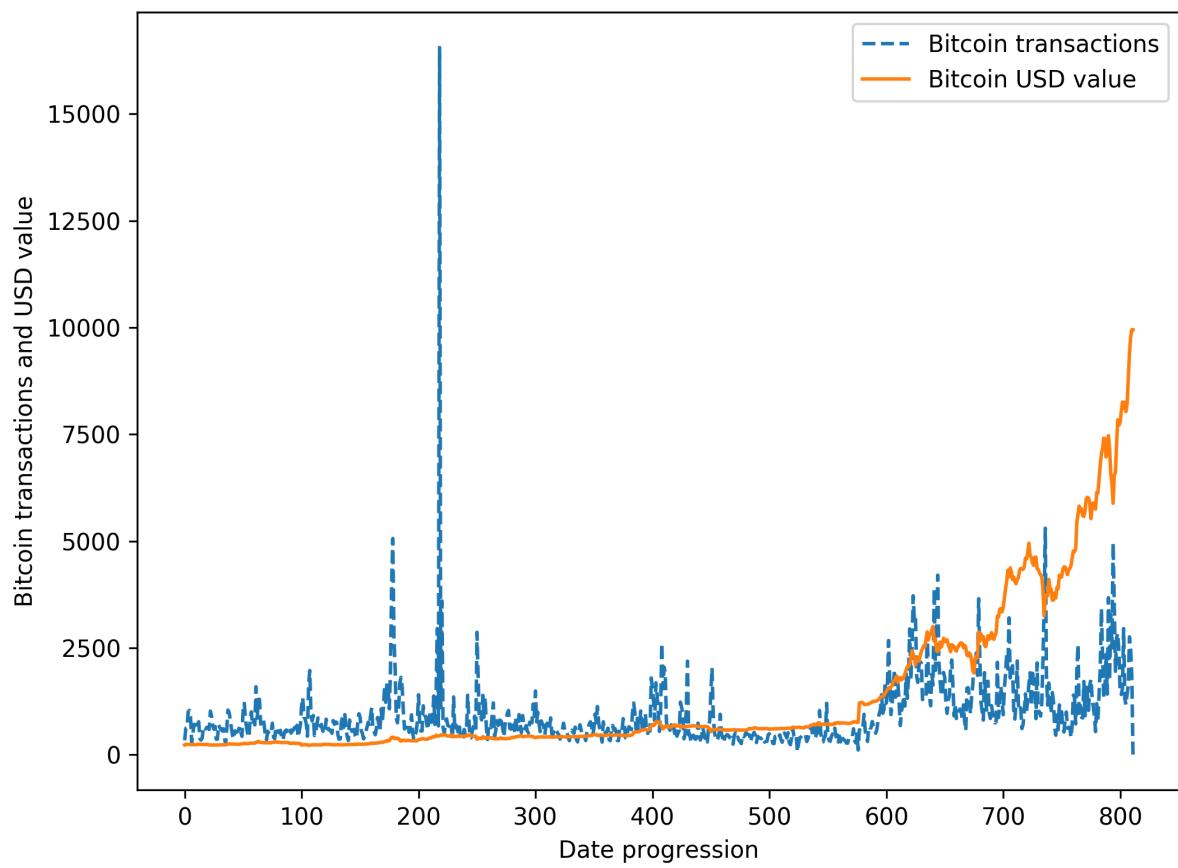
Figure 5: Ethereum's pricing on daily basis [3]

```

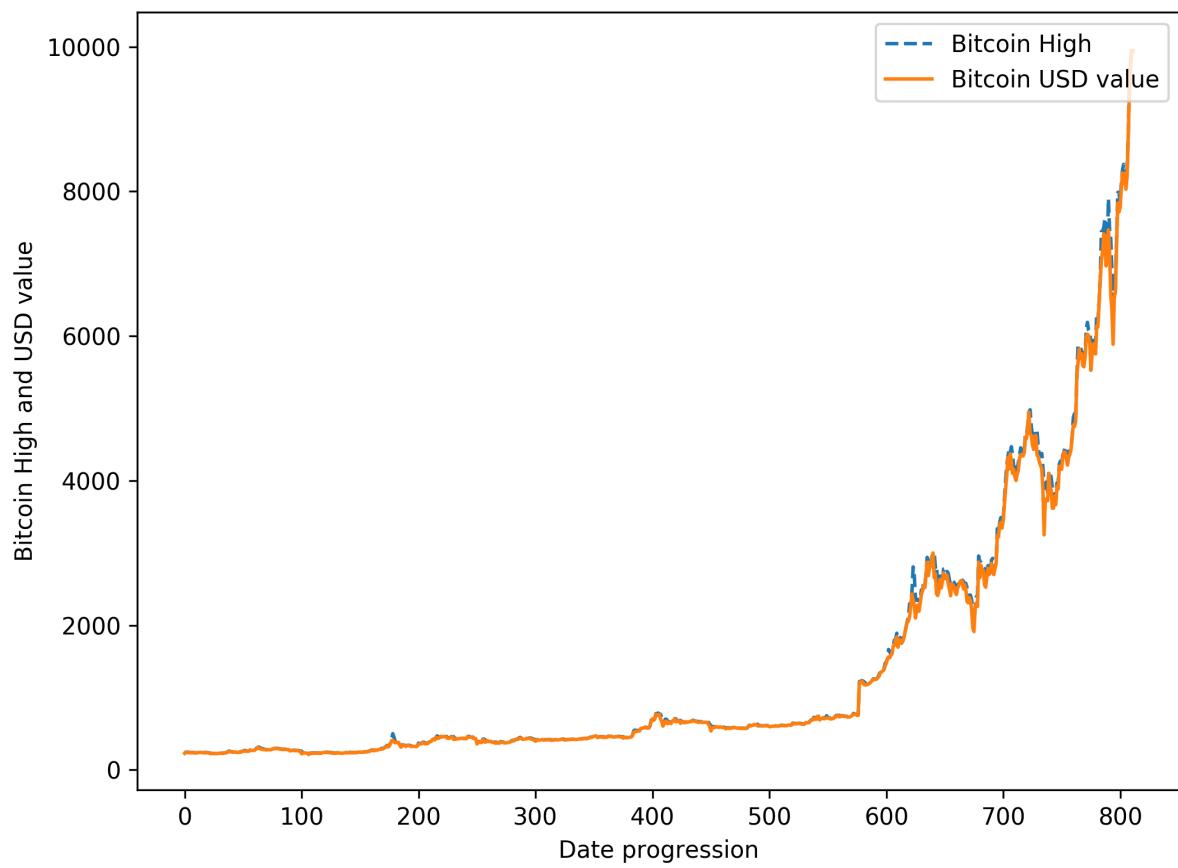
Date(UTC),UnixTimeStamp,Value
7/30/2015,1438214400,8893
7/31/2015,1438300800,0
8/1/2015,1438387200,0
8/2/2015,1438473600,0
8/3/2015,1438560000,0
8/4/2015,1438646400,0
8/5/2015,1438732800,0
8/6/2015,1438819200,0
8/7/2015,1438905600,2050
8/8/2015,1438992000,2881
8/9/2015,1439078400,1329
8/10/2015,1439164800,2037
8/11/2015,1439251200,4963
8/12/2015,1439337600,2036
8/13/2015,1439424000,2842

```

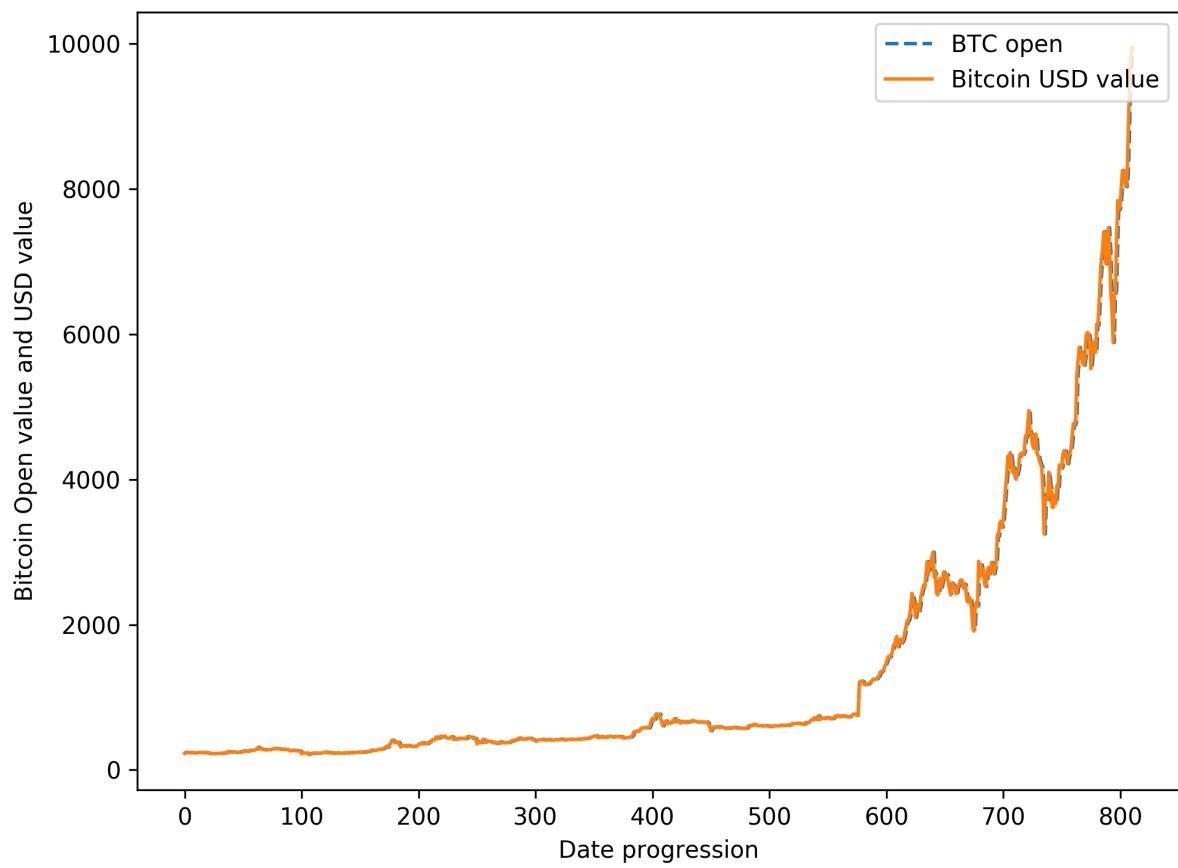
Figure 6: Ethereum transactions on daily basis [3]



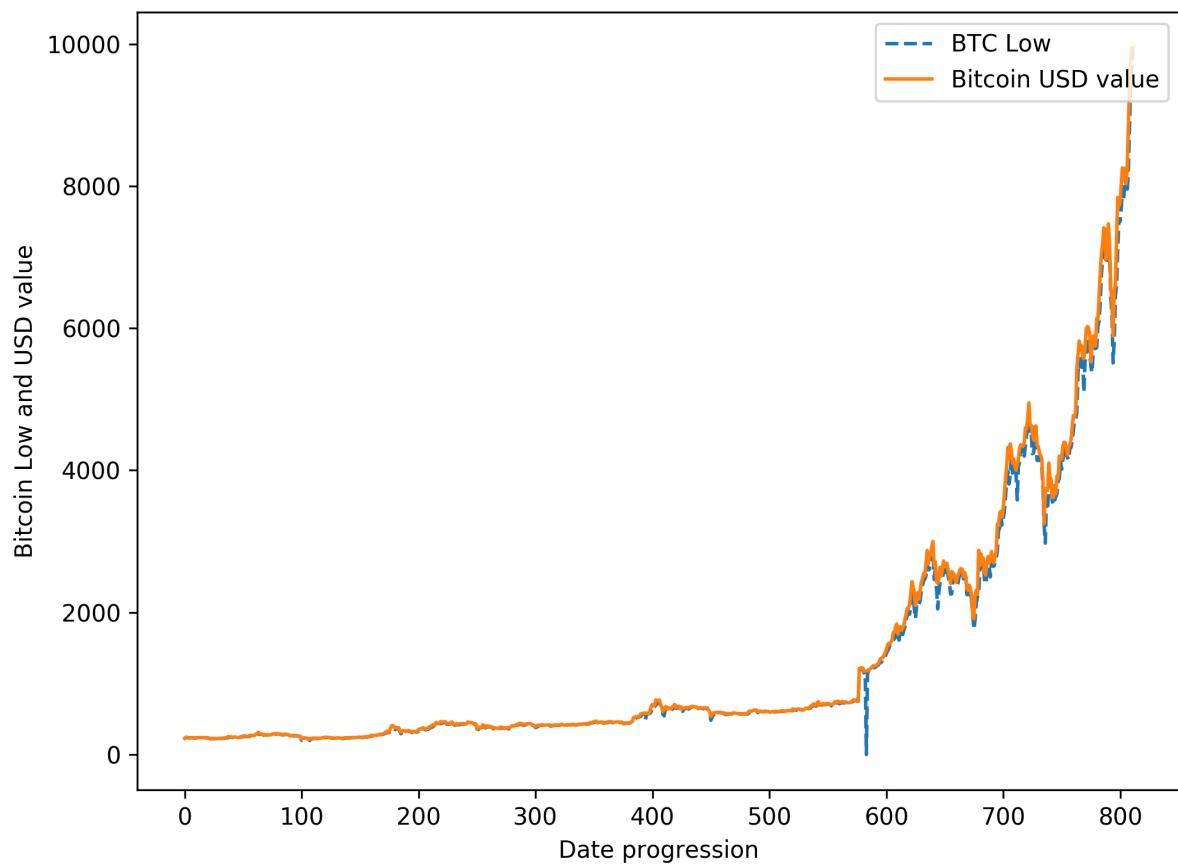
**Figure 7: Bitcoin Transaction and USD value**



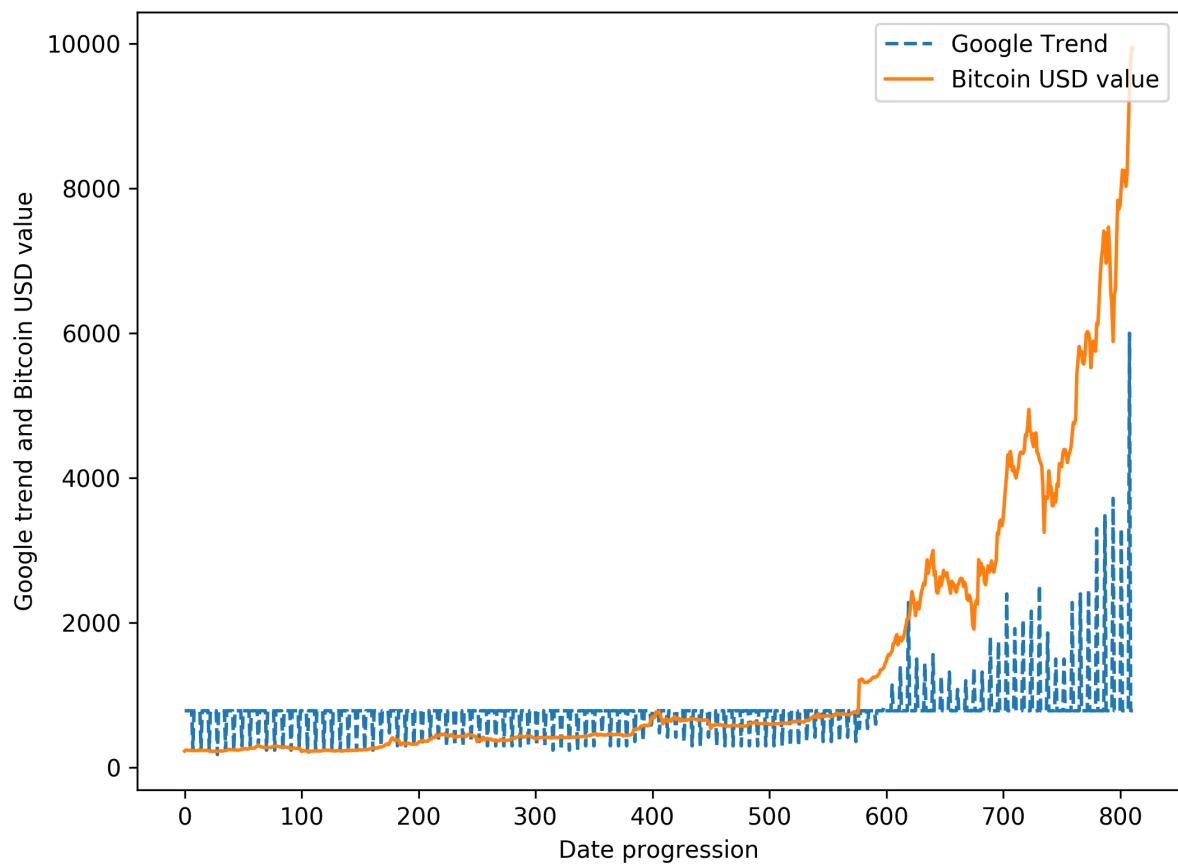
**Figure 8: Bitcoin Highest exchange value and Closing value**



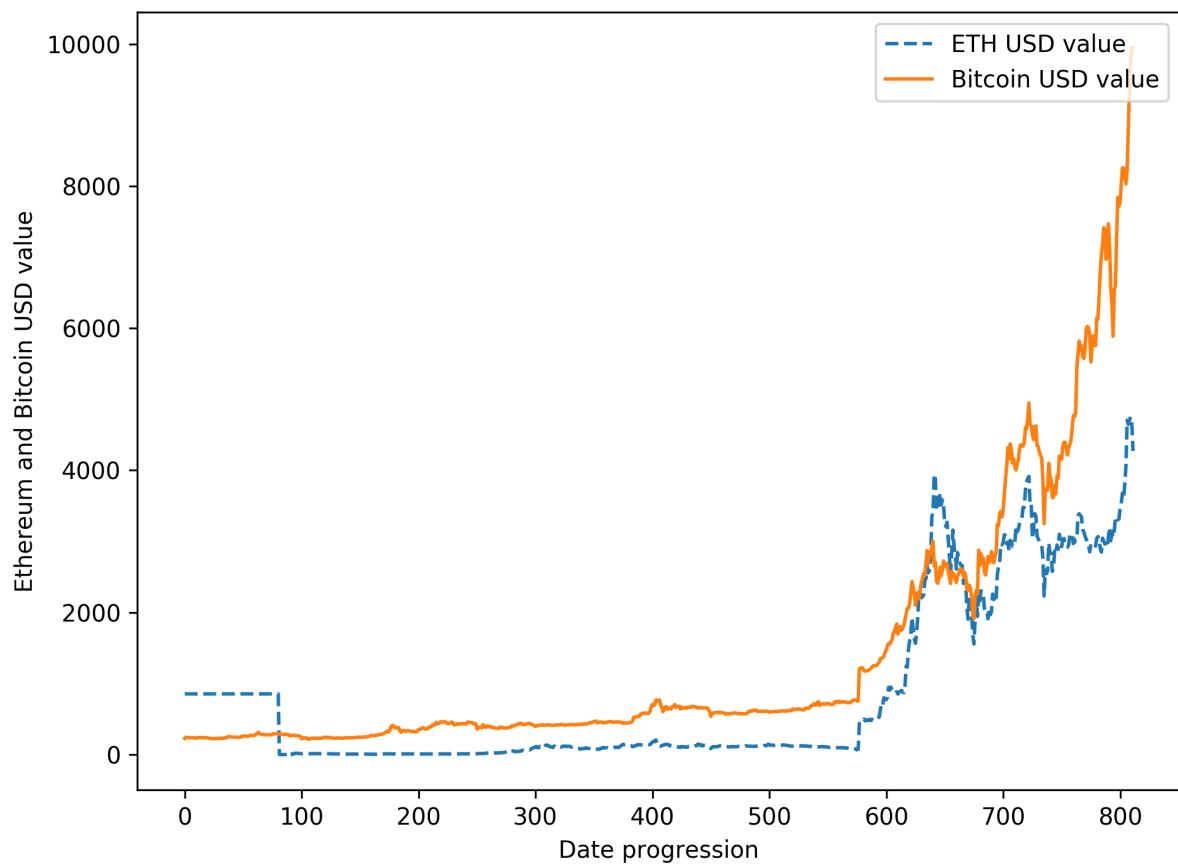
**Figure 9: Bitcoin Lowest exchange value and Closing value**



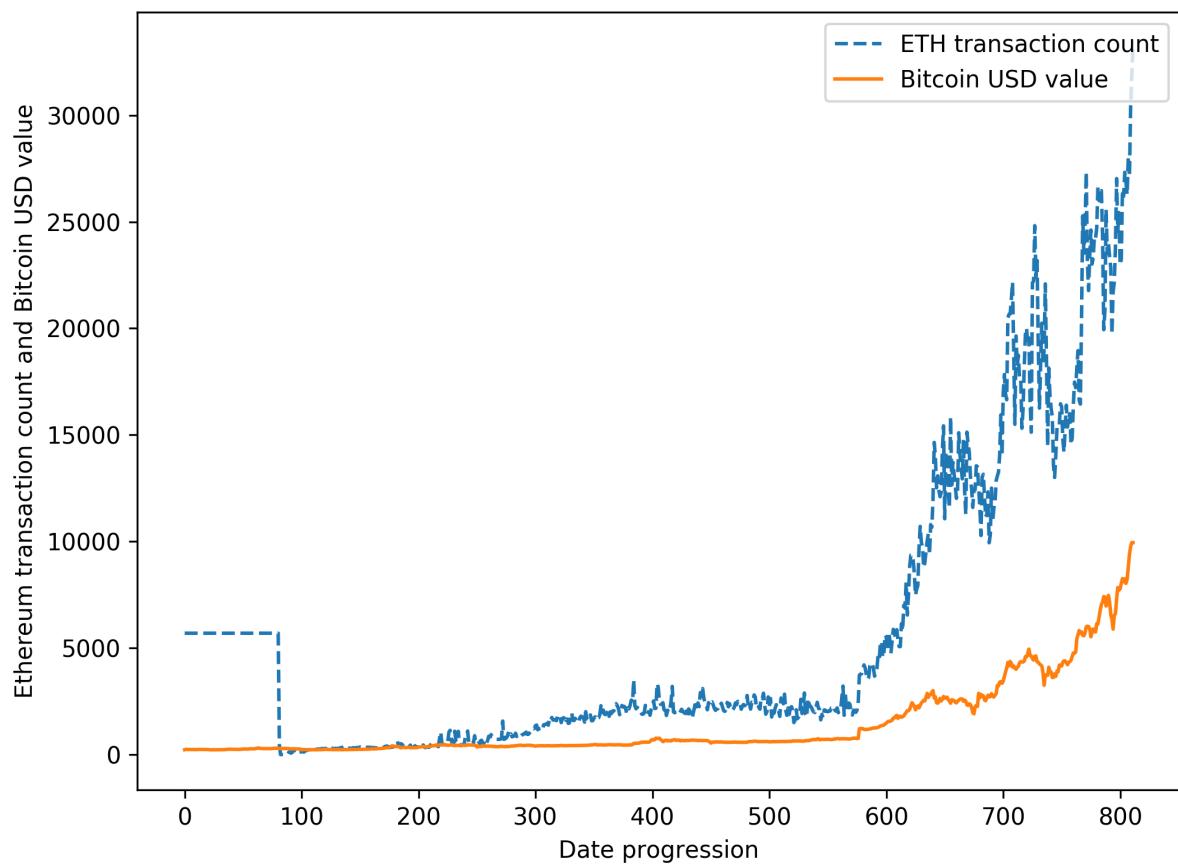
**Figure 10: Bitcoin Opening exchange value and Closing value**



**Figure 11: Bitcoin USD value and Google search trend**



**Figure 12: Ethereum price and Bitcoin price**

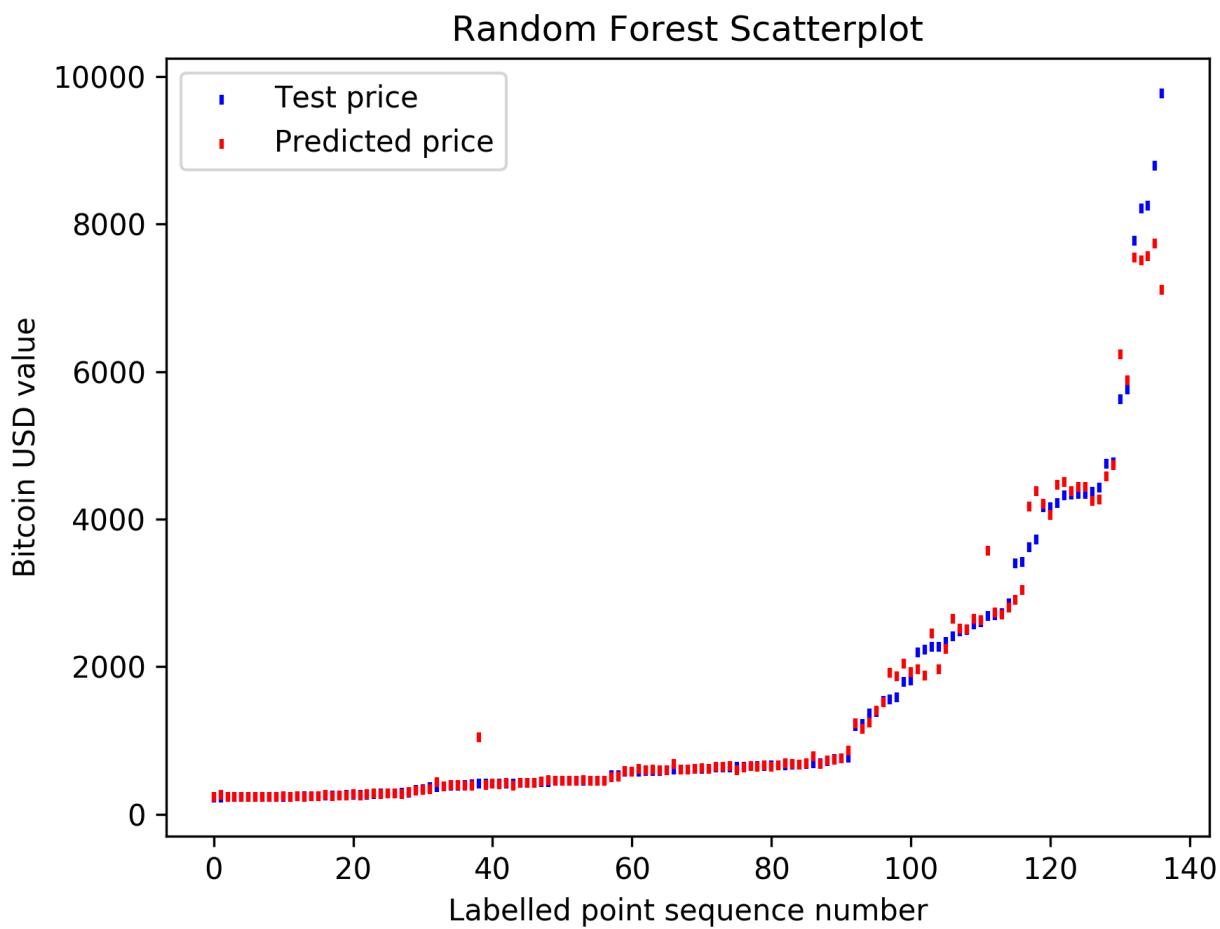


**Figure 13: Ethereum Transaction volume and Bitcoin transaction volume**

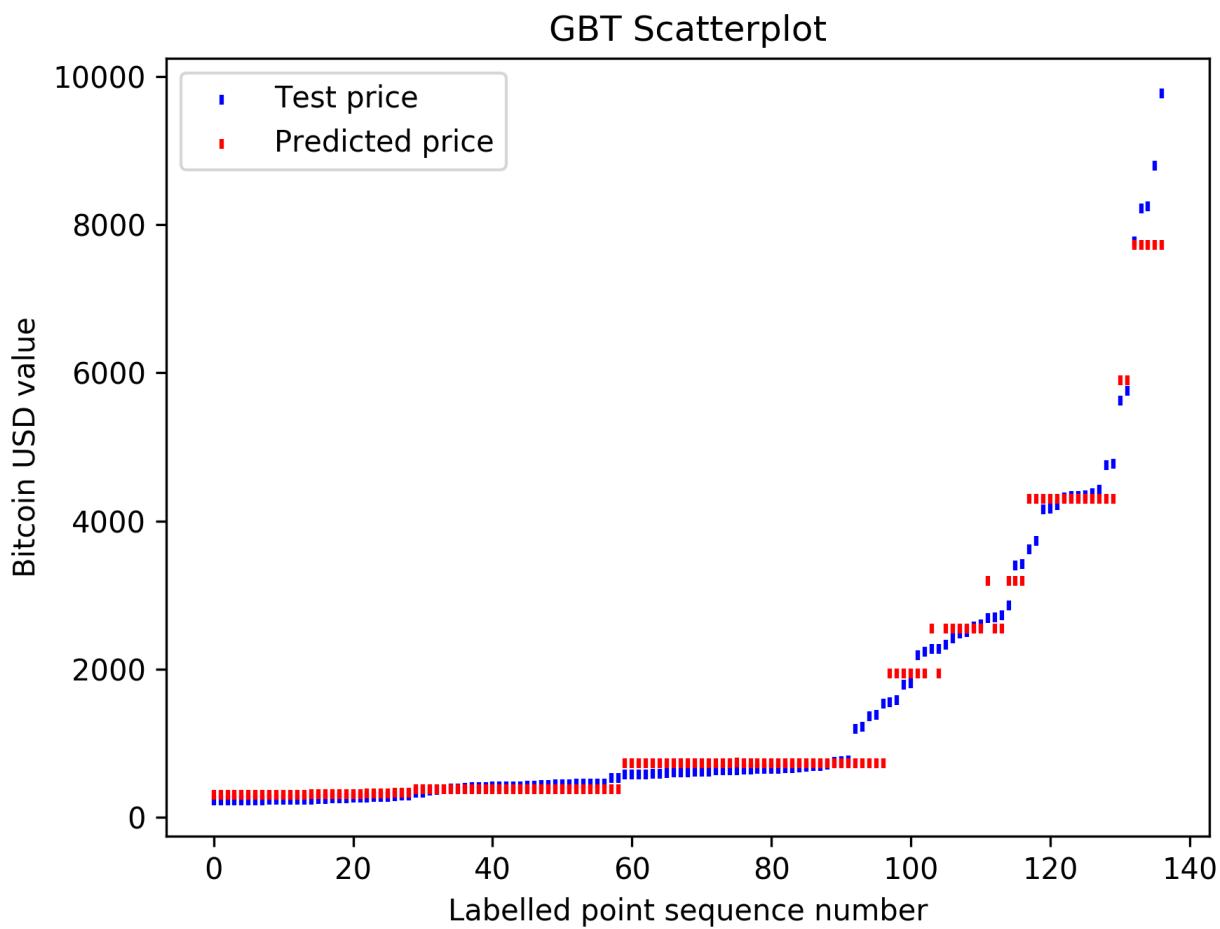
```
TreeEnsembleModel classifier with 3 trees

Tree 0:
    Predict: 1.0
Tree 1:
    If (feature 0 <= 1.0)
        Predict: 0.0
    Else (feature 0 > 1.0)
        Predict: 1.0
Tree 2:
    If (feature 0 <= 1.0)
        Predict: 0.0
    Else (feature 0 > 1.0)
        Predict: 1.0
```

Figure 14: Sample Decision tree [1]



**Figure 15: Randomforest Scatterplot**



**Figure 16: Gradient Boosted Tree Scatterplot**

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
=====
bibtext _ label error
```

```
=====
report.bib:93: AUTHOR1_EMAIL = {satoshin@gmx.com},
```

```
=====
bibtext space label error
```

```
=====
report.bib:93: AUTHOR1_EMAIL = {satoshin@gmx.com},
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
[2017-12-12 20.01.39] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
Missing character: ""
Missing character: ""
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 4.7s.
./README.yml
8:81      error    line too long (142 > 80 characters)  (line-length)
20:81     error    line too long (117 > 80 characters)  (line-length)
38:81     error    line too long (388 > 80 characters)  (line-length)
```

```
=====
Compliance Report
=====
```

```
name: Ashok Kuppuraj
```

```
hid: 324
paper1: 100% Oct 31 17
paper2: 100% Nov 6 17
project: Dec 04 17 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
(null)
wc 324 project (null) 4834 report.tex
wc 324 project (null) 5031 report.pdf
wc 324 project (null) 486 report.bib
```

```
find "
```

---

60: Feature extraction, transformation, and prediction can be synonymous with a conventional ETL methodology. Though few of the extraction is handled manually and the volume is comparably low, it is assumed that the data volume will be increased by modifying the extraction to real-time systems. When the extraction systems are changed, our code must be able to handle streaming data which can be related to "variety and volume " of the data. The next step is validating the data for anomalies, data miss and cleanse the data of issues which is synonymous with data cleansing. The later one is data processing, which includes data processing with multiple iterations and permutation consuming a lot of memory and other resources. These processing needs lead us in adopting Big data technologies in the entire lifecycle of the implementation.

```
passed: False
```

```
find footnote
```

---

```
passed: True
```

```
find input{format/i523}
```

---

```
passed: False
```

```
find input{format/final}
-----
passed: False

floats
-----
66: \begin{figure}![ht]
67: \centering\includegraphics[width=\columnwidth]{images/Sparkarchic.
png}
69: \label{fig:sparkarchi}
72: Spark's architectures given in the figure \ref{fig:sparkarchi}
provide a glimpse of how different system in Spark is interfaced.
The first level of interfacing to Spark is with high-level
languages like Scala, Java, Python and R. Users implement their
functionalities in these high -level languages. The primary
executing components in Spark are Driver and Executor modules. The
driver is the entry point for any implementation, the written
programs will be executed in the main function of the Driver
module, later converted to set of Directed Acyclic graph by the
Spark APIs. DAGs are then executed in executors in the data nodes
based on the data placement policy of the infrastructure. Four
modules built on spark for serving the user's needs are SparkSQL,
Spark Streaming, MLlib, and GraphX. Spark SQL and Machine Learning
libraries(MLlib) are consumed in our implementation and the future
improvement would be on Spark Streaming which is used for
Streaming requirements. SparkSQL and MLlibs modules contain the
implementation for DataFrames, SQL functionalities, and Machine
learning libraries. The next level of the modules is data
abstraction layer. Spark's basic data abstraction is Resilient
Distributed Dataset (RDD), which is a fault tolerant partitioned
data encapsulation datatype. The RDDs are lazily evaluated, hence
a Directed Acyclic Graph is implemented to persist the state of
the RDDs at each stage. With RDD, Spark can execute the
transformation in parallel with fault tolerance. This
implementation widely differentiates from conventional Python
implementation which lacks this advanced logic.
78: The architecture flow consists of three levels of components,
first one is the Data extraction, second is processing and the
final is visualization. The Figure \ref{Architecture:project}
describes how the implementation is fitted over Spark's
architecture.
81: \begin{figure}![ht]
82: \centering\includegraphics[width=\columnwidth]{images/Projectflow.
png}
```

```

84: \label{Architecture:project}
107: \begin{figure}[!ht]
108: \centering\includegraphics[width=\columnwidth]{images/Source1data
    .png}
110: \label{fig:sourcedata}
114: Figure \ref{fig:sourcedata} describes the snapshot layout of one
    of the source data. It has 8 columns about the Bitcoin statistics
    segregated on per day basis. The first column is the date at
    which the other columns are recorded, the second is the opening
    price of the Bitcoin compared to USD on that day, likewise third,
    fourth and fifth columns pertains to high, low and closing rates
    of Bitcoin. The sixth column represents BTC's transaction count
    on that day and seventh is the volume in terms of USD value, at
    last is the weighted price
116: \begin{figure}[!ht]
117: \centering\includegraphics[width=0.18\columnwidth]{images/googled
    ata.png}
119: \label{fig:googledata}
122: \begin{figure}[!ht]
123: \centering\includegraphics[width=0.4\columnwidth]{images/ethprice
    .png}
125: \label{fig:ethpri}
128: \begin{figure}[!ht]
129: \centering\includegraphics[width=0.4\columnwidth]{images/ethtran.
    png}
131: \label{fig:ethtran}
134: Figures \ref{fig:googledata}, \ref{fig:ethpri}, \ref{fig:ethtran}
    are the other features gathered from Google and Ethereum's mining
    pool.
162: \begin{figure}[!ht]
163: \centering\includegraphics[width=\columnwidth]{images/BTC-
    prcvsBTC-trans.png}
165: \label{1}
168: The Figure\ref{1} describes the growth pattern between Bitcoin
    transaction count and its value. The y-axis is the count of
    Bitcoin's transactions and the x-axis is the date progression, it
    means day 0 on considered as the July 30,2015 and the next day is
    considered as 1. What is inferred from the correlation is that
    the volatility of the transactions increased as the price
    increases and in other perspective the transaction counts are
    moderately consistent even though the value is increasing which
    means some other feature impacting the price more than the number
    of transactions.
170: \begin{figure}[!ht]
171: \centering\includegraphics[width=\columnwidth]{images/High.png}
173: \label{2}

```

```

176: \begin{figure} [!ht]
177: \centering\includegraphics[width=\columnwidth]{images/Open.png}
179: \label{3}
182: \begin{figure} [!ht]
183: \centering\includegraphics[width=\columnwidth]{images/low.png}
185: \label{4}
188: The Figures \ref{2},\ref{3} and \ref{4} describes the growth
    pattern between open, low and high prices of Bitcoin on the
    recorded date.
191: \begin{figure} [!ht]
192: \centering\includegraphics[width=\columnwidth]{images/googletrend
    .png}
194: \label{5}
197: The figure \ref{5} describes the pattern between the Google
    search trend and the hike in Bitcoin's price, the x-axis in the
    Date progression and the y-axis defines the counts of the
    features.
199: \begin{figure} [!ht]
200: \centering\includegraphics[width=\columnwidth]{images/ethvalue.pn
    g}
202: \label{6}
205: \begin{figure} [!ht]
206: \centering\includegraphics[width=\columnwidth]{images/ethtrancoun
    t.png}
208: \label{7}
211: Figure \ref{6} and \ref{7} describes the growth trend of
    Ethereum's price and its transaction volumes with Bitcoin's price
    in which the transaction pattern of Ethereum is more similar to
    Bitcoin's pattern.
219: \begin{figure} [!ht]
220: \centering\includegraphics[width=0.75\columnwidth]{images/Decisio
    ntree.png}
222: \label{fig:8decisiongree}
226: Figure \ref{fig:8decisiongree} give some basic idea of how
    decisions are made with the supervised decision tree based model.
258: With all parameters were carefully selected and the model is
    tuned to give the highest accuracy, Avg.closeness index of the
    algorithm is closer to 0.95. After deriving the model, the
    closeness/correctness of the predicted results was also analyzed
    and it is described in the plot \ref{scpl:ran}.
282: From the observation of scatter plots of regression model Random
    forest \ref{scpl:ran} and GBT \ref{scpl:gbt}, it is evident that
    GBT's single tree iterative model has predicted the values with
    over-fitting. Some predicted values are consistent with some
    particular time scope and changes happening in steps. The
    prediction distribution looks like a single line and not

```

widespread. Whereas, in the Random forest, the predicted values are widespread and closely aligned.

```
284: \begin{figure} [!ht]
285: \centering\includegraphics[width=\columnwidth]{images/RandomFores
tscatterplot.png}
287: \label{scpl:ran}
290: \begin{figure} [!ht]
291: \centering\includegraphics[width=\columnwidth]{images/GBTscatterp
lot.png}
293: \label{scpl:gbt}
```

figures 16

tables 0

includegraphics 16

labels 16

refs 11

floats 16

True : ref check passed: (refs >= figures + tables)

True : label check passed: (refs >= figures + tables)

True : include graphics passed: (figures >= includegraphics)

False : check if all figures are referred to: (refs >= labels)

Label/ref check

passed: True

When using figures use columnwidth

[width=1.0\columnwidth]

do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

WARNING: algorithm and above may be used improperly

```
297: For both algorithms, the closeness index is near 100\%, hence
      both predictions achieved optimal results. Other important metric
      includes r-square values which are above 95\% in both the cases,
      hence our model fits with the expectation and the parameter
```

selected for the algorithm holds good.

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

ascii

---

=====

The following tests are optional

=====

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Predicting Profitable Customers in Banking Industry

Dhanya Mathew  
Indiana University  
711 N Park Ave  
Bloomington, Indiana 47408  
dhmathew@iu.edu

## ABSTRACT

Banks often want to know the profile of their profitable top 1% or 20% customers looks like. Conversely, they may also wonder what the general profile is of the customers in the worst 1% and 20% of profit. Based on customer's data variables at any given time, a good predictive model can predict which profit group (extremely unprofitable, average, extremely profitable etc) customers fall into. This helps financial institutions to better understand what drives the customer profit and accordingly take decisions to sell their products to the right customers. Further down in banking sector, it is a challenge to identify customers who are most likely to repay the loan. Recent big data and machine learning technologies have the potential to predict good customers and open doors for banks to profitable growth. Since the banking sector has evolved over the periods, there are tremendous amount of historical data available to analyze. We show how bank's big data can be analyzed and create a model based on that, to classify customers. In addition to big data technologies, we use machine learning algorithms to build a predictive model to predict creditworthy and uncreditworthy customers from a list of new customers. Various classification algorithms like Decision Tree and Random Forest are used to build the models and trace the best model among them to achieve the goal.

## KEYWORDS

i523, HID328, Big Data, Spark, Python, Decision Trees, Random Forest

## 1 INTRODUCTION

Big data as the name implies, refers to large and complex data which continues to grow enormously day by day. Industries like financial firms, in particular, have widely adopted big data analytics to obtain better investment decisions with consistent growth. Recent survey research indicates that 71 percent of firms in the financial services industry at a global level are exploring big data and predictive analytics [22]. This number continues to grow and sectors like government, business, technology, universities, health-care, finance, manufacturing etc make use of big data to obtain meaningful information using big data technologies [32].

The finance sector contributes to the daily data generation from products and marketing, banking, business, share market etc [14]. Banking is a very sensitive field and any useful insight can make a positive impact on the overall turnover. Historic data analysis and real time data analysis are equally important in banking sector. The era of big data helps financial firms to take quality business decisions related to expanding revenues, managing costs, hiring resources etc, based on effective data analysis which provide access

to real-time insights. Data-driven decision making is one of the key advantages of big data technologies.

### 1.1 Project Goals

We aim to help banking sector to identify trustworthy customers. Specifically, help banks to take a decision driven by data, whether to approve or reject a loan application. When a new customer approaches the bank for a loan, banks would be able to identify the customers who are most likely to repay the loan by analyzing the applicant's profile and background information.

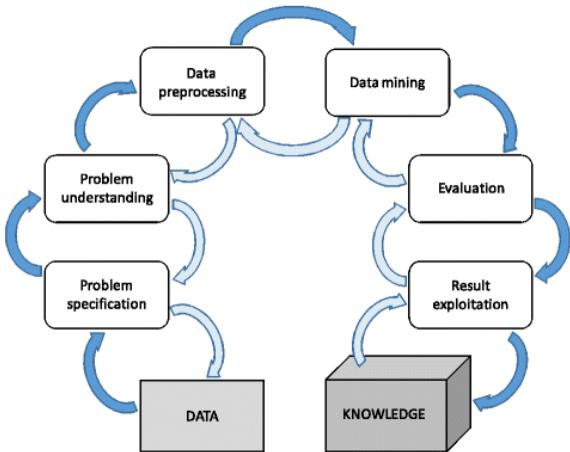
There can be two scenarios of risks associated with the bank's decision. First, if the customer is creditworthy and if the bank rejects the loan, then it is a loss to the bank in terms of interest. Second, if the customer is uncreditworthy and if the bank approves the loan, then it is a loss to the bank in terms of loan amount and interest [15]. Approving loan for an uncreditworthy customer will end up in more financial loss for the bank and accordingly is a greater risk. Hence banks would require a decision rule to follow for whom to approve the loan. We show how to build a predictive model using machine learning algorithm and a sample dataset with customer records classified as "Good" or "Bad" according to bank's opinion on the customer. With our model, we try to mitigate these risks for the banks by contributing to the decision rules. In other words, our model helps to minimize the risks and maximize the profit for the bank by understanding the customers.

### 1.2 Methods and Technologies Involved

The goal of most of the big data projects is to analyze the data and derive knowledge out of it. In other words, data is the input to the model and knowledge is the output. We also follow the same methods and processes for our project. We wrote the project code using Python3.

*1.2.1 Project Workflow.* Overall workflow of the project is shown in Figure 1. We have taken a sample data set of loan applications received by a bank. We explored the data and the requirements of the bank and based on that set the project goals as discussed in the section 1.1, before starting the project. In the real scenarios, we will not be able to apply analytical methods directly on the raw data as it likely be imperfect and containing irrelevant information. Hence we do data cleaning (data preprocessing) as the first step. Data cleaning is done using PySpark. The cleaned data has 1000 customer records with 1 classifier and 20 feature variables.

Exploratory analysis like Chi-square test is done to understand the data and feature selection for analysis as part of the data mining process. We have done graphical representations to show how the actual data is related and what are the direct insights available from the cleaned data set.



**Figure 1: Project Workflow [9]**

Machine learning approaches are used for the data evaluation and to build our predictive model. We develop various models using machine learning algorithms and compare them to identify the best model to choose for our problem solution [23]. To develop the models we first split the data set into two parts - training data and test data. We defined 2 baseline models, Decision trees and the Random Forest model. We compare all these models to identify the most effective and least penalty model. We use python as the programming language to build these models and display visualizations for easy comparison and results discussion.

**1.2.2 Python.** Python version 3 is the programming language used to develop the models and visualizations in this project. Python is a general purpose programming language that is open source, easy to use, faster to write, flexible and powerful. It has a rich set of libraries and utilities for data processing and analytics tasks [27]. Other important features of Python include the ability to process big data, scalability of applications and easiness to integrate with web applications. We use Python libraries like pandas, matplotlib, seaborn and numpy.

**Pandas:** Pandas is one of the most popular libraries in Python. Pandas is used for data manipulation and analysis [17], read data files from different sources, create data frames and some built-in visualizations [11].

**Matplotlib:** Matplotlib is the library used for plotting arrays and histograms of data in python [6].

**Seaborn:** Seaborn is a Python visualization library used for statistical visualization of data [31].

**Numpy:** Numpy is Python library which is used to operate mathematical functions on large multi dimensional arrays [35].

**1.2.3 PySpark.** Even though Python is powerful to handle complex big data analytic tasks, it alone cannot handle the big data processing. A distributed framework would require to handle a large amount of data. Spark is a distributed computing framework which supports Python [7].

PySpark is used to carry out the data preprocessing tasks and it is the Python API for Spark.

**1.2.4 Jupyter Notebook.** Jupyter notebook is an open source web application that allows to edit, run and share Python code and visualizations into a web view. It can be used to modify and re-execute program parts in a flexible way [5]. The files created in Jupyter notebook use extension ".ipynb".

**1.2.5 Machine Learning.** Machine learning enables computers to learn automatically and act accordingly without human assistance or being explicitly programmed. It is an application of Artificial Intelligence. It focuses on computer programs that can access data and learn by itself. Learning process starts by observing the data for patterns and make better decisions in future on the given scenarios [25]. There are mainly 2 categories of machine learning - Supervised and Unsupervised.

**Supervised Machine Learning Algorithms:** Supervised machine learning algorithms enable machines to get trained using a known training data set. Using these labeled examples, supervised learning algorithms can predict future events by applying already learned knowledge. These systems can be used for target definitions for new set of data after required training. Also, it can compare new data input with the intended output and give error indications [25].

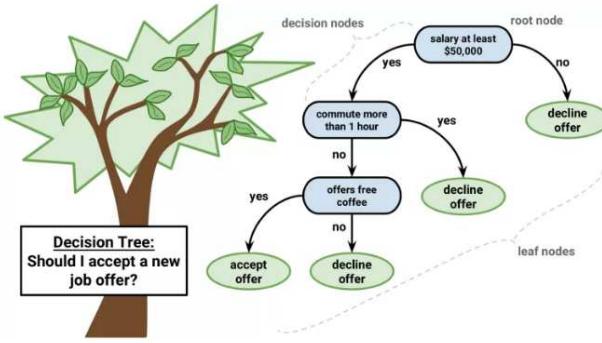
**Unsupervised Machine Learning Algorithms:** Unsupervised machine learning algorithms are used when there is not a preferred output and the data is not labeled or classified. It helps to find the hidden patterns in the data. It can describe the hidden structure of the unlabeled data but would not be useful to provide a correct, intended output [25].

There is another categorization of the machine learning algorithms depending on the preferred output. That include *Classification Algorithms* (Used for supervised learning with discrete output), *Regression Algorithms* (Used for supervised learning with continuous output), *Clustering Algorithms* (Unsupervised) etc [34].

We use supervised machine learning approaches in this project. In particular, the classification algorithms - Decision Tree and Random Forest.

**1.2.6 Decision Tree.** Decision Tree is a supervised machine learning algorithm used to solve both classification and regression problems. In Decision Tree, a trained model with a set of rules will be created based on the training data. The target class or value of a test/new data set will be predicted based on this training rules. Decision Tree algorithm is simple to understand as it uses a tree model representation to solve the problem. It starts from a root node and continues with other decision nodes. Each internal decision nodes corresponds to the feature variables and each leaf nodes corresponds to the class label [24]. Figure 2 shows the decision tree classifier.

The best attribute will be chosen as the root node. To identify the root node there are 2 methods. They are, *Information Gain* and *Gini Index*. There are statistical approaches to calculate Information gain and Gini index values for each feature variables. Attribute with better value will be considered as the root node and other attributes will be placed in the internal nodes according to the values in recursive order. Step 1 to model the decision tree is placing the root attribute. In step 2, the training data set will be divided into

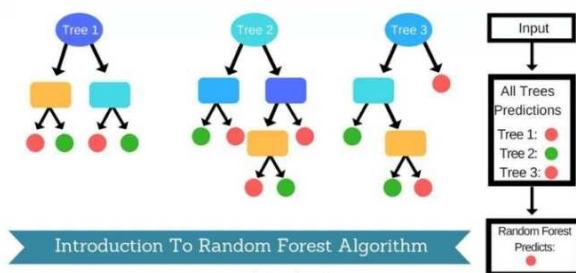


**Figure 2: Decision Tree Classifier [24]**

2 sub data sets in such a way that, both subsets will contain same attribute values for that variable. Step 1 and 2 will be repeated until we reach the leaf nodes with predicted class value [24].

*Overfitting:* Overfitting is a practical issue that can happen while building a decision tree. When the algorithm goes deeper and deeper it builds more branches because of the irregularities in data and the prediction accuracy of the model goes down accordingly. There are 2 methods can be used to avoid overfitting issues - *Pre-Pruning* and *Post-Pruning*. In Pre-pruning, we set a threshold value as a goodness measure and if it crosses, further split of the node will be stopped. In Post-Pruning, tree construction continues until all leafs are reached and pruning will be done if the model shows overfitting issues. Cross-validation data will be used to measure the improvement in this method [24].

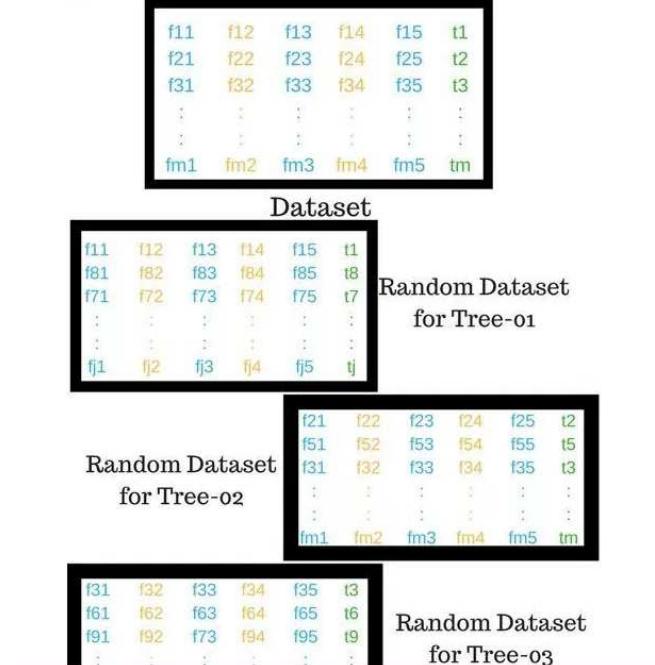
**1.2.7 Random Forest.** Like Decision Tree, Random Forest algorithm also can be used for classification as well as regression problems. It is a supervised machine learning algorithm. It uses decision tree concept as well but there will be more than one trees in a Random Forest. As the number of trees increases in the Random forest, the accuracy of the prediction also will increase accordingly. Random forest algorithm can handle missing values in the data. Also with more trees in the forest, overfitting issues will not occur in Random Forest algorithm [19]. Figure 3 shows the Random Forest model.



**Figure 3: Random Forest model [19]**

Random Forest algorithm progresses via 2 stages - Random Forest creation and Perform prediction. To create the Random Forest, we select a random number of feature variables from the total list of

feature variables in the training data and create a Decision Tree out of it. We repeat this process to create desired number of trees. These randomly created trees will form a Random Forest. Figure 4 shows how random forest algorithm works.



**Figure 4: How random forest algorithm works [19]**

The test data set will be analyzed against the rules developed by each of the trees to predict the output. To predict Random Forest output, the outputs of each of the trees are considered as votes. The top voted output is the final predicted value of the Random Forest.

### 1.3 Installations

Technologies used in this project are discussed in detail in section 1.2. The installation commands on Ubuntu 16.04 OS for each of these technologies are given in this section. Installations can be done from the terminal window.

- (1) Python installation steps for ubuntu OS are available in the askubuntu website [4].
- (2) Install pip to manage the libraries in the Python. Pip is a Python package management software used to install and manage Python libraries. pip can be installed using command "sudo pip install -U pip" [18].
- (3) Install PySpark using command "sudo pip install pyspark" [1].
- (4) Install Jupyter notebook using command "sudo pip install jupyter" [20].
- (5) Install Pandas using command "sudo pip install pandas" [16].
- (6) Install matplotlib using command "sudo pip install matplotlib" [3].
- (7) Install seaborn using command "sudo pip install seaborn" [26].

**Table 1: Variables and description [15]**

Variable	Description
Credit	Creditability: Good or Bad
Account Status	Balance of current account
Credit Months	Duration of Credit (month)
Credit History	Payment Status of Previous Credit
Purpose	Purpose of credit
Credit Amount	Amount of credit
Savings	Value Savings or stocks
Employment	Length of current employment
Installment Rate	Installment in % of current income
Personal Status	Sex and Marital Status
Guarantors	Further debtors
Residence	Duration in Current address
Property	Most valuable available asset
Age	Age in years
Other Installments	Concurrent Credits
Housing	Type of apartment
Credit Cards	No of Credits at this Bank
Occupation	Occupation
Dependents	No of dependents
Telephone	Phone number
Foreign Worker	Foreign worker

(8) Install numpy using command "sudo pip install numpy" [2]

All these installation steps are included in a make file referred in appendix A.1.

## 2 DATASET

We used the German Credit data which is publically available in the UCI Machine Learning Repository [10] and also in the website of PennState Eberly College of Science [15]. Both these sites have the cleaned dataset and not the original one. The dataset that we used (german-credit.csv) is taken from the website of PennState Eberly College of Science [15] and it is uploaded in the Github repository [12]. We recreated the original one from these data sets to understand and try out the data cleaning processes. We start our project with the recreated original data set (credit-data.csv) which is available in the Github repository [12].

Dataset includes 1000 customer records with 20 feature variables and a class variable. In the class variable, the actual class of the customer is specified - good or bad. The complete list of data set variables and their description is given in Table 1.

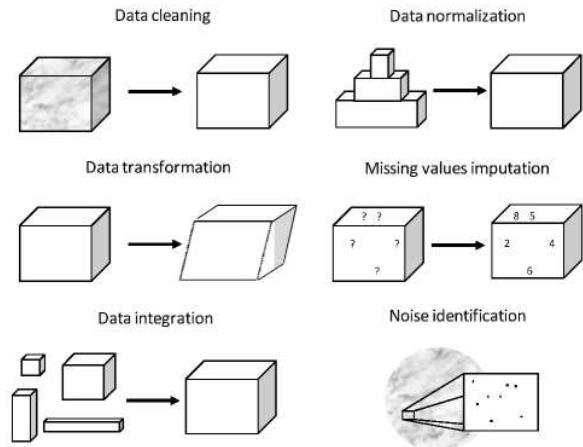
## 3 DATA CLEANSING

A massive amount of raw data is piling up in the recent years from different sources and it has been continuously getting stored as the storage mechanism is getting cheaper and the storage capacity increases day by day. This raw data cannot be analysed as it is by human or traditional applications, as the processing capacity of traditional tools has been exceeded because of the volume of the data. That is the reason why big data technologies have evolved and they use distributed systems like MapReduce, Spark, Flink etc.

Even if we have a big data solution to process the high quantity of raw data, it is not the efficiency and performance of the solution that determines the quality of the knowledge extracted but it depends on the quality of the data as well. The raw data likely to be imperfect and may contain noise, irrelevant information, missing values etc. It is well known that low quality data will lead to low quality knowledge [9]. Hence data cleaning is the major step to be performed before we continue with data mining algorithms to make sure that we are using a suitable and relevant data set.

Data cleaning has 2 parts. First part is data preparation and second part is data reduction techniques.

**3.0.1 Data Preparation.** The data going to the analytics model should be clean and noise free. Hence data preparation part includes tasks like data cleaning, data normalization, data transformation, missing value imputation, data integration and Noise identification. Figure 5 shows the data preparations tasks [9].



**Figure 5: Data Preprocessing and preparation tasks [9]**

**3.0.2 Data Reduction Techniques.** To reduce the dimensionality problem and the computational cost, because of a large number of variables and instances in the data set, we try to gather only the required set of quality data. Data reduction techniques include feature selection, instance selection and discretization. Figure 6 shows data reduction techniques [9].

With respect to our chosen data set, data reduction techniques were already applied to the raw data and 1000 customer records and 21 variables were shortlisted. All these variables are either categorical (like Account-Balance, Previous-credit, purpose etc) or continuous (Duration-of-credit, Installment-percent, dependents). As part of data preparation for our analysis, we transform the values of categorical variable's from string to scores (numerical values). For example, the variable "creditability" got 2 values - good and bad. After transformation process, "good" get replaced by "1" and "bad" get replaced by "0". Likewise, we gave scores for the values of the variables, Foreign-Worker, Telephone, Previous-Credit, Purpose, Sex-MaritalStatus, Guarantors and Type-apartment.

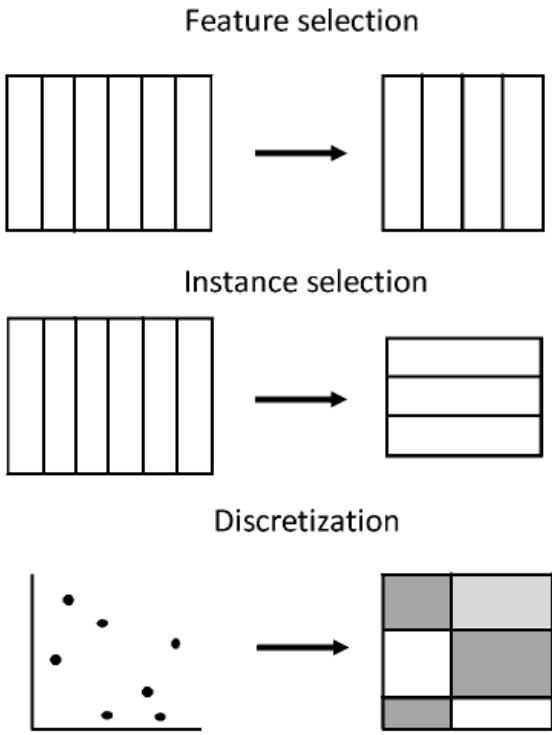


Figure 6: Data Reduction Approaches [9]

## 4 DATA ANALYSIS

Big data analysis is the process of obtaining knowledge by analyzing and understanding hidden patterns, market trends, unknown correlations, customer preferences and other relevant information from large and varied datasets [21]. Big data analytics methods include exploratory analysis, data mining, predictive analytics, machine learning, deep learning etc. The results of the analysis can be visualized using tools like Tableau, Infogram, Plotly etc or by using Python scripts. This project utilizes methods like exploratory analysis, predictive analysis, machine learning algorithms and visualizations of results using Python scripts. Python codes for all these analysis methods are given in appendix A.3.

### 4.1 Exploratory Analysis

Exploratory analysis is basically to explore the data and understand what it actually contains. It is an approach to summarize the general characteristics of the data set before we attempt to model it. Statistical methods or direct visualizations can help in data exploration [33].

**4.1.1 Direct Visualization.** After data preprocessing, our dataset includes 1000 customer records with 20 feature variable and 1 class variable. Feature variable values can be visualized to understand the characteristics and how they are related to each other - proportionally or inversely.

Figure 7 shows the histogram of credit amount disbursed with respect to frequency. From this diagram, we understand that most

of the customers are requested for loans for up to 2500 German Marks. The number of customers decreases as the loan amount increases. And very few customers fall under the loan amount category over 10000 German Marks.

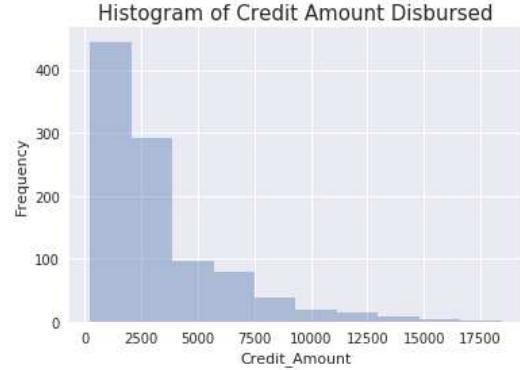


Figure 7: Credit amount vs. Frequency [28]

Figure 8 and Figure 9 shows the credit amount availed by bad customers and good customers respectively. The trend is almost the same. Maximum customers from both the classes fall under the category of up to 2500 German Marks. But there is a noticeable difference in the number of customers under 12500 range. Bad rated customers are more in this category.

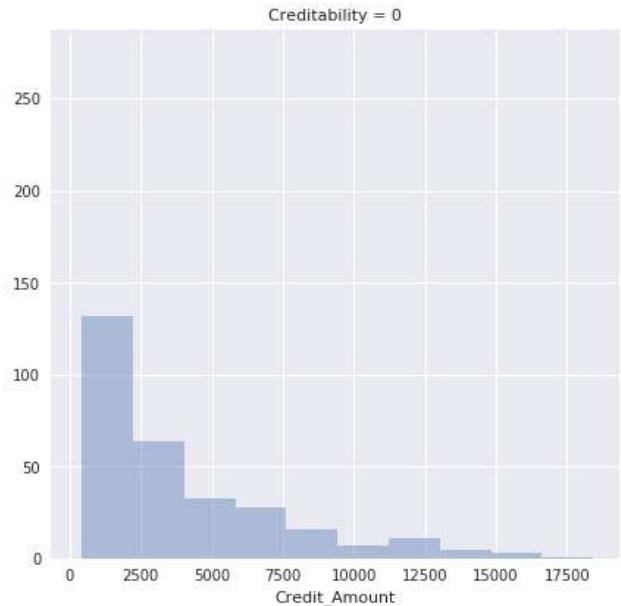
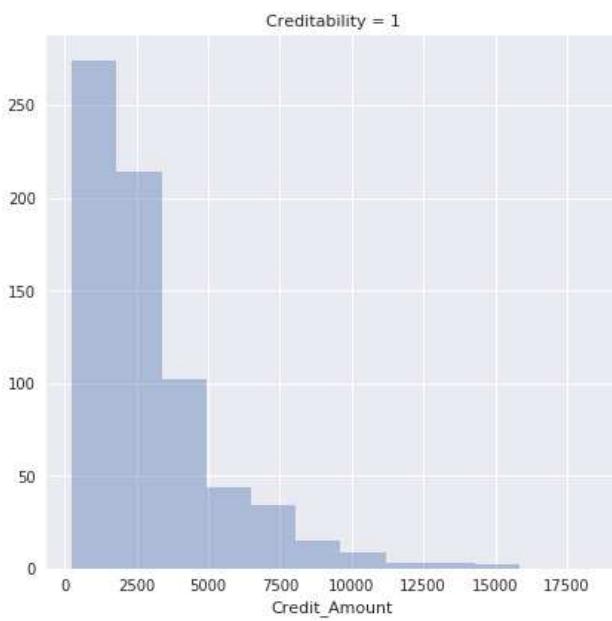
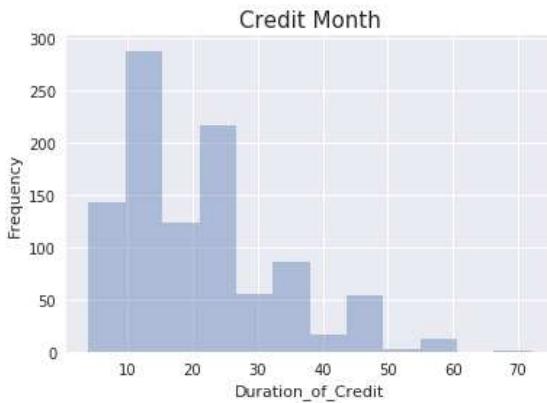


Figure 8: Credit amount vs. bad customers [28]

Figure 10 shows the duration of credit in months vs. number of customers. From this graph, we can understand that maximum number of customers opted for 10 to 15 months duration.



**Figure 9: Credit amount vs. good customers [28]**



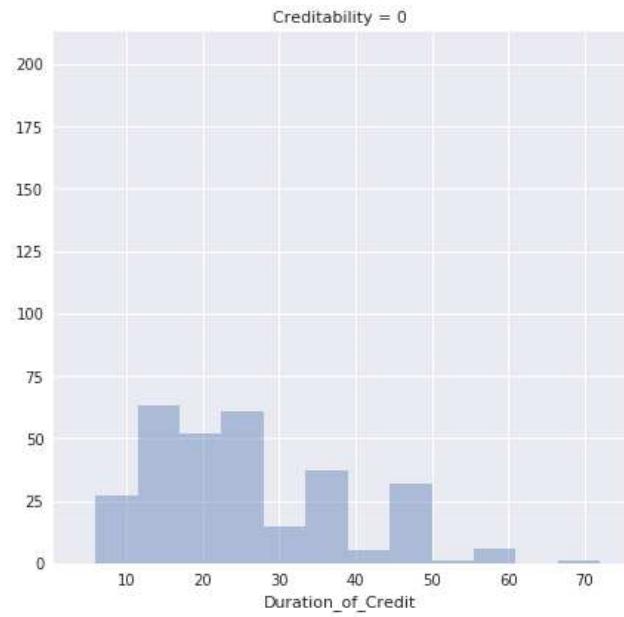
**Figure 10: Duration of credit in months vs. frequency [28]**

Figure 11 and Figure 12 shows the duration of credit in months vs number of bad customers and good customers respectively. It shows that there is not much difference in the trend.

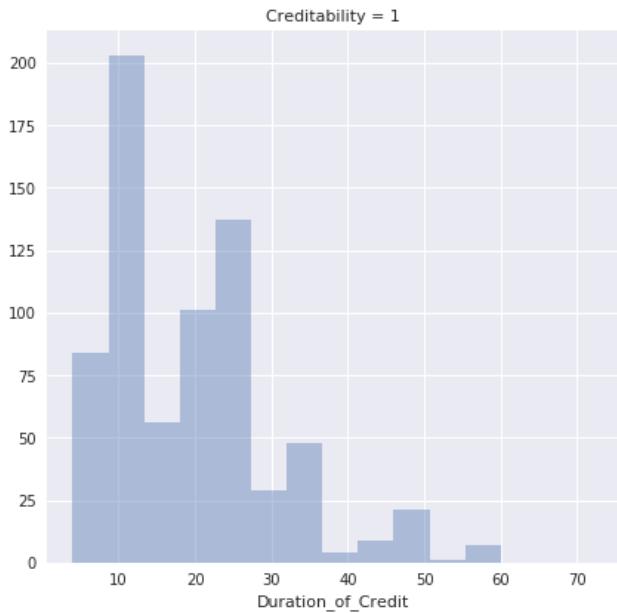
Figure 13 shows how customers are scattered with respect to age. Most of the borrowers fall under the age group of 23 to 28.

**4.1.2 Data Classification.** We have one class variable "Creditability" to classify the customers based on the bank's opinion on the actual applicants. We could extract this class information from dataset using PySpark Python script "GroupBy". Table 2 shows the output of the script.

Customers in our dataset are classified into 2 classes - Good (1 = Creditworthy) and Bad (0 = Uncreditworthy). We have 700 customers in the Good class and 300 customers in the Bad class.



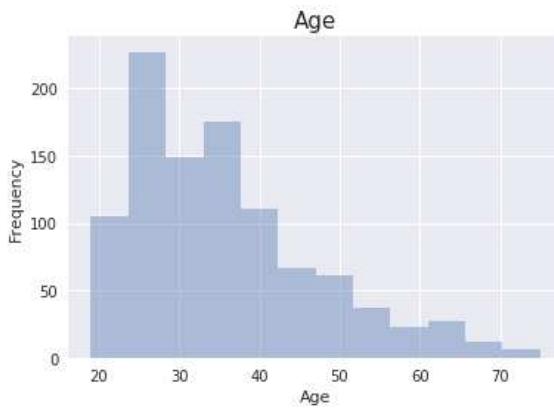
**Figure 11: Duration of credit in months vs. bad customers [28]**



**Figure 12: Duration of credit in months vs. good customers [28]**

We divide our dataset of 1000 customer records randomly into 2 parts. First part is the training dataset with 700 customer records and second part is the test dataset of 300 customer records.

**4.1.3 Interquartile Range.** Interquartile Range is a statistical method to measure the variability of the data. This will be applicable



**Figure 13: Age vs. frequency**

**Table 2: Data classification**

Creditability	Count
0	300
1	700

**Table 3: Variability in Credit-Amount**

Min	1st Qu	Median	Mean	3rd Qu	Max
250	1365.5	2319.5	3271.248	3972.25	18424

**Table 4: Variability of Duration of credit**

Min	1st Qu	Median	Mean	3rd Qu	Max
4	12	18	20.90	24	72

only for the continuous variables (Credit-amount, Duration of credit and Age). The rank-ordered data will be divided into 4 equal parts called quartiles. Values are called the First (Q1) Second (Q2) and Third (Q3) quartiles. Q2 is the Median value of the dataset [30].

We used pandas quantile function to extract this information for all the continuous variables.

Table 3 shows the variability of Credit-Amount.

Table 4 shows the variability of Duration of credit.

Table 5 shows the variability of Age.

**4.1.4 Cross-Tabulation.** Cross-Tabulation is a statistical method used to compare the relationship between categorical variables. In our scenario, we examine the relationship of the categorical variables with the class variable "creditability". We create a *contingency table* which displays the frequency of categorical variables with respect to the class [36].

Table 6 shows the contingency table created for the variable sex-marital status against class. It shows the number of good and bad customers distributed among the 4 categories of the variable sex-marital status. Category "male: married/widowed" has the maximum number of Good customers. Contingency tables are used to create the Chi-square values.

**Table 5: Variability of Age**

Min	1st Qu	Median	Mean	3rd Qu	Max
19	27	33	35.5	42	75

**Table 6: Contingency table of sex-marital status**

		Sex-Marital Status					
		1	2	3	4	Row Total	
Creditability	Good	30	201	402	67	700	
	Bad	20	109	146	25	300	
Column Total		50	310	548	92	1000	

**4.1.5 Test of Independence.** We need to identify the features that are closely related to the class/credit rating to build a predictive model. We do a test of independence on all our feature variables to identify the ones to be selected for data modeling. The method we use to do the Test of Independence is the Chi-squared test. The output of the Chi-squared test is the input to the Logistical Regression Algorithm. Variables which are not related to the class variable will be discarded from further analysis of Logical Regression.

*Pearson's Chi-squared test:* Chi-squared test is used to determine the significant difference between expected values and observed values in one or more categories. There are 2 types of Chi-squared test - Goodness of Fit and Test for Independence.

We use the second method - *Test of Independence*. It compares 2 variables in a contingency table to check if they are related. In other words, it examines if the distributions of categorical variables are different from one another.

If the calculated value is small that means, the variables are related. If the value is large that means, the data is not related and not fit for analysis [29].

*p-value:* p-value is the probability value that, when the null hypothesis is true, the chi-square value will be greater than the empirical value of the data. There is a p-value distribution chart available where it is calculated against the significance value, degrees of freedom and chi-square test value [13].

*Degrees of freedom:* Degrees of freedom is the number of scores that can be varied. It is calculated using the formula,

$$\text{Degrees of freedom} = (r - 1) * (c - 1) \quad (1)$$

The calculated values are shown in Table 7.

## 5 MODELS

Predictive models can be created using different Machine Learning algorithms such as Logistical Regression, Decision Trees, Random Forest etc. Machine learning algorithms generate models from the training data and tested against the test data to estimate the accuracy level. Before building predictive models, there are few baseline models can be created to compare and see what improvements we are actually trying to achieve. By comparing the accuracies of different predictive models against the base models, we can come up with the best model for that particular problem. The best model is saved for the future predictions on new datasets.

**Table 7: Chi-square, df and p values**

All	Chi-square	D.F	PValues
Account-Balance	123.720944	3	0.000000e+00
Duration-of-Credit	78.886937	32	7.784572e-06
Previous-Credit	61.691397	4	1.279199e-12
Purpose	33.356447	9	1.157491e-04
Credit-Amount	931.746032	922	4.045155e-01
Value-Savings-Stocks	36.098928	4	2.761214e-07
employment	18.368274	4	1.045452e-03
Instalment-percent	5.476792	3	1.400333e-01
Sex-MaritalStatus	9.605214	3	2.223801e-02
Guarantors	6.645367	2	3.605595e-02
Duration-address	0.749296	3	8.615521e-01
asset	23.719551	3	2.858442e-05
Age	57.626982	52	2.749531e-01
Concurrent-Credits	12.839188	2	1.629318e-03
Type-apartment	18.674005	2	8.810311e-05
No-of-Credits	2.671198	3	4.451441e-01
Occupation	1.885156	3	5.965816e-01
dependents	0.009089	1	9.240463e-01
Telephone	1.329783	1	2.488438e-01
Foreign-Worker	6.737044	1	9.443096e-03

**Table 8: Baseline Model 1**

Good	
Good	210
Bad	70

## 5.1 Baseline Models

Baseline models use simple summary statistics. In classification problems like our scenario, baseline models are created based on the class values. As mentioned in the data classification section 4.1.2, our total list of 1000 customer records are divided into training dataset and test dataset. Training dataset has 700 customer records and test dataset has 300 customer records. For the baseline models, we evaluate the test data of 300 customer records.

In this project we create 2 baseline models.

*Baseline Model 1:* In this model, we assume all the input test customer records (300 customer records) belongs to the "Good" class. Since out of 1000 customers, 700 falls under "Good" class, we assume among the 300 customers in test dataset 70% will fall under "Good" class and rest in "Bad" class, which means this baseline model holds 70% accuracy.

Table 8 shows the assumption in baseline model 1.

*Baseline Model 2:* In this model, we assume all the input test customer records (300 customer records) belongs to the "Bad" class. Since out of 1000 customers, 300 falls under "Bad" class, we assume among the 300 customers in test dataset 30% will fall under "Bad" class and rest in "Good" class, which means this baseline model holds 30% accuracy.

Table 9 shows the assumption in baseline model 2.

**Table 9: Baseline Model 2**

Bad	
Good	210
Bad	70

## 5.2 Decision Tree Model

To build this model, we use the machine learning algorithm - Decision Tree which is explained in section 1.2.6. PySpark's class "DecisionTreeClassifier" is used to build different Decision Tree models from training data based on different tree attributes like MaxBins, Maxdepth, Impurity etc. Impurity measures are calculated internally by this classifier to identify the root node and other internal nodes. Gini Index is the method opted in our project.

Formula to calculate Gini Index is,

$$GiniIndex = \sum_{i=1}^C f_i(1 - f_i) \quad (2)$$

We created 2 Decision Tree models to compare the accuracy.

*Decision Tree with maxDepth None:* In this model, we set the maxDepth value of the Tree to None and we calculated the accuracy using PySpark's "MulticlassClassificationEvaluator". In this case, the tree can become arbitrarily deep and complex and more chances of overfitting issues.

The accuracy of the output of this model is 0.679. Maximum number of Bins are 32. Depth is None.

*Decision Tree after adjusting the attribute values:* In this model, we set the maxDepth value to 6 and maxBins value to 20. We used the same PySpark's "MulticlassClassificationEvaluator" to calculate the accuracy. Since we have limited the maxDepth and maxBin values, the overfitting issues decreases.

- The accuracy of the output of this model is 0.716
- Number of Bins are 20
- Depth is 6

## 5.3 Random Forest

Random Forest Machine Learning algorithm which is explained in the section 1.2.7 is used to build Random Forest model. We use PySpark class "RandomForestClassifier" to generate the model from training data. We build 2 Random Forest models one with default attribute and another one with chosen attribute values.

*Random Forest with Default Settings:* In this case, the attributes of the Tree are selected by the "RandomForestClassifier" itself internally and accuracy of the model is calculated based on that.

The accuracy of the output of this model is 0.756. Maximum number of Bins are 32. Maximum Depth is 5. Maximum number of Trees are 20.

*Tuning Random Forest with cross-validator:* In this case, we tune the Random Forest model by trying different attribute values for tree attributes - maxDepth, maxBin and numTrees. We can provide multiple values for each attribute. We provided 3 values for maxDepth, 2 values for maxBins and 3 values for numTrees. We will start with some random values for these attributes.

**Table 10: Prediction matrix - Decision Tree**

Prediction	0.0	1.0
Label		
0.0	35	55
1.0	34	184

**Table 11: Prediction matrix - Random Forest**

Prediction	0.0	1.0
Label		
0.0	40	50
1.0	18	200

We use *cross-validation* techniques in this type of Random Forest model to get the best model. PySpark "CrossValidator" will analyze the values of the attributes. In this scenario, the "CrossValidator" will choose 3 values of attributes from  $3 * 2 * 3$  values. It will then try different combinations of the attribute values internally and finally, the model will get tuned to a final set of attributes which derive the best model with maximum accuracy.

- The accuracy of the output of this model is 0.779
- Number of Trees are 100

As we identified the best model with maximum accuracy is the Random Forest model, we passed the actual dataset to this model and received an accuracy of 0.845

## 6 RESULTS

Now we have all the desired models created which can predict the class of a new customer. We can compare and analyze the outputs of each of these models and conclude with the best model. We can analyze the results based on accuracy and mean penalty matrix.

### 6.1 Prediction matrix

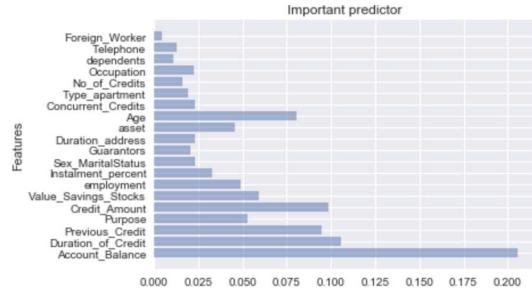
Prediction matrix can be extracted using the "groupby" option in PySpark. Table 10 and Table 11 shows the prediction matrix of Decision Tree and Random Forest respectively. Decision Tree has got 219 right predictions and Random Forest has got 240 right predictions out of 300 customer records.

### 6.2 Feature Importance

Feature Importance is the list of important predictors that are the top contributed variables towards building the predictive model. Normally the variable with maximum dependency would be treated as the root node by the algorithm. We could calculate the feature importance only for the Random forest algorithm by using the class "bestModel.featureImportances". Figure 14 shows the list of predictors. We could see that the variable "Account Balance" contributes maximum to the predictions.

### 6.3 Model Accuracy Comparison

Figure 15 shows the accuracy of different predictive models that we created. We plotted the output of "MulticlassClassificationEvaluator" for Decision Tree and Random Forest. We can understand



**Figure 14: Random Forest Important Predictors**

**Table 12: Penalty Matrix [15]**

Actual	Predicted 'Good'	Predicted 'Bad'
Good	0	1
Bad	5	0

from the graph that baseline model 2 has got the least accuracy and Random Forest has got the most.



**Figure 15: Model accuracy comparison [28]**

### 6.4 Penalty Matrix

One important aspect to consider while choosing a predictive model is the accuracy. When considering the actual goal of this project, the model should be apt to minimize the risks and to maximize the profit. The model should ensure good prediction accuracy to achieve the goal.

A penalty matrix is defined to calculate the loss to the bank. Penalty will be applied to each misclassifications and penalty value differs for wrong classifications - 'good as bad' and 'bad as good'. As discussed in the project goals section 1.1, approving loan for an uncreditworthy customer will end up in more financial loss for the bank and accordingly is a greater risk. Hence classifying a bad customer wrongly as good customer will have more penalty.

Table 12 shows the penalty matrix. For right predictions penalty is 0. If a good customer predicted as bad, the penalty is 1 and if a bad customer predicted as good, the penalty is 5. The sum of the

penalty values multiplied with the respective number of misclassified customers will provide the total amount of loss / penalty.

Figure 16 shows the penalty comparison of different predictive models. Baseline model 1 has more chances of predicting bad customers as good because it blindly assumes that, all the incoming customers are good. Hence it has got more penalty value. Baseline model 2 has got least chances of classifying bad customers as good because it assumes all incoming customers are bad. Hence baseline model 2 has minimum penalty.



Figure 16: Model penalty comparison [28]

## 6.5 Accuracy and Penalty Comparison

Figure 17 shows the accuracy and penalty comparison for all the 4 models. Random Forest is the most accurate model and with minimal penalty. Hence Random Forest is the best model out of all.

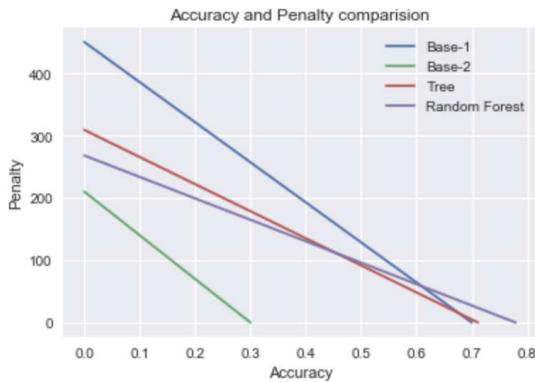


Figure 17: Model accuracy and penalty comparison [28]

## 7 DISCUSSION

We have built 4 predictive models. Baseline model 1 and 2, Decision Tree and Random Forest. We did a small study on Logistical Regression model as well. There are many other machine learning algorithms available which are suitable for classification analysis. Current analysis uses only 20 feature variables and 1000 customer records to populate the predictive models. In predictive analysis, the bigger the training dataset, the better the outcome. Current

analysis can be extended to really big data with more feature variables customer records and also data from multiple years. Data processing can be done using distributed big data processing systems available today for better accuracy. Unfortunately, such a large data is not publicly available for studies in finance area right now. Hence we tried big data technologies in a comparatively smaller dataset.

## 8 CONCLUSION

Out of 4 predictive models created, Random Forest has the maximum accuracy in classifying the customers in the right class. Even if it gives an accuracy of around 85% it is not an error free model. There are 15% chances for misclassification. The size of the dataset that we considered to develop this model may have a direct impact. If we can train the model with a larger data set with tens of thousands of customer records and feature variables, the accuracy may increase close to 100%. There might be other more advanced machine learning algorithms and tools coming up to explore the chances of increasing the overall accuracy of the predictive models in common.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski, Juliette Zurick, Miao Jiang and Saber Sheybani Moghadam for their suggestions and support to complete this project and report.

## REFERENCES

- [1] askubuntu. 2015. How do I get pyspark on Ubuntu? Web page. (June 2015). <https://askubuntu.com/questions/635265/how-do-i-get-pyspark-on-ubuntu>
- [2] askubuntu. 2016. how to install numpy for python3. Web page. (April 2016). <https://askubuntu.com/questions/765494/how-to-install-numpy-for-python3/765510>
- [3] askubuntu. 2016. Unable to install matplotlib using pip in Ubuntu 16.04. Web page. (June 2016). <https://askubuntu.com/questions/791673/unable-to-install-matplotlib-using-pip-in-ubuntu-16-04>
- [4] askubuntu. 2017. How do I install Python 3.6 using apt-get? Web page. (November 2017). <https://askubuntu.com/questions/865554/how-do-i-install-python-3-6-using-apt-get>
- [5] Charles Bochet. 2017. Get Started with PySpark and Jupyter Notebook in 3 Minutes. Web page. (May 2017). <https://blog.sicara.com/get-started-pyspark-jupyter-guide-tutorial-ac2fe84f594f>
- [6] Matplotlib development team. 2017. Matplotlib Introduction. Web page. (October 2017). <https://matplotlib.org/users/intro.html>
- [7] dezyre.com. 2017. PySpark Tutorial-Learn to use Apache Spark with Python. Web page. (September 2017). <https://www.dezyre.com/apache-spark-tutorial/pyspark-tutorial>
- [8] Dhanya. 2017. code. Web page. (November 2017). <https://github.com/bigdata-i523/hid328/tree/master/project/code>
- [9] Salvador Garcia, Sergio Ramirez-Gallego, Julian Luengo, Jose Manuel Benitez, and Francisco Herrera. 2016. Big data preprocessing: methods and prospects. Web page. (September 2016). [https://bdataalytics.biomedcentral.com/articles/10.1186/s41044-016-0014-0](https://bdataanalytics.biomedcentral.com/articles/10.1186/s41044-016-0014-0)
- [10] Dr. Hans Hofmann. 1994. Statlog (German Credit Data) Data Set. Web page. (November 1994). <https://archive.ics.uci.edu/ml/datasets/Statlog+%28German+Credit+Data%29>
- [11] Katharine Jarmul. 2016. INTRODUCTION TO DATA SCIENCE: HOW TO "BIG DATA" WITH PYTHON. Web page. (October 2016). <http://dataconomy.com/2016/10/big-data-python/>
- [12] Dhanya Mathew. 2017. dataset in excel format. Web page. (November 2017). <https://github.com/bigdata-i523/hid328/tree/master/project>
- [13] medcalc. 2015. Values of the Chi-squared distribution. Web page. (April 2015). <https://www.medcalc.org/manual/chi-square-table.php>
- [14] Trevir Nath. 2015. How Big Data Has Changed Finance. (April 2015). <http://www.investopedia.com/articles/active-trading/040915/how-big-data-has-changed-finance.asp>
- [15] PennState Eberly College of Science. 2016. Analysis of German Credit Data. Web page. (September 2016). <https://onlinecourses.science.psu.edu/stat857/node/215>

- [16] pandas. 2017. Installation. Web page. (June 2017). <https://pandas.pydata.org/pandas-docs/stable/install.html>
- [17] pandas.pydata.org. 2017. pandas: powerful Python data analysis toolkit. Web page. (October 2017). <https://pandas.pydata.org/pandas-docs/stable/>
- [18] pip.pypa.io. 2016. Installation. Web page. (July 2016). <https://pip.pypa.io/en/stable/installing/>
- [19] Saimadhu Polamuri. 2017. HOW THE RANDOM FOREST ALGORITHM WORKS IN MACHINE LEARNING. Web page. (May 2017). <https://dataaspirant.com/2017/05/22/random-forest-algorithm-machine-learning/>
- [20] rosehosting.com. 2017. How to Install Jupyter on an Ubuntu 16.04. Web page. (February 2017). <https://www.rosehosting.com/blog/how-to-install-jupyter-on-an-ubuntu-16-04-vps/>
- [21] Margaret Rouse. 2017. big data analytics. Webpage. (July 2017). <http://searchbusinessanalytics.techtarget.com/definition/big-data-analytics>
- [22] Fabrizio Saracco, Vincenzo Morabito, and Gregor Meyer. 2016. Exploring Next Generation Financial Services: The Big Data Revolution. (2016). [https://www.accenture.com/t20170314T051509\\_\\_w\\_\\_/nl-en/\\_acnmedia/PDF-20/Accenture-Next-Generation-Financial.pdf](https://www.accenture.com/t20170314T051509__w__/nl-en/_acnmedia/PDF-20/Accenture-Next-Generation-Financial.pdf)
- [23] sas. 2017. Machine Learning What it is and why it matters. Web page. (June 2017). [https://www.sas.com/en\\_us/insights/analytics/machine-learning.html](https://www.sas.com/en_us/insights/analytics/machine-learning.html)
- [24] Rahul Saxena. 2017. Introduction to Decision Tree Algorithm. Web page. (January 2017). <https://dataaspirant.com/2017/01/30/how-decision-tree-algorithm-works/>
- [25] Luca Scagliarini. 2017. What is Machine Learning? A definition. Web page. (July 2017). <http://www.expertsystem.com/machine-learning-definition/>
- [26] seaborn. 2017. Seaborn Installing and getting started. Web page. (June 2017). <https://seaborn.pydata.org/installing.html>
- [27] Sabeer Shaikh. 2016. Why Python is important for big data and analytics applications? Web page. (April 2016). <https://www.edunix.com/blog/bigdata-and-hadoop/python-important-big-data-analytics-applications/>
- [28] Srishai Sivakumar. 2014. German Credit Data Analysis. Web page. (April 2014). <http://srishai85.github.io/GermanCredit/German.html>
- [29] statisticshowto.com. 2016. Chi-Square Statistic: How to Calculate It - Distribution. Web page. (June 2016). <http://www.statisticshowto.com/probability-and-statistics/chi-square/>
- [30] Stat Trek. 2017. Statistics and Probability Dictionary. Web page. (November 2017). <http://stattrek.com/statistics/dictionary.aspx?definition=Interquartile%20range>
- [31] Michael Waskom. 2017. seaborn: statistical data visualization. Web page. (October 2017). <https://seaborn.pydata.org/>
- [32] Wiki. 2017. Big data. Web page. (Oct 2017). [https://en.wikipedia.org/wiki/Big\\_data](https://en.wikipedia.org/wiki/Big_data)
- [33] wiki. 2017. Exploratory data analysis. Web page. (October 2017). [https://en.wikipedia.org/wiki/Exploratory\\_data\\_analysis](https://en.wikipedia.org/wiki/Exploratory_data_analysis)
- [34] wiki. 2017. Machine learning. Web page. (October 2017). [https://en.wikipedia.org/wiki/Machine\\_learning](https://en.wikipedia.org/wiki/Machine_learning)
- [35] wiki. 2017. NumPy. Web page. (October 2017). <https://en.wikipedia.org/wiki/NumPy>
- [36] Yolanda Williams. 2015. Cross Tabulation: Definition & Examples. Web page. (June 2015). <http://study.com/academy/lesson/cross-tabulation-definition-examples-quiz.html>

## A PROJECT REFERENCES

All project related documents are available in the github repository i523/hid328/project: <https://github.com/bigdata-i523/hid328/tree/master/project> [12].

### A.1 Makefile

Make file is created assuming that the target system has Ubuntu OS and Python3 installed already. This can be executed from terminal window from folder i523/hid328/project/code using command "make run". Makefile is available in the github repository i523/hid328/project/code [8].

### A.2 Data Set

"credit-data.csv" is available in Google Drive /project-data/hid328/.

### A.3 Project Code

Project code is available in the Jupyter notebook "project.ipynb" in the github repository i523/hid328/project/code [8].

```
bibtext report
```

```
=====
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtext _ label error
```

```
=====
```

```
bibtext space label error
```

```
=====
```

```
bibtext comma label error
```

```
=====
```

```
latex report
```

```
[2017-12-12 20.02.02] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
No positions in optional float specifier. Default added (so using 'tbp').
Typesetting of "report.tex" completed in 1.6s.
```

```
=====
```

```
Compliance Report
```

```
=====
```

```
name: Dhanya Mathew
hid: 328
paper1: Nov 2 17 100%
paper2: Nov 6 17 100%
project: Dec 4 17 100%
```

```
yamlcheck
-----
wordcount
-----
11
wc 328 project 11 6400 report.tex
wc 328 project 11 6317 report.pdf
wc 328 project 11 1015 report.bib

find "
-----
passed: True

find footnote
-----
passed: True

find input{format/i523}
-----
passed: False

find input{format/final}
-----
4: \input{format/final}

passed: True

floats
-----
44: \subsection{Project Goals}\label{Project goals}
50: \subsection{Methods and Technologies Involved}\label{Methods and Technologies Involved}
56: Overall workflow of the project is shown in Figure
   \ref{fig:Figure1}.
57: We have taken a sample data set of loan applications received by a
   bank. We explored the data and the requirements of the bank and
   based on that set the project goals as discussed in the section
   \ref{Project goals}, before starting the project. In the real
```

scenarios, we will not be able to apply analytical methods directly on the raw data as it likely be imperfect and containing irrelevant information. Hence we do data cleaning (data preprocessing) as the first step. Data cleaning is done using PySpark. The cleaned data has 1000 customer records with 1 classifier and 20 feature variables.

```

59: \begin{figure}[htb]
61: \includegraphics[width=1.0\columnwidth]{images/Figure1.png}
64: \label{fig:Figure1}
106: \subsubsection{Decision Tree}\label{Decision Tree}
108: Decision Tree is a supervised machine learning algorithm used to solve both classification and regression problems. In Decision Tree, a trained model with a set of rules will be created based on the training data. The target class or value of a test/new data set will be predicted based on this training rules. Decision Tree algorithm is simple to understand as it uses a tree model representation to solve the problem. It starts from a root node and continues with other decision nodes. Each internal decision nodes corresponds to the feature variables and each leaf nodes corresponds to the class label \cite{decision-tree}. Figure \ref{fig:Figure2} shows the decision tree classifier.
111: \begin{figure}[htb]
113: \includegraphics[width=1.0\columnwidth]{images/Figure2.png}
116: \label{fig:Figure2}
123: \subsubsection{Random Forest}\label{Random Forest}
125: Like Decision Tree, Random Forest algorithm also can be used for classification as well as regression problems. It is a supervised machine learning algorithm. It uses decision tree concept as well but there will be more than one trees in a Random Forest. As the number of trees increases in the Random forest, the accuracy of the prediction also will increase accordingly. Random forest algorithm can handle missing values in the data. Also with more trees in the forest, overfitting issues will not occur in Random Forest algorithm \cite{random-forest}. Figure \ref{fig:Figure3} shows the Random Forest model.
127: \begin{figure}[htb]
129: \includegraphics[width=1.0\columnwidth]{images/Figure3.png}
132: \label{fig:Figure3}
135: Random Forest algorithm progresses via 2 stages - Random Forest creation and Perform prediction. To create the Random Forest, we select a random number of feature variables from the total list of feature variables in the training data and create a Decision Tree out of it. We repeat this process to create desired number of trees. These randomly created trees will form a Random Forest. Figure \ref{fig:Figure4} shows how random forest algorithm works.
137: \begin{figure}[htb]
```

```

139: \includegraphics[width=1.0\columnwidth]{images/Figure4.png}
142: \label{fig:Figure4}
150: Technologies used in this project are discussed in detail in
      section \ref{Methods and Technologies Involved}. The installation
      commands on Ubuntu 16.04 OS for each of these technologies are
      given in this section. Installations can be done from the
      terminal window.
163: All these installation steps are included in a make file referred
      in appendix \ref{Makefile}.
169: Dataset includes 1000 customer records with 20 feature variables
      and a class variable. In the class variable, the actual class of
      the customer is specified - good or bad. The complete list of
      data set variables and their description is given in Table
      \ref{tab:table1}.
171: \begin{table}
174: \label{tab:table1}
213: The data going to the analytics model should be clean and noise
      free. Hence data preparation part includes tasks like data
      cleaning, data normalization, data transformation, missing value
      imputation, data integration and Noise identification. Figure
      \ref{fig:Figure5} shows the data preparations tasks
      \cite{preprocessing}.
215: \begin{figure}[htb]
217: \includegraphics[width=1.0\columnwidth]{images/Figure5.png}
220: \label{fig:Figure5}
225: To reduce the dimensionality problem and the computational cost,
      because of a large number of variables and instances in the data
      set, we try to gather only the required set of quality data. Data
      reduction techniques include feature selection, instance
      selection and discretization. Figure \ref{fig:Figure6} shows data
      reduction techniques \cite{preprocessing}.
227: \begin{figure}[htb]
229: \includegraphics[width=1.0\columnwidth]{images/Figure6.png}
232: \label{fig:Figure6}
240: Big data analysis is the process of obtaining knowledge by
      analyzing and understanding hidden patterns, market trends,
      unknown correlations, customer preferences and other relevant
      information from large and varied datasets \cite{bigdata-
      analytics}. Big data analytics methods include exploratory
      analysis, data mining, predictive analytics, machine learning,
      deep learning etc. The results of the analysis can be visualized
      using tools like Tableau, Infogram, Plotly etc or by using Python
      scripts. This project utilizes methods like exploratory analysis,
      predictive analysis, machine learning algorithms and
      visualizations of results using Python scripts. Python codes for
      all these analysis methods are given in appendix \ref{Project}

```

Code}.

250: Figure \ref{fig:Figure7} shows the histogram of credit amount disbursed with respect to frequency. From this diagram, we understand that most of the customers are requested for loans for up to 2500 German Marks. The number of customers decreases as the loan amount increases. And very few customers fall under the loan amount category over 10000 German Marks.

252: \begin{figure}[htb]

254: \includegraphics[width=1.0\columnwidth]{images/Figure7.png}

257: \label{fig:Figure7}

260: Figure \ref{fig:Figure8} and Figure \ref{fig:Figure9} shows the credit amount availed by bad customers and good customers respectively. The trend is almost the same. Maximum customers from both the classes fall under the category of up to 2500 German Marks. But there is a noticeable difference in the number of customers under 12500 range. Bad rated customers are more in this category.

262: \begin{figure}[htb]

264: \includegraphics[width=1.0\columnwidth]{images/Figure8.png}

267: \label{fig:Figure8}

270: \begin{figure}[htb]

272: \includegraphics[width=1.0\columnwidth]{images/Figure9.png}

275: \label{fig:Figure9}

278: Figure \ref{fig:Figure10} shows the duration of credit in months vs. number of customers. From this graph, we can understand that maximum number of customers opted for 10 to 15 months duration.

280: \begin{figure}[htb]

282: \includegraphics[width=1.0\columnwidth]{images/Figure10.png}

285: \label{fig:Figure10}

288: Figure \ref{fig:Figure11} and Figure \ref{fig:Figure12} shows the duration of credit in months vs number of bad customers and good customers respectively. It shows that there is not much difference in the trend.

290: \begin{figure}[htb]

292: \includegraphics[width=1.0\columnwidth]{images/Figure11.png}

295: \label{fig:Figure11}

298: \begin{figure}[htb]

300: \includegraphics[width=1.0\columnwidth]{images/Figure12.png}

303: \label{fig:Figure12}

306: Figure \ref{fig:Figure13} shows how customers are scattered with respect to age. Most of the borrowers fall under the age group of 23 to 28.

308: \begin{figure}[htb]

310: \includegraphics[width=1.0\columnwidth]{images/Figure13.png}

312: \label{fig:Figure13}

315: \subsubsection{Data Classification}\label{Data Classification}

317: We have one class variable ''Creditability'' to classify the customers based on the bank's opinion on the actual applicants. We could extract this class information from dataset using PySpark Python script ''GroupBy''. Table \ref{tab:table2} shows the output of the script.

320: \begin{table}

322: \label{tab:table2}

342: Table \ref{tab:table3} shows the variability of Credit-Amount.

346: \begin{table}[]

349: \label{tab:table3}

358: Table \ref{tab:table4} shows the variability of Duration of credit.

361: \begin{table}[]

364: \label{tab:table4}

373: Table \ref{tab:table5} shows the variability of Age.

376: \begin{table}[]

379: \label{tab:table5}

392: \begin{table}[]

395: \label{tab:table6}

406: Table \ref{tab:table6} shows the contingency table created for the variable sex-marital status against class. It shows the number of good and bad customers distributed among the 4 categories of the variable sex-marital status. Category ''male: married/widowed'' has the maximum number of Good customers. Contingency tables are used to create the Chi-square values.

427: The calculated values are shown in Table \ref{tab:table7}.

429: \begin{table}[]

432: \label{tab:table7}

465: Baseline models use simple summary statistics. In classification problems like our scenario, baseline models are created based on the class values. As mentioned in the data classification section \ref{Data Classification}, our total list of 1000 customer records are divided into training dataset and test dataset. Training dataset has 700 customer records and test dataset has 300 customer records. For the baseline models, we evaluate the test data of 300 customer records.

471: \begin{table}

473: \label{tab:table8}

484: Table \ref{tab:table8} shows the assumption in baseline model 1.

488: \begin{table}

490: \label{tab:table9}

501: Table \ref{tab:table9} shows the assumption in baseline model 2.

505: To build this model, we use the machine learning algorithm - Decision Tree which is explained in section \ref{Decision Tree}. PySpark's class ''DecisionTreeClassifier'' is used to build different Decision Tree models from training data based on

different tree attributes like MaxBins, Maxdepth, Impurity etc. Impurity measures are calculated internally by this classifier to identify the root node and other internal nodes. Gini Index is the method opted in our project.

- 529: Random Forest Machine Learning algorithm which is explained in the section \ref{Random Forest} is used to build Random Forest model. We use PySpark class ''RandomForestClassifier'' to generate the model from training data. We build 2 Random Forest models one with default attribute and another one with chosen attribute values.
- 553: Prediction matrix can be extracted using the ''groupby'' option in PySpark. Table \ref{tab:table10} and Table \ref{tab:table11} shows the prediction matrix of Decision Tree and Random Forest respectively. Decision Tree has got 219 right predictions and Random Forest has got 240 right predictions out of 300 customer records.
- 556: \begin{table}[]  
559: \label{tab:table10}  
569: \begin{table}[]  
572: \label{tab:table11}
- 584: Feature Importance is the list of important predictors that are the top contributed variables towards building the predictive model. Normally the variable with maximum dependency would be treated as the root node by the algorithm. We could calculate the feature importance only for the Random forest algorithm by using the class ''bestModel.featureImportances''. Figure \ref{fig:Figure14} shows the list of predictors. We could see that the variable ''Account Balance'' contributes maximum to the predictions.
- 586: \begin{figure}[htb]  
588: \includegraphics[width=1.0\columnwidth]{images/Figure14.png}  
590: \label{fig:Figure14}
- 595: Figure \ref{fig:Figure15} shows the accuracy of different predictive models that we created. We plotted the output of ''MulticlassClassificationEvaluator'' for Decision Tree and Random Forest. We can understand from the graph that baseline model 2 has got the least accuracy and Random Forest has got the most.
- 597: \begin{figure}[htb]  
599: \includegraphics[width=1.0\columnwidth]{images/Figure15.png}  
602: \label{fig:Figure15}
- 609: A penalty matrix is defined to calculate the loss to the bank. Penalty will be applied to each misclassifications and penalty value differs for wrong classifications - 'good as bad' and 'bad as good'. As discussed in the project goals section \ref{Project goals}, approving loan for an uncreditworthy customer will end up

in more financial loss for the bank and accordingly is a greater risk. Hence classifying a bad customer wrongly as good customer will have more penalty.

611: \begin{table}

614: \label{tab:table12}

625: Table \ref{tab:table12} shows the penalty matrix. For right predictions penalty is 0. If a good customer predicted as bad, the penalty is 1 and if a bad customer predicted as good, the penalty is 5. The sum of the penalty values multiplied with the respective number of misclassified customers will provide the total amount of loss / penalty.

627: Figure \ref{fig:Figure16} shows the penalty comparison of different predictive models. Baseline model 1 has more chances of predicting bad customers as good because it blindly assumes that, all the incoming customers are good. Hence it has got more penalty value. Baseline model 2 has got least chances of classifying bad customers as good because it assumes all incoming customers are bad. Hence baseline model 2 has minimum penalty.

629: \begin{figure}[htb]

631: \includegraphics[width=1.0\columnwidth]{images/Figure16.png}

634: \label{fig:Figure16}

639: Figure \ref{fig:Figure17} shows the accuracy and penalty comparison for all the 4 models. Random Forest is the most accurate model and with minimal penalty. Hence Random Forest is the best model out of all.

641: \begin{figure}[htb]

643: \includegraphics[width=1.0\columnwidth]{images/Figure17.png}

646: \label{fig:Figure17}

674: \subsection{Makefile}\label{Makefile}

682: \subsection{Project Code}\label{Project Code}

figures 17  
 tables 12  
 includegraphics 17  
 labels 36  
 refs 34  
 floats 29

```
False : ref check passed: (refs >= figures + tables)
False : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
False : check if all figures are referred to: (refs >= labels)
```

Label/ref check  
 passed: True

```
When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

---

```
bibtex
```

---

```
label errors
```

```
bibtex errors
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
```

The following tests are optional

=====  
Tip: newlines can often be replaced just by an empty line

find newline  
-----

passed: True  
cites should have a space before \cite{} but not before the {

find cite {  
-----

passed: True

# Big Data and the Customer Experience Journey

Ashley Miller  
Indiana University  
admille@iu.edu

## ABSTRACT

A customer's experience journey consists of multiple touchpoints along the way as they make choices in which companies and brands to interact with and ultimately, purchasing decisions. While the customer experience journey may differ based on product, service, audience, time, as well as a company's capabilities and strategic initiatives, the need to understand the customer transcends all industries. These touchpoints are increasingly moving to the digital space through online search, mobile interaction, social media, email, in addition to other methods that may not even be in existence as of yet. Given the number of these touchpoints across customers and the ability to track customers across multiple methods, understanding the experience of customers through the use of big data provides opportunities for companies to better enhance the customer experience journey. Real-time recommendations, personalized marketing messages, and geo-targeted advertising can all play a role in *nudging* the customer appropriately when companies are looking to drive customer interaction and behavior. We will seek to explore this customer experience journey in the digital environment and introduce relevant case studies where companies and industries have started to utilize big data and analytics to better understand and customize the customer experience journey through digital efforts.

## KEYWORDS

i523, hid329, big data, analytics, customer experience journey, consumer behavior, digital marketing

## 1 INTRODUCTION

The customer experience journey has been largely explored from a psychological and behavioral standpoint [50]. Dating back to the near 1800s, marginal and expected utility of actions were detailed by Nicholas Bernoulli, among others, to better understand how purchasing decisions were made [50]. From related work that followed in this field of studying behavioral economics, research has shown that purchasing decisions are not linear and at times, are not even rational as cognitive, emotional, and social factors can all play a role into how a customer makes a purchasing decision [50]. As described by Stoicescu, the reason why researchers started to study purchasing behavior was due to the "diversification of need" [50].

However, with diversification also comes complexity. The more choices a customer is given, the harder it can become for them to make a decision [50]. With every product choice, there also is an opportunity for interaction or *touchpoints* along this customer experience journey [34]. These series of touchpoints can occur through a variety of ways and the time frame in which they take place can also vary greatly by the product or service being offered and to which audience. In figure 1 example of a customer setting

up utilities after the purchase of a new home and the multiple touchpoints they may encounter along their journey [41].

[Figure 1 about here.]

However, not all touchpoints are created equal [34]. There are some touchpoints that every customer may have to go through to get to the next step in the process and others that will produce a more valuable action, such as a purchase [34]. There are further questions today that did not exist in years past due to the advances in technology and how that affects customer behavior [29]. These advances in technology not only could influence customer behavior but also provide companies direction on which products they should produce, where these products should be placed, what price point is most optimal and how should they properly promote a particular product to their audience [29]. Big data and analytics can provide opportunity to inform the promotional piece as companies have utilized this feature to provide personalized and relevant content along the customer journey as defined in figure 2 [50].

[Figure 2 about here.]

While traditional advertising and marketing methods have included outdoor, print, television, and radio, among others, there is a growing shift in reaching customers via the digital space [29]. As of 2016, digital advertising spend reached 72 billion dollars, a 20% increase from the year prior and now accounting for a third of all advertising revenue spent in the United States [5]. With the increased move to digital from more traditional outreach methods, the customer relationship is also being managed via digital platforms such as email, social, and mobile [29]. A customer's *digital journey* can provide opportunities for big data and analytics to better understand the touchpoints along the way as well as where a company may be able to *nudge* a customer appropriately to make a purchase decision.

The objective of this work is to provide a view into the customer experience journey as it relates to big data and analytics. This overview of existing work is to allow one to see how a company or industry may start to match their big data efforts with the purchase decision that customers make as well as the multiple touchpoints included along the way. The move towards digital outreach and marketing efforts will also be defined to ensure the reader understands what is meant throughout as it relates to outreach and personalization efforts. Rather than the analysis of a specific dataset, real-world examples will be showcased across a variety of industries to provide detail as to how big data is being used to better understand the customer and enhance the journey they go through along the way. Lastly, this work will highlight the need of matching big data with the customer experience journey, challenges with pursuing this work going forward, along with recommendations on how to overcome these challenges.

## 2 WHAT IS THE CUSTOMER EXPERIENCE JOURNEY?

The way *customer experience journey* is defined can differ by industry, product, and even by place. While past work has defined the customer experience journey as the process of purchasing a product or service, in today's landscape, it has become more than that. The Harvard Business Review would define the customer experience journey as the "sum-totality of how customers engage with your company or brand, not just in a snapshot of time, but throughout the entire arc of being a customer" [42]. Traditionally, the customer experience journey and buying process were used interchangeably where a customer moves through a decision making process. Some key areas that were highlighted in a typical customer experience journey include:

- **Need Identification:** At this stage, this is where the customer decides whether they have a particular need that they believe the product or service could fill. There are times where properly identifying the need or problem can be an area of opportunity for a company [13].
- **Awareness:** In order for customers to even engage with a product or brand, they first need to be aware that it exists. Further, the customer has to decide whether the product, service, or brand is relevant to them [13].
- **Evaluation of Alternatives:** Here, a customer starts to investigate the options available and educate themselves on the benefits and drawbacks of each. This is an area where companies seek to differentiate themselves from competitors as customers go through this stage in the progress [13]. As customers continue in their research state, they can be influenced in a variety of ways such as through advertising and marketing, word-of-mouth or reviews from others, in addition to information they obtain in other ways through their own search process [29].
- **Purchase:** After a customer has gone through their choices to the best of their satisfaction, they move to the stage where they decide to make (or not make) a purchase [29].
- **Post-Action Evaluation:** After a decision is made, one way or the other, this is place where the consumer evaluates their decision which may include key questions such as [13]:
  - Were my needs adequately met?
  - Am I satisfied with my choice?
  - If given the same circumstances, would I make the same choice again?
  - Would I recommend the choice I made to others?

While the list of questions could be endless the intent is to move customers through this purchase decision process so companies create loyal customers and advocates [29]. However, that model is evolving with the shift to a multi-prong outreach approach via digital and non-digital methods [13]. A longer customer experience journey is outlined in figure 1 as a customer can enter at any stage in the process. Pre and post purchase measures can be collected, stored, and analyzed at any point along the way as shown in figure 3 [13].

[Figure 3 about here.]

## 3 WHAT DOES DIGITAL MEAN?

With the influx of big data, analytics, and technology, there is often a rallying cry among leadership teams for an effort to be more *digital*. However, when exploring the definition of *digital*, it can greatly differ by audience, industry, and objective. Even within a singular company, alignment on what digital means can vary. Instead of trying to decide what digital *is*, it may be more beneficial to think of what digital *can do*. McKinsey highlights that digital should create value of some kind and offers various ways in which this can apply to an organization [14]. Despite varying definitions, methods, and applications of what digital *is* (and *is not*), there are commonalities in digital efforts that can be used to better understand this environment [26]:

- **Customer-Centric:** Digital efforts entail putting the customer first as they examine data and processes to enrich the customer experience [26].
- **Real-Time:** Long gone are lag times between collecting, analyzing, and processing data to decision-making. Now, data collection is always on and can be pulled at any time [26].
- **Connected:** With the volume, veracity, variety, and velocity of big data alone, the ability to have data sources and storage systems talk to one another is crucial to develop meaningful insights and inform decision making appropriately and effectively [1]. This not only has to happen from a technology standpoint but also from a company culture standpoint as well to ensure appropriate units and individuals are also talking to one another to better understand the customer experience journey overall.

It's important to note that while *digital* can mean *online*, one should not assume that these actions and behaviors only occur in the online environment. However, the collection, storing, and analyzing of these behaviors can be *digital* or *online* even though they may be reflective of what is happening in an *off-line* setting. Overall, implementing digital capabilities should improve business processes, challenge new ways of thinking, and deliver ways to enhance the customer experience journey [1].

## 4 WHAT IS DIGITAL MARKETING?

While advertising and marketing methods go as far back as the 1800s where customer lists were used to determine how individuals could be influenced via direct mailing efforts, digital marketing has only come to be with the creation of the internet [10]. The internet has created opportunity for brands to directly connect with customers and likewise, for customers to engage with brands in a myriad of ways in the digital space [17]. While varying definitions of digital marketing exist, it is often categorized as a subset of traditional marketing where the "use of digital technologies create an integrated, targeted, and measurable communication" to not only attract potential customers but engage with current ones for retention and loyalty purposes [23]. Digital marketing became even more prevalent in the 2000s as companies such as Google, Yahoo, and Facebook provided opportunity to deliver ads at an individual level based on demographic and behavioral characteristics [10]. Other data collection firms offered the ability to track users across the web space to see which pages were viewed, clicked, and time

explored to help further understand the experience of a customer across the web space [10]. With these advances in technology and understanding, the customer experience journey began to also transform along with the changes in advertising from traditional to more digital.

## 5 HOW IS BIG DATA INVOLVED IN THE CUSTOMER EXPERIENCE JOURNEY AND DIGITAL MARKETING?

As the typical customer experience journey moves away from a traditional linear process and more towards an iterative approach, there is a need to understand the pathway among customers with data [17]. As of 2016, there are now approximately 3.7 billion individual users on the internet [3]. This population size coupled with the multiple methods of interaction present an opportunity for companies to better understand potential customers in an effort to deliver the right message, to the right person, at the right time. A Gartner report states that the amount of data companies are collecting is growing by nearly 40 percent year-after-year [30]. Nearly one of out of every four state that there is a need to tie big data back to marketing-related efforts [30]. At the time of the report, it was estimated that only three percent of companies surveyed had a dedicated individual responsible for big data analytics and customer intelligence insight [30]. As the touchpoints with customers increase and also move more towards digital, so does the ability to collect and track the data from these touchpoints to better understand the customer experience journey [17].

One could argue that marketing data has been *big* for quite some time given the sheer number of people exposed to efforts typically exceeds millions [10]. However, what has changed in this space is marketing's increased use of digital technologies to reach potential customers in the digital landscape across various channels including search, display, social media, email, etc. [29]. For companies to be successful in utilizing big data to inform digital marketing efforts and to better track and enhance the customer experience journey, incorporating the necessary technologies and talent is a must along with shifting the organizational culture to making data driven decisions [23]. This process can be difficult as an individual user alone can generate "billions of data signals" and attempting to understand which ones may be tied directly to a product or brand's marketing efforts can be a daunting and overwhelming task [10]. However, there are a few well-known companies that have started the shift in tracking the customer experience journey through big data analytics and applications. We will examine key industries that have leveraged this knowledge and insight to better understand and enhance their relationship with customers.

## 6 BIG DATA IN ONLINE RETAIL

Companies like Amazon and eBay are often cited as pioneers in utilizing big data analytics considering these were companies that were *born digital* [3]. While other retail companies have made their way into the big data analytics environment, often times they are brick-and-mortar establishments in addition to offering electronic commerce (e-commerce) capabilities, such as Target, Sears, or Wal-Mart. Growth in e-commerce has taken place around the world

with nearly 1.3 billion customers in existence as of 2016 [3]. In the online space, there are multiple opportunities for these companies to track the customer experience from number of visits, keywords used in search, orders and products placed, frequency of purchases, in addition to when items in their virtual cart are abandoned or even when items are returned or complaints are filed [3]. Amazon and eBay, among others, have utilized big data analytics to their advantage to create recommendations for their customers, develop predictive models, and also offer real-time changes in the customer's experience journey.

### 6.1 How Does Amazon Use Big Data?

In 1995, Amazon started its life in the online space as an electronic bookstore [25]. While early sales were still impressive totaling nearly \$20,000 a week, during their popular campaign of *Prime Day* in 2017, analysts estimated that sales for that one day alone to be around \$500 million [47]. As of July 2017, Amazon has approximately 300 million users with nearly eight out of ten that make a purchase at least once a month [47]. The amount of information tracked per user continues to increase at an exponential rate as Amazon's growth has moved beyond their days of an online bookstore and into the realm of an *everything store*, including acquiring other large companies such as Whole Foods [40]. With this, there are a number of ways that Amazon uses big data to enhance the customer experience:

- **Personalized Recommendations and Predictive Modeling:** As customers are exploring products on Amazon, they are often shown other suggested products either based on their own past purchase behavior or by what others who purchase similar items also bought [3]. These recommendations are shown in real-time, often on the same web pages as customers are exploring other products [3]. It is estimated that based on this ability alone, utilizing both structured and unstructured data, that 35% of all sales are attributed to the recommendation algorithm, which would show that their predictive efforts are meeting the needs of their customers [3].
- **Efficient Delivery:** Even though Amazon utilizes and houses large amounts of data about its customers to offer personalized recommendations and offers, the company also has to maintain a tremendous amount of data about its own operations to inform logistics and supply chain management to meet customer expectations [3]. A key selling message of Amazon is delivering product in two business days, even in some cases offering same day delivery on certain items if they are ordered within a certain timeframe CITE[21]. With the increase number of products, suppliers, and customers, Amazon is still able to rely on big data analysis to maintain a consistent experience that doesn't compromise delivery for the customer which in turn leads to a better customer experience overall [3].

### 6.2 How Does eBay Use Big Data?

eBay is a website that also started in 1995 which offered a unique opportunity to bring together buyers and sellers in the online space [15]. Sellers could place their items online where buyers could

potentially place bids, similar to if they participated in a live auction, where the item may go to the highest bidder. This allowed for others around the globe to connect and purchase items directly from another person while paying for the item through online methods. It is estimated today that there are nearly 180 million buyers and sellers and nearly 250 million search inquiries made per day on eBay [31]. Like Amazon, eBay seeks to understand and tailor the online experience for customers through the use of big data in a multitude of ways as eBay itself states “understanding the customer is key” [44]. Various methods utilized to better understand and tailor the customer experience journey include:

- **Web Page Metrics to Inform Layout:** It is estimated that among eBay customers, there is “100 million hours of interactions collected per month” [44]. Through an extensive number of experiments and A/B testing, eBay is able to optimize the web experience for customers. From their big data analytics, they can find preferred layouts of web pages which can customize anything from navigation feature to the size of photos displayed on the screen [3].
- **Ease of Finding Items:** Buyers and sellers alike utilize the search feature provided on the eBay website to find necessary items or to compare price points of like items when deciding which price point to utilize [31]. Behavior patterns of customers have been used to inform how to best optimize the search feature in an effort to get customers to the necessary items more quickly which in turn will, hopefully, produce a sale [31]. While in the past, the search algorithm would have taken words and terms in a more literal sense, though optimization eBay has been able to make the search algorithm more intuitive which has lead to more sales [31]. Such examples show that originally when customers would shorten words used in the search feature, they may not find what they need. However, after analysis of customer inputs and changes in the search algorithm, this ability was taken into account so customers could still find the necessary product without changing their behavior.

## 7 BIG DATA IN THE FINANCE INDUSTRY

There are a number of products and services available in the finance industry ranging from personal and business loans, to stocks, retirement accounts, and credit cards. Companies such as JP Chase Morgan, American Express, and Bank of America are capitalizing on big data use to inform their offerings and also better understand their customer base [52]. These companies are monitoring the customer experience journey through all touchpoints which could include web visits, phone calls, and even in-person interactions [24]. This information can also be used to detect fraud on certain accounts when activity occurs that may not be typical of their customer [52]. These algorithms and techniques can in turn ensure customers are protected which help with customer retention. Conversely, those in the finance industry may also be able to utilize big data and mining techniques to determine if they are about to lose a customer. One such company that utilized these methods to their advantage is American Express, which accounts for nearly

a quarter of all credit cards transactions and totals more than \$1 trillion annually in customer purchases [35].

### 7.1 How Does American Express Use Big Data?

In 2010, American Express invested in big data technologies and resources, including Hadoop, to increase capabilities to detect fraud, provide recommendations to current customers, predict who may close their accounts, as well as acquire new customers [52]. These methods are used to assist in efforts to maximize the customer experience journey through the use of:

- **Fraud Detection:** To minimize loss, fraud alerts have to happen quickly. To achieve this, American Express implemented machine learning algorithm techniques [32]. Data points included in the model consisted of information about the merchant where the purchase occurred, purchase details such as items bought and price, and even customer information [32]. By analyzing patterns in real-time, American Express was able to flag possible fraudulent activity in a matter of milliseconds which then allows the company and customers more time to prevent further loss with the increased capability [32]. American Express was able to identify an additional \$2 billion in fraudulent activity that that they were not able to identify before and therefore protect their customers and ensure a more positive customer experience as a result [32].
- **Personalized Recommendations:** Along with protecting their customers, American Express also seeks to understand how to better engage their customers through personalized recommendations. One such example is based on analyzing customers past transactions along with geographic location information to push specific recommendations to customers in real-time [52]. Through the use of big data analytics, the company can send recommendations on similar restaurants in the area if they see from a customer’s transactions they frequent a certain genre or area [52]. These recommendations also work on behalf of the merchants who accept American Express as the company can provide information on purchases in the area which merchants can use to create offers to entice customers to purchase products and services by using their American Express card at their particular store [16].
- **Churn Prediction Models:** American Express also uses its vast amounts of data to see if they can predict whether a customer will close their account [32]. By incorporating machine learning models, they can better understand the customer experience and appropriately jump in at different points along the journey in an effort to deter customers from closing their accounts. Through analysis of past transactions as well as nearly 100 other variables incorporated to understand customers, the company estimated that for one model, they were able to identify nearly one out of every four accounts they believed would have closed in the near future [32]. With this information, tailored marketing and messaging could be implemented to help with retention rates.

- **Acquiring New Customers:** Despite the large base of customers, merchants, and transactions, there is always a need for businesses to grow to increase revenue and capabilities for the future. One way to achieve this is through digital marketing efforts targeted at those who may be potential customers for American Express. Through their efforts, American Express was able to grow their customer base by nearly 40% through online marketing efforts [32]. With these more targeted and cost-effective measures, American Express was able to efficiently acquire new customers as compared to more traditional marketing efforts of the past, such as direct mail [32]. These optimizations further enhance the customer experience journey by delivering them a message at the right time through the right medium.

## 7.2 How Does Bank of America Use Big Data?

While big data, analytics, and predictive models can be used to better understand how to reach out, retain, and attract customers, these same techniques can be applied when determining how to optimize the customer experience journey from an internal perspective. Considering the journey can take place across a series of touchpoints, Bank of America was one major bank, among others, that utilized big data to better understand how to better serve their nearly 50 million customers [12]. One method included:

- **Customer Segmentation:** Through the use of big data, Bank of America acknowledged that their customer base could be divided into segments and therefore their behavior and needs differed [12]. By analyzing online correspondence, calls from a call center, and even visits to area branches, appropriate offers could be tailored to the customer [12]. Utilizing data points provided in the online space along with the ones that occurred elsewhere, a new program was developed by Bank of America [12]. With this new program and customized offerings, customers were more highly engaged with by Bank of America which increased customer satisfaction and experience as a result [12].

## 8 BIG DATA IN THE HEALTHCARE INDUSTRY

Rising patient volumes, increasing aging population, and mounting costs have all contributed to the growth, importance, and complexity of the healthcare industry [37]. As of 2016, it is estimated that nearly \$4.1 trillion will be spent on healthcare costs in the United States alone [37]. Nearly 290 million people in the United States have some form of insurance or healthcare coverage but that also leaves nearly 28 million who are uninsured [19]. A typical customer can interact with a number of stakeholders throughout their healthcare journey ranging anywhere from their initial doctor's visit, to filling a prescription at the pharmacy, to paying a bill to their insurance provider. One may then ask based on these interactions: how does the online space play into the healthcare industry at all?

With the move to electronic medical records (EMR), the ability to now aggregate years of information on an individual, as well as an entire population, becomes more of a reality [20]. Even though

the healthcare industry has lagged behind other industries regarding their collection and use of big data, they are one of the most important as it relates to utilizing their information to create a better experience for customers as it pertains to their health [20]. The ability to link this data across various stakeholders is also critical in understanding the full journey of a customer (or patient) to ensure effective treatment decisions are made. Health Information Exchanges (HIEs) allow for this opportunity and the HIE has information on more than 10 million patients, over a span of nearly 80 connected hospitals, and approximately 18,000 physicians have access [20]. Big data in the realm of healthcare provides tremendous opportunity to create value for customers and healthcare professionals alike. One such software company explored this use of connected data sources to better inform healthcare providers with practice-based evidence in an effort to tailor care for an individual patient [6].

## 8.1 How Does Apixio Use Big Data?

As others have stated about healthcare related data and reporting, "the problem in healthcare is not lack of data, but the unstructured nature of its data" [33]. Apixio, a cognitive computing firm based in California, wanted to take on the challenge of making unstructured healthcare related data available and easier to use in order to better aid decision making in patient treatment [33]. Their work involved taking clinical charts of patients and combining them with notes from physicians, test results, and even hospital stays to develop a more complete picture about an individual [33]. From there, Apixio was able to provide benefits based on this big data process:

- **Patient Model Development:** Data at an individual level was used to develop patient models from a series of text processing and coded healthcare data [33]. By creating a profile per individual, like individuals could then be grouped together which in turn helped to inform what treatments or procedures would work best in those individuals who fit a certain criteria [33]. Considering this information is derived from actual practice of medicine, it can better inform clinical care and also ensure that patients are set up for best optimal outcomes if treatment decisions are made based on big data collection and analysis [33].

- **Healthcare Cost Savings:** Cost of healthcare continues to be a growing concern for both customers and other key players such as healthcare professionals and insurance companies [37]. With the move to EMR and big data analytics, it is estimated that anywhere between \$300 and \$450 billion dollars can be saved in healthcare costs [37]. With the use of big data technology and methods, Apixio developed a system that could read and code patient chart information [33]. Typically, this method of coding would have been performed manually by a person or set of individuals, and with that comes a laborious and expensive process [33]. Apixio's capabilities were also found to be more accurate resulting in 20% improvement in accuracy which in turn lead to better decision making among healthcare providers [33]. The also helped individual customer to ensure they were getting billed appropriately for the right treatment or procedure as well as for the insurance

company who may be providing coverage [33]. These techniques then allow for an improved customer experience journey if costs can be mitigated through the use of big data initiatives that allow for better efficiency and accuracy.

## 9 BIG DATA IN THE ENTERTAINMENT INDUSTRY

The entertainment industry includes a wide array of forms including newspapers, movies, books, television programs, and radio [22]. As of 2016 it is estimated that this industry is worth approximately 1.8 trillion dollars in the United States alone [49]. Streaming video services such as Netflix and Hulu have entered the market in recent years and provide a further opportunity to deliver content directly to customers. As of 2016, video streaming services are the second largest category for home entertainment with customers in the United States spending \$6.2 billion [4]. The wealth of data collected from these streaming services include but are not limited to the type of content watched, when content is watched and on which type of device, as well as how often it takes for customers to make a selection down to an individual user level [8]. Netflix is one of the many video streaming leaders and has made big data and analytics a foundation to their business strategy and outreach initiatives [28].

### 9.1 How Does Netflix Use Big Data?

While Netflix once started out as a mail-subscription video rental service, the business model has shifted to provide content entirely online and caters to nearly 60 million subscribers in over 50 countries [28]. Netflix's competitive advantage in the market place stems from their ability to use big data as they estimate that they process over 10 petabytes of data a day which includes more than 400 billion new events [28]. Utilizing programs and data scientists, Netflix began to seek out additional opportunities to understand customer preferences and to also optimize the experience journey through a variety of different methods:

- **Personalized Recommendations:** Netflix not only analyzes what a particular person may watch but also what others who *look like* that user may enjoy based on data such as age, gender, or even zip code [28]. With the sophistication of the recommendation algorithm, viewers spend an average of 17.8 minutes browsing through the selections before picking a program to watch [28]. Spending more time increases the level of engagement with users and also extends the lifetime value of the customer in an effort to help with retention [8]. By delivering relevant content, Netflix estimates they save more than \$1 billion per year by their efforts in keeping customers happy [8].
- **User Choice:** In addition to providing the right recommendations, ensuring that the image or artwork for films is appropriate to the user also aids in choice [8]. Netflix engages in A/B testing of program thumbnails images and also seeks out feedback from users on which images they prefer [8]. From this process, Netflix was able to increase video viewing between 20-30% when utilizing the right images and listening to customers' preferences [8].
- **Customized Content:** Analyzing what audiences enjoy watching can provide insight as Netflix sought to create

their own content [28]. One common cited example includes the development of *House of Cards* as an original Netflix series that was created with big data information [28]. Netflix found that the original series from the British Broadcasting Corporation (BBC) did well with audiences and that Kevin Spacey movies were also popular [28]. Further using customer data, Netflix understood that customers *binge-watched* seasons of shows and therefore releasing an entire season at a time would best meet the needs of their customers versus one episode at a time [28]. The year the *House of Cards* series premiered, subscribers grew from 27.1 to 33.4 million and the show received countless Emmy and Golden Globe nominations and awards [28]. By utilizing big data, Netflix was able to create and deliver content that customers wanted and also help their bottom line [28].

## 10 BIG DATA IN THE GAMING INDUSTRY

In addition to the entertainment economy, the gaming sector also is substantial in size and revenue. In 2016, the commercial gaming industry grew to \$38.7 billion across 24 states and nearly 600 casinos [43]. Las Vegas, a leader and popular gaming destination had a record year of visitors at nearly 43 million [43]. With increased competition among entertainment resorts and casinos in Las Vegas, as well as other parts of the United States, the need to create an optimal customer experience is crucial to attract customers and also keep them engaged. Metro-Goldwyn-Mayer (MGM) Resorts International and Caesars Entertainment are two conglomerates that have capitalized on big data use to better tailor the customer experience journey.

### 10.1 How Does Caesars Entertainment Use Big Data?

Caesars has described their customer relationship optimization process as utilizing a "data-driven and closed loop approached to deliver a personalized experience" [51]. A few ways they have implemented this include:

- **Creating Customer Loyalty:** Demographic, gameplay, and other transactional data is kept on each guest to create a detailed profile [51]. Employees then across the establishment can utilize this data to personalize offerings and incentives to customers, anywhere from how he or she is greeted by staff to whether complementary services should be offered to improve the customer experience [51]. This type of treatment isn't just limited to big spenders at the casino but translates across all customers in an effort to create loyalty across multiple segments [51].
- **Efficiencies Through Mobile Application:** Caesars also offers guest the ability to utilize their mobile device to conduct tasks such as checking into a property or even ordering a drink from the bar to avoid long lines [51]. Incentives can also be pushed directly to customers based on their location and preferences such as tickets for shows or dining options in the area [51]. Considering most guests carry their phone in their pocket, engaging with them on

the casino floor can create a better customer experience to give them what they need, when they need it [51].

- **Customized Experiences:** The vast amounts of data collected on customer behavioral patterns in terms of which machines are played, when, where, and by whom can provide insight into how to best tailor offerings [46]. For example, it was observed that an elderly population visits the casino at a certain time of day and therefore with the influx of that audience, casinos are able to adjust game offerings in real-time offering enlarged text for better viewing among the visually impaired in that age group as well as bet levels for certain games [46]. By analyzing heat maps of popular games and parts of the casino, it also allows for companies to staff appropriately to ensure customer needs are being met based on predicted demand [46]. These real-time changes enhance the customer experience journey by tailoring offerings to specific customer segments.

## 10.2 How Does MGM use Big Data?

Similar to other casinos and resorts, MGM has utilized past customer data in an effort to better predict future behavior [36]. However, they have also utilized this data to create personalized marketing offers to entice frequent (and non-frequent) visitors back into the experience [36]. Though sophisticated modeling efforts, MGM is able to tailor marketing efforts to include a variety of different incentive types and levels. The final result of this process created 120 models of customer behavior with approximately 180 variables in each as well as 20,000 parameters across all which showcased an increase in revenue at a lower cost [36]. These models were used to inform marketing efforts across a variety of areas, including but not limited to [36]:

- **Hotel Room Rates:** Attributes such as room type, discount, number of times, etc., all play a role in which aspect will draw a customer back into the establishment [36].
- **Entertainment Add-Ons:** Type of entertainment offered, ticket price, or even facility features were all used as inputs in the model [36].
- **Other Offers:** Air packages, limo rides, resort credits, and many others were also used as way to determine which customers would respond to which offers [36].

## 11 BIG DATA IN THE TRANSPORTATION INDUSTRY

Whether by plane, train, car, or other means, today's American customer relies on some sort of transportation to get them to varying destinations whether it be work, school, or even vacation. An average person spends 20% more time commuting today than they did 30 years ago [7]. With this come questions to the transportation industry as to where they should expand highways, add public transit, or open additional hubs or destinations for travel. Big data can be one avenue in exploring and answering these questions as well as create a more enjoyable experience for the customer if they can spend less of their life commuting. The introduction of the ride sharing mobile application of Uber also arose based on customer needs and preferences and through the use of big data is thriving as alternative transportation option [9]. Large airline carriers have

made use of big data as they seek to understand buyer behavior so they can effectively plan flights and other amenities to meet customer needs [39].

### 11.1 How Do Airlines Use Big Data?

In just one day's time, it is estimated that there are nearly 42,000 commercial flights and 2.5 million passengers [2]. From purchasing a ticket, to taking a flight, and (hopefully) receiving their checked baggage at their final destination, airlines collect a wealth of information on their customers throughout their flying experience [39]. When looking at key attributes that are analyzed and down to an individual level, airlines collect information about purchase history, arrival, departure cities, and dates, in-flight food choices, connecting cities, travel companions, as well as miles and credit card points earned and used [18]. While airlines have succeeded in collecting this data, using it to better enhance the customer experience journey is still a work in progress [39]. Those who work in the travel software environment and frequently provide products and services to those in the airline community to better understand their data even state they have "not seen a single major airline with an integrated big data business solution" [39]. With that in mind, highlights from major airline players are explored even though full development of utilizing big data may still be on-going in this industry.

### 11.2 How Does Southwest Airlines Use Big Data?

One way that Southwest Airlines is utilizing big data is by trying to identify new opportunities for revenue [39]. By analyzing customer behavior online, Southwest is able to support their relationship with customers by offering the best rates in real-time [39]. They are also able to look at searches for destination pairs and make determinations on whether certain flights should be added to keep their customer base loyal and ultimately satisfied by getting to where they need to be, when they need to be there [18]. Not only is Southwest looking to meet the needs of customers as they make a flight choice, but they also seek to comprehend customer interaction at other points in the purchase process [18]. By utilizing a speech analytics tool, the company can better understand recorded conversations that take place with representatives as well as social media chatter [18]. These real-time insights can then inform customer service representatives as they interact with customers and guide them to deliver the optimal solution in various situations [18]. In addition to optimizing the customer experience from a satisfaction standpoint, Southwest airlines has also partnered with NASA on potential safety initiatives where machine learning algorithms can be used to spot potential abnormalities [18]. These efforts enhance the customer experience journey by not only looking out for safety of individuals but by also meeting their needs based on behavioral data.

### 11.3 How Does Delta Airlines Use Big Data?

In a quest for customer loyalty, Delta Airlines has made an intentional effort in investing in their baggage tracking system to better meet customer needs [45]. With this \$100 million dollar initiative, it not only gives airport operation teams the opportunity to identify

trends in mishandled luggage situations but also real-time information to baggage handlers when transferring or sorting through bags [45]. Similar information is also shared with travelers so they can track the progress of their bags down to the minute [45]. With approximately 130 million bags checked in a given year on Delta Airlines, there is a common concern among customers on whether their bag will arrive at their final destination [39]. Giving customers a piece of mind allows for a more beneficial customer experience and also increases satisfaction and loyalty. The luggage tracking app has been downloaded 11 million times and has reduced the rate of mishandled luggage by nearly 71% since 2007, which is better than any other airline [45].

#### 11.4 How Does Uber Use Big Data?

Founded in 2009, Uber started as a technology company and created a mobile application that connected those seeking transportation with those who were drivers [9]. Now, with nearly 8 million users who have connected with over 160,000 drivers, nearly half of the United States population has access to Uber in their city [27]. The only opportunity to connect riders and drivers is through the mobile app consolidating data collection and tracking from the start; however, the sheer volume and real-time application of data use to inform pricing and availability still presents on-going challenges [9]. Demographics, frequency of trips, destinations, price, as well as sessions that do not end with a purchase are all recorded from the application [9]. Several ways in which Uber utilizes big data to meet customer needs includes:

- **Matching Supply and Demand:** By analyzing travel transactions, Uber can appropriately plan for busy nights so customer travel needs are met [9]. Customers are also able to give feedback about their ride experience and rate drivers [6]. With this capability, the company can inspire trust and improve satisfaction if they find that certain drivers are not meeting expectations [6]. UberPool is also a new feature that has been added that allows for carpooling of customers where real-time analytics search for other customers in the area by geography [6]. This can therefore improve the customer experience for those who want to share a ride and split the cost appropriately [6].
- **Dynamic Pricing Model:** Uber is also able to adjust pricing models accordingly based on time of day [9]. Fair estimates are also able to be given in real-time which allow the customer to adjust their travel plans if needed and also pick the type of transportation, such as a sedan or sports-utility-vehicle (SUV) [9]. However, there are times that Uber uses these models to the company's advantage and offer *surge* pricing in the events of heavy demand or traffic [9]. All financial transactions take place via the application with no exchange of cash. Pre-set and transparent pricing structures allow customers to select what fits their needs, even if they find their choice is to not take a ride at a particular time. Having the necessary and accurate information provided at time or purchase makes for a more enjoyable customer experience journey [6].

#### 12 WHY IS USING BIG DATA TO OPTIMIZE CUSTOMER EXPERIENCE JOURNEY IMPORTANT?

These examples are a select few to showcase how companies can better understand and further the customer experience journey by leveraging big data. The average customer is presented with more choices today than ever before [34]. With this, companies today have to be more strategic to get the attention, time, and loyalty of customers to remain in the marketplace. Doing so can provide many advantages to both companies and customers as they utilize big data to better understand the customer experience. As Rawson et al state: "companies that excel in delivering journeys tend to win in the market" [41]. Trends presented showcase how big data can provide big benefit:

- **Retention of Customers:** It is estimated that "acquiring a new customer can be between five and 25 times more expensive than retaining an existing one" [21]. Utilizing big data to predict when customers may close accounts can help to inform company efforts and ultimately prevent potential revenue loss if they can keep existing customers. American Express showed that by using big data and predictive analytics, the company could identify these customers sooner versus wait until the customer is already lost.
- **Personalized Outreach:** Tailored communication messaging, and recommendations can give customers a better experience in getting what they need from companies but also benefit the company's bottom line as well. As Netflix and Amazon have showcased, providing recommendations to customers increases engagement and purchase behavior.
- **Company Process Efficiencies:** Utilizing big data to understand customer behavior can help companies determine whether changes or improvements need to be made in how they deliver products and services to customers. As the Delta example showed, tracking baggage was not only a concern to customers but by doing so, the company improved their mishandled luggage rates. These efficiencies not only create satisfied, and possibly loyal, customers but also ensure that companies are spending their resources effectively by not making costly and time-consuming errors.

#### 13 WHAT CHALLENGES EXIST IN UTILIZING BIG DATA FOR THE CUSTOMER EXPERIENCE JOURNEY?

While big data use is going to be a crucial component going forward in understanding the customer experience journey, companies do face challenges in making this a reality, specifically:

- **Data Ownership** Customer data can live in a variety of places within one organization. The departments in which this data lives can be in silos with multiple departments not talking to one another or not willing to share what they feel their department owns [48].
- **Company Culture** Cooperation across the organization can be a significant barrier in truly understanding the full customer experience. [48].

- **Lack of Strategy** Without a clear strategy, it can also create issue in trying to determine how to best interpret and apply the findings in the data. This can lead to gaps in the organization if it is unclear what the ultimate goal is and which parties play a role [48].
- **Resources and Skills** The technical aspects of understanding the customer experience journey can be a barrier as well. Having the right technology, people, and time in place to understand the full customer journey can also be a challenge for companies. [11]
- **Consumer Behavior Volatility** Not all decisions made by customers are rational ones and there can be a variety of factors in play that big data can not track [50]. As further detailed in other work “people do not behave like robots,” so even when all the variables are optimized, outside forces beyond the control of a company could influence choice along with a customer’s own emotions which big data doesn’t always include [42].

Since within one company there can be different systems, different processes, and a variety of people employed with different skillsets, trying to address all of these challenges can be overwhelming. However, with challenges come opportunities and areas in which companies can focus on as they strive to have data that is connected, customer-centric, and available to look at in real-time [48].

## 14 HOW CAN A COMPANY OVERCOME THESE CHALLENGES?

As companies seek to better understand their customer base through the use of big data and analytics, from the research performed, there are some steps that companies can take as they further explore opportunities to optimize the customer experience journey. Some key areas and questions to consider include:

- **Seek to Understand Your Customer:** Big data and analytics can be a valuable starting point in understanding the pathway to purchase among your customers as well as which areas where you may be losing customers in the process. However, big data should be used in conjunction with small data as companies seek to understand the *why* behind customer behavior. Gathering feedback from customers is essential in the process in optimizing their journey.
- **Set Clear Objectives and Roles:** Given that earlier research highlighted that a very small percentage of companies have a dedicated person for customer analytics, first establishing a dedicated person or team could help in developing a better understanding of the data involved in tracking the customer experience journey [38]. This person or team of people can provide guidance to others within an organization by being a central source of knowledge about the customer. A key part of research is also setting clear questions and objectives at the beginning. Which data points are truly a part of the customer experience journey? What connections do we need to establish in order to move our strategy forward? How will we measure the return on our efforts?

- **Make the Necessary Investment:** As other companies in this research highlighted, big data skillsets are necessary in understanding the customer experience journey which may mean a company may need to add data scientists, analysts, or other like positions within an organization. Additional technologies and tools may also be needed such as Hadoop or languages such as R or Python in an effort to process big data to derive insight.
- **Test, Assess, and Optimize:** As companies look to establish dedicated resources, time, and people in the process of understanding the customer experience journey, there must also be acknowledgement that this process is iterative. There could be efforts that are not fruitful or plainly, do not work. However, as other companies have shown, the ability to test can provide this insight and allow the opportunity for a company to change course if needed.

While there are likely other areas to consider, this initial outline described can provide companies and those within an opportunity to start understanding the customer experience journey from a big data and analytics perspective. A company has to also prioritize these different efforts accordingly as it may not be possible to implement these changes at once. A company must also consider what their own success will look like over time as progress is made.

## 15 CONCLUSION

The customer experience journey will continue to evolve as new technologies are developed that can influence the multitude of touchpoints one experiences along the way as they make purchasing decisions. While big data and analytics can provide a picture as to what customers are doing, leveraging learnings from this work to better understand the customer experience journey will be key as competition in the marketplace continues to increase across a variety of industries. These examples show that by having the right tools, skillset, and objectives in place that utilizing big data to better meet the needs of customers can be successful. While the undertaking of this endeavor may not be quick or necessarily easy, it can provide great benefit to both companies and customers to deliver relevant products and services with the customer experience in mind. Even though big data is a means of tracking the customer experience, big data is also changing the customer experience through digital marketing and outreach efforts in a way to effectively and efficiently engage and connect with customers. With this approach, the ability to deliver the right message, to the right person, at exactly the right time in the customer experience journey can provide tremendous opportunity for companies but also benefit the customers to have a more fulfilling experience journey with a company or brand.

## ACKNOWLEDGMENTS

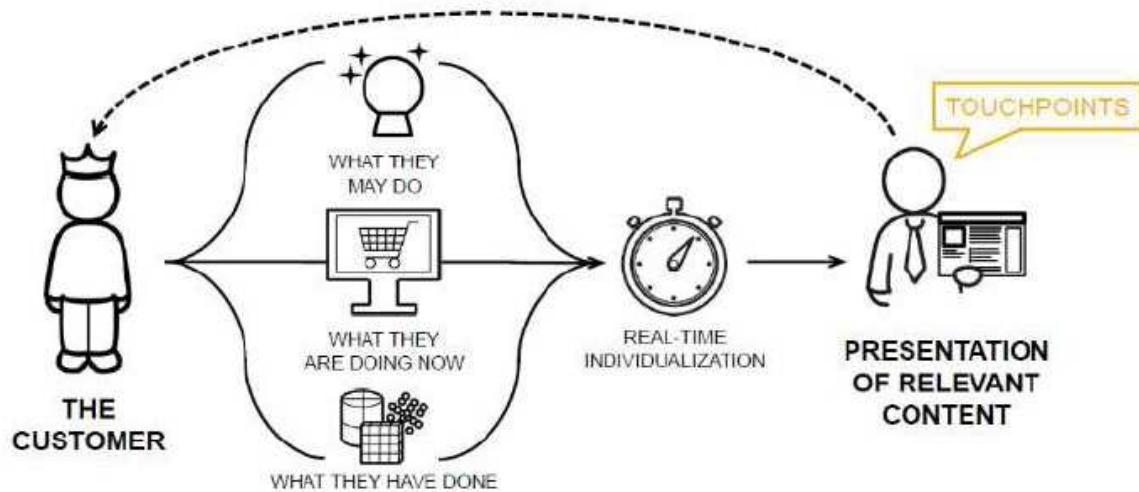
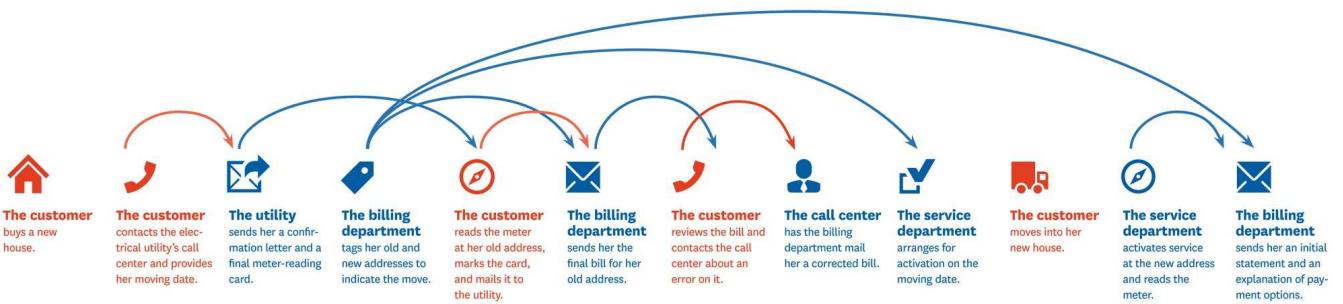
The author would like to thank Dr. Gregor von Laszewski and the teaching assistants for their support and guidance in writing this paper in addition to the resources provided by the School of Informatics, Computing, and Engineering at Indiana University in Bloomington.

## REFERENCES

- [1] Accenture. 2013. What it Means to be Digital. (2013). <https://www.accenture.com>
- [2] Federal Aviation Administration. 2017. Air Traffic by the Numbers. (2017). [https://www.faa.gov/air\\_traffic/by\\_the\\_numbers](https://www.faa.gov/air_traffic/by_the_numbers)
- [3] Shahria Akter and Samuel Fosso Wamba. 2016. Big Data Analytics in E-Commerce: A Systematic Review and Agenda for Future Research. (2016).
- [4] Claire Atkinson. 2016. Video Streaming Services Saw Giant Leap in 2016. (2016). <https://nypost.com>
- [5] Pew Research Center. 2017. Digital News Fact Sheet. (2017). <http://www.journalism.org/fact-sheet/digital-news/>
- [6] Data Science Central. 2017. The Amazing Ways Uber is Using Big Data. (2017). <https://www.datasciencecentral.com>
- [7] Tor Clifford. 2017. Five Urban Transportation Challenges that Big Data Can Help You Solve. (2017).
- [8] Jonathan Cohen. 2017. Netflix's Use of Big Data: Lessons for Brand Marketers. (2017).
- [9] Peter Cohen, Robert Hahn, Jonathan Hall, Steven Levitt, and Robert Metcalfe. 2016. Using Big Data to Estimate Consumer Surplus: The Case of Uber. (2016).
- [10] Nick Couldry and Joseph Turow. 2014. Advertising, Big Data, and the Clearance of the Public Realm: Marketers' New Approaches to the Content Subsidy. *International Journal of Communication* 8, 0 (2014), 1710–1726.
- [11] David Court. 2015. Getting Big Impact from Big Data. (2015), 8 pages.
- [12] Thomas H. Davenport and Jill Dyche. 2013. Big Data in Big Companies. (2013).
- [13] Gary DeAsi. 2017. Why the Customer Journey is Your New Marketing Funnel. (2017).
- [14] Karel Dorner and David Edelman. 2015. What 'Digital' Really Means. (2015), 5 pages.
- [15] Ebay. 2017. Our History - Ebay. (2017). [www.ebay.com](http://www.ebay.com)
- [16] The Economist. 2016. The Economist. (2016).
- [17] David C. Edelman. 2010. Branding in the Digital Age. (2010), 8 pages.
- [18] Exastax. 2017. How Airlines are Using Big Data. (2017). <https://exastax.com>
- [19] The Henry J. Kaiser Family Foundation. 2016. Health Insurance Coverage of the Total Population. (2016). <http://www.kff.org>
- [20] Peter Froves, Basel Kayyali, David Knott, and Steven Van Kuiken. 2013. The 'Big Data' Revolution in Healthcare. (2013), 23 pages.
- [21] Amy Gallo. 2014. The Value of Keeping the Right Customers. (2014).
- [22] Brian Griffith. 2017. Playing to Win with Analytics. (2017).
- [23] Ketty Grishikashvili, S. Dibb, and M. Meadows. 2014. Investigation into Big Data Impact on Digital Marketing. (2014), 26-37 pages.
- [24] Tom Groenfeldt. 2012. Banks Use Big Data To Understand Customers Across Channels. (2012). <https://www.forbes.com>
- [25] Avery Hartmans. 2017. 15 Fascinating Facts You Probably Didn't Know About Amazon. (2017). [www.businessinsider.com](http://www.businessinsider.com)
- [26] Reda Hmeid. 2017. What Does "Being Digital" Actually Mean? (2017). <https://www.infoq.com>
- [27] Statistic Brain Research Institute. 2017. Uber Company Statistics. (2017). [www.statisticbrain.com](http://www.statisticbrain.com)
- [28] Tricia Jenkins. 2016. Netflix's Geek Chic: How One Company Leveraged its Big Data to Change the Entertainment Industry. *Jump Cut: A Review of Contemporary Media* 7, 1 (2016), 1–17. Issue 57.
- [29] P.K. Kannan and Hongshuang Li. 2017. Digital Marketing: A Framework, Review, and Research Agenda. *International Journal of Research in Marketing* 34 (2017), 22–45. Issue 1.
- [30] Kelly Liyakasa. 2013. Big Data and Customer Experience Begin to Converge. (2013). [www.destinationCRM.com](http://www.destinationCRM.com)
- [31] Spandas Lui. 2012. How eBay Uses Big Data to Make You Buy More. (2012). [www.zdnet.com](http://www.zdnet.com)
- [32] Charu Mangani. 2017. American Express: Using Data Analytics to Redefine Traditional Banking. (2017). <https://digit.hbs.org>
- [33] Bernard Marr. 2016. *Big Data in Practice*. Wiley, Corporate Headquarters 111 River Street Hoboken, NJ 07030-5774.
- [34] Christopher Meyer. 2007. Understanding Customer Experience. (2007).
- [35] Timothy Pickett Morgan. 2014. Why Hadoop is the New Backbone of American Express. (2014). [www.enterprisotech.com](http://www.enterprisotech.com)
- [36] Harikesh S. Nair, Sanjog Misra, William J. Hornbuckle IV, Ranjan Mishra, and Anand Acharya. 2016. Big Data and Marketing Analytics in Gaming: Combining Empirical Models and Field Experimentation. (2016).
- [37] Raghunath Nambiar, Ruchie Bhardwaj, Adhiraj Sethi, and Rajesh Vargheese. 2013. A Look at Challenges and Opportunities of Big Data Analytics in Healthcare. In *2013 IEEE International Conference on Big Data*. 2013 IEEE Conference on Big Data, Silicon Valley, CA, USA, 17–22. <https://doi.org/10.1109/BigData.2013.6691753>
- [38] Wes Nichols. 2013. Advertising Analytics 2.0. (2013).
- [39] Katherine Noyes. 2014. For the Airline Industry, Big Data is Cleared for Take-Off. (2014). [www.fortune.com](http://www.fortune.com)
- [40] Greg Petro. 2017. Amazon's Acquisition of Whole Foods is About Two Things: Data and Product. (2017). [www.forbes.com](http://www.forbes.com)
- [41] Alex Rawson, Ewan Duncan, and Conor Jones. 2013. The Truth About Customer Experience. (2013), 10 pages.
- [42] Adam Richardson. 2010. Understanding Customer Experience. (2010).
- [43] Rubinrown. 2017. Gaming Statistics. (2017).
- [44] Cliff Saran. 2014. How Big Data is Powering Success for eBay's Customer Journey. (2014). [www.computerweekly.com](http://www.computerweekly.com)
- [45] Harvard Business School. 2015. Big Data Takes Flight at Delta Air Lines. (2015). <https://digit.hbs.org>
- [46] Natasha Dow Schull. 2012. The Touch-Point Collective: Crowd Contouring on the Casino Floor. (2012).
- [47] Craig Smith. 2017. 120 Amazing Amazon Statistics and Facts. (2017). [www.expandedramblings.com](http://www.expandedramblings.com)
- [48] Jeffrey Spiess, Yves T'Joens, Raluca Dragnea, Peter Spencer, and Laurent Philippart. 2014. Using Big Data to Improve Customer Experience and Business Performance. *Bell Labs Technical Journal* 18, 4 (2014), 3–17.
- [49] Statista. 2017. Value of the Global Entertainment ad Media Market from 2011 to 2021. (2017). <https://www.statista.com>
- [50] Christina Stoicescu. 2015. Big Data, The Perfect Instrument to Study Today's Consumer Behavior. *Database Systems Journal* 6, 3 (2015), 28–41.
- [51] Michael Welch and George Westerman. 2012. Caesars Entertainment: Digitally Personalizing the Customer Experience. (2012).
- [52] Alex Woodie. 2016. How Credit Card Companies are Evolving with Big Data. (2016). [www.datanami.com](http://www.datanami.com)

#### LIST OF FIGURES

1	Customer Experience Journey Touchpoints	12
2	Customer Experience Journey	12
3	Digital Marketing Customer Stages Model	13



## New Digital Marketing Hourglass: Customer Journey Stages Model

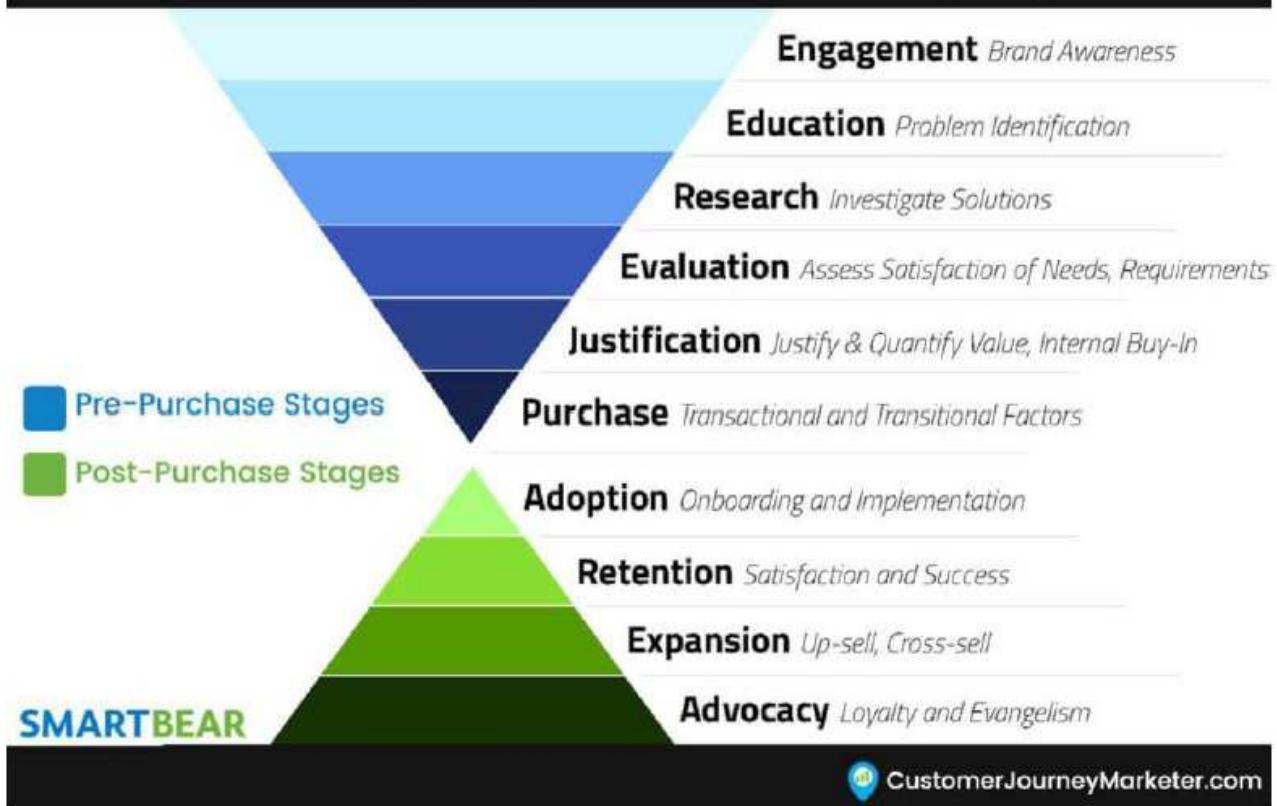


Figure 3: Digital Marketing Customer Stages Model

[13]

```
bibtext report
```

```
=====
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtext _ label error
```

```
=====
```

```
bibtext space label error
```

```
=====
```

```
bibtext comma label error
```

```
=====
```

```
latex report
```

```
[2017-12-12 20.02.09] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 1.0s.
./README.yml
35:81     error      line too long (1061 > 80 characters)  (line-length)
35:1060   error      trailing spaces  (trailing-spaces)
65:22     error      no new line character at the end of file  (new-line-at-end-of-file)
```

```
=====
```

```
Compliance Report
```

```
=====
```

```
name: Ashley Miller
hid: 329
paper1: 100% Oct 22
paper2: 100% Nov 6
project: 100% Dec 4
```

yamlcheck

---

wordcount

---

13

wc 329 project 13 8880 report.tex  
wc 329 project 13 9296 report.pdf  
wc 329 project 13 1750 report.bib

find "

---

32: The customer experience journey has been largely explored from a psychological and behavioral standpoint \cite{Stoicescu2015}.

Dating back to the near 1800s, marginal and expected utility of actions were detailed by Nicholas Bernoulli, among others, to better understand how purchasing decisions were made \cite{Stoicescu2015}. From related work that followed in this field of studying behavioral economics, research has shown that purchasing decisions are not linear and at times, are not even rational as cognitive, emotional, and social factors can all play a role into how a customer makes a purchasing decision \cite{Stoicescu2015}. As described by Stoicescu, the reason why researchers started to study purchasing behavior was due to the "diversification of need" \cite{Stoicescu2015}.

53: The way \textit{customer experience journey} is defined can differ by industry, product, and even by place. While past work has defined the customer experience journey as the process of purchasing a product or service, in today's landscape, it has become more than that. The Harvard Business Review would define the customer experience journey as the "sum-totality of how customers engage with your company or brand, not just in a snapshot of time, but throughout the entire arc of being a customer" \cite{Richardson2010}. Traditionally, the customer experience journey and buying process were used interchangeably where a customer moves through a decision making process. Some key areas that were highlighted in a typical customer experience journey include:

86: While advertising and marketing methods go as far back as the 1800s where customer lists were used to determine how individuals could be influenced via direct mailing efforts, digital marketing

has only come to be with the creation of the internet \cite{Couldry2014}. The internet has created opportunity for brands to directly connect with customers and likewise, for customers to engage with brands in a myriad of ways in the digital space \cite{Edelman2010}. While varying definitions of digital marketing exist, it is often categorized as a subset of traditional marketing where the "use of digital technologies create an integrated, targeted, and measurable communication" to not only attract potential customers but engage with current ones for retention and loyalty purposes \cite{Grishikashvili2014}. Digital marketing became even more prevalent in the 2000s as companies such as Google, Yahoo, and Facebook provided opportunity to deliver ads at an individual level based on demographic and behavioral characteristics \cite{Couldry2014}. Other data collection firms offered the ability to track users across the web space to see which pages were viewed, clicked, and time explored to help further understand the experience of a customer across the web space \cite{Couldry2014}. With these advances in technology and understanding, the customer experience journey began to also transform along with the changes in advertising from traditional to more digital.

- 91: One could argue that marketing data has been \textit{big} for quite some time given the sheer number of people exposed to efforts typically exceeds millions \cite{Couldry2014}. However, what has changed in this space is marketing's increased use of digital technologies to reach potential customers in the digital landscape across various channels including search, display, social media, email, etc. \cite{Kannan2017}. For companies to be successful in utilizing big data to inform digital marketing efforts and to better track and enhance the customer experience journey, incorporating the necessary technologies and talent is a must along with shifting the organizational culture to making data driven decisions \cite{Grishikashvili2014}. This process can be difficult as an individual user alone can generate "billions of data signals" and attempting to understand which ones may be tied directly to a product or brand's marketing efforts can be a daunting and overwhelming task \cite{Couldry2014}. However, there are a few well-known companies that have started the shift in tracking the customer experience journey through big data analytics and applications. We will examine key industries that have leveraged this knowledge and insight to better understand and enhance their relationship with customers.

- 107: eBay is a website that also started in 1995 which offered a unique opportunity to bring together buyers and sellers in the

online space \cite{Ebay2017}. Sellers could place their items online where buyers could potentially place bids, similar to if they participated in a live auction, where the item may go to the highest bidder. This allowed for others around the globe to connect and purchase items directly from another person while paying for the item through online methods. It is estimated today that there are nearly 180 million buyers and sellers and nearly 250 million search inquiries made per day on eBay \cite{Lui2012}. Like Amazon, eBay seeks to understand and tailor the online experience for customers through the use of big data in a multitude of ways as eBay itself states “understanding the customer is key” \cite{Sararn2014}. Various methods utilized to better understand and tailor the customer experience journey include:

- 110: \item \textbf{Web Page Metrics to Inform Layout}: It is estimated that among eBay customers, there is “100 million hours of interactions collected per month” \cite{Sararn2014}. Through an extensive number of experiments and A/B testing, eBay is able to optimize the web experience for customers. From their big data analytics, they can find preferred layouts of web pages which can customize anything from navigation feature to the size of photos displayed on the screen \cite{Akter2016}.
- 146: As others have stated about healthcare related data and reporting, “the problem in healthcare is not lack of data, but the unstructured nature of its data” \cite{Marr2016b}. Apixio, a cognitive computing firm based in California, wanted to take on the challenge of making unstructured healthcare related data available and easier to use in order to better aid decision making in patient treatment \cite{Marr2016b}. Their work involved taking clinical charts of patients and combining them with notes from physicians, test results, and even hospital stays to develop a more complete picture about an individual \cite{Marr2016b}. From there, Apixio was able to provide benefits based on this big data process:
- 165: Caesars has described their customer relationship optimization process as utilizing a “data-driven and closed loop approached to deliver a personalized experience” \cite{Welch2012}. A few ways they have implemented this include:
- 185: In just one day’s time, it is estimated that there are nearly 42,000 commercial flights and 2.5 million passengers \cite{Administration2017}. From purchasing a ticket, to taking a flight, and (hopefully) receiving their checked baggage at their

final destination, airlines collect a wealth of information on their customers throughout their flying experience \cite{Noyes2014}. When looking at key attributes that are analyzed and down to an individual level, airlines collect information about purchase history, arrival, departure cities, and dates, in-flight food choices, connecting cities, travel companions, as well as miles and credit card points earned and used \cite{Exastax2017}. While airlines have succeeded in collecting this data, using it to better enhance the customer experience journey is still a work in progress \cite{Noyes2014}. Those who work in the travel software environment and frequently provide products and services to those in the airline community to better understand their data even state they have "not seen a single major airline with an integrated big data business solution" \cite{Noyes2014}. With that in mind, highlights from major airline players are explored even though full development of utilizing big data may still be on-going in this industry.

- 202: These examples are a select few to showcase how companies can better understand and further the customer experience journey by leveraging big data. The average customer is presented with more choices today than ever before \cite{Meyer2007}. With this, companies today have to be more strategic to get the attention, time, and loyalty of customers to remain in the marketplace. Doing so can provide many advantages to both companies and customers as they utilize big data to better understand the customer experience. As Rawson et al state: "companies that excel in delivering journeys tend to win in the market" \cite{Rawson2013}. Trends presented showcase how big data can provide big benefit:
- 205: \item \textbf{Retention of Customers}: It is estimated that "acquiring a new customer can be between five and 25 times more expensive than retaining an existing one" \cite{Gallo2014}. Utilizing big data to predict when customers may close accounts can help to inform company efforts and ultimately prevent potential revenue loss if they can keep existing customers. American Express showed that by using big data and predictive analytics, the company could identify these customers sooner versus wait until the customer is already lost.
- 217: \item \textbf{Consumer Behavior Volatility} Not all decisions made by customers are rational ones and there can be a variety of factors in play that big data can not track \cite{Stoicescu2015}. As further detailed in other work "people do not behave like robots," so even when all the variables are optimized, outside

forces beyond the control of a company could influence choice along with a customer's own emotions which big data doesn't always include \cite{Richardson2010}.

passed: False

find footnote

---

passed: True

find input{format/i523}

---

4: \input{format/i523}

passed: True

find input{format/final}

---

passed: False

floats

---

34: However, with diversification also comes complexity. The more choices a customer is given, the harder it can become for them to make a decision \cite{Stoicescu2015}. With every product choice, there also is an opportunity for interaction or \textit{touchpoints} along this customer experience journey \cite{Meyer2007}. These series of touchpoints can occur through a variety of ways and the time frame in which they take place can also vary greatly by the product or service being offered and to which audience. In figure \ref{f:Customer Experience Journey} example of a customer setting up utilities after the purchase of a new home and the multiple touchpoints they may encounter along their journey \cite{Rawson2013}.

36: \begin{figure}[ht!]

37: \centering\includegraphics[width=\columnwidth]{example.jpg}

38: \caption{Customer Experience Journey  
Touchpoints}\cite{Rawson2013}\label{f:Customer Experience Journey}

41: However, not all touchpoints are created equal \cite{Meyer2007}.

There are some touchpoints that every customer may have to go through to get to the next step in the process and others that will produce a more valuable action, such as a purchase

\cite{Meyer2007}. There are further questions today that did not exist in years past due to the advances in technology and how that affects customer behavior \cite{Kannan2017}. These advances in technology not only could influence customer behavior but also provide companies direction on which products they should produce, where these products should be placed, what price point is most optimal and how should they properly promote a particular product to their audience \cite{Kannan2017}. Big data and analytics can provide opportunity to inform the promotional piece as companies have utilized this feature to provide personalized and relevant content along the customer journey as defined in figure \ref{f:Customer Journey} \cite{Stoicescu2015}.

43: \begin{figure}[ht!]  
44: \centering\includegraphics[width=\columnwidth]{customerjourney.jpg}  
45: \caption{Customer Experience  
Journey}\cite{Stoicescu2015}\label{f:Customer Journey}

69: While the list of questions could be endless the intent is to move customers through this purchase decision process so companies create loyal customers and advocates \cite{Kannan2017}. However, that model is evolving with the shift to a multi-prong outreach approach via digital and non-digital methods \cite{DeAsi2017}. A longer customer experience journey is outlined in figure 1 as a customer can enter at any stage in the process. Pre and post purchase measures can be collected, stored, and analyzed at any point along the way as shown in figure \ref{f:Digital Marketing} \cite{DeAsi2017}.

71: \begin{figure}[ht!]  
72: \centering\includegraphics[width=\columnwidth]{digitalmarketing.jpg}  
73: \caption{Digital Marketing Customer Stages  
Model}\cite{DeAsi2017}\label{f:Digital Marketing}

figures 3  
tables 0  
\includegraphics 3  
labels 3  
refs 3  
floats 3

True : ref check passed: (refs >= figures + tables)  
True : label check passed: (refs >= figures + tables)  
True : include graphics passed: (figures >= \includegraphics)  
True : check if all figures are referred to: (refs >= labels)

Label/ref check

68: While the list of questions could be endless the intent is to move customers through this purchase decision process so companies create loyal customers and advocates \cite{Kannan2017}. However, that model is evolving with the shift to a multi-prong outreach approach via digital and non-digital methods \cite{DeAsi2017}. A longer customer experience journey is outlined in figure 1 as a customer can enter at any stage in the process. Pre and post purchase measures can be collected, stored, and analyzed at any point along the way as shown in figure \ref{f:Digital Marketing} \cite{DeAsi2017}.

passed: False -> labels or refs used wrong

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find textwidth

---

passed: True

---

below\_check

---

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
```

---

```
The following tests are optional
```

---

```
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
passed: True
```

# IoT Application Using MQTT and Raspberry Pi Robot Car

Arnav Arnav

Indiana University Bloomington

Bloomington, Indiana 47408, USA

aarnav@iu.edu

## ABSTRACT

As the number of connected edge devices increases there is a need for fast communication between these devices, and to analyse the data collected by these devices, which is made possible by the use of a scalable lightweight communication protocol such as MQTT, which is easy to use, data agnostic, and application independent. We look at one such application of the protocol, to control a robot car remotely, over wireless network, navigating with the help of a raspberry pi camera on the car.

## KEYWORDS

i523, HID201, Edge Computing, Raspberry Pi, MQTT, Robot Car, IoT

## 1 INTRODUCTION

As the number of edge devices increases, and sensor networks become more and more common in Internet of Things (IoT) applications, the need arises to allow these resource constrained devices to communicate with each other in a power efficient and secure manner. In many cases these devices may not be able to process traditional HTTP requests efficiently, and as the number of devices increases, sending an HTTP request to each of the devices in order to get data may not be efficient [3][11].

Message Queue Telemetry Transport (MQTT) is a lightweight machine to machine (M2M) messaging protocol, that uses a client/server based publish/subscribe model and is ideal for IoT applications. The protocol has been designed on top of TCP/IP protocol for us in situations where network bandwidth and available memory are limited [39][22]. The Eclipse Paho Project currently provides support for MQTT [5]. MQTT clients are available for various languages like Python, C, and Lua.

We look at one such application here that uses MQTT for communication between a raspberry pi and a desktop. The raspberry pi controls the stepper motors of the robot car according to the message it receives over mqtt, and drives the car accordingly. Another program running on the raspberry pi uses the raspberry pi onboard camera to capture pictures and send them back to the desktop to help in navigation. Thus we create a simple robot car that can be used remotely for monitoring purposes. The robot car can be controlled from anywhere in the world, as long as both the controlling device (desktop) and the raspberry pi can connect to the MQTT broker.

We can use multiple such cars and controlling devices to control the cars independently or from a common device to drive multiple cars together, thus controlling a swarm of cars. As these cars may be using different platforms like raspberry pi or arduino, Using MQTT allows us to write the controller program independent of the subscriber programs running on the different robot cars and

even in different languages. All that is needed to control a car is that the subscriber can understand the messages sent by the controller.

## 2 RELATED WORK

There have been many edge computing applications that involve robot cars or swarm of cars.

[28] provides an example of a raspberry pi car that uses distance sensor, and face detection on the raspberry pi 2. The car is controlled over wifi and is built using the GoPiGo robot car kit [14]

Zheng Wang used raspberry pi in [38] to build a sophisticated self driving car that can detect stop signs and traffic signals and drive appropriately on a small test track. The car has a camera and a distance sensor that stream data to a TCP server running on a desktop. The system uses Haar Cascades provided in opencv to detect objects like stop signs and traffic signals and a trained neural network which uses the image to predict the direction in which the car should move. The distance is calculated using the image from the raspberry pi camera with the help of a monocular vision method proposed by Chu, Ji, Guo, Li and Wang in 2004 [16].

As the part of Eclipse IoT open challenge [2] built a robot car that is controlled using the Constrained Application Protocol (CoAP) which snaps images and communicates the images over MQTT

OpenHAB provides a vendor neutral platform that allows users to integrate various home automation systems and provides an application interface to control those devices [25]. It allows integration of various devices with MQTT.

The FloodNet project at University of Southampton [12] aims at "providing a pervasive, continuous embedded monitoring presence". The system is intelligent and obtains "environmental self-awareness and resilience to ensure robust transmission of data", ensuring data quality and allowing exploration of environments in new ways. The project uses MQTT for communicating data from the sensors on field to visualization and simulation applications.

As a part of IBM's Extreme Blue projects, Say it Sign it [32] is a sophisticated, innovative speech to sign language translation system. The application uses speech recognition and renders an avatar that signs the corresponding words in British sign Language, using MQTT and microbroker for communication.

## 3 TECHNOLOGIES AND HARDWARE

The project uses MQTT to communicate between a controller running on a desktop and a raspberry pi that drives the robot car with the help of stepper motors. We describe these technologies in detail.

### 3.1 MQTT

MQTT works via a publish-subscribe model that contains 3 entities: (1) a publisher, that sends a message, (2) a broker, that maintains

queue of all messages based on topics and (3) multiple subscribers that subscribe to various topics they are interested in [29].

This allows for decoupling of functionality at various levels. The publisher and subscriber do not need to be close to each other and do not need to know each others identity. They need only to know the broker, as the publisher and the subscribers do not have to be running either at the same time nor on the same hardware [19].

MQTT implements a hierarchy of topics that are related to all messages. These topics are recognised by strings separated by a forward-slash (/), where each part represents a different topic level. This is a common model introduced in file systems but also in internet URLs.

A topic looks therefore as follows: *topic-level0/topic-level1/topic-level2*.

All subscribers subscribe to different topics via the broker. Subscribing to *topic-level0* allows the subscriber to receive all messages that are associated with topics that start with *topic-level0*.

This is different from traditional message queues as the message is forwarded to multiple subscribers, and allows for a more flexible approach with the help of topics [19]. The basic steps in an MQTT client application include connecting to the broker, subscribing to some topics, waiting for messages and performing the appropriate action when a certain message is received [39].

MQTT allows the publisher and subscriber to respond to messages with the help of callbacks that are executed on different events, in a non-blocking manner. The paho-mqtt package for python provides callbacks methods like `on-connect()`, `on-message()` and `on-disconnect()`, which are fired when the connection to the broker is complete, a message is received from the broker, and when the client is disconnected from the broker respectively. These methods are used in conjunction with the `loop-start()` and `loop-end()` methods which start and end an asynchronous loop that listens for these events and fires the relevant callbacks, allowing the clients to perform other tasks [6].

MQTT has been designed to be flexible and options are provided to easily change the quality of service (QoS) as required by the application. Three basic levels of QoS are supported by the protocol, Atmost-once (QoS level 0), Atleast-once (QoS level 1) and Atmost-once (QoS level 2) [20][6].

The QoS level of 0 can be used in applications where some dropped messages may not affect the application. Under this QoS level, the broker forwards a message to the subscribers only once and does not wait for any acknowledgement [20] [6].

The QoS level of 1 can be used in situations where the delivery of all messages is important and the subscriber can handle duplicate messages. Here the broker keeps on resending the message to a subscriber after a certain timeout until the first acknowledgement is received. A QoS level of 2 should be used in cases where all messages must be delivered and no duplicate messages should be allowed. In this case the broker sets up a handshake with the subscriber to check for its availability before sending the message [20] [6].

The MQTT specification uses TCP/IP to deliver the messaged to the subscribers, but it does not provide any form of security by default to make it useful for resource constrained IoT devices. “It allows the use of username and password for authentication,

but by default this information is sent as plain text over the network, making it susceptible to man-in-the middle attacks” [27] [21]. Therefore, in sensitive applications some form of additional security measures are recommended which may include network layer security with the use of Virtual Private Networks (VPNs), Transport Layer Security, or application layer security [21].

Transport Layer Security (TLS) and Secure Sockets Layer (SSL) are cryptographic protocols that establish the identity of the server and client with the help of a handshake mechanism which uses trust certificates to establish identities before encrypted communication can take place [4]. If the handshake is not completed for some reason, the connection is not established and no messages are exchanged [21]. “Most MQTT brokers provide an option to use TLS instead of plain TCP and port 8883 has been standardized for secured MQTT connections” [27].

Using TLS/SSL security however comes at an additional cost. If the connections are short-lived then most of the time can be spent in the handshake itself, which may take up few kilobytes of bandwidth. In case the connections are short-lived, temporary session IDs and session tickets can be used to resume a session instead of repeating the handshake process. If the connections are long term, the overhead of the handshake is negligible and TLS/SSL security should be used [27][21].

Although MQTT protocol itself does not include authorization, many MQTT brokers include authorization as an additional feature [4]. OAuth2.0 uses JSON Web Tokens which contain information about the token and the user and are signed by a trusted authorization server [10].

When connecting to the broker this token can be used to check whether the client is authorised to connect at this time or not. Additionally the same validations can be used when publishing or subscribing to the broker. The broker may use a third party resource such as LDAP (lightweight directory access protocol) to look up authorizations for the client [10]. Since there can be a large number of clients and it can become impractical to authorize everyone, clients may be grouped and the authorizations may be checked for each group [4].

MQTT allows easy integration with other services, that have been designed to process this data.

Apache storm is a distributed processing system that allows real time processing of continuous data streams, much like Hadoop works for batch processing [1]. Apache storm can be easily integrated with MQTT as shown in [36] to get real time data streams and allow analytics and online machine learning in a fault tolerant manner [42].

ELK stack (elastic-search, logstash and kibana) is an open source project designed for scalability which contains three main software packages, the *elastic-search* search and analytics engine, *logstash* which is a data collection pipeline and *kibana* which is a visualization dashboard [7]. Data from an IoT network can be collected, analysed and visualized easily with the help of the ELK stack as shown in [34] and [33].

MQTT broker services can be utilized for enterprise and production environments. EMQ (Erlang MQTT Broker) provides a highly scalable, distributed and reliable MQTT broker that can be used in enterprise-grade applications [9].

## 3.2 Raspberry Pi

The raspberry pi is a credit card sized development board that was developed by Eben Upton with the goal to create a low cost device that can be used for education and prototyping [26]. Since its creation the board has been adapted for various different projects by educators hobbyists and in the industry [31]. The board is developed as open hardware except for the Broadcom chip that controls the main components of the board, and most raspberry pi projects are available openly with detailed documentation.

The board's Broadcom system on chip consists of an ARM processor and it can be used just like a normal computer by connecting a monitor, a keyboard and a mouse. The raspberry pi can communicate to other devices with the help of wifi and bluetooth and is capable of accessing the internet. All this put together makes the raspberry pi a very useful device [31].

The raspberry pi comes in various models, Model A+, which is one of the smallest form factors, raspberry pi2 Model B, raspberry pi3 Model B and Model B+ that have more gpio pins. The raspberry pi 3 Model B is the newest design and consists of on board wifi and bluetooth, eliminating the need to use usb wifi and bluetooth attachments. It has a 1.2 GHz ARM 8 microprocessor, 1 GB RAM, a dual core Videocore IV GPU, and 40 general purpose input and output (GPIO) pins. The board has an ethernet port and four USB ports and an HDMI port to connect to a monitor [18][17].

The raspberry pi Zero is the development board that has the smallest form factor. Even though the raspberry pi zero includes no ethernet or USB ports, and does not come with GPIO pins soldered on, its small size and cost effectiveness make it extremely useful in applications such as IoT where space is constrained [30].

The raspberry pi uses a micro SD card to boot and various operating systems, that support the ARM architecture can be used. The most common operating systems are Raspbian, a derivative of the Debian linux, and Pidora, a derivative of Fedora. There are other operating systems centered around using the raspberry pi for various purposes, like openELEC and RaspBMC, which make it easy to use raspberry pi as a multimedia center. For, users who want non-linux operating system, RISC OS may be a good choice. The raspberry pi foundation provides new users the opportunity to try out various operating systems with the help of their New Out Of The Box Software (NOOBS), which allows the users to pick which operating system they want to use [26].

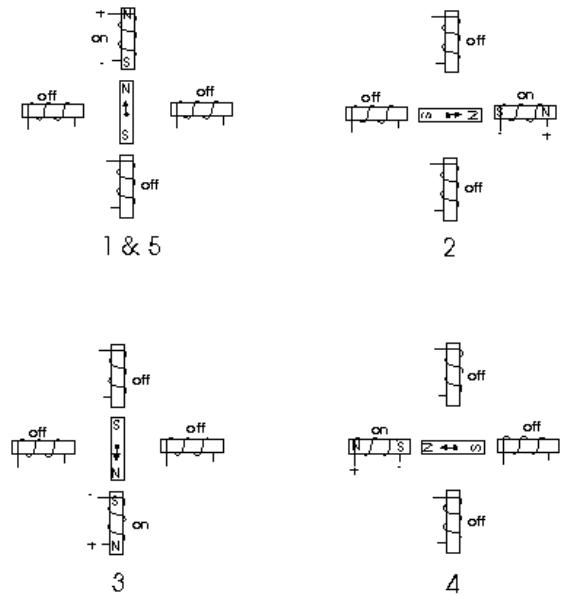
Various different shields are available for the raspberry pi that make it simple to connect to various peripherals, and extend the functionality of the raspberry pi, such as the GrovePi shield, provided by Dexter Industries, which allows simple interface with many digital and analog sensors and actuators provided by Dexter.

## 3.3 Stepper Motors

Stepper motors are brushless motors that divide the complete rotation into a number of parts known as steps. The motor consists of electromagnetic coils and a rotating core that aligns itself according to the combined magnetic effect of the coils. The stepper motor can move from one step to another and remain in a single step based on which coils are turned on. The torque of the motor can be increased or decreased with the current supplied to the coils, and the speed

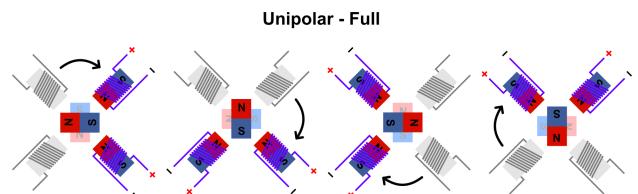
of rotation can be controlled by setting the time interval between switching the coils on and off [41].

Stepper motors can be controlled in various ways, depending on the application. Figure 1 shows how a stepper motor with a resolution of 90 degrees can be made to complete one full rotation. In practice however, the resolution (the degrees moved at each step) of most stepper motors is much higher. The process mentioned in figure 1 is known as half stepping [15].



**Figure 1: Working of a stepper motor : Full stepping using one coil at a time [15]**

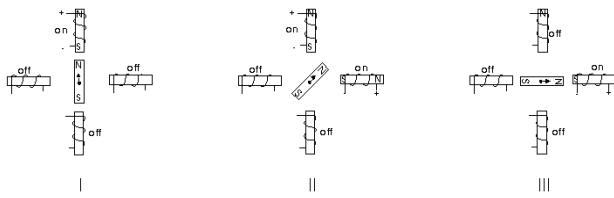
In the above method, only one coil is turned on at a time. This can be improved upon to get a higher torque. To get a higher torque, two adjacent coils are turned on at the same time, as shown in figure 2. This results in double the torque generated when using only one coil at a time [37].



**Figure 2: Working of a stepper motor : Full stepping using two coils at a time [37]**

With full stepping however, the transition between two consecutive steps is not very smooth. Therefore, a technique called Half

stepping is used, where two adjacent coils are turned on similar to full stepping, but between two steps one of the coils is turned off, so that the transition between steps is smooth. This results in a torque 70 percent of that generated in using full stepping with two coils turned on at the same time. This process is shown in figure 3 [15].



**Figure 3: Working of a stepper motor : Half stepping [15]**

For this project, the stepper motor 28BYJ-48, provided by Elegoo Industries is used. The motor is driven with the help of a ULN2003 motor driver. The motor is a unipolar stepper motor, with a five wire connection to the motor controller and can work with 5 and 12 Volts of DC power supply. When using Half stepping, the step angle of the motor is about 5.625 degrees per step, and when using full stepping the step angle is 11.25 degrees per step. The motor weighs 30 grams, and a gear ratio of 64:1 [13][35].

#### 3.4 OpenCV

The Open Source Computer Vision library (openCV) is a library of functions aimed at real time computer vision and machine learning and providing a common infrastructure to allow fast progress in the field of computer vision and machine perception [40][23].

The library was originally built by Intel and is now maintained by Itseez and is available freely under open-source BSD License. The library was originally written for C++ but has been developed as cross platform library and supports Python , C++, MATLAB and Java [23]. for Python the library has been built on top of Numpy, a library that optimizes matrix and vector operations, and takes advantage of MMX and SSE instructions whenever possible. For C++ the library uses the Standard Template Library (STL) as its backbone.

The library has more than 2500 algorithms which include a combination of simple and advanced operations allowing a wide range of operations from edge detection, color detection to object detection, face detection and automatic video stabilization, and motion detection. The opencv-contrib which is an extension to the library built collaboratively by the community contains advanced algorithms that allow processing video in real time [23].

OpenCV is widely used in the industry by startups as well as well established organizations like Google, Yahoo, Microsoft, IBM and Intel [23].

OpenCV can be used to detect faces in real time. The Haar cascades function in the library allows detecting any kind of objects. The algorithm uses a series of simple classifiers to predict whether a given image has the desired object or not. After training on a large set of positive examples (images containing faces) and negative examples (images not containing faces), the algorithm learns

various classifiers, that classify different sections of the image in a manner similar to Adaboost algorithm. Only the portions of the image that are promising are analysed further by more detailed classifiers. This allows the algorithm to run in real time, and detect multiple objects [24][43]. Once the classifiers are learned, they can be stored in an XML file which can be used to classify new images. This allows users to obtain XML files available openly for classifiers trained to detect the required object and use them in their programs. OpenCV provides XML files for classifiers trained to detect faces and eyes.

The performance of the Haar cascades suffers however, when detecting objects in new images that are present in a different orientation than the ones used to train the classifiers. The classifiers may also fail to differentiate between the object that needs to be detected and similar objects if enough negative examples are not shown while training that include similar objects.

## 4 ARCHITECTURE

The solution includes two entities the raspberry pi and the desktop, each running two programs. The raspberry pi is connected to the robot car and the raspberry pi can drive the robot car according to the message it receives from the desktop.

There are two programs running on pi, controller stepper sub.py and video pub.py, and two programs running on the desktop, controller pub.py and video sub.py.

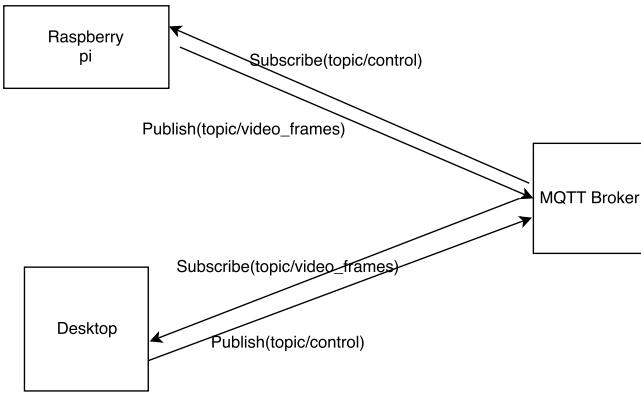
The programs on both the raspberry pi and the desktop connect to a common broker. The broker may be running on the desktop, or any other place, as long as the IP address of the broker is known. The IP address can be passed as a command line argument when running these programs.

The controller pub.py program running on the desktop continuously reads characters from the user and publishes them to the broker under the topic *topic/control*. The subscriber controller stepper sub.py running on the raspberry pi waits for these messages from the broker and when a message is received it uses the *on\_message()* callback to make the robot car move forward, move backward, turn left or turn right, using the half stepping technique described in the previous section.

For monitoring purposes, another program, video pub runs on the raspberry pi. This program uses the raspberry pi on board camera with the help of the picamera module and captures images. The images are converted to greyscale, and opencv is used to perform face detection using Haar Cascades. If a face is found, a box is drawn around the face in the image. The image is published to the broker under the topic *topic/video\_frames*. The video sub.py program running on the desktop subscribes to this topic on the broker and displays the images received. These images can be used for the navigation of the robot car remotely figure 4.

Using separate programs allow changing the functionality or replacing different parts of the program easily, while keeping the interface same. The program, controller sub.py, can be used if continuous rotation servo motors are used instead of the stepper motors without changing any other part of the application.

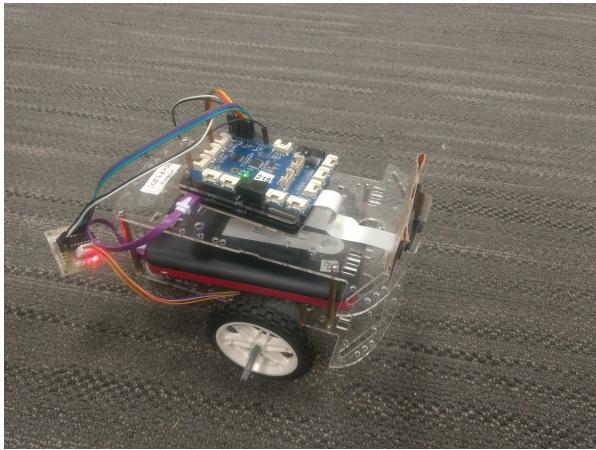
The programs can be run easily with the help of a Makefile as described in the next section



**Figure 4: Architecture of the Application**

## 5 RESULTS

This section covers the setup instructions for the project and the observations. The robot car that was built is shown in figure 5.



**Figure 5: Raspberry Pi Robot Car**

### 5.1 Setup Instructions

To run the application successfully on both the raspberry pi and the desktop, it must be ensured that all the required libraries are installed. A Makefile has been provided that can do this on both the raspberry pi and the desktop.

- First, the motors should be connected to the raspberry pi correctly. The program uses the raspberry pi GPIO pins, and assumes that for the left motor, the pins IN1, IN2, IN3, IN4 are connected to GPIO pins 7, 11, 13, and 15, and for the right motor, they are connected to GPIO pins, 8, 10, 12, 16, as shown in the connection diagram in figure 6
- On the raspberry pi, dependencies for openCV need to be installed. Since the openCV is not available in pip for the arm processor in raspberry pi, we it must be installed from

source. This takes a few hours on the raspberry pi. To complete the setup including installation of a MQTT client and opencv on the raspberry pi, clone the repository from github on the raspberry pi and navigate to the code folder, open the terminal and run the command

`make setup_pi`

- Next, install opencv and an MQTT client and MQTT broker on the desktop. For this, clone the repository from github, navigate into the code folder and run the command  
`make setup_server`
- Note the IP address of the desktop so that we can connect to the MQTT server running on it. Connect the raspberry pi and the desktop on the same wireless network.
- To run the code on the desktop, run the command  
`make run_server IP=[IP address of the MQTT broker]`
- Finally to run the code on the raspberry pi, run  
`make run_pi IP=[IP address of the MQTT broker]`
- Now the raspberry pi car can be controlled by typing in W, A, S, or D keys on the desktop in the terminal where the program is running.
- The program can be stopped on both the raspberry pi and the desktop by running  
`make kill`

### 5.2 Observations

It was observed that the communication between the raspberry pi and the desktop controller application is pretty seamless. The robot car responds without any observable delays when the network is strong. When the network is weak, however, some delays may be observed. The delay becomes more evident in the case of the images sent by the raspberry pi back to the desktop when the network is not strong.

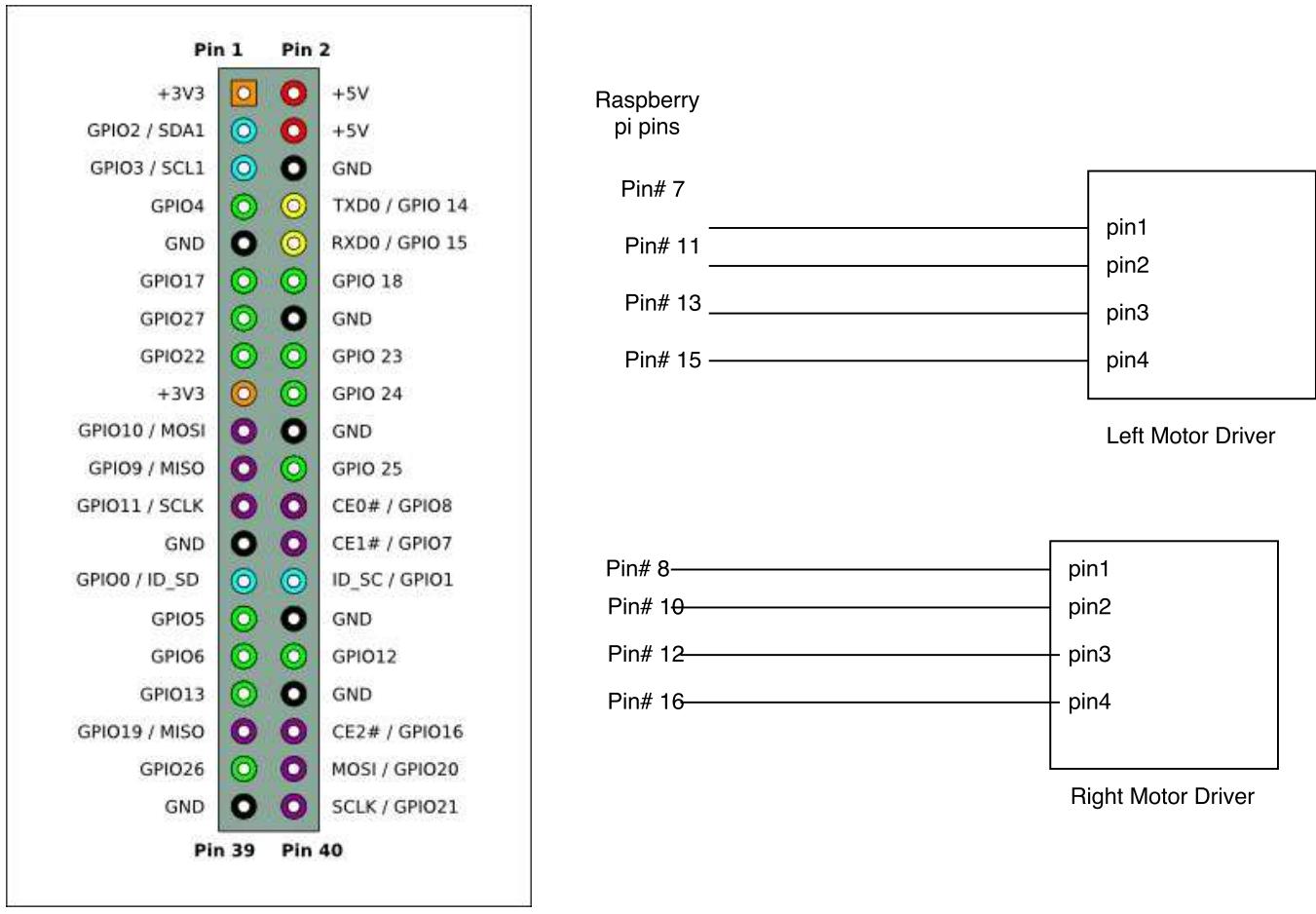
Using the stepper motors, it is difficult to set a how much a motor should turn when it receives a message. If the motor is not allowed to turn long enough, then between two messages the motor will be idle and if it is turned longer than the interval between two messages, there can be conflicts if in response to each of the messages the subscriber running on the raspberry pi tries to set a different step on the motor. Therefore, the movement can seem a little jerky at times.

However, this is not a problem with 360 degrees continuous servo motors. Since the continuous servo motors use pulse width modulation, the speed and direction of rotation can be controlled by sending a square wave with different duty cycles depending on the motor. Since, the motor can be stopped and started easily, there are no conflicts even if the motor is allowed to turn longer than the interval between two messages. However, the motor would respond to the two messages one after the other.

Thus the raspberry pi robot car can be successfully controlled over wifi using MQTT for communication

### 5.3 Improvements

The project can be improved in various ways. Firstly, even though the deployment with makefile is easy, installing opencv on raspberry pi takes around 4 hours. This can be avoided if we use docker for deployment on the raspberry pi. Two separate images would me



Raspberry pi 3 GPIO header

Figure 6: Connection Diagram [8]

needed however one for the processor on the desktop and another one for the arm 8 processor on the raspberry pi.

Machine learning can be incorporated, by collecting the images and the corresponding messages that were sent to the raspberry pi and use it to train a neural network, which could then be used to drive the robot car autonomously. This would be complicated however since car needs to be driven for a long time to get enough data for the neural network to perform well regardless of the surroundings.

Using Haar cascades for face detection leads to a problem that faces can be recognised only if they are resent in the image in the same orientation as that in the training examples. Therefore, it is challenging to recognise all faces in all orientations since it is not possible to train the classifier on images of different faces from all possible angles and rotations. A better option would be to use Convolutional Neural Networks, that help in improving accuracy for the purpose of object detection. Since training and running neural networks may be computationally expensive, it would be a good idea to run it on a server and not on the raspberry pi.

Many different sensors could be added to help improve the monitoring capability of the car, and get more information about the environment. If many controlling devices and cars are present, the cars may be controlled in groups and other functionality added to behave as a swarm of cars to complete tasks collaboratively.

## 6 CONCLUSION

MQTT is a fast and reliable data agnostic and platform independent protocol that allows communication between devices. Raspberry pi is small but powerful development board that allows users to build prototypes easily and can be used in various applications because of the significantly powerful arm 8 microprocessor. OpenCV is an open source library for computer vision that is optimised to perform operations on images efficiently and is commonly used in computer vision applications. All these technologies were used to build a robot car, controlled via MQTT over a wireless network. MQTT allows us to easily scale up the number of such cars if needed.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski for giving the opportunity to work on this project and for providing the necessary hardware to complete the project.

The author would also like to thank the associate instructors of the class for their help and for answering questions on piazza which helped everyone.

## REFERENCES

- [1] apache. [n. d.]. apache storm. apache storm website. ([n. d.]). <http://storm.apache.org/>
- [2] bitreactive. 2015. The Raspberry Pi Eclipse IoT Car. bitreactive website. (March 2015). <http://www.bitreactive.com/remote-controlled-raspberry-pi-car-part-3-2/>
- [3] Paul Caponetti. 2017. Why MQTT is the Protocol of Choice for the IoT. xively.com blog website. (august 2017). <http://blog.xively.com/why-mqtt-is-the-protocol-of-choice-for-the-iot/>
- [4] Ian Craggs. 2013. MQTT security: Who are you? Can you prove it? What can you do? IBM developer works website. (march 2013). [https://www.ibm.com/developerworks/community/blogs/c565c720-fe84-4f63-873f-607d87787327/entry/mqtt\\_security?lang=en](https://www.ibm.com/developerworks/community/blogs/c565c720-fe84-4f63-873f-607d87787327/entry/mqtt_security?lang=en)
- [5] eclipse. [n. d.]. mqtt broker. eclipse mosquitto website. ([n. d.]). <https://mosquitto.org/>
- [6] eclipse paho. [n. d.]. Python Client - documentation. eclipse paho website. ([n. d.]). <https://www.eclipse.org/paho/clients/python/docs/>
- [7] elastic.io. [n. d.]. ELK stack. elastic.io website. ([n. d.]). <https://www.elastic.co/products>
- [8] eLinux.org. 2015. File:Pi-GPIO-header.png. elinux.org website. (July 2015). <https://elinux.org/images/5/5c/Pi-GPIO-header.png>
- [9] erlang mqtt. [n. d.]. erlang mqtt broker. wmqtt website. ([n. d.]). <http://emqtt.io/docs/v2/index.html>
- [10] hive mq. [n. d.]. MQTT Security Fundamentals: OAuth 2.0 & MQTT. hivemq website. ([n. d.]). <https://www.hivemq.com/blog/mqtt-security-fundamentals-oauth-2-0-mqtt>
- [11] hivemq. [n. d.]. intrewebsite mqtt. hivemq website. ([n. d.]). <https://www.hivemq.com/blog/mqtt-essentials-part-1-introducing-mqtt>
- [12] University of Southampton IAM group. 2005. FloodNet. IAM group website. (April 2005). <http://www.iam.ecs.soton.ac.uk/projects/297.html>
- [13] Elegoo Industries. 2017. Elegoo 5 sets 28BYJ-48 5V Stepper Motor and ULN2003 Motor Driver Board for Arduino. elegoo industries website. (2017). <https://www.elegoo.com/product/elegoo-5-sets-28byj-48-5v-stepper-motor-uln2003-motor-driver-board-for-arduino/>
- [14] Dexter Industries. 2017. GoPiGo Build and Program Your Own Robot. dexter industries website. (2017). <https://www.dexterindustries.com/gopigo3/>
- [15] Images Scientific Instrumentation. 2017. How Stepper Motors Work. imagesco.com website. (2017). <http://www.imagesco.com/articles/picstepper/02.html>
- [16] Chu Jiangwei, Ji Lisheng, Guo Lie, Wang Rongben, et al. 2004. Study on method of detecting preceding vehicle based on monocular camera. In *Intelligent Vehicles Symposium, 2004 IEEE*. IEEE, 750–755.
- [17] jwatson. 2016. Raspberry Pi Models Comparison Chart Poster. element14 community website. (June 2016). <https://www.element14.com/community/docs/DOC-82195/l/raspberry-pi-models-comparison-chart-poster-free-download>
- [18] makershed.com. 2016. Raspberry pi comparison chart. makershed.com website. (2016). <https://www.makershed.com/pages/raspberry-pi-comparison-chart>
- [19] Hive mq. [n. d.]. MQTT Essentials Part 2: Publish & Subscribe. HiveMQ website. ([n. d.]). <https://www.hivemq.com/blog/mqtt-essentials-part2-publish-subscribe>
- [20] Hive MQ. [n. d.]. MQTT Essentials Part 6: Quality of Service 0, 1 & 2. Hivemq website. ([n. d.]). <https://www.hivemq.com/blog/mqtt-essentials-part-6-mqtt-quality-of-service-levels>
- [21] Hive MQ. [n. d.]. MQTT Security Fundamentals: TLS / SSL. hivemq website. ([n. d.]). <https://www.hivemq.com/blog/mqtt-security-fundamentals-tls-ssl>
- [22] Mqtt. [n. d.]. Mqtt official website. mqtt official website. ([n. d.]). <http://mqtt.org/>
- [23] OpenCV. 2017. About. opencv.org website. (2017). <https://opencv.org/about.html>
- [24] OpenCV. 2017. Face Detection using Haar Cascades. opencv website. (August 2017). [https://docs.opencv.org/3.3.0/d7/d8b/tutorial\\_py\\_face\\_detection.html](https://docs.opencv.org/3.3.0/d7/d8b/tutorial_py_face_detection.html)
- [25] OpenHAB. 2017. What is openHAB? openhab website. (November 2017). <https://www.openhab.org/introduction.html>
- [26] opensource.com. 2015. What is a Raspberry Pi. opensource.com website. (March 2015). <https://opensource.com/resources/raspberry-pi>
- [27] Todd Ouska. 2016. Transport-level security tradeoffs using MQTT. iot design website. (February 2016). <http://iotdesign.embedded-computing.com/guest-blogs/transport-level-security-tradeoffs-using-mqtt/>
- [28] pythonprogramming.net. 2014. Robotics with Python Raspberry Pi and GoPiGo Introduction. pythonprogramming.net. (April 2014). <https://pythonprogramming.net/robotics-raspberry-pi-tutorial-gopigo-introduction/>
- [29] random nerds tutorial. [n. d.]. What is MQTT and How It Works. random nerds website. ([n. d.]). <https://randomnerdtutorials.com/what-is-mqtt-and-how-it-works/>
- [30] raspberrypi.org. 2015. Raspberry Pi Zero: the 5 dollar computer. raspberrypi.org. (November 2015). <https://www.raspberrypi.org/blog/raspberry-pi-zero/>
- [31] raspberrypi.org. 2015. What is a Raspberry pi. raspberrypi.org website. (May 2015). <https://www.raspberrypi.org/help/what-%20is-a-raspberry-pi/>
- [32] IBM research. 2007. IBM Research Demonstrates Innovative 'Speech to Sign Language' Translation System. IBM website. (September 2007). <http://www-03.ibm.com/press/us/en/pressrelease/22316.wss>
- [33] smart factory. 2016. MQTT and Kibana fit! Open source Graphs and Analysis for IoT. smart factory website. (May 2016). <https://smart-factory.net/mqtt-and-kibana-open-source-graphs-and-analysis-for-iot/>
- [34] smart factory. 2016. Storing IoT data using open source. MQTT and ElasticSearch fit! Tutorial. smart factory website. (october 2016). <https://smart-factory.net/mqtt-elasticsearch-setup/>
- [35] Stan. 2014. 28BYJ-48 Stepper Motor with ULN2003 driver and Arduino Uno. 42 bolts website. (March 2014). <http://42bots.com/tutorials/28byj-48-stepper-motor-with-uln2003-driver-and-arduino-uno/>
- [36] Apache storm. [n. d.]. Storm MQTT Integration. Apache storm website. ([n. d.]). <http://storm.apache.org/releases/1.1.0/storm-mqtt.html>
- [37] Built to spec. 2015. Understanding Stepper Motors Part I fit!! A Basic Model. built-to-spec.com website. (October 2015). <http://www.built-to-spec.com/blog/2012/04/09/understanding-stepper-motors-part-i-a-basic-model/>
- [38] Zheng Wang. 2015. Self Driving RC Car. Zheng Wang wordpress website. (August 2015). <https://zhengludwig.wordpress.com/projects/self-driving-rc-car/>
- [39] Wikipedia. 2017. MQTT – Wikipedia, The Free Encyclopedia. (November 2017). <https://en.wikipedia.org/w/index.php?title=MQTT&oldid=808683219> [Online; accessed 6-November-2017].
- [40] Wikipedia. 2017. OpenCV – Wikipedia, The Free Encyclopedia. (2017). <https://en.wikipedia.org/w/index.php?title=OpenCV&oldid=811519079> [Online; accessed 4-December-2017].
- [41] Wikipedia. 2017. Stepper motor – Wikipedia, The Free Encyclopedia. (2017). [https://en.wikipedia.org/w/index.php?title=Stepper\\_motor&oldid=811220740](https://en.wikipedia.org/w/index.php?title=Stepper_motor&oldid=811220740) [Online; accessed 4-December-2017].
- [42] Wikipedia. 2017. Storm (event processor) – Wikipedia, The Free Encyclopedia. (2017). [https://en.wikipedia.org/w/index.php?title=Storm\\_\(event\\_processor\)&oldid=80871136](https://en.wikipedia.org/w/index.php?title=Storm_(event_processor)&oldid=80871136) [Online; accessed 6-November-2017].
- [43] Wikipedia. 2017. ViolaFit!Jones object detection framework – Wikipedia, The Free Encyclopedia. (2017). <https://en.wikipedia.org/w/index.php?title=Viola%20%28%20%29Jones.object.detection.framework&oldid=808683512> [Online; accessed 4-December-2017].

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--empty year in apache-storm
Warning--empty year in eclipse-mosquitto
Warning--empty year in python-paho-mqtt
Warning--empty year in elk-stack
Warning--empty year in erlang-mqtt-broker
Warning--empty year in hivemq-security-oauth
Warning--empty year in hivemq-website
Warning--empty publisher in monocular
Warning--empty address in monocular
Warning--empty year in hivemq-details
Warning--empty year in hivemq-qos
Warning--empty year in mqtt-sec-ssl
Warning--empty year in mqtt-official
Warning--empty year in how-mqtt-works
Warning--empty year in apache-storm-mqtt
(There were 15 warnings)
```

```
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
=====
[2017-12-12 19.57.16] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
Missing character: ""
Missing character: ""
Missing character: ""
```

```
Typesetting of "report.tex" completed in 0.9s.
```

```
=====
Compliance Report
=====
```

```
name: Arnav, Arnav
hid: 201
paper1: 20th Oct 2017 100%
paper2: 100%
project: 100%
```

```
yamlcheck
```

```
wordcount
```

```
7
wc 201 project 7 4877 report.tex
wc 201 project 7 5274 report.pdf
wc 201 project 7 1807 report.bib
```

```
find "
```

```
passed: True
```

```
find footnote
```

```
passed: True
```

```
find input{format/i523}
```

```
passed: False
```

```
find input{format/final}
```

```
4: \input{format/final}
```

```
passed: True
```

floats

---

- 228: Figure \ref{f:stepper1} shows how a stepper motor with a resolution of 90 degrees can be made to complete one full rotation. In practice however, the resolution (the degrees moved at each step) of most stepper motors is much higher. The process mentioned in figure \ref{f:stepper1} is known as half stepping \cite{stepper1}.
- 230: \begin{figure}[!ht]
- 231: \centering\includegraphics[width=\columnwidth]{images/stepper1.pdf}
- 232: \caption{Working of a steper motor : Full stepping using one coil at a time \cite{stepper1}}\label{f:stepper1}
- 235: In the above method, only one coil is turned on at a time. This can be improved upon to get a higher torque. To get a higher torque, two adjacent coils are turned on at the same time, as shown in figure \ref{f:stepper2}. This results in double the torque generated when using only one coil at a time \cite{stepper2}.
- 237: \begin{figure}[!ht]
- 238: \centering\includegraphics[width=\columnwidth]{images/stepper2.pdf}
- 239: \caption{Working of a steper motor : Full stepping using two coils at a time \cite{stepper2}}\label{f:stepper2}
- 242: With full stepping however, the transition between two consecutive steps is not very smooth. Therefore, a technique called Half stepping is used, where two adjacent coils are turned on similar to full stepping, but between two steps one of the coils is turned off, so that the transition between steps is smooth. This results in a torque 70 percent of that generated in using full stepping with two coils turned on at the same time. This process is shown in figure \ref{f:stepper3} \cite{stepper1}.
- 244: \begin{figure}[!ht]
- 245: \centering\includegraphics[width=\columnwidth]{images/stepper3.pdf}
- 246: \caption{Working of a steper motor : Half stepping \cite{stepper1}}\label{f:stepper3}
- 276: For monitoring purposes, another program, video\\_pub runs on the raspberry pi. This program uses the raspberry pi on board camera with the help of the picamera module and captures images. The images are converted to greyscale, and opencv is used to perform face detection using Haar Cascades. If a face is found, a box is drawn around the face in the image. The image is published to the broker under the topic {\em topic/video\\_frames}. The

video\\_sub.py program running on the desktop subscribes to this topic on the broker and displays the images received. These images can be used for the navigation of the robot car remotely figure \ref{f:arch}.

```

278: \begin{figure}[!ht]
279: \centering\includegraphics[width=\columnwidth]{images/architectur
e.pdf}
280: \caption{Architecture of the Application}\label{f:arch}
287: This section covers the setup instructions for the project and
the observations. The robot car that was built is shown in figure
\ref{f:car1}. %and figure \ref{f:car2}
289: \begin{figure}[!ht]
290: \centering\includegraphics[width=\columnwidth]{images/car1.pdf}
291: \caption{Raspberry Pi Robot Car}\label{f:car1}
295: \%begin{figure}[!ht]
296: %
\centering\includegraphics[width=\columnwidth]{images/car2.pdf}
297: \% \caption{Raspberry Pi Robot Car}\label{f:car2}
308: \ref{f:connection}
311: \centering\includegraphics[width=\textwidth]{images/connection.pd
f}
312: \caption{Connection Diagram \cite{rpi-
pinout}}\label{f:connection}
```

figures 6  
tables 0  
\includegraphics 7  
labels 7  
refs 6  
floats 6

```

True : ref check passed: (refs >= figures + tables)
False : label check passed: (refs >= figures + tables)
False : include graphics passed: (figures >= \includegraphics)
False : check if all figures are referred to: (refs >= labels)
```

Label/ref check  
passed: True

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find \textwidth

---

```
311: \centering\includegraphics[width=\textwidth]{images/connection.pd  
f}
```

passed: False

below\_check

---

WARNING: figure and above may be used improperly

235: In the above method, only one coil is turned on at a time. This can be improved upon to get a higher torque. To get a higher torque, two adjacent coils are turned on at the same time, as shown in figure \ref{f:stepper2}. This results in double the torque generated when using only one coil at a time \cite{stepper2}.

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib  
Warning--empty year in apache-storm  
Warning--empty year in eclipse-mosquitto  
Warning--empty year in python-paho-mqtt  
Warning--empty year in elk-stack  
Warning--empty year in erlang-mqtt-broker  
Warning--empty year in hivemq-security-oauth  
Warning--empty year in hivemq-website  
Warning--empty publisher in monocular  
Warning--empty address in monocular  
Warning--empty year in hivemq-details  
Warning--empty year in hivemq-qos  
Warning--empty year in mqtt-sec-ssl  
Warning--empty year in mqtt-official  
Warning--empty year in how-mqtt-works
```

```
Warning--empty year in apache-storm-mqtt
(There were 15 warnings)
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
passed: True
```

# Big Data and Edge Analytics in Weather Monitoring and Forecasting

Robert W. Gasiewicz

Indiana University  
711 N. Park Avenue  
Bloomington, IN 47408  
rgasiewi@iu.edu

## ABSTRACT

General Topic: The gathering of weather data and forecasting used to be a task left only to meteorologists or scientists with expensive, often unreliable, and heavily centralized scientific equipment. With an estimated 260,000+ weather stations in use around the world today[9], collecting and analyzing weather data has not only become inexpensive and more reliable, it has become far more decentralized. This decentralization has prompted more of the analysis to be conducted locally as opposed to in a central repository managed by large centralized weather institutions such as the National Weather Service or NOAA (National Oceanographic and Atmospheric Administration). It has also allowed reporting to achieve greater accuracy by enabling the monitoring to occur a few yards away from the person collecting the data, instead of 20 or 30 miles away. Reliability has also increased with the increased number of data points being fed to the cloud.

Specific Question: The purpose of this project is to build a versatile and compact PWS (Personal Weather Station), write a program to collect local weather data, upload it to Weather Underground, and perform an analysis of the data compared to other local weather stations collecting similar data in roughly the same geographic area. The project also explores other options for using this data with other IoT devices in order to achieve maximum energy efficiency in the home.

Method: Utilizing a Raspberry Pi 3 and Sense Hat, local weather data was collected using a Python script, and then streamed to Weather Underground's distributed weather station network. Three data types were evaluated: 1) Temperature (in Fahrenheit) 2) Humidity and 3) Barometric Pressure (in Hg). The data was analyzed along with other home weather stations in the immediate geographic vicinity to determine variance and accuracy between the weather stations as well as with the general forecast for the tested geographic area. An official non-PWS weather station was also selected as a control test. The feasibility of using the concept of edge analytics based on this data to enhance the efficiency of a Nest thermostat and Tesla solar array was also explored.

Results: Localized weather from PWS was far more accurate and reliable compared with distant, commercial weather stations and IoT devices such as Nest and the Tesla solar array, and moreover the environment, would benefit significantly from utilizing localized weather data sourced from a PWS.

## KEYWORDS

i523, HID316, Big Data, Edge Analytics, Raspberry Pi 3, Sense Hat, Python, Personal Weather Station, Weather Underground,

Meteorology, Energy Efficiency, Clean Energy, IoT, Nest, Tesla, Solar Array

## 1 INTRODUCTION

A world burgeoning with IoT devices and connected everything is upon us. As the trend in computing shifts from cloud-based computing to localized computers sending data to the cloud, weather reporting has similarly shifted in a more localized direction. Long gone are the days in which a person needs to wait until the top of the hour to hear a radio broadcast of the latest weather conditions. Even the Weather Channel itself is becoming obsolete. With the widespread availability of cheap computing and components, it is now not only possible for someone to build their own PWS for less than \$100, but they can also become a reliable source of data from which more accurate weather forecasts can be derived.

Having a general idea of what the weather might be like 12-36 hours from now isn't exactly a new concept. As conversations about the weather can attest, it is one of the most foundational elements of human interaction between two strangers. Everyone has a pretty good idea of what the weather's going to be like in the relatively near future, but this is typically based off of either secondary information or, at best, from sources in which the data was measured and analyzed many dozens of miles away. A person's decisions about when to go to a particular place, what to wear, or when to stay home may all be based on information that is only loosely tailored to their needs. Likewise, IoT devices such as thermostats and solar arrays might be indexed to the same weather data sources and might not, as a result, operate nearly as efficiently as they otherwise could be.

By pushing the currently available technology as far as it can possibly go with commercially available components and software, it was the intent of this project to explore the extent to which a small and inexpensive scratch built IoT device could be used to gather and analyze local weather data to potentially be used as an enhancement to existing energy saving IoT appliances such as Nest and a Tesla solar array. The IoT weather data collection device, will be referred to as a personal weather station, or PWS, throughout the rest of this paper. This project explored how the PWS was constructed and the Python code required to interface with the Sense Hat sensors and stream the data to Weather Underground. In order to do this, an account was required on Weather Underground. The PWS was registered as one the 260,000+ PWS submitting weather data to the site. Once submitted, this data was tracked and stored by Weather Underground at regular intervals which was and is used by the site to present a holistic picture of the weather for a given geographical

area. The data can also be downloaded and used offline for other purposes, such as the analysis for this project. Data gathered by the PWS used for this project will be compared to other various types of PWS as well as one non-PWS weather station in the general geographic area.

This data was then used to determine the variances with other PWSs and show the benefit of feeding localized weather data to other nearby IoT devices. Both of the devices used in this project meet the minimum requirements of being connected to the internet and would benefit from being connected to up-to-date and accurate weather data. The Nest connects to Weather Underground for its weather data, which is the site used to stream the PWS data used for this project, but currently connects to the site via zip code. Users have also identified many issues with the weather data not being accurate for their locations[4]. Often readings are off by 10-15 degrees Fahrenheit[10].

At some point in the future, it may be possible for Nest users to select a particular PWS, with their own being the obvious best choice. Likewise, local PWS weather data could be useful in conjunction with a Tesla solar array, both in terms of forecasting daily sunlight and energy consumption as well as temperature and increased air-conditioning use. This data could also be used to determine if solar panels would be a smart investment for a home in a particular area with a given set of weather conditions.

## 2 A BRIEF HISTORY OF METEOROLOGY

In order to understand the pressing need of getting localized, up-to-date, and accurate weather data, it is important to understand the evolution of gathering, analyzing, and modeling weather data and to do that, it is important to understand the science behind weather. The science of weather is more commonly referred to as meteorology. Meteorology is a type of atmospheric science that has its roots going back millennia, although it wasn't comprised of much more than observation and forecasting based on historical data collection until the late 1800s. It wasn't until the late 19th and early 20th centuries that the science of meteorology evolved into roughly what it is today; a network of weather observation stations sharing information on a global scale. In the beginning, weather observation stations were nothing more than a collection of scientific instruments read by a human and recorded on paper. Over time, inferences could be made about the historical data collected in order to make rudimentary weather forecasts, though the predictive accuracy of weather forecasting was somewhat low until further work had been done in the field of physics and chemistry.

The dawn of the computer age brought about significant change and rapid advancement to the world of meteorology. As weather data began to be tracked electronically, the advent of big data, and eventually weather modeling allowed for very sophisticated weather observation and forecasting. Weather data and forecasting went from cable television to mobile phone apps by the early 21st century, allowing users to have on-demand weather information available to them. Still, in its early stages, this data was mostly limited to what was gathered by expensive and highly sophisticated weather equipment at labs, research facilities, academic institutions, and meteorological centers.

As the cost curve for personal computers, and electronic components generally, continued to bend downward over the course of the early 21st century, it became possible for individuals to build, maintain, and read the data from their own personal weather stations (PWS). In tandem with this, the internet could then be used to transmit this data to central weather databases, which were only getting highly regionalized data from the aforementioned scientific facilities. Both the localization and volume of data enables much more accurate weather models, and subsequently, much more accurate weather forecasting.

## 3 PWS OVERVIEW

Personal Weather Stations can be built in a number of different ways, using a variety of components, and with virtually limitless coding possibilities. For this project, a Raspberry Pi 3 was used as the platform on which the other components - in this case a Sense Hat - were connected. The Sense Hat has three sensors for measuring temperature, humidity, and pressure. It also has an 8x8 full-color LED matrix for displaying text and symbols, which for this project, was used to indicate whether the temperature had gone up, down, or remained the same during a given period of time. Some other options for the display were experimented with, such as displaying scrolling text, but ultimately this was determined to be unreadable, as the LED matrix is only capable of displaying 1-2 characters at a time. Though it was not used regularly for this project, the Sense Hat also has a mini 5 button joystick, which can be used to control the completed IoT PWS when it's not connected to any peripherals. The Raspberry Pi 3 and Sense Hat were then wrapped in a C4 Labs Zebra Case with the add on for the Sense Hat. The add on leaves the sensors and LED matrix exposed to the elements.

## 4 BUILDING THE PWS

The physical act of building the PWS itself is relatively easy and doesn't have a significant time requirement. These are the steps that were followed:

- (1) Unboxed the Raspberry Pi 3 and Sense Hat (see Figure 1).
- (2) Connected the Sense Hat to the Raspberry Pi 3.
- (3) Attached heat sink to the Raspberry Pi 3 that were included with the C4 Labs Zebra Case. These needed to be mounted prior placing the Raspberry Pi 3 and Sense Hat into the Zebra Case.
- (4) With the Sense Hat and heat sinks attached, the Zebra Case is assembled in layers around the components, beginning with the bottom and building upward. The heatsinks should fit through the precut holes in the Zebra Case, facing downward and the Sense Hat LED matrix and sensors are facing upward.
- (5) As the layers were added, it was important to ensure the various components, especially the Raspberry Pi 3 and the Sense Hat remained aligned in the case.
- (6) Insert the screws and rivets and close the case.
- (7) Before powering on, insert a mini SD card pre-loaded with the NOOBS operating system. A 32GB card was used for this project, but since data is only being read and streamed to the cloud, a not a lot of disk space is required. Even so,

disk space still needed to be expanded during the initial setup.

Figure must use label and ref, see How I did it for Figure 1

## 5 INITIAL CONFIGURATION OF THE RASPBERRY PI 3

After building the physical infrastructure of the PWS, it was configured with the NOOBS operating system that was pre-loaded on the mini SD card and then updates were installed. These were the steps that were followed:

- (1) Plugged mini USB plug into the Raspberry Pi 3.
- (2) Plugged peripherals (monitor, keyboard, mouse) into the Raspberry Pi 3.
- (3) The device booted and began automatically installing the NOOBS operating system.
- (4) After NOOBS completed its installation, the Raspberry Pi preferences could be configured.
- (5) By selecting Preferences -> Raspberry Pi Configuration, disk space could then be expanded by clicking the "Expand Filesystem" button. This was required because the default setup ultimately leaves too little disk space for all the software required for the project. SHOW IMAGE
- (6) The hostname can also be renamed so that it can easily be found on your home WiFi network.
- (7) It's also a good idea to update the Raspberry Pi 3's software, which was done by opening a terminal window entering the following command - which updates the Raspberry Pi 3's indexes of the most up-to-date software packages:  

```
sudo apt-get update
```
- (8) After software packages were updated, entering the following command then updated the Raspbian OS to the most current configuration available:  

```
sudo apt-get upgrade
```
- (9) At this point, the device was ready to begin configuration of the PWS specific software and coding.

## 6 CONFIGURATION OF THE SENSE HAT

Once the Raspberry Pi 3 was correctly configured, the next major step was installing and configuring the Sense Hat. Since the Sense Hat utilizes its own Python libraries, they needed to be installed as well. These were the steps that were followed:

- (1) Enter the following command to install the Sense Hat libraries:  

```
sudo apt-get install sense-hat
```
- (2) Once the Sense Hat libraries were installed, a directory was created for the Python code. This was done using the following set of commands:  

```
cd ~  
mkdir pi_weather_station  
cd pi_weather_station
```



Figure 1: Unboxed Raspberry Pi 3 with heatsink attached prior to mounting on case bottom



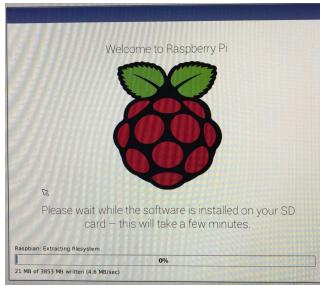
Figure 2: Sense Hat attached to the Raspberry Pi 3 with the Zebra Case assembled upward from the bottom in layers



Figure 3: SD Card inserted through the slot on the bottom of the PWS



Figure 4: PWS powered on for the first time



**Figure 5: NOOBS OS is in the process of installing**

## 7 PWS PYTHON SOURCE CODE

Overall the Python source code used for this project is fairly straightforward[8]. In essence, it is telling the Sense Hat to measure temperature, humidity, and pressure during specific intervals and to send them to Weather underground.

You need a sentence with the Figure 6. Long code must be in a figure

```
if WEATHER_UPLOAD:
    print("Uploading data to Weather Underground")
    weather_data = {
        "action": "updateraw",
        "ID": wu_station_id,
        "PASSWORD": wu_station_key,
        "dateutc": "now",
        "tempf": str(temp_f),
        "humidity": str(humidity),
        "baromin": str(pressure),
    }
    try:
        upload_url = WU_URL + "?" + urlencode(weather_data)
        response = urllib2.urlopen(upload_url)
        html = response.read()
        print("Server response:", html)
        response.close()
    except:
        print("Exception:", sys.exc_info()[0], SLASH_N)
    else:
        print("Skipping Weather Underground upload")
```

**Figure 6: YOUR CAPTION HERE**

The code also makes use of the Sense Hat's 8x8 full-color LED matrix to display with a "W" for Warmer if the moving average of the temperature has increased since the past interval or a "C" for Cooler if the moving average of the temperature has decreased since the past interval. If the moving average of the temperature remains the same since the past interval, it displays a red and blue equal sign for no change in temperature.

```
b = [0, 0, 255] # blue
r = [255, 0, 0] # red
e = [0, 0, 0] # empty
```

```
warm_up = [
    r, r, e, r, r, e, r, r,
    r, r, r, r, r, e, r, r,
    r, r, e, r, r, e, r, r,
    r, r, r, r, r, r, r, r,
    e, r, r, r, r, r, r, r,
]

cool_down = [
    e, b, b, b, b, b, b, e,
    b, b, b, b, b, b, b, b,
    b, b, e, b, b, e, b, b,
    b, b, e, b, b, e, e, e,
    b, b, e, b, b, e, e, e,
    b, b, e, b, b, e, b, b,
    b, b, b, b, b, b, b, b,
    e, b, b, b, b, b, b, e,
]

bars = [
    e, e, e, e, e, e, e, e,
    e, e, e, e, e, e, e, e,
    r, r, r, r, r, r, r, r,
    r, r, r, r, r, r, r, r,
    b, b, b, b, b, b, b, b,
    b, b, b, b, b, b, b, b,
    e, e, e, e, e, e, e, e,
    e, e, e, e, e, e, e, e,
]

There are a few nuances to the code, one of which converts the standard Sense Hat measurement of temperature from Celsius to Fahrenheit and pressure from millibars to inHG.

Celsius to Fahrenheit:
def c_to_f(input_temp):
    # conversion of the temp from Celsius to Fahrenheit
    return (input_temp * 1.8) + 32

Another issue that had to be overcome was the warmth of the Raspberry Pi 3 and Sense Hat causing the temperature readings to be about 10-15 degrees warmer in Fahrenheit than the ambient temperature. Weather Underground will eventually disconnect PWSs which display erroneous and incorrect data. This was overcome by employing a "hack" available from the Pi Foundation[1]:
def get_temp():
    t1 = sense.get_temperature_from_humidity()
    t2 = sense.get_temperature_from_pressure()
    t = (t1 + t2) / 2
    t_cpu = get_cpu_temp()
    # Calculation for the real temperature
    t_corr = t - ((t_cpu - t) / 1.5)
    # average over 3 readings
    t_corr = get_smooth(t_corr)
    return t_corr

def main():
    global last_temp
```

```

last_minute = datetime.datetime.now().minute
last_minute -= 1
if last_minute == 0:
    last_minute = 59

```

Another nuance to the data collection aspect is the moving average. Though the PWS is only sending weather data to Weather Underground every 10 minutes, it is reading the data locally on the device every 5 seconds and sending the moving average to Weather Underground.

```

def get_smooth(x):
    if not hasattr(get_smooth, "t"):
        get_smooth.t = [x, x, x]
    get_smooth.t[2] = get_smooth.t[1]
    get_smooth.t[1] = get_smooth.t[0]
    get_smooth.t[0] = x
    # average of the last 3 smooth temps
    xs = (get_smooth.t[0] + \
           get_smooth.t[1] + \
           get_smooth.t[2]) / 3
    return xs

```

For this project, the above source code was saved as `personal_weather_station.py` and placed in the `pi_weather_station`

directory that was created during steps we did for configuring the Sense Hat. In addition to the `personal_weather_station.py` code, a configuration file is also required in order for the PWS to be able to interface with Weather Underground. The configuration file is fairly simple, comprised of just 3 lines of code:

```

class Config:
    STATION_ID = ""
    STATION_KEY = ""

```

Both the Station ID and the Station Key are obtained when setting up an account on Weather Underground. More on that next.

## 8 REGISTERING THE PWS ON WEATHER UNDERGROUND

Why Weather Underground? Weather Underground started in 1995 as an internet weather service, initially with the sole purpose of displaying real-time weather data on the web. By 2012 the Weather Channel (The Weather Company) had acquired Weather Underground and by 2017 Weather Underground had over 260,000+ PWSs feeding weather data into its cloud-based weather tracking and analysis system. These observations are used in conjunction with official National Weather Service weather stations to provide very detailed and dynamically-updated features on Weather Underground and Weather Channel's forecasting service as well as Google's Map base.

Setting up a PWS on Weather Underground network wasn't particularly difficult, but some basic requirements need to be met. First, the PWS of choice must be able to interface with Weather Underground's servers. The Raspberry Pi 3 and Sense Hat are perfect for this and hence why they were used for this project. The following are the steps that were followed for setting up the device:

- (1) From the <http://www.wunderground.com> web page, an account must be registered following the standard procedure for doing something like this. Given that the PWS that was registered is keyed into a particular geographic location, an address as well as elevation must be provided.
- (2) A name was also picked for the PWS, and for the purposes of this project, the name "Deer Ridge" was selected.

After completing these steps, the Station ID and Station Access Key were provided but were not yet entered into the `config.py` file in the `pi_weather_station` directory on the PWS. It was only after successful completion of testing and automation that this final step was taken.

## 9 INITIAL TESTING AND AUTOMATION

Prior to placing the PWS outside (where it will no longer be easy to plug in its peripherals), some initial testing was conducted before automating the startup of the `personal_weather_station.py` script and submitting potentially false and inaccurate data to Weather Underground. It was also during this testing that the Sense Hat warm temperature sensor issue first presented itself and it was determined that it needed to be fixed prior to configuring the device to send data to Weather Underground.

After plugging in the device and manually launching the main source code script, it was confirmed that the script was working as expected, including the readouts on the LED matrix display. Data began populating at 5 second intervals in the terminal window and the correct readouts were displaying on the LED matrix. However, according to the Nest in my home the ambient temperature in the house was 70 degrees Fahrenheit. Yet the PWS was registering at 81 degrees Fahrenheit and climbing. Thus, as it was explained in the above section on the project source code, a workaround had to be implemented in the code to compensate for this temperature.

Once that issue was resolved, it was time to configure the PWS scripts to run automatically upon PWS startup. The advantages to doing this allowed the PWS to be moved (unplugged from its power source) and to maintain a constant stream of weather data to Weather Underground in the event of a power outage or WiFi reboot.

This automated startup can be accomplished by opening a terminal window and navigating to the `pi_weather_station` directory on the PWS. Once there, the project's Bash script file can be turned into an executable using the following command:

```
chmod +x start-station.sh
```

Once this command was entered, then the autostart file can be opened and the following line of code can be added:

```
@lxterminal -e /home/pi/pi_weather_station/start-station.sh
```

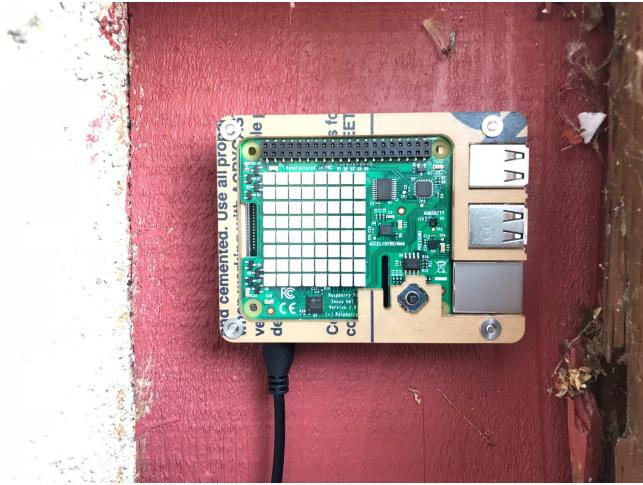
After rebooting the PWS, the `personal_weather_station.py` then started automatically. The script was then stopped and the Station ID and Station Access Key that were provided by Weather Underground during registration were entered into the `config.py` file in the `pi_weather_station` directory on the PWS.

## 10 PWS LOCATION SELECTION

Before turning on the PWS and transmitting data to Weather Underground, a suitable location needed to be selected for the PWS.

The basic requirements for this were that the sensors need to be as out in the open and exposed to the outdoor elements as much as possible while also not getting wet or exposed to too much wind and dust. Weather Underground suggests placement of at least 5 feet off the ground and away from concrete, asphalt, and any other heat-producing appliances such as air conditioners or solar inverters.

The most reasonable location available for this project was the inside of a fence post, tucked under the eaves of the house. This way, the PWS was not in direct sunlight, in danger of getting wet, and also near a power supply. The PWS was mounted on the fence post about 5 feet off the ground and plugged into a power source.



**Figure 7: PWS mounted in an outdoor, protected area, out of direct sunlight**

The geographic location chosen for the PWS was Northern California with the time setting for this project over the course of an 8 day period during the month of November, from 11/21/2017 to 11/28/2017. This is a time in which weather conditions in this part of the country are in flux and make for some interesting readings. The PWS is also at roughly 300 feet of elevation in the foothills east and in the rain shadow of large mountain with approximately 4,000 feet of elevation. The PWS is located roughly 60 miles east of the Pacific Ocean and therefore is exposed to rapidly changing weather patterns in the fall. These patterns are born out in the data.

## 11 OFFICIAL WEATHER DATA SOURCE SELECTION

Both the geography and topography of the area around the site of the PWS built for this project vary greatly within 1-5 miles let alone 10-20 miles. Roughly half of the people who live in the United States live within 17 miles of an airport, while 90 percent live within 58 miles of an airport.[7] In nearly all cases, airports are equipped with the most advanced weather station and data collection technology, so they are often most cited for their data. As an official weather source for this project, the KSCK Stockton Airport WS weather station is 31 miles away and is the closest major airport to the location of the PWS built for this project. The Stockton Airport

WS weather station collects a variety of comprehensive weather data, though for this project, we are only comparing temperature, humidity, and pressure.

## 12 ADDITION PWS DATA SELECTION

In addition to the official weather source from Stockton Airport WS, 3 additional PWSs in varying proximity to the Deer Ridge PWS (but not further away than Stockton Airport WS) were selected to collect temperature, humidity, and pressure data for a date range of 11/21/2017 to 11/28/2017. The stations selected were (ordered by distance from Deer Ridge PWS):

## 13 ADDITION PWS DATA SELECTION

### 13.1 Deer Ridge Country Club PWS

Type: Netatmo Weather Station, located less than 1 mile from the Deer Ridge PWS at an elevation of 173 feet.



**Figure 8: Location of the Deer Ridge PWS (Blue Dot in relation to Stockton Airport PWS (Red Dot)**

### 13.2 Campanello PWS

Type: Netatmo Weather Station, located 2.2 miles from the Deer Ridge PWS at an elevation of 88 feet.

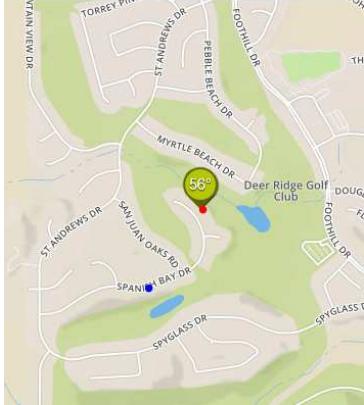
### 13.3 Morgan Territory PWS

Type: AcuRite Pro Weather Center, located 4.8 miles from the Deer Ridge PWS at an elevation of 820 feet.

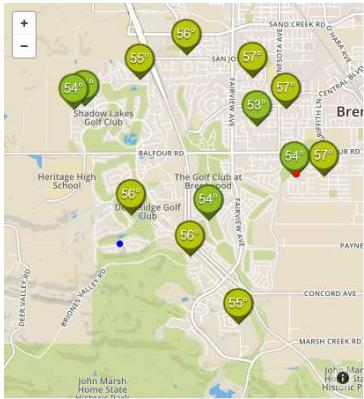
## 14 PWS DATA ANALYSIS

Once making these selections, collecting the data was as simple as pulling down the data from Weather Underground as each PWS and the Stockton Airport WS have their own webpages with relevant data hosted on Weather Underground.[5] Data was collected in CSV format and added to the local Python Directory. Using iPython Notebook, Pandas, and Matplotlib, analysis was performed on the temperature, humidity, and pressure data collected that is useful in determining whether or not:

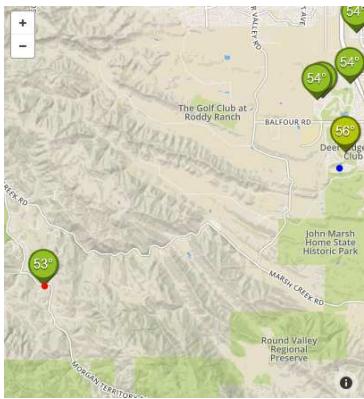
- (1) Weather data coming from local PWSs is more accurate than weather data observed at the nearest major weather station, which in the case of this project, is Stockton Airport WS.
- (2) Weather data coming from local PWSs can be used to interface with Nest and a Tesla Solar Array



**Figure 9: Location of Deer Ridge PWS (Blue Dot) in relation to Deer Ridge Country Club PWS (Red Dot)**



**Figure 10: Location of Deer Ridge PWS (Blue Dot) in relation to Campanello PWS (Red Dot)**



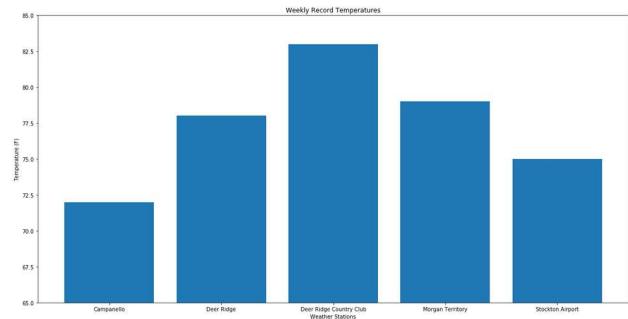
**Figure 11: Location of Deer Ridge PWS (Blue Dot) in relation to Morgan Territory PWS (Red Dot)**

A total of 6 data elements were collected from 5 weather stations:

- (1) Date
- (2) Time
- (3) PWS Name
- (4) Temperature (Fahrenheit)
- (5) Humidity (Percentage)
- (6) Pressure (inHG)

## 14.1 Outliers

The first part of the analysis that was performed as to determine if there were any outliers in the data that could, if used to feed a Nest or Tesla Solar Array, cause equipment to operate inefficiently. Obviously, given that the over-arching goal of this project is to conserve energy and allow equipment to function in the most efficient manner possible based on the most localized weather data possible, it must be determined if these sources are usable. In order to do this, Pandas was used to create a DataFrame from a CSV in iPython Notebook and Matplotlib was used to generate a bar graph. The first analysis performed was weekly record (max values) with regard to temperature, humidity, and pressure for each PWS. While the differences in pressure were negligible, there were some significant variances in both temperature and humidity, not only between the various local PWSs, but also when compared to Stockton.

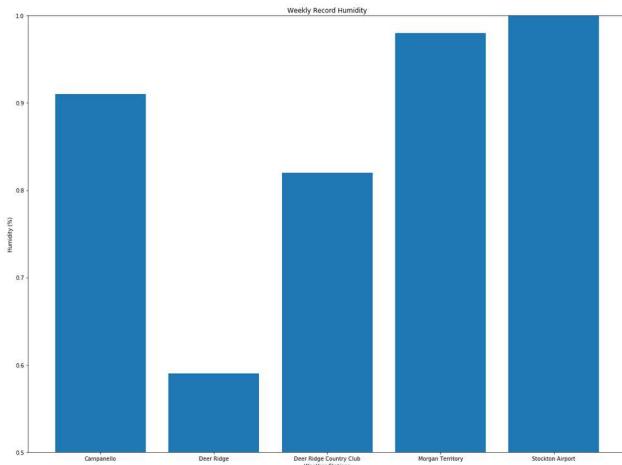


**Figure 12: Weekly Record High Temperatures**

The most significant differences were between Campanello PWS and Deer Ridge Country Club PWS, which are less than 5 miles apart and yet there was a full 12 degree difference between the two in terms of highest temperature recorded during the period in which data was collected. Another striking observation was the 5 degree difference in record high temperature between Deer Ridge PWS and Deer Ridge Country Club PWS. There is also a 5 degree difference between Campanello PWS and Deer Ridge PWS, but in the opposite direction from Deer Ridge PWS vs. Deer Ridge Country Club PWS.

With Deer Ridge PWS falling near the average of the 5 weather stations, it would seem that the Deer Ridge Country Club PWS is either having calibration issues or is mounted in a place that is less than ideal, such as on or near a concrete surface or in direct sunlight. The Deer Ridge PWS is also closest to the Stockton Airport WS, so this is very positive news in terms of furthering the goal of obtaining the most accurate, local weather.

With just a cursory glance at the weekly records for humidity for each of the 5 weather stations, one would have to conclude that



**Figure 13: Weekly Record High Humidity**

the seems to be an issue with Stockton Airport WS. The average humidity for this part of California tends to be pretty low as the climate is generally a mix between Mediterranean/Semi-Arid. Even with the onset of the fall and winter season and the ensuing rain that comes with it, there doesn't seem to be any reasonable explanation for why Stockton Airport WS's humidity should register at greater than 70 percent more than 14 percent of the time. One explanation for this could possibly be that it has inadvertently come into contact with water, perhaps from an errant sprinkler nozzle or something similar. This might explain why the humidity hangs at 100 percent for such long periods of time and then tapers off, which is a totally unrealistic scenario.

In fact, despite the fact that the Deer Ridge PWS seems like it is reporting low humidity, it in fact is not when compared with other PWSs that were not factored into the data, as well as from reports from the National Weather Service[6], which reported the average humidity for the period of observation to be 54 percent. This coincides with the humidity measurements that were observed on the Deer Ridge PWS, which is yet another positive aspect in proving the theory that local weather is better weather.

#### 14.2 PWSaaS

Broadly speaking, PWS data would be a far better candidate for feeding IoT home devices such as Nest and a Tesla Solar Array than the currently available data from Weather Underground. As was demonstrated above, even data provided by the Stockton Airport WS contained significant outliers. Though not even other local PWSs in closer vicinity to the Deer Ridge PWS were providing accurate readings. This means that selecting the correct location for a weather station is probably even more crucial than selecting the type of equipment itself. Even with a Raspberry Pi 3 and rudimentary sensors, the data collected by it was far more close to the average than other more expensive weather stations. As was mentioned in the introduction section of this project, the cost of the Raspberry Pi 3 and its components came to less than \$100. With all of its accessories, the Netatmo PWS can cost upwards of \$ 500[2]. The Stockton Airport WS is no doubt many thousands if not tens

of thousands more than these price points, though no details are provided on Weather Underground as to type or specifications for this particular WS.

The bottom line for the Nest is that if Weather Underground can come up with an inexpensive method of certifying PWS data, it would make sense, based on the findings of this project, to release an update to their existing software that would allow Nest users to select the PWS of their choice, rather than the currently configured generic Weather Underground data.

In terms of the Tesla Solar Array, according to Tesla's website, the only way they are currently utilizing weather data is during the design phase when they are determining feasibility for installing a solar array at client's home or business[3]:

"We will review past utility bills, sunlight patterns, and weather data for your area and create a custom system design for your home."

What Tesla doesn't say is from where they are sourcing their data. If similar to Nest's sourcing, then Tesla's design process would also benefit from using more accurate, localized weather data. Additionally, given that Tesla solar systems are also IoT devices in that they interface both with the utility company and Tesla for the purposes of metering and monitoring, respectively, it would also be beneficial for Tesla to begin utilizing real-time weather data as well for the purposes of enhancing efficiency and energy productivity. Moreover, Nest (owned by Google) and Tesla could partner to use localized, highly accurate weather data observation and forecasting to automate two systems that manage virtually all of the energy needs of 21st century living. Personal Weather Stations as a Service (PWSaaS) could quickly become another fixture of the wired home.

## 15 CONCLUSION

As technology continues to progress in the 21st century, it is clear that many of the rapid advances with IoT devices once thought impossible even a decade ago are not only possible now, but are inexpensive, more accurate, and wholly underutilized. The results of this project are clear and undeniable: Individually and locally sourced weather data is far more accurate and reliable than it ever has been in the past and is clearly superior to weather data sourced from legacy weather stations at airports and meteorological centers. Given the pressing need to conserve energy and use our limited natural resources more efficiently, the need for the most accurate weather data is now far more pressing, now that IoT energy management devices such as Nest and Tesla's solar array utilize weather data for design and operation. The findings of this project are that local weather data is more accurate, but only if PWS are well-placed. This localized data will only be truly beneficial if PWSs can be certified for accuracy. If this issue of consistency can be overcome, the possibilities for integrating this data with household IoT devices are virtually limitless.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski for his support and encouragement in helping to refine the topic of this paper.

## REFERENCES

- [1] 2016. Accurate temperature reading from Raspberry PI Sense HAT. (2016). Retrieved November 20th, 2017 from <http://yaab-arduino.blogspot.co.uk/2016/08/accurate-temperature-reading-sensehat.html>
- [2] 2017. Netatmo Personal Weather Stations. (2017). Retrieved December 1st, 2017 from <https://www.netatmo.com/en-US/product/weather/>
- [3] 2017. Tesla Solar Panel FAQs. (2017). Retrieved November 30th, 2017 from <https://www.tesla.com/support/solar/solar-panels-faqs>
- [4] NEST Official Twitter Account. 2017. NEST on Twitter. (2017). Retrieved December 3rd, 2017 from <https://twitter.com/nest/status/222434981576843266>
- [5] Robert Gasiewicz. 2017. Deer Ridge KCABRENT56. (2017). Retrieved November 21st, 2017 from <https://www.wunderground.com/personal-weather-station/dashboard?ID=KCABRENT56>
- [6] NOAA. 2017. Brentwood, CA Weather Forecast. (2017). Retrieved November 28th, 2017 from <https://weather.com/weather/today/l/USCA0128:1:US>
- [7] Mark Pearson. 2017. How Far Are People on Average from Their Nearest Decent-Sized Airport? (2017). Retrieved December 1st, 2017 from <http://www.mark-pearson.com/airport-distances/>
- [8] Weather Underground. 2017. Personal Weather Station Hardware and Software. (2017). Retrieved November 19th, 2017 from <https://www.wunderground.com/weatherstation/hardwareandsoftware.asp>
- [9] Weather Underground. 2017. Personal Weather Station Network. (2017). Retrieved November 19th, 2017 from <https://www.wunderground.com/weatherstation/overview.asp>
- [10] Anonymous Reddit User. 2017. Weather source change? (2017). Retrieved December 3rd, 2017 from [https://www.reddit.com/r/Nest/comments/4q34l4/weather\\_source\\_change/](https://www.reddit.com/r/Nest/comments/4q34l4/weather_source_change/)

```
bibtext report
```

---

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--no key, author in PiFoundationHack2017
Warning--no author, editor, organization, or key in PiFoundationHack2017
Warning--to sort, need author or key in PiFoundationHack2017
Warning--no key, author in Netatmo2017
Warning--no author, editor, organization, or key in Netatmo2017
Warning--to sort, need author or key in Netatmo2017
Warning--no key, author in Tesla2017
Warning--no author, editor, organization, or key in Tesla2017
Warning--to sort, need author or key in Tesla2017
Warning--no key, author in Netatmo2017
Warning--no key, author in Netatmo2017
Warning--no key, author in PiFoundationHack2017
Warning--no key, author in PiFoundationHack2017
Warning--no key, author in Tesla2017
Warning--no key, author in Tesla2017
Warning--no key, author in PiFoundationHack2017
Warning--no author, editor, organization, or key in PiFoundationHack2017
Warning--empty author in PiFoundationHack2017
Warning--no key, author in Netatmo2017
Warning--no author, editor, organization, or key in Netatmo2017
Warning--empty author in Netatmo2017
Warning--no key, author in Tesla2017
Warning--no author, editor, organization, or key in Tesla2017
Warning--empty author in Tesla2017
(There were 24 warnings)
```

```
bibtext _ label error
```

---

```
bibtext space label error
```

---

```
bibtext comma label error
```

---

```
latex report
```

---

```
[2017-12-12 20.01.06] pdflatex report.tex
```

```
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Typesetting of "report.tex" completed in 1.4s.
```

---

```
Compliance Report
```

---

```
name: Robert Gasiewicz
hid: 316
paper1: 100% Oct 25 17
paper2: 100%
project: 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
9
wc 316 project 9 5906 report.tex
wc 316 project 9 5765 report.pdf
wc 316 project 9 329 report.bib
```

```
find "
```

---

```
125: \item By selecting Preferences -> Raspberry Pi Configuration,
      disk space could then be expanded by clicking the "Expand
      Filesystem" button. This was required because the default setup
      ultimately leaves too little disk space for all the software
      required for the project. SHOW IMAGE
```

```
173: print("Uploading data to Weather Underground")
```

```
175: "action": "updateraw",
```

```
176: "ID": wu_station_id,
```

```
177: "PASSWORD": wu_station_key,
```

```

178: "dateutc": "now",
179: "tempf": str(temp_f),
180: "humidity": str(humidity),
181: "baromin": str(pressure),
184: upload_url = WU_URL + "?" + urlencode(weather_data)
187: print("Server response:", html)
190: print("Exception:", sys.exc_info()[0], SLASH_N)
192: print("Skipping Weather Underground upload")
197: The code also makes use of the Sense Hat's 8X8 full-color LED
matrix to display with a "W" for Warmer if the moving average of
the temperature has increased since the past interval or a "C"
for Cooler if the moving average of the temperature has decreased
since the past interval. If the moving average of the temperature
remains the same since the past interval, it displays a red and
blue equal sign for no change in temperature.
247: Another issue that had to be overcome was the warmth of the
Raspberry Pi 3 and Sense Hat causing the temperature readings to
be about 10-15 degrees warmer in Fahrenheit than the ambient
temperature. Weather Underground will eventually disconnect PWSs
which display erroneous and incorrect data. This was overcome by
employing a "hack" available from the Pi
Foundation\cite{PiFoundationHack2017}:
275: if not hasattr(get_smooth, "t"):
301: STATION_ID = ""
302: STATION_KEY = ""
316: \item A name was also picked for the PWS, and for the purposes of
this project, the name "Deer Ridge" was selected.
passed: False
find footnote
-----
```

```
passed: True

find input{format/i523}
-----
passed: False

find input{format/final}
-----
4: \input{format/final}

passed: True

floats
-----
66: \item Unboxed the Raspberry Pi 3 and Sense Hat (see Figure
   \ref{F:rasp}).
75: \TODO{Figure must use label and ref, see How I did tit for Figure
   \ref{F:rasp}}
77: \begin{figure}[p]
79: \includegraphics[width=0.6\columnwidth]{images/RASP3_1.jpg}
80: \caption{Unboxed Raspberry Pi 3 with heatsink attached prior to
   mounting on case bottom}\label{F:rasp}
85: \%begin{figure}[htb]
87: \includegraphics[width=0.6\columnwidth]{images/SENSE_Case1.jpg}
93: \%begin{figure}[htb]
95: \includegraphics[width=0.6\columnwidth]{images/Bottom_Case.jpg}
101: \%begin{figure}[htb]
103: \includegraphics[width=0.6\columnwidth]{images/ON.jpg}
114: \begin{figure}[htb]
116: \includegraphics[width=0.5\columnwidth]{images/Raspbian_Boot.jpg}
168: \TODO{You need a sentence with the Figure \ref{F:upload}. Long
   code must be in a figure}
170: \begin{figure}[htb]
194: \caption{YOUR CAPTION HERE}\label{F:upload}
354: \begin{figure}[htb]
356: \includegraphics[width=\columnwidth]{images/Location1.jpg}
377: \begin{figure}[htb]
379: \includegraphics[width=\columnwidth]{images/DR_Stockton.PNG}
381: \label{Image 1: Deer Ridge}
384: \begin{figure}[p]
386: \includegraphics[width=.56\columnwidth]{images/DR_DRCC.PNG}
392: \%begin{figure}[htb]
```

```
394: \includegraphics[width=.56\columnwidth]{images/DR_Campinello.PNG}
400: \%begin{figure}[htb]
402: \includegraphics[width=.56\columnwidth]{images/DR_MTP.PNG}
411: \begin{figure}[htb]
443: \includegraphics[width=\columnwidth]{images/WK_REC_TEMP.PNG}
451: \begin{figure}[htb]
453: \includegraphics[width=\columnwidth]{images/WK_REC_HUM.PNG}
```

figures 13

tables 0

includegraphics 12

labels 3

refs 3

floats 13

True : ref check passed: (refs >= figures + tables)

True : label check passed: (refs >= figures + tables)

True : include graphics passed: (figures >= includegraphics)

True : check if all figures are referred to: (refs >= labels)

Label/ref check

passed: True

When using figures use columnwidth

[width=1.0\columnwidth]

do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

WARNING: code and above may be used improperly

288: For this project, the above source code was saved as

WARNING: code and above may be used improperly

325: After plugging in the device and manually launching the main source code script, it was confirmed that the script was working as expected, including the readouts on the LED matrix display.

Data began populating at 5 second intervals in the terminal window and the correct readouts were displaying on the LED matrix. However, according to the Nest in my home the ambient temperature in the house was 70 degrees Fahrenheit. Yet the PWS was registering at 81 degrees Fahrenheit and climbing. Thus, as it was explained in the above section on the project source code, a workaround had to be implemented in the code to compensate for this temperature.

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--no key, author in PiFoundationHack2017
Warning--no author, editor, organization, or key in PiFoundationHack2017
Warning--to sort, need author or key in PiFoundationHack2017
Warning--no key, author in Netatmo2017
Warning--no author, editor, organization, or key in Netatmo2017
Warning--to sort, need author or key in Netatmo2017
Warning--no key, author in Tesla2017
Warning--no author, editor, organization, or key in Tesla2017
Warning--to sort, need author or key in Tesla2017
Warning--no key, author in Netatmo2017
Warning--no key, author in Netatmo2017
Warning--no key, author in PiFoundationHack2017
Warning--no key, author in PiFoundationHack2017
Warning--no key, author in Tesla2017
Warning--no key, author in Tesla2017
Warning--no key, author in PiFoundationHack2017
Warning--no author, editor, organization, or key in PiFoundationHack2017
Warning--empty author in PiFoundationHack2017
Warning--no key, author in Netatmo2017
Warning--no author, editor, organization, or key in Netatmo2017
Warning--empty author in Netatmo2017
Warning--no key, author in Tesla2017
Warning--no author, editor, organization, or key in Tesla2017
Warning--empty author in Tesla2017
```

(There were 24 warnings)

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

5: OPTjournal = "",  
6: OPTarticleno = "",  
8: OPTvolume = "",  
9: OPTnumber = "",  
11: OPTyear = "",  
14: OPTacmid = "",  
15: OPTnote = "",  
23: OPTmonth = "",  
32: OPTmonth = "",  
41: OPTmonth = "",  
46: OPTauthor = "",  
50: OPTmonth = "",  
55: OPTauthor = "",  
59: OPTmonth = "",  
68: OPTmonth = "",  
77: OPTmonth = "",  
82: OPTauthor = "",

```
86: OPTmonth =      "",  
95: OPTmonth =      "",  
104: OPTmonth =      "",  
passed: False
```

ascii

---

---

```
=====  
The following tests are optional  
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

find newline

---

```
passed: True  
cites should have a space before \cite{} but not before the {
```

find cite {

---

```
passed: True
```

# Face Detection and Recognition Using Raspberry Pi Robot Car

Mani Kumar Kagita

Indiana University

107 S. Indiana Avenue

Bloomington, Indiana 43017-6221

mkagita@iu.edu

## ABSTRACT

Face recognition is an exciting and emerging field of computer vision with many applications to hardware and devices. Using embedded platforms like the Raspberry Pi, a camera module and open source computer vision libraries like OpenCV, purpose is to add face recognition to Robot car and also facial recognition using free developer version of Kairos Facial Recognition software. In today's modern world, face recognition playing an important role for the purpose of security and surveillance and hence there is a need for an efficient and cost effective system. So the main goal is to explore the feasibility of implementing Raspberry Pi based facial recognition system using conventional face detection and recognition techniques such as Haarcascade detection and Kairos. An obstacle avoidance Robot car is integrated with Raspberry Pi and a camera module aiming at taking face recognition to a level in which the system can identify the humans who are stuck in buildings during earth quakes. Raspberry Pi kit provides the system cost effective and easy to use, with high performance.

## KEYWORDS

Raspberry Pi, Robot Car, Face Recognition, Face Identification, I523, HID319

## 1 INTRODUCTION

A Computer Vision application which has always encouraged people, concern about the capability and capacity of robots and computers to determine, detect, recognize and interact with human beings [4]. We will prevail the advantage of cheaper tools that are available in market for computing and detecting human face from the image, recognizing the face using hardware like Raspberry Pi and a video camera that is dedicated to Raspberry Pi. Simple and open source software like OpenCV is used to detect human face from the video that is being captured and the image will be sent to Kairos facial recognition software which allows a high level approach to this process.

In this fastest information era, every information is travelled in split of seconds. There is much more need for accurate and fastest methods in identifying, recognizing and authentication of humans. In the present world, Facial recognition had became most important and crucial form of human identification methods. As per Literature survey statistics in face recognition, the two trends to receive significant attention for the past several years are; the first is the law enforcement applications and also wide range of commercial techniques, and the second is exponential booming of applications and feasible technologies after 30 years of research [6].

The aim is achieved by a possibility to locate human beings or their parts like faces from the live video capture and within the

pictures context. Most advanced human detection applications have this functionality already available. When the picture is capture and loaded into the system, it will scan the picture and will look for human faces in it. Current implementation is to detect face and register them with a name. If the face is detected and not recognized, Robot car will ask to register the detected face with a name. If the human is already registered in Kairos, then once the face is detected, Robot car will greet the human with the associated name. This whole process determines the Face detection and Face recognition techniques using Raspberry Pi and Robot car.

Facial biometric data is to be computed first in creating a complete recognition system. This biometric data is then compared with the face database and to associate with the human identity. The difference between a human and machine is, a human can easily and quickly identify characteristics of a human face but then can only save few hundreds of faces. Whereas a machine or computers prevails at storing and mapping human characteristics and meta data. In current generation, facial recognition softwares can identify a human face with in millions of images from the database in seconds. Humans tend to forget human faces as time pass by. Machines stores them forever. Most of the Law firms across the world follow the process and spend huge money with development of these facial recognition systems that can easily identify criminals in real-time. A well-known example is studying human faces in airports and bus stations.

The design of the Robot car integrated with Face recognition system will navigate through dangerous or natural disaster locations where humans unable to enter. Robot car while avoiding obstacles on its way, will continuously monitor for human faces who got stuck or in danger and will recognize the faces based on the user database. Once the human face is recognized, it will intimate to corresponding authorities about the human and will help in guiding assistance.

## 2 FACE DETECTION

Face Detection is a technique referred to computer vision technology which is able to identify human faces within digital images [3]. Face detection applications works using algorithms and machine learning formulas for detecting human faces in the visual images. Identifying only human faces from these images which can contains landscapes, houses, animals is called Face Detection technique.

Face Detection is termed to only identify if there are any humans present in the image or a video. It lacks in ability to recognize which human face is present. Common widely used face detection techniques are in auto-focus of a digital camera. During auto-focus, camera lens will look for human faces in the range and identify them to have focus in that particular area. Face Detection techniques will

be widely used in counting how many number of visitors attending a particular event.

## 2.1 How Face Detection Works

While Face Detection process is somewhat complex, the algorithms will start off by searching for human eyes at first. Eyes usually represents a valley region and its the easiest feature in human face to detect. Once the eyes are detected, then the algorithms will look for rest of the characteristics of a human face such as iris, nose, mouth, eyebrows and nostrils. Face detection algorithm then summarizes the data and shows that it has successfully detected a human face from the facial region. An additional tests can be conducted by the algorithm to make sure and validate if its detected human face or not [8].

## 3 FACE RECOGNITION

Like most of the biometrics solutions, face recognition technology will be used for identification and authentication purposes by measuring and matching the unique facial characteristics of a human face. Using a digital camera connected to raspberry pi, once the face is detected, facial recognition software will quantify the characteristics of face and then will match with the stored images in database. Once the match is positive, then the corresponding name will be displayed as output [2].

Face biometrics can be integrated to any system having a camera. Border control agencies use face recognition to verify identities of the travellers and can separate them from the trespassers. Government Law agencies replace all the security cameras around the world with biometric applications to scan faces in CCTV footage, and to identify persons of interest in the field. Face recognition has become one of the fastest and human unintervention techniques to find out the identity of a particular human [2].

For the past few years, Face recognition has become one of the most commonly used bio-metric authentication techniques. It mainly deals with the Pattern recognition and analyzing the images. Two main tasks of Facial recognition are: Face verification and Face Identification. Face Verification is comparing a human face in an image with a template image and recognizing the correct patterns. Face Identification is comparing human face in an image with multiple images in the database. Face recognition techniques have more advantages than any other biometrics. With well sophisticated algorithms and coding, Face recognition has a high recognition rate or high identification rate of more than 90% [6].

[Figure 1 about here.]

## 4 SOFTWARE AND HARDWARE SPECIFICATIONS

OpenCV is to be installed in Raspberry Pi to detect human faces with in the captured images. Kairos Facial recognition software is used to recognize human face and identify with the corresponding name.

## 4.1 Software Used

**4.1.1 Raspbian OS.** This is the recommended OS for Raspberry Pi 3. Raspbian OS is debian based OS. It can be installed from noobs installer. Raspbian comes with pre-installed softwares such as Python, Sonic Pi, Java, Mathematica for programming and education.

**4.1.2 Putty.** PuTTY is an SSH and telnet client, developed originally by Simon Tatham for the Windows platform. PuTTY is open source software that is available with source code and is developed and supported by a group of volunteers. Here we are using putty for accessing our raspberry pi remotely.

**4.1.3 OpenCV.** OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD-licensed product, OpenCV makes it easy for businesses to utilize and modify the code. The library has more than 2500 optimized algorithms, which includes a comprehensive set of both classic and state-of-the-art computer vision and machine learning algorithms. These algorithms can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera movements, track moving objects and extract 3D models of objects [5].

**4.1.4 Python 2 IDE.** Python 2.7.x version Integrated Development Environment is used to compile python program in Raspberry Pi. IDE is a text editor plus terminal combination which is used to work on large projects with complex code bases.

**4.1.5 Kairos Facial Recognition Software.** Kairos is an artificial intelligence company specializing in face recognition. Through computer vision and machine learning, Kairos can recognize faces in videos, photos, and the real-world. A captured image is sent to Kairos using an API call and then Kairos will search with the face database. If it matches then will reply with the human name.

- Identity
- Emotions
- Demographics

Kairos navigates the complexities of face analysis technology.

## 4.2 Hardware Used

**4.2.1 Raspberry Pi 3.** Raspberry Pi 3 is the latest version of Raspberry Pi. Unless previous versions, this have an unbuilt Bluetooth platform and a wi-fi support module. There are total 40 pins in RPI3. Of the 40 pins, 26 are GPIO pins and the others are power or ground pins (plus two ID EEPROM pins.) There are 4 USB Port and 1 Ethernet slot, one HDMI port, 1 audio output port and 1 micro usb port and also many other things you can see the diagram on right side. And also we have one micro sd card slot wherein we have to install the recommended Operating system on micro sd card. There are two ways to interact with your raspberry pi. Either you can interact directly through HDMI port by connecting HDMI to VGA cable, and keyboard and mouse or else you can interact from any system through SSH(Secure Shell) [7]

**4.2.2 Raspberry Pi Camera.** The Raspberry Pi camera module can be used to take high-definition video, as well as stills photographs. It's easy to use for beginners, but has plenty to offer advanced users if you're looking to expand your knowledge. There are lots of examples online of people using it for time-lapse, slow-motion and other video cleverness. You can also use the libraries we bundle with the camera to create effects.

**4.2.3 Robot Car Chassis Kit.** The Mechanical design of the Robot car includes hardware such as motor and wheel placement and body setup. Robot car uses two gear-motors attached to wheels and one free wheel for forward, backward, left and right movements. Free wheel ball is placed at rear side of the robot which helps for 360 degrees free movement [1]. L298N DC Stepper Motor Drive controller is used to control the speed and direction of the two gear motor wheels. Ultrasonic sensors are placed at front side of the robot which is capable to detect the objects on its path.

## 5 SYSTEM ARCHITECTURE

System Architecture consists of following blocks :

- a) Raspberry Pi
- b) Raspberry Pi Camera Module
- c) L298N Dual H-Bridge Stepper Motor Controller
- d) DC power supply 12v and 5v
- e) Robot Car chassis kit
- f) HC-SR04 Ultrasonic Sensor
- g) SG90 Servo Motor.
- h) Wires, Breadboard, Small PCB.

The Mechanical design of the Robot car includes hardware such as motor and wheel placement and body setup. Robot car uses two gear-motors attached to wheels and one free wheel for forward, backward, left and right movements. Free wheel ball is placed at rear side of the robot which helps for 360 degrees free movement. L298N DC Stepper Motor Drive controller is used to control the speed and direction of the two gear motor wheels. Ultrasonic sensors are placed at front side of the robot which is capable to detect the objects on its path. Raspberry Pi Camera module is used to monitor the live stream and recognize the face if its detected.

## 6 SETUP

### 6.1 Connect Raspberry Pi

This section includes connectivity of Raspberry Pi over Wifi.

- Download Raspbian OS to an SD card with a minimum capacity of 8GB.
- Plug in USB power cable, keyboard, mouse and monitor cables to Raspberry Pi.
- Insert the SD card with Raspbian OS into Pi and boot the system. Once the Pi is booted up, a window will appear with Raspbian operating system. Click on Raspbian and Install.
- When the install process has completed, the Raspberry Pi configuration menu (raspi-config) will load. Here set the time and date for your region.
- Enable wifi on upper right corner and connect to wifi sid.

### 6.2 Connect Raspberry Pi Camera Module

- Install the Raspberry Pi Camera module by inserting the cable into the Raspberry Pi.
- The cable slots into the connector situated between the Ethernet and HDMI ports, with the silver connectors facing the HDMI port.
- Boot up your Raspberry Pi and run below commands in command prompt.
  - sudo apt-get install python-pip
  - sudo apt-get install python-dev
  - sudo pip install picamera
  - sudo pip install rpio
  - From the prompt, run "sudo raspi-config".
  - If the "camera" option is not listed, you will need to run a few commands to update your Raspberry Pi. Run "sudo apt-get update" and "sudo apt-get upgrade"

**6.2.1 Enable Camera.** For Face Detection, PiCamera should be enable from Raspberry Pi. Below list of figures shows the detailed steps on how to enable PiCamera from Raspberry Pi.

- [Figure 2 about here.]
- [Figure 3 about here.]
- [Figure 4 about here.]

### 6.3 Install OpenCV and Required Libraries

OpenCV computer vision library is used to perform face detection and recognition. For this, first need to install OpenCV dependencies on Raspberry Pi. Below commands needs to be executed.

- sudo apt-get update
- sudo apt-get upgrade
- sudo apt-get install build-essential
- cmake pkg-config python-dev libgtk2.0-dev libgtk2.0-zlib1g-dev libpng-dev libjpeg-dev libtiff-dev libjasper-dev libavcodec-dev swig unzip
- Select yes for all options and wait for the libraries and dependencies to be installed

Download opencv-2.4.9 zip file to Raspberry Pi. Change the directory and execute cmake command as below.

- cd opencv-2.4.9
- sudo apt-get install build-essential cmake pkg-config
- sudo apt-get install libjpeg-dev libtiff5-dev libjasper-dev libpng12-dev
- sudo apt-get install python-dev python-numpy libtbb2 libtbb-dev libjpeg-dev libpng-dev libtiff-dev libjasper-dev libdc1394-22-dev
- sudo apt-get install python-opencv
- sudo apt-get install python-matplotlib
- Latest version of OpenCV is now installed in Raspberry Pi

### 6.4 Integration of Raspberry Pi with Robot Car

Raspberry Pi connected with PiCamera is integrated with Robot car to navigate using webserver. During the navigation, robot car will look for human faces using PiCamera and then detects the face. Once the face is detected, python program will call Kairos facial detection software to identify the person and greet with the name.

If the human face is unidentified then robot car will ask human to register their name.

As shown in the figure below, connect a Robot car chassis to raspberry pi and follow the circuit connections.

[Figure 5 about here.]

- Motor1A : 16 (GPIO 23 - Pin 16)
- Motor1B : 18 (GPIO 24 - Pin 18)
- Motor1Enable : 22 (GPIO 25 - Pin 22)
- Motor2A : 21 (GPIO 9 - Pin 21)
- Motor2B : 19 (GPIO 10 - Pin 19)
- Motor2Enable : 23 (GPIO 11 - Pin 23)

## 6.5 Kairos Face Recognition Setup

Kairos Face Recognition system has a free developer account which is used to identify the human name from the images. Once registered a human name with an image, the code will call Kairos API with a newly detected human face and will look for the registered name. Kairos will do a quick lookup in human database from the registered account and if it matches, will send the name of the human back to the code.

Setup as follows:

- Register will https://www.kairos.com as a free developer account
- Login with registered username and password
- Create an Appname
- An App ID and a key are generated. Save this for future use
- Enroll users and a gallery name with the user images

```
POST /enroll HTTP/1.1
Content-Type: application/json
app_id: 4985f625
app_key: aa9e5d2ec3b00306b2d9588c3a25d68e
{
  "image": "http://media.kairos.com/user.jpg",
  "subject_id": "User",
  "gallery_name": "MyGallery"
}
```

## 7 CODE EXPLANATION

### 7.1 Face Detection

Import all the related libraries including PiCamera and PiRGBArray libraries for camera to operate in Raspberry Pi. These libraries will help to capture video and images from the PiCamera.

```
from picamera.array import PiRGBArray
from picamera import PiCamera
import time
import cv2
import sys
import imutils
from fractions import Fraction
import base64
import requests
import json
import random
```

```
import os
```

Haarcascade is a tool to capture the frontal features of face. This tool will help to continuous monitoring for any human face to detect. Once detected a human face, the output values will provide as Human Face Detected from the capturing video.

```
# Get user supplied values
cascPath = './haarcascade_frontalface_default.xml'

# Create the haar cascade
faceCascade = cv2.CascadeClassifier(cascPath)
```

Camera settings needs to be updated in the code as per below suggestions. The capture image is to be sent to Kairos for Facial recognition and so we will set the resolution to a lower level. This will help to send the image faster over the network without any delay.

```
# initialize the camera and grab a reference to the raw
camera capture
camera = PiCamera()
camera.resolution = (160, 120)
camera framerate = 32
rawCapture = PiRGBArray(camera, size=(160, 120))
```

Below code represents PiCamera continuously monitor for human faces detected from the grayscale video capture. Once the human face is detected, espeak function in Raspberry Pi will send the voice to a connected speaker and will output as “Human face detected”. This detected image is then saved as “User-Image.jpg” which is then will be sent to Kairos during Face recognition.

Here are the front, sideviews of the face detected images.

[Figure 6 about here.]

[Figure 7 about here.]

[Figure 8 about here.]

```
# allow the camera to warmup
time.sleep(0.1)
lastTime = time.time()*1000.0
# capture frames from the camera
for frame in camera.capture_continuous(rawCapture,
    format="bgr", use_video_port=True):
    # grab the raw NumPy array representing the image, then
    # initialize the timestamp
    # and occupied/unoccupied text
    image = frame.array
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

    # Detect faces in the image
    faces = faceCascade.detectMultiScale(
        gray,
        scaleFactor=1.1,
        minNeighbors=5,
        minSize=(30, 30),
        flags = cv2.cv.CV_HAAR_SCALE_IMAGE
    )
```

```

print time.time()*1000.0-lastTime," Found {0}
faces!".format(len(faces))
lastTime = time.time()*1000.0

# Draw a circle around the faces
for (x, y, w, h) in faces:
    cv2.circle(image, (x+w/2, y+h/2), int((w+h)/3),
               (255, 255, 255), 1)

# show the frame
cv2.imshow("Frame", image)
key = cv2.waitKey(1) & 0xFF
if len(faces) == 1:
    print("Taking image...")
camera.capture("foo.jpg")
os.system('espeak "Human face detected"')
inputImage= "./foo.jpg"
del camera
break
# clear the stream in preparation for the next frame
rawCapture.truncate(0)

# if the `q` key was pressed, break from the loop
if key == ord("q"):
    del camera
    exit()

```

## 7.2 Face Recognition

For the Face Recognition, we use Kairos to detect the facial characteristics. A json config file is to be placed in the same folder as of the code with Kairos API app id and key value. When the human face is detected, code will generate an API call to Kairos software along with the gallery name, API app id and key values. Image when sending to Kairos, it will be base64 encrypted and will send over the network for security purpose. This encrypted image will then be decrypted at Kairos platform.

```

KAIROS = "api.kairos"
KairosGallery = 'MyFace'
KairosConfig = './kairos_config.json'

def trainKairos(image, name):
    global KairosGallery
    headers = {
        'app_id': 'd39fc1b1',
        'app_key': '468d508d9463c8d24395926adabb1769'
    }
    data = {
        'image': base64.b64encode(image),
        'gallery_name': KairosGallery,
        'subject_id': name
    }
    r = requests.post('http://api.kairos.com/enroll',
                      headers=headers, data=json.dumps(data))
    print(r.text)
    return(None)

```

```

class Recognize():
    def __init__(self, API, config_file):
        self.api = API
        self.config = config_file

    #def recognize(self, image_path):
    #    return self.__recognizeKairos(image_path)

    def recognizeKairos(self, image):
        with open(image, "rb") as image_file:
            encoded_string =
                base64.b64encode(image_file.read())
        with open(self.config, "rb") as config_file:
            config = json.loads(config_file.read())
        data = {
            "image": encoded_string,
            "gallery_name": config["gallery_name"]
        }

        headers = {
            "Content-Type": "application/json",
            "app_id": config["app_id"],
            "app_key": config["app_key"]
        }

```

Output from Kairos software is in json format. The output is then segregated as per the key value pairs and then saved into local variables. When the image is recognized, a success transaction message will be obtained from Kairos along with subject id and face id.

```

try:
    r = requests.post("https://api.kairos.com/recognize",
                      headers=headers, data=json.dumps(data))
    data = r.json()
    print data
    # print json.dumps(data, indent=4)
    faces = []
    if "images" in data:
        for obj in data["images"]:
            if obj["transaction"]["status"] == "success":
                face_obj = {}
                face_obj["person"] =
                    obj["transaction"]["subject_id"]
                    .decode("utf_8")
                #face_obj["faceid"] =
                #    obj["candidates"][0]["face_id"]
                #    .decode("utf_8")
                face_obj["confidence"] =
                    obj["transaction"]["confidence"]
                faces.append(face_obj)
            elif obj["transaction"]["status"] == "failure":
                face_obj = {}
                face_obj["person"] = "unidentified"
                face_obj["confidence"] = 0
                faces.append(face_obj)
            else:

```

```

        print "its in last loop"
        return faces
    except requests.exceptions.RequestException as exception:
        print exception
        return None

Output from Kairos face recogniion software is to be read to understand if the person name is identified or not. If its identified then the person name sill be listed according to the corresponding person in the image. If the human is not identified, then code will suggest if the user wants to registered for face recognition. Once the user key in the name, Kairos API call is generated while sending newly registered name and the gallery name to that corresponding app id. Here the newly recognized user will be registerd with the name and his image. When the user is reconized by camera in next corresponding events, then Robot car will greet the user with his name.

if __name__ == "__main__":
    r = Recognize(KAIROS, "kairos_config.json")
    x = r.recognizeKairos(inputImage)

    #print x
    #print x["person"]
    #print x[0]["person"]
    string1 = x[0]["person"]
    #print string1
    os.system('espeak "Hello...""{}''.format(string1)')
    if x[0]["person"] == "unidentified":
        os.system('espeak "Please enter your name to
                    Register"')
        nameToRegister = raw_input("Please enter your name
                                   to Register :")
        binaryData = open(inputImage, 'rb').read()
        print('Enrolling to Kairos')
        trainKairos(binaryData, nameToRegister)
        print "You are now Registered as :", nameToRegister
        os.system('espeak
                    "Hello...""{}''.format(nameToRegister)')
        exit()

```

### 7.3 Robot Car Navigation

```

import RPi.GPIO as GPIO
from time import sleep

GPIO.setmode(GPIO.BOARD)

#Connecting two wheel motors to Raspberry Pi GPIO
#Left Motor (Motor 1) connections
Motor1A = 16 #(GPIO 23 - Pin 16)
Motor1B = 18 #(GPIO 24 - Pin 18)
Motor1Enable = 22 #(GPIO 25 - Pin 22)

#Right Motor (Motor 2) Connecctions
Motor2A = 21 #(GPIO 9 - Pin 21)

```

```

Motor2B = 19 #(GPIO 10 - Pin 19)
Motor2Enable = 23 #(GPIO 11 - Pin 23)

#Ouptut of Morors to set as OUT
GPIO.setup(Motor1A,GPIO.OUT)
GPIO.setup(Motor1B,GPIO.OUT)
GPIO.setup(Motor1Enable,GPIO.OUT)
GPIO.setup(Motor2A,GPIO.OUT)
GPIO.setup(Motor2B,GPIO.OUT)
GPIO.setup(Motor2Enable,GPIO.OUT)

# Defining function for Robot car to move forward
def forward():
    GPIO.output(Motor1A,GPIO.HIGH)
    GPIO.output(Motor1B,GPIO.LOW)
    GPIO.output(Motor1Enable,GPIO.HIGH)
    GPIO.output(Motor2A,GPIO.HIGH)
    GPIO.output(Motor2B,GPIO.LOW)
    GPIO.output(Motor2Enable,GPIO.HIGH)

    sleep(2)

# Defining function for Robot car to move backward
def backward():
    GPIO.output(Motor1A,GPIO.LOW)
    GPIO.output(Motor1B,GPIO.HIGH)
    GPIO.output(Motor1Enable,GPIO.HIGH)
    GPIO.output(Motor2A,GPIO.LOW)
    GPIO.output(Motor2B,GPIO.HIGH)
    GPIO.output(Motor2Enable,GPIO.HIGH)

    sleep(2)

# Defining function for Robot car to turn right
def turnRight():
    print("Going Right")
    GPIO.output(Motor1A,GPIO.HIGH)
    GPIO.output(Motor1B,GPIO.LOW)
    GPIO.output(Motor1Enable,GPIO.HIGH)
    GPIO.output(Motor2A,GPIO.LOW)
    GPIO.output(Motor2B,GPIO.LOW)
    GPIO.output(Motor2Enable,GPIO.LOW)

    sleep(2)

# Defining function for Robot car to turn left
def turnLeft():
    print("Going Left")
    GPIO.output(Motor1A,GPIO.LOW)
    GPIO.output(Motor1B,GPIO.LOW)
    GPIO.output(Motor1Enable,GPIO.LOW)
    GPIO.output(Motor2A,GPIO.HIGH)
    GPIO.output(Motor2B,GPIO.LOW)
    GPIO.output(Motor2Enable,GPIO.HIGH)

```

```

sleep(2)

# Defining function for Robot car to stop
def stop():
    print("Stopping")
    GPIO.output(Motor1A,GPIO.LOW)
    GPIO.output(Motor1B,GPIO.LOW)
    GPIO.output(Motor1Enable,GPIO.LOW)
    GPIO.output(Motor2A,GPIO.LOW)
    GPIO.output(Motor2B,GPIO.LOW)
    GPIO.output(Motor2Enable,GPIO.LOW)

response = make_response(redirect(url_for('index')))
return(response)

#set up the server in debug mode to the port 8000
app.run(debug=True, host='0.0.0.0', port=8000)

```

## 7.4 Controloing Robot Car using webserver

```

from flask import Flask, render_template, request,
    redirect, url_for, make_response
import RPi.GPIO as GPIO
import motors

#set up GPIO
GPIO.setmode(GPIO.BOARD)

#set up flask server
app = Flask(__name__)

#when the root IP is selected, return index.html page
@app.route('/')
def index():

    return render_template('index.html')

#recieve which pin to change from the button press on
#index.html
#each button returns a number that triggers a command in
#this function
#
#Uses methods from motors.py to send commands to the GPIO
#to operate the motors
@app.route('/<changePin>', methods=['POST'])
def reroute(changePin):

    changePin = int(changePin) #cast changePin to an int

    if changePin == 1:
        motors.turnLeft()
    elif changePin == 2:
        motors.forward()
    elif changePin == 3:
        motors.turnRight()
    elif changePin == 4:
        motors.backward()
    else:
        motors.stop()

```

## 8 APPLICATION

There are lots of applications of face recognition. Face recognition is already being used to unlock phones and specific applications. Face recognition is also used for biometric surveillance. Banks, retail stores, stadiums, airports and other facilities use facial recognition to reduce crime and prevent violence.

## 9 CONCLUSION

### ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski for his support and suggestions in writing this paper.

### REFERENCES

- [1] Arduino. 2015. Arduino Software (IDE). (2015). <https://www.arduino.cc/en/Guide/Environment>
- [2] BIOMETRICS. 2014. Facial Recognition. FINDBIOMETRICS. (Jan. 2014). <https://findbiometrics.com/solutions/facial-recognition/>
- [3] Brijesh B. Mehta Divyarajsinh N. Parmar. 2013. Face Recognition Methods & Applications. *Int.J.Computer Technology & Applications* 4 (2013), 84–86. <https://arxiv.org/ftp/arxiv/papers/1403/1403.0485.pdf>
- [4] Boris Landoni. 2014. Raspberry Pi and the Camera Pi module: face recognition tutorial. OPENELECTRONICS. (Oct. 2014). <https://www.open-electronics.org/raspberry-pi-and-the-camera-pi-module-face-recognition-tutorial/>
- [5] OpenCV. 2017. About OpenCV. OpenCV. (2017). <https://opencv.org/about.html>
- [6] Shruti B. Yagnik Riddhi Patel. 2013. A Literature Survey on Face Recognition Techniques. *International Journal of Computer Trends and Technology* 5 (Nov. 2013), 189.
- [7] Deligence Technologies. 2017. MQTT to Connect Raspberry Pi to Internet of Things. HACKADAY. (Sept. 2017). <https://hackaday.io/project/27344-mqtt-to-connect-raspberry-pi-to-internet-of-things>
- [8] JESSE DAVIS WEST. 2017. FACE DETECTION VS. FACE RECOGNITION. FACEFIRST. (May 2017). <https://www.facefirst.com/blog/face-detection-vs-face-recognition/>

#### LIST OF FIGURES

1	Block Diagram of a Face Recognition System	9
2	Edit raspi-config file from command line	9
3	Select Camera from the options	9
4	Enable Camera	10
5	Raspberry Pi Robot Car Integration	11
6	Front View of Face detection	12
7	Side view 1 of Face detection	13
8	Side view 2 of Face detection	14

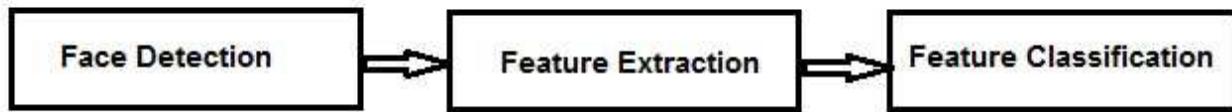


Figure 1: Block Diagram of a Face Recognition System

The programs included with the Debian GNU/Linux system are free software; the exact distribution terms for each program are described in the individual files in /usr/share/doc/\*/\*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent permitted by applicable law.

Last login: Mon May 29 18:17:10 2017  
pi@raspberrypi:~ \$ sudo raspi-config

Figure 2: Edit raspi-config file from command line

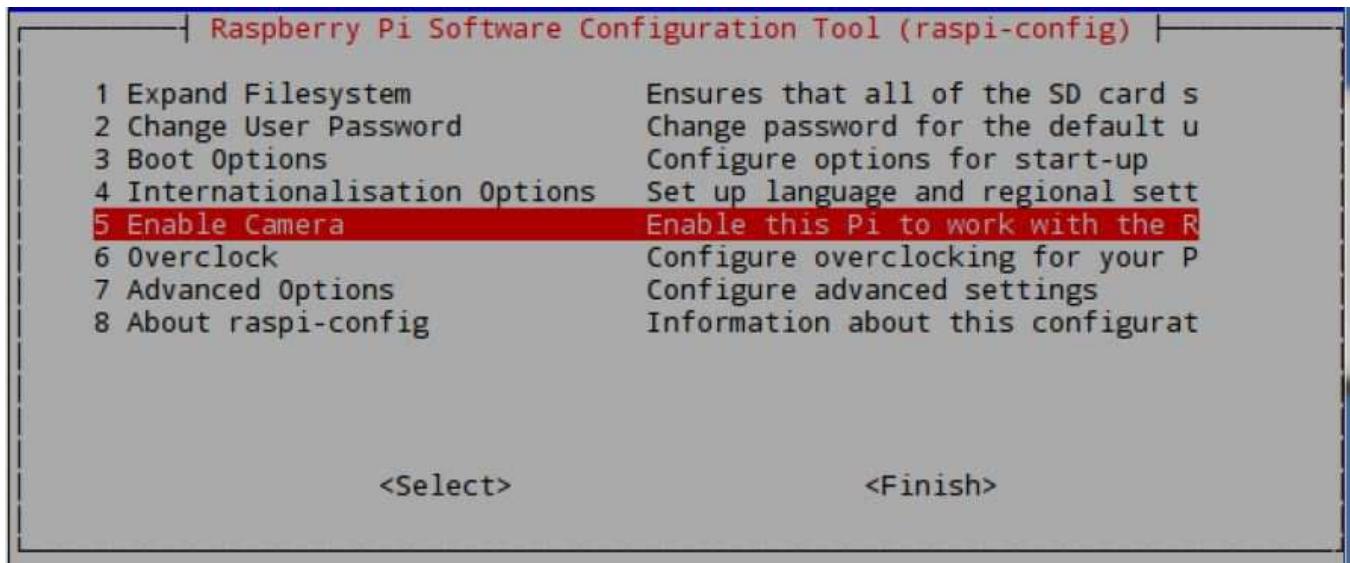


Figure 3: Select Camera from the options

Would you like the camera interface to be enabled?

<Yes>

<No>

Figure 4: Enable Camera

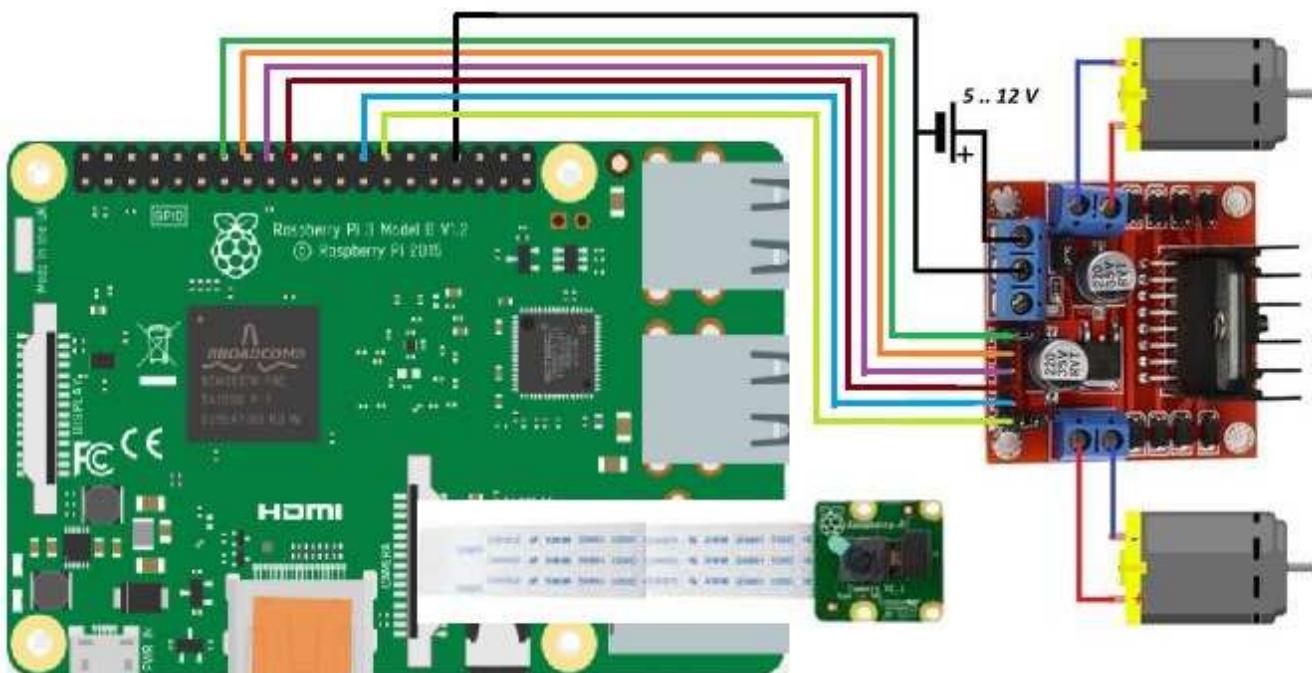


Figure 5: Raspberry Pi Robot Car Integration



**Figure 6: Front View of Face detection**



**Figure 7: Side view 1 of Face detection**



**Figure 8: Side view 2 of Face detection**

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
=====
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
=====
[2017-12-12 20.01.13] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
Missing character: ""
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 1.1s.
./README.yml
54:81     error    line too long (101 > 80 characters)  (line-length)
55:81     error    line too long (96 > 80 characters)  (line-length)
```

```
=====
Compliance Report
```

```
=====
name: Mani Kumar Kagita
hid: 319
paper1: 100%
paper2: 100%
project: 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
14
```

```
wc 319 project 14 4252 report.tex  
wc 319 project 14 4266 report.pdf  
wc 319 project 14 225 report.bib
```

```
find "
```

---

```
233: "image":" http://media.kairos.com/user.jpg ",  
  
234: "subject_id":"User",  
  
235: "gallery_name":"MyGallery"  
  
304: for frame in camera.capture_continuous(rawCapture, format="bgr",  
    use_video_port=True):  
  
318: print time.time()*1000.0-lastTime," Found {0}  
    faces!".format(len(faces))  
  
325: cv2.imshow("Frame", image)  
  
328: print("Taking image...")  
  
329: camera.capture("foo.jpg")  
  
330: os.system('espeak "Human face detected"')  
  
331: inputImage= "./foo.jpg"  
  
338: if key == ord("q"):  
  
349: KAIROS = "api.kairos"  
  
381: with open(image, "rb") as image_file:  
  
383: with open(self.config, "rb") as config_file:
```

```
386: "image": encoded_string,  
387: "gallery_name": config["gallery_name"]  
391: "Content-Type": "application/json",  
392: "app_id": config["app_id"],  
393: "app_key": config["app_key"]  
401: r = requests.post("https://api.kairos.com/recognize",  
                      headers=headers, data=json.dumps(data))  
406: if "images" in data:  
407: for obj in data["images"]:  
408: if obj["transaction"]["status"] == "success":  
410: face_obj["person"] = obj["transaction"]["subject_id"]  
411: .decode("utf_8")  
412: #face_obj["faceid"] = obj["candidates"][0]["face_id"]  
413: .decode("utf_8")  
414: face_obj["confidence"] = obj["transaction"]["confidence"]  
416: elif obj["transaction"]["status"] == "failure":  
418: face_obj["person"] = "unidentified"  
419: face_obj["confidence"] = 0  
422: print "its in last loop"  
432: if __name__ == "__main__":  
433: r = Recognize(KAIROS, "kairos_config.json")  
437: #print x["person"]  
438: #print x[0]["person"]  
439: string1 = x[0]["person"]
```

```
441: os.system('espeak "Hello...""{}"'.format(string1))

442: if x[0] ["person"] == "unidentified":

443: os.system('espeak "Please enter your name to Register"')

444: nameToRegister = raw_input("Please enter your name to Register
   :")

448: print "You are now Registered as :", nameToRegister

449: os.system('espeak "Hello...""{}"'.format(nameToRegister))

514: print("Going Right")

528: print("Going Left")

542: print("Stopping")

passed: False

find footnote
-----
passed: True

find input{format/i523}
-----
4: \input{format/i523}

passed: True

find input{format/final}
-----
passed: False

floats
-----
72: \begin{figure}[ht!]
73: \includegraphics[width=\columnwidth]{images/Face-recognition.jpg}
162: \begin{figure}[ht!]
163: \includegraphics[width=\columnwidth]{images/enablecamera1.jpg}
```

```
167: \begin{figure}[ht!]
168: \includegraphics[width=\columnwidth]{images/enablecamera2.jpg}
172: \begin{figure}[ht!]
173: \includegraphics[width=\columnwidth]{images/enablecamera3.jpg}
202: \begin{figure}[ht!]
203: \includegraphics[width=\columnwidth]{images/RaspPi_Robot.jpg}
283: \begin{figure}[ht!]
284: \includegraphics[width=\columnwidth]{images/Face-detect-
    frontview.png}
288: \begin{figure}[ht!]
289: \includegraphics[width=\columnwidth]{images/Face-detect-
    sideview1.png}
293: \begin{figure}[ht!]
294: \includegraphics[width=\columnwidth]{images/Face-detect-
    sideview2.png}
```

```
figures 8
tables 0
\includegraphics 8
labels 0
refs 0
floats 8
```

```
True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= \includegraphics)
True : check if all figures are referred to: (refs >= labels)
```

```
Label/ref check
passed: True
```

```
When using figures use columnwidth
[width=1.0\columnwidth]
do not change the number to a smaller fraction
```

---

```
find textwidth
```

---

```
passed: True
```

---

```
below_check
```

---

```
WARNING: figure and below may be used improperly
```

160: For Face Detection, PiCamera should be enable from Raspberry Pi.  
Below list of figures shows the detailed steps on how to enable  
PiCamera from Raspberry Pi.

WARNING: figure and below may be used improperly

200: As shown in the figure below, connect a Robot car chassis to  
raspberry pi and follow the circuit connections.

WARNING: code and below may be used improperly

269: Camera settings needs to be updated in the code as per below  
suggestions. The capture image is to be sent to Kairos for Facial  
recognition and so we will set the resolution to a lower level.  
This will help to send the image faster over the network without  
any delay.

WARNING: code and below may be used improperly

279: Below code represents PiCamera continuously monitor for human  
faces detected from the grayscale video capture. Once the human  
face is detected, espeak function in Raspberry Pi will send the  
voice to a connected speaker and will output as “Human face  
detected”. This detected image is then saved as “User-  
Image.jpg” which is then will be sent to Kairos during Face  
recognition.

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

ascii

---

non ascii found 8217

=====

The following tests are optional

=====

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# The Intersection of Big Data and IoT

Peter Russell  
Indiana University  
petrusse@iu.edu

## ABSTRACT

Big Data and IoT share a symbiotic relationship with one another that is leading to incredible innovations that were inconceivable just 18 years ago. As a result of this relationship, it has become easier than ever for individuals to customize and monitor various elements of their life if they choose to do so. A project is undertaken to demonstrate how accessible IoT has become to leverage Big Data analysis, how IoT and Big Data are being utilized together in some of the most interesting current use cases and how the technology will need to adapt in coming years.

## KEYWORDS

i523, HID 334, Edge Computing, Raspberry Pi, IoT

## 1 INTRODUCTION

In 2020, it is estimated that 95 percent of electronics will contain IoT technology [41]. This technology, commonly abbreviated for the “Internet of Things”, is expected to be so pervasive due to how the technology is defined and how impactful it has already become.

At the highest level, IoT is intended to describe devices that collect and relay information via the Internet. This leaves IoT is broadly defined in the type of application, which could come in the form of a phone, vehicle, a home device like a thermostat or television, but the technology is rather specific in its intended application. That is, these devices are generally made to serve a single purpose and they are extremely adept at that function. In its most powerful applications, massive data sets are created from these individual IoT devices as they are synthesized together to meet a larger need, as we will see.

The specific purpose of an IoT device is what differentiates this emerging technology from traditional computers. With the exception of recent developments, which will be explored in depth, early IoT devices were not intended to do the heavy computing like a computer would do. However, with rapid advancements in computing power and speed, the line differentiating the two has begun to blur. It is this increase in computing power that has lead IoT and Big Data to have a cooperative relationship to create some of the most exciting technology that's available today.

The ability to collect and process more data has increased the utility of these devices as they're able to become more personalized, spurring tremendous growth recently, on the order of 30% annually. In 2017, it is expected to be the year that the number of IoT devices exceeds the number of people on Earth [18]. This personalization is not without consequence though, which will be discussed later, so the relationship between IoT and Big Data is still evolving.

To begin, we examine how the IoT came to be and continuously evaluate how it is integrated with Big Data. Then, a demonstrative project will be outlined to show the Big Data can be used in an IoT

device. Next, we discuss high level implementations of these technologies in modern use before discussing some of the challenges the industry is facing.

## 2 EMERGENCE OF IOT

Given the massive and recent popularity of IoT, it might be a surprise to some to learn that this concept has been around since 1999. The idea to have multiple, remote devices communicating with one another to gain insights to a single problems was originally conceived by Kevin Ashton as a solution to supply chain management [16]. At that point, the idea was ahead of its time as the internet was still gaining widespread adoption. However, as computing power and sensor costs have declined, IoT has become a main an indispensable aspect of most people's lives. One such example could be the integration of global positioning systems (GPS) into cellphones, which was introduced in just 2004, but has become a staple for nearly every phone released [50].

### 2.1 What Defines IoT?

Given the ascension of so many new technologies, it could be helpful to understand what technically constitutes an IoT device. This will be useful later when discussing the sample project undertaken and how these both relate to Big Data analysis.

As stated earlier, at a high level, IoT is meant to describe devices that use internal or external sensors to connect to the Internet. These sensors could come in the form of the well known types, such as Wi-Fi, Bluetooth or RFID, to the perhaps less widely known, such as NFC (Near Field Communication) or Zigbee [43].

For these IoT devices, the Internet allows them to be tremendously influential in the advancement of Big Data by virtue of the amount of data the devices are able to collect. Specifically, IoT allows its users to quantify the world around them in ways that were previously not possible. For corporations, this yields tremendous advantages when it comes to business planning or equipment monitoring. For example, the average wind farm can generate 150,000 data points *per second* and an engine turbine could give 500 gigabytes of data [28]. Additionally, for individuals, IoT enables people to monitor their activity on a daily basis through wearable fitness devices and customize their homes to save on energy consumption. It has been estimated the average household generates approximately 2,000 gigabytes of data a year and this is expected to increase five fold by 2020 [52]. As we will explore, this rapid increase is due in large part to the computing power of the individual devices, which allow for a greater volume of data to be collected. For example, if a person enjoys a simple bike ride and purchases the Garmin Edge 500 watch, on a single ride they are producing data across 61 different variables for statistics such as heart rate, elevation gained, cadence and output produced continuously for the duration of their ride [17].

## 3 IOT PROJECT

### 3.1 IoT Device

The Raspberry Pi 3 (Model B) was chosen as an example IoT device to demonstrate how these devices can be used to from Big Data analytics. The Raspberry Pi has drawn tremendous accolades for its initiative to get inexpensive, but powerful computing power into the hands of aspiring programmers and hobbyists. Equipped with 1GB of RAM, a 1.2GHz quad-core processor and Bluetooth/Wi-Fi capability, one can purchase the device for just \$35.

### 3.2 Description

The goal of this device is to create a personalized interface that gives the user a morning snapshot for relevant, important information to begin their day. As it relates to IoT, this project uses IoT technology through Wi-Fi to source the output of Big Data projects undertaken by others (ie. Google and Weather Underground as will be shown).

### 3.3 Implementation

For those unfamiliar with the Raspberry Pi, the initial setup could be somewhat intimidating the first time around. Specifically, the Raspberry Pi comes as a truly blank slate and to begin using it, one will need to write the OS, Raspbian, onto the Pi. Several tutorials are available online to get to the desktop, so in the interest of brevity, the discussion below will assume that the user has been able to successfully get the Pi operational and to the Linux prompt with Python installed to run the script.

The application was developed using Python, utilizing the Kivy package for GUI development, the requests and Beautiful Soup packages for the user location, news stories and sports scores along with Yahoo Weather/Weather Underground via the Weather package. Outside of these, standard Python library packages were used.

### 3.4 Results

As part of the display, a continuous running clock was added, which necessitated the application to be on a constant refresh. This was implemented successfully and at a relatively low cost with no significant delays. The total build of the application consumed 966,565 bytes with each refresh using just 1032 bytes. At the initialization of the program, the application uses the user's IP address to find their zip code to populate the local weather forecast and local news. For the weather, the user will get the current temperature with a high/low for the current day and each day in the five day forecast.

Additionally, as news stories are published to the WSJ news feed, they will be read into the application and refreshed. Stories are shown in chronological order along with their time stamp of publication and each is hyperlinked directly to the full story if the user wants more information.

### 3.5 Application to Big Data

One of the main benefits of IoT is synthesizing data across numerous platforms and data sources into a desired output. Our desired output is a one-stop interface with interesting information that can be displayed anywhere with an outlet, internet connection and monitor.

The various components of the monitor are only made possible by the creativity by the providers in solving difficult Big Data issues, such as the clustering of news (Google) and weather forecasting (Yahoo/Weather Underground). Each provider's relationship to Big Data is worth examination and will be the topic of the following sections.

### 3.6 Google News

*3.6.1 Big Data Description.* Google News has evolved into a central source of information for how a large share of the population receives its news. In fact, as a display of the trust that users place in Google to deliver the most information in the most efficient manner, it was found that users are more likely to trust a Google news headline than that same headline from the original source [26]. Additionally, 44% of users were found to read nothing more than the headlines [22]. This is a testament to their ability to simplify the universe of world news into succinct rankings.

Entering into its fifteenth year, Google News aggregates from 50,000 news sources worldwide across 30 different languages. In 2012, they reported the division was receiving 1 billion unique visits a week[4]. For reference, major individual news providers, such as CNN and the New York Times receive 125 million and 99 million unique visitors per month [3]. These statistics further demonstrate Google's successful navigation of the Big Data problem for news stories in the eyes of its users. It's relatively clear why this is an important Big Data problem, but one might be curious how they're able to effectively navigate the problem. Unfortunately, the full design from start to finish is a well kept secret, but pieces have been released and one can piece together a mosaic view of what might be going on under the hood. The decision to not disclose the techniques for ranking news stories is understandable, but it has been a lightening rod of controversy nonetheless. Some view the decision of Google's scoring as effectively acting as a censor for the internet while they maintain it is to keep the integrity of the algorithm so that news stories cannot be written purely for traffic, known as search engine optimization [12].

On the surface, one might question the economic value of Google News to the larger company since it is a free service for both users and providers. However, there is a tremendous amount to be gained in solving this Big Data problem. Even though Google does not show ads on its news site, it was estimated to generate spillover traffic into its search engine that leaves the News entity worth \$100 million in 2008 [60]. The current valuation is undoubtedly higher, but it remains undisclosed. So while there are profits to be made for Google in this quest, publishers of these stories have a tremendous amount of interest in this problem as well. Some providers don't believe content should be indexed to Google's search algorithm for free and Google should pay them for their investigative research. One such provider, who happened to be Germany's largest news source, decided to remove themselves from the index for two weeks. The results were devastating for the site as traffic through the site dropped by 40% [59]. It was a quick lesson in how critical positioning can be in the Big Data world of news aggregation.

*3.6.2 Big Data Solution.* Just as news is constantly evolving, so are Google's solutions to this Big Data problem. As we've seen recently, news aggregation services are under pressure to become

more intelligent on what news is shown in the hopes of preventing fake news from making it into the top results.

The technical specifics of what Google is implemented has largely been kept under wraps, but we did learn a few of the techniques and platforms in 2007. In at least the early versions, Google used MinHash, Probabilistic Latent Semantic Indexing and Covisitation to solve this Big Data. Specifically, these methods will compare historical clicks with other similar users for recommendations, decipher key words and phrases from an article for grouping and track how news stories are clicked within a certain time frame to find stories that were read successively. For processing these queries, Google uses MapReduce and Hadoop architecture [55].

For the inputs into these algorithms, Google will analyze several metrics of a provider to see how they should be ranked along with the user preferences. These metrics include things like how large the staff is, how many articles they put out, how many websites reference that news source (PageRank) and the breadth of news topics covered [15].

### 3.7 Weather Underground via Yahoo API

**3.7.1 Big Data Description.** Weather is a primary concern in business planning for many industries, such as airlines or agriculture. As a result, companies are willing to dedicate a tremendous amount of resources towards accurate forecasts. One of the most innovative companies and a great example of the intersection of IoT and Big Data is Weather Underground.

Weather Underground is a weather forecasting service that was once owned by the Weather Channel and recently, partially by IBM to integrate with its growing IoT ecosystem. What makes the company unique is how their forecasts are formulated. In their model, they couple traditional forecasting tools with IoT. The traditional readings come from the National Weather Service (NWS), which aggregates data from airports and weather balloons. IoT has lead to a new dimension of forecasting as personalized weather stations are distributed to its users for live forecasts in places that traditional instruments might not be available. As of now, they have 250,000 users set up on the platform. This setup provides an additional layer of information, yielding more frequent data, longer forecast windows and greater certainty for a given area. Namely, users can get new forecasts every 15 minutes (versus every 4 hours on the NWS) and forecasts up to two weeks in advance (compared to one week for NWS) [54]. This use of the IoT, specifically edge computing, which will be expanded on later, provides a tremendous example of how IoT can be used to enhance Big Data analysis.

For those that choose to participate in the service, they will purchase a Personal Weather Station (PWS) that allows them to measure temperature, humidity, pressure, rainfall, wind speed and direction via sensors. The major advantage of the PWS comes from its pressure and wind metrics as users can get a better idea of humidity and wind chill, giving a more accurate representation of current conditions. Neither of these are available through the NWS. In the end, this amounts to around 3 billion data points for the Weather Underground model, servicing around 26 billion inquiries a day [24].

**3.7.2 Big Data Solution.** To process its data in the past, which amounts to multiple terabytes daily, Weather Underground has

stored its forecasts, radar data and satellite data using Apache Hadoop and Amazon Web Services [47]. In fact, IBM has stated a large reason for their motivation to have an ownership stake in the company was due to the cloud infrastructure that Weather Underground had built for fielding the massive volume of requests and forecasts it processes daily.

### 3.8 Limitations

While this demonstrative program shows what an IoT device can achieve with Big Data, the most influential uses of IoT come when devices are able to communicate with one another and create more data that can be implemented back into future improvements in the device, as we have seen. The limitation of this current program is that it is a singular instance of the application. Allowing multiple applications to be deployed where information can be collected on *volunteered* information would be orders of magnitude more difficult to implement, but could be an interesting addition to gain better insight on the user base. Then, this data can be pooled together for how the application could be tailored to meet geographic or demographic preferences.

Additionally, with a large enough user base, we would be interested in tracking the number of downloads, active users and which panels of the display are clicked most often. All of these metrics can be readily accessed through integration with Google Analytics, which allows one to analyze different events within the application [20].

## 4 EDGE COMPUTING

With the Personal Weather Systems, we were able to see how IoT can complement Big Data analysis. This is an example of an emerging technology known as “edge computing” that is transforming how the cloud is utilized.

Edge computing gains its name from how the information being processed by the device. Prior to this recent innovation, information was gathered, sent to the cloud, processed there, and then the output is pushed back to the device. Namely, it was a centralized process. However, with edge computing, devices are more intelligent in what information they choose to send, providing a much more efficient process. For example, rather than having a camera monitor an area constantly, even when there is no motion, modern IoT cameras have been equipped with motion detection so information is only sent when there is something to actually record. Since this decision and processing is made on the actual device, it is considered to be at the *edge* of the network.

Traditionally, IoT devices that were intended to work in conjunction, such as surveillance cameras, were simple in their functionality and storage. Namely, a group of cameras would record individually and send their results back to a central server. However, with improvements in image quality, this becomes a Big Data problem very quickly as these cameras are running around the clock collecting footage. In the historical model of a centralized server, this setup eventually creates problems as bandwidth and storage issues emerge. These limitations are the problems that edge computing seeks to circumvent and has become a major catalyst in the growth of IoT devices [51].

Circling back to the original project that was undertaken, the application benefited from edge computing through the weather data, but the device itself serves as a great example of why edge computing is even possible in the first place. Specifically, it is possible due to the dramatic decrease in computing costs. For the cost of \$10 one can get a single-board computer with 1 GHz and 512 MB RAM through the Raspberry Pi. This type of processing is close to becoming the majority as it is expected that by 2019, 45% of all data collected by IoT devices will be processed at the edge of the network [37]. As we will see, this technology is allowing early adopters to gain unique, real-time insights through Big Data analytics into the health and composition of their businesses.

## 4.1 Use Case: Fraud Detection

Fraudulent transactions represent just 1% of all transactions. However, while the relative size of these transactions to the overall market are small, their absolute impact is enormously detrimental to merchants and financial services companies. In 2015, total fraudulent transactions created damages of \$22 billion [29].

The economic impact of these transactions has given these companies a tremendous incentive to innovate their way out of this problem. The marriage of IoT and Big Data has now provided them the opportunity to have near real-time analytics, which is necessary to effectively manage the problem. This is because the approval process for a transaction needs to be as close to instantaneous as possible. If shortcuts are taken in the analysis to increase speed, fraudulent transactions could slip through and not get flagged. IoT has helped make this trade-off between accuracy and speed less of an issue with new innovations, such as Visa's Ready program.

Visa Ready is an innovative program enables payments through IoT for both security and convenience. Instead of traditional means of payment authorization, such as simply swiping your credit card at a vendor, IoT enables Visa to take advantage of improvements in biometric technology [57]. Visa has introduced multi-dimension verification through biometrics by letting users endorse a payment through their fingerprint, iris scan, face scan and even their voice [58]. This type of technology is gaining adoption and there are expected for be 500 million devices with biometric sensors by 2018 and 26 billion by 2020 [48].

Complementing biometric data, as IoT devices become more mainstream, companies such as FICO are using behavioral data in fortifying their analysis of whether a transaction is fraudulent or not. This type of analysis is not new in and of itself as it has been established as a way to identify e-commerce fraud, but the application through IoT is providing a new dimension of analysis. Traditionally, behavior data was tracked to see how a user interacts with a website to reduce the number of false positives that get flagged, which could occur if a user was on a business trip and abruptly logged into their account to buy something from an IP in another country [14]. With IoT, this adds a tremendous amount of data to an already Big Data problem. Now these companies will have data on how users interact with an IoT device, such as how they hold their device in the case of a phone or their tendencies when using the keyboard [25]. From a business perspective, this all occurs in the background without the user's experience without the product being interrupted.

As a testament to the future of this relationship between IoT and Big Data, Visa has partnered with IBM. This was done in an effort to gain maximum benefit from this new biometric technology by leveraging Visa's payment infrastructure with IBM's efforts in artificial intelligence and Big Data analysis with IBM Watson [31].

## 4.2 Use Case: Autonomous Vehicles

In many ways, autonomous vehicles represent the pinnacle of edge computing to date in unifying IoT and Big Data. Among its many goals, this technology is trying to use Big Data to resolve one of the modern tragic realities of our modern world - automobile fatalities. Automobile accidents cause 1.2 million deaths a year, 94% of which are attributable to human error [30]. For this reason, in conjunction with expected energy savings from car designs with this technology, the technology is expected to experience adoption rates that rivals mobile phones with significantly more impact [23]. Traditional car makers have taken notice of the potential future and as an example of this, General Motors recently hired an Uber engineer to lead its self-driving initiative as the company's first ever Chief Technology Officer [5].

The relation of autonomous cars to IoT via edge computing is once again out of necessity for real-time functionality. A car that processes it should stop two seconds too late is as potentially useful as never making the calculation in the first place, so timing is of the utmost importance. Amazing progress has already been made in the speed and complexity of calculations these autonomous vehicles can handle. One of the highest profile graphic card manufacturers, Nvidia, recently announced their system for autonomous vehicles at the rate of 320 *trillion* operations a second [21]. Since these vehicles are equipped with various types of sensors to process its environment, this type of computing power is a near necessity to tackle this Big Data problem in real-time.

Kevin Ashton's original vision for the IoT was to have an accurate view of inventory as RFID scanners synced over the Internet. In just 18 short years, these autonomous vehicles are achieving the same end of communication with one another on an incredible scale. In what's known as "vehicle to vehicle communication" autonomous cars will be able to send one another information on important considerations, such as road hazards or conditions, allowing GPS to take the most optimal route to its destination. Similarly, speed limit signs can take weather conditions into account, dynamically adjust the speed limit of the road and relay this to the car's navigation system [1].

The companies that are pursuing autonomous driving are largely having the cars learn through the experiences of its sensors. It would be impossible to code every possible scenario a car could face, so instead, data is collected from the various sensors and loaded to the cloud for later analysis. For example, Tesla is accumulating a million miles worth of data across its sensors every 10 hours, leaving it with 780 million through mid-2016 [7]. These sensors on board, which will be briefly described to show their application, are expected to generate 4,000 gigabytes of data *daily* [38] [19]. This is another instance of the familiar union between IoT and Big Data.

### 4.3 Use Case: Health Care

The United States, like the world as a whole, is experiencing an aging crisis in its population. In both the world and the United States, the number of adults aged 65 and over is expected to double by 2025. In the United States, this demographic of the population will move from 15% to 25%. While this jump is not negligible, the most alarming aspect of this statistic is that in 2010, the elderly portion of the population was just 10%, but accounted for 34% of medical expenditures [34].

For this reason of high future expenditures, much of today's public policy debates center around how resources will be pooled to meet this not so distant future need. Currently, one of the most promising use cases for edge computing is coming from health care and how the technology can be used to provide better care to a wider range of people.

Through edge computing, doctors have the ability to gain insights into their patients through sensors that can be worn by their patients, such as a heart monitor. This allows for early identification of irregular patterns and allows for an earlier diagnosis, potentially saving the patient's life compared to earlier times when a heart attack could strike abruptly without warning. This usage is directly related to Big Data as doctors now can get continuous, real-time assessments of their patients. This makes way to more accurate future diagnoses as more insights can be gleaned between the true cause and effect of a particular ailment [42].

Outside of data analysis by doctors, the patients themselves are expected to receive numerous benefits from this type of monitoring. Namely, those who are less mobile no longer need to make a physical trip to see the doctor as the doctor has the diagnostics they typically need and at a much more granular level [6].

In addition to the elderly, this type of real-time feedback system through edge computing can be incredibly transformative for those with health conditions that require nearly continuous monitoring. One such example has been demonstrated with epileptic patients. An edge computing solution has been introduced that epileptic patients can use and if a patient experiences an epileptic episode, an immediate alert is sent to family members and doctors [53]. This type of technology is only possible through edge computing because the alerts are triggered by monitoring historical metrics versus live readings in areas like heart rate and sudden movements. The delay that would be incurred by sending this data to the cloud and waiting for a response would have too much latency to be an effective solution to this problem.

Another promising area for edge computing within health care is for those suffering from mental diseases, such as dementia or Alzheimer's. With this technology, family members can monitor and set alerts if a particular perimeter is breached from where their loved one is supposed to be staying [8].

### 4.4 Use Case: Retail Shopping

Worth \$2.6 trillion, the United States retail industry comprises 15% of national gross domestic product [13]. The ground is shifting underneath this industry though as brick and mortar stores are under siege from a surging market share by Amazon, which is up 150% since 2013.

These traditional stores still hold the top rankings in the retail sales by size, but the ability of Amazon to utilize Big Data for a personalized shopping experience online is forcing these top retailers to adapt with a competing level of customization. Amazon's recommendation engine allows them to see into a user's purchase history, viewing history, rating history and search history, which are all used to point the customer to the most likely product they're looking for. In fact, Amazon is even working on an IoT sensor that they intend will act as a personalized stylist. The device will take a picture of your outfit and make recommendations of what would look best, based on the recommendations of its algorithms that are supplemented by fashion stylists to reflect current trends [33]. As a result, IoT gives Amazon a level of scalability to its entire customer base to create more information and data about the customer that is simply not available to the brick and mortar stores.

To try and compete with this personalization though, brick and mortar retailers are using edge computing to introduce technology that was science fiction 15 years ago in the movie Minority Report. In the movie, which takes place in 2054, the main character is rushing through a busy shopping center when he passes various kiosks that address him by name and ask about his recent purchases in the store. This is the reality that retailers are now using through real-time facial recognition, enabled by edge computing to integrate IoT and Big Data. With this, they are also collecting broader demographic statistics by tracking customers' ages, ethnicity and gender [32]. In fact, America's largest retailer, Wal-Mart, is currently using facial technology to sense customer's moods and find those who are dissatisfied [40].

While we haven't quite hit the personalization depicted in Minority Report for the general public, those with celebrity can expect that high-end stores they visit will recognize them upon entry. For example, one such jewelry store in Los Angeles is equipped with facial recognition technology, stocked with a database of celebrity pictures from Google Images and when someone is recognized, an alert is sent to the manager with purchase history and sizes [46].

Outside of custom shopping, facial recognition is also being used by traditional stores to deal with a risk that e-commerce is not exposed to - shoplifting. With this technology, a retail store can identify when a known shoplifter is most likely to re-visit the store and when, which were previously unquantifiable. Once they are identified on site, management is sent an instant alert and the customer is escorted from the store to prevent further loss in the future [11]. Additionally, RFID sensors are being used on items individually to better track items outside of the store for loss prevention like this and better supply chain management [10].

## 5 CONCERN WITH IOT

As exciting as these use cases are about what the future might hold, innovation is outpacing legislation for IoT. As we will expand upon below, a race to release products has left consumers susceptible to hacking in some cases as security measures have not been fully developed yet for these devices. Additionally, with the customization that comes with IoT, consumer information is being sold to advertising agencies in many cases without the consumer's knowledge.

## 5.1 Security

While we have discussed some of the most exciting and interesting developments in IoT, this blistering pace of innovation has come at a price. There are experts in this field that believe the connectivity of these devices are a gateway of vulnerability as many IoT devices do not have sufficient security measures, allowing malicious actors direct access into some of people's most private details.

For most utilizing IoT, the technology is used to make their lives easier in some respect. However, when it comes to security, it is believed this approach of a "hands off" relationship with IoT leaves users susceptible to security breaches. Specifically, users need to be diligent in making sure their software is up to date across *all* devices. The reason for this is that with a large network of IoT devices, hackers now have multiple fronts on which they get behind the firewall whereas their only avenues traditionally were the computer and more recently, smart phones. As a result, negligence in one area could be enough of an opening for a comprised network where hackers could take control of a device, which is particularly worrisome in the case of an autonomous car.

Another dimension of risk for IoT security sits with the creators of this technology. Underlying in the assumption about users being diligent in updating their software to prevent breaches is that the developers of the software are actually making continuous updates to adapt along with hackers. However, as time goes on, new products are likely to draw a company's limited resources away from maintaining older products.

In response to these risks, two significant changes have been undertaken to mitigate some of the risks. Namely, companies have introduced automatic updates and used the same operating system across later models of a particular product. These automatic updates then take the burden off of the user of IoT technology, which is an attractive feature as many adopt the technology to simplify their daily life. Additionally, when companies are able to use the same underlying operating system across later products, they're able to update all products in lockstep with the developing security community, ensuring no older products are left behind as an opening behind the firewall [39].

Fortunately, these security concerns with IoT have largely played out in the hypothetical. In fact, surveys have found that the majority of consumers are unaware of IoT security risks and once made aware, do not consider the risks serious. In fact, surveyors even found that if a device had a known security flaw, 20% of consumers are still willing to buy the product [9].

For this reason, with no major attacks to date, adopters of IoT have possibly felt insulated as an overwhelming majority are not threatened by the security risks IoT could pose. This is not to insinuate that IoT attacks do not regularly happen, but instead that they have not occurred on the scale that some of the largest security breaches in recent years have occurred, such as the Target Corporation's incident in 2013. In that breach, 110 million consumer credit card numbers were stolen, along with personally identifying information like their address, e-mail and phone number. The entire episode was estimated to have cost Target \$162 million [2].

While an IoT originated attack like this has not happened yet on this scale, these attacks do occur with frequency. One such statistic demonstrating this unsettling fact is that half of all companies that

have adopted some element of IoT technology have experienced a security breach. In the end, these breaches have cost an average of 13% of annual revenue [45].

The closest demonstration of IoT risks came in October 2016 through the "Mirai" malware, which was used to attack DNS servers and bring down high traffic websites, such as Netflix and Amazon. Disturbingly, "Mirai" translates to "future" in Japanese. With Mirai, the program is continuously scanning the internet for IoT connected devices that have left the default user name and password. Then, once a device is found, it is turned into a bot that is used to amplify a DDoS attack. Incredibly, the average IoT device is scanned every two minutes with this bot, leaving an extremely small margin for error in being compromised [44].

This breach demonstrated the downside of the highly connected nature of IoT. Against the benefit of having devices that can communicate with one another, in the event of an attack, these devices are intertwined and will be equally compromised. The network of IoT devices has gotten so complicated for some companies that one survey found 66% of IT professionals aren't sure how many devices are in their environment [35].

## 5.2 Privacy

It is rather commonplace knowledge, for better or worse, that the apps we use daily are collecting data on us. We're aware that it is on going, but in many cases it's unclear what data is actually being collected. This data aggregation is one of the main debates around IoT. Ironically, one of IoT's primary benefits makes it also one of the most unsettling for others, fearing how the data could be used in the wrong hands. In fact, in 2014, it was found that of the top 200 free apps in the Apple store, 95% were engaging in "risky behavior" [36]. These risky behaviors, are defined as activities such as tracking locations, accessing users' contact lists or selling registration data to ad agencies.

Due to this pervasive data collection, one of the consequences of a security breach via an IoT device would be having personal information compromised. However, outside of this direct relationship, there are concerns on privacy as it relates to usage as laws are behind technology in how this data can be used. The only major pieces of legislation that concern privacy at the federal level are through HIPAA for medical records and the Fair Credit and Reporting Act. Outside of these, the task of regulating privacy is left to states, which are behind the curve in today's fast paced, data driven world.

In a similar conundrum as the security concerns with IoT, one of its greatest features in its ability to continuously monitor and collect this data into Big Data sets is also the reason some hold reservations on the technology. This is mainly due to the fact that this data is not collected into a central repository, like your credit, to see what information is being associated with you. To take it a step further, it is not even clear who has what data on a particular user.

In a shock to most on how little personal privacy may exist in our technology saturated world, it was discovered that the CIA and MI-5 intelligence agencies were using "smart" TVs to eavesdrop on conversations in people's homes. For security experts, this was no surprise and known to be an easily accessible device, but

those outside of that community felt an invasion of privacy [49]. Discovered in 2016, the program was used in 2014 by exploiting the voice enabled features that Samsung included in its TVs to listen to conversations. The power button was even programmed to look as if the TV was off while this recording was happening [56].

While this spying was alleged to have just been on “people of interest”, the average consumer with a smart TV has likely experienced spying they were unaware of through their viewing habits. By default, Vizio TVs were found to be recording their customers activities by logging metrics such as date, time, show, whether it was live or recorded and how long it was watched. This is estimated to have affected 11 million TVs in the end before the FTC outlawed the practice of having these settings turned on by default [27]. This would be a utilization of IoT and Big Data that few would be comfortable forfeiting without their consent.

## 6 CONCLUSION

As we’ve seen, IoT cannot realize its full potential without Big Data. The IoT universe represents the senses by which Big Data is collected for later insights and innovations. For this reason, the IoT revolution has the potential to completely change the world as we currently know. It could be a world in which automobile accidents are no longer a tragic reality or a world where health care delivers the most personalized plan with attention on every minute detail. Additionally, users are able to benefit from the increase in computing power per dollar spent, allowing them more flexibility than ever to design their own IoT device, as was demonstrated in the application made for this paper. However, against this rapid pace of innovation in IoT, some of its most attractive features of interdependency among devices expose the technology to some of its greatest vulnerabilities. Keeping this growth rate in the products in step with security will prove to be one of the biggest challenges in coming years.

## A CODE COMPILATION AND SAMPLE OUTPUT

The following urls are intended to direct to various parts of the project.

- Packages required to compile the project along with sample input
  - <https://github.com/bigdata-i523/hid334/tree/master/project>
- Python code to create the monitor:
  - <https://github.com/bigdata-i523/blob/master/project/code/project.py>
- Weather codes:
  - <https://github.com/bigdata-i523/blob/master/project/weathercodes.py>
- Kivy file:
  - <https://github.com/bigdata-i523/blob/master/project/DailyView.kv>

## ACKNOWLEDGMENTS

The author would like to thank Professor Dr. Gregor von Laszewski, Juliette Zerick and the other Associate Instructors for their support and suggestions in exploring this topic.

## REFERENCES

- [1] Philip Adams. 2017. Why self-driving cars can't start without edge computing. Website. (07 2017). <https://knect365.com/cloud-enterprise-tech/article/b4751c4b-7b5d-4407-8789-420289799988/autonomous-cars-cant-start-without-edge-computing>
- [2] Taylor Armerding. 2017. The 16 biggest data breaches of the 21st century. (10 2017). <https://www.cscoonline.com/article/2130877/data-breach/the-16-biggest-data-breaches-of-the-21st-century.html>
- [3] Jeremy Barr. 2016. The New York Times Pulls Back Ahead of the Washington Post for Unique Visitors. Website. (02 2016). <http://adage.com/article/media/york-times-pulls-back-ahead-washington-post/302720/>
- [4] Krishna Bharat. 2012. Google News turns 10. Website. (09 2012). <https://blog.google/topics/journalism-news/google-news-turns-10/>
- [5] Johana Bhuiyan. 2017. GMfis self-driving division has hired a former top Uber engineer as its first CTO. Website. (11 2017). <https://www.recode.net/2017/11/30/16720994/gm-cruise-cto-susan-fowler>
- [6] Isaac Christiansen. 2017. The Internet of Things and the Evolution of Elderly Care. Website. (06 2017). <http://www.iotevolutionworld.com/smart-home/articles/432936-internet-things-the-evolution-elderly-care.htm>
- [7] Michael Coren. 2016. Tesla has 780 million miles of driving data, and adds another million every 10 hours. Website. (05 2016). <https://qz.com/694520/tesla-has-780-million-miles-of-driving-data-and-adds-another-million-every-10-hours/>
- [8] Reenita Das. 2017. 10 Ways The Internet of Medical Things Is Revolutionizing Senior Care. (05 2017). <https://www.forbes.com/sites/reenitadas/2017/05/22/10-ways-internet-of-medical-things-is-revolutionizing-senior-care/#5e01a7965c8f>
- [9] Gary Davis. 2017. A Cybersecurity Carol: Key Takeaways From This Year’s Most Hackable Holiday Gifts. Website. (11 2017). <https://securingtomorrow.mcafee.com/consumer/consumer-threat-notices/most-hackable-gifts/>
- [10] Jim Donaldson. 2016. Why Retailers Are Turning To RFID For Loss Prevention. Website. (Aug. 2016). <https://www.mojix.com/retailers-rfid-loss-prevention/>
- [11] The Daily Dose. 2017. Stopping Shoplifters Goes High-Tech. Website. (June 2017). <http://www.ozy.com/fast-forward/stopping-shoplifters-goes-high-tech/78920>
- [12] Robert Epstein. 2016. The New Censorship. Website. (06 2016). <https://www.usnews.com/opinion/articles/2016-06-22/google-is-the-worlds-biggest-censor-and-its-power-must-be-regulated>
- [13] National Retail Federation. 2017. The Economic Impact of the U.S. Retail Industry. Website. (2017). <https://nrf.com/resources/retail-library/the-economic-impact-of-the-us-retail-industry>
- [14] FICO. 2017. Behavioral Analytics Attack Fraud, Cyber and Financial Crime. (04 2017). <http://www.fico.com/en/blogs/analytics-optimization/behavioral-analytics-for-fraud-cyber-and-financial-crime/>
- [15] Frederic Filloux. 2013. Google News: the secret sauce. Website. (02 2013). <https://www.theguardian.com/technology/2013/feb/25/1>
- [16] Arik Gabbai. 2015. Kevin Ashton Describes the Internet of Things. Magazine. (01 2015). <https://www.smithsonianmag.com/innovation/kevin-ashton-describes-the-internet-of-things-180953749/>
- [17] Garmin. 2017. Garmin Edge 500. Website. (2017). <https://buy.garmin.com/en-US/US/p/36728#overview>
- [18] Gartner. 2017. Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016. (02 2017).
- [19] Christian Gilbertson. 2017. Here's How The Sensors in Autonomous Cars Work. Website. (03 2017). <http://www.thedrive.com/tech/8657/heres-how-the-sensors-in-autonomous-cars-work>
- [20] Google. 2017. Mobile App Reporting in Google Analytics - iOS. Website. (2017). [https://developers.google.com/analytics/devguides/collection/firebase/ios/#how\\_does\\_it\\_work](https://developers.google.com/analytics/devguides/collection/firebase/ios/#how_does_it_work)
- [21] Andrew Hawkins. 2017. Nvidia says its new supercomputer will enable the highest level of automated driving. Website. (10 2017). <https://www.theverge.com/2017/10/10/16449416/nvidia-pegasus-self-driving-car-ai-robotaxi>
- [22] Patrick Hoge. 2010. Survey: 44% stop at Google News headlines. Website. (01 2010). <https://www.bizjournals.com/sanfrancisco/stories/2010/01/18/daily24.html>
- [23] Nabeel Hyatt. 2017. Autonomous driving is here, and it's going to change everything. Website. (04 2017). <https://www.recode.net/2017/4/19/15364608/autonomous-self-driving-cars-impact-disruption-society-mobility>
- [24] IBM. 2015. IBM Plans to Acquire The Weather Company’s Product and Technology Businesses; Extends Power of Watson to the Internet of Things. Press Release. (10 2015). <http://www-03.ibm.com/press/us/en/pressrelease/47952.wss>
- [25] Ajit Jaokar. 2017. Behavioural Biometrics, IoT and AI. Website. (10 2017). <https://www.datasciencecentral.com/profiles/blogs/behavioural-biometrics-iot-and-ai>
- [26] Search Engine Journal. 2016. Over 60% of People Trust Google for News vs. Actual News Sources. Website. (01 2016). <https://www.searchenginejournal.com/google-news-2/154475/>
- [27] Jacob Kastrenakes. 2017. Most smart TVs are tracking you fi? Vizio just got caught. (02 2017). <https://www.theverge.com/2017/2/7/14527360/>

- vizio-smart-tv-tracking-settlement-disable-settings
- [28] Suzanne Kattau. 2015. Research from Gartner: Real-Time Analytics with the Internet of Things. Website. (06 2015). <https://www.rtinsights.com/research-from-gartner-real-time-analytics-with-the-internet-of-things-dw/>
- [29] John Kiernan. 2017. Credit Card & Debit Card Fraud Statistics. Website. (02 2017). <https://wallethub.com/edu/credit-debit-card-fraud-statistics/25725/>
- [30] Sam Levin and Mark Harris. 2017. The road ahead: self-driving cars on the brink of a revolution in California. Website. (03 2017). <https://www.theguardian.com/technology/2017/mar/17/self-driving-cars-california-regulation-google-uber-tesla>
- [31] Karen Lewis. 2017. Visa and IBM are bringing the world secure payment experiences through the IoT. (02 2017). <https://www.ibm.com/blogs/internet-of-things/visa/>
- [32] Annie Lin. 2017. Facial recognition is tracking customers as they shop in stores, tech company says. Website. (11 2017). <https://www.cnbc.com/2017/11/23/facial-recognition-is-tracking-customers-as-they-shop-in-stores-tech-company-says.html>
- [33] Jon Markman. 2017. Amazon Using AI, Big Data To Accelerate Profits. Website. (06 2017). <https://www.forbes.com/sites/jonmarkman/2017/06/05/amazon-using-ai-big-data-to-accelerate-profits/#12f29cb6d55>
- [34] Mark Mather. 2016. Fact Sheet: Aging in the United States. Media Guide. (01 2016). <http://www.prb.org/Publications/Media-Guides/2016/aging-unitedstates-fact-sheet.aspx>
- [35] Kayla Matthews. 2017. 4 Statistics That Reveal Major Problems With IoT Security. Website. (02 2017). <https://channels.theinnovationenterprise.com/articles/4-statistics-that-reveal-major-problems-with-iot-security>
- [36] Neil McAllister. 2014. How many mobile apps collect data on users? Oh ... nearly all of them. Website. (02 2014). [https://www.theregister.co.uk/2014/02/21/appthority\\_app-privacy\\_study/](https://www.theregister.co.uk/2014/02/21/appthority_app-privacy_study/)
- [37] Microsoft. 2017. Five ways edge computing will transform business. Website. (09 2017). <https://blogs.microsoft.com/iot/2017/09/19/five-ways-edge-computing-will-transform-business/>
- [38] Patrick Nelson. 2016. Just one autonomous car will use 4,000 GB of data/day. Website. (12 2016). <https://www.networkworld.com/article/3147892/internet/one-autonomous-car-will-use-4000-gb-of-datataday.html>
- [39] University of Missouri System. 2016. Securing the Internet of Things (IoT). Website. (11 2016). [https://www.umsystem.edu/makeitsafe/securing\\_the\\_internet\\_of\\_things\\_iot](https://www.umsystem.edu/makeitsafe/securing_the_internet_of_things_iot)
- [40] Dan O'Shea. 2017. Report: Walmart developing facial-recognition tech. Website. (07 2017). <https://www.retaildive.com/news/report-walmart-developing-facial-recognition-tech/447478/>
- [41] Kasey Panetta. 2017. Gartner Top Strategic Predictions for 2018 and Beyond. Website. (10 2017). <https://www.gartner.com/smarterwithgartner/gartner-top-strategic-predictions-for-2018-and-beyond/>
- [42] Nevon Projects. 2017. IOT Heart Attack Detection & Heart Rate Monitor. Website. (2017). <http://nevonprojects.com/iot-heart-attack-detection-heart-rate-monitor/>
- [43] Lopez Research. 2013. An Introduction to the Internet of Things (IoT). Research Report. (11 2013). [https://www.cisco.com/c/dam/en\\_us/solutions/trends/iot/introduction\\_to\\_IoT\\_november.pdf](https://www.cisco.com/c/dam/en_us/solutions/trends/iot/introduction_to_IoT_november.pdf)
- [44] Symantec Security Response. 2016. Mirai: what you need to know about the botnet behind recent major DDoS attacks. Website. (10 2016). <https://www.symantec.com/connect/blogs/mirai-what-you-need-know-about-botnet-behind-recent-major-ddos-attacks>
- [45] Freddie Roberts. 2017. Half of US companies hit by IoT security breaches, says survey. (06 2017). <https://internetofbusiness.com/half-us-iot-security-breach/>
- [46] Brenda Salinas. 2013. High-End Stores Use Facial Recognition Tools To Spot VIPs. Website. (07 2013).
- [47] Antony Savvas. 2014. The Weather Company turns to open source big data analytics. Website. (11 2014). <https://www.computerworlduk.com/data/kpmg-launches-big-data-investment-fund-3489089/>
- [48] Claire Scholz. 2015. Biometrics to Secure the Internet of Things. Website. (12 2015). <https://blog.bioconnect.com/2552/biometrics-to-secure-the-internet-of-things/>
- [49] Stilgherrian. 2013. Smart TVs are dumb, and so are we. Website. (10 2013). <http://www.zdnet.com/article/smart-tvs-are-dumb-and-so-are-we/>
- [50] Mark Sullivan. 2012. A brief history of GPS. Website. (08 2012). <https://www.pcworld.com/article/2000276/a-brief-history-of-gps.html>
- [51] Raj Talluri. 2017. Why edge computing is critical for the IoT. Website. (10 2017). <https://www.networkworld.com/article/3234708/internet-of-things/why-edge-computing-is-critical-for-the-iot.html>
- [52] Versa Technology. 2017. How much Data will The Internet of Things (IoT) Generate by 2020? Website. (10 2017). <https://www.versatek.com/blog/how-much-data-will-the-internet-of-things-iot-generate-by-2020/>
- [53] Heather Thompson. 2017. Edge computing: It's what healthcare IoT craves. Website. (03 2017). <http://www.medicaldesignandsourcing.com/edge-computing-healthcare-iot-craves/>
- [54] Weather Underground. 2017. Weather Underground - About Our Data. Website. (2017). <https://www.wunderground.com/about/data>

## bibtex report

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

bibtext \_ label error

bibtext space label error

bibtext comma label error

latex report

[2017-12-12 20.02.36] pdflatex report.tex

```
=====
Compliance Report
=====
```

```
name: Peter Russell
hid: 334
paper1: Oct 28 17 100%
paper2: Nov 24 17 100%
project: Dec 04 17 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
8
wc 334 project 8 6920 report.tex
wc 334 project 8 7546 report.pdf
wc 334 project 8 1887 report.bib
```

```
find "
```

---

```
passed: True
```

```
find footnote
```

---

```
passed: True
```

```
find input{format/i523}
```

---

```
4: \input{format/i523}
```

```
passed: True
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

```
figures 0
tables 0
includegraphics 0
labels 0
refs 0
floats 0
```

```
True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
True : check if all figures are refered to: (refs >= labels)
```

```
Label/ref check
passed: True
```

```
When using figures use columnwidth
[width=1.0\columnwidth]
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

---

```
bibtex
```

---

```
label errors
```

```
bibtex errors
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
passed: True
```

# Big Data and Its Application in Education

Weipeng Yang

School of Education, Indiana University Bloomington  
201 N Rose Ave  
Bloomington, Indiana 47405  
yang306@umail.iu.edu

Geng Niu

School of Education, Indiana University Bloomington  
201 N Rose Ave  
Bloomington, Indiana 47405  
Niugeng@umail.iu.edu

## ABSTRACT

The development of big data is changing the society in a dynamic way. With high speed internet and high penetration rate of mobile devices, every individual becomes a source of data and is constantly provide these data to various organizations who want to make profits or want to utilize these data to contribute to a certain end. Big data helps online retailers to add new strategies to increase their selling; it also helps medicare organizations to make more accurate diagnosis to patients; it even changes the sports industry. Because big data is changes various industries profoundly, it will certainly in a point change the way people acquire new knowledge. For this reason, it is important to review how big data bring changes to different industries and how education strategies could adjust to the fast-change world. In order to have a clear picture of in what ways big data will influence educational strategies, we will use education recommendation system and medicare education which is transformed by big data, as a case to see how educators should adjust their strategies with the benefits brought by big data..

## KEYWORDS

i523, HID236,HID218, big data, education

## 1 INTRODUCTION

When we search the definition of education, we will find that it is defined as process of facilitating learning or the acquisition of knowledge, skills, values and beliefs and habits [43]. However, when we talk about education, we regard education as academic education such as K-12 education and higher education. In reality, education is happening all the time and everywhere. When you are sitting in a classroom, you are learning to get a degree and plan for your career life. When you are working in the office, you gradually learn how to accommodate what you learn at school to what the reality is in the workplace. When you are watching TV, you are getting information about what is happening around the world and you gain your first impression of different countries around the globe. And even when you are shopping online, you are learning how to identify the product is good or bad by reading the reviews. Therefore, in the 21st century when educators look into education, it will cover not only school education but also corporate training and other forms of informal learning.

## 2 A LOOK BACK AT LEARNING

It is very difficult not to think of Confucius and Socrates, two great men who are regarded as the most important people in terms of influence on education in the East and West. Confucius emphasized the importance of education and proposed that education should be equal to everyone. He was a teacher himself and taught students

morality, proper speech, government and refined arts. “He never discourses at length on a subject. Instead he poses questions, cites passages from the classics, or uses apt analogies, and waits for his students to arrive at the right answers” [30]. Confucius set an example of teachers in ancient China and other regions in Asia such Korea and Japan. Teachers in these parts of world should be much better learned than students and are examples in terms of morals. Because of this, students should imitate teachers. By contrast, Socrates adopted a different view of learning. fSocrates does not believe that any one person or any one school of thought is authoritative or has the wisdom to teach “things.” Socrates repeatedly disavows his own knowledge and his own methods. However, this appears to be a technique for engaging others and empowering the conversator to openly Dialogue [2]. This may be one of the reason why the learning style in the East and the West is so different. But when we look back at education in schools in the past, no matter where the school or the learning place is located, learning is highly teacher-centered. In ancient China, teachers still follow the learning style of confucius. The teachers had authority over their students and students were supposed to treat their teachers like their fathers. In return, teachers should be selfless enough to pass what they knew to their students. In the West, the situation was similar. And one of the reasons might be the lack of resources in teaching. In ancient times, only limited number of books were available due to printing technique and the number of scholars who could write books. In the year of 1500, the illiteracy rate of men and women in English is 90 and 100 respectively. And in Qing Dynasty around 1880, literacy rate is around 30-45 in men and 2-10 in women. It is not hard to deduce that these numbers are much lower in 1500s [28]. Knowledge or information was in the hand of the top 10 of people which make knowledge more precious. Therefore, teaching must be teacher-centered and teachers have much authority over the students. However, it is never true today. The volume of books will take a person’s whole life to read; TV has changed the way of how people get information; and the internet revolutionizes how information is created and transmitted. As a result, teachers are no longer just knowledge providers and it is impossible for them to be mere knowledge providers because learners have access to almost infinite source of knowledge.

## 3 WHAT IS INSTRUCTIONAL DESIGN?

“Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources” [13]. Instructional technology started from instructional media , the use of which can date back to the first 10 years of 20th century in school museums. The use of different media in instruction or

learning have gone through visual instruction, audio-visual instruction and the use of communication theories to today the integration of computers and internet technologies [29].

However, the turning point of the birth of educational technology began as visual education. At the turn of the 20th century, educators were exploring the potentials of motion pictures and projected slides. In the 1950s, the advent of television added new dimension of widespread of audio-visual programming. At this time, the design materials only focused on creating attractive and creative presentations which are pleasing to learners' eyes and ears. But a shift happened in the next decade. Educators not only cared about the appeal of the teaching or learning materials, but also cared about what learners are doing. In the next few decades, the focus of learning design continued to change because of the advent of the internet which allows learners to collaborate anytime anywhere. Also, computers became a powerful assistant in learning with the advances made in CPU and storage [25].

Instructional design has several names such as instructional system technologies, learning design and educational technology. Although universities which have program on instructional design prefer different names, they have similar courses and goals of training. The definition of instructional design has been revised several times in history and those changes were caused by different opinions held by experts in the field and most important caused by advances of science and technology.

#### **4 THE DEVELOPMENT OF EDUCATION PSYCHOLOGY**

Behaviorists believe that performance of people can be changed by contingencies of reinforcement combined with changes in the environment [42]. For example, drivers or passengers of a car may not want to or forget to fasten the safety belts. In order to prevent that from happening, a machine would give out a loud "beep" noise which is annoying to tell people in the car that you need to fasten the belt. This is called a negative reinforcement. In order to avoid something awful to occur, people will behave in certain way. Opposite to this is positive reinforcement. For instance, teachers would give a student who has the high scores in a exam a gift and verbal appraise as a way to encourage all the students to study harder. Behaviorism has great impact on programmed instruction in both academic education and military training [34]. However, the behaviorist approach to learning has two problems. The first one is the use of proper reinforcement. As learners grow older, instructors have to find reinforcement that learners will value. But it is really difficult to provide such reinforcement to adult learners. The other problem is that behaviorists seem to ignore the process of learning.

By contrast, cognitivists focus on how people process information. The core components of cognitive approach to learning are perception and sensory stores, short-term memory, and long-term memory. Perception is about how people select what information to pay attention to; "sensory stores are capable of storing almost complete records of what we attend to but hold those records very briefly"; short-term memory helps people to rehearse the information coming through sensory stores but it has limited capacity; Long-term memory is where information is stored in a certain

way permanently and is ready to be retrieved [41]. A good example of using cognitive theory in learning or information is the design of presentation slides. A good PowerPoint presentation may contain clear contrast between the texts and the background or different categories of information. It also only contains keywords of a topic so viewers will be well-guided by the slides when listening to the speakers. Although cognitive approach of learning helps learners to process information, what learners can do if they need to learn an ill-defined topic?

Constructivism made one more step forward towards learning. Learning, according to constructivist theory, is a process of meaning making, a process of solving problems when encountering cognitive conflict and a social activity such as collaboration and negotiation [44]. Put it simply, constructive theory advocates simulation of the real world environment. A topic is ill-defined and learners are required to formulate their own strategies to look for relevant information and experiment potential solutions to solve a problem.

#### **5 PROBLEM-BASED LEARNING AND MEDICAL EDUCATION:**

Problem-based learning is based on constructive approach to learning. "Participation in valued activities within different domains is fundamental to how students learn." People who advocate this problem-based approach suggest that learning happens when other people involve such peers, tutors or mentors. And cooperation in activities can lead to higher reasoning level. Students may change their perspective of thinking and their opinions about a topic because in collaboration more ideas are involved and those ideas will be discussed in an environment in which sharing and collaboration are promoted. Lev Vygotsky found the construct of the zone of proximal development to explain how people can facilitate knowledge construction. This framework shows that if instructors can reduce the distance between what the learners can do completely by themselves and the things that can be accomplished by themselves with the assistance from others, then the instruction can be successful. "PBL is a form of education in which information is mastered in the same context in which it will be used" [6]. Another definition of PBL is "a learning method based on the principle of using problems as a starting point for the acquisition and integration of new knowledge" [23]. Problem-based learning can also refer to problem-and-task-centered approaches of learning. It is one of educational technologies designed to situate instruction in authentic or meaningful settings. It has been employed in many different fields of studies such as medicine, science, law, business and mathematics. And the goals of PBL differs from each other. In medicine PBL requires learners to work in groups to practice their skills to diagnose patient cases and the ability to use clinical knowledge in practice. But in science and humanities, students in a PBL class to come up with explanations for a certain phenomenon through activities such as defining a question, seeking evidence, and outlining and argument. Moreover, in law and business related courses students will engage in the study of cases and they will be encouraged to seek and summarize critical information from those cases and present their finds to peers in the classroom. By the end of their presentation, instructors will provide feedback. In math and science PBL courses, students work together in an environment in

which constructive feedback is provided to each other or by tutors or teachers. Although the goals of learning in different fields are different, in PBL the core value is to put education in authentic tasks so the learning is more meaningful.

Savery and Duffy proposed a framework of how to conduct problem-based learning: Anchor all learning activities to a larger task or problem

Support the learner in developing ownership for the overall problem or task

Design an authentic task

Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning

Give the learner ownership of the process used to develop a solution

Design the learning environment to support and challenge the learner's thinking

Encourage testing ideas against alternative views and alternative contexts

Provide opportunity for and support reflection on both the content learned and the learning process [35]

Medical education is very suitable for Problem-based learning because the advances made in medicare makes it impossible to include everything in lectures. And in the field of medicare, doctors will face various problems with patients which are highly likely beyond what medical students can learn from school. Therefore, in order to foster the ability to solve problems, critical thinking and experiment potential solutions, PBL serves as a critical part of medical education. PBL has been employed in many medical schools around the world. "It was introduced in the medical school at Mc-Master University in Canada in the late 1960s and is now a common curriculum component in medical and health science schools around the world" [23]. "The University of New Mexico was the first to adopt a medical PBL curriculum in the United States and Mercer University School of Medicine in Georgia was the first U.S medical school to employ PBL as its only curricular offering" [6].

Here we will present how to use this framework with medical education. The first step of designing PBL for medical students is to find an authentic task. By saying authentic task, we don't mean the task must be the same with what happens in a hospital every day. It means the task will require similar cognitive load to a real problem. The specific difficulty of the task is designed by the instructor according to the level of the course. As is often the case, instructors will create scenarios to represent an authentic task. Before creating a scenario, instructors should formulate objectives of the course, and create a scenario in which all of these objectives will be accomplished. The complexity or the difficulty of the problem should be appropriate to the curriculum and the level of students' understanding. It is better if the scenario is appealing enough to attract students' attention. Basic science should be included in the context of a clinical scenario to encourage integration of knowledge. Although the problem presented in a PBL class should be ill-defined, the PBL scenario should have cues to stimulate discussion and push students to seek reasonable explanation to the issues involved in the scenario. At last, the scenarios should promote participation by

the students in the seek of explanation [46].

The next step is to gather all relevant information which can be useful or useless to the final solution to the diagnosis. However, this information will not be provided to students directly. Besides relevant information, the instructor should also have other resources such as equipments, lab or simulation of the environment in a real hospital. Then students will have a meeting with the instructor to talk about the basic information of the patient such as age and gender and symptoms he or she has. Then the task will almost completely hand to the students. Here comes to an important point of the whole learning experience. The learners should be told that there is no correct answer to the task and it is the students' responsibility to find a possible solutions.

A tutor should be assigned to the students and the tutor is not necessarily an expert in medicare because the tutor's job is not to provide suggestions to the students. Or the instructor can be the tutor. But the responsibility of the tutor is to ask leading questions such as why do you choose this? or how did this happen? By asking these questions we hope students will spot their own mistakes or loopholes in the process of finding a solution to the diagnosis. In this way students will revise their strategy of work. Another responsibility of the tutor or instructor is to provide key information if the students are seriously off the track. And in order to ensure the quality of the course, tutors or instructors have to do so. Speaking of the roles of tutor in PBL, we have to talk about scaffolding. A real or physical scaffold is a structure to support learners to complete a task and it is not permanent. When a task is accomplished, the structure will be removed. It is still the same when we talk about scaffolding in education. It will be removed when it is not needed. Scaffolding is designed to assist learners to complete tasks which are otherwise beyond their reach. This suggests that the design of scaffolding must be very careful. So there are several questions for tutor and instructors to think when they design such a structure: what is needed to support, when and in what way to support the students, how much support should be provided to learners, and when and how to fade scaffolding.

In PBL in a medicare course, students are required to write reports weekly or bi-weekly on how they collaborate, what problems occur and how they solve these problems. Also, by knowing the progress students make, it is much easier for instructors to see how they grow and how they should adjust some elements of the learning environment. And a final report to summarize the whole process of collaboration and the working process will be submitted at the end of the semester.

Such courses can also be conducted in multiple groups. Every group will have their own way of collaboration and propose different solutions to a diagnosis. And instructors should create an environment where different groups are eager to share their own progress because they can always get constructive feedback from their peers. Moreover, such a sharing environment will make the learning more dynamic and accelerate the growth of learners. Tutorials are also an important element in PBL. Usually, the PBL tutorial has a group of students which has no more than 10 and a tutor who provides scaffolding to the session. The duration of the session varies. It depends on how long it takes for a certain group to have good dynamics. Moreover, for each tutorial session, a different

leader or chair should be elected so every member of the team will contribute and free ride can be avoided [46].

Here we want to elaborate tools and activities can be included in PBL in the Internet era. Basically, PBL courses can include activities such as generating lists, scaling down the scope of topics, making outlines of options, debating issues, and even voting. Today, many activities can happen in virtual environment. Wikis enable learners to have meeting in a virtual community and collaborate on projects and solve problems. And meeting tools such as Zoom, Goggle Hangouts and Adobe Connect enable online meetings of a large group of students and share screens and notes. Moreover, blogs also provide virtual space for learners to practice their writing skills and share their writing with audiences beyond their teacher. In a PBL class, web 2.0 tools can also be included such as Skype, Twitter, Instagram.

Here are some examples of how Mercer University conducted PBL in its medical courses. At Mercer University, a series of tutorial sessions were used to substitute the lectures. And during each session, faculty members and students would meet to discuss the actual case problems. In other programs which are related to clinical skills and community science, students need to deal with simulated patients and spend some afternoons with local primary-care practitioners. "In this way, real life clinical practice in a rural community becomes a laboratory exercise for the illustration of basic science theory." In Mercer University, tutors were called "faculty overseers" who are neither to be the source of all information nor even to have information about every area being discussed. The responsibility of these overseers is to keep student participation and knows enough to prevent gross mistakes. On the contrary, students were teachers and learners. Without giving lists of what to know, students need to generate a list of what to look for according to importance of relevant information.

Although small groups of meeting played essential role in the PBL of Mercer University, lectures are still used to some extent. The students may have some lectures on one or two basic science lectures every week but these sessions were not mandatory. The evaluation of the course was intense. Students at Mercer University were tested by both intramural and extramural means. At the end of each of the thirteen curricular phases, students would have a 200-item, cross-disciplinary, objective examination and a forty minutes case analysis oral examination.

The majority of faculty members favor PBL over the conventional way of teaching. The reason is very simple: it is a more natural way of learning. PBL simulate the environment where people generate knowledge. For example, students became better prepared in the learning process. That is the ownership was handed to the students instead of the instructors. If a student came to the discussion session without any preparation, she or he would be complaint by other members. Another benefit of PBL is that students became more flexible in learning. Students at Mercer University used texts, mono graphs, periodical literature and various resources in their learning. In the past, the learning is very lecture centered and students were actually not actively engaged in the learning. By contrast, when they were on their own, they tried every alternatives to find useful

resources and developed flexibility in learning [23].

From the history of the evolution of educational technology we can see the changes are brought by technological development made in other fields of studies. Those technologies were not intended to contribute to education but they are all utilized in education. And to successfully employ PBL in an academic learning environment, instructors and instructional designers must build a proper environment. As a result, the development of big data can provide new thoughts in how to advance current instructional design and improve the building of a proper PBL learning environment.

## 6 CHALLENGES OF LEARNING IN THE INFORMATION ERA

The challenges of learning in 21 first century is that the explosion of information brought too much information whose credibility is uncertain. Many people, especially scholars, question the accuracy of information of Wikipedia. However, Wikipedia may be the most popular sites for all kinds of information ranging from entertainment to academia. And because of the affordable and high speed internet, everyone has a say in the virtual world. One can find people argue on an issue in online forums, express their own opinions in blogs and social media. However, these information could be wrong and there is no third party to verify if the information is correct. By the end, people tend to believe in the opinions presented by the most popular sites or people. For example, in China a high school history teacher goes visual on the internet and he starts to have his own online courses about history in China and other parts of the world. His courses are pretty interesting because a lot of humor is involved and various media are used such as animation and movies. Therefore, a lot of students prefer to watch his online courses instead of taking the face-to-face class at school. However, the opinions presented by this history teacher are very different from main-stream scholars especially in the history of the second world war and civil war in China. And this caused problems at schools. In this case I presented, the teacher actually unconsciously took advantage of the populism of teenagers at high school. Students at this age can be very disobedient and do not want to engage in the old tradition.

And here comes another problem and the internet era. It is often the case that who has the most resources to populate an opinion will finally be the person who has the most say. It seems that the internet give people equal opportunity to express. However, what really happens is that people can only find limited opinions or values. For example, many news agency can use the resources they have to control media on what to be reported and what not to be reported. The fake news of several US news agency proves that it is real. In addition, the internet world is actually not so different from the physical reality. One is likely to find that the best resources on the internet are also expensive and only open to a few instead of the public general. That is also one of the reason why Wikipedia can be so popular because it is free to everyone. Because the best resources are only open to a small group of people that may widen the gap between the well-educated and the ill-educated. That is also the reason why the education community are working on Open

**Education Resources.** Work with people from the academia, these open resources can be affordable or even completely free and still they have high quality. Massive Open Online Courses can be viewed as the most popular representatives of OER. However, there is still a long way to go in promoting education equality due to political and financial reasons.

**Challenges to instructional design** The last challenge is how to do a thorough analysis of learning. In instructional design, ADDIE model is the most used model of doing the design process. ADDIE stands for analysis, design, development and evaluation. In the analysis phase, instructional designers need to work with subject-matter experts to formulate learning objectives. The learning objectives are specific performance which can be observed or evaluated in other ways. And learner analysis will include the traits of learners, the learning styles of learners, the motivation, confidence, prior knowledge of learners and the potential satisfaction of learners. Also a context analysis will also include. In the design phase, instructional designers will script and finalized learning strategies and tactics for the entire learning experience based on the analysis made in the first phase and the learning materials given by instructors. Then they enter the development phase in which the final education product is made. In the evaluation phase, instructional designers will conduct trials of the course and general a report on what needs to be modified and summative evaluation will be formulated to test learners' performance change in the end.

However, in the internet internet era, the number of online learners can be bigger than 2,000. In many popular MOOCs, there are more than 2,000 people registered. As a consequence, it is impossible to do a learner analysis. Not only the number of students is big, the learning styles, motivations and level of prior knowledge vary drastically. Even if a comprehensive learner analysis is possible, the result might be that the learning environment is too complex and the course may be out of control of the instructors' hand. And in reality it is true. In many MOOC courses, learners have different expectations toward the same course, once they feel disappointed about the course, they drop. And the result is only a very small percentage of learners finally complete the course. And because of the huge number of students, the discussion forum goes out of control and instructors and teaching assistants cannot monitor the discussion and the discussion result in nothing.

## 7 HOW BIG DATA INFLUENCE DIFFERENT INDUSTRIES

Before we look at how big data will influence education or more specifically influence instructional design of medical courses in a PBL environment, we will first examine how big data have influenced other industries. The experience from these industries will provide guidance on how education community utilize big data. Big data has become the buzz words for today's world. One of the reasons is that big data increase benefits of many business. The traditional way of costumer consumption has lasted for centuries. In the ancient time, people would go to fairs to buy groceries, hardware and clothes. But at that time, fairs were not standardized, and the conditions of those fair can be terrible. It was impossible to guarantee the quality of the goods bought by customers. Later, in

the industrialized world, cities were built and shopping mall appeared. In a shopping mall, customers could buy good qualities in different stores. Instead, they would go to supermarket to buy groceries. This mode of doing business remained until the beginning of e-commerce. In the web 2.0 era, search engines enabled consumers to look for products in virtual shops and sellers can collect feedback of consumers' satisfaction in their website [3]. Today, with big data technology, it is possible for online retailors to monitor activities of consumers online. Business owners can have better understanding of consumers and formulate more targeted strategies of how to increase profits. Because of the ability of monitoring online activities and better understanding behaviors of consumers, online retailers can provide personalized services. This is realized through the use of recommender system. Online buyers will be labelled according to their online activities and they will receive emails or suggestions of what to buy on the internet. 35 percent of Amazon's revenue is created by the recommendation system. Users of Amazon can click the recommendation section and see the products selected by the recommendation system. For example, if a learner is looking for a backpack, he or she will probably see some recommended backpack [17]. Dynamic pricing is also a strategy brought by big data technology. "Some business set different prices for their products or services based on algorithms that take into account competitor pricing, supply and demand and other external factors in the market. It is a common practice in industries such as hospitality, travel, entertainment, retail, electricity and public transport" [43]

Before big data was brought to the face of the healthcare system, the role of data in the healing process of patients was minimal. Data such as name, age, disease description, diabetic profile, medical reports and family history of illness were collected. These data could only reflect limited view of a patient. For example, a doctor may know that the reason of a patient with heart disease can be traced back to his or her family, but there are many possible perspectives on why the patient has such disease.(Pal2016) "The influence of big data on medicine is that we can build better health profiles and predictive models around individual patients so that we can better diagnose and treat disease." The pharmaceutical industry is facing the limitation of insufficient understanding of the biology of disease. But big data can help in building the understand of what constitutes a disease such as causes from DNA, proteins and metabolites to cells, tissues, organs, organisms, and ecosystems [36]. The problem for the medical research is that enterprise is unable to follow the pace of the information needs of patients, clinicians, administrators and policy makers. *fiThe flow of new knowledge is too slow, and its scope is too narrow.* The consequence of the medical research community not adopting big data technology is that hospitals are ill prepared for a more precise diagnosis. Now the medical research community need new thinking in their work. The new thinking must involve the integration of new technologies. "For instance, researchers can use big data to reveal clusters of patient groups that might suggest new taxonomies of disease based on how similar they are according to a broad range of characteristics, including outcomes." Advances in prediction can simply attribute to the learning of data and creating a mechanism which is highly reproducible and has consistent performance [18]. "Big data has helped healthcare

institutions take a 360 degree view of a patient's health problems." With the help of big data, new findings, innovative methods of treatment plans and more precise diagnosis can be realized. Here is an example of how it is possible to build better health profiles. Some diseases are more common among a certain race of people due to genetical reasons. When a patient from this race is found suffering from heart disease, the doctors can look at the data of patients belonging to the same race who have same problems. By examining their life style, genetic structure, family DNA and other elements, they can build health profiles for these group of people. Wearable devices can also play a role in the detection of potential health problems even if no apparent symptoms are presented. Wearable devices can help see some indicators of health. And doctors can make certain conclusions and decide on the future action on them. The devices today are already able to record data such as heart rate, pulse, glucose levels and calorie levels. And big data will also have the potential to personalize medicine. The NCI-MATCH trial is examine 1000 people who have tumors that do not respond to standard cancer treatments. Researchers hope that they can match drugs to this kind of tumor to produce the best result [27]. "In the very near future, you could also be sharing this data with your doctor who will use it as part of his or her diagnostic toolbox when you visit them with an ailment. Even if there's nothing wrong with you, access to huge, ever growing databases of information about the state of the health of the general public will allow problems to be spotted before they occur, and remedies - either medicinal or educational - to be prepared in advance" [24].

## 8 HOW BIG DATA WILL INFLUENCE EDUCATION IN GENERAL

The first change we will see in education is the rise of adaptive learning. Adaptive learning means that students can learning knowledge whose difficulty is suitable for their ability. This is enabled by the availability of online application, classroom activity software, social media, blogs and surveys of staff. With adaptive learning comes the universities' ability to provide personalized feedback to students, monitor student satisfaction, increase attainment and give students' opportunities to reflect on their own learning. On the other hand, instructors will receive real-time reports which will enable them to adjust teaching strategies for the best outcomes [20]. Because learning is more adaptive, students can advance their learning in different paces. Big data and data analysts will inform instructors who is learning faster and can advance to a more difficult class and who need support from teachers [14].

Since learning of different learners will at different paces, it is important for learners to develop self-management. For example, in a PBL class, students need to solve an ill-defined problem and the process of learning is almost unguided. As a result, students need to take the initiatives and actively contribute to the project. Also learners will monitor their own process of learning and submit a report to summarize this process. So they must develop their meta-cognitive skills which means the learners are able to learn how to learn. Another reason why self-management is more important in the big data era is the widespread of informal learning. As mentioned before, people today are learning anytime anywhere. Social media, blogs, news and anything connected to the internet

will serve as a source of learning. Therefore, it is impossible for teachers to monitor learning of students all the time.

## 9 BIG DATA MINING

Big data mining refers to the procedure in which a gigantic amount of data from a wide variety of source is collected, and analyzed with a wide spectrum of means to discover inner mechanism or other information via pattern [45]. Being used in almost every field such as business marketing, science and engineering, medicine, design and education industries to provide such functions as intelligence, research and marketing. Oftentimes, big data mining will be carried out on individual persons. When someone is doing activities online, their data will be collected. They could also be providing these data via questionnaires, surveys or other means. This massive amount of data collected on everyone are commonly called big data by the industry and corporations and companies will utilize them to figure out what need one have or what kind of personal trait one may carry. As the big data industry found itself in rapid development, concerns and other critiques are also rising on the ethical issue of big data. Heated discussions were talking about the insult to privacy and abuse of such data. However, big data have already set foot in so many industries and almost all aspects of our daily lives[40].

Data mining sees Artificial Intelligence and Machine Learning as its inception. During data mining, patterns are discovered, and data scientists could utilize such patterns to carry out more versatile functions. The system could get to understand an individual via the data collected about this one. The Recommendation Engine, or so called the Recommender System, is one application for data mining. The recommendation engine filters information and uses data mining techniques to figure out the specific suggestion to one person for information or other assets that may help them with current or future needs.

One commonly used example of the recommender system would be the online shopping websites. When someone shops on it, he or she will be given information about merchandise that related to this purchase. Such recommendations require various kinds of variables, such as this person's shopping history, the gender, age, and occupation of the person, or the items other bought after purchasing the same item. Another example will be after someone searched for a merchandise or service online, the advertisement will pop out for them showing related products.

These kinds of systems require algorithm with high complexity to give out recommendations following patterns discovered via enormous amount of data from mining. Such presentation will be oftentimes beneficial to individuals as they no longer need to go through such amount of information to find their desired service or product. Instead, targeted recommendation will be directly presented to the individual and sometimes the individual will have little awareness that they may need such product or service. As a result, the system will greatly enhance the efficiency for the user, it will also be a blessing for the services or products so that they could be utilized more often.

With such benefits, the recommendation engine is wildly used amongst all online websites, including but not limited to online shopping, searching, streaming and social media websites[39].

## 9.1 Types of Recommendation Engines

A good deal of recommendation engines is backed with such technique called as collaborative or content-based filtering technologies. Collaborative filtering resembles a person making purchases on the gathered information from other via verbal or other means. It could also be understood as crowdsourcing[38]. In many online websites, people could give out ratings or feedbacks for others to reference. It is an interesting phenomenon that customers will more likely to read crowdsourcing comment first rather than the information provided by the seller. The collaborative filtering based system took one step further by categorizing commenters into different subcategories and present different person with different information or resources that might only be beneficial to him or her. Such patterns as statistical models are utilized to calculate everyone's correlation, thus giving out a value of recommendation. Some examples might be Twitter, eBay, Steam and Apple Store. They are all using collaborative filtering systems.

On the other hand, content based systems focus on different properties of a resource, in comparison with the properties of a person. As a person's total using time accumulates, the system will become more and more accurate as the user will demonstrate more personal traits and preferences in using the system. Examples of this kind of content based system will be Netflix and other streaming websites. Moreover, a developed recommendation engine could involve both collaborative and content based filtering techniques to bring prediction accuracy to a new level.

## 9.2 Math Models of the Recommendation Engine

The math models that standing in the back of the data mining engines include such technologies as association, classification and clustering means. Clustering refers to the procedure of combining individual with certain characteristics and trait being recognized as high value in the recommendation system. Such values as ratings, tones of comments are taken weighted average of all members in the cluster to identify the how the individuals in this cluster would recommend this product or service. More complicated systems would involve multiple clusters and calculated overall weighted averages across all the clusters that one individual belongs to[37]. Classification identifying technique are also utilized as the cornerstone of interconnecting different person with different appreciation to different items. Fundamental version of classification systems only works as primary filter to figure out how relevant individuals with desired kind of resources. As an example, only providing infant nutrition food for those who just give birth to a baby. This example only provides a crude vision of classification while more complicated ones will be able to perform prediction recommendations with higher complexity, and thus higher accuracy[33]. Association on the other hand provide more sophisticated recommendation rules with the introduction of correlation amongst different items or different individuals. With such rules, the system will be granted the ability to determine what a person needs most currently, rather than giving recommendations based on the person's previous activity history in the system. One example will be that if someone is looking for an oven in the kitchen, but he or she was browsing a dishwasher 2 months ago, the system will begin to give

recommendations on oven or other cooking utensils, rather than kitchen cleaning utensils. Like mentioned before, a more complicated version of the association rule will give out recommendation with more complicated consideration and calculations. The recommendation system will be referencing different traits of a person or by viewing at a variety of items being browsed in the system by the user. One supplementary of the association recommendation system will be using dynamic analyzing to provide recommendations for future use when the user wished to need some resources that related to the current inquiry. An example would be a person who bought or browsed an oven today may be provided information of recommendation on oven recipe, or aluminum foil tomorrow.

## 9.3 Big Data Recommendation Engines in Education

As we have mentioned before, recommendation engines based on data mining are proving to be beneficial to almost all fields in our lives, and education is one of them.

The field in education that involves big data mining are often referred as learning analytics. It focuses on how big data mining could be utilized for teaching and learning purposes ranging from personalized teaching, learning, evaluations and assessments for individuals to providing data to decision makers of various levels of education (for example, a director of a department or a government official of education). Big data mining has provided benefits to many aspects of education such as teaching, learning, education leadership, adult education, special education, enrollment decision, talent education, etc. The new millennium has seen the rapid development of educational big data mining and the field is hunger for talents that possess not only profound understanding in educational theory, but also the capability to carry out statistics, research and evaluation in education[32].

As the examples mentions above, the educational recommendation systems have deep similarities with commercial recommendation systems as they both strive to introduces the user to their desired products or services. However, educational recommendation system could also provide interconnection between learners, their desired course, their personal traits and educational resources that could serve the learners to help them reaching maximum efficiency in learning and to reach their academic goals. These beneficial factors make the educational recommendation engines a state-of-the-art asset for students to excel in personalized online learning systems. In such system, learner's characteristics, track selection and knowledge gained in previous learning could all be quantized into values to serve as a filtering and weighing standard to learners in e-learning. As one can see, such system has great flexibility and are highly adaptive to different learners. In this way, the efficiency of learning is greatly enhanced, and students are more motivated in engaging in learning[31].

The history of the e-learning recommendation system could be traced back to computer assisted instruction systems, also known as CAI. One major concept called Time-shared, Interactive, Computer-Controlled, Information Television (TICCIT) was invented in the last 70s. This could be the cornerstone of nowadays educational recommendation engine. TICCIT is developed so that the learner

could have higher control in their own learning with the help of a mentor giving suggestions and advices from time to time. The education recommendation has met its rapid development afterward ever after the introduction of TICCIT as they could provide personalized advice and suggestions to learners according to their daily usage and browsing history of the system. Students could spend less time on looking for the education resources on their own or filtering out valued teaching and learning resources from a gigantic amount of information on the internet or within the e-learning system. In such way they could devote all their valuable time to learning, rather than being in a frustrated state without guidance[22].

As mention before, the recommendation system's ability to provide an accurate result relies on massive amount of data collected from individuals and their behavior on the e-learning website. In this way, e-learning websites with a considerable number of users could better contribute to the learning process of the recommendation engine. For instance, Massive Open Online Courses (MOOCs) could have hundreds or thousands of active users on the website, or even learning the same course at one time. In such way, the recommendation engine evolves quickly, and user could benefit from it. Moreover, online learning websites have a social learning ecosystem which have great resemblance to social media networks. This lays the groundwork for the recommendation system to make full utilization of its huge user database to provide more relevant courses for learners. It is worth mentioning that these e-learning systems with social element are more likely to be involved with informal or professional learning. An example would be info of a user in career development system will be put under comparison to his or her colleague's information to carry out a performance evaluation[16].

Also, when he or she wishes to visit some of the resources on the career training website, the system could filter out his or her colleague's recommendation, comment, rate of one course and then utilize algorithm to provide this user with resources not only capable of helping him or her reaching current goals, but also courses and information that may become useful in the future[21]. Lots of educational teaching and learning systems with data mining and recommendation feature are established on online learning systems that could be easily visited from a mobile phone or a tablet. Such convenience no doubt made collecting data at great ease and allows more users to participate in such process. This could be a beneficial cycle: the ever-growing user base allows the algorithm to be more accurate and provide more personalized learn guidelines, and such feature will not only attract more user but will also let remaining users to provide more data to the system.

Learning analytics could also find itself useful other than the scenario of teaching and learning systems. Data mining and recommendation engines could be also used in supporting students in daily learning. For instance, a system that feature in college application could use a recommendation engine to provide learning track for students to better prepare for a certain university's requirements. Such method could be also used with other kinds of online learning motivation techniques such as badges. Badges are like achievement system in which when a student accomplish certain goals, he or she will be award a badge. He or she could get to know the global percentage of student holding that badge and get

motivated in making more accomplishments[19].

One more application would be the student retention system, in which students' data are monitored and a baseline is set based on the overall performance of all the student within. If one student's performance is below par, the system will receive alert and will send support or intervention staff as soon as they can to help the student and prevent him or her from dropping the course. In addition, big data also provide new thinking on how to conduct the PBL learning process. For example, when learners are working in the virtual environment, tutors can monitor the contribution of students in a certain group. In this way, the tutor can quickly identify who is not contributing to the team and take certain measures to intervene the performance of this student. Moreover, in a conventional PBL environment, the timing of proving scaffolding and removing scaffolding is very hard to master. But with the help of big data, tutors can analyze the process of learning in a team and spot the time when the team make minimal progress[15]. In this way, the instructors and tutors can provide in-time support. And tutors can also spot the time when a team have sufficient knowledge and ability of accomplishing the task, so tutors can fade scaffolding. From the learners' perspective, big data give them space to try new ideas. Instead of having group discussions and debates of different ideas, students can also learn from what the data tells them and gain empirical experience. With big data technology, learners can also formulate more up-to-date solutions to a task[18].

Big data also provide powerful tools to instructional designers. With the help of data, instructional designers can label learners just as the way online retailers label customers. Then those labels will be put into different categorizes. This is very important for conducting learner analysis. Instructional designers will be able to see clearly the motivations they have, the prior knowledge they possess to determine the scope of learning. Also with such data, instructional designers can design proper strategies to motivate learners and increase the satisfaction rate. The learning style data will help the development of teaching strategies. Designers and subject-matter experts can integrate different ways of learning in one semester based course and let learners with different learning habits to collaborate to foster flexibility in learning.

## 10 WEB ANALYSIS

Web analysis is also an uprising branch that belongs to the learning analytics and being supported by big data mining. It focuses on how to collect and analyze data gained on websites or applications that needs to connect to internet before using. These kinds of data are often a result of user's activities on the internet. Web analytics are often utilized to boost the study and learning efficiency of students in a specific Learning Management System(LMS). It could also help the administrator of the website to monitor and support student's learning progress and to help oversee the functioning of the website[17].

Web analytics are also utilized by administrators to get a better understanding of what kinds of personal traits one user may carry and how would this one interacts with various function on the website. It could be utilized to make a prediction on what kind of educational

products or courses will be more welcomed by certain students and learners. After analyzing such data as how many people have visited one page and what kind of activities they are most likely to carry out, the administrator could be informed that what kind of needs one student possesses and how they can develop in the future to cater to their needs. For the education website owners, the web analysis can also be used as a mean to find out any hidden security risks online and could help them gaining evidence for court should an attack really happens.

In the world of academics, web analytics is also beneficial in helping the college to make strategic plans. For instance, with a growing number of traditional courses, tutoring services are going to be changed into their online version, web analytic will find out how to deploy these courses and servers better so that they could get maximum visit from those who are interested in them. Since many data and information are distributed on different websites, they call for the facilitation of web analytics to perform an integration to the scattered resources. Moreover, the educational corporations, both online and offline, could easily get to know how the traffic flow changes every day on their online learning systems[1].

## 10.1 Web Analytics Anatomy

Normally, the history of web analytics could be traced back to last 60s when scientists start to analyze web logs. These logs could be transaction or search types. The transaction type takes direct actions such as user's clicks, how long they have spent on one page into consideration while search type focuses more on the behavior on how the users carry out the searching activities.

Depending on the data provided by the servers, web analytics send small package of data (commonly known as cookies) to the user. Cookies will start collecting data and send them back to the server. Such process is called as server-side data collection. On the other hand, this kind of data collection would render itself not accurate. Internet service provider (ISP) provides IP address to users while user many set blockade to some cookies. To the contrary, client-side data collection is more flexible and can be more accurate. By implanting tags into the website being visited by the client, client-side data collection could carry out more versatile missions.

The word Human Computer Interaction(HCI) have been a buzzword nowadays and it have been embedded into our daily lives. Web analytics could also have utilized such different methods as interviews, questionnaires to establish more convincing reports. Key Performance Indicators (KPI) are set up to differentiate various kinds of web analytics. As of an example, one university that introduced with a new kind of LMS are facing difficulty because too much people are using its social features and it needs some backup support. The web based analysis will be performed to assess the resource the university possesses and evaluate the need to figure how to employ capable person to perform certain kinds of maintenance work as well. The KPI within could be able to indicate how many clicks can one user click before reaching the help page, how long will a user spend on the help page, how easy the help material could be comprehended, how visible are the various icons to the viewer and so on. Then the KPIs are collected and analyzed to compose a report[4].

## 10.2 Web Analytics and Education

In the field of education, web analytics are utilized to form reports that are driven by data to help such functions as facilitating students, managing staffs and supporting researches. Also, web analytics are used to figure out how well a student could perform, how would the student and online tutor would normally interact, how effective one course could be and how well the student is progressing in the course. One specific kind of web analysis is called as academic analytics. It would evaluate the overall performance on an online teaching website to provide information so that administrators could better make decisions.

Learning analytics, as mentioned before, focuses on the collection and analysis of data that have relation to the learners and the courses and learning materials. Learning analytics are also utilized in documenting students' overall learning efficiency in computer facilitated learning and could facilitate student to get accustomed to the online teaching and learning environment better. With big data gained and stored in the systems, learning analytics made many contributions to lots of fields that could help students reaching their academic success. For example, they could note down where the students are now in the middle of a course; if a student misses too much class, they could figure it out and send intervene staff quickly; assess different aspect of the Learning management system; give out help and facilitation that could cater to a student's need[5].

As one way to lead students to academic success, learning analytics could trace all students' activity and other behaviors in the online environment, with data collected via the student information system (SIS). In a class that is one hundred percent online, instructors could fully utilize learning analytic to carry out formative evaluation, which could help the teacher to learn about how the students are performing, how could they make modification to ongoing courses, and how he or she could demonstrate such course materials to the students. An example would be that the teacher could track how many time the student have entering the LMS in the allotted time and use it as evidence of attendance record. Also, the teacher could record how many clicks are carried out in one content page or during one course, or how long the student has spent in different sections of the course. All the data collected above could give out information on how the user behave and how the relations of learners and teaching and learning materials have been. With the deployment of web learning analytic in the LMS, the instructor could figure out abnormal activities of students and give out interventions that cater to the student's needs.

To boost the efficiency of the learning analysis system to the maximum level, learning analytic could also reach to qualitative data such as the discussions in students' forums, students' cooperative wiki pages, and many other social learning assets to form more persuasive and convincing data to website administrators. This requires natural language processing kit (NLTK) to perform semantic analysis so that these qualitative data could be better transcribed into data that would be better analyzed. These data gained could be utilized to perform some higher-level assessments, such as the creativity and critical thinking level of a student[7]. With different teaching and learning goals, KPI could help student, or make modifications of online course in the online learning website with the facilitation of quantitative and qualitative data. They can also

run course diagnose for learners and teachers. The KPI mentioned could be collected and analyzed with such techniques as students' characteristics and performance tracking, investigating a group of students with same traits, giving out content recommendations of learning materials on history activities and make prediction to future developments.

## 11 THE INTELLIGENT TUTORING SYSTEMS

The term intelligent tutoring system are used to describe a computer system that could act as a human mentor to some extent to facilitate a student in getting to understand and have firm understanding of the learning materials. Such system is often designed to make learning with a higher efficiency as well as providing inspiration to students while learning. It requires the support of big data and are considered one of the rising learning technologies in the field[26]. Taking a human mentor for example, he or she will be preparing for the learning material for the student first, then he or she will try the best to get the student motivated for learning. When the student is facing difficulties in learning, he or she will stand out and provide necessary guidance for them to overcome the barrier. Likewise, AI of the intelligent tutoring system could be evaluated and determined whether it could qualify as a human teacher. Such system need to negotiate and communicate with a student to get accustomed to newer conditions, and when a student make requests of learning materials or asks question on certain items, the system will adjust automatically to cater to student's need better. In a word, intelligent tutoring system is different from commonplace e-learning websites as it is more flexible and could provide more detailed education contents. This system could store gigantic amount of data, ready to respond to unique needs of students under different scenarios[12].

### 11.1 Anatomy of the ITS

Such system has provoked the wide interest amongst researcher and programmer thus many have devoted themselves into designing it, which makes one kind of such system greatly differs from another. It is worthwhile to notice that even these systems have distinctive design theories, they are share the similarities of the following elements: domain, learner, pedagogical and interaction model.

Domain model mainly answer the question on how to represent the core knowledge on the computer. It could be demonstrated as flow charts, diagrams, semantic networks, etc. It is mainly consisted of the fundamental logic, strategies and rules to solve ongoing questions. It is the logical core of the system, as it will provide assessment standard when the student's progress is going through evaluation. Moreover, it will also serve as a detector of abnormal behaviors[8].

Learner's model will be demonstrating the systematic evaluation on how well the student is going through one course, what kind of error the student will most likely to make, what kind of learning style the student prefers, what characteristic the student possesses, etc. Such information is collected via students' activities on the system. This kind of model is also utilized in self-regulated learning,

which relies little on the help of other human instructors.

Pedagogical model focuses more on using best teaching and learning strategies to the student according to the teaching environment. It will check on the student's learning progress, and give out appropriate information or facilitation accordingly.

Interaction model, also known as the interactive model are more like a translator between the system and the student. It will need to receive student's input and give out response that could meet the student's needs. Not only this model requires information on the learning material, it would also need information on the common sense of mankind. It was based on verbal texts but nowadays one could identify users' interaction from a variety of sources such as facial expressions, body temperature and moisture, minor gestures, etc.

These four models are all under the management of a database. Moreover, the models are designed under the guidance of different educational theories and uprising technologies. As for interactive model, it is based on various multimedia means. To better understand one student's input, NLTK is involved as well as voice recognition software. AIs are introduced to interactive model to automatically output text and voice messages. Capturing technologies are also involved to capture the student's facial expressions and body gestures. Researchers are also trying to bring virtual and augmented reality to the model. This model involves psychology related content as well as researchers are managing to deploy emotional detection technology to determine one's affection state as it might cast profound impact on the learning effect of an individual. When the internet haven't reached today's popularity, many of the ITS were installed on the PC and cannot get frequent upgrade. Due to the hardware limitations of PCs at that time, the function of such ITS is highly limited, as there was little storage space, and PC didn't have high processing speed at that time[9].

With the rapid development of the internet and PC, ITS have entered an new era as many calculation and data could be processed on the cloud. This have removed the blockade of those who with to be guided by ITS and it is making a growing number of learners benefit from ITS. Nowadays the needed learning materials could be searched and retrieved in no time thanks to ever-developing searching techniques. Moreover, more online wikis are being established which provided supplementary source of domain knowledge to help broaden the borders of domain models.

Learners have also witnessed the rapid development of mobile learning in the field of ITS. Wherever there is internet, learner could easily get in touch with ITS at every corner of the world. As smart cell phones and tablets became almost necessities of everyone, ITS have also taken a leap forward and keep absorbing the newest discoveries in such field as machine learning and big data mining. Learners nowadays could get authentic and quick feedback from ITS, which could be a great motivation to the process of learning.

### 11.2 Designing ITS

To design an ITS system, researchers have to follow certain procedures, which have certain resemblance with designing a learning management system, or a teaching and learning software. It is commonly agreed that such process take place in four steps: Needs

assessment to carry out the anatomy of learner goals and discussion with the instructor and course material designer for the course; Cognitive task analysis to start building models mentioned before, preparing to tackle any issues in the developmental process; Initial mentor implementation to set up the ecosystem of the ITS and to provide learning facilitation; Evaluation to start trial runs of the ITS and to testify the overall steadiness and robustness of the ITS and give out a holistic assessment to the system.

### 11.3 Applying ITS

One of the most outstanding feature of ITS is that it possesses the capability to give out immediate response to students' needs without a human teacher. Moreover, it can also give timely support, choosing different learning goals for students with different demands, giving individualized coaching and provide mental reinforcement. As a consequence, ITS are more likely to be deployed at institutions, army camps, and business where tutoring and mentoring is required in training yet lacks enough human tutor. Ergo, it have a wide spectrum of application, ranging from kindergarten education, to training on jobs, and even lifelong learning. Researchers have profound interest in studying the efficiency and other benefits of ITS. Such aspects of students as how well they could comprehend the course materials, how eager are they when learning about new contents, how much would they devote themselves into learning and how satisfied they will be after the learning are all taken into consideration. They will even arrange human tutoring session to compare the overall efficiency between human and computer tutors. Some researchers have found out that there is only Little difference between the effect of human tutoring and machine tutoring[10].

As the developers have reached the goal of giving response immediately and provide escalated tutoring techniques, they are facing new challenges now. Due to the complexity of such system, ITS is not economy-friendly to design and deploy. As a result, researchers and developers are researching and developing means to make deploying these systems at a lower cost.

### 11.4 Envisioning ITS

As mentioned before, the most vital feature of ITS is it does not require extra human tutor to give help to the student. What is more, it could also generate and comprehend natural language for better communication between the machine and the learners. There are many undiscovered areas for researchers to venture in as the recognition rate of the system are still in a moderate level and still have rooms for development. Also, the natural language output give by the ITS sometimes are not considered authentic enough for students to understand. Researchers are also calling for the research on the identification of students' affection state so that the dialogue may change to different mood the student is in accordingly. The system should also be capable of know how the student will be most motivated, thus planning for motivation strategies.

The researchers also have the ambition to upgrade the ITS from a system to an environment. It could adapt to more kinds of learners, providing more reliable content and support to learners, and have greater flexibility in the tutoring process. The most advanced ITS

could still only function in questions that have clear boundaries and finite solutions. It is all researchers' hope that in the future the ITS will be able to support student with question that have open answers[11].

## 12 CONCLUSION

For centuries, the learning style of countries around the world remains similar. The teachers are served as the center of information. Students go to school to acquire information they otherwise do not know if they just stay at home. That is the reason why behaviorism was proposed as the main theory of learning. However, with the development of science of technology, people have more tools of getting information such as radio, television and movies. Such development pushed educators to revise their educational strategies in order to make education attractive. Then cognitive theory came into being and provided guidance of how to facilitate the process of learning. However, with the increase of publishing of books and the development of affordable and high speed internet, teachers can no longer serve as people who provide information to students in the fast-changing world. Therefore the strategy of teaching must again change the suit the world. The shift is to foster students ability to solve ill-defined problems through collaboration with minimal guidance from instructors and develop meta-cognitive skills. Data mining and recommendation engine have proven their importance nowadays and will continue to shine and make more impact in the foreseeable future in the field of education. The specific field of learning analytic will continue to make more contribution to online learning. However, we must take the ethical use of big data into consideration and make sure we maximize the benefit of big data in education while preventing misusing the data and protect individual's privacy at all costs. Another issue might be the ever-complex algorithms and codes will be a challenge to education specialists and school or learning website admins while the programmer may have limited knowledge in education. However, with the rapid development of educational recommendation system, many new job opportunities will be created, thus encouraging specialists to carry out interdisciplinary research and there will be a growing number of talents that excel both in education theories and programming. It also calls for the tight collaboration between education expert and programmers to make sure that the ever growing education recommendation system backed by big data mining will lead countless of learner to their academic success. The potential of big data on education is still not clear. Although big data have been employed in commerce, healthcare, artificial intelligence and other industries, educators are still waiting to see its implication on learning. However, we can predict big data will bring positive changes to learning as a whole and provide new perspective to instructional design.

## A CONCLUSION OF ROLES IN THE TERM PAPER

In this term paper my partner Weipeng Yang and I participated in the discussion of the general topic of the paper. We finalized the topic through a meeting. Since we are all students of the Instructional System Technology department at the school of education, we reached an agreement that the topic should be how big data can

influence instructional design.

Then in the following meetings we had , we generally came up the the structure of the paper. Instructional design is a subject of education. However, instructional design itself is still a broad topic. Therefore, we want to put our focus on Problem-based learning which is an important learning strategy. In addition, we also took our audience into consideration. The potential readers of the paper are not necessarily in the field of instructional design, so we thought it is important to introduce this field of study, the development of instructional design first. And then we will focus on Problem-based learning and give a few examples.

And because we are not in the field of big data and this field is really strange to us, we wanted to summarize topics involved in big data and then present how big data will influence instructional design.

In this term paper, my responsibility was to focus on the instructional design part and Weipeng was in charge of the big data part. But we also participated in each other's work to keep the group go smoothly.

## REFERENCES

- [1] S Aher and L Lobo. 2013. Combination of machine learning algorithms for recommendation of courses in e-learning system based on historical data. *Knowledge-Based Systems* (2013).
- [2] Bob Burgess. 2011. The Educational Theory of Socrates. (2011). <http://www.newfoundations.com/GALLERY/Socrates.html>
- [3] Hsinchun Chen, Roger H. L. Chiang, and Veda C. Storey. 2012. BUSINESS INTELLIGENCE AND ANALYTICS: FROM BIG DATA TO BIG IMPACT. *MIS QUARTERLY* 36, NO.4 (Dec. 2012), 1168–1169.
- [4] W Chughtai, A Selama, and I Ghani. 2013. Short systematic review on e-learning recommender systems. *Journal of Theoretical & Applied Information Technology* (2013).
- [5] B Clifton. 2008. (2008). <http://www.ga-experts.com/web-data-sources.pdf>
- [6] R S Donner and H Bickley. 1993. Problem-based learning in American medical education: an overview. *Bulletin of the Medical Library Association* 81, 3 (1993), 294–298.
- [7] P Dwivedi and K Bharadwaj. 2013. Effective trust-aware e-learning recommender system based on learning styles and knowledge levels. *Educational Technology & Society* (2013).
- [8] R Ferguson. 2012. Learning analytics: Drivers, developments and challenges. *International Journal of Technology Enhanced Learning* (2012).
- [9] J Gray, T Boyle, and C Smith. 1998. A constructivist learning environment implemented in Java. In *Proceedings of the 6th Annual Conference on the Teaching of Computing and the 3rd Annual Conference on Integrating Technology Into Computer Science Education: Changing the delivery of computer science education* (pp. 94f97).
- [10] T Gunz and M Hollingsworth. 2013. The implementation and assessment of a shared 21st century learning vision: A districtbased approach. *Journal of Research on Technology in Education* (2013).
- [11] M Hofer and N Grandgenett. 2012. TPACK development in teacher education: A longitudinal study of preservice teachers in a secondary M.A.Ed. Program. *Journal of Research on Technology in Education* (2012).
- [12] B Jansen. 2009. *Understanding user-web interactions via web analytics*. San Rafael, CA: Morgan & Claypool.
- [13] A. Januszewski and M Molenda. 2008. *Definition. In Educational Technology: A Definition with Commentary*. New York: Lawrence Erlbaum Associates, Chapter 1, 1–14.
- [14] Dan Kerns. 2013. 10 Ways Big Data is Changing K-12 Education. (2013). <http://www.dreambox.com/blog/10-ways-big-data-changing-k-12-education-2>
- [15] M Kim and E Lee. 2013. A multidimensional analysis tool for visualizing online interactions. *Journal of Educational Technology & Society* (2013).
- [16] K Kingsley and J Brinkerhoff. 2011. Web 2.0 tools for authentic instruction, learning and assessment. *Social Studies and the Young Learner* (2011).
- [17] Tom Krawiec. 2017. The Amazon Recommendations Secret to Selling More Online. (2017). <http://rejoiner.com/resources/amazon-recommendations-secret-selling-online/>
- [18] Harlan M. Krumholz. 2014. Big Data And New Knowledge In Medicine: The Thinking, Training, And Tools Needed For A Learning Health System. *Health Aff (Millwood)* (2014).
- [19] C Lankshear and M Knobel. 2006. *New literacies: Everyday practices & classroom learning* (2nd ed.). New York, NY: Open University Press.
- [20] How Big Data Will Boost Learning and Teaching in Higher Education. 2016. Cogbooks. (2016). <https://www.cogbooks.com/2016/10/05/big-data-will-boost-learning-teaching-higher-education/>
- [21] J Lucas, S Segarra, and M Moreno. 2012. Making use of associative classifiers in order to alleviate typical drawbacks in recommender systems. *Expert Systems With Applications* (2012).
- [22] R Maloy, R Verock-O'Loughlin, S Edwards, and B Woolf. 2014. *Transforming learning with new technologies* (2nd ed.). Boston, MA: Pearson.
- [23] DI Mansur, SR Kayastha, R Makaju, and M Dongol. 2012. Problem Based Learning in Medical Education. *Kathmandu University Medical Journal* 10, 4 (2012), 78–82.
- [24] Bernard Marr. 2015. How Big Data Is Changing Healthcare. (2015). <https://www.forbes.com/sites/bernardmarr/2015/04/21/how-big-data-is-changing-healthcare/#86305c528730>
- [25] M. Molenda and E Boling. 2008. *In Educational Technology: A Definition with Commentary*. New York: Lawrence Erlbaum Associates, Chapter 4, 81–83.
- [26] Office of Educational Technology. 2013. Expanding evidence approaches for learning in a digital world. (2013). <http://tech.ed.gov/files/2013/02/Expanding-Evidence-Approaches.pdf>
- [27] Kaushik Pal. 2016. What is the influence of Big Data in Medicine? (2016). <https://www.kdnuggets.com/2016/03/influence-big-data-medicine.html>
- [28] Evelyn Sakakida RaWski. 1979. Education and Popular Literacy in China Michigan. (1979).
- [29] R. A. Reiser and J. V. Dempsey. 2012. *Trends and issues in instructional design and Technology*: (3 ed.). Boston, MA: Pearson Education, Inc., Chapter What field did you say you were in? Defining and naming our field, 1–7.
- [30] Jeffrey Riegel. 2013. Confucius. (2013). <https://plato.stanford.edu/entries/confucius/>
- [31] C Romero, S Ventura, and E Garcia. 2008. Data mining in course management systems: Moodle cases study and tutorial. *Computers & Education* (2008).
- [32] C Romero, S Ventura, A Zafra, and P de Bra. 2009. Applying Web usage mining for personalizing hyperlinks in Web-based adaptive educational systems. *Computer and Education* (2009).
- [33] J Rountree, N Rountree, A Robins, and R Hannah. 2005. Observations of student competency in a CS1 course. In *Proceedings of the 7th Australasian Conference on Computing Education: Vol. 42*.
- [34] P Saettler. 1990c. *Behaviorism and educational technology: 1950 - 1980*. Englewood, CO: Libraries Unlimited, Chapter 10, 293.
- [35] J. R. Savery and T. M Duffy. 2001. *Problem-based learning: An instructional model and its constructivist framework*. Technical Report 16. Indiana University Bloomington.
- [36] Eric Schadt. [n. d.]. The role of big data in medicine. ([n. d.]). <https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/the-role-of-big-data-in-medicine>
- [37] J Schafer. 2005. *The application of data mining to recommender systems*. Hershey, PA: Idea Group.
- [38] L Schrum and B Levin. 2009. *Leading 21st century schools: Harnessing technology for engagement and achievement*. Thousand Oaks, CA: Corwin.
- [39] S Shum and R Ferguson. 2012. Social learning analytics. *Journal of Educational Technology & Society* (2012).
- [40] G Siemens. 2013. Learning analytics: The emergence of a discipline. *American Behavioral Scientist* (2013).
- [41] K. H. Silber and W. R Foshay. 2006. *Handbook of human performance technology*. San Francisco: Pfeiffer, Chapter Designing instructional strategies: A cognitive perspective, 371.
- [42] B.F. Skinner. 1954. The science of learning and the art of teaching. *Harvard Educational Review* (1954).
- [43] Wikipedia. 2017. Education. (2017). <https://en.wikipedia.org/wiki/Education>
- [44] B. G Wilson. 2012. *Trends and issues in instructional design and technology* (3 ed.). Boston, MA: Pearson Education, Chapter Constructivism in practical and historical context, 45.
- [45] P Winoto, T Tang, and G McCalla. 2012. Contexts in a paper recommendation system with collaborative filtering. *International Review of Research in Open and Distance Learning* (2012).
- [46] Diana F Wood. 2003. ABC of learning and teaching in medicine. *Clinical review* 326 (2003), 328–329.

bibtext report

=====

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib  
Warning--entry type for "Wikipedia2017" isn't style-file defined  
--line 94 of file report.bib  
Warning--entry type for "Riegel2013" isn't style-file defined  
--line 101 of file report.bib  
Warning--entry type for "Burgess2011" isn't style-file defined  
--line 109 of file report.bib  
Warning--entry type for "Schadt" isn't style-file defined  
--line 146 of file report.bib  
Warning--entry type for "Pal2016" isn't style-file defined  
--line 152 of file report.bib  
Repeated entry--line 184 of file report.bib  
: @article{Wikipedia2017  
:  
,  
I'm skipping whatever remains of this entry  
Warning--entry type for "Marr2015" isn't style-file defined  
--line 191 of file report.bib  
Warning--entry type for "clifton2008" isn't style-file defined  
--line 198 of file report.bib  
Warning--entry type for "Office2013" isn't style-file defined  
--line 330 of file report.bib  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing--line 3085 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing--line 3131 of file ACM-Reference-Format.bst

Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001 while executing---line 3131 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001 while executing---line 3131 of file ACM-Reference-Format.bst  
Warning--no number and no volume in Aher2013  
Warning--page numbers missing in both pages and numpages fields in Aher2013  
Warning--no number and no volume in Chughtai2013  
Warning--page numbers missing in both pages and numpages fields in Chughtai2013  
Warning--no number and no volume in Dwivedi2013  
Warning--page numbers missing in both pages and numpages fields in Dwivedi2013  
Warning--no number and no volume in Ferguson2012  
Warning--page numbers missing in both pages and numpages fields in Ferguson2012  
Warning--empty publisher in Gray1998  
Warning--empty address in Gray1998  
Warning--page numbers missing in both pages and numpages fields in Gray1998  
Warning--no number and no volume in Gunn2013  
Warning--page numbers missing in both pages and numpages fields in Gunn2013  
Warning--no number and no volume in Hofer2012  
Warning--page numbers missing in both pages and numpages fields in Hofer2012  
Warning--empty address in Jansen2009  
Warning--empty address in Januszewski2008  
Warning--no journal in Kerns2013  
Warning--no number and no volume in Kerns2013  
Warning--page numbers missing in both pages and numpages fields in Kerns2013  
Warning--no number and no volume in Kim2013  
Warning--page numbers missing in both pages and numpages fields in Kim2013  
Warning--no number and no volume in Kingsley2011  
Warning--page numbers missing in both pages and numpages fields in Kingsley2011  
Warning--no journal in Krawiec2017  
Warning--no number and no volume in Krawiec2017  
Warning--page numbers missing in both pages and numpages fields in Krawiec2017  
Warning--no number and no volume in Krumholz2014  
Warning--page numbers missing in both pages and numpages fields in Krumholz2014  
Warning--empty address in lankshear2006  
Warning--no journal in Learning2016  
Warning--no number and no volume in Learning2016  
Warning--page numbers missing in both pages and numpages fields in Learning2016  
Warning--no number and no volume in lucas2012  
Warning--page numbers missing in both pages and numpages fields in lucas2012  
Warning--empty address in Maloy2014  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end while executing---line 3229 of file ACM-Reference-Format.bst

Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Warning--empty address in Molenda2008  
Warning--no journal in RaWski1979  
Warning--no number and no volume in RaWski1979  
Warning--page numbers missing in both pages and numpages fields in RaWski1979  
Warning--empty address in Reiser2012  
Warning--no number and no volume in Romero2008  
Warning--page numbers missing in both pages and numpages fields in Romero2008  
Warning--no number and no volume in Romero2009  
Warning--page numbers missing in both pages and numpages fields in Romero2009  
Warning--empty publisher in Rountree2005  
Warning--empty address in Rountree2005  
Warning--page numbers missing in both pages and numpages fields in Rountree2005  
Warning--empty address in Saettler1990c  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing---line 3229 of file ACM-Reference-Format.bst  
Warning--empty year in Schadt  
Warning--can't use both author and editor fields in Schafer2005  
Warning--empty address in Schafer2005  
Warning--empty address in Schrum2009  
Warning--no number and no volume in Shum2012  
Warning--page numbers missing in both pages and numpages fields in Shum2012  
Warning--no number and no volume in Siemens2013  
Warning--page numbers missing in both pages and numpages fields in Siemens2013  
Warning--empty address in Silber2006  
Warning--no number and no volume in Skinner1954  
Warning--page numbers missing in both pages and numpages fields in Skinner1954  
Warning--empty address in Wilson2012  
Warning--no number and no volume in Winoto2012  
Warning--page numbers missing in both pages and numpages fields in Winoto2012  
(There were 21 error messages)  
make[2]: \*\*\* [bibtex] Error 2

latex report

=====

[2017-12-12 19.59.53] pdflatex report.tex

## Compliance Report

name: Yang Weipeng  
hid: 236  
paper1: Oct 22 17 - 100%  
paper2: Nov 7 17 - 100%  
project: Dec 4 17 - 100%

## yamlcheck

## wordcount

```
12  
wc 236 project 12 12097 report.tex  
wc 236 project 12 12584 report.pdf  
wc 236 project 12 1481 report.bib
```

```
find "
```

passed: True

```
find footnote
```

---

```
12: \renewcommand\footnotetextcopyrightpermission[1]{} % removes  
      footnote with conference information in first column
```

```
passed: False
```

```
find input{format/i523}
```

---

```
passed: False
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

```
figures 0  
tables 0  
includegraphics 0  
labels 0  
refs 0  
floats 0
```

```
True : ref check passed: (refs >= figures + tables)
```

```
True : label check passed: (refs >= figures + tables)
```

```
True : include graphics passed: (figures >= includegraphics)
```

```
True : check if all figures are refered to: (refs >= labels)
```

```
Label/ref check
```

```
passed: True
```

```
When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction
```

```
find textwidth
```

---

passed: True

below\_check

---

WARNING: figure and above may be used improperly

190: As one way to lead students to academic success, learning analytics could trace all students' activity and other behaviors in the online environment, with data collected via the student information system (SIS). In a class that is one hundred percent online, instructors could fully utilize learning analytic to carry out formative evaluation, which could help the teacher to learn about how the students are performing, how could they make modification to ongoing courses, and how he or she could demonstrate such course materials to the students. An example would be that the teacher could track how many time the student have entering the LMS in the allotted time and use it as evidence of attendance record. Also, the teacher could record how many clicks are carried out in one content page or during one course, or how long the student has spent in different sections of the course. All the data collected above could give out information on how the user behave and how the relations of learners and teaching and learning materials have been. With the deployment of web learning analytic in the LMS, the instructor could figure out abnormal activities of students and give out interventions that cater to the students needs. \\

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--entry type for "Wikipedia2017" isn't style-file defined
--line 94 of file report.bib
Warning--entry type for "Riegel2013" isn't style-file defined
--line 101 of file report.bib
```

```
Warning--entry type for "Burgess2011" isn't style-file defined
--line 109 of file report.bib
Warning--entry type for "Schadt" isn't style-file defined
--line 146 of file report.bib
Warning--entry type for "Pal2016" isn't style-file defined
--line 152 of file report.bib
Repeated entry---line 184 of file report.bib
: @article{Wikipedia2017
:
I'm skipping whatever remains of this entry
Warning--entry type for "Marr2015" isn't style-file defined
--line 191 of file report.bib
Warning--entry type for "clifton2008" isn't style-file defined
--line 198 of file report.bib
Warning--entry type for "Office2013" isn't style-file defined
--line 330 of file report.bib
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3085 of file ACM-Reference-Format.bst
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3085 of file ACM-Reference-Format.bst
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001
while executing---line 3085 of file ACM-Reference-Format.bst
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3131 of file ACM-Reference-Format.bst
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end
while executing---line 3131 of file ACM-Reference-Format.bst
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001
while executing---line 3131 of file ACM-Reference-Format.bst
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001
while executing---line 3131 of file ACM-Reference-Format.bst
Warning--no number and no volume in Aher2013
Warning--page numbers missing in both pages and numpages fields in Aher2013
Warning--no number and no volume in Chughtai2013
Warning--page numbers missing in both pages and numpages fields in Chughtai2013
Warning--no number and no volume in Dwivedi2013
Warning--page numbers missing in both pages and numpages fields in Dwivedi2013
```

Warning--no number and no volume in Ferguson2012  
Warning--page numbers missing in both pages and numpages fields in Ferguson2012  
Warning--empty publisher in Gray1998  
Warning--empty address in Gray1998  
Warning--page numbers missing in both pages and numpages fields in Gray1998  
Warning--no number and no volume in Gunn2013  
Warning--page numbers missing in both pages and numpages fields in Gunn2013  
Warning--no number and no volume in Hofer2012  
Warning--page numbers missing in both pages and numpages fields in Hofer2012  
Warning--empty address in Jansen2009  
Warning--empty address in Januszewski2008  
Warning--no journal in Kerns2013  
Warning--no number and no volume in Kerns2013  
Warning--page numbers missing in both pages and numpages fields in Kerns2013  
Warning--no number and no volume in Kim2013  
Warning--page numbers missing in both pages and numpages fields in Kim2013  
Warning--no number and no volume in Kingsley2011  
Warning--page numbers missing in both pages and numpages fields in Kingsley2011  
Warning--no journal in Krawiec2017  
Warning--no number and no volume in Krawiec2017  
Warning--page numbers missing in both pages and numpages fields in Krawiec2017  
Warning--no number and no volume in Krumholz2014  
Warning--page numbers missing in both pages and numpages fields in Krumholz2014  
Warning--empty address in lankshear2006  
Warning--no journal in Learning2016  
Warning--no number and no volume in Learning2016  
Warning--page numbers missing in both pages and numpages fields in Learning2016  
Warning--no number and no volume in lucas2012  
Warning--page numbers missing in both pages and numpages fields in lucas2012  
Warning--empty address in Maloy2014  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 3 in "DI Mansur, and SR Kayastha and R Makaju, and M Dongol" has a comma at the end  
while executing---line 3229 of file ACM-Reference-Format.bst  
Warning--empty address in Molenda2008  
Warning--no journal in RaWski1979  
Warning--no number and no volume in RaWski1979  
Warning--page numbers missing in both pages and numpages fields in RaWski1979  
Warning--empty address in Reiser2012  
Warning--no number and no volume in Romero2008

Warning--page numbers missing in both pages and numpages fields in Romero2008  
Warning--no number and no volume in Romero2009  
Warning--page numbers missing in both pages and numpages fields in Romero2009  
Warning--empty publisher in Rountree2005  
Warning--empty address in Rountree2005  
Warning--page numbers missing in both pages and numpages fields in Rountree2005  
Warning--empty address in Saettler1990c  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing---line 3229 of file ACM-Reference-Format.bst  
Name 1 in "Savery, J. R., and Duffy, T. M" has a comma at the end for entry Savery2001  
while executing---line 3229 of file ACM-Reference-Format.bst  
Warning--empty year in Schadt  
Warning--can't use both author and editor fields in Schafer2005  
Warning--empty address in Schafer2005  
Warning--empty address in Schrum2009  
Warning--no number and no volume in Shum2012  
Warning--page numbers missing in both pages and numpages fields in Shum2012  
Warning--no number and no volume in Siemens2013  
Warning--page numbers missing in both pages and numpages fields in Siemens2013  
Warning--empty address in Silber2006  
Warning--no number and no volume in Skinner1954  
Warning--page numbers missing in both pages and numpages fields in Skinner1954  
Warning--empty address in Wilson2012  
Warning--no number and no volume in Winoto2012  
Warning--page numbers missing in both pages and numpages fields in Winoto2012  
(There were 21 error messages)

#### bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

---

ascii

---

non ascii found 8220  
non ascii found 8220

```
non ascii found 8221
non ascii found 8217
non ascii found 8220
non ascii found 8221
non ascii found 8217
```

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
-----
```

```
passed: True
cites should have a space before \cite{} but not before the {
```

```
find cite {
-----
```

```
passed: True
```

# Big Data Analytics in Monitoring Outdoor Air Quality

Janaki Mudvari Khatiwada  
Indiana University, Bloomington  
P.O. Box 1212  
Bloomington, Indiana 43017-6221  
jmudvari@iu.edu

## ABSTRACT

Outdoor air pollution is one of the risk factors of public health. Air pollution adds burden to public health. Both developing and developed world use new technology and expertise to monitor outdoor air quality. United States Environmental Protection Agency (USEPA) collects outdoor air quality data from state, local and tribal agencies through outdoor air quality monitors across the country. The data get collected into the Air Quality System (AQS) database. This data can be used for variety of purposes such as education, research and regulatory. Data from this data-mart is available for different time-series like hourly, daily, weekly, monthly and yearly. It gives us a real picture of outdoor air quality and measurements of pollutants present in the air in a particular time period. The data can be used for comparing air quality among different regions, raise awareness to general public so that they can play a role in reducing household air pollutants, to see the trend of air pollutants at different time periods in a day or a season, it can also be combined with emissions data for comparative study. Data analysis of pollutants help identify pollution hot spots. Since air quality is vital for public health and environmental health, air quality monitoring possesses great significance from public health perspective. It is worth looking at simple statistical values and level of air quality index value for the pollutants described as criteria pollutants as described by World Health Organizations. Simple statistical calculations in bigger datasets help understand the extent and source of problem. It helps in comparing past statistics with the present so helps in evaluations of action being taken during past periods. Looking at the overall mean value of criteria pollutants of 2016 and 2006 reveals improved air quality level to some extent for all core-based statistical areas. But the mean value of carbon monoxide has significantly increased over the ten years period.

## KEYWORDS

i523, hid330, Outdoor Air Quality, Big Data, Air Quality Index

## 1 INTRODUCTION

Outdoor air is a valuable natural resource that is vital to the health and existence of human beings and other forms of life. The outdoor air not only has clean air but has presence of various pollutants. Several health research have revealed that air pollutants are contributing factors for lung cancer, cardiovascular disease, acute and chronic respiratory conditions. World Health Organization (WHO) in 2013 has assessed that air pollution is carcinogenic to humans [14]. "In 2012 WHO estimated that 72 percent of outdoor air pollution-related premature deaths were due to ischaemic heart disease and strokes" [14]. Being aware of this fact, governments along with the scientists and the environmentalists help make policies to

combat air pollution. Each country has set their own standards for outdoor air quality to protect their citizen's health. Every nation's standards depend upon their economic, cultural, social and political needs. "The United States enacted its Clean Air Act (CAA) in 1970 and was amended in 1990 as a way to set stage for combating air pollution challenges" [1]. Since then, the country has made a lot of progress in improving air quality while sustaining a constant economic growth. After the enactment of CAA significant progress has been made in improving the outdoor air quality, reducing emissions levels from vehicles and power-plants. Over the period of 1990 and 2015, "national concentrations of air pollutants improved 85 percent for lead, 84 percent for carbon monoxide, 67 percent for sulfur dioxide (1-hour), 60 percent for nitrogen dioxide (annual), and 3 percent for ozone" [1]. Particulate matters "concentrations (24-hour) improved 37 percent and coarse particle concentrations (24-hour) improved 69 percent" between 2000 and 2015 [1]. Today, United States, European nations, India, China and other developing countries monitor outdoor air quality and use the collected data for identifying the particles present in the air, their contribution to various health problems, their sources, health research and also to find out the solutions to minimize their production level.

Thousands of air quality monitors are placed across the united States including US Virgin Islands and Puerto Rico. They are stationed based upon the significance of air quality effects on health. These monitors stream outdoor air quality data to a national air database system called Air Quality System (AQS). As a result big outdoor air data is generated constantly everyday. Air Quality System database is a national database where state, local and tribal agencies submit all of the data collected from thousands of air quality monitors across the United States. These huge databases are easily accessible in EPAs air data website via AQS. Besides air data, AQS database system has weather and emissions data. Emissions data provides data from vehicular, industrial and powerplants emissions records. Weather plays an important role in the quality of outdoor air. For example, high wind may disperse concentration of chemical particles. AQS database also called AQS Data Mart, has summary of yearly air quality data since the year of 1957. These data give an understanding of outdoor air quality and different particles present in the air and their sources. Source of air particles can be natural or human generated. Pollen, smoke from wildfires, mold, dust are some of the natural air pollutants. Similarly, emissions from power-plants, industries and vehicles, different substances and solutions that human have generated for various purpose are human generated air pollutants.

To set standard for air quality, Air Quality Guidelines was published by WHO in 1987 and have been revised in 1997 [11]. WHO guidelines set an international standard for air quality based on which countries around the world set their own standards to achieve

the goal set by WHO. Nitrous Oxide (NO<sub>2</sub>), Sulphur dioxide (SO<sub>2</sub>), Carbon Monoxide (CO), ground level Ozone, Particulate Matter (PM) among others, are some of the common hazardous air pollutants. Particulate matters are categorized into two categories, PM2.5 and PM10, based on the size of fine particle. Based on the value of Air Quality Index (AQI), USEPA has classified Outdoor air quality, AQI level as ‘Good’, ‘Moderate’, ‘Unhealthy for sensitive Groups’, ‘Unhealthy’, ‘Very Unhealthy’ and ‘Hazardous’ [7]. The AQI value range from 0 to 500. The agency has assigned colors (‘Green’, ‘Yellow’, ‘Orange’, ‘Red’, ‘Purple’ and ‘Maroon’ respectively) to each of the air quality categories [7]. It is shown in figure 2.

## 2 BIG DATA AND OUTDOOR AIR QUALITY

In US there are about 4,000 outdoor air quality monitors operated by state environmental agencies [6]. They constantly collect air data on harmful suspended particles present in the air and send them to a national database center which is AQS database. EPA has air quality database from last 27 years from around the states [2]. The size of EPA’s database is 25 GB. The data contains valuable information about the concentrations of different air pollutants in different time series; hourly, daily, weekly and yearly. Besides air quality data, AQS database also contains emissions data and weather data which are vital to the outdoor air air quality. Emissions data is basically data from vehicular and industrial emissions. They help to understand the source of different air pollutants and their role in air quality as well as they can be used for furthering research in limiting their emissions. Yearly summary data of AQS Data Mart can also be used to see the progress made in reducing harmful air pollutants over the years. For example, EPA reported that emission of SO<sub>2</sub> has reduced by 73 percent from 1990 to 2011 which is resulted primarily from electric utilities. Study of Emissions and air quality data gives an insight into the source of air pollutants and scientists can use these data to build a better industrial and vehicular models that reduces the emissions of pollutants. Similarly policy makers set vehicle emissions standards and industrial waste management.

India and China, two bigger economies in the world are battling worst air pollution. In recent years IBM is doing collaborative work with local authorities to combat air pollution in cities like Delhi, Beijing and Johannesburg by providing its data analysis platform called ‘Green Horizons’ [3]. The platform uses machine learning tools to analyze past weather forecasts data along with real time data from optical sensors, air quality monitors and satellites to understand past forecasting models and build a better prediction models for future forecasts [3]. This prediction model helped Beijing enforce air quality control measures on traffic, construction and industry.

Weather directly affects outdoor air quality. For example in a windy day PMs can easily be spread in a neighboring regions and high temperatures increases ground level ozone [3]. Similarly, another example of relationship between big data analysis and air pollution is use of Microsoft’s tools in incorporating Beijing’s outdoor air data collected from conventional monitors along with data from “environmental monitoring stations, traffic systems, weather satellites, topographic maps, economic data, and even social media” [4].

Furthermore, OpenAQ is another platform besides EPA–AQS repository, which holds and hourly updates near–live air quality data from around the world. It claims to have “collected 133,494,377 air quality measurements from 8,054 locations from 47 countries. Data are aggregated from 98 government level and research-grade sources” [2]. The platform helps general public identify global hotspots for poor air quality and allow to have a look at the outdoor air quality where they live [2]. There is another open forum site called ‘Air–Now International’ where users from around the world can participate in sharing and information about air quality data. “It is an international version of USEPA’s air now system”[8]. Big volume of EPA’s data can be combined with another big data, census data to find out the portion of population breathing polluted air. This gives an understanding of health effects among general public. Since, monitoring stations generate big volume of air pollution data and regularly stream into, EPA’s open source, air database, any concerned individual can access live raw data from the website to find out about the quality of air they are breathing.

## 3 AIR POLLUTANTS

EPA has prioritized six major air pollutants that are commonly found all over the US. They pose significant threat to public health and environment. They are called ‘Criteria Pollutants’ and they are ground level ozone, fine particles or particulate matter (PM2.5 and PM10), nitrogen dioxide, sulphur dioxide, lead and carbon monoxide [1]. WHO has set the guidelines for each of these pollutants as shown in figure1.

PM<sub>2.5</sub> are particles less than or equal to 2.5 micrometers in diameter while PM 10 are particles less than or equal to 10 micrometers. “Sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water are the main components of PM ” [14]. These components combine with each other to form variety of mixtures in the air and can easily enter our lungs. Longer exposure to these substances increases the risk of lung cancer and cardiovascular disease [14].

Data on emissions from powerplants, industries and motor vehicles shows that emitted pollutants like various volatile substances and various forms of nitrogen oxides (NO<sub>2</sub>) are responsible for the formation of ground level ozone. Chemical reactions between these substances create ground level ozone directly in the air [1]. Chest pain, coughing, throat irritation and inflammation are common problems caused by ozone air pollution. The main source of NO<sub>2</sub> is emissions from heating, power generation and engines in vehicles and ships. SO<sub>2</sub> is another air pollutant produced mainly from burning of fossil fuels. Volcano is a natural resource so<sub>2</sub> release in the outdoor air. Longer exposure to this pollutant causes inflammation of respiratory tract [14]. The data on these pollutants have been regularly analyzed to see their trend. They have also been used in health research to have an understanding of their impact on people’s health. Keeping track of problems and source of problems help us in keeping problem at check. Some air pollutants are characterized as hazardous or toxic air pollutants. Some of the examples include benzene, cadmium, mercury, lead and asbestos.

## 4 HEALTH HAZARDS

Air pollutants, such as hazardous air particles can easily reach our lungs when we breathe. The effects are itchy, irritated throat, nose and inflammation of respiratory tract. Pollutants such as PM 20 block our airtubes. These pollutants badly affects people with asthma and bronchitis. WHO had estimated that in 2012, 3 million premature deaths worldwide due to outdoor air pollution, particularly due to exposure to particulate matter of 10 microns or less [14]. And in 2014 WHO has reported 7 million premature deaths worldwide [14]. Other pollutants such as lead, pesticides, arsenic also called as toxic pollutants are carcinogenic hence are responsible for lung cancer which is one of premature deaths. Carbon monoxide a very common air pollutant generated by combustion has been called a silent killer. Its health effects include nausea, vomiting and reduced neuro and cardiovascular behavior as it blocks oxygen transfer inside the body thereby might lead to death without knowing the real cause of death. Exposure to higher level of ground level ozone have serious health issues, while it affects people with asthma and bronchitis, other groups of people also experience coughing, shortness of breath, eventually inflammation of airways and development of chronic obstructive pulmonary disease [9].

Sulphur dioxide (so<sub>2</sub>) is a highly poisonous gas present in ambient air. It is a byproduct of burning of sulphur or product containing sulphur. Its main source is burning of fossil fuels especially in the powerplants and other industrial facilities. This pollutant can harm the environment by causing acid rain [10]. It harms human health by causing breathing difficulty and coughing. It combines with other particle pollutants present in the air causing haze.

## 5 AIR QUALITY INDEX

AQI is the index, for five major air pollutants discussed above, calculated by special formula developed by EPA. EPA uses its own formula to convert daily concentrations of measurement of each pollutant into AQI value of each pollutant [7]. Among all the highest AQI value is reported as the daily AQI value for that day [7]. Generally AQI 100 is the acceptable index set by EPA to protect public's health and it ranges from 0 to 500 [7]. The higher the value of AQI, greater is the pollution level and greater is the health risk. Based on hourly data collection from air quality monitors, stakeholders can constantly monitor AQI value in their cities or respective location. So weather channels in different media outlets such as local radio, television stations and newspapers also report about AQI index in order to inform general public about air quality in their area. Figure 2 shows the AQI classification for each pollutant as recommended by WHO and implemented by U. S. EPA. EPA is requires to report any AQI value greater than 100 specifically in larger cities with population more than 350,000 [7].

## 6 OUTDOOR AIR QUALITY MONITORING STATIONS

Outdoor(Ambient) air quality monitors are specified based on the significance of monitoring a particular pollutant [8]. The purpose might be to protect public health or environment in a densely populated areas. They might be stationed nearby, schools, hospitals, parks and recreational areas. While they are operated by several different agencies they are regulated by U. S. EPA. According to

EPA these stations should meet all the requirements for designs and operations as regulated by EPA themselves. These stations not only provide data on air quality they help in evaluating the effectiveness of programs and policies on emissions control.

## 7 WHO GUIDELINES AND CLEAN AIR ACT

WHO guidelines for air quality is applied worldwide. This guidelines was revised in 2005 [14]. The guidelines set standards for different air pollutants. According to the guidelines which is based on scientific evidence WHO has set standards for Ozone (o<sub>3</sub>), SO<sub>2</sub>, NO<sub>2</sub> and PM. WHO guidelines try to limit the lowest possible values for these pollutants. For example WHO limit values for PM2.5 is 10 micrograms per cubic meter is annual mean and 25 micrograms per cubic meter is 24-hour mean and limit value for PM10 is 20 micrograms/m<sup>3</sup> annual mean and 50 micrograms/m<sup>3</sup> 24-hour mean [14] 1. "The 2005 WHO Air quality guidelines" offer global guidance on thresholds and limits for key air pollutants that pose health risks. The Guidelines indicate that by reducing particulate matter (PM10) pollution from 70 to 20 micrograms per cubic metre, we can cut air pollution-related deaths by around 15 percent [14].

United States' Clean Air Act (CAA), first enacted in 1970 and with major revisions in 1990, is a federal law which is defined as "The Act that regulates air emissions from area, stationary, and mobile sources" [1]. CAA . EPA is the administrator of CAA [12]. As required by law, EPA regulates emissions standards for vehicles, industries, aircrafts and powerplants among others in order to protect environment and public health. Today, with the availability of new technology and analytical tools air quality data from the monitors across the regions can be accessed in an instant and can be analyzed for daily reporting. Based on daily AQI value, respective authorities can take appropriate actions to save outdoor air quality in areas where pollution level is insignificant and to identify measures to be taken in areas where air quality is poor.

## 8 METHODS

### 8.1 Air Quality Dataset

Outdoor air quality data sets are available in the USEPA.gov website called 'Air Data'. The data on 'Air Data website comes from AQS database where outdoor air data generated from thousands of air quality monitors from all over the country is collected. As mentioned, all states, local and private monitoring agencies send outdoor pollutants concentrations measurement data to the AQS database [1]. Besides, Air Data there are other sources of data as well, they are briefly discussed below;

- 'Air Now' which has air quality forecasts and real-time data in visual form.
- 'AirCompare' that has data about Counties' AQI summaries.
- 'AirTrends' data is about trends of air quality and emissions.
- 'Air Emissions Sources' has emissions data with national, state and county-level summaries for criteria pollutant emissions.
- 'Remote Sensing Information Gateway (RSIG)' that has air quality monitoring, monitoring and satellite data.
- 'Air Data' datasets have raw dataset, AQI summary datasets. Summary reports consists of AQI report which displays a

- yearly summary of AQI values in a county or city or Core Based Statistical Area (CBSA). The AQI values are summarized by maximum percentile and median and count of days in each AQI category and the count of days when AQI could be attributed to each criteria pollutant [1].
- “ Quality Statistics Report has yearly summaries of air pollution values for a city or county. It shows the maximum values reported during the year by all monitors in CBSA or county” [1].
  - Monitor Values Report that has yearly summary of the measurements at individual monitors and has descriptive information about the site [1].
  - Monitor Values Report-Hazardous Air Pollutants that shows HAPs summary data for individual monitoring sites [1].
  - Air Quality Index Daily Values Report that has information about AQI values for specified year and location [1].

The dataset that are being used for analysis are “Daily AQI by CBSA 2016” and “daily AQI by CBSA 2006”, from EPA’s air data website. Air data has different categories of outdoor air quality data. There are datasets for hourly as well as monthly time period broken down by single criteria pollutant of ‘Hazardous Air Pollutants’ (HAPs). There are county level monitors and stations and datasets grouped by “Core Based Statistical Area (CBSA)”. Each datasets have more than 17,000 data points.

CBSA is designed by Office of Management (OMB) as a geographical area that consists of one or more than one counties and similar surroundings that are associated with at least one core urbanized area of at least 10,000 population plus adjacent counties which are associated with each other in terms of social, economic and daily commutes [5]. CBSA collectively refers to Metropolitan and Micropolitan statistical areas. “OMB defined Metropolitan and Micropolitan statistical areas in 2003 based on application of the 2000 standards with Census 2000 data. It became effective in 2003” [5]. There are 922 CBSAs in total [5]. Metropolitan statistical areas are urbanized areas with population of 50,000 and its adjacent areas while Micropolitan statistical areas are areas with population of at least 10000 or less than 50,000 [5].

CBSA AQI datasets fits the scenario for monitoring outdoor air quality. Because the designed statistical areas are significantly populated along with higher concentrations of motor vehicles running, higher number of day to day activities, less natural habitats or and most of the areas are within industrial areas and powerplant generators. Also, the first look at the dataset give a general information about AQI value of each ‘Criteria Pollutant’ for a day in a year of each monitoring stations in CBSAs.

## 8.2 Methods

The comma separated dataset “daily aqi by cbsa 2016” was downloaded from data source “<https://aqs.epa.gov/aqsweb/airdata>”. The dataset shows AQI value of each “criteria pollutants” for each CBSA recorded per day per station for the year 2016. Criteria pollutants recorded in the dataset are, PM2.5, PM10, Ozone, SO2, NO2 and CO. It also has a column for number of stations for each CBSA and location of the monitoring stations per CBSA.

In order to have a comparative study of any changes in AQI value for each parameter for the listed CBSA, dataset for the year

2006 is also being analyzed. This gives us a picture of changes if any for the duration of 10 years. Since real world datasets may not be perfect, there are slight or negligible amount of discrepancies among the two datasets. Criteria pollutants recorded in the dataset varies within each CBSAs depending on their significance in the region or monitoring stations. Similarly, record date per station per CBSA is not continuous, there are certain interval for recording and reporting data. For example, data is recorded on January 1st 2016 and the next date is January 3rd and 6th and so on. This pattern is seen in the whole dataset. Also, number of monitoring stations varies per CBSAs.

Using jupyter notebook with python2.7 as the interpreter, the dataset is fetched and converted into pandas dataframe for and analysis. Next, only the columns needed for analysis are selected and created a clean pandas dataframe ready for manipulation. Jupyter Notebook is an open source web application which is powerful in data cleaning, manipulation, data analysis and visualizations. The notebook is not sufficient in itself for a variety of data manipulations, it needs to have all sorts of python packages as per requirement of data analysis. Matplotlib, pandas, numpy and pandas datetime are the packages used for air quality data analysis.

## 9 ANALYSIS

The requirements for the analysis are python’s jupyter notebook and the packages pandas, matplotlib and numpy. Using the pandas dataframe, average AQI value is calculated for each ‘Defining Parameter’ grouped by CBSA. Since AQI value determines the level of risk factor as shown in figure 2, it is worth calculating the mean of that value which helps in determining which CBSA is affected by which ‘defining Parameter’. It also helps identify the source of the pollutant so that responsible stakeholders can take required actions to solve the problem. The purpose of using the data set is to find out level of AQI per CBSA for the year 2016. The reason of using 2016 data set is it the most recent complete set of data for a year. While 2017 data set would have been the most recent look at AQI level in the United States but as of this analysis the 2017 data set contains air quality data until the month of May 2017. This data set wold be completed as a full years data only in the upcoming spring [6]. In order to do a general comparison of the changes, positive or negative, if any similar data set for the year 2006 is selected. This would allow us to look at differences in AQI values in a decade time frame.

### 9.1 CBSA Average AQI for 2016

Simple statistical measures such as mean, maximum, count and minimum value for any variable provides some insights into the degree of variation between each measure of the variable within a period of time. So, as a first test mean value of “Criteria Pollutants” for all the listed CBSAs have been calculated. Then the results have been plotted into a bar-chart as shown in figure 5. It shows that among all, Ozone and PM 2.5 have highest average among CBSAs while CO, NO2, SO2 and PM10 have slightly lower average AQI for the year 2016.

Furthermore, figure 3 illustrates the average AQI value for overall CBSAs for the year 2016 by month. The table illustrates that AQI value, which is 53.56, for Ozone is the highest during the month of

June of last year. This AQI value of ozone comes under the category of 'unhealthy for sensitive groups'. This value is followed by CO which has the highest mean value for two consecutive months, May and June. From the table it can be said that during 2016 the most significant criteria pollutants were Ozone, CO, and PM2.5.

In order to look at monthly average AQI per 'Defining Parameter', first 'Date' series is converted into pandas datetime format and then the series is bucketed into month of the year column. Then mean is calculated by using 'groupby' function, mean is calculated grouped by 'Defining Parameter' and 'month of year'. The result illustrated in figure 7 shows that there is no significant change in mean AQI for SO2 and PM10 while significant change can be seen for CO and Ozone. AQI average for CO shows a sharp increase in May.

For the purpose of finding out CBSA with highest and lowest average AQI value for the year 2016, for specified pollutant, aggregate function is used with groupby function with descending value of AQI. The result is shown in figure 9. The table shows CBSA 'Madison, WI' has lowest AQI value for SO2, followed by Fayetteville, NC for the same parameter. Similarly, as seen figure 10 Hilo, Hawaii has the highest AQI value for parameter SO2 which is 151.79. This means AQI value is unhealthy and people may experience health effects with sensitive groups people with asthma, bronchitis and chronic obstructive pulmonary disease (COPD) might have very serious health effects as stated in figure 2. The reason for highest AQI value for SO2 might be the release of SO2 gas from active volcanoes around the CBSA region as SO2 is one of the gases released from volcanoes. Hilo, HI is followed by 'Riverside– San Bernardino–Ontario, CA with AQI value 126.53 for 2 with category 'unhealthy'. Other CBSAs in the top ten list are Lansing–East Lansing, MI, San Juan–Carolina–Caguas, PR, Bishop, CA, Durango, CO, Riverside–San Bernardino–Ontario, CA, Philadelphia–Camden–Wilmington, PA–NJ–DE–MD, Los Angeles–Long Beach–Anaheim, CA and Minneapolis–St.Paul–Bloomington, MN–WI. All of these CBSAs have at least one defining parameter with 'Unhealthy' AQI value. It is also significant that Riverside–San Bernardino–Ontario, CA have two highest AQI value for two defining parameters that is ozone and PM 10.

In order to have a visual picture of level of AQI value, count measure is used grouped by 'CBSA', 'Defining Parameter' and 'Category' and visualized the result in a boxplot. This basically counted number of days in each category of AQI. The figure 11 shows, that there are significant number of 'good days' during 2016 followed by 'moderate', 'unhealthy for sensitive groups' and rest of the three categories have less range of days. As seen in bar chart the mean value for Ozone is higher for the months May and August in comparison to other pollutants Columns for the months of June and July are missing at this point.

## 9.2 Comparative AQI for 2006 and 2016

To compare AQI per CBSA for criteria pollutants, exactly similar data set for the year 2006 is used to calculate average AQI value and plotted into a bar chart which is shown in figure 6. As the result can be compared with that of 2016. average AQI value for ozone and SO2 is significantly higher compared to 2016 while that of carbon monoxide (CO) has increased significantly from 2006 to 2016. For other parameters there are not so significant changes.

Similarly, average AQI for SO2 is also higher in 2006 compared to 2016. There is also some changes in overall average AQI value. This figure shown here 4 illustrates the AQI average for the year 2006. As seen in barplot this figure shows the highest mean for Ozone at the top of the list when mean is grouped by month of the year and output is sorted in descending order by mean. Interestingly, most of the highest mean value are for the month of June, July and August. To be more specific AQI value for Ozone is mostly during above listed months. Similar result can also be seen in the analysis of 2016 dataset.

While comparing top ten CBSA with highest average AQI value for 2016 with that of 2006, top ten CBSAs with highest average AQI for 2006 is shown in figure 8. Compared to 2016 there is no sharp increase in mean value for CO any of the month as has been in 2016. Its mean value remains comparatively in same range, in between 17 and 16. Whereas, the value for Ozone is significantly higher for the months of March, April, May, August and September. For other months as well it has higher level of mean AQI compared to other pollutants except for SO2 which has the second highest AQI throughout the months. Average value for all of the pollutants throughout the months have higher values compared to that of year 2016 except for CO. Average CO AQI for 2016 is higher than that of the year 2006.

Another comparison can be done by looking at the list of top most CBSAs with higher mean AQI. We have already discussed about this for year of 2016. Now we will look at similar output for 2006 which is shown in figure 12. The mean output is generated by grouping the CBSA and defining parameter. Here, Bishop, CA has highest yearly average for PM10 which is 435.21 followed by CBSA Phoenix–Mesa–Scottsdale, AZ, Carlsbad–Artesia, NM have yearly mean value of 127 for SO2. In comparison to the same statistics for year 2016, mean value is lower than that of 2006. This indicated that there is progress made in lowering the measurement in air pollutant.

## 10 FURTHER STUDIES

It would be effective to look at the factors that helped lower the mean AQI value within a decade. Are there any policy differences between now and then? Are there less economic activities compared to 2016 or did any of the technology have any role to play to make such change? It would be effective to look at the factors that helped lower the mean AQI value within a decade. As can be seen from the analysis above average ozone has highest average value among all. Finding out or looking at the contributing factors can be another area of furthering this research. and it would be interesting to see any changes if any during the year of 2017. The analysis presented here showcases just the level of pollutants by AQI value. For furthering the studies different models for lowering AQI value for a single pollutant within certain periods of time can be developed. Since vehicular, industrial or air transportation emissions are some of the main sources of criteria pollutants, it would be very effective to analyze monthly emissions data with AQI data to have an understanding of level of pollutants generated from these sources. This analysis can be combined with weather data in order to find out the effects of weather or seasonal variations on increasing or lowering pollutants. There is an increased AQI value

for CO from 2006 to 2016. Factors responsible for poor AQI value can be the next research topics.

Looking at difference in emissions policy during the past decade will also provide some insight into why certain parameters have lower AQI value. Looking at effects of AQI value in international boundaries that is effect evaluation of pollutants of country affecting the air quality of surrounding country could be a whole new topic of outdoor air quality study.

## 11 CONCLUSION

Air quality monitors across the United States and its territories, Puerto Rico and Virgin Islands collects everyday air data in order to collect data on pollutants present in outdoor air. These generates a huge volume of data. Air data contains measurements of concentrations of pollutants, commonly called as criteria pollutants, present in outdoor air. These monitors are under the management of state, local or private environmental agencies. They collectively send these data to a national database system called air quality system. For analytical purpose the air data from the AQS website which is an source of air data, is directly accessed through jupyter notebook. Simple statistical measures are calculated to have a look at the level of pollutants present in ambient year.

The air data by CBSA, for the year of 2016 have been analyzed to see the average value of AQI for each defining parameter or criteria pollutants. This analysis identifies that average AQI value for Ozone is significantly higher compared to other pollutants. The analysis also shows that AQI value varies by month of the year. The results shows that Ozone AQI is higher in the months of March to August. While calculating overall average AQI, among all of the criteria pollutants level of ground level ozone has the highest value during the year of 2016 as well as 2006. It can also be concluded that overall level of AQI value have been improved over the years period while comparing the value from 2006 with that of 2016. Interesting enough AQI value of CO have been significantly increased from 2006 to 2016.

Air quality monitoring have become an important and effective policy for reducing the concentrations of different criteria pollutants. Since the adoption of clean air act in United States significant progress has been made in improving outdoor air quality. Thereby reducing the development of health risk factors for general public. Air quality monitoring stations collect everyday measurement values of criteria pollutants which generates a big volume of air data. This gives us information on daily level of pollutants present in the air thereby letting us know the quality of air that we breathe everyday. This information is shared to the public through various media outlet. This raise awareness among general public about the importance of outdoor air and their health.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski for his motivating words and attitude and support to achieve our best. Also I would like to express my gratitude to teaching assistants Juliette Zerick, Saber and Miao for their encouraging attitude and technical support and suggestions while writing this paper.

## REFERENCES

- [1] United States Environmental Protection Agency. 2017. Overview of the Clean Air Act and Air Pollution. Webpage. (April 2017). <https://www.epa.gov/clean-air-act-overview>
- [2] Mike Hamborg. 2017. *U.S. EPA and OpenAQ air quality data now available in BigQuery*. Technical Report. Google Cloud Platform. <https://cloud.google.com/blog/big-data/2017/06/us-epa-and-openaq-air-quality-data-now-available-in-bigquery>
- [3] Alexander Howard. 2015. *How IBM Is Using Big Data To Battle Air Pollution In Cities*. Report. HuffPost. [https://www.huffingtonpost.com/entry/ibm-big-data-air-pollution\\_us\\_56684e44e4b080edd565510](https://www.huffingtonpost.com/entry/ibm-big-data-air-pollution_us_56684e44e4b080edd565510)
- [4] Lucas Laursen. 2016. *AI and Big Data vs. Air Pollution*. Technical Report. IEEE-org. <https://spectrum.ieee.org/energy/environment/ai-and-big-data-vs-air-pollution>
- [5] United States Census Bureau. 2012. Geography. webpage. (December 2012). [https://www.census.gov/geo/reference/gtc/gtc\\_cbsa.html](https://www.census.gov/geo/reference/gtc/gtc_cbsa.html)
- [6] United States Environmental Agency. 2017. Air Data Basic Information. webpage. (October 2017). <https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information#what>
- [7] United States Environmental Protection Agency. 2016. webpage. (August 2016). <https://airnow.gov/index.cfm?action=aqibasics.aqi>
- [8] United States Environmental Protection Agency. 2016. Air Quality Management Process. webpage. (August 2016). <https://www.epa.gov/air-quality-management-process/managing-air-quality-ambient-air-monitoring>
- [9] United States Environmental Protection Agency. 2017. Health Effects of Ozone Pollution. webpage. (January 2017). <https://www.epa.gov/ozone-pollution/health-effects-ozone-pollution>
- [10] United States Environmental Protection Agency. 2017. Health Effects of Ozone Pollution. webpage. (January 2017). <https://www.epa.gov/so2-pollution/sulfur-dioxide-basics#effects>
- [11] WHO. 2005. Air quality guidelines global update 2005. Webpage. (2005). [http://www.who.int/phe/health\\_topics/outdoorair/outdoorair\\_aqg/en/](http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/)
- [12] Wikipedia. 2016. Clean Air Act (United States). webpage. (2016). [https://en.wikipedia.org/wiki/Clean\\_Air\\_Act\\_\(United\\_States\)](https://en.wikipedia.org/wiki/Clean_Air_Act_(United_States))
- [13] World Health Organization. 2005. *Air quality guidelines Global update 2005 Particulate matter and ozone and nitrogen dioxide and sulfur dioxide* (2005 ed.). WHO, UN City Marmorvej 51 DK-2100 Copenhagen Denmark. <http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines-global-update-2005>.
- [14] World Health Organization. 2016. Ambient (outdoor) air quality and health. Webpage. (September 2016). <http://www.who.int/mediacentre/factsheets/fs313/en/>

[Figure 1 about here.]

[Figure 2 about here.]

[Figure 3 about here.]

[Figure 4 about here.]

[Figure 5 about here.]

[Figure 6 about here.]

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

[Figure 10 about here.]

[Figure 11 about here.]

[Figure 12 about here.]

## LIST OF FIGURES

1	WHO Guidelines Source And Health Effects [13]	8
2	Air Quality Index [7]	9
3	Top Ten Mean AQI Value for the Year 2016	10
4	Top Ten Mean AQI Value for the Year 2006	11
5	CBSA Average AQI for Criteria Pollutants	12
6	CBSA Average AQI for Criteria Pollutants 2006	13
7	Mean AQI per Month per Criteria Pollutant 2016	13
8	Mean AQI per Month per Criteria Pollutant 2006	14
9	Lowest Mean AQI per CBSA 2016	14
10	Highest Mean AQI per CBSA 2016	15
11	Boxplot Grouped by Category, 2016	16
12	Highest Mean AQI per CBSA 2006	17

Pollutant	Source types and major sources	Health effects	WHO guidelines
Particulate matter	Primary and secondary- Anthropogenic: burning of fossil fuel, wood burning, natural sources (e.g., pollen), conversion of precursors (NO <sub>x</sub> , SO <sub>x</sub> , VOCs) Biogenic: dust storms, forest fires, dirt roads	Respiratory symptoms, decline in lung function, exacerbation of respiratory and cardiovascular disease (e.g., asthma), mortality	PM <sub>10</sub> Annual mean: 20 µg/m <sup>3</sup> 24-hour mean: 50 µg/m <sup>3</sup> PM <sub>2.5</sub> Annual mean: 10 µg/m <sup>3</sup> 24-hour mean: 25 µg/m <sup>3</sup>
Ozone	Secondary- Formed through chemical reactions of anthropogenic and biogenic precursors (VOCs and NO <sub>x</sub> ) in the presence of sunlight	Decreased lung function, increased respiratory symptoms, eye irritation, bronchoconstriction	8-hour mean: 100 µg/m <sup>3</sup>
Nitrogen dioxide	Primary and secondary- Anthropogenic: fossil fuel combustion (vehicles, electric utilities, industry), kerosene heaters Biogenic: biological processes in soil, lightning	Decreased lung function, increased respiratory infection Precursor to ozone. Contributes to PM and acid precipitation	Annual mean: 40 µg/m <sup>3</sup> 1-hour mean: 200 µg/m <sup>3</sup>
Sulfur dioxide	Primary Anthropogenic: combustion of fossil fuel (power plants), industrial boilers, household coal use, oil refineries Biogenic: decomposition of organic matter, sea spray, volcanic eruptions	Lung impairment, respiratory symptoms. Precursor to PM. Contributes to acid precipitation	Annual mean: 20 µg/m <sup>3</sup> ; 10-minute mean: 500 µg/m <sup>3</sup>

Figure 1: WHO Guidelines Source And Health Effects [13]

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects.
Hazardous	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected.

Figure 2: Air Quality Index [7]

<b>month_year</b>	<b>Defining Parameter</b>	<b>Mean</b>
<b>2016-06</b>	<b>Ozone</b>	<b>53.56</b>
<b>2016-05</b>	<b>CO</b>	<b>51.96</b>
<b>2016-06</b>	<b>CO</b>	<b>51.61</b>
<b>2016-05</b>	<b>Ozone</b>	<b>49.07</b>
<b>2016-07</b>	<b>Ozone</b>	<b>48.35</b>
<b>2016-04</b>	<b>Ozone</b>	<b>47.86</b>
<b>2016-07</b>	<b>CO</b>	<b>47.27</b>
<b>2016-08</b>	<b>Ozone</b>	<b>44.83</b>
<b>2016-11</b>	<b>PM2.5</b>	<b>43.21</b>
<b>2016-01</b>	<b>PM2.5</b>	<b>42.18</b>

Figure 3: Top Ten Mean AQI Value for the Year 2016

<b>month_year</b>	<b>Defining Parameter</b>	<b>Mean</b>
<b>2006-07</b>	<b>Ozone</b>	<b>69.58</b>
<b>2006-06</b>	<b>Ozone</b>	<b>69.29</b>
<b>2006-08</b>	<b>Ozone</b>	<b>61.31</b>
<b>2006-05</b>	<b>Ozone</b>	<b>58.31</b>
<b>2006-04</b>	<b>SO2</b>	<b>54.97</b>
	<b>Ozone</b>	<b>54.70</b>
<b>2006-08</b>	<b>PM2.5</b>	<b>51.20</b>
<b>2006-07</b>	<b>PM2.5</b>	<b>50.58</b>
<b>2006-05</b>	<b>SO2</b>	<b>50.36</b>
<b>2006-12</b>	<b>PM2.5</b>	<b>48.96</b>

Figure 4: Top Ten Mean AQI Value for the Year 2006

### CBSA Average AQI for Criteria Pollutants

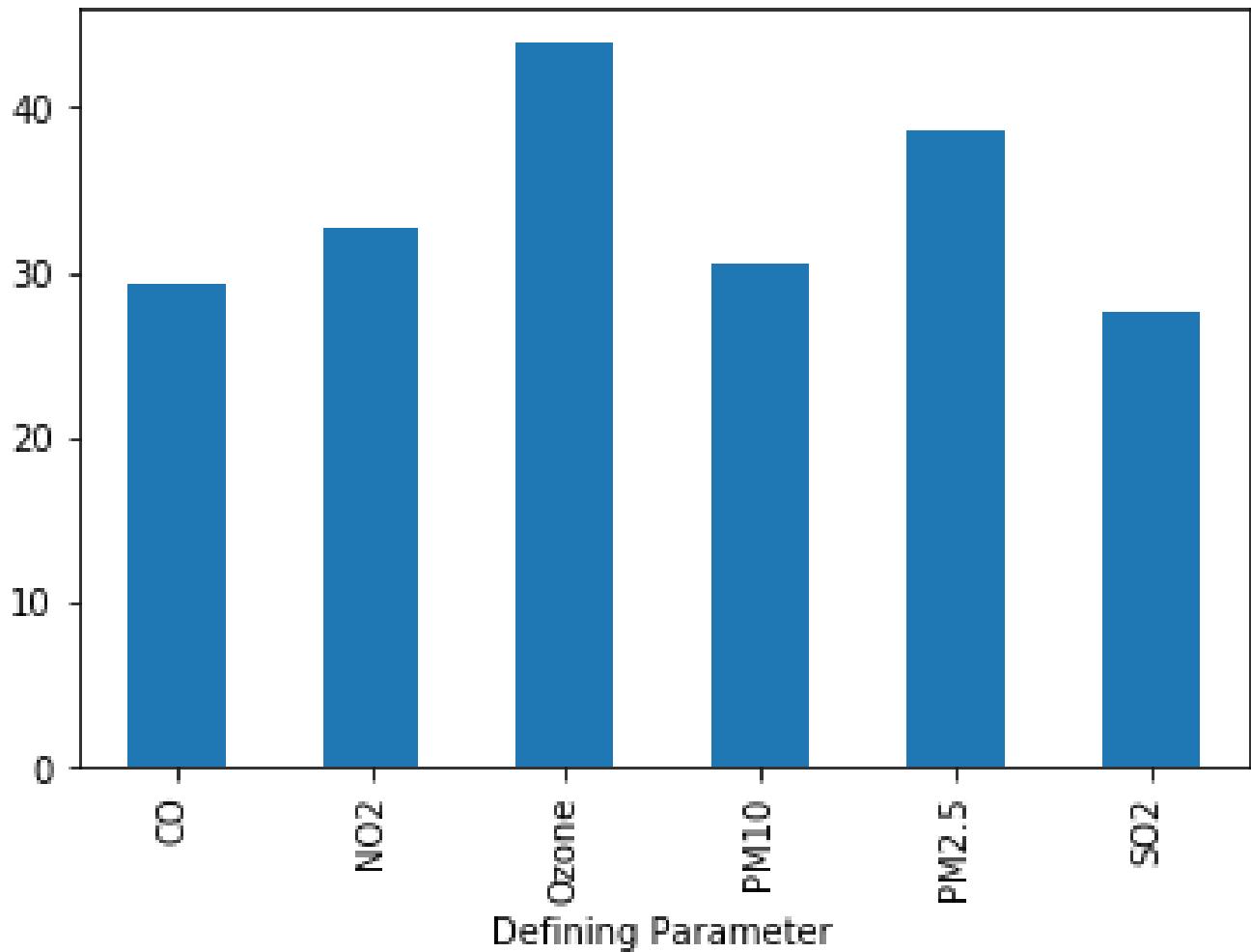


Figure 5: CBSA Average AQI for Criteria Pollutants

### CBSA Average AQI for Criteria Pollutants

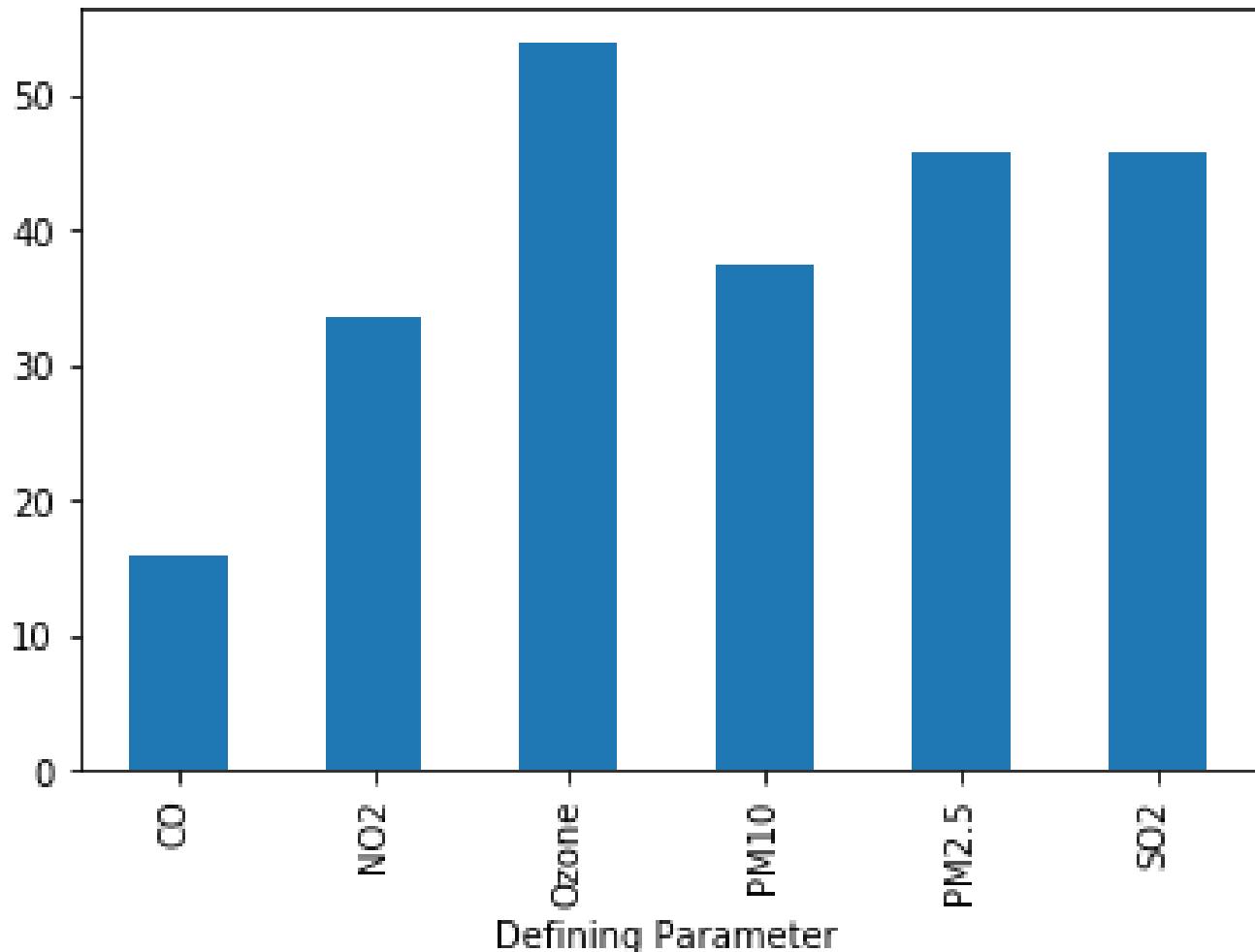


Figure 6: CBSA Average AQI for Criteria Pollutants 2006

Defining Parameters	2016-01	2016-02	2016-03	2016-04	2016-05	2016-08	2016-09	2016-10	2016-11	2016-12
CO	7.19	4.00	8.20	26.00	51.96	16.77	31.25	NA	26.00	2.60
NO <sub>2</sub>	33.18	33.07	33.69	39.00	34.41	22.90	40.43	31.27	33.11	30.39
Ozone	33.97	38.48	41.20	47.86	49.07	44.83	40.91	37.61	34.75	31.07
PM10	19.67	28.82	33.31	30.04	28.67	28.01	32.62	36.89	32.55	25.61
PM2.5	42.18	38.99	35.76	33.30	35.21	36.74	35.90	36.71	43.21	40.82
SO <sub>2</sub>	25.89	26.83	26.83	29.64	24.92	27.51	32.42	32.20	25.99	23.33

Figure 7: Mean AQI per Month per Criteria Pollutant 2016

Defining Parameters	2006-01	2006-02	2006-03	2006-04	2006-05	2006-08	2006-09	2006-10	2006-11	2006-12
CO	17.06	15.07	12.40	15.59	15.15	13.75	20.15	17.97	17.22	16.74
NO2	31.93	38.34	37.99	39.54	33.84	24.79	34.36	32.77	32.60	31.97
Ozone	32.99	37.80	46.22	54.70	58.31	61.31	46.37	38.06	33.51	29.79
PM10	45.46	48.20	32.75	36.07	36.64	31.49	37.91	36.17	40.79	33.55
PM2.5	43.23	45.92	43.81	39.97	43.43	51.20	47.00	41.82	47.47	48.96
SO2	43.84	44.25	44.65	54.97	50.36	48.75	45.89	47.61	43.86	42.40

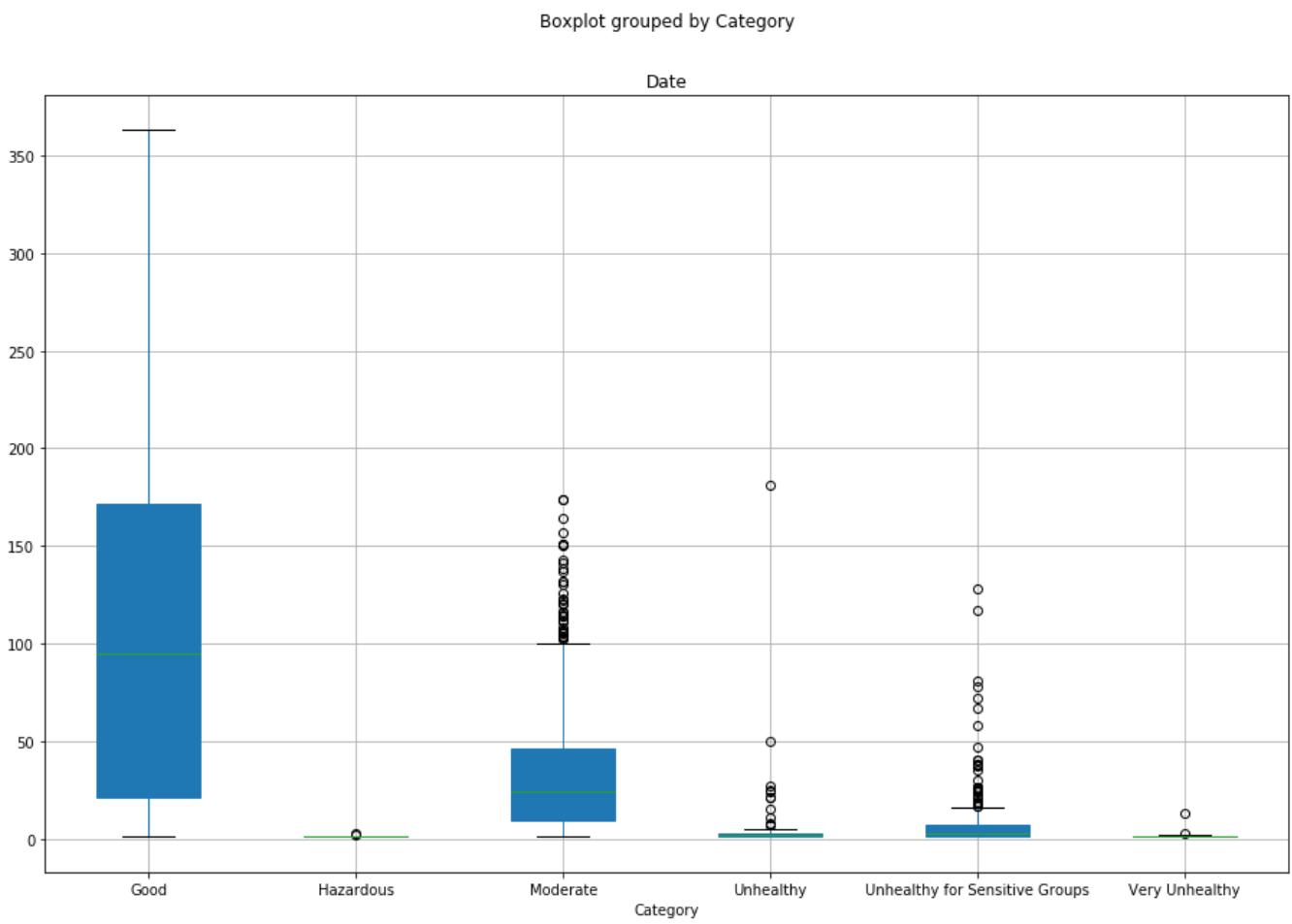
Figure 8: Mean AQI per Month per Criteria Pollutant 2006

CBSA	Defining Parameter	mean
College Station-Bryan, TX	SO2	1.75
Wilmington, NC	SO2	1.44
Rochester, MN	SO2	1.00
Corning, NY	SO2	1.00
Jamestown-Dunkirk-Fredonia, NY	SO2	1.00
Kapaa, HI	SO2	0.50
Gulfport-Biloxi-Pascagoula, MS	SO2	0.50
Seneca, SC	SO2	0.46
Fayetteville, NC	SO2	0.38
Madison, WI	SO2	0.00

Figure 9: Lowest Mean AQI per CBSA 2016

CBSA	Defining Parameter	mean
Hilo, HI	SO2	151.79
Riverside-San Bernardino-Ontario, CA	Ozone	126.53
Lansing-East Lansing, MI	SO2	123.00
San Juan-Carolina-Caguas, PR	SO2	119.61
Bishop, CA	PM10	117.66
Durango, CO	NO2	109.00
Riverside-San Bernardino-Ontario, CA	PM10	108.20
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	SO2	107.00
Los Angeles-Long Beach-Anaheim, CA	Ozone	105.46
Minneapolis-St. Paul-Bloomington, MN-WI	SO2	105.00

Figure 10: Highest Mean AQI per CBSA 2016



**Figure 11: Boxplot Grouped by Category, 2016**

CBSA	Defining Parameter	mean
Bishop, CA	PM10	435.21
Phoenix-Mesa-Scottsdale, AZ	PM10	185.33
Carlsbad-Artesia, NM	SO2	161.00
El Centro, CA	SO2	127.50
Riverside-San Bernardino-Ontario, CA	Ozone	123.17
Bakersfield, CA	Ozone	119.92
Atlanta-Sandy Springs-Roswell, GA	Ozone	119.33
Houston-The Woodlands-Sugar Land, TX	Ozone	118.44
Birmingham-Hoover, AL	Ozone	114.16
St. Louis, MO-IL	SO2	112.85

Figure 12: Highest Mean AQI per CBSA 2006

```
bibtext report
```

```
=====
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

```
bibtext _ label error
```

```
=====
```

```
bibtext space label error
```

```
=====
```

```
bibtext comma label error
```

```
=====
```

```
latex report
```

```
[2017-12-12 20.02.16] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Typesetting of "report.tex" completed in 1.3s.
./README.yml
9:81     error    line too long (86 > 80 characters) (line-length)
10:81    error    line too long (88 > 80 characters) (line-length)
24:81    error    line too long (92 > 80 characters) (line-length)
25:81    error    line too long (99 > 80 characters) (line-length)
26:81    error    line too long (98 > 80 characters) (line-length)
27:81    error    line too long (102 > 80 characters) (line-length)
28:81    error    line too long (100 > 80 characters) (line-length)
29:81    error    line too long (87 > 80 characters) (line-length)
30:81    error    line too long (103 > 80 characters) (line-length)
31:81    error    line too long (99 > 80 characters) (line-length)
32:81    error    line too long (99 > 80 characters) (line-length)
33:81    error    line too long (87 > 80 characters) (line-length)
34:12    error    trailing spaces (trailing-spaces)
37:9     error    trailing spaces (trailing-spaces)
38:8     error    wrong indentation: expected 8 but found 7 (indentation)
46:81    error    line too long (103 > 80 characters) (line-length)
```

```
47:81    error    line too long (102 > 80 characters) (line-length)
48:81    error    line too long (103 > 80 characters) (line-length)
49:81    error    line too long (102 > 80 characters) (line-length)
50:81    error    line too long (101 > 80 characters) (line-length)
51:81    error    line too long (98 > 80 characters) (line-length)
52:81    error    line too long (98 > 80 characters) (line-length)
53:81    error    line too long (104 > 80 characters) (line-length)
54:81    error    line too long (100 > 80 characters) (line-length)
55:81    error    line too long (101 > 80 characters) (line-length)
56:81    error    line too long (103 > 80 characters) (line-length)
57:81    error    line too long (104 > 80 characters) (line-length)
58:81    error    line too long (102 > 80 characters) (line-length)
59:81    error    line too long (100 > 80 characters) (line-length)
60:81    error    line too long (106 > 80 characters) (line-length)
61:81    error    line too long (102 > 80 characters) (line-length)
62:81    error    line too long (99 > 80 characters) (line-length)
63:81    error    line too long (98 > 80 characters) (line-length)
64:81    error    line too long (93 > 80 characters) (line-length)
65:81    error    line too long (104 > 80 characters) (line-length)
66:81    error    line too long (101 > 80 characters) (line-length)
70:25    error    trailing spaces (trailing-spaces)
76:79    error    trailing spaces (trailing-spaces)
79:1     error    trailing spaces (trailing-spaces)
```

---

## Compliance Report

---

name: Janaki Mudvari Khatiwada  
hid: 330  
paper1: 100% Review date nov 1  
paper2: 100%  
project: 100%

yamlcheck

---

wordcount

---

17

wc 330 project 17 6041 report.tex  
wc 330 project 17 6089 report.pdf

wc 330 project 17 466 report.bib

find "

---

passed: True

find footnote

---

passed: True

find input{format/i523}

---

4: \input{format/i523}

passed: True

find input{format/final}

---

passed: False

floats

---

53: 'Very Unhealthy' and 'Hazardous' \cite{airnow-gov}. The AQI value range from 0 to 500. The agency has assigned colors ('Green', 'Yellow', 'Orange', 'Red', 'Purple' and 'Maroon' respectively) to each of the air quality categories \cite{airnow-gov}. It is shown in figure \ref{AQI}.

68: EPA has prioritized six major air pollutants that are commonly found all over the US. They pose significant threat to public health and environment. They are called 'Criteria Pollutants' and they are ground level ozone, fine particles or particulate matter (PM2.5 and PM10), nitrogen dioxide, sulphur dioxide, lead and carbon monoxide \cite{epa-gov}. WHO has set the guidelines for each of these pollutants as shown in figure\ref{WHOGuidelines}.

80: AQI is the index, for five major air pollutants discussed above, calculated by special formula developed by EPA. EPA uses its own formula to convert daily concentrations of measurement of each pollutant into AQI value of each pollutant \cite{airnow-gov}. Among all the highest AQI value is reported as the daily AQI value for that day \cite{airnow-gov}. Generally AQI 100 is the acceptable index set by EPA to protect public's health and it

ranges from 0 to 500 \cite{airnow-gov}. The higher the value of AQI, greater is the pollution level and greater is the health risk. Based on hourly data collection from air quality monitors, stakeholders can constantly monitor AQI value in their cities or respective location. So weather channels in different media outlets such as local radio, television stations and newspapers also report about AQI index in order to inform general public about air quality in their area. Figure \ref{AQI} shows the AQI classification for each pollutant as recommended by WHO and implemented by U. S. EPA. EPA is required to report any AQI value greater than 100 specifically in larger cities with population more than 350,000 \cite{airnow-gov}.

- 88: WHO guidelines for air quality is applied worldwide. This guidelines was revised in 2005 \cite{www-who}. The guidelines set standards for different air pollutants. According to the guidelines which is based on scientific evidence WHO has set standards for Ozone (O<sub>3</sub>), SO<sub>2</sub>, NO<sub>2</sub> and PM. WHO guidelines try to limit the lowest possible values for these pollutants. For example WHO limit values for PM<sub>2.5</sub> is 10 micrograms per cubic meter is annual mean and 25 micrograms per cubic meter is 24-hour mean and limit value for PM<sub>10</sub> is 20 micrograms/m<sup>3</sup> annual mean and 50 micrograms/m<sup>3</sup> 24-hour mean \cite{www-who} \ref{WHOGuidelines}. ‘‘The 2005 WHO Air quality guidelines’’ offer global guidance on thresholds and limits for key air pollutants that pose health risks. The Guidelines indicate that by reducing particulate matter (PM<sub>10</sub>) pollution from 70 to 20 micrograms per cubic metre, we can cut air pollution-related deaths by around 15 percent \cite{www-who}.
- 131: The requirements for the analysis are python’s jupyter notebook and the packages pandas, matplotlib and numpy. Using the pandas dataframe, average AQI value is calculated for each ‘Defining Parameter’ grouped by CBSA. Since AQI value determines the level of risk factor as shown in figure \ref{AQI}, it is worth calculating the mean of that value which helps in determining which CBSA is affected by which ‘defining Parameter’. It also helps identify the source of the pollutant so that responsible stakeholders can take required actions to solve the problem. The purpose of using the data set is to find out level of AQI per CBSA for the year 2016. The reason of using 2016 data set is it the most recent complete set of data for a year. While 2017 data set would have been the most recent look at AQI level in the United States but as of this analysis the 2017 data set contains air quality data until the month of May 2017. This data set would be completed as a full years data only in the upcoming spring \cite{outdoor-air}. In order to do a general comparison of the changes, positive or negative, if any similar data set for the

year 2006 is selected. This would allow us to look at differences in AQI values in a decade time frame.

- 133: Simple statistical measures such as mean, maximum, count and minimum value for any variable provides some insights into the degree of variation between each measure of the variable within a period of time. So, as a first test mean value of ‘‘Criteria Pollutants’’ for all the listed CBSAs have been calculated. Then the results have been plotted into a bar--chart as shown in figure \ref{Average CBSA AQI 2016}. It shows that among all, Ozone and PM 2.5 have highest average among CBSAs while CO, NO<sub>2</sub>, SO<sub>2</sub> and PM10 have slightly lower average AQI for the year 2016.
- 135: Furthermore, figure \ref{Top Ten Mean AQI Value for the Year 2016} illustrates the average AQI value for overall CBSAs for the year 2016 by month. The table illustrates that AQI value, which is 53.56, for Ozone is the highest during the month of June of last year. This AQI value of ozone comes under the category of ‘unhealthy for sensitive groups’. This value is followed by CO which has the highest mean value for two consecutive months, May and June. From the table it can be said that during 2016 the most significant criteria pollutants were Ozone, CO, and PM2.5.
- 137: In order to look at monthly average AQI per ‘Defining Parameter’, first ‘Date’ series is converted into pandas datetime format and then the series is bucketed into month of the year column. Then mean is calculated by using ‘groupby’ function, mean is calculated grouped by ‘Defining Parameter’ and ‘month of year’. The result illustrated in figure \ref{Mean AQI per Month 2016} shows that there is no significant change in mean AQI for SO<sub>2</sub> and PM10 while significant change can be seen for CO and Ozone. AQI average for CO shows a sharp increase in May.
- 139: For the purpose of finding out CBSA with highest and lowest average AQI value for the year 2016, for specified pollutant, aggregate function is used with groupby function with descending value of AQI. The result is shown in figure \ref{Lowest Mean AQI per CBSA 2016}. The table shows CBSA ‘Madison, WI’ has lowest AQI value for SO<sub>2</sub>, followed by Fayetteville, NC for the same parameter.
- 140: Similarly, as seen figure \ref{Highest Mean AQI per CBSA 2016} Hilo, Hawaii has the highest AQI value for parameter SO<sub>2</sub> which is 151.79. This means AQI value is unhealthy and people may experience health effects with sensitive groups people with asthma, bronchitis and chronic obstructive pulmonary disease (COPD) might have very serious health effects as stated in figure \ref{AQI}. The reason for highest AQI value for SO<sub>2</sub> might be the release of SO<sub>2</sub> gas from active volcanoes around the CBSA region as SO<sub>2</sub> is one of the gases released from volcanoes. Hilo, HI is followed by ‘Riverside-- San Bernardino--Ontario, CA with AQI

value 126.53 for \ref{AQI} with category ‘unhealthy’. Other CBSAs in the top ten list are Lansing--East Lansing, MI, San Juan --Carolina--Caguas, PR, Bishop, CA, Durango, CO, Riverside--San Bernardino--Ontario, CA, Philadelphia--Camden--Wilmington, PA--NJ --DE--MD, Los Angeles--Long Beach--Anaheim, CA and Minneapolis--St.Paul--Bloomington, MN--WI. All of these CBSAs have at least one defining parameter with ‘Unhealthy’ AQI value. It is also significant that Riverside--San Bernardino--Ontario, CA have two highest AQI value for two defining parameters that is ozone and PM 10.

- 142: In order to have a visual picture of level of AQI value, count measure is used grouped by ‘CBSA’, ‘Defining Parameter’ and ‘Category’ and visualized the result in a boxplot. This basically counted number of days in each category of AQI. The figure \ref{boxplot} shows, that there are significant number of ‘good days’ during 2016 followed by ‘moderate’, ‘unhealthy for sensitive groups’ and rest of the three categories have less range of days. As seen in bar chart the mean value for Ozone is higher for the months May and August in comparison to other pollutants Columns for the months of June and July are missing at this point.
- 147: To compare AQI per CBSA for criteria pollutants, exactly similar data set for the year 2006 is used to calculate average AQI value and plotted into a bar chart which is shown in figure \ref{Average CBSA AQI 2006}. As the result can be compared with that of 2016.
- 149: There is also some changes in overall average AQI vlaue. This figure shown here \ref{Top Ten Mean AQI Value for Year 2006} illustrates the AQI average for the year 2006. As seen in barplot this figure shows the highest mean for Ozone at the top of the list when mean is grouped by month of the year and output is sorted in descending order by mean. Interestingly, most of the highest mean value are for the month of June, July and August. To be more specific AQI value for Ozone is mostly during above listed months. Similar result can also be seen in the analysis of 2016 dataset.
- 151: While comparing top ten CBSA with highest average AQI value for 2016 with that of 2006, top ten CBSAs with highest average AQI for 2006 is shown in figure \ref{Mean AQI per Month 2006}. Compared to 2016 there is no sharp increase in mean value for CO any of the month as has been in 2016. Its mean value remains comparatively in same range, in between 17 and 16. Whereas, the value for Ozone is significantly higher for teh months of March, April, May, August and September. For other months as well it has higher level o mean AQI compared to other pollutants except for SO<sub>2</sub> which has the second highest AQI throughout the months.

Average value for all of the pollutants throughout the months have higher values compared to that of year 2016 except for CO.

Average CO AQI for 2016 is higher than that of the year 2006.

- 153: Another comparison can be done by looking at the list of top most CBSAs with higher mean AQI. We have already discussed about this for year of 2016. Now we will look at similar output for 2006 which is shown in figure \ref{Highest Mean AQI per CBSA 2006}. The mean output is generated by grouping the CBSA and defining parameter. Here, Bishop, CA has highest yearly average for PM10 which is 435.21 followed by CBSA Phoenix-Mesa-Scottsdale, AZ, Carlsbad-Artesia, NM have yearly mean value of 127 for S02. In comparison to the same statistics for year 2016, mean value is lower than that of 2006. This indicated that there is progress made in lowering the measurement in air pollutant.
- 187: \begin{figure}[htb]
- 188: \includegraphics[width=1.0\columnwidth]{images/sourceandhealtheffects.png}
- 190: \label{WHOGuidelines}
- 193: \begin{figure}[htb]
- 194: \includegraphics[width=1.0\columnwidth]{images/aqiclassification.png}
- 196: \label{AQI}
- 200: \begin{figure}[htb]
- 201: \includegraphics[width=1.0\columnwidth]{images/top10meanaqi2016.png}
- 203: \label{Top Ten Mean AQI Value for the Year 2016}
- 206: \begin{figure}[htb]
- 207: \includegraphics[width=1.0\columnwidth]{images/top10meanaqi2006.png}
- 209: \label{Top Ten Mean AQI Value for Year 2006}
- 213: \begin{figure}[htb]
- 214: \includegraphics[width=1.0\columnwidth]{images/averageaqi2016.png}
- 216: \label{Average CBSA AQI 2016}
- 219: \begin{figure}[htb]
- 220: \includegraphics[width=1.0\columnwidth]{images/averageaqi2006.png}
- 222: \label{Average CBSA AQI 2006}
- 225: \begin{figure}[htb]
- 226: \includegraphics[width=1.0\columnwidth]{images/avaqibymonth2016.png}
- 228: \label{Mean AQI per Month 2016}
- 232: \begin{figure}[htb]
- 233: \includegraphics[width=1.0\columnwidth]{images/avaqibymonth2006.png}
- 235: \label{Mean AQI per Month 2006}

```
239: \begin{figure}[htb]
240: \includegraphics[width=1.0\columnwidth]{images/lowestmeanaqipercent
sa.png}
242: \label{Lowest Mean AQI per CBSA 2016}
245: \begin{figure}[htb]
246: \includegraphics[width=1.0\columnwidth]{images/cbsahighestaqi.png
}
248: \label{Highest Mean AQI per CBSA 2016}
251: \begin{figure}[htb]
252: \includegraphics[width=1.0\columnwidth]{images/boxplotofcountofaq
ibycategory2016.png}
254: \label{boxplot}
257: \begin{figure}[htb]
258: \includegraphics[width=1.0\columnwidth]{images/top10cbsamean2006.
png}
260: \label{Highest Mean AQI per CBSA 2006}
```

```
figures 12
tables 0
includegraphics 12
labels 12
refs 15
floats 12
```

```
False : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
True : check if all figures are referred to: (refs >= labels)
```

```
Label/ref check
passed: True
```

```
When using figures use columnwidth
[width=1.0\columnwidth]
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

---

WARNING: table and above may be used improperly

80: AQI is the index, for five major air pollutants discussed above, calculated by special formula developed by EPA. EPA uses its own formula to convert daily concentrations of measurement of each pollutant into AQI value of each pollutant \cite{airnow-gov}. Among all the highest AQI value is reported as the daily AQI value for that day \cite{airnow-gov}. Generally AQI 100 is the acceptable index set by EPA to protect public's health and it ranges from 0 to 500 \cite{airnow-gov}. The higher the value of AQI, greater is the pollution level and greater is the health risk. Based on hourly data collection from air quality monitors, stakeholders can constantly monitor AQI value in their cities or respective location. So weather channels in different media outlets such as local radio, television stations and newspapers also report about AQI index in order to inform general public about air quality in their area. Figure \ref{AQI} shows the AQI classification for each pollutant as recommended by WHO and implemented by U. S. EPA. EPA is required to report any AQI value greater than 100 specifically in larger cities with population more than 350,000 \cite{airnow-gov}.

WARNING: figure and above may be used improperly

149: There is also some changes in overall average AQI value. This figure shown here \ref{Top Ten Mean AQI Value for Year 2006} illustrates the AQI average for the year 2006. As seen in barplot this figure shows the highest mean for Ozone at the top of the list when mean is grouped by month of the year and output is sorted in descending order by mean. Interestingly, most of the highest mean value are for the month of June, July and August. To be more specific AQI value for Ozone is mostly during above listed months. Similar result can also be seen in the analysis of 2016 dataset.

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux

The style file: ACM-Reference-Format.bst  
Database file #1: report.bib

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

---

ascii

---

=====  
The following tests are optional  
=====

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Agricultural Data Science: Then, Now, and Beyond

Ross Wood

HID345

rmw@indiana.edu

## ABSTRACT

As the human population swells to staggering numbers that historians of yesteryear could not imagine, one very important question seems to keep coming up over and over again. How do we feed all of these people? Thankfully, humans are intelligent beasts and are figuring out ways to farm and produce larger amounts of food using methods and techniques more sophisticated than ones humanity has relied on in the past. The party is just getting started as farming meets the era of big data. As more and more data is generated from farming, techniques and processes become more sophisticated, cleaner, and more efficient. The kind of data being analyzed to improve agricultural endeavours comes in many forms, and can be statistical data like amount of food grown using how much land, actual data generated from using farm tools and other smart farming equipment, or any other kind of agricultural activity that can produce datafies actions and procedures. However, data science is helping in other ways, too, as scientists and engineers are taking advantage of all this newly available data and helping create new technology to improve food production and increase yields. With all this new information available, new farming endeavours are being undertaken. Farming within closed systems such as urban or vertical farming, practicing precision agricultural techniques, or even laboratories using genetics data on different plant strains to crossbreed the various plant strains in order to produce new breeds that can grow in the harshest of environments while using minimal resources. As the population grows, we are finding that not only is the production of food vital, but also that sustainable farming techniques are of paramount importance for long term agricultural need. Data Science and its applications are most definitely changing the way people produce food and the very nature of farming itself.

## KEYWORDS

i523, HID345, Agricultural Data Science, Smart Farming, Vertical Farms, Urban Farming, Big Data Farming, Smart Farming Tools, Precision Agriculture

## 1 INTRODUCTION

Humans have not always lived in the amazing concrete and technological jungles that we have surrounded ourselves with today. Indeed, the ability to stop being nomadic and settle down in one area is a relatively new development in regards to the grand scale of human existence. However, if there is one technological advancement which is considered to be the most directly responsible for allowing humans to change how they lived and thrive in a harsh and unforgiving world, it would be when ancient humans evolved into the first agrarian societies by figuring out how to plant crops and grow food. By making their societies agriculture based instead of hunting based, humans were able to live in one place and do a lot of gathering, in addition to the hunting they were used to. This

regular supply of food and less dependency on hunting allowed ancient humans time to develop other aspects of human society, such as language, writing, and building. This was about 12,000 years ago and ever since that time, humanity has been gathering data on farming and slowly but surely refining the techniques we use for food production. Humanity has not just been gathering data and knowledge on how to grow food, but also information on what kinds of crops to grow when and where, how to deal with insect, rodent, and pests and other external threats to crops, and how what to do and how to manage different weather and environmental setbacks. These are a few of the many examples of information that humanity has accumulated over the millennia that have allowed humans to improve their farming and agricultural techniques, which has enabled humanity to thrive around the world.

The advances humans have made in their early years of farming will pale in comparison to the advances that humanity has the potential to make in the modern era using big data analytics and sophisticated technology that improves farming methods. With population statistics indicating that there is no sign of our population growth slowing down, the question is becoming even more relevant today than it has been in the past. With estimates putting the world population at 11.2 billion by the year 2100, solving the hunger problem is imperative [13]. Using data science and modern data analysis techniques and models, humans are able to look at the concept of agriculture as a whole and start making decisions based on data that had never been readily available in the past. This data is useful to farmers and serves as kind of risk management system through which farmers can make informed decisions about changes they might want to implement on their farms. The rise of smart farming with a focus on sustainability, the ability to analyze information in ways not possible in the past, and the invention of tools like monitoring sensors and machines that datafie work are changing agriculture for the better. The desire for more efficiency, greater food production, and meeting the demands of a steadily growing population are the driving forces behind why this field continues to be researched and expanded. Closed farms that eliminate the need for pesticides and rodenticide use while also helping the environment by cleaning the air in urban areas are a couple of unique ways this field has branched off from traditional farming practices and techniques.

Modern technology and data science are making new agricultural endeavours possible in ways that previously could not have been attempted with any hope of such success modern farmers are finding. One new technique is called urban, or vertical farming. A vertical farm is a farm constructed in an urban area that goes up instead of out. Ideally built in a parking garage like structure, vertical farms use data analysis to make their crop yields extremely efficient. There are plans for their construction coming up in more and more cities over the next couple decades and they are already beginning

to appear in developing nations that have problems meeting the demand for fresh fruits and vegetables in major urban centers. Other examples of how data science is changing the agriculture game is through the invention of more sophisticated computer software and languages that allow for the analysis of farming and crop data in ways that could never have been done in the past. This new way of looking at growing, storing, and transporting food and agricultural goods is making humanity second guess a lot of the ways we used to do things with regard to food. The explosive growth of big data and the rise of data science are already changing the way the world works and how we go about our daily lives. Data science is already improving agricultural endeavours in a myriad of ways, just like it does in most fields that it used to solve problems in. The positive benefits of this transition to new approaches in agriculture are already beginning to be seen.

## 2 HISTORICAL AGRICULTURAL DATA SCIENCE

The rise of big data analytics software and technology was the turning point where society began to really be able to take advantage of the ever growing amounts of data being produced by farms and their workers. As computer components began to get smaller, cheaper, and more powerful, this enabled more wide spread use of data analysis to be performed, which made it easier for companies and other organizations to adopt these new techniques and get in on the ground floor of solving agricultural problems and changing the way people farm around the world. Despite all these positive steps happening in the fields of technology, data analysis, and data creation, only small groups of people, usually limited to college university campuses, were actually receiving funding to analyze agricultural research data. This lack of funding meant that, although models for agricultural analysis were being developed, they were not being improved upon, leaving the power of data science in the field of agriculture unrealized until it could be adopted by more people and organizations [16].

### 2.1 Early Agricultural Analysis

In early to mid 1950s, computers and funding were still only available mostly at universities, which meant that universities were where most data analysis was being done in that era. Despite this, great steps were still being made to lay the foundation of modern agricultural data science and all that that encompasses. From the mid 1950s and onward, modeling was done by various institutions to find things like best water balance, photosynthesis and growth statistics, models to evaluate land and zoning properties, and pinning down economic risk management models, to name a few [16]. These models acted as guidelines and risk management tools in food production decisions making processes. As the availability and use of modeling technology became more widespread and more people and organizations began adopting them, so too did their positive impact on the real world become more apparent and visible. The changes, technological advances, and new techniques that were being proposed to farmers may have been met with some skepticism at first, but by the mid 1970s, these new processes were reportedly responsible for saving the lives of billions of people around the world by helping aid world hunger relief efforts. Like dominoes

falling, this led to increases in funding, which led to better and more accurate models being developed, which led to even more advances, which led to more funding, and so on. This self sustaining cycle of budget increases and technological innovation at the beginning of the agricultural data science boom led to the development of new ways of thinking about growing food and led to the development of tools that are still used today. These agricultural systems were developed for many reasons, but the top three reasons they are developed are typically “the intended use of the model, approaches taken to develop the models, and their target scales” [16]. Whatever their intent for development, very quickly it was evident that the proof was in the pudding.

### 2.2 New Tools for Agricultural and Risk Modeling

One data analysis tool for statistical decision making that was developed during the early days of agricultural data analysis was a software called Statistical Analysis System, or SAS for short. SAS was developed and “started out as a tool for statisticians: Goodnight originally developed it to analyze agricultural-research data in North Carolina” [16]. The development and utilization of SAS made sifting through the piles of random agricultural data much more manageable, and helped proto-data scientists find patterns, make connections, and gleam wisdom from the available agricultural data that they would not have been able to find without using SAS. Being able to manipulate and understand all the available data gave the farmers and data scientists a statistical edge when making choices about changing their farming practices. Economic risk management models would later be developed which helped make farmers more knowledgeable and able to hedge their bets whenever they were attempting new processes and techniques for improving their crops and growing capacity [25]. All of these new models made it easier for farmers to make decisions about making changes in how they produced their crops. The ability to make informed decisions about potentially big changes made farmers less reticent to try new approaches to farming and different techniques in how they produced their crops.

Since the development and implementation of SAS, other techniques have been developed to help take the pressure off of farmers when making educated and informed decisions. Commonly referred to as decision support tools, they have been developed to help farmers and data scientists make heads or tails of all the data that their trade is generating on a day to day basis. Thanks to the development of these kinds of tools and models and their improvement over the years, the decades since their adoption by farmers have seen farms produce more food per acre and increase their own sustainability for the years to come. These tools are incredibly useful to farmers, and “lead users through clear steps and suggest optimal decision paths or may act as information sources to improve the evidence base for decisions” [25]. These tools were slow to be developed because of funding problems, but once they began to catch on, they were quickly adopted by farmers to help improve their yields. A statistical analysis of farmers and the tools they used found that the odds of using decision support tools and software increased greatly depending on the size of the farm. The bigger the farm, the better the chances are that they use some kind of

decision support tools software [25]. The growth of urbanization and major cities meant that there were less farmers, which means that the farms that did exist were becoming bigger and bigger to fill the vacuum. Larger farms led to more widespread of adoption of the then modern technology and approaches to increase yields, improve efficiency, and improve farming conditions and overall food production.

### 2.3 Food Explosion, Courtesy of Data Science

Slowly but surely, the world, and especially developing nations, began to see the effects of applied data science to agricultural and farming endeavours. It was in the 1960s that a kind of critical mass was reached where the benefits of this field became undeniable. This led to the eventual development of precision farming with a focus on sustainability. All of these new breakthroughs in environmental science helped plant the seeds for what would be the growing environmental movements. In the mid to late 20th century, scientists like Norman Borlaug, who would later win a Nobel Peace Prize for his research, pioneered the way in using analysis models on plant genetics in order to improve yield by finding which breeds were best to cross and grow in different environments. These experiments led directly to the development of high yield crops in 1960s Mexico, and would later do the same in India [5]. Analysis of crop data allowed for the scientist to breed genetically superior strains of cereal grains that could withstand harsher climates, thrive on fewer resources like water and fertilizer, and produce a greater yield per acre than strains that Mexican farmers had previously been using. These new strains were potent and unlike anything the world had ever seen. When the Mexican farmers adopted these strains that Borlaug and his team had developed, they immediately began to see an improvement in their ability to meet the food demand of their population. While not alleviating the problem of hunger entirely, these developments proved that applying data science solutions to agricultural problems yields great results. These developments helped stymie off a hunger epidemic, and when Borlaug received his Nobel Peace Prize in 1970, it was officially for “saving over a billion lives” [4]. This quick turnaround showed definitively that research and development in agricultural data science was worth the investment, as less than 25 years after these new processes and models were being worked out, they were able to be used to save billions of lives.

These achievements, fantastical as they may be, only helped stymie off the threat of hunger around the world temporally, as these kinds of advances could only go so far. Growing populations steadily defeat advancements in food production, and humanity has to keep adapting and refining our methods and techniques in order to continually meet the needs of the many [22]. Luckily, humans are clever creatures, and our innovation and technological achievements have grown exponentially with our massive populations. More powerful computers and data analysis methods are constantly making humans better at producing food and meeting the staggering population demands. The gradual advance in sophistication of humankind’s ability to produce food and knowledge of best techniques and practices continues to evolve with technology and available data. Data science is just the newest and sharpest tool

in humanity’s toolbox and its use is improving farming in every way.

### 2.4 The End of the Past

History is a gradual process which only seems instantaneous when reading about it in a history book. When talking about agricultural data science and its past, present, and future, it would be easier to think about it like stepping stones. The future did not just come to be, but contributions from the farmers and data scientists in the past helped to build it up to where it is today. But which stepping stones are the most important ones to be looking at when thinking agricultural data science’s past? Ultimately, the best example the past can provide is that working together and openly is the most beneficial approach for everyone involved.

Some of the biggest developments from the 20th century of agriculture came about because of the open nature of the field, but there were other circumstances that led to great leaps in agricultural data science. Other circumstances that have led to advances in this field are: 1) the ability to capitalize on a crisis, 2) advances in technology and hardware, 3) keeping the data open and harmonized, 4) making the data easily applicable so that it can be used in other disciplines, 5) developing and maintaining standards and protocols, and 6) making sure the data remains user friendly and user-driven [16]. These approaches represent ideal ways to handle and manage agricultural data so that it can be used and expanded upon by all parties that might be interested. Keeping the data open allows for greater innovation as it becomes a problem that is solved on a societal level, not an individual one. This helps keep the data user friendly and driven as well. All of these different examples represent the various stepping stones that have worked together to bring the field of agricultural data science from its roots in human history and changes in the 20th century, to the modern way we look at agriculture and farming in the 21st century.

## 3 MODERN AGRICULTURAL DATA SCIENCE

In the 21st century, humanity has the hindsight to know that data science and its endeavours yield their own rewards. As a result, funding for the study of agricultural endeavours using data science is no longer too difficult to come by. The different areas under the umbrella that is agricultural data science have, in many ways, become fields unto themselves. Urban and precision farming, net-worked farms, and agricultural technological innovation all have their own sub-fields, but they all belong to the field of agriculture data science in one way or another. All of these different fields that make up modern agricultural data science have one attribute in common, however, and that one attribute is a focus on sustainability in whatever agricultural endeavour that is being undertaken. Indeed, modern data scientists and farmers would have a difficult time encouraging and practicing new processes that did not take sustainability into account. With the world’s population expected to keep growing, and the amount of food needed to feed the population expected to double by 2050 [13], this new focus on sustainability is an ever growing piece of the modern farming puzzle, whose importance and juxtaposition along side traditional and modern beliefs about agriculture can no longer afford to be overlooked. Data science factors into this tremendously as it enables farmers

and agriculturalists to analyze their data and figure out if their new approaches and techniques are actually working and worth continuing.

Focusing on sustainability and changing things around the farm are not the only new tricks that modern farmers and data scientists have up their sleeves. New techniques and advances in computing technology, both hardware and software, have helped pave the way towards making the analysis of farming data easier and more available than ever so that farmers and agriculturalists can make informed decisions about how they grow their crops and produce food. One example of a new technique that has been developed is based on an old approach: selective breeding. Selective and cross breeding different strains of plants is nothing new. However, thanks to modern technology and new techniques, farmers can work with data scientists to dig down to an even greater degree of analysis based on data that was not available in the past. One study's model, for example, analyzed how different nighttime temperatures and amounts of nitrogen fertilizer used impacted growth rates of rice. The study found that high night time temperatures "substantially reduces yields of cereal crops" [26]. Studies and experiments like this are specific examples of how agricultural data science is changing the ways farmers grow food. Because of studies like this, farmers are now breeding their rice strains selecting for traits that tolerate high nighttime temperatures. All of this data was obtained from sensors that were developed for the express purpose of gathering this kind of data. It is in this way that data science is encouraging agricultural advancement. But will improving the success rates of plants and a focus on sustainability be enough to help farmers provide food to so many people in the future? Time will tell, but data science is an incredibly useful tool when applied to producing food.

The focus on sustainability and hardier plants that produce more food, while an important part of the food puzzle, are not the only pieces that humanity needs to focus on in order to feed future populations. Architectural endeavours like vertical farms, designing and implementing a connected farms that take advantage of Internet of Things technology in farm equipment, using drone and wireless sensor monitoring systems technology, and using computing networks and sensors to figure out new information about insect and rodent infestation rates and crop losses are just a few examples of the kinds of outside the box thinking that is being done to improve agriculture. Through the use of technology and approaches developed from the use of data science practices, the agriculture sector as a whole continues to improve and is stepping up to meet the modern demands of an ever growing population.

### 3.1 Growing Urban Populations and the Greater Demand for Food

More and more humans are beginning to live in centralized places like major urban cities while at the same time, people are leaving rural areas and communities in greater and greater numbers. This is having an impact on farming and agriculture in a number of ways. First and foremost, this is leading to a major reduction of the number of farmers and agriculture workers. According to the 2012 US Census of Agriculture data, less than 2% of the population of workers in the United States classify themselves as farmers - about

3.2 million people classify themselves as farmers, ranchers, or some other kind of agriculture related occupation [30]. This reduction in available farmers and agricultural workers means that the job of providing food to an ever growing population and society falls to fewer and fewer people. It also means that providing fresh fruits and vegetables to the growing and expanding urban populations is going to become more and more difficult due to the logistics of growing larger quantities of food, storing it, and then by getting it from point A to point B. One upside to this population shift is that the farms that still exist are getting much bigger to meet demands, and larger farms typically use more support tool and decision management data science tools. This means that more data than ever is being created, and more data is the cornerstone to using data science as a tool to improve agricultural production, efficiency, and sustainability.

[Figure 1 about here.]

[Figure 2 about here.]

Being able to produce food within urban areas is a dynamic approach to helping solve several problems. This process of growing food and other greenery in urban areas would not only help ease the demand for food from sources outside the urban areas, but it also helps to create less of an environmental impact while simultaneously promoting a sustainable model. By again causing even less strain on the farming resources outside of the urban sectors, this enables them to focus on a more manageable demand [21]. Growing what is needed locally within urban areas is a great way to help the environment, increase availability while also providing food and agricultural goods for a growing population, and encourage a sustainable agricultural model. One major benefit of farming in a close system like an urban farm is that since the system is closed, the urban farmers do not have to worry about insects, rodents, or other pest infestations that might destroy their crops. But more importantly, the nature of the closed system means they do not have to used insecticides, pesticides, or rodenticides. This means the urban crops are safer for consumption and that they leave a much smaller environmental foot print than their rural cousins [21]. This closed system method also allows the urban farmers to use the precise amount of resources that their data indicates they should be using to grow their plants. This increase in efficiency is not only an economic boost, but further improves this model of sustainability by making the environmental footprint of farming even smaller. Data science is also helping improve these endeavours in the same way it helped with farmers in the mid to late 20th century: by applying rigorously tested computing models to agricultural jobs, urban farmers are pushing the envelope in regards to how much food they can grow with limited spaces while saving on resources [1].

The United States and other developed nations are not the only places taking advantage of these advances in farming technology, newly developed processes for improving production, and taking advantage of agriculture data analysis. Developing nations are also benefiting from this new era where agriculture is meeting modern technology. As world populations grow and nations develop further, the demand for more and varied goods increases, including a demand for more varied foods. By taking advantage of data science practices, farmers and food providers in developing nations are

discovering new and innovative ways to meet this new demand placed on them for their goods. These new approaches are helping developed nations two fold: not only are they helping farmers to produce greater and more varied quantities of food, but they are also helping to limit the environmental footprint, created from farming, in places that are more sensitive to environmental change, or where environmental laws are not as heavily enforced [12]. The ability to meet food demands, curtail the effects of climate change on the surrounding environment, maximize the efficiency of resource use, and take advantage of advances in food storage and distribution are helping to transform developing nations in ways that all of their citizens can benefit from. Limiting and reducing the environmental footprint of farming and other agriculture processes is also extremely beneficial for developing countries and places that are facing more extreme, contemporary threats from climate change, as opposed to other nations whose economies and well being are less dependent upon their agriculture sector [12]. The direction that modern farmers in developing nations are taking, and their focus on sustainability, are only possible because data analysis tools have brought the world's agricultural expertise to this point. Keeping the data open and friendly allows for cross applicability of the data, which leads to more insights and discoveries, which in turn continues to benefit the farmers and agriculturalists even more.

### 3.2 Focusing On Sustainability

As mentioned previously, the growing focus on sustainability is helping to drive technological innovation and advancements and new techniques that produce more and better food while also limiting and reducing the environmental footprint required to do so. This is good news for farmers who are facing a shrinking population of agricultural workers in the face of growing demand for food in centralized urban areas. This growing demand has not gone unnoticed by the governments of the world, and many of them are actively taking steps by working with farmers and providing resources for research and development of farming practices that leave the ones farmers have been using in the dust. This focus on sustainability is not just for places like the United States who have the resources to explore new and dynamic avenues for agricultural experimentation. These new techniques and processes are also being quickly adopted by developing nations around the world in order to combat their countries' own hunger and resource problems. With the looming threat of climate change, whose impact is already beginning to make itself more and more apparent around the world, the demand and pursuit of data oriented precision agriculture is increasing at an exponential rate [29]. Since the well being of many developing nations is tied so closely with their agricultural production, they are the most susceptible to climate changes and the damage it can cause to food production [22]. Humanity is good at overcoming adversity, however, and data science is clearly helping to tackle the effects of climate change on agricultural endeavours and food production. The threat of climate change itself is driving entirely new agricultural fields whose sole focus is on sustainability.

There are many factors driving the technological innovation in data science focused agriculture. But of all of them, human caused climate change is perhaps one of the biggest factors driving the

changes and modern focus on sustainability, especially in developing nations. "Because most developing countries depend heavily on agriculture, the effects of global warming on productive croplands are likely to threaten both the welfare of the population and the economic development of the countries" [22]. Since developing nations are more sensitive to the effects of climate change because their economies and well being are often directly dependent on their agriculture sector, they are the ones who are benefiting the most from all the advancements in this field. These benefits are having a stabilizing effect in areas where these practices are being used, allowing for these places to develop further in areas that they ordinarily would not be able to focus on if they were still struggling to meet food requirements. By being able to focus on other parts of their society, these nations are able to further develop themselves and achieve greater and greater standards of living and freedoms for their citizens [20]. This is just one example of how agricultural data science has positive effects on society outside of the agricultural and environmental sectors. These effects, when used with noble intentions, are good for everyone.

### 3.3 Urban and Vertical Farming

As touched upon briefly earlier, when farmers begin producing some of the fruits and vegetables that people need inside of urban areas instead of on farmlands, this helps ease another one of the biggest problems farmers have encountered in the past, the problem of land availability. Again, as populations continue to grow, the stress they put on the demand for resources becomes more and more extreme. Land and resources becomes more and more scarce, not only because they are required for people to live on, but also because lots of other resources are required to handle large populations. Land resources for building roads for transportation, food and retail zones, resources such as land fills, waste removal, hazardous storage, water treatment, and power plants are just a few of the many other land resource demands that increase hand-in-hand as urban populations increase. One novel solution being used by many countries to tackle the problem of scarce geographic resources comes from thinking dynamically about the problem and realizing that, technically, farmland is not required in order to grow food and have a farm. Instead of expanding outward in order to grow more food, some modern farms are being rethought and built upwards or in repurposed, closed and controlled facilities in major urban areas. By utilizing or building multi-level structures laid out over a semi large area, farmers are able to grow different crops at different levels. These installations can be built in major urban areas, but any open urban space will do. This has the bonus side effect of reusing old buildings that might not have previously been in use anymore, which adds to and promotes a sustainable model. These structures allow for the same kind of closed system farming techniques that precision farming benefits from, while also allowing farmers to control everything that is done to their crops [11]. Having all the plants in urban areas also has the benefit of naturally cleaning the air. Plants use many of the gases released in vehicle emissions for their life functions. Taking these harmful gases out of the air is beneficial to humans, the plants, and the surrounding environment [11]. Building urban farms like this is a win for everyone involved, and as people and governments begin to take a more active role

in regards to improving and pursuing sustainable models of food production and environmental protection, urban farms are likely to gain in popularity and start popping up all around the world.

Another angle that can be taken in regards to vertical farming is the idea of growing plants on all available flat surfaces. Not only floors, but also ceilings and walls where available. One problem major urban areas can have is a lack of green spaces available. This takes away from the aesthetics of these urban locations, while also allowing for pollution to go to choke out major areas in cities. Growing plants on some walls and buildings around major cities will help reduce the impact of both of these problems on the people and their environment. The plants being around the city take care of the lack of green places on its own, transforming concrete jungles into lush, semi-green cities. Meanwhile, the plants themselves will help clean up pollutants in the air from human emissions and simultaneously reduce amounts of noise pollution in their immediate vicinity. These green walls can even be limited to urban agricultural buildings themselves and would still be effective and have a positive impact on their immediate environment [28] Again, data science makes all of this possible by allowing analysts and farmers to figure out the best ways to execute their agricultural endeavours, how to grow their plants, which and how much of their resources they need to use, and so forth. Technically, all of this could have and has been done in the past; it is not difficult to grow plants on the sides of buildings. But now urban populations are reaching heights that have never been seen, and the demand on environmental resources and human emissions are ever increasing. These simple approaches to the problems presented above are a means for cities to tackle a lot of the problems in city living, along with helping ease their dependency on farmlands for resources [28]. When urban farmers and city planners have access to data science and analysis tools that allow them to review and analyze information at a much deeper level, they are able to find new insights into the problems they are trying to solve. These new insights are driving urban farming to the level it needs to be at in order to meet the needs of an ever growing population and increased urban demand on resources.

### 3.4 Precision Farming: Networked Farms

The idea of a connected farm is paramount in moving beyond the historical approach to farming and agriculture. The cornerstone of understanding and finding better techniques to improve farming is data, and a networked, or smart farm, does just that. By using technology that networks the farmland, the farmer now has access to a decisions support network, which allows farmers the ability to keep track of all the happenings taking place on their property in ways they have not been able to in the past. This new attention to detail taking place allows farmers and agriculturalists to engage in a practice called precision agriculture. Precision agriculture “concentrates on providing the means for observing, assessing, and controlling agricultural practices” [17]. In essence, precision agriculture, or smart farming, focuses on sustainability and finding the sweet spot between resource use and crop growth and food production. Being able to hit that efficiency spot allows farmers to save on resource use while getting the most bang for their buck in regards to crops grown and sold per acre. Farmers are able to take advantage of all kinds of new data at their disposal. They

have access to modern technology, which allows them access to things like satellite telemetry data on not only the weather, but also insect populations and blooms, as well as a myriad of data on other farming techniques and practices that are still evolving to improve efficiency and production.

By taking advantage of new technology, as well as Internet of Things based technology, farmers and agriculturalists are able to tap into a source that humans have never been able to use in the past. Examples of modern agricultural technology include advances in wireless sensor technology that allow for the monitoring and changes in environmental conditions, resource use and precision agriculture, warehouse and storage management for storing crops and other perishables, technology that allows for large amounts of automation, and RFID technology that allows for tracking of the distribution of goods from farms [32]. All of these new technologies work in conjunction with one another to improve all aspects of the farm by making it possible to accurately monitor for and detect small problems that might arise and get them taken care of before they turn in to big problems. This proactive process of monitoring for problems fits with the growing importance of sustainability. Getting to problems and fixing them before they become larger issues can help the farm in countless ways. Practical ways in which data science technology can help improve farms are detecting insects, rodents, or other pests before they become an infestation, monitoring environmental conditions outside or in storage spaces in order to ensure that the crops they have stay fresh longer and do not become tainted in any way, determining the precise amount of resources required for individual plots of land or crops being grown so the farm’s resources are being used more efficiently, soil analysis to determine the best kinds of plant strains for their specific farmland, and tracking the distribution of their farm goods in order to more accurately distribute them to retailers. All of these agricultural techniques come together to form the larger picture that shows how much data science has really changed the agriculture sector. All of these technologies only came into existence in the last 25 years [32].

[Figure 3 about here.]

### 3.5 Modern Agricultural Data Science Beyond Food

Data science has the power to improve farming and agriculture in ways beyond just precision agriculture and growing food in ways and places that have never been done before. By taking a look at the entire picture, it is possible to shave even more off the proverbial top in terms of efficiency and improving sustainability in relation to farming and agriculture. Data science can improve the economic returns of local farmers while also helping to minimize the environmental footprint that is produced from the production and transportation of goods. Modern technology and machines enable for the harvesting, gathering, and preparation of food goods to be automated, faster, and much more efficient than if it was done by hand [32]. Modern technology also allows for the farmer and business owners to keep track of how much of their products are being sold and in which locations. This allows the retailer to order more precise amounts to fit their needs while also informing the farmer which crops are best to grow, when to grow them, and what

quantities to shoot for. GPS and other transportation technology can be used in the transportation process to make sure that the drivers have the most direct and efficient routes possible while delivering their goods, and advances in communications technology make it easy for orders to be changed or updated at the last minute [29]. The goal of all of this is to produce less overall waste and put less stress on the environment. Data science helps mitigate problems that would produce more waste and add stress to the environment, so in this way, it is one of the most important tools humanity has in solving these problems and continually improving the agriculture sector to meet the demands of bigger populations.

### 3.6 Setbacks and Steps Towards the Future

The ability to analyze agriculture data with modern technology is leading to many unexpected discoveries. With sustainability and combating climate change being two of the most important driving factors in innovation, scientists and farmers are finding are using data science models to find dynamic solutions to problems, both old and new. At this point one of the biggest problems holding back agricultural data science, despite the fact that more and more data is being generated everyday, is the distinct lack of data. There are many challenges that must be overcome as we move towards the future of agriculture, but one of the greatest obstacles “is to obtain reliable data on farm management decision making, both for current conditions and under scenarios of changed bio-physical and socio-economic conditions” [6]. In other words, it is not a question of having reliable data, as much as it is a question of having reliable data that pertains to scenarios and circumstances that are difficult to reproduce, that have not happened yet, but are speculated to happen as the climate change. Despite this, the modern data that has been collected is obviously still being put to good use and helping to solve major problems that humanity knows will be immense obstacles in the future.

One example of a modern solution to an old problem is fighting emissions that pollute the earth. Although it is often thought that vehicle and airplane emissions cause the most air pollution, but of all of humankind’s endeavours, it is factory farming that is having the biggest impact on our environment and exacerbating the effects of climate change [7]. Agricultural data science is being used to help combat the effects of factory farming in a number of unorthodox ways. One recent example of agricultural data science making a breakthrough in this area came when scientists discovered that feeding cows, who are by far the biggest producers of methane and other remissions, ground up bits of seaweed with their regular feed will radically reduce the amount of methane they produce while having no negative affect on the animals [19]. The wireless monitoring sensors and models used to ascertain these findings were only available because they were created from investments in the pursuit of agricultural data science practices. As findings like this become more common and see widespread adoption, the environmental footprint of factoring farming will begin to decline. This will be incredibly useful for developed nations whose factoring farming emissions levels are continuing to rise [7].

[Figure 4 about here.]

## 4 THE FUTURE OF AGRICULTURAL DATA SCIENCE

The future of agricultural data science is concerning itself with not only continuing to solve and improve the same old problems, but also exploring entirely new, out of this world concepts in regards to farming and growing foods. In the past, agricultural data science was focused on gathering data and growing the field. Modern agricultural data scientists are taking on problems like climate change, staggering populations and their demand for food, and finding new ways to improve sustainable agricultural models. So, then, it seems that the future of agricultural data science is beginning to come into focus. Although new problems and fields are bound to arise, the focus of the future of agricultural data science seems to be on automation and enhanced sustainability through disturbing the environment as little as possible [18]. Since machines are able to perform tasks more efficiently than humans can, reaching a point of agricultural automation is one of the potential goals of sustainable models. A mostly automated farm is much more efficient than one that relies on the human element to perform jobs and work. That is not to say that there will never be a human element involved, but the future farmers may have more in common with data scientists and programmers than they do with their modern and historical counterparts who worked in fields most of the day [23]. As technology improves in ways we cannot imagine right now, the possibilities of how data science will influence agriculture in the future are great.

The future may seem like science fiction in many ways, but modern technology and agricultural procedures may have seemed like science fiction if they were explained to a farmer from the 1950s. That does not mean that we are not able to see where a lot of different areas or advancing, to theorize technology and procedures that farmers and agriculturalists are not able to take advantage of now because they are too expensive. But as technology becomes cheaper and new methods and data science models are built, the future quickly becomes the present as humans catch up with their imaginations. Advances in automation, bloodless food production, extra-solar farming, and eventually terraforming, when realized, have the potential to transform our society in astonishing ways, possibly even leading to a post scarcity society where everyone’s basic needs are met. Where agriculture itself enabled humankind to stop focusing on strictly survival and evolve into societies, so too might automated agriculture and food production allow for humanity to achieve a new level of societal evolution [10].

The coming changes in agricultural data science are not simply limited to technological or physical. Indeed, even now as humanity’s understanding of its impact on the climate and surrounding environment is coming to be better understood, world governments are beginning to realize the importance of sustainability and limiting the environmental footprint that is created from food production. World governments taking an active interest is having a positive effect on the research and development being done in the fields related to agricultural data science [6]. This new emphasis is changing the way many politicians think about agriculture and making them eager to use political leverage to enact changes in government which put guidelines into place and make resources available

that enable agricultural researches to analyze their data and make informed decisions when attempting new agricultural endeavours.

#### 4.1 The Future and Automation

Much as sustainability and environmental impact are big tent poles driving innovation in agricultural data science and technology, so too will they continue to be in the future. However, a third piece of the puzzle is being thought of as more data is generated and analyzed, and that piece is automation. Automation is when technology and machines work to perform the jobs and tasks that humans would ordinarily do. Automation makes work far more efficient because, typically, a machine requires less resources to perform work than a human does. The resources a machine requires come largely in the form of costs upfront, but they quickly pay for themselves [18]. Automation allows for producers to produce their product around the clock, so too would the crops on an automated farm receive constant care and attention that a human would be unable to provide. This fine attention to detail would increase the amount of food produced and improve resource use efficiency for growing food.

This concept is not referring to an enormous, single intelligent farm that knows all. Instead, an automated smart farm would actually be a collection of many smaller, automated systems that all work together to ensure the success of the farm and its food production requirements. Not all farms would need to be completely autonomous in order to benefit from this technology. For example, some farms are already taking advantage of available technology to automate simple tasks and jobs that humans used to perform, such as automated irrigation systems [14] and tools that automatically extract key data bits from current crop conditions and executes automated commands to tend the farm, based on a set of predefined variables [9]. Nonetheless, as more and more automated systems are made available and become less expensive, more farms will be adopting them, leading to an even greater level of automation and requiring even fewer workers with diverse skill sets than ever before.

#### 4.2 Meat Grown in Labs

Climate change is one of the biggest threats spurring research and interest in efforts to improve sustainable agriculture practices. As mentioned earlier, the one human activity that by far has the greatest impact on the environment is factory farming, which is a process of raising cattle and other livestock in controlled conditions [7]. Similar in approach to precision agriculture, factory farming in developed nations is having a substantial impact on the environment from all the emissions the animals produce, as well as the resources that are required to operate factory farming facilities. This poses a problem for future generations since it is an unsustainable model. One solution being aided by data science that is currently too expensive is the possibility of growing meat in a laboratory setting without requiring the growing and slaughtering of actual animals. Basically, this process is “a novel idea of producing meat without involving animals with the help of tissue engineering techniques” [2]. At present levels of technology, this process is possible but far too expensive to be a practical solution to producing food on a large scale. However, data science models are helping to drive

down costs by allowing scientists to analyze their data and find more efficient ways to accomplish their goals. Once it becomes less expensive to grow meat in a lab that is indistinguishable from traditional meat, protein farms will likely start popping up all over the world [2].

There are other benefits to think about when considering the impact of switching from traditional meat production to lab grown. The biggest, as mentioned slightly above, is that it will help to dramatically reduce the environmental footprint being created by factory farming practices. Growing meat in labs, once costs and techniques are worked out, has the potential to be radically more sustainable model than humankind’s current practices [15]. Once it becomes possible and feasible to be able to grow all the healthy meat needed to satisfy the demands of the growing population in a lab, this model will begin to be adopted because of the economic and environmental advantages to its use that come with following a model focused on sustainability. Data science is helping to make this more of a reality by producing more advanced models that help scientists and engineers get their jobs done and find newer, cheaper ways to produce this lab grown meat [15].

[Figure 5 about here.]

#### 4.3 Farming in Space

One undeniable truth about humanity is that humans expanding and exploration seem to be hardwired into our genetic makeup. Since the beginning of humankind’s history, exploration and settlement have been a big part of what drives human innovation. Necessity is the mother of invention, as the saying goes. It is in the spirit of that saying that future agricultural endeavours are being theorized and planned for today. One big possibility on the horizon is the necessity to grow food and farm off-world because of lack of space, resources, or environmental factors making the available farmland incapable of meeting the demands of future populations [23]. Once agricultural development and food production reach a tipping point in regards to demands and human population, there will be no choice but to start farming in space. Enormous and fantastical space stations could be constructed where food could be grown in closed systems. This endeavour, though expensive, would eventually pay for itself and allow for a level of control, efficiency, and automation not available on Earth [23]. By designing and constructing a station like this from the ground up, with things like sustainability and efficiency in mind, food will be able to be produced in a way never before practiced by humanity. This has the added benefit of having absolutely no impact on the environment, since it is not even being done on Earth. Right now, space travel and getting super structures like this built are prohibitively expensive. However, the costs of such things are expected to go down as technology advances and methods of space travel become more available [31].

#### 4.4 Terraforming Worlds: the Height of Agriculture

At the most extreme end of outside the box thinking comes the most fantastic sounding concept yet: terraforming. Terraforming is the process of making another planet or heavenly body habitable for humans to live and thrive on. In the distant future there may come

a time when humanity needs to take steps to become a multi-planet species. Data science will be invaluable when achieving this level of agricultural endeavour as the amount of data to be processed and understood will require data analysis models and techniques that have not even been invented yet [8]. The ability to adapt a planet to human life would require a complete mastery of agriculture which could only be obtained through refined understanding of unimaginably large amounts of data created from attempting such a task. Right now, scientists can only re-create extraterrestrial soil in a labs and perform experiments to grow food there, so any work done in this field is mostly hypothetical, but not outside the realm of possibility. If humans continue to advance at the exponential pace at which they are, one thing begins to become undeniable clear. Given a long enough timeline, environmental, societal, or geographical conditions will come about that will one day make it a necessity for humans to start living on multiple planets. Although this is science fiction now, data science and the insights its use grants us are making the impossible possible everyday.

One applicable experiment that was performed to test the validity of adapting the soil on Mars to growing terrestrial flora was when scientists looked at the recent volcanic iron deposits in Santorini, Greece. The bizarre lifeforms that were found living in this environment “provides a potentially useful ecosystem for Mars terraforming experiments” [24]. Using data science to gather and make sense of the data generated on terrestrial locations that are similar to extraterrestrial ones brings humanity one step closer to terraforming, even if it is a baby step. As fantastical a concept as bending another planet to humanity’s will is, if you stop to think about it, this is nothing new. Humans have been terraforming the Earth for thousands of years already, just not in the ways we would prefer. Terraforming on a large scale is theoretically possible, but it will never be possible without the data science tools and techniques to analyze the mountains of data that would be need to be analyzed to achieve such a advantageous goal that may one day be a necessity.

#### 4.5 Restructuring Society

The possibility of achieving a post-scarcity society, while seemingly outlandish considering humanity’s current problems, could become a reality in the future. Having all of humanity’s food needs met automatically through space aged inventions like massive orbiting space farms and home or lab grown meat would lead to a restructuring of society humans have not seen since we first started farming twelve thousand years ago [10]. Should humanity ever achieve this level of societal progress, data science methods and models will be largely to thank for allowing humans to understand and improve their work by analyzing the data it produces. A largely automated society would produce an enormous amount of data to be analyzed, which as previously discussed, has the benefit of becoming even more sophisticated as more data is generated to learn from [3]. This self reinforcing system of generating data, improving from it, then generating more is showing no signs of slowing down as humanity is only just now beginning to see the benefits of complex automation. Self driving vehicles and automated farms are on the horizon, as well as a myriad of other technological innovations, and data

science and its versatile applications are one of the biggest reasons that humanity has to thank for these technological possibilities.

### 5 CONCLUSION

Humanity’s modest roots as simple nomads who discovered that they could grow their own food and use agriculture as a tool to build civilizations lasted for thousands and thousands of years. There were advancements, sure, but they were slow in coming and lacking in sophistication. However, in the last 75 years or so, humanity has seen the agriculture sector explode with new developments in techniques, technologies, and practices that have increased food production and allowed the agricultural sector to keep pace with growing populations that have a greater demand for food and agricultural resources. How was the agricultural sector able to revolutionize itself when in the past, changes came about much more slowly and incrementally? The answer, of course, is that the field of data science has been one of the chief tools used to solve agricultural problems and find solutions that meet the demands of today.

Technological advancements in hardware and modeling systems are ushering in a whole new era of human agriculture that focuses on sustainability. Producing as little waste as possible, while also impacting the environment in ways that contribute to climate change in as few of ways as they can are among the most important goals of modern day agriculture and food production, and data science is helping farmers and agriculturalists achieve these beefy goals. By creating vast networked farms, modern day farmers and agriculturalists have access to a level of data analysis that has not been available in the past, enabling them to make informed decisions and change the way they do things in order to improve the efficiency and output of their farms. This analysis is also leading to improved sustainability practices on farms by allowing the farmers to understand statistics about resource use and relation to crop growth like they could not in the past. Urban farming is also proving to be a modern solution to food distribution problems in highly populated areas, while also having the beneficial side effect of the plants helping to clean and detoxify the potentially harmful human made emissions that are found in major cities around the world.

The field of data science, from its origin to its current state as one of the premiere methods of human problem solving, is only going to continue to become more and more sophisticated as time goes on. With computer technology continuing to become smaller, cheaper, and more powerful, as well as data analysis models increasing in their reach and sophistication, the future of decision management tools and informed decision making that is going to be available to farmers and agricultural workers will be staggering. The future that agricultural data science is enabling seems like science fiction, but it is rapidly becoming a reality. Major projects like orbiting farms that meet the demands of the Earth’s people to terraforming entire planets are going to require advanced tools and models that only sophisticated data science techniques and models will be able to provide in the future. Although humanity is still going through the growing pains of becoming a global, connected community, the future looks bright, statistically speaking. World hunger is still a problem humans are trying to solve, but data science has empowered us to fight it on a level battlefield where. Assuming

human innovation continues at the exponential rate it has set for itself, the struggle to feed every human is a battle data science will help us to win.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski, Miao Jiang, and Juliette Zerick for assistance with my assignments and using github.

## REFERENCES

- [1] Hermann Auernhammer. 2001. Precision farming – the environmental challenge. *Computers and Electronics in Agriculture* 30, 1-3 (feb 2001), 31–43. [https://doi.org/10.1016/s0168-1699\(00\)00153-8](https://doi.org/10.1016/s0168-1699(00)00153-8)
- [2] Zuhail Fayaz Bhat, Sunil Kumar, and Hina Fayaz Bhat. 2015. In vitro meat: A future animal-free harvest. *Critical Reviews in Food Science and Nutrition* 57, 4 (may 2015), 782–789. <https://doi.org/10.1080/10408398.2014.924899>
- [3] Alain Biem, Maria A. Butrico, Mark D. Feblowitz, Tim Klinger, Yuri Malitsky, Kenney Ng, Adam Perer, Chandra Reddy, Anton V. Riabov, Horst Samulowitz, Daby Sow, Gerald Tesauro, and Deepak Turaga. 2015. Towards Cognitive Automation of Data Science. In *Proceedings of the Twenty-Ninth AAAI Conference on Artificial Intelligence (AAAI'15)*. AAAI Press, Austin, Texas, Article AAAI'15, 2 pages. <http://dl.acm.org/citation.cfm?id=2888116.2888360>
- [4] Norman E. Borlaug. 2002. Feeding a world of 10 billion people: The miracle ahead. *In Vitro Cellular & Developmental Biology - Plant* 38, 2 (mar 2002), 221–228. <https://doi.org/10.1079/ivp2001279>
- [5] Norman E. Borlaug. 2007. Sixty-two years of fighting hunger: personal recollections. *Euphytica* 157, 3 (jun 2007), 287–297. <https://doi.org/10.1007/s10681-007-9480-9>
- [6] Susan M. Capalbo, John M. Antle, and Clark Seavert. 2017. Next generation data systems and knowledge products to support agricultural producers and science-based policy decision making. *Agricultural Systems* 155 (jul 2017), 191–199. <https://doi.org/10.1016/j.agsy.2016.10.009>
- [7] Dario Caro, Steven J. Davis, Simone Bastianoni, and Ken Caldeira. 2014. Global and regional trends in greenhouse gas emissions from livestock. *Climatic Change* 126, 1-2 (jul 2014), 203–216. <https://doi.org/10.1007/s10584-014-1197-x>
- [8] Amber Dance. 2016. Science and Culture: Terraforming a volcano, artfully. *Proceedings of the National Academy of Sciences* 113, 16 (apr 2016), 4234–4235. <https://doi.org/10.1073/pnas.1603563113>
- [9] Jnaneswar Das, Gareth Cross, Chao Qu, Anurag Makineni, Pratap Tokekari, Yash Mulgaonkar, and Vijay Kumar. 2015. Devices, systems, and methods for automated monitoring enabling precision agriculture. In *2015 IEEE International Conference on Automation Science and Engineering (CASE)*. IEEE, Austin, TX, Article 10.1109/coasee.2015.7294123, 12 pages. <https://doi.org/10.1109/coasee.2015.7294123>
- [10] Matthew David. 2017. Sharing: post-scarcity beyond capitalism? *Cambridge Journal of Regions, Economy and Society* 10, 2 (feb 2017), 311–325. <https://doi.org/10.1093/cjres/rxs003>
- [11] Dickson Despommier. 2013. Farming up the city: the rise of urban vertical farms. *Trends in Biotechnology* 31, 7 (jul 2013), 388–389. <https://doi.org/10.1016/j.tibtech.2013.03.008>
- [12] T. Garnett, M. C. Appleby, A. Balmford, I. J. Bateman, T. G. Benton, P. Bloomer, B. Burlingame, M. Dawkins, L. Dolan, D. Fraser, M. Herrero, I. Hoffmann, P. Smith, P. K. Thornton, C. Toumlin, S. J. Vermeulen, and H. C. J. Godfray. 2013. Sustainable Intensification in Agriculture: Premises and Policies. *Science* 341, 6141 (jul 2013), 33–34. <https://doi.org/10.1126/science.1234485>
- [13] Rhys E. Green, Stephen J. Cornell, Jörn P. W. Scharlemann, and Andrew Balmford. 2005. Farming and the Fate of Wild Nature. *Science* 307, 5709 (2005), 550–555. <https://doi.org/10.1126/science.1106049>
- [14] Joaquin Gutierrez, Juan Francisco Villa-Medina, Alejandra Nieto-Garibay, and Miguel Angel Porta-Gandara. 2014. Automated Irrigation System Using a Wireless Sensor Network and GPRS Module. *IEEE Transactions on Instrumentation and Measurement* 63, 1 (jan 2014), 166–176. <https://doi.org/10.1109/tim.2013.2276487>
- [15] Olive Heffernan. 2017. Sustainability: A meaty issue. *Nature* 544, 7651 (apr 2017), S18–S20. <https://doi.org/10.1038/544s18a>
- [16] James W. Jones, John M. Antle, Bruno Basso, Kenneth J. Boote, Richard T. Conant, Ian Foster, H. Charles J. Godfray, Mario Herrero, Richard E. Howitt, Sander Janssen, Brian A. Keating, Rafael Munoz-Carpenna, Cheryl H. Porter, Cynthia Rosenzweig, and Tim R. Wheeler. 2017. Brief history of agricultural systems modeling. *Agricultural Systems* 155 (jul 2017), 240–254. <https://doi.org/10.1016/j.agsy.2016.05.014>
- [17] Mohamed Rawidean Mohd Kassim, Ibrahim Mat, and Ahmad Nizar Harun. 2014. Wireless Sensor Network in precision agriculture application. In *2014 International Conference on Computer, Information and Telecommunication Systems (CITS)*. IEEE, Austin, TX, Article 10.1109/cits.2014.6878963, 9 pages. <https://doi.org/10.1109/cits.2014.6878963>
- [18] Michael Kassler. 2001. Agricultural Automation in the new Millennium. *Computers and Electronics in Agriculture* 30, 1-3 (feb 2001), 237–240. [https://doi.org/10.1016/s0168-1699\(00\)00167-8](https://doi.org/10.1016/s0168-1699(00)00167-8)
- [19] Robert D. Kinley, Rocky de Nys, Matthew J. Vucko, Loreenna Machado, and Nigel W. Tomkins. 2016. The red macroalgae Asparagopsis taxiformis is a potent natural antimethanogenic that reduces methane production during in vitro fermentation with rumen fluid. *Animal Production Science* 56, 3 (2016), 282. <https://doi.org/10.1071/an15576>
- [20] David R. Lee. 2005. Agricultural Sustainability and Technology Adoption: Issues and Policies for Developing Countries. *American Journal of Agricultural Economics* 87, 5 (nov 2005), 1325–1334. <https://doi.org/10.1111/j.1467-8276.2005.00826.x>
- [21] F Martellozzo, J-S Landry, D Plouffe, V Seufert, P Rowhani, and N Ramakutty. 2014. Urban agriculture: a global analysis of the space constraint to meet urban vegetable demand. *Environmental Research Letters* 9, 6 (2014), 064025. <http://stacks.iop.org/1748-9326/9/i=6/a=064025>
- [22] R. Mendelsohn and A. Dinar. 1999. Climate Change, Agriculture, and Developing Countries: Does Adaptation Matter? *The World Bank Research Observer* 14, 2 (aug 1999), 277–293. <https://doi.org/10.1093/wbro/14.2.277>
- [23] L. Purdy. 2016. Farming from space. *Engineering & Technology* 11, 2 (mar 2016), 40–44. <https://doi.org/10.1049/et.2016.0203>
- [24] Eleanor Iberall Robbins, Chrysoula Kourtidou-Papadeli, Arthur S. Iberall, Gordon L. Nord, and Motoaki Sato. 2015. From Precambrian Iron-Formation to Terraforming Mars: The JIMES Expedition to Santorini. *Geomicrobiology Journal* 33, 7 (sep 2015), 1–16. <https://doi.org/10.1080/01490451.2015.1074322>
- [25] David C. Rose, William J. Sutherland, Caroline Parker, Matt Lobley, Michael Winter, Carol Morris, Susan Twining, Charles Foulkes, Tatsuya Amano, and Lynn V. Dicks. 2016. Decision support tools for agriculture: Towards effective design and delivery. *Agricultural Systems* 149 (nov 2016), 165–174. <https://doi.org/10.1016/j.agsy.2016.09.009>
- [26] Wanju Shi, Gui Xiao, Paul C. Struiik, Krishna S.V. Jagadish, and Xinyou Yin. 2017. Quantifying source-sink relationships of rice under high night-time temperature combined with two nitrogen levels. *Field Crops Research* 202 (feb 2017), 36–46. <https://doi.org/10.1016/j.fcr.2016.05.013>
- [27] Neil Stephens and Martin Ruijkamp. 2016. Promise and Ontological Ambiguity in the in vitro Meat Imagescape: From Laboratory Myotubes to the Cultured Burger. *Science as Culture* 25, 3 (jul 2016), 327–355. <https://doi.org/10.1080/09505431.2016.1171836>
- [28] Suparwoko and Betri Taufani. 2017. Urban Farming Construction Model on the Vertical Building Envelope to Support the Green Buildings Development in Sleman, Indonesia. *Procedia Engineering* 171 (2017), 258–264. <https://doi.org/10.1016/j.proeng.2017.01.333>
- [29] A Trauger. 2009. Social agency and networked spatial relations in sustainable agriculture. *Area* 41, 2 (jun 2009), 117–128. <https://doi.org/10.1111/j.1475-4762.2008.00866.x>
- [30] "U.S. Census Bureau". 2014. 2012 Census. U.S. Department of Agriculture. (May 2014).
- [31] Maria Antonietta Viscio, Eugenio Gargioli, Jeffrey A. Hoffman, Paolo Maggiore, Andrea Messidor, and Nicole Viola. 2014. A methodology for innovative technologies roadmaps assessment to support strategic decisions for future space exploration. *Acta Astronautica* 94, 2 (feb 2014), 813–833. <https://doi.org/10.1016/j.actaastro.2013.10.004>
- [32] Ning Wang, Naiqian Zhang, and Maohua Wang. 2006. Wireless sensors in agriculture and food industry—Recent development and future perspective. *Computers and Electronics in Agriculture* 50, 1 (jan 2006), 1–14. <https://doi.org/10.1016/j.compag.2005.09.003>

#### LIST OF FIGURES

1	The decline of US farmers [30].	12
2	Farm occupation statistics [30].	12
3	Projections show how quickly the technology was growing at the start of the 21st century [32].	13
4	Cattle emissions rate trends over the years [7].	13
5	Simplified process by which stem cells grow edible meat [27].	14

## Number of U.S. Farmers, 2007 and 2012

<b>Operators</b>	<b>2007</b>	<b>2012</b>	<b>% change</b>
Principal	2,204,792	2,109,303	-4.3*
Second	931,670	928,151	-0.4
Third	145,072	142,620	-1.7
All	3,281,534	3,180,074	-3.1

\*Statistically significant change.

Source: USDA NASS, 2012 Census of Agriculture.

Figure 1: The decline of US farmers [30].

### Gender, Primary Occupation, and Years on Farm, 2012 (percent)

Farm Operators	Gender		Primary Occupation		Years on Farm	
	Male	Female	Farm	Other	<10	10+
Principal	86	14	48	52	22	78
Second	33	67	37	63	31	69
Third	61	39	43	57	45	55
All	70	30	44	56	26	74

Source: USDA NASS, 2012 Census of Agriculture.

Figure 2: Farm occupation statistics [30].

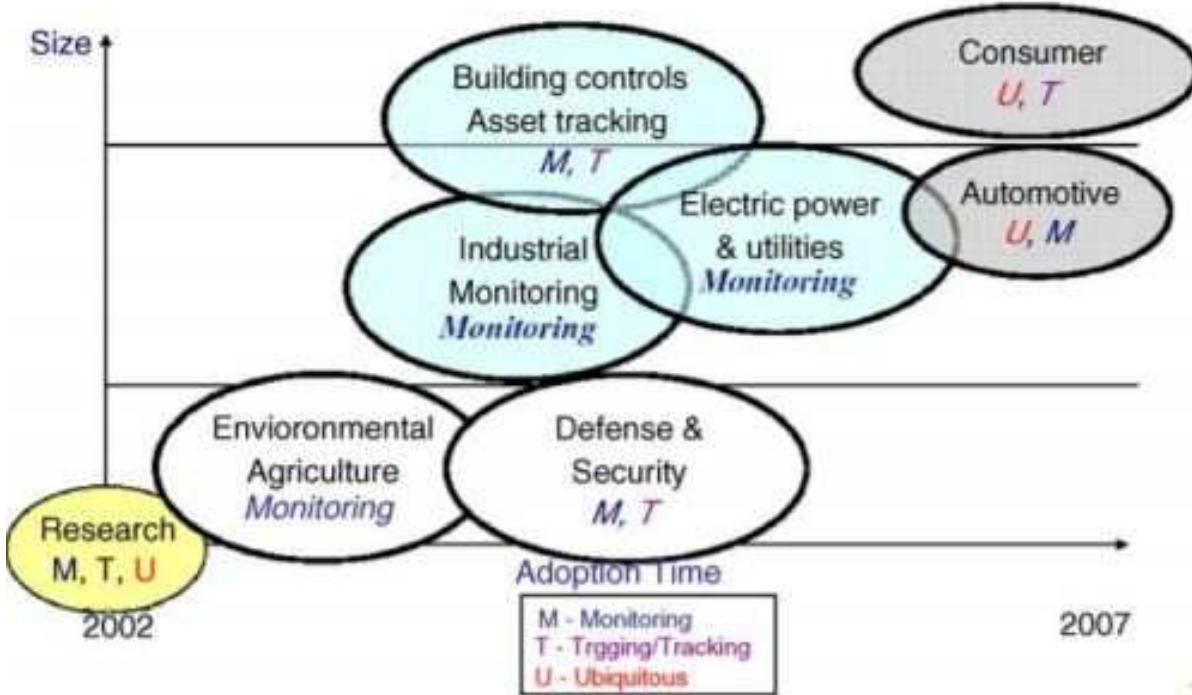


Figure 3: Projections show how quickly the technology was growing at the start of the 21st century [32].

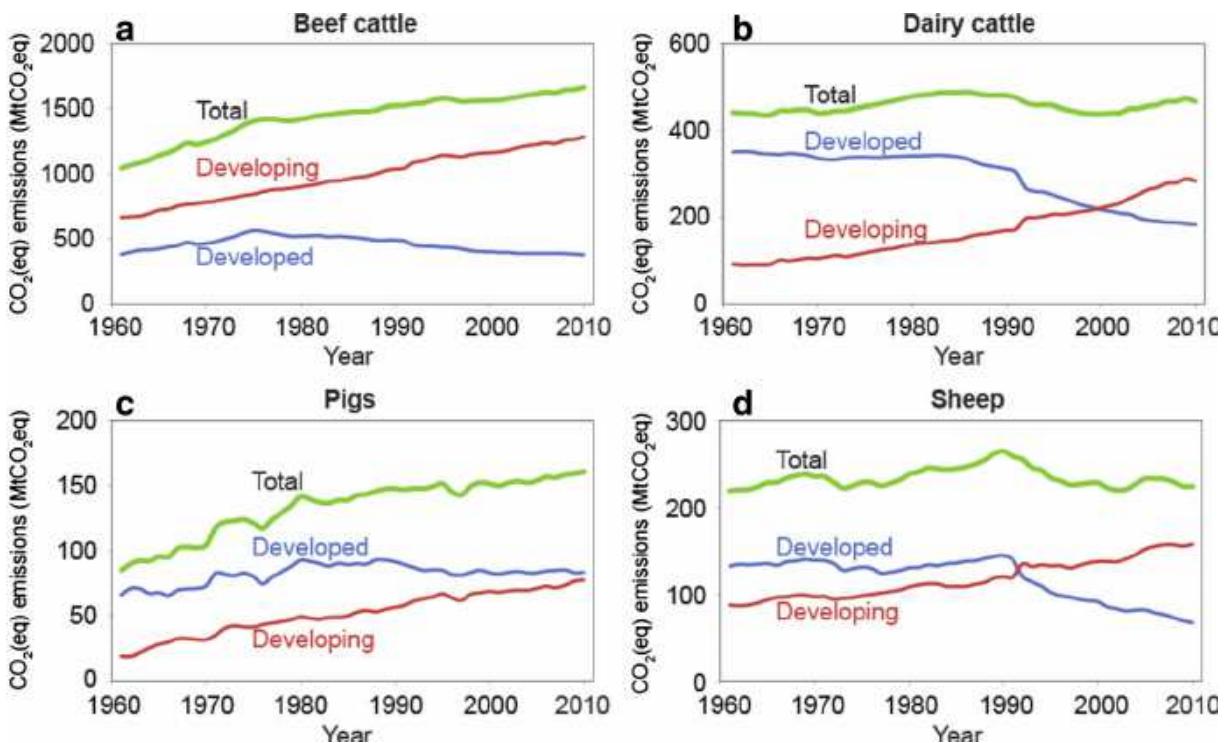


Figure 4: Cattle emissions rate trends over the years [7].

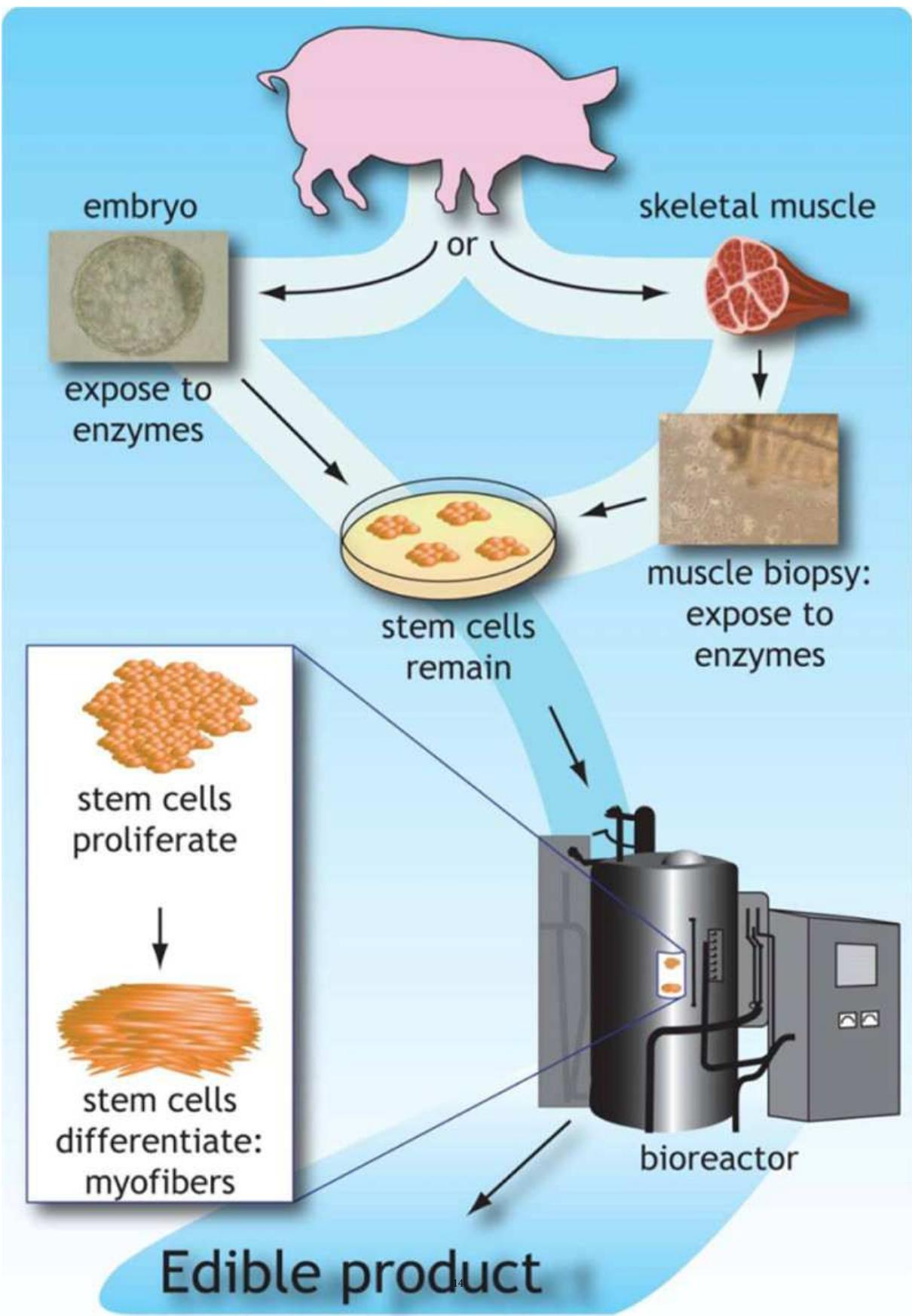


Figure 5: Simplified process by which stem cells grow edible meat [27].

```
bibtext report
```

---

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Ibera
while executing---line 3085 of file ACM-Reference-Format.bst
Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Ibera
while executing---line 3085 of file ACM-Reference-Format.bst
Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Ibera
while executing---line 3229 of file ACM-Reference-Format.bst
Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Ibera
while executing---line 3229 of file ACM-Reference-Format.bst
(There were 4 error messages)
make[2]: *** [bibtex] Error 2
```

```
latex report
```

---

```
[2017-12-12 20.03.14] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Float too large for page by 49.44307pt.
Typesetting of "report.tex" completed in 1.1s.
```

---

```
Compliance Report
```

---

```
name: Ross Wood
hid: 345
paper1: 100% re-review on 10/25/17
paper2: 100%
project: 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
14
wc 345 project 14 9943 report.tex
wc 345 project 14 10593 report.pdf
wc 345 project 14 2295 report.bib

find "
-----
passed: True

find footnote
-----
passed: True

find input{format/i523}
-----
4: \input{format/i523}

passed: True

find input{format/final}
-----
passed: False

floats
-----
71: \begin{figure}
72: \includegraphics[width=.9\columnwidth]{images/fig1.png}
76: \begin{figure}
77: \includegraphics[width=.9\columnwidth]{images/fig2.png}
103: \begin{figure}
104: \includegraphics[width=.9\columnwidth]{images/fig3.png}
118: \begin{figure}
119: \includegraphics[width=.9\columnwidth]{images/fig4.png}
143: \begin{figure}
144: \includegraphics[width=.9\columnwidth]{images/fig5.png}

figures 5
tables 0
includegraphics 5
labels 0
```

```
refs 0
floats 5
```

```
True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
True : check if all figures are referred to: (refs >= labels)
```

```
Label/ref check
passed: True
```

```
When using figures use columnwidth
[width=1.0\columnwidth]
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

---

```
WARNING: figure and above may be used improperly
```

95: Another angle that can be taken in regards to vertical farming is the idea of growing plants on all available flat surfaces. Not only floors, but also ceilings and walls where available. One problem major urban areas can have is a lack of green spaces available. This takes away from the aesthetics of these urban locations, while also allowing for pollution to go to choke out major areas in cities. Growing plants on some walls and buildings around major cities will help reduce the impact of both of these problems on the people and their environment. The plants being around the city take care of the lack of green places on its own, transforming concrete jungles into lush, semi-green cities. Meanwhile, the plants themselves will help clean up pollutants in the air from human emissions and simultaneously reduce amounts of noise pollution in their immediate vicinity. These green walls can even be limited to urban agricultural buildings themselves and would still be effective and have a positive impact on their immediate environment \cite{suparwoko2017} Again, data science makes all of this possible by allowing analysts and farmers to figure out the best ways to execute their agricultural endeavours,

how to grow their plants, which and how much of their resources they need to use, and so forth. Technically, all of this could have and has been done in the past; it is not difficult to grow plants on the sides of buildings. But now urban populations are reaching heights that have never been seen, and the demand on environmental resources and human emissions are ever increasing. These simple approaches to the problems presented above are a means for cities to tackle a lot of the problems in city living, along with helping ease their dependency on farmlands for resources \cite{suparwoko2017}. When urban farmers and city planners have access to data science and analysis tools that allow them to review and analyze information at a much deeper level, they are able to find new insights into the problems they are trying to solve. These new insights are driving urban farming to the level it needs to be at in order to meet the needs of an ever growing population and increased urban demand on resources.

bibtex

---

label errors

bibtex errors

This is BibTeX, Version 0.99d (TeX Live 2016)

The top-level auxiliary file: report.aux

The style file: ACM-Reference-Format.bst

Database file #1: report.bib

Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Iberall" while executing---line 3085 of file ACM-Reference-Format.bst

Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Iberall" while executing---line 3085 of file ACM-Reference-Format.bst

Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Iberall" while executing---line 3229 of file ACM-Reference-Format.bst

Name 4 in "Eleanora Iberall Robbins and Chrysoula Kourtidou-Papadeli and Arthur S. Iberall" while executing---line 3229 of file ACM-Reference-Format.bst

(There were 4 error messages)

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
```

---

```
The following tests are optional
```

---

```
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
passed: True
```

# Big Data Analysis for Wild File Prevention, and Tracking

Zachary Meier  
Indiana University  
Bloomington, Indiana 47408  
zrmeier@indiana.edu

## ABSTRACT

In Southern California, wildfires never seem too out of place and seem to be a commonly accepted as a norm for the most part. Over the years this problem has only continued to get worse. These fires started to cause massive amounts of property damage, loss of life, and hazardous conditions for everyone. When wildfires break out they soon become unpredictable due to wind conditions and vegetation. To amplify problems further, most places where burns take place are hard to reach by the emergency crews fighting them. The combination of these factors results in scattered resources, playing catch up rather than preventing the spread and evacuating large areas. Using Predictive analytics to not only know where a fire is going but, possibly preventing it in the first place may help save lives and billions of dollars.

## KEYWORDS

hid346, i523

## 1 INTRODUCTION

Wildfires are a large part of life in Southern California, and just like any other type of event has a large effect on the population, we as humans do our best to prepare for it. Originally, it was building houses with stucco and tile roofs so they were less likely to catch fire. Now with the advancement of big data, there is a new way to look at and defend against wildfires. These new technology and methods will allow first responders to be ahead of the fire. Allowing for them to set backfires, and protect properties more efficiently, as well as help prevent new fires popping up from Santa Ana winds which help carry fire embers to new locations. There are a couple new technologies that help deal with this exact type of problem.

## 2 THE DATA

Data, the gold of the information era we currently live in. However, in some ways it is a much more complex item to mine for. It is ubiquitous, which end up adding more layers to the complexity of squiring the gold we are after. To fine the information we are after we need to understand what we are looking for. Most times it is something already in place, and needs no new real creation to squire it. Only by manipulating this data, can we get the answers we need. Below will give a brief insight into the data and framework usage. Then we can start to look at how programs are being built to harness this data in new, creative, and useful ways.

### 2.1 Capturing Fire

For years fire has always been seen as something natural and unpredictable. The same we would view a wild animal. There is a certain mystery to it yet it is a force that demands respect. Though the respect of this powerful force of nature may never dwindle.

The mysteries of how it moves, burns and it's overall behavior are becoming less so. To know where fire is going to go, and to simulate it correctly you need two types of data. There is a need for static data, and a need for dynamic data. These two types are dependent. If static data were to be used only, we would know what a fire would like to burn most likely, but that is about it. However if you layer dynamic data into that situation, you create many possibilities that mirror real life conditions, and allow for fire fighters to, know where the fire is going to spread.

### 2.2 Static Data

The static data that will most likely be seen in this instance are maps. The understanding of vegetation in the geographic area allows of an understanding of what is most likely to fuel the fires spread. In addition there are topographic maps which show elevation of the land, which can also help understand how a fire might move through different terrains.

### 2.3 Dynamic Data

This is the information captured that can help understand what affects fire behavior and spread in a certain amount of time. This data for wild fires can be broken up in to two different categories, Graphical User Interface (GIS) fire perimeters, and meteorological variables.

*2.3.1 User Interface Fire Perimeters.* In order to predict the fire and its behavior there is a need of accurately identifying where it is located and where it is going via satellite. The use of satellites equipped with MODIS (Moderate Resolution Imaging Spectroradiometer) Which are used to create high resolution pictures of the area while being able to actually see where the fire is located without interference from weather conditions and smoke [3].

*2.3.2 Meteorological Variables.* These variables are really the main cause of fire spread. Many environmental factors such as temperature and humidity play a decent role in the behavior of the fire. However, the largest contributing factor to fire spread and overall behavior is wind. When wind speeds reduce typically fires are much easier to control. In harnessing data about wind conditions in Southern California, there maybe hope for creating real time, accurate fire spread data. Thus helping fire fighters react appropriately to where the fire is going, rather than just reacting to the fire itself. therefore, helping save money in property damage and live, and resources.

## 3 FIREMAP

Fire map is an interactive web based application in which you can simulate wildfire models. It also utilizes WIFIRE's data sets. It allows users to explore the map and work with multiple layers. The

layers can be changed, or have their opacities changed, allowing for multiple layers to be built upon one another. This give the user customizable data and better insight in the data.

### 3.1 Pylaski

To make Firemap to be interactive and useful to users it must be able to provide all the different types data from the multiple sources where the data is located. To do this Pylaski uses a rest service to query internal as well as external sources for date. It send a query for each individual request and then returns all the data at once back to the client. Pylaski is also able to use different schema's as well as different formats. This works fairly well creating an idea prediction. However as it is collecting massive amounts of data it is unable to query all of the data request because of size limitations. Though limiting it is most likely able to satisfy the requirements of the user [4].

### 3.2 GeoServer

GeoServer is a open source server for geographical datasets. It allows you to get data from a large number of geospatial data collection agencies. With these you can pull up a large number of maps.

**Historical Fires:** These are file that were collected on previous fire parameters. There were recoded for the whole United States from the years 2000-2015. In addition there are many records from California specifically from 1878-2014. All which if clicked on, tell you descriptions of the fire in detail.

**Satellite Detection:** Used thermal imaging and MODIS satellites to produce high resolution photos of fires from above. These fly over about two time a day, and are uploaded to NASA.

**Smoke Areas:** Show smoke plumes and help possibly identify the start of new wildfires. Data comes from NOAA

**Red Flag Areas:** Red flag areas are places where conditions are right for a possible fire occur. These are typically indicated by high wind speed or low relative humidity. this data comes from the National Wildfire Coordinating Group.

**Census Block:** The census block comes from the US Census which keep track of population density. Allowing for consideration of people affected by a fire.

**Surface Fuels:** Used thirteen ways to categorize fuel for fires through vegetation. This is a large factor in how fires will spread as they need easy to burn fuel to keep burning.

**Canopy Cover:** The percentage of forest floor covered by trees. Crutal in analyzing model crown fires which spread from top layers of trees.

**Camera Viewsheds:** Geographical areas with visibility of surrounding areas in which the HPWREN and AlertTahoe cameras are used to visualize the area of the fire.

## 4 WIFIRE

Wildfires in the right setting are beneficial to health of an ecosystem. However, when you put millions of people within that ecosystem, it becomes a problem. This is the problem that the WIFIRE project started at University of California San Diego is trying to remedy.

The have created an end to end cyber infrastructure system to create real time prediction, visualization for wildfires in San Diego Counter. They use real time data from sensors and satellite for observation as well as meteorological study in order to create up to date predictions. Being that San Diego county sees many wildfires, it is a prime location for testing this project out. The most recent fire in 2007 cost over one billion dollars and causes half a million people to be evacuated from their homes[1]. In order to collect the correct and most up to date information for tracking a wild fire they call upon the High Performance Wireless Research and Education Network known as HPWREN. In addition, the use various partner sites that also collect large amounts of data. These come from various types of data, such as, meteorology, vision and audio and hydrology. To make all of relevant and precise for the end users, such as the fire fighters.

### 4.1 Systems

Their systems for collecting this heterogeneous data uses a few different layers of architecture. There is a pipeline composed of many different sensors from the San Diego county, such as ground based sensors, SDG& E (San Diego Gas & Electric), Water Meteorology Stations and the HPWREN as well as collect satellite imagery. With all this heterogeneous data coming in the needed a way to process all the data. They achieved this with an open source workflow system called Kepler which organized the execution of the real time data processed. Then that system distributed it to a portal for end user consumption. This system is meant to handle large data input as well as execute computation in parallel so all data given is up to date [2].

### 4.2 Subsystems

The most important part of all this system is the data pipeline. Which in their workflow is called the Data Communication Subsystem. This system handles the large input of data and works with integration many different data sets and information from imaging, whether it be satellite or camera. The influx of data is come is produced by three types of communication systems. Meteorology stations, still cameras around San Diego County, and Satellite and Aerial data. This data communication layer uses REST services to take in the data to the database and the who process is done in memory to keep processing time as low as possible.

### 4.3 Data Mining

Big data today would not be what it is today if not for the fundamental process of data mining. Predicting trends based out of huge amounts of data, in order to understand exploit that data for practical use and application. WIFIRE also uses this methodology to find data relating to Santa Ana winds. Analyzing the data from the meteorological stations from around the county can help them realize when and where a Santa Ana wind possible. This data would be useful to the firefighter, because it would allow them to know the fire may have a chance to spread further. In addition this data can also be put into fire modeling to help predict wildfires movement even better in the future.

#### 4.4 Visualization

Using visual this project's goal is provide the most transparent data to first responders. Using satellite imagery to understand areas that have been previously scarred by fires and less likely to burn, while identifying areas that may be more susceptible to burning. This uses the topography and analization from previous fires to give them a better picture of how fires moved throughout the county. In addition to using the aerial data, the project is trying to create an application for pedestrians and bystanders to use to help track active fires from the ground. The premise of this idea is that if enough users take photos they can recreate where that photo was taken in a 3D space and track the fire that way. It would also help identify the fires over all perimeter. Once again helping first responders, more effectively fight the fires and know the whole area it covers and where it is heading.

#### 4.5 Assimilation

Most programs on the market are based off of just pure data, and produce a simulation base of that. The problem with that is fires and still not predictable. Using the behavior of real fires from real time data, and compares that against stimulation's, to correct the errors based off of the simulation alone. The system uses recursive algorithms created by Extended Kalman Filter and a Ensemble Kalman Filter. It uses existing fire models such as those in FARSITE in a separate workflow. Allowing for the real time fire date to run in process, and compare them against the simulation data previously provided. This allows them to be compared and move them to the update step, which is where the data assimilation takes place. Correcting previous errors for the simulation, allowing the simulations for future predictions to be much more accurate.

#### 4.6 Santa Ana Winds

Due to the amount of wildfires that spur up per year in the area, the amount of data received over wildfire may very. However, one of the biggest factors in wildfires and their spreading ability is with Santa Ana Winds. They are based off a couple key conditions, such as direction, speed and relative humidity. All of which create extremely dangerous situations for fires. Luckily there are many sensor around San Diego County that can detect this happening. The issues is however, is when an alert is sent, it is only for a specific point. With the kepler workflow they are able to take in data from those individual stations and run it through a program called WindNinja which can take vegetation, topography and weather stations into account produce a mapping of the areas affected. These are ran through the workflow breaking down tiles from the stations in 50km by 50km blocks for marking the wind occurrence. This then runs through a data processing software such as Spark or Hadoop.

### 5 CONCLUSION

In conclusion, the use of big data in fire prevention and tracking is an impressive system. It incorporates a multitude of sensors and data from various sources. Creating predictions of fires and creating data models which will help first responders saves lives, and protect property from damage. This application will allow efficient of firefighter resources and allow for them to be one step ahead of

the fire. Which until now was impossible. Only when the weather changed, were we able to change and react. With the predictive modeling and machine learning, the models will continue to get more accurate as the topography and fire interactions continue into the future. While this system will not prevent all wild fires, it will be instrumental in slowing them down and containing them. Once again man will try to tame fire as we have tried to do since the beginning of our existence.

### ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski and the TA's for their help and support.

### REFERENCES

- [1] 2007. Cost of California Wildfires Is More than 1 Billion. (October 2007). <https://www.npr.org/templates/story/story.php?storyId=15603441>
- [2] Ilkay Altintas, Jessica Block, Raymond de Callafon, Daniel Crawl, Charles Cowart, Amarnath Gupta, Mai Nguyen, Hans-Werner Braun, Jurgen Schulze, Michael Gollner, Arnaud Trouve, and Larry Smarr. 2015. Towards an Integrated Cyber-infrastructure for Scalable Data-driven Monitoring, Dynamic Prediction and Resilience of Wildfires. *Procedia Computer Science* 51, Supplement C (2015), 1633 – 1642. <https://doi.org/10.1016/j.procs.2015.05.296> International Conference On Computational Science, ICCS 2015.
- [3] C. Brun, T. Artes, A. Cencerrado, T. Margalef, and A. Corts. 2017. A High Performance Computing Framework for Continental-Scale Forest Fire Spread Prediction. *Procedia Computer Science* 108, Supplement C (2017), 1712 – 1721. <https://doi.org/10.1016/j.procs.2017.05.258> International Conference on Computational Science, ICCS 2017, 12-14 June 2017, Zurich, Switzerland.
- [4] Daniel Crawl, Jessica Block, Kai Lin, and Ilkay Altintas. 2017. Firemap: A Dynamic Data-Driven Predictive Wildfire Modeling and Visualization Environment. *Procedia Computer Science* 108, Supplement C (2017), 2230 – 2239. <https://doi.org/10.1016/j.procs.2017.05.174> International Conference on Computational Science, ICCS 2017, 12-14 June 2017, Zurich, Switzerland.

```
bibtext report
```

```
=====
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--no key, author in NPR
Warning--to sort, need author or key in NPR
Warning--no key, author in NPR
Warning--no key, author in NPR
Warning--no key, author in NPR
Warning--empty author in NPR
(There were 6 warnings)
```

```
bibtext _ label error
```

```
=====
bibtext space label error
```

```
=====
bibtext comma label error
```

```
=====
latex report
```

```
=====
[2017-12-12 20.03.20] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
Missing character: ""
Missing character: ""
Typesetting of "report.tex" completed in 0.9s.
```

```
=====
Compliance Report
```

```
=====
name: Zachary Meier
hid: 346
paper1: Nov 25 17 100%
paper2: Nov 28 17 100%
```

```
project: Dec 08 17 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
3
```

```
wc 346 project 3 2573 report.tex  
wc 346 project 3 2615 report.pdf  
wc 346 project 3 555 report.bib
```

```
find "
```

---

```
passed: True
```

```
find footnote
```

---

```
passed: True
```

```
find input{format/i523}
```

---

```
3: \input{format/i523}
```

```
passed: True
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

```
figures 0  
tables 0  
includegraphics 0  
labels 0  
refs 0  
floats 0
```

```
True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
True : check if all figures are refered to: (refs >= labels)
```

Label/ref check  
passed: True

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--no key, author in NPR
Warning--to sort, need author or key in NPR
Warning--no key, author in NPR
Warning--no key, author in NPR
Warning--no key, author in NPR
Warning--empty author in NPR
(There were 6 warnings)
```

bibtex\_empty\_fields

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
passed: True
```

# Gerrymandering Detection Using Data Analysis

Kevin Duffy  
Indiana University  
4014 E. Stop 10 Rd.  
Indianapolis, Indiana 46237  
kevduffy@iu.edu

## ABSTRACT

Can the evergreen issue of partisan gerrymandering be solved using data and algorithms? That question is closer to being solved than ever, as a method developed by University of Chicago researchers in 2014 is currently pending approval by the United States Supreme Court. We give a brief overview of the issue of partisan gerrymandering in American politics and why an objective data-informed measure is needed. We examine the method, known as the efficiency gap model, using data from Indiana's recent State Senate and House elections. We then evaluate the effectiveness of this model and take stock of any substantial critiques.

## KEYWORDS

Big Data, Elections, Gerrymandering, Voting, Efficiency gap, i523, HID310

## 1 INTRODUCTION

In 1964 the Supreme Court established in constitutional law the principle of "one-person, one-vote".[?] The idea appears self-evident; the value of any citizen's vote is equal to that of any other citizen's vote. But could anything still exist in our institutions of our democracy that resists this principle? Beyond obvious impediments to voting such as the since-repealed prohibition on women or racial minorities voting, what other barriers could exist? And why has "one-person, one-vote" become an issue as important, and contentious, as ever?

The barrier, many will argue [? ][? ][? ], lies in the concept of "gerrymandering", or the manipulation of legislative district lines for the benefit of one political player over another. But determining whether something is gerrymandered has proven to be a difficult task. And even once you decide something is gerrymandered, what can be done about it? Answers to these questions may be coming in the form of both advanced data analysis, and simple arithmetic.

In this paper we will lay the foundation of the issue: what is gerrymandering, when has it been used successfully, and what have people done to attempt to curb it? It is important to have meaningful context to the loaded political realities behind the term as well as why it is so relevant today. This will lead us into court cases currently being debated today which set up the necessity for data and objective measures to determine the existence of gerrymandering.

We will explore possible tests to identify gerrymandering, particularly the efficiency gap method which is the centerpiece to a court case currently awaiting a decision from the United States Supreme Court. This case could have the potential to make our data-informed measure a legal reality.

We will replicate the efficiency gap method in Python using data from Indiana's recent State Senate and House elections to gauge the

level of partisan gerrymandering baked into the state's legislative maps. We will discuss any complicating factors in this data and make provisions to account for them. We will evaluate these results, seek to find corroborating evidence for the model's accuracy, and suggest further courses of study.

It is our hope that this analysis will provide a clear picture of the state of gerrymandering politics in America today, explain how big data can be used to bring clarity and objectivity to the debate, and showcase how to put these ideas into practice using data-powered applications.

## 2 WHAT IS GERRYMANDERING?

The building blocks of America's democratic republic are legislative districts. Any one American lives in three overlapping districts: their State Senate district, their State House of Representatives district, and their U.S. House of Representatives (congressional) district. There is a set limit of 435 congressional districts dispersed to the 50 states based on population measured at the last U.S. Census. Within each state, each congressional district must be exactly the same size. Across the nation as a whole, the average population of a district is 710,000 residents. State House and Senate districts are given a 10 percent population range, as long as it is not systematically used to give one party an advantage. The federal government leaves it to the states to draw the lines all three of these maps. While there is some variance, most states have these lines drawn by the state legislature themselves. The lines are redrawn every ten years, after the census is conducted, in a process called redistricting.[? ][? ][? ]

Gerrymandering, simply put, is the process by which a political party in power uses redistricting to "manipulate district boundaries to create maps that systematically advantage the party in control and lock in an advantage for the party in future elections", according to the NYU Brennan Center of Justice.[?] In other words, the political party seeks to maximize the efficiency of each vote for their candidates, while decreasing the efficiency of the opposite party. This is done primarily through by "cracking" and "packing" the district maps:

- *Cracking* means splitting up a bloc of voters loyal to one party into several other districts, thus diluting the power of their collective vote and maximizing the amount of districts the preferred party is competitive in.
- *Packing* means concentrating a bloc of voters loyal to the opposing party into one district, giving them an overwhelming share of the vote in that district, but decreasing their power in several other districts. [? ]

The overall effect of cracking and packing is maximize the "wasted votes" of the disfavored party, while minimizing those of the favored

party. The concept of wasted votes is crucial to the model we will examine further. A wasted vote can be defined as one of the following:

- For the winning candidate (party A), a wasted vote is any vote beyond the threshold needed to win, or 50 percent of the vote.
- Every vote for the losing candidate (party B) is considered wasted, as the vote did not net a seat for that party.<sup>[?]</sup>

You can clearly see the potential for cracking and packing to greatly effect the amount of wasted votes a certain party receives. When a party's voters are cracked into several different districts, the net effect is that their votes go to various losing candidates, thus the votes are all wasted. When a party's voters are packed into one concentrated district, the net effect is that their votes overwhelmingly elect just one candidate, well beyond the needed threshold to win. Thus, all the votes beyond that threshold are wasted.

## 2.1 History

This is not merely a theoretical exercise. Gerrymandering has been utilized throughout the history of the United States by virtually every political party that has been in power. In fact, the term "gerrymander" dates back to 1812, when the *Boston Gazette* used the phrase to decry a unfairly-drawn redistricting plan signed into law by Massachusetts Governor Elbridge Gerry.<sup>[?]</sup> A famous political cartoon depicts one particularly contrived looking district as a dragon-esque creature, while others compared its shape to that of a salamander. The colloquial term became "gerry-mander" after the governor who enabled such a result.

The utilization and effectiveness of gerrymandering does not appear to have lessened with time. One of the most effective uses of the practice happened earlier this decade.

In 2008, the national Republican Party was in a dire position. Barack Obama had just been elected president in a sweep that included control of both houses of Congress. They held the House of Representatives by the largest margin seen in almost 20 years.<sup>[?]</sup> Journalist Michael Grunwald presented a grim narrative for the party in Time magazine in 2009, writing that "polls suggest that only one-fourth of the electorate considers itself Republican, that independents are trending Democratic and that as few as five states have solid Republican pluralities." In addition, he pointed out that the overall population was decreasing in demographics that had proven to be solidly Republican - "less white, less rural, less Christian".<sup>[?]</sup>

Fast-forward to 2017: Republicans control the White House and Congress, owning the House by almost as large a margin as the Democrats did just 8 years earlier.<sup>[?]</sup> What happened to produce results that so starkly contrast with the outlook Grunwald predicted?

## 2.2 REDMAP

In the wake of the 2008 election, the Republican State Leadership Committee launched the Redistricting Majority Project (REDMAP).<sup>[?]</sup> The strategy of the plan was brilliant in its simplicity: use their funding to target state legislature races in order to control as many state legislatures as possible when the next redistricting occurred in 2011. In most states, the task of drawing new district boundaries

is left to the state legislatures.<sup>[?]</sup> Redistricting occurs after each census to reflect changes in population densities and demographics. The strategy paid off in giving Republicans control of the redistricting process in many of the states. From there, partisan politics began its work.

REDMAP was a clear success as evidenced by the ensuing 2012 election, the year in which Barack Obama won reelection. In Michigan, for example, voters cast 240,000 more votes overall for Democrats in congressional races, but 9 Republicans were elected and only 5 Democrats. In Pennsylvania, voters cast 83,000 more votes overall for Democrats in congressional races, but 13 Republicans were elected and only 5 Democrats. Across the nation, Republicans won 54 percent of house seats and 58 out of 99 state legislative chambers, while winning only 8 out of 33 Senate races (which are gerrymander-proof as they do not rely on district lines).<sup>[?]</sup>

The effect of gerrymandering is evident in the results of REDMAP. Republicans maximized the wasted votes of the Democrats and minimized the wasted votes of the Republicans. Although in many cases Democrats had more votes statewide, more Republicans candidates were sent to Congress.

Gerrymandering is an issue seen by many in both parties as problematic. Representative Brian Fitzpatrick (R-PA) wrote in *The Hill* that gerrymandering has caused the nation to stray from its ideal of representative leadership, as it has "has undermined community-focused representation by forcing lawmakers to ideological extremes and exacerbating electoral complacency that causes lawmakers to focus on accumulating power rather than serving constituents."<sup>[?]</sup>

However, despite bipartisan efforts in the legislature such as those lauded by Fitzpatrick, the most promising avenue for curbing gerrymandering may lie in a different branch of government: the United States Supreme Court.

## 2.3 The Supreme Court and Gerrymandering

The court has already banned racial gerrymandering in the decision on *Thornburg v. Gingles* in 1986. They determined that a district map in North Carolina violated the Voting Rights Act by gerrymandering the districts in a way that unfairly diluted the power of black voters.<sup>[?]</sup>

But up until recently, partisan gerrymandering has been left to the states to police themselves. The Supreme Court has heard around 50 cases in its history imploring the court to intervene against a partisan gerrymandered map, and each time has deferred.<sup>[?]</sup> The last major case was *Vieth v. Jubelirer* in 2004. Justice Antonin Scalia, since deceased, delivered the majority opinion stating that the courts were not responsible for partisan gerrymandered maps as they were "non-justiciable".<sup>[?]</sup>

But the court is not unanimous in the opinion that partisan gerrymandering cannot be solved through judicial means. The vote in *Vieth* was a narrow one, and even those following Justice Scalia's lead had a range of views on the subject. Justice Anthony Kennedy, for example, is reliable in his unreliability - he serves as the court's "swing vote", as court observers are often unsure which way he'll fall on a given issue until the decision is handed down. Given the court's ideological polarity often leads to close votes, this arguably makes him the most powerful justice on the bench.

In *Vieth*, Kennedy voted along with the majority opinion that upheld the allegedly-gerrymandered maps. However, he left open the possibility of the court adjudicating gerrymanders, if a clear standard could be found for determining whether a map is gerrymandered or not.<sup>[?]</sup> Kennedy's logic was clear - the objective nature of a partisan map should not be left up to the subjective nature of a given judge's disposition. Any given judge could invent his or her own criteria for a map to be gerrymandered, and the nation would be buried in lawsuits alleging every map was gerrymandered. But if there were one, universally agreed upon measure that could serve as a standard from which to judge gerrymandering, this problem would not arise. Kennedy had not yet seen such a standard by the time he had voted in *Vieth*, but he did not write off the possibility that a standard could be developed that satisfied his criteria.

Such a standard has not been apparent until, perhaps, now.

### 3 THE EFFICIENCY GAP

In 2017, a case reached the Supreme Court alleging that the Wisconsin State Assembly was gerrymandered in such an extremely partisan way as to render it unconstitutional. The plaintiffs, savvy enough to recognize Justice Kennedy as the potential swing vote and remembering his desire for a clear standard, argued their case using the "efficiency gap" method.<sup>[?]</sup>

The efficiency gap method was developed by University of Chicago law professor Nicholas Stephanopoulos and Eric McGhee, a researcher at the Public Policy Institute of California.<sup>[?]</sup>

The efficiency gap is a relatively simple formula, based on the aforementioned concept of wasted votes. The formula takes the total statewide wasted votes of party A and subtracts the total statewide wasted votes of party B, and then divides that number by the total number of statewide votes to find the efficiency gap score.<sup>[?]</sup>

$$Gap = \frac{Waste(A) - Waste(B)}{TotalVotes}$$

Another way it can be written:

$$\text{Gap} = (\text{Seat margin}) - (2 \times \text{Vote margin})$$

The "seat margin" is the percentage of seats you win from the statewide allotment minus 50 percent, and the "vote margin" is the total percentage of the vote you win minus 50 percent. A negative result means the map is biased against you.<sup>[?]</sup> This is a helpful format when we begin measuring the net effect of gerrymandering in congressional districts.

If the two parties have similar numbers of wasted votes, or neither party has a significant amount of wasted votes, the efficiency gap score for that state will be low indicating acceptable levels of map bias. However, if one party has a disproportionate number of wasted votes compared to its opponent, the result will be a higher efficiency gap score indicating unacceptable levels of map bias.

This method captures the effects of both cracking and packing: packing will be detected by the wasted votes from an excessive victory, and cracking will be detected excessive amounts of losing votes statewide.

Let's apply this to an example. Let's say Party A and Party B are competing in a state with ten congressional districts of 100 people each (see Table 1).

[Table 1 about here.]

In Districts 01, 04, 06, and 09, Party A wins by an overwhelming margin. In the rest of the districts, Party B wins by narrow margins. This results in more votes being cast for Party A statewide, but Party B gets more seats as shown in Table 2:

[Table 2 about here.]

These races result in an overwhelming amount of wasted votes for Party A, and a minimal amount for Party B as shown in Table 3.

[Table 3 about here.]

We can see that Party A has many more wasted votes than Party B, indicating the map may be drawn to minimize the efficiency of Party A. We then add up the total number of votes cast statewide and plug these numbers into our efficiency gap formula:

$$\frac{448 - 52}{1000} = \frac{396}{1000} = 0.396$$

So our efficiency gap, written as a percentage, is 39.6 percent. The map is clearly tilted in favor of Party B. But is it considered illegal gerrymandering? In their paper, the authors establish thresholds for when an efficiency gap indicates levels of illegal gerrymandering:

- For state legislature maps, an efficiency gap score above eight percent is considered illegally gerrymandered. The mere percentage is used as each legislature is an entity unto itself, elected wholly by voters in the state. This along with variances in size among state legislatures, makes efficiency gap the best way to normalize disparate state houses for comparison.
- For congressional maps, a state is considered illegally gerrymandered if the map costs a party two seats. In contrast to state houses, the authors contend, "aggregate House seats are the parties' main objective". In that regard, seats are the best way to normalize disparate state sizes for comparison.<sup>[?]</sup>

If we write our formula in the format (Seat margin) - (2 x Vote margin), we can measure how many seats were lost as a result of the biased map. In this example, Party A won 64.8 percent of the vote, but was awarded only 4 out of the 10 seats. For Party A:

$$\begin{aligned} (.40 - .50) - (2 \times .148) \\ -.10 - .296 \\ -.396 \end{aligned}$$

Now let's give Party A enough seats to make the efficiency gap score as close to 0 as possible. We will say that Party A in this alternate scenario received 8 seats, represented as .80 in the seat share value:

$$\begin{aligned} (.80 - .50) - (2 \times .148) \\ .30 - .296 \\ .004 \end{aligned}$$

We have brought the score effectively to 0. So using this formula, we have determined that the efficiency gap derived from the biased map cost Party A a total of 4 seats, well above the threshold for illegal gerrymandering.

The question remains whether this standard will be used to measure map bias and judge gerrymandering. During oral arguments for *Whitford* in October 2017, Chief Justice John Roberts referred to the theory as "sociological gobbledegook".[?] But some court observers are anticipating Justice Kennedy, the swing vote, to vote in favor of the efficiency gap test.[?]

### 3.1 Criticism

As with any politically-charged debate, the efficiency gap has drawn criticism for simplifying the electoral process too much to come to its result. Critics contend that there are several factors the method ignores that may explain the phenomenon of gerrymandering. Two such critics, Chris Winkelman, an attorney for the National Republican Congressional Committee and Phillip Gordon, an outside attorney, filed a brief with the Supreme Court in the *Gill v. Whitford* case exposing what they saw as flaws in the efficiency gap formula.[?] These are indicative of the major arguments against the efficiency gap that we have found.

- (1) The method assumes that voters' party loyalties are static. In predicting the future, the model assumes that voters never change their minds and are not swayed by the contextual candidates involved. Winkelman and Gordon point to the 2012 and 2016 elections. They contend that studies have shown between 11 to 15 percent of voters chose Barack Obama, a Democrat, in 2012 and then chose Donald Trump, a Republican, in 2016. In addition, in 2016 12 Democrats won in districts that elected Trump while 23 Republicans won in districts that elected Clinton.
  - The efficiency gap method accounts for this by taking into account several elections in a row, rather than one single election. With more data smoothing out any abnormalities in partisan preference (for example, voters in blue-collar districts turning out in overwhelming numbers in 2016 to vote for Donald Trump), this should lessen any "pendulum" effect on the overall efficiency gap score.
- (2) The method ignores the effect of partisan geometry. The method assumes that partisan loyalties are spread out evenly among a state, when this is not the case. Typically, Democrats tend to concentrate heavily in urban areas, while Republicans are more thinly spread out among rural and suburban areas. This makes drawing maps in a compact and contiguous manner, which most agree is the ideal way to draw a map as opposed to winding, snake-like districts that are clearly to lump chosen groups of voters together, naturally beneficial to Republicans.
  - The efficiency gap authors concede that the measure may capture legitimate redistricting methods under the purview of gerrymandering. Thus, in outlining their proposed court test, they allow that states above the threshold could show that the the gap was the result of either the "consistent application of legitimate policies", or "inevitable due to the states' underlying political geography".[?]

## 4 APPLICATION

We implemented the efficiency gap method into a python application powered by real-world election data in order to determine whether the district maps for Indiana's House of Representatives and State Senate pass or fail the efficiency gap thresholds.

Indiana was chosen arbitrarily, primarily because it is the home to both the author and institution of this paper. In addition, Indiana's legislature gives us clean and uniform data to work with, as there are an even number of senators and representatives elected, no special elections, and no run-off elections to complicate the data. However, after implementation of the application, it became apparent that it was fortunate Indiana was chosen as the results showcase important teaching moments in understanding the efficiency gap and its applications.

Because we were evaluating state legislatures, we did not have to calculate seats lost, so the results are given in raw efficiency gap score.

### 4.1 Data sourcing and cleaning

For our data, we use the election results from the 2016 Indiana House of Representatives races[?], and the 2014 and 2016 Indiana State Senate races[?][?]. The data was collected from Ballotpedia, an online election and candidate encyclopedia. For context, each member of the House is elected every even year for a two-year term. There are 100 representatives. Each member of the Senate is elected to a four-year term, with elections occurring every two years to elect half of the members. There are 50 senators. Thus, to receive a full sample of the House races, we only needed to collect data from one election year. But for the Senate, we needed two election years in order to collect data for the full senate.

There were two complicating factors with the data that needed to be cleaned before implementation into our model:

- (1) One third of the races in 2016 were uncontested, meaning the winning candidate had no opposition to compare to. In 2014, almost half were uncontested. Depending on the county data recording, these are represented in one of two ways.
  - (a) The votes cast for the winner are displayed, resulting in an election that looks like 20,000 votes were cast for candidate A, and 0 votes were cast for candidate B.
  - (b) No votes are displayed, and the winner is simply displayed as a default.

Both of these taken at face value are problematic for our model. In the first case, plugging these results into our model could overstate how many wasted votes there were for the winning candidate, as the model would think that the winner received 20,000 more votes than they needed to, and the loser received no wasted votes. This is unlikely to occur in reality if the opposing party had fielded a candidate. Even if it is not a close race, the loser would accumulate enough votes to alleviate the amount of wasted votes accrued by the winner and increase the amount of wasted votes for the loser.

In the second case, rather than overstating the wasted votes, they are understated. The race is treated as a draw in

terms of wasted votes, when uncontested elections would in reality be a major symptom of an efficiency gap and wasted votes should be accrued.

Clearly, they cannot be ignored. The efficiency gap authors provide guidance on what to do with these races. For state house races, they ran a multi-level model using a fixed effect for incumbency and random effects for year, state, and district. If the district had been contested in its past, the value was derived from other districts in the state during that year along with the same district in other years. If not, they had a random draw of random effects. [?]

The results were a mean Democratic vote share of 66 percent for uncontested Democratic candidates, with 90 percent of values falling between 52 and 83 percent. Democratic vote share for races with uncontested Republicans was placed at 36 percent, with 90 percent of values falling between 22 and 43 percent. The authors do not hold this solution to be the be-all-end-all model for computing vote shares of uncontested candidates, as they "encourage scholars to explore a range of imputation techniques." [?]

Our solution was to uncritically use the authors' figures of 34 percent share for Republicans in uncontested Democratic seats, and 36 percent share for Democrats in uncontested Republican seats. For those seats that had no winning vote data available, we took the average population of a district, adjusted for that year's vote turnout, and applied the percentages to that number. For those seats with winning vote data, we simply took half of the winning votes as the loser's share of votes.

If further work to be undergone on this application, we would recommend fine tuning these calculations, particularly if one were to specifically focus on a particular state legislature, as vote shares for a given political party would most likely vary from state to state.

(2) The other complicating factor for this experiment was the existence of third parties. In the efficiency gap calculations, third party votes are ignored, relying on the two-party vote. [? ] For most districts, the effect that third parties have is marginal:

- The United States is a two-party system, mostly due its "winner take all" election rules (where the party with the most votes is the singular winner in a given race, whereas a proportional system would give distribute legislative seats proportionally based on vote share). Third parties therefore have a difficult time gaining any sort of power:
  - The highest vote share of any third party in the 2016 presidential election was 4 percent for the Libertarian Party, the highest share the Libertarian Party had ever received in a presidential election. [? ]
  - There are no third party members of the Indiana House of Representatives and the Indiana State Senate. [? ][? ]
  - There are no third party members of the U.S. House of Representatives. [? ]

- Third parties are varied; there is no one singular third party to claim a stake in the redistricting process. Thus, their voice is diluted by diversification.
- When we establish that we are operating under a binary party system, third parties make no difference in the efficiency gap formula, as a vote cast for a third party candidate is wasted for Democrats and Republicans equally, thus cancelling itself out.

The solution was straightforward - we simply removed third party votes from our calculations and operated under a two-party vote system.

## 4.2 Implementation

The application made moderate use of the Python Pandas module. We began by importing two dataframes: the 2016 House results, and the 2014 and 2016 Senate results combined into one dataframe. Because the efficiency gap is a simple formula, the values needed are similarly simple. The only values needed were the Republican votes and Democratic votes for each district (see Table 4):

[Table 4 about here.]

With the data imported, the first step is to calculate the wasted votes for both parties. We have two separate functions to calculate Democratic wasted votes and Republican wasted votes.

```
def dwaste(row):
    if row['dvotes'] > row['rvotes']:
        val = row['dvotes'] - ((row['dvotes'] + row['rvotes']) * .5)
    else:
        val = row['dvotes']
    return val
```

The Republican wasted votes function is identical except the 'dvotes' and 'rvotes' values are switched. This portion of the script goes line by line through the dataframe to calculate the wasted votes for each party per district. This needs to be done row by row as wasted votes cannot be found as an aggregate statewide total, but by looking at each individual district race.

Next, we applied the rwaste() and dwaste() functions to our data frames, and then we can get our statewide totals of wasted votes by party:

```
df['rwaste'] = df.apply(rwaste, axis=1)
rtotal = df['rwaste'].sum()
```

From there, we plugged the statewide wasted votes totals into our efficiency gap formula:

```
((total-rtotal)/((df['rvotes'].sum()+df['dvotes'].sum()))*100
```

Finally, we implemented a simple function that serves as our threshold test. If the formula falls above 8, it triggers an "UNCONSTITUTIONAL GERRYMANDER" response:

```
def eg():
    if final > 8
        print("UNCONSTITUTIONAL GERRYMANDER")
    else:
        print("ACCEPTABLE")
```

Since the data used for this particular experiment is small, the application was able to be executed on a personal computer using an Ubuntu virtualbox.

In short, the input for this application is a .csv dataframe of every seat's Democratic and Republican votes, and the output is the efficiency gap score in percentage form and an indication whether the legislative map exceeds the threshold for unconstitutional gerrymandering. This framework is simple in the data needed and could easily be replicated for any state legislative body.

### 4.3 Results

The application revealed that the House of Representatives, with 2,992,624 votes cast, had 838,675 Democratic wasted votes and 657,637 Republican wasted votes resulting in an efficiency gap score of 6.05 percent in favor of Republicans. This falls under the 8 percent threshold, indicating that if the efficiency gap were to be adopted as a court standard by the Supreme Court, this map would be ruled constitutional.

On the other hand, the Senate, with 2,107,263 votes cast, has 661,509 Democratic wasted votes and 347,122 Republican wasted votes resulting in an efficiency gap score of 15.58 percent in favor of Republicans. This lands well above the gerrymandering threshold. If this standard were to be adopted by the Supreme Court, there is a decent chance the Senate map would be ruled unconstitutional.

There are a few factors to consider that may be used to explain the discrepancy with the Senate vote:

- If we take at face value that the Senate is twice as gerrymandered as the House, a major reason could be district size. The House has twice as many districts as the Senate over the same land area. The more granular a district is, the more difficult it becomes for a map to be gerrymandered, as you have smaller populations and smaller land areas per district. People of similar ideologies and political leanings tend to group together, so with smaller parameters, it becomes more difficult to group some of these individuals with opposing parties in order to "crack" their vote.
- If we are skeptical, the results could be explained by the fact that half of the Senate data was taken from the 2014 midterm election, while all of the House data was taken from the 2016 presidential election.
  - Midterm elections tend to have lower voter turnout, so the data may not be as accurately reflect the true political landscape of a region. In 2014, Indiana had a voter turnout rate of 28 percent, the lowest in the nation that year[?], compared to 58 percent in 2016.[?]
  - Historically, Republicans tend to have higher turnout in midterm elections. Nationally, Republicans were 20 percent more likely to vote in 2010 and 2014 than Democrats were, according to an analysis by the New York Times' Nate Cohn. [?]

Further analysis would need to be done in order to determine if this explanation suffices. It would, in fact, be in the Republicans best interest to find an alternative explanation other than gerrymandering. Again, it can be allowed that states above the threshold could show that the the gap was the result of either the "consistent application of legitimate policies", or "inevitable due to the states' underlying political geography".[?]

However, when compared to other Indiana political measures, the Senate result is not especially surprising. While the Indiana is admittedly a "red state", or a state predominantly partial to Republicans, the Senate seat share appears to be out of sync with other measures. Currently, there are only 9 Democrats to 41 Republicans in the Indiana State Senate[?][?], meaning the Democrats have a 18 percent seat share. Compare this with the last three statewide elections for governor in Indiana:

[Table 5 about here.]

Meanwhile, the House of Representatives has 30 Democrats to 70 Republicans[?], which, while slightly lower than the gubernatorial vote share, can be explained as a "winner's bonus", or a small surplus of votes for the overall winning party. This is accepted by the efficiency gap authors and political scientists as a common feature in American political systems. They also accept that the USA is not a proportional representation system, where vote share corresponds virtually 1:1 with seat share.[?] Therefore measures like gubernatorial vote share versus legislative seat share cannot be used to prove partisan gerrymandering on its own, however, when drastic enough, it can certainly be used as a symptom to correspond with a more direct objective measure.

### 5 LIMITATIONS

Considering we developed an application for one state out of 50 from just one election cycle, and we did not develop an application for a congressional analysis, the scope of our analysis is limited.

If further research and applications were to be conducted, especially in the realm of big data, it may prove to be beneficial to scrape data from all 50 states to create a time series of state legislature efficiency gap changes across the entire country. This could be coded to import election results dynamically as they are held. This would be useful in observing changes in efficiency gap scores in response to implementations of redistricting plans, identifying ideal redistricting methods, and generating data for use in speculative algorithm-based redistricting applications.

There is also much big data potential in gerrymandering solutions and redistricting methods, while we have been limited to detection. AI and machine learning applications applied to the currently human-driven redistricting effort could prove to be revolutionary for this aspect of our electoral system.

### 6 CONCLUSION

An objective way to measure gerrymandering? Or, as Chief Justice John Roberts so colorfully put it, "sociological gobbledegook"? That definitive answer to that question lies outside the scope of this analysis, and the relevance of that question lies solely with the United States Supreme Court. They have the power, in coming months, to either make this measure the standard with which to measure all district maps moving forward, or toss it aside and continue this country's long history of ignoring partisan gerrymandering as far as the law is concerned.

We have shown how data can be used to transform the debate around partisan gerrymandering, taking what used to be a heated back and forth based on the arguers' political persuasions and elevating it to a debate on which mathematical standard should be

used to measure gerrymandering. Though, some still contend that it cannot be measured objectively whatsoever.

We have demonstrated on a preliminary basis some correlation between an excessive efficiency gap score and a disproportionate vote share in the case of the Indiana State Senate.

At the very least, we have sought to prove that the efficiency gap is indeed easy to calculate based on the parameters specified by the method's creators. For someone such as Chief Justice John Roberts, simpler may be better.

## **ACKNOWLEDGMENTS**

The author would like to thank Dr. Gregor von Laszewski and all TA's for their tireless work in ensuring this class goes smoothly.

## **REFERENCES**

LIST OF TABLES

1	Election Scenario A	9
2	Scenario A Total Votes and Net Seats by Party	9
3	Scenario A Wasted Votes by Party	9
4	Indiana House votes sample [? ]	9
5	Indiana Gubernatorial results by year	10

**Table 1: Election Scenario A**

District	Party A votes	Party B votes
01	<b>90</b>	10
02	49	<b>51</b>
03	45	<b>55</b>
04	<b>95</b>	5
05	45	<b>55</b>
06	<b>90</b>	10
07	49	<b>51</b>
08	45	<b>55</b>
09	<b>95</b>	5
10	45	<b>55</b>

**Table 2: Scenario A Total Votes and Net Seats by Party**

	Party A	Party B
Votes	648	352
Seats	4	6

**Table 3: Scenario A Wasted Votes by Party**

District	Party A Wasted votes	Party B Wasted votes
01	40	10
02	49	1
03	45	5
04	45	5
05	45	5
01	40	10
02	49	1
03	45	5
04	45	5
05	45	5
<b>Total</b>	<b>448</b>	<b>52</b>

**Table 4: Indiana House votes sample [? ]**

district	dvotes	rvotes
1	15561	7780
2	24820	12786
.	.	.
99	24820	12786
100	14110	7055

**Table 5: Indiana Gubernatorial results by year**

Year	Republican	Democrat
2008	58.8%	40.0%
2012	49.4%	46.5%
2016	51.3%	45.4%

bibtext report

=====

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
I couldn't open database file gerrymander.bib
---line 83 of file report.aux
 : \bibdata{gerrymander}
 :
I'm skipping whatever remains of this command
I found no database files---while reading file report.aux
Warning--I didn't find a database entry for "oneperson"
Warning--I didn't find a database entry for "wapo"
Warning--I didn't find a database entry for "chicago"
Warning--I didn't find a database entry for "thornburg"
Warning--I didn't find a database entry for "maps"
Warning--I didn't find a database entry for "population"
Warning--I didn't find a database entry for "govtrack"
Warning--I didn't find a database entry for "brennan"
Warning--I didn't find a database entry for "griffith"
Warning--I didn't find a database entry for "house"
Warning--I didn't find a database entry for "distress"
Warning--I didn't find a database entry for "redmap"
Warning--I didn't find a database entry for "bipartisan"
Warning--I didn't find a database entry for "chicagoformula"
Warning--I didn't find a database entry for "chicagothreshold"
Warning--I didn't find a database entry for "gilltranscript"
Warning--I didn't find a database entry for "analysis"
Warning--I didn't find a database entry for "winkelmann"
Warning--I didn't find a database entry for "houseresults"
Warning--I didn't find a database entry for "senateresults2014"
Warning--I didn't find a database entry for "senateresults2016"
Warning--I didn't find a database entry for "chicagouncontested"
Warning--I didn't find a database entry for "gill"
Warning--I didn't find a database entry for "libertarian"
Warning--I didn't find a database entry for "2014turnout"
Warning--I didn't find a database entry for "2016turnout"
Warning--I didn't find a database entry for "cohn"
(There were 2 error messages)
make[2]: *** [bibtex] Error 2
```

latex report

=====

[2017-12-12 20.00.37] pdflatex report.tex

This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)  
Label ‘tab:freq’ multiply defined.  
p.1 L31 : [oneperson] undefined  
p.1 L33 : [wapo] undefined  
p.1 L33 : [chicago] undefined  
p.1 L33 : [thornburg] undefined  
p.1 L44 : [maps] undefined  
p.1 L44 : [population] undefined  
p.1 L44 : [govtrack] undefined  
p.1 L46 : [brennan] undefined  
p.1 L50 : [chicago] undefined  
p.2 L55 : [chicago] undefined  
p.2 L60 : [griffith] undefined  
p.2 L64 : [house] undefined  
p.2 L64 : [distress] undefined  
p.2 L66 : [house] undefined  
p.2 L70 : [redmap] undefined  
p.2 L70 : [maps] undefined  
p.2 L72 : [redmap] undefined  
p.2 L76 : [bipartisan] undefined  
p.2 L81 : [thornburg] undefined  
p.2 L83 : [chicago] undefined  
p.2 L83 : [wapo] undefined  
p.2 L87 : [wapo] undefined  
p.3 L92 : [wapo] undefined  
p.3 L94 : [chicago] undefined  
p.3 L96 : [chicagoformula] undefined  
p.3 L106 : [chicagoformula] undefined  
p.3 L205 : [chicagothreshold] undefined  
p.3 L230 : [gilltranscript] undefined  
p.3 L230 : [analysis] undefined  
p.4 L234 : [winkelmann] undefined  
p.4 L242 : [chicagothreshold] undefined  
p.4 L257 : [houseresults] undefined  
p.4 L257 : [senateresults2014] undefined  
p.4 L257 : [senateresults2016] undefined  
p.5 L270 : [chicagouncontested] undefined  
p.5 L272 : [chicagouncontested] undefined  
p.5 L277 : [gill] undefined  
p.5 L281 : [libertarian] undefined  
p.5 L282 : [senateresults2016] undefined  
p.5 L282 : [houseresults] undefined

```
p.5  L283  : [house] undefined
p.6  L373  : [2014turnout] undefined
p.6  L373  : [2016turnout] undefined
p.6  L374  : [cohn] undefined
p.6  L376  : [chicagothreshold] undefined
p.6  L379  : [senateresults2014] undefined
p.6  L379  : [senateresults2016] undefined
p.6  L397  : [houseresults] undefined
p.6  L397  : [chicagoformula] undefined
p.8   L4    : [houseresults] undefined
p.9   L81   : [houseresults] undefined
p.9   L81   : [houseresults] undefined
Font shape 'OML/LinuxLibertineT-TLF/m/n' undefined using 'OML/nxlmi/m/it' instead for sy
Empty 'thebibliography' environment.
There were undefined citations.
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Some font shapes were not available, defaults substituted.
There were multiply-defined labels.
Typesetting of "report.tex" completed in 0.9s.
./README.yml
7:14      warning  truthy value is not quoted  (truthy)
22:1      error    trailing spaces  (trailing-spaces)
43:1      error    trailing spaces  (trailing-spaces)
```

---

## Compliance Report

---

```
name: Kevin Duffy
hid: 310
paper1: Nov 20 17 100%
paper2: Nov 06 17 100%
project: Dec 04 17 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
10
wc 310 project 10 6120 report.tex
```

wc 310 project 10 5754 report.pdf  
wc 310 project 10 954 report.bib

find "

---

- 32: In 1964 the Supreme Court established in constitutional law the principle of "one-person, one-vote".\cite{oneperson} The idea appears self-evident; the value of any citizen's vote is equal to that of any other citizen's vote. But could anything still exist in our institutions of our democracy that resists this principle? Beyond obvious impediments to voting such as the since-repealed prohibition on women or racial minorities voting, what other barriers could exist? And why has "one-person, one-vote" become an issue as important, and contentious, as ever?
- 34: The barrier, many will argue \cite{wapo}\cite{chicago}\cite{thornburg}, lies in the concept of "gerrymandering", or the manipulation of legislative district lines for the benefit of one political player over another. But determining whether something is gerrymandered has proven to be a difficult task. And even once you decide something is gerrymandered, what can be done about it? Answers to these questions may be coming in the form of both advanced data analysis, and simple arithmetic.
- 47: Gerrymandering, simply put, is the process by which a political party in power uses redistricting to "manipulate district boundaries to create maps that systematically advantage the party in control and lock in an advantage for the party in future elections", according to the NYU Brennan Center of Justice.\cite{brennan} In other words, the political party seeks to maximize the efficiency of each vote for their candidates, while decreasing the efficiency of the opposite party. This is done primarily through by "cracking" and "packing" the district maps:
- 53: The overall effect of cracking and packing is maximize the "wasted votes" of the disfavored party, while minimizing those of the favored party. The concept of wasted votes is crucial to the model we will examine further. A wasted vote can be defined as one of the following:
- 61: This is not merely a theoretical exercise. Gerrymandering has been utilized throughout the history of the United States by virtually every political party that has been in power. In fact, the term

"gerrymander" dates back to 1812, when the \textit{Boston Gazette} used the phrase to decry a unfairly-drawn redistricting plan signed into law by Massachusetts Governor Elbridge Gerry.\cite{griffith} A famous political cartoon depicts one particularly contrived looking district as a dragon-esque creature, while others compared its shape to that of a salamander. The colloquial term became "gerry-mander" after the governor who enabled such a result.

- 65: In 2008, the national Republican Party was in a dire position. Barack Obama had just been elected president in a sweep that included control of both houses of Congress. They held the House of Representatives by the largest margin seen in almost 20 years.\cite{house} Journalist Michael Grunwald presented a grim narrative for the party in Time magazine in 2009, writing that "polls suggest that only one-fourth of the electorate considers itself Republican, that independents are trending Democratic and that as few as five states have solid Republican pluralities." In addition, he pointed out that the overall population was decreasing in demographics that had proven to be solidly Republican - "less white, less rural, less Christian".\cite{distress}
- 77: Gerrymandering is an issue seen by many in both parties as problematic. Representative Brian Fitzpatrick (R-PA) wrote in \textit{The Hill} that gerrymandering has caused the nation to stray from its ideal of representative leadership, as it has "has undermined community-focused representation by forcing lawmakers to ideological extremes and exacerbating electoral complacency that causes lawmakers to focus on accumulating power rather than serving constituents."\cite{bipartisan}
- 84: But up until recently, partisan gerrymandering has been left to the states to police themselves. The Supreme Court has heard around 50 cases in its history imploring the court to intervene against a partisan gerrymandered map, and each time has deferred.\cite{chicago} The last major case was \textit{Vieth v. Jubelirer} in 2004. Justice Antonin Scalia, since deceased, delivered the majority opinion stating that the courts were not responsible for partisan gerrymandered maps as they were "non-justiciable".\cite{wapo}
- 86: But the court is not unanimous in the opinion that partisan gerrymandering cannot be solved through judicial means. The vote in \textit{Vieth} was a narrow one, and even those following Justice Scalia's lead had a range of views on the subject. Justice

Anthony Kennedy, for example, is reliable in his unreliability - he serves as the court's "swing vote", as court observers are often unsure which way he'll fall on a given issue until the decision is handed down. Given the court's ideological polarity often leads to close votes, this arguably makes him the most powerful justice on the bench.

- 93: In 2017, a case reached the Supreme Court alleging that the Wisconsin State Assembly was gerrymandered in such an extremely partisan way as to render it unconstitutional. The plaintiffs, savvy enough to recognize Justice Kennedy as the potential swing vote and remembering his desire for a clear standard, argued their case using the "efficiency gap" method.\cite{wapo}
- 107: The "seat margin" is the percentage of seats you win from the statewide allotment minus 50 percent, and the "vote margin" is the total percentage of the vote you win minus 50 percent. A negative result means the map is biased against you.\cite{chicagoformula} This is a helpful format when we begin measuring the net effect of gerrymandering in congressional districts.
- 206: \item For congressional maps, a state is considered illegally gerrymandered if the map costs a party two seats. In contrast to state houses, the authors contend, "aggregate House seats are the parties' main objective". In that regard, seats are the best way to normalize disparate state sizes for comparison.\cite{chicagothreshold}
- 231: The question remains whether this standard will be used to measure map bias and judge gerrymandering. During oral arguments for \textit{Whitford} in October 2017, Chief Justice John Roberts referred to the theory as "sociological gobbledegook".\cite{gilltranscript} But some court observers are anticipating Justice Kennedy, the swing vote, to vote in favor of the efficiency gap test.\cite{analysis}
- 239: \item The efficiency gap method accounts for this by taking into account several elections in a row, rather than one single election. With more data smoothing out any abnormalities in partisan preference (for example, voters in blue-collar districts turning out in overwhelming numbers in 2016 to vote for Donald Trump), this should lessen any "pendulum" effect on the overall efficiency gap score.
- 243: \item The efficiency gap authors concede that the measure may

capture legitimate redistricting methods under the purview of gerrymandering. Thus, in outlining their proposed court test, they allow that states above the threshold could show that the gap was the result of either the "consistent application of legitimate policies", or "inevitable due to the states' underlying political geography."`\cite{chicagothreshold}`

273: The results were a mean Democratic vote share of 66 percent for uncontested Democratic candidates, with 90 percent of values falling between 52 and 83 percent. Democratic vote share for races with uncontested Republicans was placed at 36 percent, with 90 percent of values falling between 22 and 43 percent. The authors do not hold this solution to be the be-all-end-all model for computing vote shares of uncontested candidates, as they "encourage scholars to explore a range of imputation techniques."`\cite{chicagouncontested}`

280: \item The United States is a two-party system, mostly due its "winner take all" election rules (where the party with the most votes is the singular winner in a given race, whereas a proportional system would give distribute legislative seats proportionally based on vote share). Third parties therefore have a difficult time gaining any sort of power:

345: Finally, we implemented a simple function that serves as our threshold test. If the formula falls above 8, it triggers an "UNCONSTITUTIONAL GERRYMANDER" response:

352: `print("UNCONSTITUTIONAL GERRYMANDER")`

356: `print("ACCEPTABLE")`

371: \item If we take at face value that the Senate is twice as gerrymandered as the House, a major reason could be district size. The House has twice as many districts as the Senate over the same land area. The more granular a district is, the more difficult it becomes for a map to be gerrymandered, as you have smaller populations and smaller land areas per district. People of similar ideologies and political leanings tend to group together, so with smaller parameters, it becomes more difficult to group some of these individuals with opposing parties in order to "crack" their vote.

377: Further analysis would need to be done in order to determine if this explanation suffices. It would, in fact, be in the Republicans best interest to find an alternative explanation

other than gerrymandering. Again, it can be allowed that states above the threshold could show that the the gap was the result of either the "consistent application of legitimate policies", or "inevitable due to the states' underlying political geography." \cite{chicagothreshold}

- 380: However, when compared to other Indiana political measures, the Senate result is not especially surprising. While the Indiana is admittedly a "red state", or a state predominantly partial to Republicans, the Senate seat share appears to be out of sync with other measures. Currently, there are only 9 Democrats to 41 Republicans in the Indiana State Senate \cite{senateresults2014} \cite{senateresults2016}, meaning the Democrats have a 18 percent seat share. Compare this with the last three statewide elections for governor in Indiana:
- 398: Meanwhile, the House of Representatives has 30 Democrats to 70 Republicans \cite{houseresults}, which, while slightly lower than the gubernatorial vote share, can be explained as a "winner's bonus", or a small surplus of votes for the overall winning party. This is accepted by the efficiency gap authors and political scientists as a common feature in American political systems. They also accept that the USA is not a proportional representation system, where vote share corresponds virtually 1:1 with seat share. \cite{chicagoformula} Therefore measures like gubernatorial vote share versus legislative seat share cannot be used to prove partisan gerrymandering on its own, however, when drastic enough, it can certainly be used as a symptom to correspond with a more direct objective measure.
- 408: An objective way to measure gerrymandering? Or, as Chief Justice John Roberts so colorfully put it, "sociological gobbledegook"? That definitive answer to that question lies outside the scope of this analysis, and the relevance of that question lies solely with the United States Supreme Court. They have the power, in coming months, to either make this measure the standard with which to measure all district maps moving forward, or toss it aside and continue this country's long history of ignoring partisan gerrymandering as far as the law is concerned.

passed: False

find footnote

---

passed: True

```
find input{format/i523}
-----
4: \input{format/i523}

passed: True

find input{format/final}
-----
passed: False

floats
-----
115: \begin{table}
117: \label{tab:freq}
147: \begin{table}
149: \label{tab:freq}
163: \begin{table}
165: \label{tab:freq}
296: \begin{table}
298: \label{tab:freq}
382: \begin{table}
384: \label{tab:freq}

figures 0
tables 5
includegraphics 0
labels 5
refs 0
floats 5

True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= includegraphics)
False : check if all figures are referred to: (refs >= labels)

Label/ref check
112: Let's apply this to an example. Let's say Party A and Party B are competing in a state with ten congressional districts of 100 people each (see Table 1).
144: In Districts 01, 04, 06, and 09, Party A wins by an overwhelming margin. In the rest of the districts, Party B wins by narrow margins. This results in more votes being cast for Party A
```

statewide, but Party B gets more seats as shown in Table 2:  
160: These races result in an overwhelming amount of wasted votes for  
Party A, and a minimal amount for Party B as shown in Table 3.  
293: The application made moderate use of the Python Pandas module. We  
began by importing two dataframes: the 2016 House results, and  
the 2014 and 2016 Senate results combined into one dataframe.  
Because the efficiency gap is a simple formula, the values needed  
are similarly simple. The only values needed were the Republican  
votes and Democratic votes for each district (see Table 4):  
passed: False -> labels or refs used wrong

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not cahnge the number to a smaller fraction

find textwidth

---

passed: True

---

below\_check

---

WARNING: table and above may be used improperly

243: \item The efficiency gap authors concede that the measure may capture legitimate redistricting methods under the purview of gerrymandering. Thus, in outlining their proposed court test, they allow that states above the threshold could show that the the gap was the result of either the "consistent application of legitimate policies", or "inevitable due to the states' underlying political geography." \cite{chicagothreshold}

WARNING: table and above may be used improperly

377: Further analysis would need to be done in order to determine if this explanation suffices. It would, in fact, be in the Republicans best interest to find an alternative explanation other than gerrymandering. Again, it can be allowed that states above the threshold could show that the the gap was the result of either the "consistent application of legitimate policies", or "inevitable due to the states' underlying political geography." \cite{chicagothreshold}

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
I couldn't open database file gerrymander.bib
---line 83 of file report.aux
 : \bibdata{gerrymander}
 :
I'm skipping whatever remains of this command
I found no database files---while reading file report.aux
Warning--I didn't find a database entry for "oneperson"
Warning--I didn't find a database entry for "wapo"
Warning--I didn't find a database entry for "chicago"
Warning--I didn't find a database entry for "thornburg"
Warning--I didn't find a database entry for "maps"
Warning--I didn't find a database entry for "population"
Warning--I didn't find a database entry for "govtrack"
Warning--I didn't find a database entry for "brennan"
Warning--I didn't find a database entry for "griffith"
Warning--I didn't find a database entry for "house"
Warning--I didn't find a database entry for "distress"
Warning--I didn't find a database entry for "redmap"
Warning--I didn't find a database entry for "bipartisan"
Warning--I didn't find a database entry for "chicagoformula"
Warning--I didn't find a database entry for "chicagothreshold"
Warning--I didn't find a database entry for "gilltranscript"
Warning--I didn't find a database entry for "analysis"
Warning--I didn't find a database entry for "winkelman"
Warning--I didn't find a database entry for "houseresults"
Warning--I didn't find a database entry for "senateresults2014"
Warning--I didn't find a database entry for "senateresults2016"
Warning--I didn't find a database entry for "chicagouncontested"
Warning--I didn't find a database entry for "gill"
Warning--I didn't find a database entry for "libertarian"
Warning--I didn't find a database entry for "2014turnout"
Warning--I didn't find a database entry for "2016turnout"
Warning--I didn't find a database entry for "cohn"
(There were 2 error messages)
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

```
ascii
```

---

```
=====
The following tests are optional
=====
```

```
Tip: newlines can often be replaced just by an empty line
```

```
find newline
```

---

```
passed: True
```

```
cites should have a space before \cite{} but not before the {
```

```
find cite {
```

---

```
passed: True
```

# Can Blockchain Adoption Mitigate the Opioid Crisis Through More Secure Drug Distribution?

Saurabh Kumar

Indiana University

Bloomington, IN 47408, USA

kumarsau@iu.edu

Mathew Schwartzer

Indiana University

Bloomington, IN 47408, USA

mabschwa@iu.edu

Nicholas J Hotz

Indiana University

Bloomington, IN 47408, USA

nhotz@iu.edu

## ABSTRACT

Like TCP/IP in the 1970s and 1980s, blockchain is a new, intriguing but grossly misunderstood technology that is still in its infancy. It is commonly misunderstood as just a technology for Bitcoin and cryptocurrencies. However, blockchain's use cases extend beyond just financial transactions and cryptocurrencies, and have the potential to transform nearly every industry including healthcare and supply chain. As the technology matures, additional transformative use cases could expand into drug distribution and specifically to opioid supply chains. Despite this potential, a publicly-available blockchain specifically for opioid supply chains was not found. Therefore, to demonstrate how a blockchain would function on a simplified opioid supply chain, a blockchain, using Python code, was developed as a proof of concept. This source code is publicly available to allow others to further develop the blockchain model for more complex and real-world opioid supply chains. The collective review and analysis of blockchain, pharmaceutical supply chains, the opioid crisis, and the demonstrated blockchain model suggest that the adoption of blockchain systems for prescription opioid supply chains would enable numerous capabilities that could mitigate certain aspects of the opioid crisis.

## KEYWORDS

HID 210, HID 212, HID 225, i523, blockchain, opioid epidemic, pharmaceutical supply chain, healthcare

## 1 INTRODUCTION

### 1.1 The Need to Modernize Global Record Keeping

Contracts, transactional records, and verification systems are part of the foundational core of the global economy. However, as Iansiti and Lakhani [37] explain, these tools have not modernized to keep up with the needs of the rapidly evolving global economy and are “like a rush-hour gridlock trapping a Formula 1 car.” Records and transactions are still being managed as they were in the 20th century which creates broad consequences for nearly every industry including supply chain and healthcare.

In supply chain, data management methods for records and logistics are usually inconsistent across the different levels of a supply chain [7]. The outdated record management method encourages redundant data to be stored at the same organization as well as across the supply chain which increases IT maintenance costs and decreases trust and transparency [30]. These issues prevent a tertiary party, like the government, to effectively scrutinize records.

Outdated data management processes also negatively impact healthcare. In the USA in 2014 healthcare fraud cost an estimated

\$272 billion [22], and in 2016, healthcare data breaches impacted over 27 million patients [16]. Today, medical data management is stifled by antiquated technology that limits patients' ability to manage and control access to their electronic medical records [23].

In addition, pharmaceutical supply chains are enervated by current record-keeping technologies. Transactional records are rarely shared across pharmaceutical supply chain organizations which consequently increases inventory levels [52]. As a result, total healthcare cost and the opportunity for counterfeit drugs increases [66]. In addition, verification systems are often independent among supply chain retailers and prescribers. The lack coordination opens the door for “doctor shopping” and greater prescription medication abuse [24].

### 1.2 Rational Exuberance for Blockchain

The adoption of blockchain, “an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way” [37], has the potential to resolve these and other fundamental problems of the global economy by overcoming many of the antiquated shortcomings of the traditional means of managing and verifying contracts and transactions. However, like TCP/IP in the 1970s and 1980s, blockchain is an immature technology that faces numerous challenges to mass adoption. In spite of its current limitations, blockchain is already seeing promising applications in various industries extending beyond just finance including healthcare and supply chain.

One particularly exciting use case sits at the intersection of healthcare and supply chain. Blockchain could provide a more secure distribution system for opioid medications that would develop enabling and foundational capabilities that would potentially mitigate certain aspects of the opioid crisis. To further develop and evaluate this potential use case, a blockchain model based on a simplified pharmaceutical supply is presented with publicly-available source code for further development.

## 2 BLOCKCHAIN OVERVIEW

Blockchain's secure distributed ledger framework includes three data types and has the potential to deliver numerous benefits but faces major hurdles toward mass adoption. Proper application of design principles can overcome these hurdles and accelerate the realization of these benefits.

### 2.1 The Blockchain Framework

Blockchain is a foundational technology comprised of numerous technological processes and entities [37]. Some of the most significant pieces follow.

**2.1.1 Node.** Nodes are the individual units connected to the blockchain network. They are computers with adequate software to maintain a blockchain. The blockchain network connects all the nodes and can read and write data to a block [65] [40].

**2.1.2 Block.** Blocks are the group of records, bundled together by nodes. They follow a specific set of rules and have limited size. Blocks are also linked to the last generated block, thus forming a chain [65].

**2.1.3 Smart Contracts.** Smart contracts are the codes with timestamps to represent a contract [65]. Iansiti and Lakhani [37] believe that “smart contracts” may be the most transformative blockchain application at the moment,” because they allow for automatic payments whenever contract conditions are met.

**2.1.4 Submit Transaction.** In case of a new transaction submission to the network, an individual node circulates it to all the other nodes in the network [65]. The main purpose of circulation is approval.

**2.1.5 Transaction Approval.** When a transaction is submitted and circulated in the network, each node verifies it. Invalid transactions are deleted [65].

**2.1.6 Consensus.** For multiple systems to work in a distributed network, they must have an agreement. Such a structure is useful in case of fault tolerance when those agreed set of protocols help to restore the data [65].

## 2.2 Data Types in Blockchain

There are three major types of data stored on a blockchain, namely un-encrypted, encrypted, and hashed [30].

**2.2.1 Un-encrypted Data.** All the organizations have read access to the un-encrypted data. Such data is fully transparent and facilitates immediate dispute resolution [30].

**2.2.2 Encrypted Data.** The encrypted data can only be read by the organizations with the access to such data. This means an organization should have a decryption key to read to read the encrypted data. Encrypted data provides restricted access but is also stored in every node in the blockchain. In case of a dispute, the decryption key could be used by different organizations to rectify the entry or deletion of any record [30].

**2.2.3 Hash Data.** Hash data is also a hidden data type, where hash keys act like fingerprints to represent changes or entry for any data record. Each organization can easily confirm their hash keys. Breaking the hash key is nearly impossible. Only the hash key is in the blockchain while the record data is stored off-chain by individual organizations. Data could be revealed, in case of a dispute, by the respective organization [30].

## 2.3 Benefits of Blockchain

The exuberance surrounding blockchain stems from the fundamental benefits that are cornerstones to nearly every industry.

**2.3.1 Trust.** Blockchains enable parties that do not know each other to trust each other. No single organization is trusted to maintain the records. Instead, all organizations must approve the contents of the record in order to avoid disputes. Therefore, records should have a timestamp and an origin proof. Normally, a third party facilitates this requirement. Blockchains can provide an alternate solution, where organizations jointly manage the records and preventing corruption by a single organization [30].

**2.3.2 Access.** Blockchains allow for greater control over what information is and is not accessible. The technology enforces identical data to be stored by each organization. When one copy is updated, all the other copies are also updated. This eliminates the need for a third party to facilitate management of records [38]. Alternatively, different levels of read and write access could be provided to different organizations. Although some meta data should be stored in the public ledger.

**2.3.3 Redundancy.** Blockchain also assists in providing security by disallowing redundancy at the same node. The core logic of blockchain does not allow duplicate entries to be created in the same place which obviates the risk of duplicate entry, either intentional or accidental [7]. For example, one of the major benefits of Bitcoin is that the same coins can be spent in multiple places, overcoming the so-called “double spend” problem [69].

**2.3.4 Transparency.** Transparency in a business helps to grow trust among organizations. Sharing information can improve relationships among these organizations. Without blockchain, transparency is hard to achieve. Blockchains can help improve the visibility of contracts, legal documents as well as other inter-organization data [65]. Organizations are not obligated to show all of their data. Varying levels of access can be provided for data that could be useful to other organizations and a shared collection of records can also be stored and managed by co-operation from different organizations [69].

**2.3.5 Low Transaction Costs.** Through by-passing third-party verification systems such as brokers, lawyers, or banks, blockchain could significantly reduce transaction costs. Not only will this lower costs for existing transactions, it could open up the market for micro-payments [37].

## 2.4 Challenges to Blockchain Mass Adoption

While blockchain adoption has the potential to help a wide variety of the world’s problems, it should not be viewed as a panacea. Blockchain is not mature enough to support mass-market adoption and faces numerous challenges. Rabah [62] states that to be effective, blockchain needs to overcome its shortcomings of lacking standard protocols, unclear regulation, large energy and computing power consumption, privacy, cultural adoption, and high initial capital requirements. Tapscott and Tapscott [69] agree that its current technical infrastructure is not sufficient, its energy consumption and computational requirements are not sustainable, and user-friendly systems have yet to be designed that would allow for mass market adoption.

Society would have to dismantle many technological, governance, organizational, and cultural barriers to create new foundations for a new world economy that relies heavily on blockchain [37]. This will come at the cost of some existing societal norms, core business functions, and people's jobs [37] [62].

## 2.5 Technology Adoption Lifecycle

Iansiti and Lakhani [37] argue that the process for mass adoption of blockchain may take longer than expected but will follow a fairly predictable technology adoption pattern that parallels the adoption of TCP/IP (transmission control protocol / internet protocol). TCP/IP started as *single-use* and matured to *localized uses, substitutions, and transformations*. It was introduced as a *single-use* in 1972 for e-mail in ARPAnet, a precursor to commercial internet for the US Department of Defense. Met with skepticism, this technology slowly gained traction among some firms in the 1980s and early 1990s for *localized use* and did not become mainstream until the emergence of World Wide Web in the mid-1990s. This then paved the road for infrastructure companies to provide the necessary hardware and software to establish "plumbing" systems for the internet. Once the technical infrastructure was mature enough, companies then developed businesses that *substituted* existing services with online services (such as Amazon books instead of Borders). Finally, a wave of companies created *transformative* applications that fundamentally changed service experiences (such as Napster in the music industry or Skype in telecommunications).

Similarly, blockchain was also launched for a *single use* in 2009 for Bitcoin, a virtual currency. Blockchain has matured to extend beyond cryptocurrencies and is now being applied for various *localized uses* including in healthcare and supply chain. It took over 30 years for TCP/IP to realize its potential, and blockchain will likewise require decades to mature into a revolutionary economic force. However, companies can start planning for this revolution today and implement blockchains that follow seven key design principles [37] [69].

## 2.6 Seven Design Principles for Blockchain

Tapscott and Tapscott [69] in their book *Blockchain Revolution* propose seven design principles that, when appropriately applied, can help blockchain move down the technology adoption lifecycle and create more honest, cost-effective, and accountable systems.

**2.6.1 Networked integrity.** Because all organizations on the blockchain must approve updates, "Participants can exchange value directly with the expectation that the other party will act with integrity" [69].

**2.6.2 Distributed Power.** Since the blockchain is distributed across a broad network, it cannot be dismantled by authoritarian power, hackers, or other bad actors. There are no single points of failure and the blockchain can still perpetuate even if numerous nodes are compromised [69].

**2.6.3 Value as Incentive.** Blockchains can align incentives of individual participants with the interests of the entire blockchain. This minimizes organization problems and conflicts of interests [69].

**2.6.4 Security.** Blockchains can protect against hackers, malware, ransomware, and identity theft by using a variety of security features. Public key infrastructures, private keys, public keys, and verification methods verify participant activities and prevent bad actors from overriding the network [69].

**2.6.5 Privacy.** Blockchains can and should provide participants with the freedom to expose as little or as much information about themselves as they desire. This allows a participant to act anonymously when desired or to share sensitive information with only appropriate parties when needed [69].

**2.6.6 Rights Preserved.** To protect against counterfeit items, a blockchain can serve as a public ledger of ownership [69].

**2.6.7 Inclusion.** Currently, access to certain financial services is limited to those who are deemed "creditworthy". Blockchains can and should have significantly lower bars of entry that are not managed by banking institutions so that even a poor rural farmer on a remote corner of Earth who isn't creditworthy, could participate in the blockchain [69].

## 3 BLOCKCHAIN APPLICATIONS IN SUPPLY CHAIN AND HEALTHCARE

In the broad public's view, blockchain is mostly known for Bitcoin; however, people are beginning to realize its potential to transform nearly every industry [37]. Two such industries include supply chain and healthcare.

### 3.1 Supply Chain

Blockchain, being a public ledger, can be used in different domains with slight variation in its core attributes. While the general implementation says that the data of a single block is public to all the nodes, different sets of access rights could be provided to different classes of users. Such implementation of blockchain could be applied to a supply chain network.

A supply chain requires the involvement of various parties helping each other. This is generally a one-to-one chain network. Often, each organization uses different technologies for record keeping. Record keeping could involve any information ranging from direct communications to logistics. Trust is an important issue between organizations. Most of the organizations in a supply chain keep individual records, which are not public to other organizations in the supply chain. Organizations share some information like contracts or notarized data. An efficient management of such shared data can be accomplished using a blockchain. The blockchain provides the ability to collect, record, and notarize different types of shared data [30].

Blockchain could also facilitate storing and maintaining logistics data. Such an application could be useful in the field of healthcare, where the government wants to monitor the supply of drugs. By simplifying the storage and management of information, blockchain could provide easy access of such critical public sector information to government organizations while providing data security [10]. Blocks comprise of the data records. When these blocks are added to the chain, they become immutable. This means they cannot be deleted or changed by a single organization [10]. A consensus has to be reached by a majority of the organizations for changing any

record. Such a feature helps to maintain the security of the records by eliminating data corruption. Each block is verified and managed using some shared protocols. This process can be automated to allow ease of data entry.

### 3.2 Healthcare

Representing over 17% of the United States' GDP, healthcare costs continue to soar [24]. Healthcare data in the United States reached 150 exabytes in 2011 with Kaiser Permanente, California's health network, reportedly having between 26.5 and 44 petabytes alone [14]. The volume of healthcare data is likewise soaring, doubling every 12-14 months [20], and the diversity of this data scattered across disparate systems further complicates its analysis [28]. More effective data management could address many of healthcare's fundamental issues, and according to a 2011 McKinsey report [48], more effective health data management could save \$300 billion annually. Current innovations focus on placing patients at the center, privacy and access, completeness of information, and cost [24]. Three interesting applications of blockchain for healthcare are in claims adjudication, cyber security and healthcare IoT, and electronic medical records [16].

**3.2.1 Claims Adjudication and Fraud Prevention.** The Economist [22] estimated that in 2014 the United States wasted \$272 billion dollars on healthcare fraud. Blockchain could not only minimize fraudulent billing; but, by automating claims adjudication and billing processes, obviate the need for administrative and transactional costs through third parties. Gem Health and Capital One are developing a blockchain-based solution for healthcare claims management [16].

**3.2.2 Cyber Security and Healthcare IoT.** In 2016, there were 450 reported health data breaches, impacting 27 million patients. Hacking and ransomware were responsible for 27% of these breaches. Each additional connected medical device serves as a potential entry point for bad actors. With an estimated 20-30 billion healthcare IoT devices by 2020, blockchain could secure these devices and protect confidential data. Telstra, IBM, and Tierion are three companies that are developing cyber security solutions for connected healthcare devices [16].

**3.2.3 Electronic Medical Records.** Beleaguered by stifled technology development, limited ownership control by patients, fragmented information systems, and risks of electronic protected health information hacking, electronic medical records have perhaps the most important use cases for blockchain [76]. Blockchain can provide interoperability of healthcare information, improved security, patient-centric control, and immutable records [16]. Three examples of blockchain-based EMRs include MedRec, Medicalchain, and the Estonian eHealth Foundation. First, by leveraging smart contracts on the Ethereum blockchain, MedRec is a prototype system that provides patients with "one-stop-shop access to their medical history" and shows promise to give ownership of health information back to the patients who can selectively share access through a modern API interface in a secure manner [23]. Second, Medicalchain is a permissioned blockchain distributed on networks of international healthcare providers that allow patients to transfer medical records across national borders [24]. Third, a data security

company called Guardtime is using its Keyless Signature Infrastructure system in partnership with the Estonian eHealth Foundation to store Estonian health records on a blockchain.

## 4 THE OPIOID CRISIS

The United States opioid crisis is an overwhelming, tangled web of issues with increasingly severe health and financial consequences. The private sector, government, and academia are suggesting and implementing critical mitigation strategies to combat the crisis.

### 4.1 Addiction Risk

Since the late 1990s, pharmaceutical companies have downplayed the addictive risk of opioids [55]. However, the addictive nature of prescribed opioid painkillers increases the "potential for unforeseen adverse events for the patient, including overdose, experience of physiological dependence and subsequent withdrawal, addiction, and negative impacts on functioning" [72]. Patients with wholesome medical intentions often fall victim to the pills' addictive nature. Misuse and eventual abuse of prescribed opioid painkillers is common: 21%-29% of patients prescribed opioids for chronic pain misuse them while 7.8%-11.7% develop an addiction [72]. Moreover, an opioid addiction often serves as a gateway to other illegal drug use. With similar highs, prescription opioid addicts often transition to heroin, an illicit street-made opioid, since it is cheaper and easier to obtain. In fact, 4%-6% of patients using prescribed opioids develop a heroin addiction [55]. Whereas, 75% of heroin users began their opioid addiction with prescription opioids [12].

Despite these risks, opioids are still prescribed at alarming rates. In fact, the United States, with about 5% of the world's population, consumed 80% of the world's opioid prescriptions from 2001-2010 [72]. Between 1999 and 2015 the number of prescribed opioids painkillers such as codeine, fentanyl, oxycodone, Demerol, and Vicodin quadrupled. In the same time period, opioid-related deaths also quadrupled.

### 4.2 Health Impact

The epidemic has become so severe that in October 2017 President Trump was forced to declare it "a national health emergency" [54]. With no signs of stopping, this epidemic is burgeoning across America killing nearly 91 people a day [61].

In 2015, 33,091 Americans died from an opioid overdose with rural white males at the greatest risk of an opioid overdose. White Americans (27,056) died the most, followed by black Americans (2,741), and Hispanic Americans (2,507). Generally the middle-aged population was most at risk with the following percent mortality distributions by age group [27]:

- Aged 0-24: 10% of the opioid-related deaths
- 25-34: 26%
- 35-44: 23%
- 45-54: 23%
- 55+: 19%

Males die nearly twice as frequently from an opioid overdose, representing 65% deaths compared with 35% for females [27].

### 4.3 Financial Impact

The health impacts are the primary reason for concern, but the financial liability associated with the epidemic is also increasing. The estimated financial impact of the crisis grew from \$55.7 billion in 2007 [5] to \$78.5 billion in 2013 [25]. Of the total economic burden, roughly 25% or \$20 billion is conveyed to the public sector [25]. Partitioned between workplace, healthcare, and criminal justice costs, the overall financial burden will continue to rise until a reversal in current opioid abuse trends.

Opioid drug makers are also exposed to significant financial and legal liabilities as lawsuits accusing pharmaceutical companies of deceptive marketing are commonplace. After a U.S. Justice Department probe in 2007, the maker of OxyContin pleaded guilty to federal charges and paid \$634.5 million. In later cases, OxyContin maker Purdue Pharma LP settled two additional cases for a combined \$43.5 million. Similar to the tobacco industry in the 1990's, over 100 state, city, and county governments are taking their turn litigating drug makers role in the rise in opioid addictions. In fact, lawsuits against tobacco companies resulted in over \$200 billion in court-ordered payouts and similar payouts are expected for opioid makers [60]. Most cases follow the same legal jargon. For example, in a suit filed in April 2017 against the three largest drug retailers in the USA - CVS, Walgreens, and Walmart - lawyers for plaintiffs Cherokee Nation claim that the "Defendants turned a blind eye to the problem of opioid diversion and profited from the sale of prescription opioids to the citizens of the Cherokee Nation in quantities that far exceeded the number of prescriptions that could reasonably have been used for legitimate medical purposes" [34].

### 4.4 Responses to Mitigate the Crisis

The private sector, government, and academia alike recognize the importance of solving this crisis and are implementing strategies to help mitigate the opioid crisis.

**4.4.1 Private Sector.** Drug retailers are taking immediate action. In September 2017, CVS pharmacy announced actions to limit patient supply of prescription opioids to seven days, to restrict the strength of opioids dispensed for first time patients, and to install 750 more in-store drug disposal kiosks [9] [31].

A longer-term private sector solution is through the use of radio frequency identification (RFID) technology as a method to improve supply chain security [70] [74]. RFID tracking tags are small microchips that are either printed, etched, stamped, or vapor-deposited onto product labels and are intended to replace barcodes. RFID can be read without direct line of sight and at distances up to 30 feet. Research shows that RFID tags have the potential to reduce costs, increase transparency, and identify counterfeit lots. RFID tags have many advantages over current barcode tracking methods. RFID tags can hold up to 32,000 alphanumeric characters compared to just 20 in a barcode. RFID tags have a much higher upfront cost but decrease total supply chain cost due to the timely process to scan each individual barcode. And unlike RFID tags, barcodes are susceptible to wear and tear and are easily replicated. RFID technology also has its flaws. In addition to the higher upfront cost, each tag costs between 5-10 US cents, significantly higher than bar-

codes. Moreover, they are vulnerable to electromagnetic interference and poor manufacturing, are larger, and require a much larger IT infrastructure [70] [39].

**4.4.2 Government.** Through policy and politics, the federal government is attempting to find solutions to the epidemic. In the same address President Trump declared the opioid epidemic a national health crisis, he proposed "really tough, really big, really great advertising" [19]. Tom Price of the U.S. Department of Health and Human Services (HHS) outlined a more detailed federal long-term plan including, "improving access to treatment and recovery services, promoting use of overdose-reversing drugs, strengthening our understanding of the epidemic through better public health surveillance, providing support for cutting edge research on pain and addiction, and advancing better practices for pain management" [59]. Additionally, President Trump's Commission on Combating Drug Addiction and the Opioid Crisis repeatedly mentions "data sharing" as a method to cope and limit the opioid crisis [54].

Multiple studies indicate that states with strong prescription drug monitoring programs (PDMPs) show a significant reduction in the number of opioid-related deaths [57] [58]. Unfortunately, evidence suggests that 72% of physicians were aware of their states' PDMPs in 2015, but only 52% used their services. Physicians noted difficulties understanding the data formats and retrieval systems as the main barriers to continual use of PDMPs [64]. As a result, low registration rates are common in the 49 states that offer some form PDMPs [32].

Increasing access to Naloxone, an opioid antagonist that rapidly reverses the opioid overdose damage, may be the most important immediate solution to reducing opioid-related deaths [32]. Between 1998 and 2014, 52,283 naloxone kits were distributed among the 30 states with naloxone distribution programs resulting in 26,453 overdose reversals [32]. 27 states have "third-party prescription" laws that allow physicians to prescribe Naloxone to family and friends of individuals with an opioid addiction [32]. To further reduce opioid-related deaths states must reduce malpractice liability for physicians prescribing Naloxone and make Naloxone available without a prescription [32].

In addition, states have started to pass legislation protecting Good Samaritans. As of 2014, 23 states had laws protecting cooperating bystanders, from low-level misdemeanors and drug possession. Without these laws, bystanders are subject to criminal charges and even murder if it is proven they supplied the deadly drugs. Consequently, these laws are necessary to encourage immediate life-saving calls to 911 [8] [32].

Other solutions states should consider is access to medical marijuana, as Pardo [57] found that states with legal medical marijuana dispensaries have lower opioid-related deaths.

**4.4.3 Academia.** Academic research is helping to propose effective solutions to the opioid crisis. For example, Indiana University announced plans to commit \$50 million and 70 researchers to find solutions that lead to a decline in opioid-related deaths [63]. In a similar proposal to the HHS, researchers at the Network for Public Health Law, Boston University, and Northeastern University proposed a four-step solution including "improving clinical decision making and access to evidence-based treatment, investing

in comprehensive public health approaches, and re-focusing law enforcement response” [18].

## 5 PHARMACEUTICAL SUPPLY CHAINS

At the intersection of supply chain and healthcare, pharmaceutical supply chains have not substantially evolved with the adoption of new technologies. Stifled by outdated processes, the weaknesses of existing pharmaceutical supply chains contribute to problems in the opioid crisis which has led several to look towards blockchain to transform the industry.

### 5.1 Supply Chain Participants

Participants in pharmaceutical supply chains engage in both forward and reverse activities. Forward facing supply chain activities occur before a customer purchase. In a pharmaceutical supply chain, forward facing nodes includes manufacturers, warehouses, distributors, and retailers. Reverse facing supply chain activities occur after the sale and include collecting, recycling, redistributing, and disposing of unwanted medications.

*5.1.1 Primary Manufactures.* Primary manufactures produce the main active ingredient [67].

*5.1.2 Secondary Manufactures.* Often at a different geographic location for tax and labor reasons, secondary manufacturers combine the active ingredients produced by primary manufacturers and excipient substances. Secondary manufacturers produce distribution ready SKU medications through one or more of the following processes: granulation, compression, coating, and packaging [67].

*5.1.3 Market Warehouses and Distribution Centers.* Due to the cost of setup and cleaning, it is common for primary manufacturers to produce a years’ worth of active ingredients for a particular medication in one batch. This strategy creates a lot of excess finished and work-in-progress inventory which is then stored in warehouses and distribution centers [67].

*5.1.4 Wholesalers.* Wholesalers sell large quantities to retailers at low costs. Roughly 80% of demand flows through wholesalers. The pharmaceutical wholesaling industry is highly competitive and consolidated. The largest five wholesalers accounted for roughly 45% of industry revenue [67] [36].

*5.1.5 Pharmacies and Hospitals.* Pharmacies and hospitals are the last node on the pharmaceutical forward facing supply chains before medications are distributed at a patient level. Major retailers include pharmacies CVS, Walgreens, Walmart, and Rite Aid and hospital systems such as Community Health Systems, Hospital Corporation of America, and Ascension Health [67].

*5.1.6 Patients.* Patients are prescribed opioids for pain management. They are the end consumer and represent the final nodes of the supply chain.

### 5.2 Weaknesses

The nature of the current pharmaceutical production and supply chain system creates multiple weaknesses.

*5.2.1 Lead Time.* Lead times, the time it takes between manufacturing and end sale, can take up to 300 days [67]. As a result, high safety stocks are needed to react to future demand.

*5.2.2 High Service Levels.* The necessity for on-time pharmaceutical products forces retailers to maintain high service levels, the targeted rate of stock-outs. In many cases and especially in hospitals, patient health relies on having the right medication at the right time. A failure to meet this immediate demand could lead to fatal consequences [43] [51].

*5.2.3 Imbalance of Information.* Another major disadvantage is the lack of collaboration between raw material suppliers, manufacturers, warehouses, wholesalers, and retailers. “The problem is that the different decision-makers do not have access to the same information regarding the state of the entire supply chain network, and in addition they usually operate under different objective functions” [66]. In this decentralized method, manufacturers have a difficult time forecasting demand. In addition, an imbalance of information between supply chain nodes increases cost and stock-outs. However, Nematollahi, Hosseini-Motlagh, and Heydari [52] found that collaborative decision making through information sharing can increase economic benefits for the entire supply chain while also increasing drug fill rate.

*5.2.4 Manufacturing Strategy.* The mixture of manufacturers ‘push’ strategy and retailers ‘pull’ strategy, results in high safety stocks. At any given point, there is usually 4 to 24 weeks of finished goods that have yet to be delivered to patients [67].

*5.2.5 Large Network.* Medications pass through several nodes before they are delivered to the market. Safety and security issues face organization conflicts as the capital cost to prevent theft and mismanagement is not equally spread across the supply chain. The number of nodes also increases the likelihood for counterfeits to enter the market. Between each node, medications are shipped and handled between multiple parties and often times across national and state borders [67].

*5.2.6 Counterfeits.* High inventory levels increase supply chain cost, the potential for theft, and the introduction of counterfeits. It is estimated that 10% of the worldwide pharmaceuticals are counterfeit and approaching 25% in developing countries [42]. Pharmaceutical companies lose an estimated \$200 billion annually due to counterfeit drugs [16].

*5.2.7 Disposal.* The reverse supply chain is often overlooked as a key component of the pharmaceutical supply chain network. Few people take their unwanted medications to proper collection sites. Instead, medications are discarded in the trash and sewage. In fact, in 2003 at least \$760 million worth of prescription medications were inappropriately disposed around the world [51]. By 2014, this number ballooned to an estimated \$5 billion [47]. The roughly 10 million unused and unexpired prescription medications could be recycled and reused, but instead improper disposal leads to dangerous compounds in water ranging from sewage to drinking water [51] [47]. Hua, Tang, and Wu [51] suggest a combination of government subsidies, penalties, and marketing to encourage drug makers to collect unwanted and expired medications.

### 5.3 Government Response

In response to these problems, the government heavily regulates pharmaceutical supply chains to ensure a safe and steady supply of medications. The Drug Quality and Security Act [1] signed by President Barack Obama in 2013 introduced new regulations for the manufacturing and the distribution of pharmaceutical products. The policy mandates the creation of systems to trace lot-level transactions and systems to verify product legitimacy. In addition, any company within the supply chain must obtain federal licensure and authenticate the licensure of their trading partners. These required changes place immense financial pressure on pharmaceutical companies, drug distributors, and prescribers to develop sustainable supply chain solutions. The 2023 deadline gives pharmaceutical companies time to test and implement the most sustainable and practical solution [26].

### 5.4 Moving Drug Distribution onto the Blockchain

The shortcomings of existing pharmaceutical supply chains contribute to the opioid crisis. Inefficiencies lead to higher costs which could create financial strain for patients. Imbalanced information presents difficulties to appropriately track opioid distribution, counterfeit risk exists but is largely unknown, and improper disposal opens the door for others to use opioids not prescribed to them, which could contribute to further addictions. As such, in addition to the previously mentioned responses to mitigate the opioid crisis, researchers are suggesting blockchain as a solution. However, there are no comprehensive models or suggestions on how to implement blockchain in opioid distribution. Rather, current research and commentary focuses on the benefits of blockchain implementation [21] [29]. More broadly, commentary on the benefits of blockchain in healthcare exists [46] [2] [68] [50] [17], but again the authors present little evidence towards tangible implementation steps.

The first step to moving opioid distribution onto the blockchain rests in the initial infrastructure investment plan for development and maintenance. The next step is to establish the policies and security clearances of each organization [11]. Once these critical questions are answered, an opioid distribution blockchain would be similar to blockchains in other industries. Each blockchain would start with the genesis node created by the primary manufacturer. From there on, each additional downstream node would timestamp an additional hash. When the opioid eventually reaches the patient, the block would contain information on all supply chain nodes with timestamps and distribution information including prescribing physician and pharmacist.

An opioid blockchain should follow the Hyperledger design principles [13] [71], Tapscott and Tapscott's seven design principles for blockchain [69], and BlockSci [41] analysis protocols.

In the first tangible step towards creating a blockchain network for drug distribution, The Centers for Disease Control and Prevention (CDC) recently announced plans to research ways to implement blockchain [56]. Creating more open source research can help quicken blockchain adoption.

## 6 A BLOCKCHAIN MODEL FOR OPIOID DISTRIBUTION

Despite the discussion surrounding blockchain's potential to mitigate the opioid crisis, none of the researched sources provide an actual blockchain model. Such a model is an important initial step along the long road of blockchain adoption for drug distribution.

### 6.1 The Supply Chain Model

To develop an initial blockchain model for opioid distribution, a simplified, hypothetical supply chain was conceptualized. This supply chain includes a limited number of participants across seven different stages:

- (1) Raw Material Provider ( $\text{raw}_1, \text{raw}_2, \text{raw}_3$ ): Three suppliers of opioid raw materials.
- (2) Primary Manufacturer ( $\text{m}_1, \text{m}_2$ ): Two primary manufacturers who mix the active ingredients in opioids.
- (3) Secondary Manufacturer ( $\text{sm}_1$ ): One secondary manufacturer to create the consumable opioid.
- (4) Warehouse ( $\text{w}_1$ ): One secure warehouse facility to store the opioids.
- (5) Distributor ( $\text{d}_1, \text{d}_2$ ): Two distributors who move opioids from the warehouse to the retailers.
- (6) Pharmacies ( $\text{rp}_1, \text{rp}_2, \text{hp}_1$ ): Three retailers including two retail and one hospital pharmacy. Each pharmacy includes a pharmacist who provides prescriptions for the purchase of the drug. The prescriber is not directly in the supply chain but plays an important role.
- (7) Patient ( $\text{p}_1, \text{p}_2, \dots, \text{p}_{99}$ ): 100 patients who are prescribed opioid medication. Each patient receives opioids from at least one pharmacy and possibly all three.

The opioids flow through the supply chain participants as diagrammed in Figure 1.

### 6.2 The Blockchain Model

Primary manufactures create a new block for every new opioid batch. As a manufacturer creates a new block, they update the block with raw material data. Only the primary manufacturer has the rights to create a block, as primary manufacturers are the only nodes that creates a new batch of opioids. All other nodes update the block data as the opioids move downstream through the supply chain.

The primary manufacture assigns a unique hash key for every new block. These keys are shared across the supply chain for others to update the block. Only nodes with the hash key table are able to update the block data. When a batch of drugs pass though each stage of the supply chain, the ID of the stage node is updated. In addition, The timestamp when the batch of drug arrived and left the facility is also added to the block data. In the model, we assume data entry is integrated with on-site scanners at each node. When a batch of drugs is scanned, the information is automatically added to the block data. For example, the purchase data for any batch is represented by the timestamp that the pharmacy provides as to when the drugs left their facility. In regards to the reverse supply chain, pharmacies, distributors, and warehouses have the capability

to update the block with the corresponding node ID and timestamp. Data present in each block is shown in Figure 2.

### 6.3 Blockchain Model Development

The blockchain model is implemented in Python2.7. The model uses a self-generated data set which is created through Python code.

**6.3.1 Data Curation.** The model creates a blockchain with 2000 blocks [44]. Each block has its separate piece of data. Blockchain is implemented as a Python class and each block is an object of the Python class.

Most of the data is created using random package in Python. The model uses random normal function to create data points for the 2000 blocks. Data is created for every stage in section 6.1. Hash keys are created using the hash lib library in Python. Different nodes at each stage, like the distributor 1 or 2, is also chosen using random functions. Data is completely created using the create data function.

**6.3.2 Code Overview.** The model [45] defines a blockchain class and the first block added to the class is called the genesis block. The primary manufacturers create these blocks and the subsequent blocks. New block function creates a new block as well as assigns it with essential data like timestamp, ID, and hash key. Each new block added is linked to the last block to form a chain. The create data function is used for randomized creation of data for each block. Previous block object is used for creation of next block.

The hash key information is stored separately as a table containing the block ID and the respective hash key. This table should be provided to every node in the supply chain network. The update function uses the hash key table for verification. Then a node is allowed to update the data for any block.

The model provides few analysis results. These results can be used by the government to scrutinize the details of opioid crisis and find any disturbing trends. While creation of data, the randomization has been done in such a way, that few clear trends are visible through simple analysis.

**6.3.3 Blockchain Execution.** The model is executed on a local virtual box on Ubuntu version 16.04 with four gigabytes of ram on an i7 processor. The run time for the complete model, along with data creation took 9.166 minutes.

The model was also executed on the Chameleon Cloud virtual machine on a single node. The execution time for the complete model was 6.015 minutes.

### 6.4 Blockchain Model Limitations and Future Work

The demonstrated blockchain model presented should not be viewed as practical but rather as an initial model that could be further developed for academic and eventual industry use. Shortcomings include over simplification, security, mutual agreement, data management, the lack of user-friendly features, and the lack of counterfeit detection and reverse supply chain functionalities. The source data [44] and source code [45] are publicly available for others to build towards a more functional blockchain model.

**6.4.1 Overly Simplified.** The most obvious shortcoming of the blockchain model is that it is built for an unrealistic and overly simplified drug supply chain. The model has been used on a simplified stem of a supply chain distribution tree. Many more variables are required to actually scale it to a real supply chain. For a country-wide or even a state-wide network, it will become a big data problem, and a robust data architecture must be required to handle the huge number of variables.

**6.4.2 Security.** Advanced level of security must be applied to safeguard the creation and adaption of data. The model uses hash key table which is to be shared with every node in the distribution network. This is a trivial method of security which can be easily hacked. A dedicated security system is needed with regular patches to update the system. The security system can be developed in-house or through a security vendor.

**6.4.3 Mutual Agreement.** All the stages in the supply chain will have to come to a mutual agreement of making the supply data transparent and setting up a system for conducting such a model. A non co-operation from a single stage or node will make the data non-transparent. This will also make the blockchain model ineffective as track of data flow will be lost.

**6.4.4 Data Management.** Data management for a shared database system like a blockchain should meet the few basic requirements like maintaining consistency and providing security. The data should be changed dynamically across the network, when a block is added or updated. Single node in the distribution network cannot be trusted with the data management. The model uses a single data set that is shared across the network. A voting mechanism must be made to notify and request approval from each node in the distribution network before adding or updating a block in the blockchain. Only then the model will become a truly decentralized data management system, that is required for a blockchain.

**6.4.5 User-Friendly.** The model is a piece of python code, that is either run through a command line or an iPython notebook. A practical application would have a user interface for wider use. For each stage, the system that scans the bar codes must be connected with the blockchain model, to provide hassle-free updates to a block's data. It will internally require approval from the security system for the scan. This will require front-end application development. The model will also require servers for database and running back-end code. Either the nodes in the supply chain network or the government must bear the initial cost of setting up the system.

**6.4.6 Counterfeit Detection.** The model does not take into consideration the theft or counterfeit replacement during transportation. The hash keys are connected to the block ID, which in the real-world represents a bar code for a batch of drugs. If the drugs are replaced while keeping the original packaging, then duplicate drugs can be entered into the supply chain.

**6.4.7 Reverse Supply Chain.** The model does not currently have functionality to accurately represent the reverse supply chain. The model used only three variables which represent the return time of a batch across different stages. The field of reverse supply chain

must be explored further as it is important when distributors and pharmacies overstock the drugs.

## 7 DISCUSSION

An analysis of blockchain, the opioid crisis, pharmaceutical supply chains, and the demonstrated blockchain model for opioid distribution provides a more comprehensive picture for how blockchain could be applied to drug distribution. In particular, sample analytics were generated from the blockchain model and are provided as a snapshot of the overall analytic capabilities of a blockchain. Benefits of blockchain adoption are diverse but broadly fall into administrative capabilities and analytic capabilities. Effective use of these capabilities provide numerous benefits, including several which could mitigate certain issues of the opioid crisis. However, actual implementation must overcome significant challenges to adoption.

### 7.1 Sample Analytics from Blockchain Model

**7.1.1 Spikes in Sale Over Time.** The basic analysis to perform on the supply chain data, keeping the opioid crisis in mind, is to show the drug sale over time. Figure 3 shows the number of batches of opioid sold every year. An increase in sale can be noted after year 2005. The sale remains high for the later years. Such an analysis for country wide data can be helpful in finding the spike in sale of drugs and look further into the causes. The model uses sold date provided by the pharmacy for this task.

**7.1.2 Number of Prescription Over Time.** This is another important analysis that should be performed in case of a crisis like opioid crisis. The increase in sale of prescription drug is mainly due to increase in prescriptions that are provided by the doctors and physicians. Such a case should be looked in depth. After finding the areas with most sale of drug over time, the prescription data should be analyzed to find any defaulter. Since the opioid crisis is mostly due to over prescription of drug, this analysis is very important. Figure 4 shows ids for doctors that gave away too many prescriptions. The prescription data is provided by the pharmacy. In the figure 4, the doctor with id pres1 gave away most prescriptions while pres3 id doctor was the most nominal in giving away prescriptions.

**7.1.3 Zip-codes that Abuse the Drug.** In any drug crisis, the main analysis is localizing the point in time when the excessive sale happened and the area in which it happened. To find the area of excessive sale the model performs analysis on the zip code data provided by the pharmacy. Figure 5 shows results of such an analysis. Zip3 and Zip2 contribute towards most of the sale of opioid. Such areas should be studied into further. This analysis simplifies the process of finding the factors contributing towards the drug crisis.

**7.1.4 Average Number of Days for Stocking Drug.** Another major factor in the opioid crisis was overstocking of drugs by different nodes in the supply chain. To dive deeper into this problem an analysis should be done finding the average number of days a batch of drug was stocked across the different nodes in the supply chain. The defaulters can be easily found out, when the average number of stock days for that node is high. Figure 6 shows such an analysis on the supply chain. Stocked days are found out by

the difference in time as to when the batch of drugs arrived at that node and when it left the node. This time data is provided by each node in the supply chain. Figure 6 shows that the manufacturers, warehouses and pharmacies, for this given example, stocked the drugs for higher number of days. Some stocking should be allowed, as sales cannot be predicted accurately, but excessive stocking should be looked into further and rules against excessive stocking should be implemented. Especially for drugs like opioid.

### 7.2 More Comprehensive Capabilities

A more fully-functioning blockchain can provide numerous benefits that allow for administrative efficiencies and provide richer information and analytics.

**7.2.1 Cost Savings.** As a proactive cost saving maneuver, drug makers and retailers can move onto the supply chain to prevent future litigation [53]. In addition, blockchain automation saves time and operating costs [71].

**7.2.2 Reduced Lead Times.** Collaborative record-sharing is the foundation and ultimate strength of blockchain technology. Nematiollahi, Hosseini-Motlagh, and Heydari [52] show that collaborative record-sharing among pharmaceutical nodes increases both the social and economic effectiveness of the supply chain. The economic benefits realized through the reduction of the total supply chain inventory levels also decreases lead times.

**7.2.3 Post-Sale Opioid Collection.** Blockchain technology can also increase the usefulness of post-sale opioid collection. Current medication packaging lacks 2D Data Matrix bar codes making it nearly impossible to identify historical information such as who is returning their medication, who prescribed and sold the medication, and when the medication was prescribed and returned [73]. Blockchain can trace this information leading to better post-sale analysis. In turn, this information can be studied to improve prescribing methodology.

**7.2.4 Payment Facilitation.** The blockchain provides a framework from which smart contracts can be written for the automatic transference of payment based upon certain conditions being met [37] [69]. By adding smart contracts to the pharmaceutical supply chain blockchain, payments will transfer seamlessly and automatically with significantly lower transaction costs and risks for payment dispute. The end impact results in lower costs.

**7.2.5 Collaborative Information Sharing.** The adoption of blockchain technology provides capabilities that have the potential to reduce the opioid epidemic through transparent and decentralized record keeping. In particular, blockchain adoption has the potential to identify prescription drug fraud. Currently without blockchain, opioid addicts can take advantage of the incomplete feedback between physicians and pharmacists by "doctor shopping", modifying, and duplicating prescriptions [24]. With pharmaceutical records on the blockchain, this type of activity is easily identifiable.

Blockchain can reduce illegal opioid prescribing and distribution. In the current centralized record keeping system, the U.S. Drug Enforcement Administration (DEA) relies the Controlled Substances Act of 1970, that requires drug companies to disclose large or suspicious drug purchases [35]. Drug makers, on the other hand claim

their responsibility to report is too vague. As a result, identifying “pill mills” is unnecessarily difficult and time-consuming. The DEA’s pharmaceutical unit has 600 investigators [35]. With blockchain, record keeping is standardized and accessible to all parties with the correct cryptographic keys.

**7.2.6 Counterfeit Detection.** Blocks are immutable, that is once a block is created it cannot be deleted or erased. In addition, each batch of product can be traced back to its origin. This means that each batch will have a block of code associated with it. If a batch does not have its presence in the blockchain, then it can be deemed as a counterfeit [10]. Furthermore, blocks with abnormal distribution patterns can be flagged and removed from the supply chain. Creating illicit blocks is easily identifiable as all new blocks must be approved by all parties on the blockchain. Consequently, drugs that are distributed through a blockchain supply chain enable doctors, pharmacists, and patients identify whether the medication is genuine with much greater certainty [24].

**7.2.7 Traceability.** In the areas of logistics and inventory data, blockchain provides a new approach to supply chain management. The core logic of blockchain does not allow duplicate entries to be created in the same place [7]. A unique inventory can have a single entry with multiple updates, but not duplication. This prevents the organizations from creating false information. In the example of a drug inventory, the shipment status for a batch of drugs will be updated for everyone, everywhere. Each entry could be traced back to its origin [7].

**7.2.8 Data Analysis.** Academic institutions and researchers should have access to superkeys to analyze the blockchain [49]. Data analysis can provide both a descriptive and predictive overview of the opioid supply chain. Blockchain can also improve the repeatability of clinical studies and allow access to the raw data [4]. Because the information streams are more comprehensive with lower lag times, high-risk scenarios and communities could be predicted or identified in time for agencies to intervene and provide outreach and emergency planning that could mitigate the risk of fatalities.

### 7.3 Adoption Challenges and Recommendations

Moving drug distribution onto the blockchain without a full understanding of its capabilities is perilous [37]. Rather the reality for such a system is likely still at least a decade in the future as the pharmaceutical and supply chain industries need to overcome numerous hurdles before effective adoption.

In addition to the general blockchain adoption challenges discussed by Tapscott and Tapscott [69], Rabah [62], and Iansiti and Lakhani [37], an opioid distribution blockchain must overcome its own unique barriers prior to adoption.

**7.3.1 Security.** The need to protect patient data is critical as inaccurate information could lead to fatal consequences. One unique weakness to blockchain is a 51% attack. This occurs when one node or a coalition of nodes controls at least 51% of the network. When this happens, the single node or coalition of nodes controls the entire network. A 51% attack is more likely in a network with a small amount of genesis nodes [3]. In addition, future quantum

computing power may be strong enough to break cryptographic keys [24]. Security setup must meet the standards of the Security Rule, a subset of the Health Insurance Portability and Accountability Act (HIPPA), which provides rigid administrative, physical, and technical safeguards [33].

**7.3.2 Regulation.** Beyond just the Security Rule, the entire Health Insurance Portability and Accountability Act (HIPPA) must be at the forefront of designing any portion of an opioid distribution blockchain that involves electronic Protected Health Information (ePHI). Also, like most transformative technology, regulations are slow to conform. A lack of uniform regulations will create a road-block and slow blockchain adoption [33].

**7.3.3 Transparency and Confidentiality.** One of the major strengths of blockchain technology is transparency, but current in-use blockchain technology, Bitcoin, only provides pseudonymity. This poses a major threat to patient confidentiality as users are identifiable through the transnational location of IP addresses [6]. Encryption technology is necessary for adoption in opioid distribution. Collaboration between drug makers, supply chain organizations, and patient representatives must reach an agreement on specific protocols to protect patient identity and company level trade secrets.

**7.3.4 Speed and Scalability.** Blockchain adoption will require adequate transnational speeds for full-scale adoption. Currently, the most widely adopted blockchain network, Bitcoin takes at least ten minutes to confirm transactions and can only process seven transactions per second. Comparatively, Visa Credit Cards can confirm transactions within seconds and can process up to 56,000 transactions per second [15]. Speed and scalability requirements for an opioid supply chain blockchain have yet to be determined.

**7.3.5 Size.** Current standards limit the size of one block to 1 megabyte, which limits each block to roughly 500 transactions [75]. In opioid distribution, the genesis node is created at the primary manufacturer. One batch of opioids may easily have over 500 transactions.

**7.3.6 Bandwidth.** At current throughput levels, the Bitcoin network is over 50,000 megabyte. Adoption of blockchain in healthcare could increase the throughput to levels seen in credit card companies. At that level, the blockchain network would grow up to 241 petabyte a year [75]. Reducing the cost of acquiring bandwidth and storage is necessary for adoption. Research shows that at current prices, each transaction costs \$0.0154 [15].

**7.3.7 Error Handling.** It is reasonable to assume mistakes will occur during shipping, handling, and retailing of opioids. Since blocks are immutable, these errors would remain permanently attached to the block. Updates can be made to correct these mistakes but the record-keeping may not be easily interpretable. One mitigating strategy is to implement a one hour grace period before transactions are confirmed. For example, a hospital doctor may scan an opioid prescription to a patient, but then never give the patient the drugs. A system of confirmation is needed to prevent misleading data in the network.

**7.3.8 Data Input.** Blockchain technology allows for more automatic data creation but ultimately manual entry will still be required.

Encouraging accurate data entry will ultimately define the usability of blockchain in opioid drug distribution [24].

**7.3.9 Status Quo and Learning Curve.** The current system of opioid distribution has been in place for decades. Blockchain has immense social benefits, but companies may be unwilling to invest in the new and relatively unknown technology. Due to the initial learning curve, lead times may increase in the early days of implementation. Businesses may ignore the idea based on the hassle and the initial investment for setting up such a model. Training cost will also be substantial, but with the fast approaching 2023 mandate of The Drug Quality and Security Act [1], pharmaceutical supply chain organizations may have the necessary regulatory incentives to invest in blockchain technology more quickly than in an unregulated market.

## 8 CONCLUSION

Although still in its infancy, blockchain has the potential to be just as transformative as TCP/IP. Early and potential applications in healthcare and supply chain suggest that blockchain is indeed moving along the path of technology adoption. Because blockchain is a low-cost solution for supply chain management and provides security and transparency, it could theoretically be used for digital data and communication to overall the distribution of controlled substances such as opioids.

From a technical feasibility standpoint, the blockchain proof of concept presented shows that the blockchain can be applied to a hypothetical and simplified drug supply chain. Although useful as a starting point, this model is far from practical adoption. The authors welcome other collaborators to build upon the source code to further expand the blockchain model for use in more complex and realistic drug supply chains.

The presenting question: “Can blockchain adoption mitigate the opioid crisis through more secure drug distribution?” has yet to be tested in practice. However, blockchain use cases in healthcare and supply chain, the technical maturation of blockchain including the drug distribution blockchain proof of concept presented, and scholarly, business, and health industry articles suggest that blockchain can become an effective foundational tool that would open a Pandora’s box of innovation. In turn, smart applications built into or on top of the blockchain framework would enable numerous capabilities that could help mitigate certain problems of the opioid crisis. Specifically, effective development and adoption of such innovations could reduce prescription costs, help match supply with demand, shorten lead times, and enable more secure post-sale opioid collection. Moreover, by arming administrators, organizations, and regulatory agencies with more comprehensive real-time information and analytics, they will be able to more securely track opioids, help identify counterfeits and fraud, conduct thorough research, and intervene in communities that are predicted to have an increased risk of fatalities.

Realistically, this transformation will require at least a decade before its benefits can be fully realized. Blockchain progression for highly regulated industries such as drug distribution where consequences could literally be fatal will develop even more slowly than in other industries. Yet, with lives at stake, the government, researchers, and private industry should take steps now that progress

toward functional blockchain solutions for drug distribution. This progress should not be viewed as a single monumental task but rather as a series of incremental improvements that collectively provide capabilities to help mitigate the opioid epidemic and provide broader benefits. Application of agile product management philosophies and open source collaboration are key to the maturation of this blockchain concept. The authors invite others to build upon their incremental work as one of the numerous steps toward an effective blockchain solution for drug distribution.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski and Juliette Zerick for their support and suggestions to develop this blockchain model and to write this paper.

## REFERENCES

- [1] 113th Congress. 2013. H.R.3204 - Drug Quality and Security Act. (Nov. 2013). <https://www.congress.gov/bill/113th-congress/house-bill/3204> Sponsor Rep. Fred Upton.
- [2] Suveen Angraal, Harlan M. Krumholz, and Wade L. Schulz. 2017. Blockchain Technology. *Circulation: Cardiovascular Quality and Outcomes* 10, 9 (2017), e003800. <https://doi.org/10.1161/CIRCOUTCOMES.117.003800> arXiv:<http://circoutcomes.ahajournals.org/content/10/9/e003800.full.pdf>
- [3] A. Beikverdi and J. Song. 2015. Trend of centralization in Bitcoin’s distributed network. In *2015 IEEE/ACM 16th International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD)*. IEEE, Takamatsu, Japan, 1–6. <https://doi.org/10.1109/SNPD.2015.7176229>
- [4] Mehdi Benchoffu and Philippe Ravaud. 2017. Blockchain technology for improving clinical research quality. *Trials* 18, 1 (19 Jul 2017), 335. <https://doi.org/10.1186/s13063-017-2035-z>
- [5] Howard G. Birnbaum, Alan G. White, Matt Schiller, Tracy Waldman, Jody M. Cleveland, and Carl L. Roland. 2011. Societal Costs of Prescription Opioid Abuse, Dependence, and Misuse in the United States. *Pain Medicine* 12, 4 (2011), 657–667. <https://doi.org/10.1111/j.1526-4637.2011.01075.x>
- [6] Alex Biryukov, Dmitry Khovratovich, and Ivan Pustogarov. 2014. Deanonymisation of clients in Bitcoin P2P network. *CoRR* abs/1405.7418 (2014), 15. arXiv:1405.7418 <http://arxiv.org/abs/1405.7418>
- [7] Paul Brody. 2017. How Blockchain Revolutionizes Supply Chain Management. (Aug. 2017). <http://www.digitalistmag.com/finance/2017/08/23/how-the-blockchain-revolutionizes-supply-chain-management-05306209>
- [8] Scott Burris, Joanna Norland, and Brian R Edlin. 2001. Legal aspects of providing naloxone to heroin users in the United States. *International Journal of Drug Policy* 12, 3 (2001), 237 – 248. <http://www.sciencedirect.com/science/article/pii/S095395901000809>
- [9] Shamard Charles. 2017. CVS to Limit Opioid Prescriptions to 7-Day Supply. (Sept. 2017). <https://www.nbcnews.com/storyline/americas/heroin-epidemic/cvs-limit-opioid-prescriptions-7-day-supply-n803486>
- [10] Steve Cheng, Matthias Daub, Axel Domeyer, and Martin Lundqvist. 2017. Using blockchain to improve data management in the public sector. (Feb. 2017). <https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/using-blockchain-to-improve-data-management-in-the-public-sector>
- [11] K. Christidis and M. Devetsikiotis. 2016. Blockchains and Smart Contracts for the Internet of Things. *IEEE Access* 4 (06 2016), 2292–2303. <https://doi.org/10.1109/ACCESS.2016.2566339>
- [12] Theodore Cicero, Matthew Ellis, Hilary L Surratt, and Steven Kurtz. 2014. The Changing Face of Heroin Use in the United States A Retrospective Analysis of the Past 50 Years. *JAMA psychiatry* 71 (05 2014), E1–E6.
- [13] Sharon Cocco and Gari Singh. 2017. Top 6 technical advantages of Hyperledger Fabric for blockchain networks. (Aug. 2017). <https://www.ibm.com/developerworks/cloud/library/cl-top-technical-advantages-of-hyperledger-fabric-for-blockchain-networks/index.html>
- [14] Mike Cottle, Waco Hoover, Shadaab Kanwal, Marty Kohn, Trevor Strome, and N Treister. 2013. *Transforming Health Care Through Big Data Strategies for leveraging big data in the health care industry*. Technical Report. Institute for Health Technology Transformation. 1–24 pages.
- [15] Kyle Croman, Christian Decker, Ittay Eyal, Adem Efe Gencer, Ari Juels, Ahmed Kosba, Andrew Miller, Prateek Saxena, Elaine Shi, Emin Gun Sirer, Dawn Song, and Roger Wattenhofer. 2016. On Scaling Decentralized Blockchains. In *Financial Cryptography and Data Security: FC 2016 International Workshops, BITCOIN, VOTING, and WAHC, Christ Church, Barbados, February 26, 2016, Revised Selected Papers*, Jeremy Clark, Sarah Meiklejohn, Peter Y.A. Ryan, Dan Wallach, Michael

- Brenner, and Kurt Rohloff (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 106–125. [https://doi.org/10.1007/978-3-662-53357-4\\_8](https://doi.org/10.1007/978-3-662-53357-4_8)
- [16] Reenita Das. 2017. *Does Blockchain Have A Place In Healthcare?* Technical Report. Forbes. <https://www.forbes.com/sites/reenitadas/2017/05/08/does-blockchain-have-a-place-in-healthcare/#5ebcaa6d1c31>
- [17] Reenita Das. 2017. Does Blockchain Have A Place In Healthcare? (May 2017). <https://www.forbes.com/sites/reenitadas/2017/05/08/does-blockchain-have-a-place-in-healthcare/#dbdfb081c31e>
- [18] Corey Davis, Traci Green, and Leo Beletsky. 2017. Action, Not Rhetoric, Needed To Reverse the Opioid Overdose Epidemic. *Journal of Law, Medicine & Ethics* 45 (2017), 20 – 23. <http://proxyiub.uits.iu.edu/login?url=https://search-ebscohost.com.proxyiub.uits.iu.edu/login.aspx?direct=true&db=aph&AN=122737813&site=ebook-live&scope=site>
- [19] Julie Hirschfeld Davis. 2017. Trump Declares Opioid Crisis a fiHealth Emergencyfi but Requests No Funds. (oct 2017). [https://www.washingtonpost.com/investigations/cherokee-nation-sues-drug-firms-retailers-for-flooding-communities-with-\discretionary{-}{\}{opiods}/2017/04/20/03d04a74-2519-11e7-b503-9d616bd5a305\\_story.html?utm\\_term=.ee0423b994ba](https://www.washingtonpost.com/investigations/cherokee-nation-sues-drug-firms-retailers-for-flooding-communities-with-\discretionary{-}{\}{opiods}/2017/04/20/03d04a74-2519-11e7-b503-9d616bd5a305_story.html?utm_term=.ee0423b994ba)
- [20] Ivo D Dinov. 2016. *Volume and value of big healthcare data*. Technical Report. Health and Human Services.
- [21] Joe Durbin. 2017. Battling the Opioid Crisis with Big Data, Analytics, and Blockchain. (Nov. 2017). <https://www.csra.com/media-room/article/battling-opioid-crisis-big-data-analytics-and-blockchain>
- [22] The Economist. 2014. *The 272 billion dollar swindle*. Technical Report. The Economist. <https://www.economist.com/news/united-states/21603078-why-thieves-love-americas-health-care-system-272-billion-swindle>
- [23] Ariel Ekblaw, Asaf Azaria, Thiago Vieira, and Andrew Lippman. 2016. *MedRec: Medical Data Management on the Blockchain*. Technical Report. pubpub.org.
- [24] Mark A. Engelhardt. 2017. Hitching Healthcare to the Chain: An Introduction to Blockchain Technology in the Healthcare Sector. *Technology Innovation Management Review* 7 (10/2017 2017), 22–34. [https://www.researchgate.net/publication/320682444\\_Hitching\\_Healthcare\\_to\\_the\\_Chain\\_An\\_Introduction\\_to\\_Blockchain\\_Technology\\_in\\_the\\_Healthcare\\_Sector](https://www.researchgate.net/publication/320682444_Hitching_Healthcare_to_the_Chain_An_Introduction_to_Blockchain_Technology_in_the_Healthcare_Sector)
- [25] Curtis Florence, Chao Zhou, Feijun Luo, and Likang Xu. 2016. The Economic Burden of Prescription Opioid Overdose, Abuse, and Dependence in the United States, 2013. *Medical Care* 54 (01 2016), 901–906.
- [26] U.S. Food and Drug Administration. 2014. Title II of the Drug Quality and Security Act. (Dec. 2014). <https://www.fda.gov/Drugs/DrugSafety/DrugIntegrityandSupplyChainSecurity/DrugSupplyChainSecurityAct/ucm427033.htm>
- [27] Kaiser Family Foundation. 2015. Opioid Overdose Deaths by Race/Ethnicity. (july 2015). <https://www.kff.org/other/state-indicator/opioid-overdose-deaths-by-raceethnicity/?currentTimeframe=0&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D>
- [28] Sullivan Frost. 2015. Drowning in big data? reducing information technology complexities and costs for healthcare organizations. (2015).
- [29] Susan Galer. 2017. Betting On Blockchain As Miracle Cure For The \$7B Opioid Crisis. (Sept. 2017). <https://blogs.sap.com/2017/09/05/betting-on-blockchain-as-miracle-cure-for-the-7b-opioid-crisis/>
- [30] Gideon Greenspan. 2016. Four genuine blockchain use cases. (May 2016). <https://www.multichain.com/blog/2016/05/four-genuine-blockchain-use-cases>
- [31] Claire Hansen. 2017. CVS to Limit Opioid Prescriptions. (Sept. 2017). <https://www.usnews.com/news/national-news/articles/2017-09-22/cvs-to-enforce-new-limits-on-opioid-prescriptions>
- [32] Kathryn Hawk, Federico E. Vaca, and Gail D’Onofrio. 2015. Reducing Fatal Opioid Overdose: Prevention, Treatment and Harm Reduction Strategies. *The Yale journal of biology and medicine* 88 (09 2015), 235–245.
- [33] David Henderson. 2017. Blockchain Regulation In Europe And Potential Hurdles. (Oct. 2017). <http://www.nasdaq.com/article/blockchain-regulation-in-europe-and-potential-hurdles-cm854360>
- [34] Scott Higham and Lenny Bernstein. 2017. Cherokee Nation sues drug firms, retailers for flooding communities with opioids. (april 2017). [https://www.washingtonpost.com/investigations/cherokee-nation-sues-drug-firms-retailers-for-flooding-communities-with-opioids/2017/04/20/03d04a74-2519-11e7-b503-9d616bd5a305\\_story.html?utm\\_term=.ee0423b994ba](https://www.washingtonpost.com/investigations/cherokee-nation-sues-drug-firms-retailers-for-flooding-communities-with-opioids/2017/04/20/03d04a74-2519-11e7-b503-9d616bd5a305_story.html?utm_term=.ee0423b994ba)
- [35] Scott Higham and Lenny Bernstein. 2017. THE DRUG INDUSTRYfIS TRIUMPH OVER THE DEA. (Oct. 2017). [https://www.washingtonpost.com/graphics/2017/investigations/dea-drug-industry-congress/?utm\\_term=.86b20fd58f4](https://www.washingtonpost.com/graphics/2017/investigations/dea-drug-industry-congress/?utm_term=.86b20fd58f4)
- [36] Hoovers. 2017. Drug Wholesalers. (2017). <http://subscriber.hoovers.com/H/industry360/overview.html?industryId=1493>
- [37] Marco Iansiti and Karim R. Lakhani. 2017. *The Truth About Blockchain*. Technical Report. Harvard Business Review.
- [38] Marco Iansiti and Karim R. Lakhani. 2017. The Truth About Blockchain. (feb 2017). <https://hbr.org/2017/01/the-truth-about-blockchain>
- [39] RFID Journal. 2017. How much does an RFID tag cost today? (Aug. 2017). <http://www.rfidjournal.com/faq/show?85>
- [40] H. Kakavand, N. Kost De Serves, and B. Chilton. 2017. The Blockchain Revolution: An Analysis Of Regulation And Technology Related To Distributed Ledger Technologies. (april 2017). <http://www.fintechconnective.com/wpcontent/uploads/2016/11/Luther-Systems-DLA-Piper-Article\discretionary{-}{\}{onBlockchain-Regulation-and-Technology-SK}.pdf>
- [41] Harry A. Kalodner, Steven Goldfeder, Alishah Chator, Malte Moser, and Arvind Narayanan. 2017. BlockSci: Design and applications of a blockchain analysis platform. *CoRR* abs/1709.02489 (oct 2017), 1–14. <http://arxiv.org/abs/1709.02489>
- [42] Theodore Kelesidis, Iosif Kelesidis, Petros I. Rafailidis, and Matthew E. Falagas. 2007. Counterfeit or substandard antimicrobial drugs: a review of the scientific evidence. *Journal of Antimicrobial Chemotherapy* 60, 2 (2007), 214–236. <https://doi.org/10.1093/jac/dkm109> arXiv:oup/backfile/content\_public/journal/jac/60/2/10.1093\_jac.dkm109/1/dkm109.pdf
- [43] Peter Kelle, John Woosley, and Helmut Schneider. 2012. Pharmaceutical supply chain specifics and inventory solutions for a hospital case. *Operations Research for Health Care* 1, 2 (2012), 54 – 63. <https://doi.org/10.1016/j.orhc.2012.07.001>
- [44] Saurabh Kumar. 2017. Final Project. (2017). <https://github.com/bigdata-i523/hid212/tree/master/project/data>
- [45] Saurabh Kumar. 2017. Final Project. (2017). <https://github.com/bigdata-i523/hid212/blob/master/project/blockchain.py>
- [46] Tsung-Ting Kuo, Hyeon-Eui Kim, and Lucila Ohno-Machado. 2017. Blockchain distributed ledger technologies for biomedical and health care applications. *Journal of the American Medical Informatics Association* 24, 6 (2017), 1211–1220. <https://doi.org/10.1093/jamia/ocx068>
- [47] Jeanne Lenzer. 2014. US could recycle 10 million unused prescription drugs a year. *BMJ* 349 (2014), g7677. <https://doi.org/10.1136/bmj.g7677>
- [48] James Manyika, Michael Chui, Brad Brown, Jacques Bughin, Richard Dobbs, Charles Roxburgh, and Angela Hung Byers. 2011. *Big data: The next frontier for innovation, competition, and productivity*. Technical Report. McKinsey Global Institute. <https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/big-data-the-next-frontier-for-innovation>
- [49] Steven McKie. 2015. The Blockchain Meets Big Data and Real-time Analysis. (June 2015). <https://bitcoinmagazine.com/articles/blockchain-meets-big-data-realtime-analysis-1435183048>
- [50] Mike Miliard. 2017. How does blockchain actually work for healthcare? (April 2017). <http://www.healthcareitnews.com/news/how-does-blockchain-actually-work-healthcare>
- [51] Mei na Hua, Hua jun Tang, and Zi lin Wu. 2016. Analysis of a pharmaceutical reverse supply chain based on unwanted medications categories in household. In *Industrial Engineering and Engineering Management (IEEM), 2016 IEEE International Conference on*. IEEE, IEEE, Bali, Indonesia, 1493–1497.
- [52] Mohammadreza Nematollahi, Seyyed-Mahdi Hosseini-Motlagh, and Jafar Heydari. 2017. Economic and social collaborative decision-making on visit interval and service level in a two-echelon pharmaceutical supply chain. *Journal of Cleaner Production* 142, Part 4 (2017), 3956 – 3969. <https://doi.org/10.1016/j.jclepro.2016.10.062>
- [53] Yuki Noguchi. 2017. 41 States To Investigate Pharmaceutical Companies Over Opioids. (Sept. 2017). <https://www.npr.org/sections/thetwo-way/2017/09/19/552135830/41-states-to-investigate-pharmaceutical-companies-over-opioids>
- [54] Commission on Combating Drug Addiction and the Opioid Crisis. 2016. Commission Interim Report. (june 2016). <https://www.whitehouse.gov/sites/whitehouse.gov/files/ondcp/commission-interim-report.pdf>
- [55] National Institute on Drug Abuse. 2017. Opioid Crisis. (june 2017). <https://www.drugabuse.gov/drugs-abuse/opioids/opioid-crisis#one>
- [56] Mike Orcutt. 2017. Why the CDC Wants in on Blockchain. (Oct. 2017). <https://www.technologyreview.com/s/608959/why-the-cdc-wants-in-on-blockchain/>
- [57] Bryce Pardo. 2017. Do more robust prescription drug monitoring programs reduce prescription opioid overdose? *Addiction* 112, 10 (2017), 1773–1783. <https://doi.org/10.1111/add.13741> ADD-16-0812.R1
- [58] Stephen W. Patrick, Carrie E. Fry, Timothy F. Jones, and Melinda B. Buntin. 2016. Implementation Of Prescription Drug Monitoring Programs Associated With Reductions In Opioid-Related Death Rates. *Health Affairs* 35, 7 (2016), 1324–1332. <https://doi.org/10.1377/hlthaff.2015.1496>
- [59] Tom Price. 2017. Strategy for Fighting Opioid Crisis. (april 2017). <https://www.hhs.gov/about/leadership/secretary/speeches/2017-speeches/secretary-price-announces-hhs-strategy-for-fighting-opioid-crisis/index.html> Tom Price’s remarks at the National Rx Drug Abuse and Heroin Summit.
- [60] Mattie Quinn. 2017. The Opioid Files: More Than 100 States and Cities Are Suing Drug Companies. (Nov. 2017). <http://www.governing.com/topics/health-human-services/gov-opioid-lawsuits-companies-states-cities.html>
- [61] Rudd RA, Seth P, David F, and Scholl L. 2016. Increases in Drug and Opioid Involved Overdose Deaths United States. *MMWR Morb Mortal Wkly Rep* 2016, 65:1445fi?1452 (May 2016), 1445fi?1452. <http://dx.doi.org/10.15585/mmwr.mm655051e1>
- [62] Kefa Rabah. 2017. Overview of Blockchain as the Engine of the 4th Industrial Revolution. *Mara Research Journal of Business & Management-ISSN: 2519-1381 1, 1* (2017), 125–135.

- [63] Shari Rudavsky. 2017. Indiana has an opioid crisis. See what the state's leading university is doing to help. (Oct. 2017). <https://www.indystar.com/story/news/2017/10/10/state-has-opioid-crisis-see-whats-leading-university-pledges-50-million-discretionary-/-\{}address-opioid-crisis/747151001/>
- [64] Lainie Rutkow, Lydia Turner, Eleanor Lucas, Catherine Hwang, and G. Caleb Alexander. 2015. Most Primary Care Physicians Are Aware Of Prescription Drug Monitoring Programs, But Many Find The Data Difficult To Access. *Health Affairs* 34, 3 (2015), 484–492. <https://doi.org/10.1377/hlthaff.2014.1085>
- [65] Krystsina Sadouskaya. 2017. *Adoption of Blockchain Technology in Supply Chain and Logistics*. Master's thesis. Mikkeli University of Applied Sciences.
- [66] Nihar Sahay and Marianthi Ierapetritou. 2013. Centralized vs. Decentralized Supply Chain Management Optimization. (11 2013). <https://aiche.confex.com/aiche/2013/webprogram/Paper319958.html>
- [67] Nilay Shah. 2004. Pharmaceutical supply chains: key issues and strategies for optimisation. *Computers & Chemical Engineering* 28, 6 (2004), 929 – 941. <https://doi.org/10.1016/j.compchemeng.2003.09.022> FOCAPO 2003 Special issue.
- [68] Udit Sharma. 2017. Blockchain in healthcare: Patient benefits and more. (Oct. 2017). <https://www.ibm.com/blogs/blockchain/2017/10/blockchain-in-healthcare-patient-benefits-and-more/>
- [69] Don Tapscott and Alex Tapscott. 2016. *Blockchain Revolution: How the Technology behind Bitcoin is changing Money, Business, and the World*. Penguin Random House LLC, 375 Hudson St, New York, New York 10014.
- [70] Douglas Taylor. 2014. RFID in the Pharmaceutical Industry: Addressing Counterfeits with Technology. *Journal of Medical Systems* 38, 11 (12 Oct 2014), 141. <https://doi.org/10.1007/s10916-014-0141-y>
- [71] TheLinuxFoundationProject. 2017. Revolutionizing the Supply Chain. (2017). <https://www.hyperledger.org/projects/sawtooth/seafood-case-study>
- [72] Kevin Vowles, Mindy McEntee, Peter Julnesm, Tessa Frohe, John Ney, and David N van der Goes. 2015. Rates of opioid misuse, abuse, and addiction in chronic pain. *Pain* 156, 4 (04 2015), 569–576.
- [73] Dan Walles. 2017. Track and trace is on the way. Is your drug supply chain ready? (June 2017). <https://medcitynews.com/2017/06/track-and-trace-are-you-ready/>
- [74] David C. Wyld. 2008. Genuine medicine?: Why safeguarding the pharmaceutical supply chain from counterfeit drugs with RFID is vital for protecting public health and the health of the pharmaceutical industry. *Competitiveness Review* 18, 3 (2008), 206–216. <https://doi.org/10.1108/10595420810905984>
- [75] Jesse Yli-Huumo, Deokyoon Ko, Sujin Choi, Sooyong park, and Kari Smolander. 2016. Where Is Current Research on Blockchain Technology? A Systematic Review. *PLOS ONE* 11, 10 (10 2016), 1–27. <https://doi.org/10.1371/journal.pone.0163477>
- [76] Ben Yuan, Wendy Lin, and Colin McDonnell. 2016. *Blockchains and electronic health records*. Technical Report. MIT.

We include an appendix with common issues that we see when students submit papers. One particular important issue is not to use the underscore in bibtex labels. Sharelatex allows this, but the proceedings script we have does not allow this.

When you submit the paper you need to address each of the items in the issues.tex file and verify that you have done them. Please do this only at the end once you have finished writing the paper. To do this change TODO with DONE. However if you check something on with DONE, but we find you actually have not executed it correctly, you will receive point deductions. Thus it is important to do this correctly and not just 5 minutes before the deadline. It is better to do a late submission than doing the check in haste.

## A ISSUES

DONE:

Example of done item: Once you fix an item, change DONE to DONE

### A.1 Assignment Submission Issues

DONE:

Do not make changes to your paper during grading, when your repository should be frozen.

## A.2 Uncaught Bibliography Errors

DONE:

Missing bibliography file generated by JabRef

DONE:

Bibtex labels cannot have any spaces, \_ or & in it

DONE:

Citations in text showing as [?]: this means either your report.bib is not up-to-date or there is a spelling error in the label of the item you want to cite, either in report.bib or in report.tex

## A.3 Formatting

DONE:

Incorrect number of keywords or HID and i523 not included in the keywords

DONE:

Other formatting issues

## A.4 Writing Errors

DONE:

Errors in title, e.g. capitalization

DONE:

Spelling errors

DONE:

Are you using *a* and *the* properly?

DONE:

Do not use phrases such as *shown in the Figure below*. Instead, use *as shown in Figure 3*, when referring to the 3rd figure

DONE:

Do not use the word *I* instead use *we* even if you are the sole author

DONE:

Do not use the phrase *In this paper/report we show* instead use *We show*. It is not important if this is a paper or a report and does not need to be mentioned

DONE:

If you want to say *and* do not use & but use the word *and*

DONE:

Use a space after . , :

DONE:

When using a section command, the section title is not written in all-caps as format does this for you

\section{Introduction} and NOT \section{INTRODUCTION}

## A.5 Citation Issues and Plagiarism

DONE:

It is your responsibility to make sure no plagiarism occurs. The instructions and resources were given in the class

DONE: Claims made without citations provided	DONE: Do use <code>label</code> and <code>ref</code> to automatically create figure numbers
DONE: Need to paraphrase long quotations (whole sentences or longer)	DONE: Wrong placement of figure caption. They should be on the bottom of the figure
DONE: Need to quote directly cited material	DONE: Wrong placement of table caption. They should be on the top of the table
<b>A.6 Character Errors</b>	
DONE: Erroneous use of quotation marks, i.e. use “quotes”, instead of ” ”	DONE: Images submitted incorrectly. They should be in native format, e.g. .graffle, .pptx, .png, jpg
DONE: To emphasize a word, use <code>emphasize</code> and not “quote”	DONE: Do not submit eps images. Instead, convert them to PDF
DONE: When using the characters & # % - put a backslash before them so that they show up correctly	DONE: The image files must be in a single directory named “images”
DONE: Pasting and copying from the Web often results in non-ASCII characters to be used in your text, please remove them and replace accordingly. This is the case for quotes, dashes and all the other special characters.	DONE: In case there is a powerpoint in the submission, the image must be exported as PDF
DONE: If you see a ffigure and not a figure in text you copied from a text that has the fi combined as a single character	DONE: Make the figures large enough so we can read the details. If needed make the figure over two columns
<b>A.7 Structural Issues</b>	
DONE: Acknowledgement section missing	DONE: Do not worry about the figure placement if they are at a different location than you think. Figures are allowed to float. For this class, you should place all figures at the end of the report.
DONE: Incorrect README file	DONE: In case you copied a figure from another paper you need to ask for copyright permission. In case of a class paper, you must include a reference to the original in the caption
DONE: In case of a class and if you do a multi-author paper, you need to add an appendix describing who did what in the paper	DONE: Remove any figure that is not referred to explicitly in the text (As shown in Figure ..)
DONE: The paper has less than 2 pages of text, i.e. excluding images, tables and figures	DONE: Do not use <code>textwidth</code> as a parameter for <code>includegraphics</code>
DONE: The paper has more than 6 pages of text, i.e. excluding images, tables and figures	DONE: Figures should be reasonably sized and often you just need to add <code>columnwidth</code>
DONE: Do not artificially inflate your paper if you are below the page limit	e.g. <code>/includegraphics[width=\columnwidth]{images/myimage.pdf}</code>

## A.8 Details about the Figures and Tables

DONE: Capitalization errors in referring to captions, e.g. Figure 1, Table 2
---

## B WORK BREAKDOWN

- (1) Nick Hotz - Lead paper editor and team project manager. Co-author across all sections.
- (2) Saurabh Kumar - Lead coder. Co-author of blockchain overview, blockchain model, and discussion sections.
- (3) Matthew Schwartzter - Lead author for opioid crisis and supply chain sections. Led paper formatting and bibliography. Co-author of discussion section.

[Figure 1 about here.]

[Figure 2 about here.]

[Figure 3 about here.]

[Figure 4 about here.]

[Figure 5 about here.]

[Figure 6 about here.]

#### LIST OF FIGURES

1	The flow chart for a pharmaceutical supply chain	17
2	The data fields that are stored in a block	18
3	Number of opioid batches sold each year	19
4	Number of prescriptions by each doctor/physician	19
5	Number of buyers by each zipcode	20
6	Average number of days opioid stocked	20

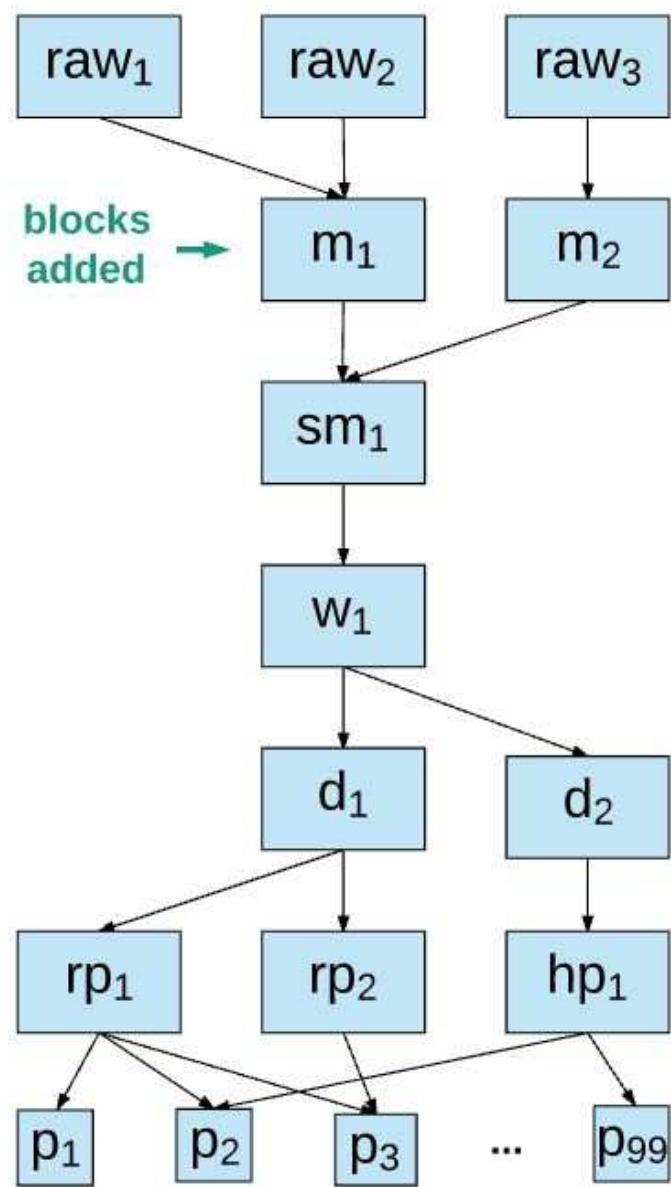


Figure 1: The flow chart for a pharmaceutical supply chain

```
print ("Data for 1012th block\n")
print (blockchain[1012].data)
```

Data for 1012th block

rawmaterial_supplier	raw2
manufacturer_id	m1
manufacturer_t1	2009-10-23 12:47:13.412781
manufacturer_t2	2009-11-25 21:53:47.774749
smanufacturer_id	sml
smanufacturer_t1	2009-12-04 00:05:09.454538
smanufacturer_t2	2010-01-01 05:15:57.344100
warehouse_id	w1
warehouse_t1	2010-01-13 04:19:37.169847
warehouse_t2	2010-02-15 13:26:11.531815
distributer_id	d2
distributer_t1	2010-02-25 02:09:30.423126
distributer_t2	2010-03-06 14:52:49.314437
pharmacy_id	hp1
pharmacy_t1	2010-03-14 20:51:50.723182
pharmacy_t2	2010-03-25 12:26:34.086122
prescriber_id	pres1
patient_id	87
zipcode	zip1
pharmacy_returntime	None
distributer_returntime	None
warehouse_returntime	None

Figure 2: The data fields that are stored in a block

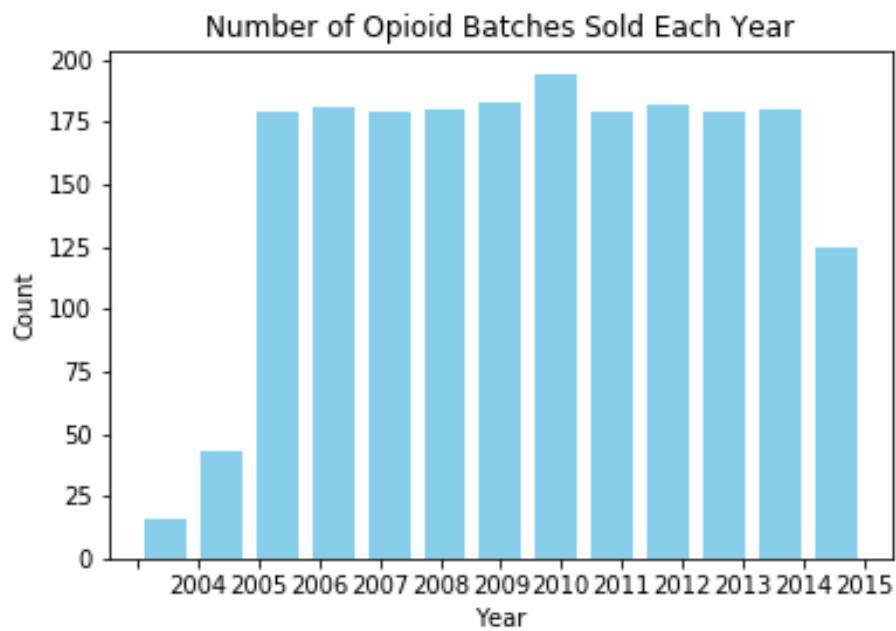


Figure 3: Number of opioid batches sold each year

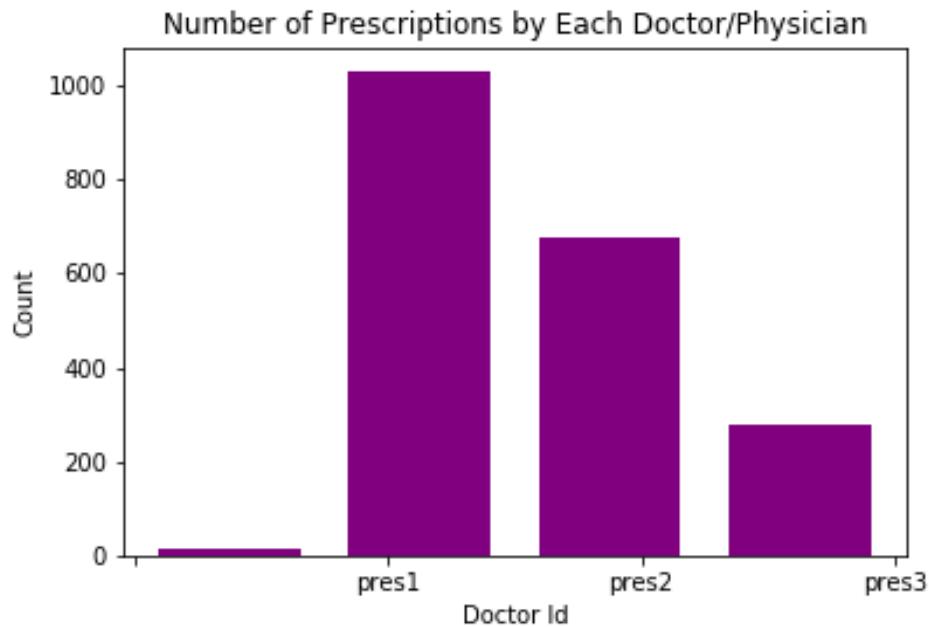


Figure 4: Number of prescriptions by each doctor/physician

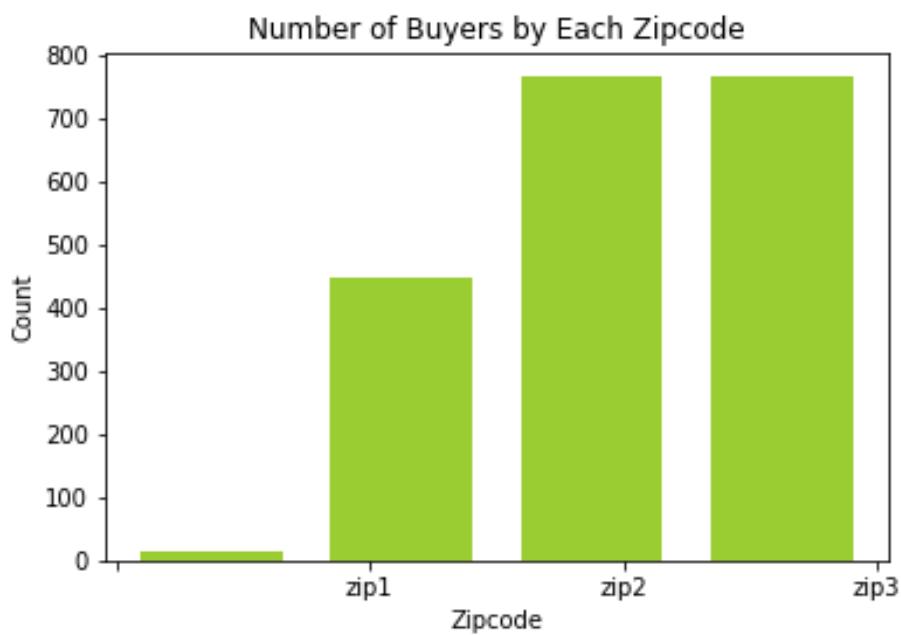


Figure 5: Number of buyers by each zipcode

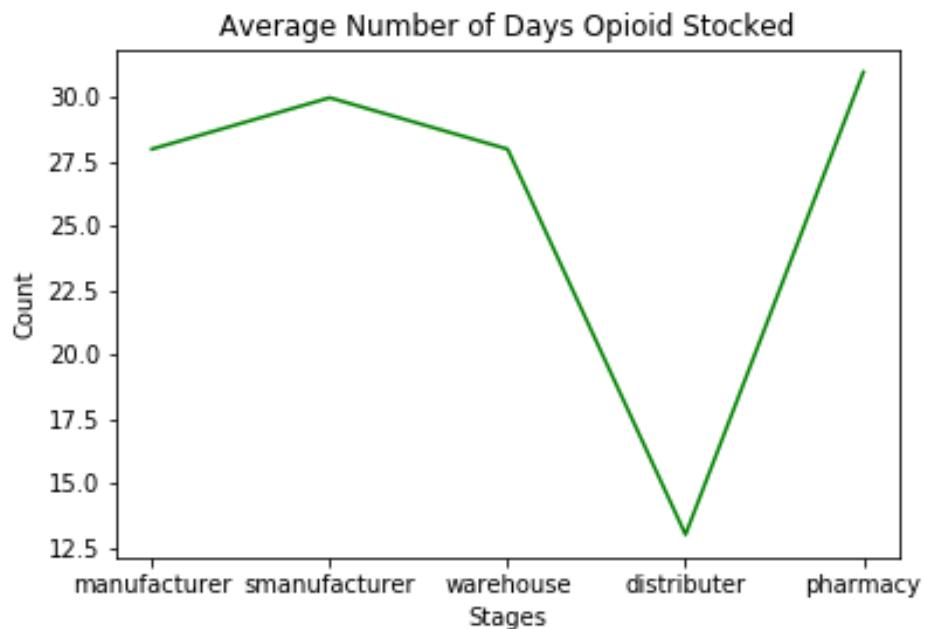


Figure 6: Average number of days opioid stocked

# Big data and hearing disability

Rahul Velayutham  
Indiana University Bloomington  
2661 H 7th St  
Bloomington, Indiana 47408  
rahuvela@umail.iu.edu

## ABSTRACT

Big Data is rapidly becoming a crucial component in the majority of the fields, be it from medicine to software. Big data technologies help in processing humongous amounts of data in a rapid manner while enabling us to achieve results fast and accurately. Hearing disability is a huge problem to the very fabric of society. It causes great discomfort among those who suffer from it and in some extreme cases can cause alienation. Thus there is a need for society to accept the difficulties faced by those affected with hearing disabilities and enhance the traditional solutions offered with the latest technologies so that they can lead a life without difficulties and live a normal life. The paper shows how the latest big data trends can be applied to existing traditional solutions like hearing aid, captions and also suggests how it can be used to proactively avoid situations that could lead to hearing loss. It is hoped that an interest will be generated towards further research and implementation towards combining Big data with hearing difficulty solutions.

## KEYWORDS

Big Data, i523 , HID 232 , Rain Water Harvesting

## 1 INTRODUCTION

Hearing loss or impairment is defined as the partial or total inability to hear and may occur in one or both ears and may result in a person having little to no hearing. This loss can be either temporary or permanent depending on the mode of affliction. The causes of hearing loss are many but the most prominent factors can be narrowed down to genetics, ageing, exposure to noise, some infections, birth complications, trauma to the ear, and certain medications or toxins, chronic ear infections and the like. Infections that may have no relation to hearing loss like syphilis and rubella may also cause hearing loss if infected during pregnancy. If a person feels that their hearing is not sharp they can undergo tests to confirm which sets the bar at 25 decibels, if a person cannot hear at that range then they can be diagnosed as suffering from hearing loss. Hearing loss can be categorized as mild, moderate, moderate-severe, severe, or profound[19]. Hearing loss can further be categorized into two sections Congenital Hearing Loss and Acquired Hearing Loss. Under Congenital Hearing Loss two chief factors are Genetic and Prenatal Issues. Under Acquired Hearing Loss the chief factors can be listed as Chronic ear infections, medications that can affect aspects of hearing, Diseases that affect hearing (Mnire's Disease, etc.), Head injury, Perforated eardrum[1].

Generally, genetic factors have been found to be responsible for pediatric hearing loss. This occurs when inherited genes work against the development of the patient's body and this impacts the development of the hearing system as a result. As it is with genetics

it can target any part of the body in this case it spares no part of the ear and can target any part from the outer ear to the deepest part of the inner ear. The degree of hearing loss can vary depending on which part is affected. When applicable solutions like hearing aids, implants etc provide for some relief [19].

As of 2013 hearing loss affects about 1.1 billion people to some degree[19]. It causes disability in 5% (360 to 538 million) and moderate to severe disability in 124 million people [19]. Of those with moderate to severe disability 108 million live in low and middle-income countries. Of those with hearing loss, it began in 65 million during childhood. Those who use sign language and are members of Deaf culture see themselves as having a difference rather than an illness. Most members of Deaf culture oppose attempts to cure deafness and some within this community view cochlear implants with concern as they have the potential to eliminate their culture. The term hearing impairment is often viewed negatively as it emphasizes what people cannot do. Despite all of the solutions and rationalizations being made, it cannot be denied however that hearing loss is becoming an important problem in today's society and one whose numbers is constantly increasing[19].

Big data is perhaps the most interesting technological advancement made in the current era, it has roots in almost all fields right from health care to education to even government policies. It is the far reach that makes big data important, it allows users and clients to make better-informed decisions by taking into account almost all factors. Doctors are looking towards big data to make more accurate diagnostics and look for new medicines, economists are looking towards big data to make more accurate models. The paper will look into how it can enhance some of the solutions provided for those hard of hearing like hearing aids, closed caption etc. It will also suggest enhancements towards preemptively preventing situations that could lead to hearing loss[19].

## 2 BIG DATA IN HEARING AIDS

### 2.1 Introduction

Hearing aids are small electronic devices that you wear in or behind your ear they improve the hearing and speech comprehension of people. It makes some sounds louder so that a person with hearing loss can listen, communicate, and participate more fully in daily activities. A hearing aid can help people hear more in both quiet and noisy situations. A hearing aid has three basic parts: a microphone, amplifier, and speaker as can be seen from the figure 1.

[Figure 1 about here.]

The microphone receives sound, which converts it into electrical signals and sends them to an amplifier. The amplifier increases the power of the signals and then sends them to the ear through a speaker basically it is magnifying sound vibrations entering the ear.

The eardrum then passes these vibrations to the nerve cells which then pass these signals to the brain. The more severe the hearing loss, and the greater the hearing aid amplification needed to make up the difference. However, there are practical limits to the amount of amplification a hearing aid can provide. However, if the inner ear is too damaged, a hearing aid would be ineffective [11]. Hearing aids can be classified into three distinct categories [11] they are Behind-the-ear (BTE), In-the-ear (ITE) and Canal as can be seen in the figure 2.

[Figure 2 about here.]

BTE hearing aids consist of a hard plastic case worn behind the ear and connected to a plastic earmold that fits inside the outer ear. The electronic parts are held in the case behind the ear. Sound travels from the hearing aid through the earmold and into the ear. BTE aids are used by people of all ages for mild to profound hearing loss. ITE aids fit completely inside the outer ear and are used for mild to severe hearing loss. The case holding the electronic components is made of hard plastic. Canal Aids fit into the ear canal and are available in two styles. The in-the-canal (ITC) hearing aid is made to fit the size and shape of a person's ear canal. A completely-in-canal (CIC) hearing aid is nearly hidden in the ear canal. Both types are used for mild to moderately severe hearing loss[11].

Hearing aids can further be classified based on their inner circuitry which is analogue and digital. Analog aids convert sound waves into electrical signals, which are amplified. The aid is programmed by the manufacturer according to the specifications recommended by your audiologist. An audiologist can program the aid using a computer, and you can change the program for different listening environments from a small, quiet room to a crowded restaurant etc. Digital aids convert sound waves into numerical codes, similar to the binary code of a computer, before amplifying them. Because the code also includes information about a sound's pitch or loudness, the aid can be specially programmed to amplify some frequencies more than others. Digital circuitry gives an audiologist more flexibility in adjusting the aid to a user's needs and to certain listening environments and can be programmed to focus on sounds coming from a specific direction[11].

Hearing aids are a fairly popular solution among most age groups and users use them for about 8-9 hours a day [2]. The process of getting a hearing aid is fairly simple. First, you confirm with an ENT / audiologist that you are indeed in need of one. Then a series of audiotometry tests are performed to determine the extent of damage / hearing loss incurred. Hearing sensitivity can be measured for a range of frequencies and plotted on an audiogram. Another method for quantifying hearing loss is a speech-in-noise test, which gives an indication of how well one can understand speech in a noisy environment. A person with a hearing loss will often be less able to understand speech, especially in noisy conditions. This is especially true for people who have a sensorineural loss if? which is by far the most common type of hearing loss. A recently developed digit-triple speech-in-noise test may be a more efficient screening test. The audiologist then programs the hearing aid to amplify at an acceptable level.

## 2.2 Big data in hearing aids

The working of hearing aids was covered in detail in the previous section now we shall focus on the areas where big data can be applied to help both the doctors and the patients as much as possible. We know that in order to determine the extent of hearing loss an audiotometry test will be performed. The test proceeds with a patient being made to sit in a soundproof room and being subjected to listening to a wide variety of sounds ranging from the softest possible sound they can perceive to the loudest possible. The audiologist then charts a graph to figure out the extent of hearing loss. It will look like the below graph shown as per the figure 3.

[Figure 3 about here.]

The problem with this process is it's still random and despite audiologists having great skill and lowering the margin as much as possible they can never be totally accurate nor can they test too much because it is physically demanding on the patient too. Big data can be a great help here. Data collected from multiple patients (with their consent) can be stored making use of technologies like apache pig , hive etc. Then when an initial audiotometry analysis has been performed we can use deep learning or simple statistical sampling to obtain a few similar cases via technologies like say apache-spark. From these cases, we can perform a more streamlined audiotometry test rather than guesswork and further accurately narrow down the loss coefficients.

After the hearing loss estimates are charted down. It is time to program the hearing aid (a hearing aid model is selected by the audiologist in accordance with the hearing loss estimates). The aid is programmed to amplify sound waves in the range where losses are observed and then various simulated environments are performed to determine the level of comfort and extent to which the hearing aid is helping and perform fine-tuning. The problem is the same as previous a very limited range of environment that may / may not be useful to the patient is observed. Using big data once again a more accurate test can be conceived. A user can be presented with the environments patients from the similar range of hearing loss faced and this can be used as a basis for fine-tuning. This process has slowly been making its way into research [13] and a few companies [14] have already started commercialising it.

These days most people make use of digital hearing aids. As previously mentioned digital hearing aids are well equipped to make use of big data in a way they do make use of it albeit in a micro manner. The behavioural patterns of the patient are recorded like the range of volume increase or decrease in various modes, amount used etc. When the patient visits the audiologist the next time this data is analysed and then corrective changes are made towards the programming of the hearing aid. Big data can play a very big role in proactively doing so. These days most hearing aids have moved on from using a separate remote control towards making use of smartphone apps as a remote. This can be viewed as a huge enabler for big data technologies. Since mobile phones will most of the time be connected to the internet this will enable (with consent) real-time load and store of data using technologies like pig and hadoop of user environments and the current sound wave patterns and amplification used along with other useful data like if the patient is increasing or decreasing volume. Hearing aids are

certainly growing smarter in the sense when a mobile communication device is brought near the aid the electromagnetic pulses from the phone is detected by the aid and automatically switches to a phone mode, however for most of the part the user has to switch manually to other modes like theatre, noisy etc. Big data can play a huge role in automatic detection. For starters, big data can be employed to dynamically observe the fluctuations in loudness levels as well observe the fluctuations in background noise to help determine what mode should aid change to. Aside from observing fluctuations it can also compare the current scenario to those who have already encountered such scenarios under similar conditions (and with a similar hearing loss) rate and then perhaps adjust the volume/setting to a safe appropriate level. note that this would be highly experimental and could also create more problems than it solves. As much as we have powerful machine learning algorithms like deep learning it is impossible for them to predict a solution that best suits a patient after all different patients have different problems and conditions but as it learns more and gains more data (the hallmark of deep learning to learn with more data) there will be a good chance that the algorithms will provide a solution that really suits the patient.

So far we have looked at how big data can make use of sound waves in terms of loudness background noise etc, but there is one more aspect in which big data can help us. Analysing the contents of the speech itself. It has been previously mentioned Big data in language and speech processing is a well-established topic and plenty of papers and discussions exists [3] [17]. Most speech can be well predicted these days and when we take into account that hearing aids these days can make out the direction of which the sound is coming from. Making use of this and the ability of deep learning to possibly predicts parts of speech we can leverage this to accordingly increase or decrease volume. certain words will have pronunciations that are hard to understand or have lower tones or have a high frequency to be repeated. we can take advantage of this. Also, the hearing aid can be programmed to automatically increase the volume when it detects a repetition of sentences/words either due to the patient asking the opposite person to repeat his/her sentence. this can be achieved either by listening to keywords like what, sorry, repeat yourself, etc or by analysing the sound waves and learning from that if the same pattern is being repeated.

### 2.3 Data processing and Technologies

Pattern recognition is a branch of machine learning that focuses on the recognition of patterns and regularities in data. Pattern recognition systems are in many cases trained from labelled "training" data (supervised learning), but when no labelled data are available other algorithms can be used to discover previously unknown patterns (unsupervised learning). In machine learning, pattern recognition is the assignment of a label to a given input value. An example of pattern recognition is classification, which attempts to assign each input value to one of a given set of classes (for example, determine whether a given email is "spam" or "non-spam"). However, pattern recognition is a more general problem that encompasses other types of output as well. Other examples are regression, which assigns a real-valued output to each input; sequence labeling, which assigns a class to each member of a sequence of values (for example, part

of speech tagging, which assigns a part of speech to each word in an input sentence); and parsing, which assigns a parse tree to an input sentence, describing the syntactic structure of the sentence [12].

From the above explanation, it becomes clear the manner in which we can apply pattern matching for hearing aids. We could use the binary stream as a basis for calculation and from this stream try to match it to existing patterns and predict the future patterns. If any of the generated patterns are found to have speech that is hard to decipher at that range signals can be sent to the hearing aid to accordingly raise the volume of the hearing aid. Aside from that we can make use of the binary sequences and try to find the best fit pattern match, we can eliminate noise because most hearing aids these days have excellent noise cancelling technology so we can be assured that the sound stream is that of the person who is speaking to the patient. Once we get the best fit we can make a correlation between the pattern identified and the next action to be performed. The discussed methods need not only be limited to merely volume increase and decrease. they can also be applied to the fitting process as we have discussed in detail previously, after obtaining the initial estimate graph we can take the plot points and use it to find the best-fit match of another patient and fine-tune the hearing aid accordingly saving a lot of time and effort and allowing the entire experience to be pleasant and more productive.

Apache hadoop, hive etc are just data warehousing software, used for distributed storage and processing of dataset of big data using the MapReduce programming model. It consists of computer clusters built from commodity hardware. All the modules in Hadoop are designed with a fundamental assumption that hardware failures are common occurrences and should be automatically handled by the framework. we have previously seen how data is being made available for us the next logical question that comes to mind is how do we store it and using what. The answer to what is somewhat easier to explain. As mentioned previously we can make use of sound waves which gets converted to numerical codes. Mobile phones used to control the hearing aids which have access to the internet can make use of hadoop framework. We can send this data to some API which then uses map reduce to accordingly save it to a location which represents that pattern. while looking for a pattern the analysis made at real time can be used to query the API which will use map reduce to obtain all patterns relevant to the range of hearing loss and then use pattern matching to figure out best fits and suggest feasible solutions. Audiologists can make use of this in the same manner only instead of making use of the API via mobile phones they can do it conventionally by a computer which will allow for stronger processing.

### 2.4 Section Summary

Hearing aids are the most assistive technology a person with hearing impairments could receive which do not require surgery. They are fast becoming an important industry especially with the rising problem of hearing loss. The process of obtaining a hearing aid is simple and straightforward and for a long time it remained static. However with the advent of big data the world of hearing aids has been shaken from its static foundations and is undergoing a paradigm shift in the same manner mobile phones evolved to the

current smart model. Right from the process of fitting to using the hearing big data can be applied to almost every stage. the entire process is still in its infancy and there is a huge scope for further development. Pattern matching , deep learning all the concepts are only the tip of the iceberg there are many algorithms and designs that can Be implemented. Thus there is a huge market both towards improving the current crop of hearing aids available and as well as creating jobs.

### 3 BIG DATA IN CLOSED CAPTIONING

#### 3.1 Introduction

The importance of video in today's world cannot be stated enough. in the field of education, more and more classes are being shifted to the online model, professors are moving towards keeping their lecturers in places like udemy, youtube, pluralsight etc because there they are allowed the total freedom to take the course in their own direction without the constraints of time and classroom size. Certain sites like youtube even offer a source of remuneration. Thanks to the advancements in technology like smartphones and cheaper internet the general public is not satisfied with just listening to the audio, they want to watch the video and embrace the whole experience and artists have contributed to it by making their videos so colourful. TV is ever present with people preferring to watch news comfortably and be updated on the go rather than rifle through a newspaper. Even in communication, there is a paradigm shift from normal audio based conversations heading towards video calls, facetime, Whatsapp video chat are just a few of the most popular options available.

Now that an accord has been reached on how popular the video format is becoming, its time to talk about how difficult it's becoming for people who have hearing disabilities to cope with this changing world. These are people who are struggling to understand communication face to face and now are tasked with trying to understand something available on a digital platform and something they may not even have the power to ask for a repeat in case they misheard. the problem with digital media is mainly the distortion that comes with it. If it is too loud it becomes illegible to understand if it's too soft it is not loud enough to understand and the middle ground isn't much of a help more often than not. Aside from videos hearing impaired patients also find it difficult to perform most of their daily life activities like attending a class etc.

So what solution do we have that is capable of solving most of the above problems. It can be observed that the community has gone about finding different ways to solve their problems. Sign language translators, lip reading etc. They are all convenient methods of getting by but the problem with them is as good as they are they are way too situational. A more reliable method would be that of closed captions. Note that the art of captions is one that already exists and is made mandatory by governments to make such resources available on request and in general people are very receptive towards these technologies and often go out of their way to enable them. For students perhaps the most common use of captions is the CART(Communication Access Real Time) systems, where an individual types a captioning of what the teacher is saying and the students view this in real time there will always be a delay of a few microseconds but it is still extremely useful [19] . In

the case of tv, most channels already have implemented a subtitle system. Pre-recorded shows already have subtitles generated in advance and they are displayed. In case of live settings, the same text from the teleprompter is used as a subtitle or a cart like a system is used where a person types in the text being spoken and it is displayed a few seconds later.In the case of online videos, most content providers have provided the option of loading the subtitle file. The problem now lies in generating/obtaining the subtitle files. Good Samaritans always exist and for important videos more often than not the uploader or someone else will generate their own subtitles. The society is slowly recognizing the need for subtitles and in general, you will find the subtitles of the files you are looking for if you look hard enough. There also exist professional agencies who will create subtitles either for free or for a price, though in general, the free ones are already hard at work. The issue at hand today is generating good quality subtitles and fast. The traditional method of generating subtitles by having a person listen and then type the subtitles is fine but it is too slow and cumbersome. It would be faster to have a computer generate the subtitles and have a human change/modify errors. Youtube has its own automatic subtitle generation, Facebook too is developing a similar feature on the same lines. Watson IBM have developed an API that leverages the power of Watsons AI to generate subtitles.

*3.1.1 Manual caption generation.* Manual caption generation as previously stated is a very tedious job it involves a person listening to the audio and then accordingly typing out the captions and storing them for later use. Big data can play a significant role in making thing easier for both the generator and the consumer. First lets deal with the generator. In terms of manual caption generation, there is not much that can be done to aid the person unless he switches to an automatic caption generation system. A few simple steps, however, can make his/her life much simpler. Using big data the video could be analysed for segments which have very common phrases / repeated segments and then these segments could be stored using map reduce. the next could be using map reduce find if there were translations available previously and generate the captions or store it till the user enters the caption. There are multiple benefits of such a method, perhaps the most important benefit would be it serves as an error detection mechanism improving the subtitle accuracy. Another benefit is it serves as a great training tool for supervised and semi-supervised learning algorithms. For the consumers, the biggest problem is finding subtitles. Using Apache Hadoop etc we can create an API that acts as a centralized database. However, this is an initiative that should be encouraged by the government. This is a problem that affects all citizens and having the government take care of it adds responsibility and accountability.

*3.1.2 Automatic caption generation.* Automatic caption generation has made huge strides in the recent years thanks to the development in the field of AI, semantic web, statistical models etc. In the case of automatic caption generation, the process is amazingly straightforward. First, you select the video for which you want to generate. then you upload/send the data to the respective API. The API then generates the captions you need which you can then embed into the video or load into the video.The favourite method seems to be that of youtube API which gives a very high accuracy rating of around 94%. [18] . Aside from youtube, there exists IBM

Watson which boasts of one of the most powerful deep learning features [22]. It should be noted that the youtube method is not exactly real-time sure it can work in real time with a delay of a few seconds but it requires the video to be clipped and sent at regular intervals in order for it to be real time to return a caption response with a slight delay. That being said it doesn't mean that youtube cannot do it in real time its a feature that has not been made available to the public yet, to clarify the speech to text conversion happens at a real-time rate it is just the communication between sender and server that will take some time. Youtube API much like Watson makes use of powerful and complex deep learning neural networks. While the exact process has not been made to the public quite understandably so the general concept will be explained along with an additional Hidden Markov model method.

**3.1.3 Automatic caption generation markov model.** First, we shall explain a simple and relatively straightforward hidden Markov model a simple but powerful AI algorithm. A formal definition from Wikipedia that helps in understanding the concept of Markov models is given as " In simpler Markov models (like a Markov chain), the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters, while in the hidden Markov model, the state is not directly visible, but the output, dependent on the state, is visible. Each state has a probability distribution over the possible output tokens. Therefore, the sequence of tokens generated by an HMM gives some information about the sequence of states. The adjective hidden refers to the state sequence through which the model passes, not to the parameters of the model; the model is still referred to as a hidden Markov model even if these parameters are known exactly." [20]. A markov model looks like this figure 4

[Figure 4 about here.]

The thought process that follows the following explanation is that of a semi-supervised learning. The training data will compose of just words(audio) with their respective speech tag. Also, the training data will comprise a good set of perfectly captioned videos. More than the videos it is the caption files that are important. The individual words file merely provide us with a corpus file of what words to expect. it is the caption files however that allow us to build the Markov model around which the entire caption generation process will be built upon. Now that we have our corpus file we can begin analysis on the caption file to build the model. What we will be doing is using a very simple probabilistic equation[20], The probability of observing a sequence  $Y = y(0), y(1), \dots, y(L-1)$  of length of  $L$  is given by,

$$P(Y) = \sum_X \frac{P(Y/X)}{P(X)}$$

. To explain this in a more understandable manner we are looking for relationships between words. For example, when a person is introducing themselves a common sentence is "Hello my name is xyz" or "hello I am xyz". Another assumption we will have to make at this point at least with respect to the current Markov method is that we will work with more complete words that span at least 3 or more syllables so that the model can detect them better. With that, the previous sentences become "hello name xyz" and "hello

xyz", from this reduction we can now get a new relationship, two of them in fact. the word hello leads to the follow up of the word name and this leads to the follow up of xyz whatever and hello leads to xyz. Now this relationship will be remembered. Now we can also make use of this concept but towards sentences. First, we will have to determine via some statistical method what would be the best average length [ time duration] for sentences. Now we can use the previous principle to observe if there exist any relationship between sentences and remember them. Now we get on to processing the data to generate the captions. First, we have to eliminate noise from the audio. Then we need to split it into n appropriate sections [ n = total length of video/time of average sentence calculated previously]. Now using MapReduce we can quickly determine how many segments already have a translation [ ie find if there are any perfect/reasonable matches] and obtain the captions for those. If there are none available then we go to the next stage of getting captions word by word. After converting it to a data format appropriately [ this has been discussed this previously in the hearing aid section, another alternative manner will be discussed shortly]. Now we determine the first word, again using map reduce we can match the word to a list of probable similar sounding words. To obtain the actual word the magic of probability comes into play. remember the Markov model we had discussed earlier, from it we can calculate the probabilities of a word occurring as the first word and accordingly make a very educated guess on which word is the right word. Following that using the Markov model once we can determine what the next word could be after first narrowing down the suspects we can use the model to infer what the next word could be. that is, given the current word what is the probability that the next word will be the selected word.

This way we go about generating captions for every word in the sentence. After this is done for all sentences we can generate a caption file for the entire duration of the video. This method is likely to have a lot of errors since the Markov model described here is rather simplistic therefore the onus will have to be on the administrator to go over the captions generated and accordingly make the corrections. This will not only be useful to the people with disabilities but also help improve the accuracy of the system on the whole. Studies have been carried out and more complex implementation of the same idea has been performed with a rather high accuracy rate can be found here [6].

**3.1.4 Automatic caption generation Deep neural network model.** Now the concept of a neural network will be explained. A neural network is based on the on the same idea of how our brains work [21] . A collection of neurons for information processing and to model the world around us. A very brief explanation would be a neuron sums all the inputs and if the resulting value is higher than a specified threshold it fires. A neural net can be represented as the following figure 5.

[Figure 5 about here.]

The above configuration is called a perceptron. It has  $n$  inputs and  $n$  weights are real numbers and can be positive or negative. The perceptron consists of weights, summation processor and an activation function. the inputs are multiplied by the individual weights and the summation of all of these is passed to an activation function,

we will make use of a step activation function which fires 1 if above the threshold a 0 otherwise[21]. We need to train the perceptron now. This essentially means modifying weights after observing the inputs such that the activation function fires correctly. For all inputs,  $i$ ,  $W(i) = W(i) + a^*(T-A)^*P(i)$ , where  $a$  is the learning rate, here,  $W$  is the weight vector.  $P$  is the input vector.  $T$  is the correct output that the perceptron should have known and  $A$  is the output given by the perceptron [21]. When an entire pass through all of the input training vectors is completed without an error, the perceptron has learnt. A deep neural network is thus a collection of perceptrons or to be more accurate it is a multiple layered architectures which compromises of an input and output layer and in between them multiple hidden layers [15].[multilayer network image] From the image we can observe Each input from the input layer is fed up to each node in the hidden layer, and from there to each node on the output layer. We should note that there can be any number of nodes per layer and there are usually multiple hidden layers to pass through before ultimately reaching the output layer. But to prepare this we require a learning calculation which ought to be able to tune not as it were the weights between the output layer and the hidden layer but moreover the weights between the hidden layer and the input layer. Clearly, it becomes obvious that we will need to tune the inputs between the input layer and hidden layer for this we shall make use of a technique called backpropagation which essentially means we carry the error to the next stage of input and then use these errors to modify the input stage of every layer. To be brief we can summarize it as follows We present a training sample to the neural network (initialised with random weights). Compute the output received by calculating activations of each layer and thus calculate the error. Having calculated the error, we readjust the weights (according to the above-mentioned equations) such that the error decreases. We continue the process for all training samples several times until the weights are not changing too much [7].

Now that we have a good understanding of how neural networks work we shall look into how ASR happens via neural networks [5]. We shall go about this step by step. The first problem will be converting sound to bits. We have previously seen digital hearing aids automatically convert sound waves into numerical codes and have extended this concept in multiple places. We shall now go into this a little more in detail and provide an insight into how this could happen. Consider the below wave of sound 6.

[Figure 6 about here.]

This can be represented on a graph as a simple expression of height vs time. The annotations towards height can be amplitude, frequency whatever a person chooses that suits their purpose best. However, note that this is a bit too scattered and not very uniform which is understandable because over digital media the voice can break. Let us attempt to smooth this signal using one of the many transformation algorithms available[ Nyquist theorem for example]. The result will look like this 7.

[Figure 7 about here.]

Recall it was mentioned that we can simply take the graph as a function of height vs time, so to help visualize this consider the 8.

[Figure 8 about here.]

To represent this in a text format it would look like [ 100,-20,30,89,789,-400,...,345] where each value is a measure of height over a designated unit of time. We need to be careful about how we select this unit of time. The idea is that different syllables have a different pitch we want to exploit that [4] . Hence we want to select a unit of time such that each unit possibly corresponds to one letter. The figure 9.

[Figure 9 about here.]

gives an insight into how the overall model should look. So after we have trained the network to recognize each letter based on value/set of values we proceed with feeding the current input stream and thereby obtaining each letter. We can then pair these letters to form a word. Note that there is a high chance that many letters could be repeated, decisions must be made based on observations if we need to replace repetitions. Once we have obtained these words there is a possibility of spelling errors using an auto-correct program [there are many good algorithms available on the internet] we can then use the Markov model we previously explored to verify its correctness [ if the word generated fits the model observed]. To save some time we could use map-reduce again to find out if similar patterns exist before and then use it accordingly to determine if there were similar instances before.

*3.1.5 Using Image Processing to generate captions.* It is well known how powerful OCR is it can convert text images into a text file by "reading". What if we could apply a similar concept when people are speaking. People who have hearing disabilities especially those who have severe hearing disabilities and cannot always make use of sign language to get by make use of lip reading. Lip reading has existed for a long time and there is no particular skill or technique about it. People familiarize themselves with the movements of the lips with respect to different sounds and then make use of that pattern. We will not go too deep into the specifics of how to process features and use them to recognise these patterns, we have already exhaustively covered neural networks and Markov models in great detail. Depending on how the features were extracted and stored learning can occur. We shall instead focus on the process of obtaining the images for processing the features. Since we are going to be focusing on extracting the facial features we need a device that can focus on the face. Two devices that could be used are the smartphones and perhaps a not so popular option in google glass. Both devices have powerful cameras with which pictures can be taken. Note that captions generated will be with some delay. Converting these devices into IoT devices shouldn't be particularly hard. Using map reduce we can effectively store these images and in a quick manner, to save data however we could probably convert the image into an rgb matrix text file and send. Map reduce plays a very very important role here, rather than sending the same image again and again if a mapping is found to exist already we can make use of it. To extract features OpenCV has a great library that could aid in the feature extraction making use of these features for processing depends on the implementation. Note that big data here if a good bunch of people are observing the same thing, like for example watching a news broadcast, seminar etc. We can use a combination of big data and IOT to determine these similar users and make one person the central hub, he/she will process while the results are shared between all or alternatively each person can

send sections at regular intervals to reduce the processing time. For example, if 4 persons are detected person each person can do 10 seconds order depending on implementation this should help keep the process more real time. Note that however, this would be very situational but in situations where transcripts are not made available and the environment is way too noisy for a speech to text caption system to be implemented this comes very handy. While we are on the topic of using these devices as IoT a future possible implementation, especially for smart TVs, would be to do detect such devices and send the subtitles to the device. Too many times if watching from a distance subtitles from a distance a person am not be able to read them having it sent n the device would mean the person can see the tv and read comfortably especially in the case of google glass.

*3.1.6 Captions for the blind and deaf.* It has been covered in detail how we can go about to help those who are hard of hearing. But there are many people who are both deaf and blind. It is appropriate that we consider the difficulties these people face too and think of a possible solution. All considered one of the most important thing blind and deaf people would need is a braille machine ( provided they know braille). There exists technologies that create Braille on the fly and are IoT supported. Combining all of the previous discussed technologies with this wont be particularly hard the only note able difference is instead of outputting captions they need to be converted to a braille format instead.

### 3.2 Data Processing and Technologies

Data processing has been covered in advance very well in the previous sections. For those who are unable to build a custom neural network or are struggling to implement it can make use of the Watson API. Watson was created as a question answering (QA) computing system that IBM built to apply advanced natural language processing, information retrieval, knowledge representation, automated reasoning, and machine learning technologies to the field of open domain question answering. When created, IBM stated that, "more than 100 different techniques are used to analyze natural language, identify sources, find and generate hypotheses, find and score evidence, and merge and rank hypotheses." In recent years, the Watson capabilities have been extended and the way in which Watson works has been changed to take advantage of new deployment models (Watson on IBM Cloud) and evolved machine learning capabilities and optimized hardware available to developers and researchers. It is no longer purely a question answering (QA) computing system designed from Q&A pairs but can now 'see', 'hear', 'read', 'talk', 'taste', 'understand', 'reason', 'interpret', 'learn' and 'recommend' [22]. This article [8] provides a very good explanation on how to use the watson API to generate captions.

### 3.3 Section conclusion

Captions are a very important methods of understanding conversations and proceedings. with advancements being made it AI the challenge is now geared towards generating captions with 100% accuracy. Players both big and small are starting to take up the process of caption generation more seriously. Aside from helping people who are hard of hearing caption generation is important because of its other uses , it can overcome the language barrier and

become a very powerful tools for envoys possibly removing the need for interpreters. There should be more funding and activity from the government over this issue. Getting captions most of the time is not easy and the current guidelines are reactive rather than proactive. Technologies exist , personnel exist , motivation for doing such helpful work is at an all time high all that is needed is a little push. On the technical front as mentioned all the big tech giants are actively focusing on AI but they all are looking at the bigger picture. AI to perform tasks on the whole. there is always a chance for smaller corps to pick up small important pieces of detail that could really make a difference. for example, the google glass project has not really made much progress and caption generation is not their priority. However, companies exist who have made facial expressions to captions a reality on devices like smart phones. Someone could put two and two together and make a device that costs lesser than a hearing but delivers the same impact.

## 4 BIG DATA AND NOISE POLLUTION

### 4.1 Introduction

Every day, we experience sounds in our environment, such as the sounds from television and radio, household appliances, and traffic. Normally, these sounds are at safe levels that donfit damage our hearing. But sounds can be harmful when they are too loud, even for a brief time, or when they are both loud and long-lasting. These sounds can damage sensitive structures in the inner ear and cause noise-induced hearing loss (NIHL).NIHL can be immediate or it can take a long time to be noticeable [10] . It can be temporary or permanent, and it can affect one ear or both ears. Based on a 2011-2012 CDC study involving hearing tests and interviews with participants, at least 10 million adults (6 percent) in the U.S. under age 70fi!and perhaps as many as 40 million adults (24 percent)fi!have features of their hearing test that suggest hearing loss in one or both ears from exposure to loud noise [10].Loud noises like explosions, repeated exposure to loud music for extended periods of time are few of the factors that lead to NIHL.Sound is measured in units called decibels. Sounds of less than 75 decibels, even after long exposure, are unlikely to cause hearing loss. However, long or repeated exposure to sounds at or above 85 decibels can cause hearing loss. The louder the sound, the shorter the amount of time it takes for NIHL to happen.

### 4.2 Big data and how to tackle noise pollution

So far a very reactive approach was taken towards tackling hearing loss and while they all are good approaches as the saying goes prevention is better than cure.Now we shall take a look at how integrating big data with the IoT devices we have at hand can go towards helping us curb NIHL. The device is none other than the mobile phone. The mobile phone is one of the pinnacle devices that leads the IoT trend. The fact it has the high processing power and can access the internet almost anytime allow for many desirable solutions. So how do we go about tackling this problem, quite straightforwardly it is a good practice to avoid sources of loud sounds. How can we do this, two ways one we can proactively scourge the internet and google maps for situations like traffic, construction sites and other such noise pollutants and then analysing these chart routes to avoid them. This works well only if we have

such data available via maps, internet. The other way is to use the same implementation of the previous but rather than depending on internet and maps have people update this information via an API. One more possible implementation is to use the speakers on the phone and use it as a sensor and then use GPS data to accordingly update information. If the majority of the public agrees to this then the amount of data will be humongous and definitely big data technologies like Hadoop, pig, hive will be required to store efficiently but this method will have loads of data charges and will be a drain on the battery life. It could help if governments could fund for specific IoT devices that listen to crucial junctions like signals that the government and or public could use. This way the governments could have a portal maintained by them that actually suggests places of high noise pollutions. The added benefit to this is that the government can monitor round the clock violators of noise pollution and can proactively set out to catch these offenders. While the above may/may not be implemented yet one way we can protect ourselves is by using ear plugs, But the most common complaint would then be that of boredom and discomfort. Most head and earphone companies these days make use of excellent noise cancellation technology. We can use big data and mobile phones to play music that is at the opposite frequency of the sound to cancel out such unwarranted noise. Aside from external noise we now must consider how harmful is the music we listen to. Music has evolved the music of these days have evolved from peaceful melodies to high-intensity powerful tunes. More often than not we get lost in the euphoria of these tunes and subconsciously increase the volume to maximize the effect of this rush. Using big data we can control these habits via big data we can dynamically analyse which songs are most likely to cause such situations by looking at the loudness distribution of the music and then collectively comparing the instances when other people suddenly increase their volumes. note that no one can dictate a person what to do unless they have explicitly given permission settings to do so. What we can do is whenever a person suddenly increases the volume that way past a safe threshold we can display warning messages that will alert the user that he/she is at risk of damaging their eardrums.

### 4.3 Section Conclusion

There are many unique possible solutions to counter the problem of NIHL. Ultimately both the government and its people need to be proactive and neither should wait for the other to make the first move. Governments need to start creating more awareness about the effects of NIHL and need to start funding research into tracking NIHL digitally if they do not have the required personnel to track manually. With everything going digital ultimately this implementation will have to happen somewhere down the line. However the sooner they get a start to it the sooner this problem can be curbed. people too can be proactive about this and try to keep their environment as sound friendly as possible. noise cancellation technology at the minute is rather limited towards to just ear and headphones but if the current noise pollution level trends continue it wont be long before we look at buildings being built with a mandatory soundproofing scheme.

## 5 BIG DATA AND HEARING LOSS, MEDICAL

### 5.1 Introduction

Hearing loss can occur due to a myriad of medical reasons from colds to trauma to accidents. While a lot of these don't have facets where we can apply big data to reduce the probability of hearing loss occurring Big data can help in identifying the early symptoms of these problems and suggest preventive actions. The first-way and most hearing loss can occur due to medical reasons is that of the common cold. When we contradict a common cold the ear nose and throat being interconnected the infection spreads everywhere. this infection causes a buildup of fluid in the middle ear, making it difficult for sounds to travel efficiently from the outer ear to the eardrum. Individuals may notice a clicking sound in their ear or that conversations and noises are muffled. The congestion may also lead to an ear infection, caused by bacteria or a virus in the middle ear, and lead to temporary hearing loss [19]. The other factor that leads to hearing loss is the disease meningitis. Meningitis is an inflammation of the membranes (meninges) surrounding your brain and spinal cord. The swelling from meningitis typically triggers symptoms such as a headache, fever and a stiff neck [9]. Studies have shown how dangerous meningitis in particular bacterial meningitis is towards causing hearing loss [9].The cause for the hearing loss enters the realm of biology, but the article [16] states that meningitis leads to lesions developed in the meninges layer and causes neurological damage. The next cause of hearing loss we shall look at is that caused due to trauma to the head due to accidents.

### 5.2 Applying Big data

It should be noted that leading a healthy lifestyle to prevent illness is an onus that should remain on the person, There are very detailed national registries that provide checklists of which vaccines to take and when. The prerogative thus remains on the person to be healthy and vaccinated. That being said using big data and IoT one can track their everyday activities and then use these details to compare it to a centralized plan and modify their activities. plenty of such apps exist but they are not entirely smart as they require manual input but are a good start. Improvements in terms of implementations of IoT devices to track such changes would be very useful. We can make use of these features to lead a healthier lifestyle and build more robust immune systems a natural way. Aside from this we also would be able to track any sudden changes in our health, if we suddenly show symptoms of a cold etc the change in regular pattern would be detected, a cold could lead to body temperature to increase , lethargy, etc these changes could be compared to people with similar fluctuations and then a plan for corrective action could be suggested this is very much like looking up your symptoms online through a portal like WebMD only that you now have data to back it up. Also, this data could be very vital to when you visit a doctor as a doctor could analyse these logs and they could provide a more detailed information than the normal guesswork of replies the doctor would normally receive. A lot of research has been done in detecting diseases like meningitis using big data however this enters the realm of biology and is another paper in its own right. We instead shall focus on analysing MRI images to detect anomalies that could be caused by diseases like meningitis. Note that we

would be able to just detect anomalies but there is a high chance these anomalies could be just noise. The purpose of using big data is to minimize the risk of being misdiagnosed as treatments for meningitis could cause more harm if misdiagnosed. Ultimately it is safer to get a second opinion and treat the analysis provided by the big data with a pinch of salt.

Safety of an individual ultimately lies in their own hands, discounting factors such as bad luck and freak accidents things that cannot be controlled. Also, note there is nothing much that can be done in the event of an accident occurring other can call paramedics, it more risky to make the situation worse by performing actions that could be detrimental to the situation it is best to remain calm and wait for help and follow very basic first aid practices. That being said big data can be sued to help the respective authorities reach and react faster to accidents and lessen the damage trauma can cause. IoT devices installed in accident prone/ busy zones can be trained to detect crashes. When a crash occurs it can be used to notify the nearest hospital with enough available resources. So we are looking at an implementation of having data of all hospitals in a region and their available resources by this we mean available ambulances ready for use and perhaps logistics like available trauma specialists and the like, this way people in distress won't have to wait too long for medical attention and everyone is covered better. Aside from separate IoT devices personal devices like mobile phones, wrist health meters can be trained to detect sudden changes in the body like falling blood pressure, etc and alert the user if the user doesn't respond then the device alerts the nearest hospital. A specialist in the hospital can monitor these details to decide if this is due to negligence or a person is actually in distress.

### 5.3 Section Conclusion

Big data has a lot of applications in the field of medicine, but the motivation to stay healthy should come from the persons themselves. There is a lot of research happening in the field of medicine to make the process of getting a diagnosis at least a lot cheaper than the current rates. But these diagnoses always should be taken with a pinch of salt. most programs only look at what is in front of them and may not be able to determine relationships between different diseases, they may however at least bring to attention potential anomalies which may have been missed and suggest a second opinion may be a good idea. In terms of hearing loss and medical big data cannot yet play a big part, once more co-relations have been made between data and meningitis detection it will have to be limited towards potential MRI detection, but by no means is this a small feat MRI is very costly and big data may reduce the need to undergo multiple MRIs as it could help it confirming the presence of anomalies or rule them out altogether. The same can be said of trauma prevention. Big data can be merely sued to make sure help is received sooner. It can be used as a preventive measure to make sure people don't use accident-prone routes etc.

## 6 CONCLUSION

Hearing loss is a problem and once upon a time it could be considered creating a liability on the society, however, the application of big data and emerging technologies could help turn this liability

into something positive. It certainly is creating a lot of job opportunities for one. there are multiple new startups created to develop on facets like speech to text conversion via a mobile phone, big players are trying to reach overall 100% accuracy. people affected by hearing disabilities now find themselves with much more options than before and also have opportunities to contribute and be a part of something big. Another positive is that the application of big data is providing a paradigm shift and is now creating more new kinds of hearing aids each of which incorporates more and more powerful features. it may not be too soon before this hearing aids down the line become new "smart earphones". Caption generation has a huge potential market too but it is only the big players who are making significant headlines. The race for 100% is wide open and anyone stands a chance to make a name for themselves. The current set of government policies and funding are more that of a reactive than proactive approach changes can help drive research and also create new jobs to make resources available everywhere for anyone to use. Big data has a lot of applications in healthcare which is constantly evolving there will always be new avenues to apply big data, it is, however, a risky move because any misdiagnosis or wrong suggestion could lead to fatalities which could lead to lawsuits. The benefits, however, outweigh the risks and most patients are smart enough to know that predictions from a computer are to be used as a reference and not the rule.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor von Laszewski for his support and suggestions to write this paper.

## REFERENCES

- [1] AG Bell Academy. 2017. causes of hearing loss. *ag bell* 1, 1 (Dec. 2017), 1. <http://www.agbell.org/learn/hearing-loss-explained/causes-of-hearing-loss.aspx>
- [2] J Am Acad Audiol. 2017. Hearing Aid Use and Mild Hearing Impairment: Learnings from Big Data. *jaaa* 1, 1 (Sept. 2017), 1. <https://www.ncbi.nlm.nih.gov/pubmed/28906244>
- [3] I-Hsin Chung. 2017. Parallel Deep Neural Network Training for Big Data on Blue Gene/Q. *jaaa* 1, 1 (Dec. 2017), 1. <http://ieeexplore.ieee.org/document/7013048/?reload=true>
- [4] Adam geitgey. 2017. Machine Learning is Fun Part 6: How to do Speech Recognition with Deep Learning. *medium* 1, 1 (Dec. 2017), 1. <https://medium.com/@ageitgey/machine-learning-is-fun-part-6-how-to-do-speech-recognition-with-deep-learning-28293c162f7a>
- [5] Phil Green. 1999. Robust automatic Speech Recognition with missing and unreliable data. *unknown* 1, 1 (Dec. 1999), 1. <https://labrosa.ee.columbia.edu/Montreal2003/abstracts/cooke2001a.pdf>
- [6] Dilek Hakkani-Tur. 2017. ACTIVE LEARNING FOR AUTOMATIC SPEECH RECOGNITION. *AT&T Labs-Research* 1, 1 (Dec. 2017), 1. [https://www.researchgate.net/profile/Dilek\\_Hakkani-Tur/publication/2935348\\_Active\\_Learning\\_For\\_Automatic\\_Speech\\_Recognition/links/02e7e5171c9ee8820c000000.pdf](https://www.researchgate.net/profile/Dilek_Hakkani-Tur/publication/2935348_Active_Learning_For_Automatic_Speech_Recognition/links/02e7e5171c9ee8820c000000.pdf)
- [7] harsh Pokarna. 2017. neural net images. *jaa* 1, 1 (Dec. 2017), 1. <https://medium.com/technologymadeeasy/for-dummies-the-introduction-to-neural-networks-we-all-need-c50f6012d5eb>
- [8] Adam Massachi. 2017. Closed Captioning Provided by fi Watson! *medium* 1, 1 (Dec. 2017), 1. <https://medium.com/ibm-data-science-experience/closed-captioning-provided-by-watson-89c244e3de6>
- [9] mayo clinic. 2017. meningitis. *mayo clinic* 1, 1 (Dec. 2017), 1. <https://www.mayoclinic.org/diseases-conditions/meningitis/symptoms-causes/syc-20350508>
- [10] NIDCD. 2017. noise induced hearing loss. *nidcd* 1, 1 (Dec. 2017), 1. <https://www.nidcd.nih.gov/health/noise-induced-hearing-loss>
- [11] NIHCD. 2017. explanations on hearing aids. *NIHCD* 1, 1 (Dec. 2017), 1. <https://www.nidcd.nih.gov/health/hearing-aids>
- [12] Wikipedia pattern recog. 2017. pattern Recognition. *wikipedia* 1, 1 (Dec. 2017), 1. [https://en.wikipedia.org/wiki/Pattern\\_recognition](https://en.wikipedia.org/wiki/Pattern_recognition)

- [13] peter nordquist. 2017. Quality assurance in health care based on Big Data. *jaaa* 1, 1 (Dec. 2017), 1.
- [14] phonak. 2017. phonak uses big data. *phonak* 1, 1 (Jan. 2017), 1. [https://www.phonakpro.com/content/dam/phonakpro/gc\\_hq/en/resources/evidence/field\\_studies/documents/fsn\\_autosense\\_os\\_big\\_data.pdf](https://www.phonakpro.com/content/dam/phonakpro/gc_hq/en/resources/evidence/field_studies/documents/fsn_autosense_os_big_data.pdf)
- [15] Harsh pokarna. 2017. multiple neural networks explained. *medium* 1, 1 (Dec. 2017), 1. <https://medium.com/technologymadeeasy/for-dummies-the-introduction-to-neural-networks-we-all-need-part-2-1218d5dc043>
- [16] Dr Martin Richardson. 1997. Hearing loss during bacterial meningitis. *BMJ: British Medical Journal* 1, 1 (Dec. 1997), 1. <http://adc.bmjjournals.org/content/76/2/134>
- [17] Bjrn W. Schuller. 2015. Speech Analysis in the Big Data Era. *jaaaaa* 1, 1 (Dec. 2015), 1. [https://link.springer.com/chapter/10.1007/978-3-319-24033-6\\_1](https://link.springer.com/chapter/10.1007/978-3-319-24033-6_1)
- [18] TheDeafCaptioner. 2017. Youtube caption accuracy. *blog* 1, 1 (Dec. 2017), 1. <https://medium.com/@mlockrey/youtube-s-incredible-95-accuracy-rate-on-auto-generated-captions-b059924765d5>
- [19] Wikipedia. 2017. Hearing loss. *wikipedia* 1, 1 (Dec. 2017), 1. [https://en.wikipedia.org/wiki/Hearing\\_loss#Causes](https://en.wikipedia.org/wiki/Hearing_loss#Causes)
- [20] Wikipedia. 2017. markov model. 11, 1 (Dec. 2017), 1. [https://en.wikipedia.org/wiki/Hidden\\_Markov\\_model](https://en.wikipedia.org/wiki/Hidden_Markov_model)
- [21] wikipedia. 2017. neural nets exolanation. *wiki* 1, 1 (Dec. 2017), 1. [https://en.wikipedia.org/wiki/Artificial\\_neural\\_network](https://en.wikipedia.org/wiki/Artificial_neural_network)
- [22] Wikipedia. 2017. About Watson IBM. *wikipedia* 1, 1 (Dec. 2017), 1. [https://en.wikipedia.org/wiki/Watson\\_\(computer\)](https://en.wikipedia.org/wiki/Watson_(computer))

#### LIST OF FIGURES

1	parts of hearing aid	12
2	types of hearing aids	13
3	audiometry graph	14
4	markov model	14
5	neuralnetwork image	15
6	soundwave	15
7	smooth wave	15
8	sampled wave	16
9	overall neural net model	16

1. Microphone
2. Microchip
3. Amplifier
4. Battery
5. Receiver



Figure 1: parts of hearing aid



Figure 2: types of hearing aids

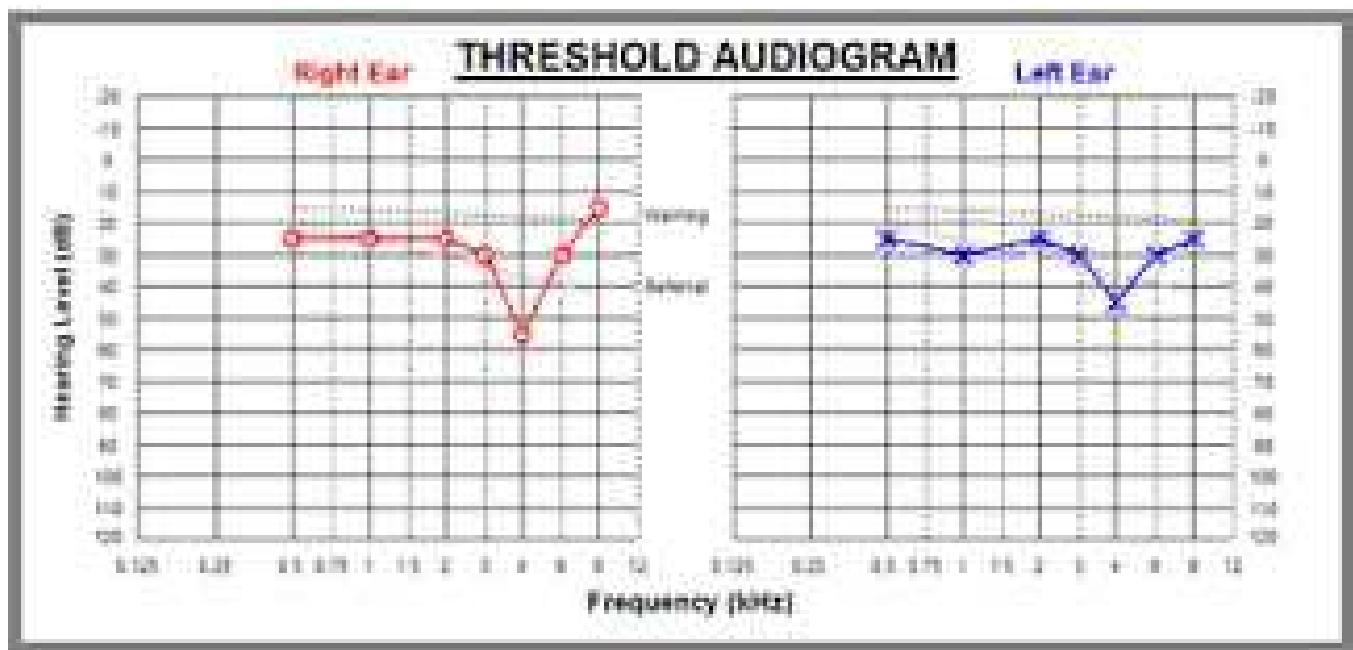


Figure 3: audiometry graph

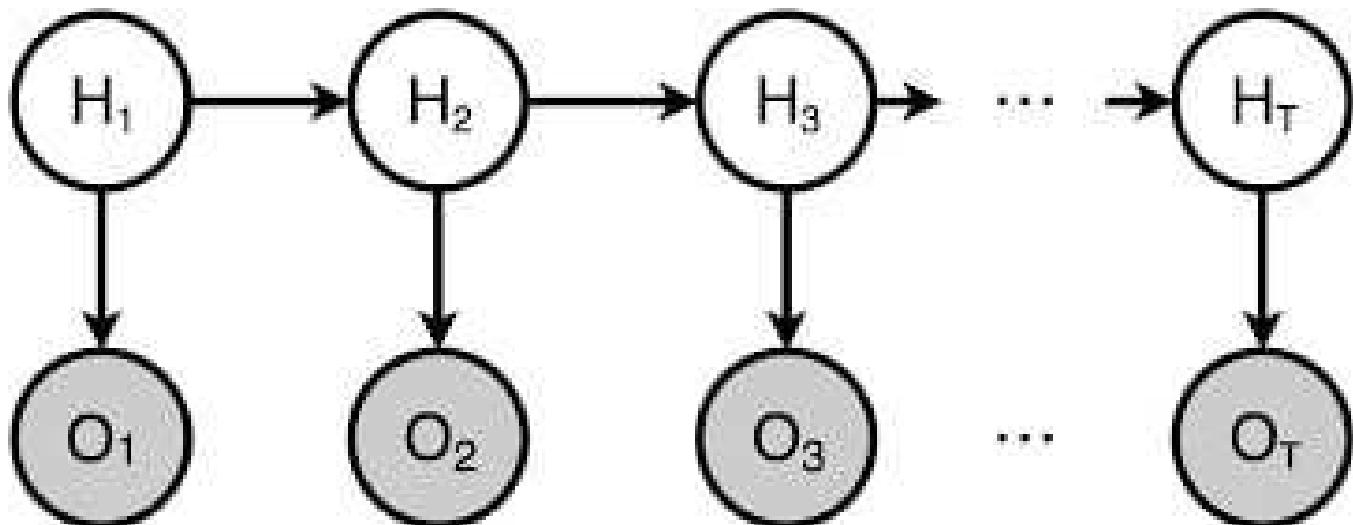
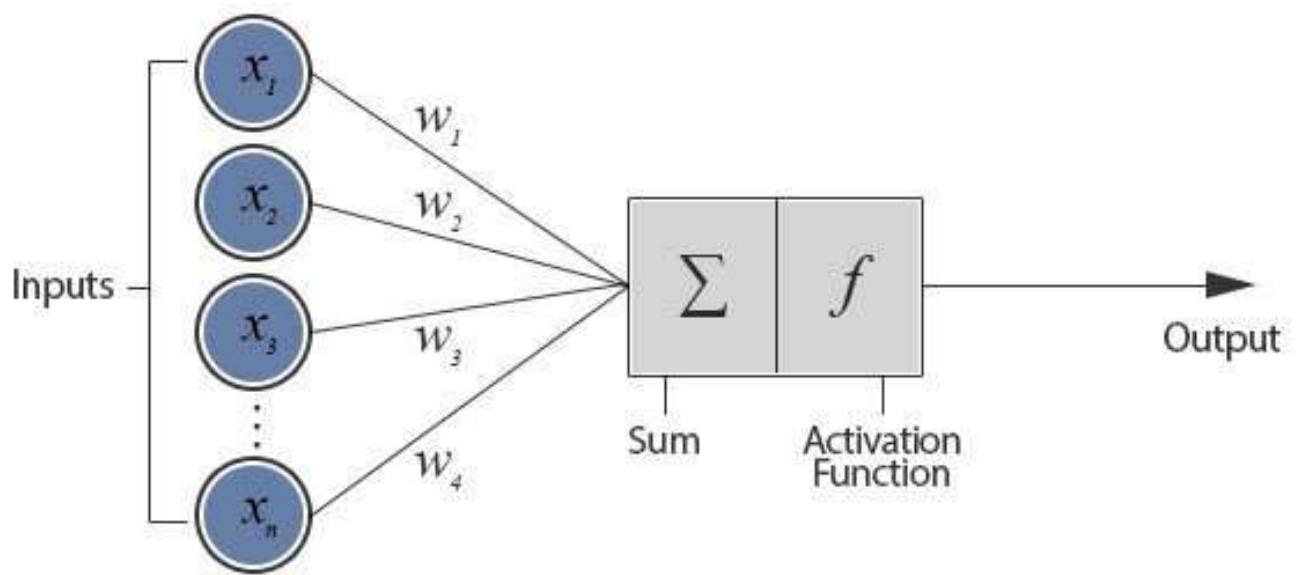
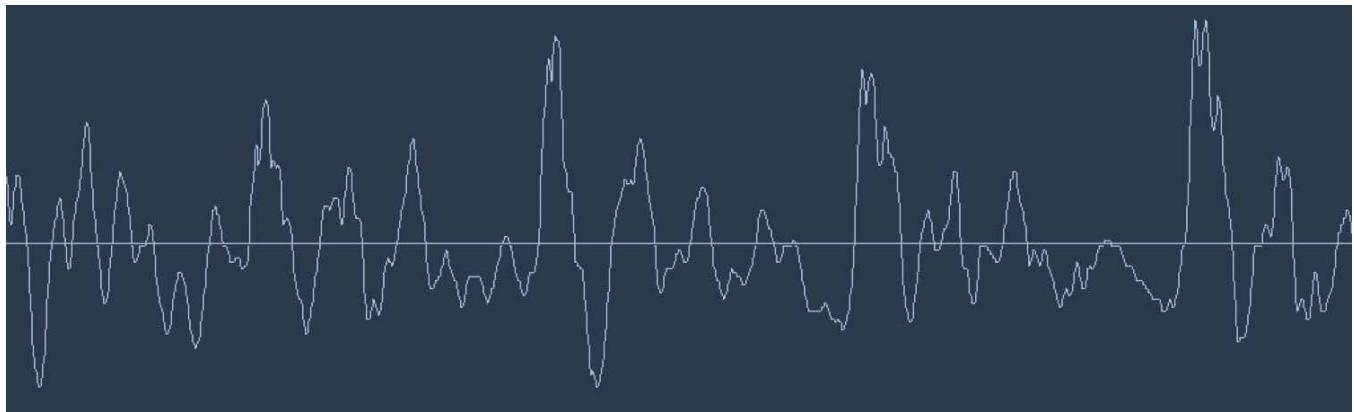


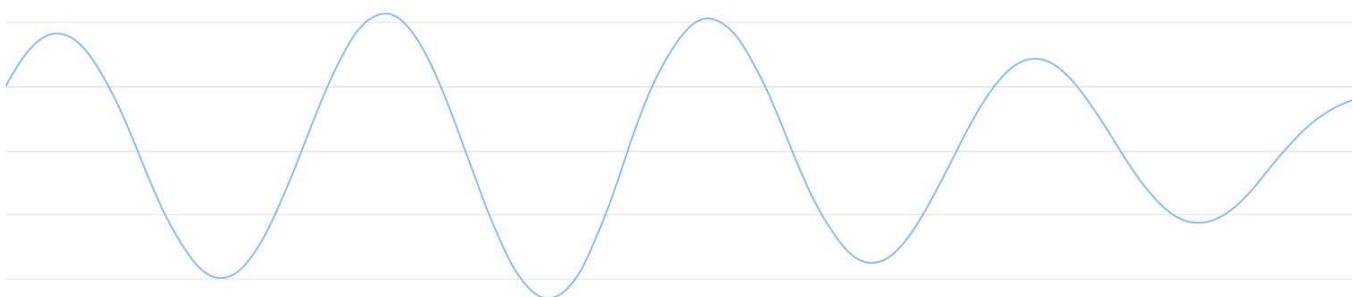
Figure 4: markov model



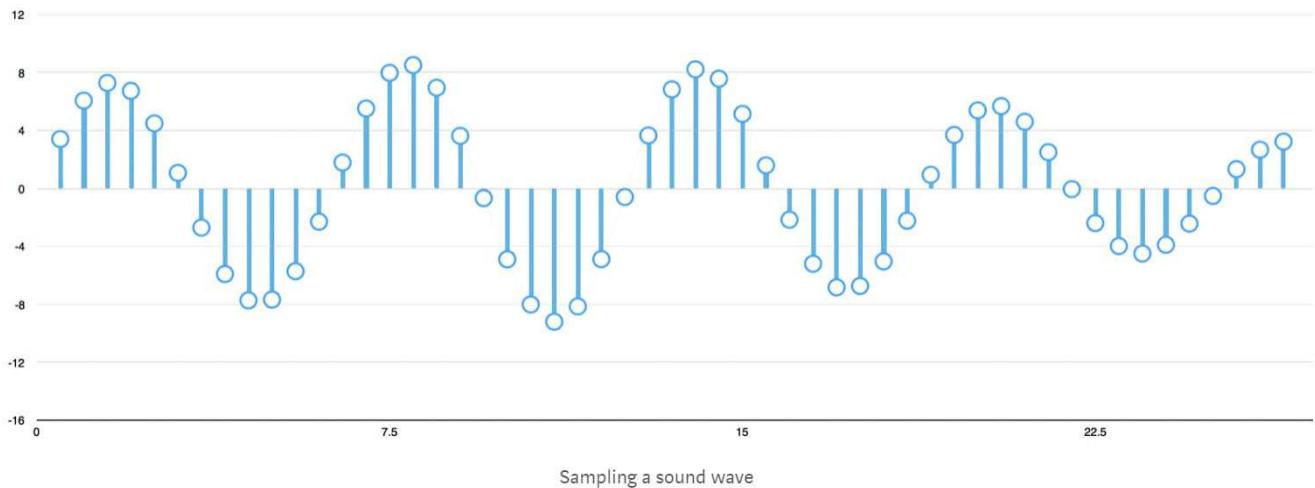
**Figure 5: neuralnetwork image**



**Figure 6: soundwave**



**Figure 7: smooth wave**

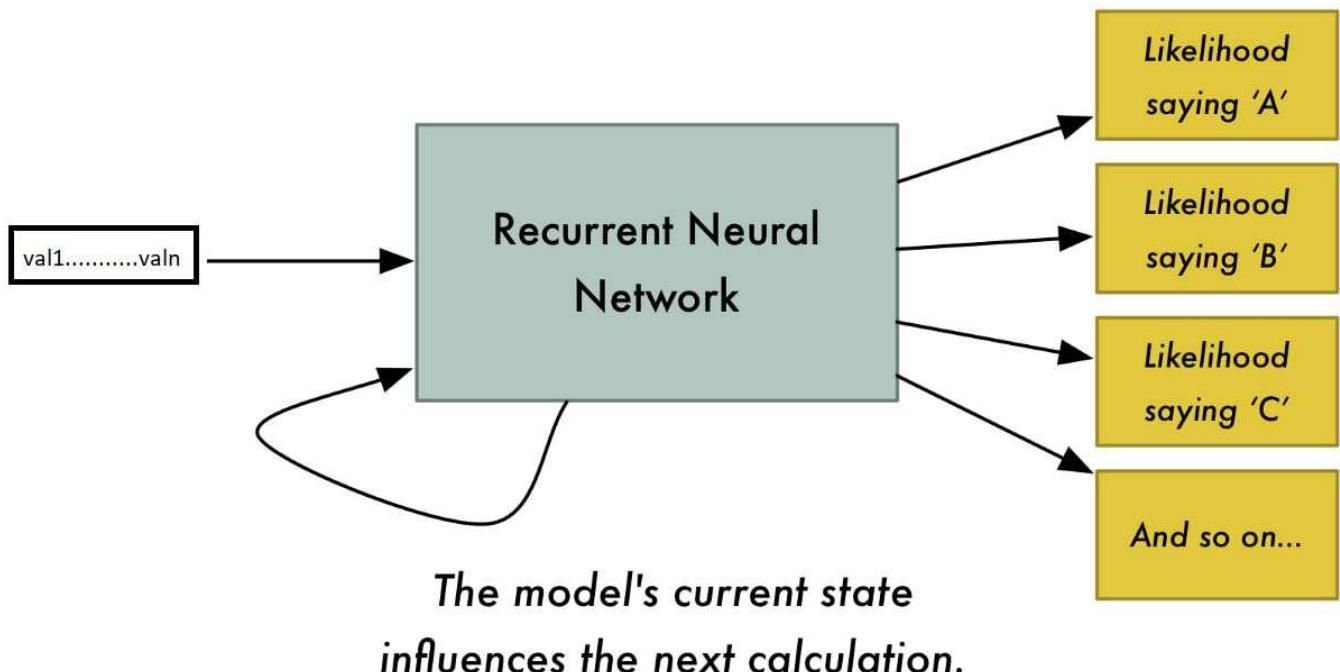


**Figure 8:** sampled wave

**Input**

**Stateful Model**

**Output**



**Figure 9:** overall neural net model

## bibtex report

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

bibtext \_ label error

bibtext space label error

bibtext comma label error

# latex report

[2017-12-12 19.59.29] pdflatex report.tex

The anchor of a bookmark and its parent's must not be the same. Added a new anchor.  
Typesetting of "report.tex" completed in 1.2s.

---

## Compliance Report

---

```
name: Rahul Velayutham
hid: 232
paper1: 2017-10-29 100%
paper2: 100%
project: 100%
```

```
yamlcheck
```

---

```
wordcount
```

---

```
16
wc 232 project 16 10125 report.tex
wc 232 project 16 10177 report.pdf
wc 232 project 16 940 report.bib
```

```
find "
```

---

89: Pattern recognition is a branch of machine learning that focuses on the recognition of patterns and regularities in data. Pattern recognition systems are in many cases trained from labelled "training" data (supervised learning), but when no labelled data are available other algorithms can be used to discover previously unknown patterns (unsupervised learning). In machine learning, pattern recognition is the assignment of a label to a given input value. An example of pattern recognition is classification, which attempts to assign each input value to one of a given set of classes (for example, determine whether a given email is "spam" or "non-spam"). However, pattern recognition is a more general problem that encompasses other types of output as well. Other examples are regression, which assigns a real-valued output to each input; sequence labeling, which assigns a class to each member of a sequence of values (for example, part of speech tagging, which assigns a part of speech to each word in an input sentence); and parsing, which assigns a parse tree to an input

sentence, describing the syntactic structure of the sentence \cite{2017b}.

127: First, we shall explain a simple and relatively straightforward hidden Markov model a simple but powerful AI algorithm. A formal definition from Wikipedia that helps in understanding the concept of Markov models is given as " In simpler Markov models (like a Markov chain), the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters, while in the hidden Markov model, the state is not directly visible, but the output, dependent on the state, is visible. Each state has a probability distribution over the possible output tokens. Therefore, the sequence of tokens generated by an HMM gives some information about the sequence of states. The adjective hidden refers to the state sequence through which the model passes, not to the parameters of the model; the model is still referred to as a hidden Markov model even if these parameters are known exactly." \cite{Wikipedia2017a}. A markov model looks like this figure \ref{f:markov}

133: The thought process that follows the following explanation is that of a semi-supervised learning. The training data will compose of just words(audio) with their respective speech tag. Also, the training data will comprise a good set of perfectly captioned videos. More than the videos it is the caption files that are important. The individual words file merely provide us with a corpus file of what words to expect. it is the caption files however that allow us to build the Markov model around which the entire caption generation process will be built upon. Now that we have our corpus file we can begin analysis on the caption file to build the model. What we will be doing is using a very simple probabilistic equation\cite{Wikipedia2017a}, The probability of observing a sequence  $Y = y(0), y(1), \dots, y(L-1)$  of length of  $L$  is given by, 
$$P(Y) = \prod_{i=1}^{L-1} P(y_i | y(0), y(1), \dots, y(i-1))$$
. To explain this in a more understandable manner we are looking for relationships between words. For example, when a person is introducing themselves a common sentence is "Hello my name is xyz" or "hello I am xyz". Another assumption we will have to make at this point at least with respect to the current Markov method is that we will work with more complete words that span at least 3 or more syllables so that the model can detect them better. With that, the previous sentences become "hello name xyz" and "hello xyz", from this reduction we can now get a new relationship, two of them in fact. the word hello leads to the follow up of the word name and this leads to the follow up of xyz whatever and hello leads to xyz.

Now this relationship will be remembered. Now we can also make use of this concept but towards sentences. First, we will have to determine via some statistical method what would be the best average length [ time duration] for sentences. Now we can use the previous principle to observe if there exist any relationship between sentences and remember them. Now we get on to processing the data to generate the captions. First, we have to eliminate noise from the audio. Then we need to split it into n appropriate sections [  $n = \text{total length of video}/\text{time of average sentence}$  calculated previously]. Now using MapReduce we can quickly determine how many segments already have a translation [ ie find if there are any perfect/reasonable matches] and obtain the captions for those. If there are none available then we go to the next stage of getting captions word by word. After converting it to a data format appropriately [ this has been discussed this previously in the hearing aid section, another alternative manner will be discussed shortly]. Now we determine the first word, again using map reduce we can match the word to a list of probable similar sounding words. To obtain the actual word the magic of probability comes into play. remember the Markov model we had discussed earlier, from it we can calculate the probabilities of a word occurring as the first word and accordingly make a very educated guess on which word is the right word. Following that using the Markov model once we can determine what the next word could be after first narrowing down the suspects we can use the model to infer what the next word could be. that is, given the current word what is the probability that the next word will be the selected word. \newline

- 170: It is well known how powerful OCR is it can convert text images into a text file by "reading". What if we could apply a similar concept when people are speaking. People who have hearing disabilities especially those who have severe hearing disabilities and cannot always make use of sign language to get by make use of lip reading. Lip reading has existed for a long time and there is no particular skill or technique about it. People familiarize themselves with the movements of the lips with respect to different sounds and then make use of that pattern. We will not go too deep into the specifics of how to process features and use them to recognise these patterns, we have already exhaustively covered neural networks and Markov models in great detail. Depending on how the features were extracted and stored learning can occur. We shall instead focus on the process of obtaining the images for processing the features. Since we are going to be focusing on extracting the facial features we need a device that can focus on the face. Two devices that could be used

are the smartphones and perhaps a not so popular option in google glass. Both devices have powerful cameras with which pictures can be taken. Note that captions generated will be with some delay. Converting these devices into IoT devices shouldn't be particularly hard. Using map reduce we can effectively store these images and in a quick manner, to save data however we could probably convert the image into an rgb matrix text file and send. Map reduce plays a very very important role here, rather than sending the same image again and again if a mapping is found to exist already we can make use of it. To extract features OpenCV has a great library that could aid in the feature extraction making use of these features for processing depends on the implementation. Note that big data here if a good bunch of people are observing the same thing, like for example watching a news broadcast, seminar etc. We can use a combination of big data and IOT to determine these similar users and make one person the central hub, he/she will process while the results are shared between all or alternatively each person can send sections at regular intervals to reduce the processing time. For example, if 4 persons are detected person each person can do 10 seconds order depending on implementation this should help keep the process more real time. Note that however, this would be very situational but in situations where transcripts are not made available and the environment is way too noisy for a speech to text caption system to be implemented this comes very handy. While we are on the topic of using these devices as IoT a future possible implementation, especially for smart TVs, would be to do detect such devices and send the subtitles to the device. Too many times if watching from a distance subtitles from a distance a person am not be able to read them having it sent n the device would mean the person can see the tv and read comfortably especially in the case of google glass.

- 177: Data processing has been covered in advance very well in the previous sections. For those who are unable to build a custom neural network or are struggling to implement it can make use of the Watson API. Watson was created as a question answering (QA) computing system that IBM built to apply advanced natural language processing, information retrieval, knowledge representation, automated reasoning, and machine learning technologies to the field of open domain question answering. When created, IBM stated that, "more than 100 different techniques are used to analyze natural language, identify sources, find and generate hypotheses, find and score evidence, and merge and rank hypotheses." In recent years, the Watson capabilities have been extended and the way in which Watson works has been changed to

take advantage of new deployment models (Watson on IBM Cloud) and evolved machine learning capabilities and optimized hardware available to developers and researchers. It is no longer purely a question answering (QA) computing system designed from Q\&A pairs but can now 'see', 'hear', 'read', 'talk', 'taste', 'understand', 'reason', 'interpret', 'learn' and 'recommend'  
\cite{Wikipedia2017ibm} . This article \cite{Massachi2017} provides a very good explanation on how to use the watson API to generate captions.

210: Hearing loss is a problem and once upon a time it could be considered creating a liability on the society, however, the application of big data and emerging technologies could help turn this liability into something positive. It certainly is creating a lot of job opportunities for one. there are multiple new startups created to develop on facets like speech to text conversion via a mobile phone, big players are trying to reach overall 100\% accuracy. people affected by hearing disabilities now find themselves with much more options than before and also have opportunities to contribute and be a part of something big. Another positive is that the application of big data is providing a paradigm shift and is now creating more new kinds of hearing aids each of which incorporates more and more powerful features. it may not be too soon before this hearing aids down the line become new "smart earphones". Caption generation has a huge potential market too but it is only the big players who are making significant headlines. The race for 100\% is wide open and anyone stands a chance to make a name for themselves. The current set of government policies and funding are more that of a reactive than proactive approach changes can help drive research and also create new jobs to make resources available everywhere for anyone to use. Big data has a lot of applications is healthcare which is constantly evolving there will always be new avenues to apply big data, it is, however, a risky move because any misdiagnosis or wrong suggestion could lead to fatalities which could lead to lawsuits. The benefits, however, outweigh the risks and most patients are smart enough to know that predictions from a computer are to be used as a reference and not the rule.

passed: False

find footnote

---

passed: True

```
find input{format/i523}
-----
4: \input{format/i523}

passed: True

find input{format/final}
-----
passed: False

floats
-----
50: Hearing aids are small electronic devices that you wear in or
    behind your ear they improve the hearing and speech comprehension
    of people. It makes some sounds louder so that a person with
    hearing loss can listen, communicate, and participate more fully
    in daily activities. A hearing aid can help people hear more in
    both quiet and noisy situations. A hearing aid has three basic
    parts: a microphone, amplifier, and speaker as can be seen from
    the figure \ref{f:hearingaidparts}.
52: \begin{figure}![ht]
53: \centering\includegraphics[width=\columnwidth]{images/hearingaidbreakdown.jpg}
54: \caption{parts of hearing aid}\label{f:hearingaidparts}
59: Hearing aids can be classified into three distinct categories
    \cite{NIHCD2017} they are Behind-the-ear (BTE), In-the-ear (ITE)
    and Canal as can be seen in the figure \ref{f:typesofaids}.
60: \begin{figure}![ht]
61: \centering\includegraphics[width=\columnwidth]{images/typesofaids.jpg}
62: \caption{types of hearing aids}\label{f:typesofaids}
73: The working of hearing aids was covered in detail in the previous
    section now we shall focus on the areas where big data can be
    applied to help both the doctors and the patients as much as
    possible. We know that in order to determine the extent of hearing
    loss an audiometry test will be performed. The test proceeds with
    a patient being made to sit in a soundproof room and being
    subjected to listening to a wide variety of sounds ranging from
    the softest possible sound they can perceive to the loudest
    possible. The audiologist then charts a graph to figure out the
    extent of hearing loss. It will look like the below graph shown as
    per the figure \ref{f:audiometrygraph}.
74: \begin{figure}![ht]
```

```

75: \centering\includegraphics[width=\columnwidth]{images/audiometrygraph.jpg}
76: \caption{audiometry graph}\label{f:audiometrygraph}
127: First, we shall explain a simple and relatively straightforward hidden Markov model a simple but powerful AI algorithm. A formal definition from Wikipedia that helps in understanding the concept of Markov models is given as " In simpler Markov models (like a Markov chain), the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters, while in the hidden Markov model, the state is not directly visible, but the output, dependent on the state, is visible. Each state has a probability distribution over the possible output tokens. Therefore, the sequence of tokens generated by an HMM gives some information about the sequence of states. The adjective hidden refers to the state sequence through which the model passes, not to the parameters of the model; the model is still referred to as a hidden Markov model even if these parameters are known exactly." \cite{Wikipedia2017a}. A markov model looks like this figure \ref{f:markov}
129: \begin{figure}![ht]
130: \centering\includegraphics[width=\columnwidth]{images/markovmodel.jpg}
131: \caption{markov model}\label{f:markov}
137: Now the concept of a neural network will be explained. A neural network is based on the same idea of how our brains work \cite{wikipedia2017} . A collection of neurons for information processing and to model the world around us. A very brief explanation would be a neuron sums all the inputs and if the resulting value is higher than a specified threshold it fires. A neural net can be represented as the following figure \ref{f:neuralnet}.
139: \begin{figure}![ht]
140: \centering\includegraphics[width=\columnwidth]{images/neuralnet.jpg}
141: \caption{neuralnetwork image}\label{f:neuralnet}
146: Now that we have a good understanding of how neural networks work we shall look into how ASR happens via neural networks \cite{Green1999}. we shall go about this step by step. The first problem will be converting sound to bits. We have previously seen digital hearing aids automatically convert sound waves into numerical codes and have extended this concept in multiple places. We shall now go into this a little more in detail and provide an insight into how this could happen. Consider the below wave of sound \ref{f:soundwave}.
147: \begin{figure}![ht]
148: \centering\includegraphics[width=\columnwidth]{images/hellowwave.

```

```

    jpg}
149: \caption{soundwave}\label{f:soundwave}
151: This can be represented on a graph as a simple expression of
height vs time. The annotations towards height can be amplitude,
frequency whatever a person chooses that suits their purpose
best. However, note that this is a bit too scattered and not very
uniform which is understandable because over digital media the
voice can break. Let us attempt to smooth this signal using one of
the many transformation algorithms available[ Nyquist theorem for
example]. The result will look like this \ref{f:smooth}.
152: \begin{figure}[!ht]
153: \centering\includegraphics[width=\columnwidth]{images/rephello.jp
g}
154: \caption{smooth wave}\label{f:smooth}
156: Recall it was mentioned that we can simply take the graph as a
function of height vs time, so to help visualize this consider
the \ref{f:samplegraph}.
157: \begin{figure}[!ht]
158: \centering\includegraphics[width=\columnwidth]{images/soundwavesa
mpled.jpg}
159: \caption{sampled wave}\label{f:samplegraph}
161: To represent this in a text format it would look like [
100,-20,30,89,789,-400,.....345] where each value is a measure of
height over a designated unit of time. We need to be careful
about how we select this unit of time. The idea is that different
syllables have a different pitch we want to exploit that
\cite{2017a} . Hence we want to select a unit of time such that
each unit possibly corresponds to one letter. The figure
\ref{f:modeloverall}.
162: \begin{figure}[!ht]
163: \centering\includegraphics[width=\columnwidth]{images/neuralnetim
gsound.jpg}
164: \caption{overall neural net model}\label{f:modeloverall}

```

```

figures 9
tables 0
\includegraphics 9
labels 9
refs 9
floats 9

```

```

True : ref check passed: (refs >= figures + tables)
True : label check passed: (refs >= figures + tables)
True : include graphics passed: (figures >= \includegraphics)
True : check if all figures are referred to: (refs >= labels)

```

Label/ref check  
passed: True

When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction

find textwidth

---

passed: True

below\_check

---

WARNING: figure and below may be used improperly

73: The working of hearing aids was covered in detail in the previous section now we shall focus on the areas where big data can be applied to help both the doctors and the patients as much as possible. We know that in order to determine the extent of hearing loss an audiometry test will be performed. The test proceeds with a patient being made to sit in a soundproof room and being subjected to listening to a wide variety of sounds ranging from the softest possible sound they can perceive to the loudest possible. The audiologist then charts a graph to figure out the extent of hearing loss. It will look like the below graph shown as per the figure \ref{f:audiometrygraph}.

WARNING: code and below may be used improperly

146: Now that we have a good understanding of how neural networks work we shall look into how ASR happens via neural networks \cite{Green1999}. we shall go about this step by step. The first problem will be converting sound to bits. We have previously seen digital hearing aids automatically convert sound waves into numerical codes and have extended this concept in multiple places. We shall now go into this a little more in detail and provide an insight into how this could happen. Consider the below wave of sound \ref{f:soundwave}.

bibtex

---

label errors

bibtex errors

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
```

bibtex\_empty\_fields

---

entries in general should not be empty in bibtex

find ""

---

passed: True

ascii

---

```
non ascii found 233
non ascii found 232
non ascii found 8217
non ascii found 8217
non ascii found 8217
non ascii found 8211
non ascii found 8217
non ascii found 8212
non ascii found 8212
```

---

The following tests are optional

---

Tip: newlines can often be replaced just by an empty line

find newline

---

58: \newline

65: \newline  
79: \newline  
81: \newline  
83: \newline  
90: \newline  
92: \newline  
94: \newline  
109: \newline  
111: \newline  
114: \newline  
124: \newline

133: The thought process that follows the following explanation is that of a semi-supervised learning. The training data will compose of just words(audio) with their respective speech tag. Also, the training data will comprise a good set of perfectly captioned videos. More than the videos it is the caption files that are important. The individual words file merely provide us with a corpus file of what words to expect. It is the caption files however that allow us to build the Markov model around which the entire caption generation process will be built upon. Now that we have our corpus file we can begin analysis on the caption file to build the model. What we will be doing is using a very simple probabilistic equation\cite{Wikipedia2017a}, The probability of observing a sequence  $Y = y(0), y(1), \dots, y(L-1)$  of length of  $L$  is given by, 
$$P(Y) = \prod_{i=1}^{L-1} P(y_i | y(0), y(1), \dots, y(i-1))$$
. To explain this in a more understandable manner we are looking for relationships between words. For example, when a person is introducing themselves a common sentence is "Hello my name is xyz" or "hello I am xyz". Another assumption we will have to make at this point at least with respect to the current Markov method is that we will work with more complete words that span at least 3 or more syllables so that the model can detect them better. With that, the previous sentences become "hello name xyz" and "hello xyz", from this

reduction we can now get a new relationship, two of them in fact. the word hello leads to the follow up of the word name and this leads to the follow up of xyz whatever and hello leads to xyz. Now this relationship will be remembered. Now we can also make use of this concept but towards sentences. First, we will have to determine via some statistical method what would be the best average length [ time duration] for sentences. Now we can use the previous principle to observe if there exist any relationship between sentences and remember them. Now we get on to processing the data to generate the captions. First, we have to eliminate noise from the audio. Then we need to split it into n appropriate sections [  $n = \text{total length of video/time of average sentence calculated previously}$ ]. Now using MapReduce we can quickly determine how many segments already have a translation [ ie find if there are any perfect/reasonable matches] and obtain the captions for those. If there are none available then we go to the next stage of getting captions word by word. After converting it to a data format appropriately [ this has been discussed this previously in the hearing aid section, another alternative manner will be discussed shortly]. Now we determine the first word, again using map reduce we can match the word to a list of probable similar sounding words. To obtain the actual word the magic of probability comes into play. remember the Markov model we had discussed earlier, from it we can calculate the probabilities of a word occurring as the first word and accordingly make a very educated guess on which word is the right word. Following that using the Markov model once we can determine what the next word could be after first narrowing down the suspects we can use the model to infer what the next word could be. that is, given the current word what is the probability that the next word will be the selected word. \newline

135: \newline

145: \newline

190: \newline

203: \newline

passed: False

cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Analyzing everyday challenges of people with visual impairments

Tousif Ahmed  
Indiana University  
150 S Woodlawn Avenue  
Bloomington, Indiana 47405  
touahmed@indiana.edu

## ABSTRACT

People with visual impairments face varieties of problem in their daily lives. Nowadays, modern technology especially camera-based technologies are helping people with visual impairment in their everyday tasks ranging from daily household activity to navigation. Users are using camera based applications where they are sharing photos and asking questions. Based on the asked question and shared photo, automated tools or human crowd workers are helping the visually impaired people in their tasks. By exploring the questions, it is possible to understand the problems and challenges of people with visual impairments. However, the volume of such data makes it impossible to analyze the questions manually. Big data analytics could help us to understand the challenges of people with visual impairments. To understand the challenges, we analyzed the VizWiz data set which contains more than 33,500 questions asked by people with visual impairments. In this paper, we report on the data and shed light on the challenges.

## KEYWORDS

E534, HID 237, Big Data, Accessibility Issues, People with Visual Impairments

## 1 INTRODUCTION

People with visual impairments face a variety of problems in their daily lives and need assistance. They need assistance with detecting objects, identifying money, navigation, transportation, household activities, cooking, and various other activities. Sighted person on rely on vision on so many things that it is almost impossible to visualize and understand the problems of people with visual impairments. Although there are variety of tools available to simulate the challenges and experiences of people with visual impairments, the challenges of people with visual impairments is not well understood. To help visually impaired people with technologies, we need to understand their problem first.

One possible to understand the challenges of people with visual impairments is qualitative analysis or ethnographic studies with people with visual impairments. Simply, researchers can follow or conduct interviews with people with visual impairments. Although qualitative studies are widely accepted research methods, it has limitations. Specially to understand the problems of people with visual impairments, qualitative studies have severe limitations. As the challenges vary with the experiences of people with visual impairments, these studies can not capture or depict the whole picture. Besides, these studies are very expensive and need ample

human effort. Therefore, we need a better way to understand the challenges of people with visual impairments.

Big data analytics could be a potential alternative. To understand how big data can help people with visual impairments, we need to understand the background first. Nowadays, people with visual impairments uses different technologies for their problems. A wide range of technologies such as talking watch, braille reader, navigation helper are available in the market to help the visually impaired in their daily tasks. Since the introduction of smartphone, smartphone based applications gained huge popularities among people with visual impairments. Now, mobile and smartphone applications like Seeing AI [7], AiPoly [2], LookTel [9], and other such camera based applications are helping people with visual impairments in object recognition, face recognition, color detection, human emotion detection, activity recognition, and other such tasks that was not possible before. Figure 1 depicts an example from Seeing AI which shows that how camera based applications are helping people with visual impairments by describing nearby person's activity (Figure 1b) and their facial emotions (Figure 1a).

[Figure 1 about here.]

Most of the camera assisted assistive applications works in one simple way. The user uploads an intended photo and asks a question about that. Applications have its simple iq engine which tries to answer the problem first. If it's not able to answer that question, it shares the questions and images with the user's friends and family. Sometimes, the image is shared with a web based human worker. This crowd worker is essential for such system, because the iq engine is not sophisticated yet. We can not completely trust the automated approaches. Besides, visually impaired user's can not efficiently take photos. Sometimes they point at totally wrong objects or items, sometimes they share blurry photos, and even sometimes the question does not match with the photos [3, 5, 6]. Therefore, to give a correct answer of the questions, technologies require human intelligence. Questions and answer based applications like TapTapSee [8] and VizWiz [3] uses this approach. LookTell [9] and BeMyEyes does not have any automated approach, it directly broadcasts the video feed to the volunteers and volunteers answer their questions. Some applications are trying to move towards the fully automated approach, however, due to the limitations of automated approaches they did not gain much popularity yet.

Human based systems have privacy issues, because these users are uploading their photos which may contain sensitive information. Often they ask about medical information, their address, and various other sensitive information which can be exploited by the malicious crowd workers. Even sometimes, the users shares their credit card image and asks the system to about their credit card

information which have severe privacy and security implications. Moreover, cameras and images shared by them can be extremely risky for people with visual impairments, because often they do not know the contents of the photo. Photos can be uploaded in error, sensitive data can be shared unintentionally. Ahmed et al. [1] reported a scary story of one of the VizWiz users, who accidentally shared her naked photo with a crowd worker. Such evidents suggests that such systems has severe privacy and security implications. However, visually impaired needs such tool in their daily lives. Therefore, the ideal solution would be an completely automated approach. However, to design a flawless system we need to improve the existing tools first and we need to understand the challenges first.

The challenges of people with visual impairments can be easily understood from the images uploaded and questions asked by the user. Although it is extremely difficult for people with visual impairments to take a good photo, still they are using these tools because of their challenges. Therefore, the data uploaded in these applications are probably a good way to understand the challenges. However, due to the volume of the data it is not possible to manually identify the problems. Therefore, big data analytics can be helpful in this context to understand the challenges of people with visual impairments. However, due to privacy issues all but one data sets are not publicly available.

In this paper, we analyzed the VizWiz data set containing more than 35000 images and questions [3]. Based on the questions asked, we tried to categorize their problems which eventually help the researchers to design and develop a fully automated system. Previous researches [4] explored the same problem with the same data set. However, they only explored 1000 images and performed a qualitative study and identified four categories of problem. Since manual analysis is not possible on 35000 data, we used big data tools to automatically analyze the questions and images. In this paper, we report on analysis performed and the visual challenges of people with visual impairments.

## 2 METHODOLOGY

In this section, we discuss the methodology for identifying the challenges of people with visual impairments.

### 2.1 Data Set

We used VizWiz data set which is the only available data set in this category. VizWiz is an iPhone application that allows visually impaired users to get quick responses of their challenges. The app tries to find an answer by using automatic IQ engine and anonymous crowd workers [11]. VizWiz was released in May, 2011.

VizWiz application helped more than ten thousand users by answering more than 100,000 questions. However, they only shared half of their data from those participants who gave consent. Therefore, around 50,000 data are available for the researchers. However, the researchers removed around 6,000 data due to sensitive contents in the images. The rest of the 43,543 images were made public. All images and questions redundantly checked and anonymized. We downloaded this data set for research purposes in May. Recently, the data is not available to download. Therefore, we urge the instructors to not distribute the data.

Based on the images shared and questions uploaded, we found only 33,580 images and their related questions. The questions were shared in json format and images are shared in a compressed directory. The questions data set have three columns which I described next:

- **image:** The name of the image file.
- **private:** If the image is marked as private.
- **question:** Asked questions of the user. Some questions are missing.
- **response:** Each question can have multiple responses. As mentioned earlier, some questions were tried to answer using the IQ engine and some questions were sent to the web workers. For each question, there can be one to 11 responses. However, on average three responses were received. The distribution of the responses shown in Figure 2. From the figure, we can see that most of the questions either received three or four responses.

[Figure 2 about here.]

### 2.2 Data Cleaning and Preparation

Since this data was collected from a research group, the data is very clean. We did not need any further cleaning except we discarded the private column. Since the researchers did not share the private images, therefore, all the rows in private columns shows false. Therefore, this column does not add any values to our analysis. We also noticed that lot of questions are missing, but an image is available. We can safely assume that these images were asked without questions and the users assumed that the images are self describing. Since the images can be interesting, therefore, we still kept the questions and labeled those questions as 'NoQues'. We used 'pandas' for storing the data. We also uploaded the images in the specified Google Drive folder.

### 2.3 Data Analysis

We performed analysis on both the questions and image data sets. The image data set only used to detect the blurred images. However, we rigorously analyzed the questions to identify various issues of people with visual impairments. In this section, we mainly discussed the text analysis methods. The full analysis can be found in 'question\_analysis' jupyter notebook. The image analysis can be found in 'image\_analysis' notebook.

**2.3.1 Question Analysis.** To understand the challenges of people with visual impairments we performed unigram, bigram, and trigram analysis. Based on the analysis, we identified several issues which is presented in the results. The process of identifying the challenges is discussed in next section.

## 3 RESULTS

In this section, we present our results that we identified from the analysis:

### 3.1 Identifying the challenges of people with visual impairments

The questions asked by people with visual impairments explains some of their challenges in their daily lives. Whenever they are

facing issues, they are asking questions in VizWiz. Therefore, the questions asked could give us some insights about their challenges.

[Figure 3 about here.]

To understand the challenges, we first calculated the frequency of the words. There are around 4500 unique words in the questions. The most frequent 50 words is shown in Figure 3. If we closely examine the words, we can see that the most frequently used word is ‘what’. ‘What’ appeared 22793 times which is approximately 70% of all of the worlds. The second and third most frequent words are ‘this’ and ‘the’. Since, this is a set of questions, therefore, all the above words are justifiable. Although, ‘what’ is somewhat giving us an indication that users are asking about objects or subjective questions mostly, ‘this’ and ‘the’ is not adding that much value. Next, we performed the same analysis by removing the most commonly used words in English. That unigrams gave us some additional insights. The list of most frequently used interesting words can be found in Figure 4. If we remove the commonly used words, then for the majority of the questions had no questions. Those questions were asked by just uploading the photos. We assume that the users thought that the app could automatically answer those questions. Other three most frequently used words are ‘color’, ‘tell’, and ‘please’. Among these three the most interesting is ‘color’. Combination of ‘what’ and ‘color’ indicates that people with visual impairments faces issues with color detection, and often they ask the workers about the color of the objects and items. Therefore, we found **color detection** problem of people with visual impairments from the analysis. If we just consider the nouns and pronouns from the 30 most frequently used words, we find ‘box’, ‘picture’, ‘color’, ‘screen’, ‘shirt’, ‘bottle’, ‘flavor’, ‘brand’, ‘coffee’, ‘label’, and ‘product’. From this keywords, we can safely assume three other problems: they face issues with screens (screen), there are issues with objects (brand), and the users face issues with reading labels. Therefore, from the initial analysis we found four problems that people with visual impairments regularly face: **color detection, object detection, reading screens (mobile/ computer), and reading labels.**

[Figure 4 about here.]

After checking the most frequently used words, we explored the most interesting pairs of words. If we check the bigrams (Figure 14 and 15 in Appendix), it gives confidence of our identified problems. The most frequently used two words are ‘what’ and ‘this’ which suggests that most questions were asked to identify the object. Therefore, people with visual impairments definitely face problems with detecting objects. ‘What’ and ‘color’ also suggests that users face color detection problem frequently. If we check the bigrams of most frequently used interesting words (Figure 15), we find some additional insights. If we ignore ‘NoQues’, then we again see color detection and computer screen reading problem. However, now we can find another interesting pairs of words ‘look’ and ‘like’. This pair indicates a subjective question, where the user is asking how the user is looking like. This identifies another challenges of people with visual impairments **Impression Management**. Another interesting common pair of words are ‘long’ and ‘cook’ which indicates reading label issues, however this can be a household activity issue. The trigrams also gave us some new interesting insights (Figure 16). Most of the trigrams confirms above mentioned challenges,

however, there are some new issues. One interesting trigram is ‘display’, ‘treadmill’, and ‘tell’ which indicates the health fitness related issues or **Health Management Issue**. Due to the accessibility issues in health monitoring and fitness monitoring issues, they can not manage health effectively. Therefore, the users often seek help for reading the display. Another interesting three words are ‘pregnancy’, ‘test’, ‘show’ which can also be put into health Management category. However, this seems a private information, but still people with visual impairments have to share this information due to their visual challenges.

### 3.2 Challenges

Based on the rigorous analysis, we identified some challenges of people with visual impairments. In this section, we discuss the challenges:

**3.2.1 Object Detection:** The most frequently asked question in VizWiz is ‘What is this’ or ‘What is that’. ‘What’ appeared more than 22,000 questions. Among those 22,000 questions around 7,000 questions are ‘What is this?’ and ‘What is that?’. People asks variety of object detection questions ranging from everyday objects to personal objects. Some examples of object detection problem is shown in Figure 5. By manually analyzing some photos, it seems most of them are related to household activities. Therefore, with better tools it is possible to detect the objects.

[Figure 5 about here.]

**3.2.2 Color Detection:** Another most frequent problem that people with visual impairments face is to detect colors. Most of the time they use VizWiz to identify colors of their cloths, items, foods, and others. Some examples of color detection is shown in Figure 6. Based on the images, automatically detecting the colors seems a challenging task. Because, if we examine figure 6 we can see in the image there can be other objects. Automatically detecting the object of interest will be difficult. For example, in the right most photo the user is asking about the color of the dress in hand, however, there are other objects visible in the photo. Therefore, identifying the color automatically will be challenging.

[Figure 6 about here.]

**3.2.3 Reading Screens:** Nowadays, people with visual impairments use smartphones and computers. They use screen reading software which generates synthesized speech to relay the information from screen. However, sometimes these software fail and visually impaired need to seek help from crowd workers. Another issue is the accessibility issues of CAPTCHA, people with visual impairments struggle with CAPTCHA. Therefore, they seek people who can read the CAPTCHA for them. Some examples of reading screen problems are shown in Figure 7.

[Figure 7 about here.]

**3.2.4 Reading documents or labels:** Another obvious challenges of people with visual impairments is reading documents. The paper documents are not often accessible and people need help from others to read that. People might use scanners to read documents, however, scanning documents can be time consuming. Especially, for scanning food or medicine labels can be difficult. Therefore, participants seek help to read labels for them. Figure 8 shows some

examples of reading issues. However, there can be potential score for technology for this types of problem. If the user is asking for reading helps, a simple OCR can help. However, OCR might not work well with food labels. One suggestion could be for food related reading question, the system could look for barcode and identify necessary information.

[Figure 8 about here.]

**3.2.5 Impression Management:** Based on the analysis, we explored that managing impressions can be challenging. As a social norm, we often present our better selves to others by wearing consistent dresses. For example, we do not want to present ourselves in social places in such way that may misrepresent ourselves. Some words that we found in the questions are ‘look’, ‘like’ which we assume that users are asking to understand their appearance. Therefore, impression management for people could be challenging. Sometimes, the questions can be appearance related. Some examples of impression management challenges is shown in Figure 9.

[Figure 9 about here.]

**3.2.6 Health Management:** Health management is important for everyone. However, people with visual impairments face lot of challenges to maintain healthy behavior. They struggles to cook, therefore, they need to eat outside or eat packaged foods. They can not read the package’s well, so miss the nutrition info. Managing medicine can be issue. Some other issues can be attributed to visual representation of results. For examples, weight scales show visual weights, pregnancy scales convey visual feedback, health monitoring instruments like treadmill convey visual information. All these visual information makes it difficult for managing health issues. Therefore, health management can be challenging. For that reasons, people with visual impairments often ask such applications to help them with various visual indicators in health and fitness. Figure 10 shows three different health realted issues of people with visual impairments. Figure 10a depicts the issues of medicine management, users often can not identify the required medicine. Figure 10b shows asking the result of pregnancy test, which can be sensitive. Figure 10c asking questions about the weight of the user. Since, such applications can forward these questions to friends and family members all these images can be sensitive. However, technology can potentially address this issue by automating the responses.

[Figure 10 about here.]

**3.2.7 Taking Photos:** Like sighted people, visually impaired people also wants to take photos. However, taking photos are challenging since the users can not seen the image. Therefore, they often struggle to take photos. The irony of applications like VizWiz is that these services require a challenging task to solve other challenges. Although none of the questions mention anything about taking photos, the responses of the web workers illustrates the photo taking challenges of people with visual impairments. Around 4000 images have been detected as blurry and not understandable by human workers. Apart from blurry images, sometimes photos can be out of focus and misplaced.

[Figure 11 about here.]

Figure 11 depicts the some not understandable photos taken by people with visual impairments. However, such images takes resources and often cost money. If the system can early detect such images and prevent those images from sending then it can save resources. Misplaced or blurry photos can be early detected. Another potential scope of technology is to automatically fix the blurry images.

We identified various challenges of people with visual impairments. There can be other challenges, however, from the VizWiz data set these seven seems some major problems. We also discovered that there can be privacy issues with the shared images (i.e., pregnancy test results) and such data need to be handled carefully. Although existing services require manual efforts, technology has various scopes to help people with visual impairments. Due to poor quality of images, such system may consume significant user resources and early detection of the quality of images can save the resources. In the next section, we discuss one such approach and the evaluation of the approach using VizWiz data set.

### 3.3 Automatically Detecting Blurry Images

We have already give some examples of the struggles of taking photos by the user. Often their photos are out of focus and blurry. Using OpenCV, we can detect blurry images. From the web workers responses we have an estimation that some photos are very blurry and can not be recognizable by human. If the system can early detect the blurry photos and asks the user to retake the photos it could reduce human effort. In this analysis, our task is if we can automatically identify the blurred images. The ‘Image Analysis’ jupyter notebook shows some the analysis that we performed in this section.

**3.3.1 Estimation of Ground Truth Data.** We set up the ground truth from the web workers responses. If any of the web workers mentioned that the image is blurry, then we set the image as blurry. From that, we found a list of 3580 images which can be considered as blurry. We then divided the data frame into two different sets: blurred set and not blurred set.

**3.3.2 Detecting Blurry Photos.** We followed pyimagesearch’s tutorial to detect the blur images [10]. Following that tutorial, we used variance of the Laplacian to detect the blurred images. Then, we run the algorithm on 33,580 images.

**3.3.3 Calculating F1 score.** We made an assumption for the accuracy of blur detection. If we consider the real case scenario, if the user need to take a photo more than once to avoid blurring that is not a problem. Although, they have difficulties of taking photos but it is still possible to take a better photo and there is no cost of taking photos. However, if we send a blurry photo to web worker it wastes resources. The system need to pay the web workers for their tasks and the system somehow charges that money to the users. Therefore, taking a blurry photo is costly. Therefore, for such a system it is better to be some false positives than false negatives. Therefore, this system tries to reduce the false negatives. Hence, we tried to improve the recall. However, too much false positive can affect the usability of a system. Therefore, Our target is to find the best accuracy over blurred images minimizing false positive rates. F1 score will help us to find a correct threshold. Our initial threshold of 150 gave us F1 score of 21.36%.

**3.3.4 Identifying a good threshold.** We run the algorithm with various thresholds. The F1 score graph against various thresholds did not improve the accuracy. Figure 12 shows the accuracy of blur detection.

[Figure 12 about here.]

**3.3.5 Implications of result.** The poor accuracy of the blur detection algorithms depicts some problems of real world data set. Although Laplacian blur detection is a good indicator is a good indicator of blurred images, the algorithm failed in this case. The failure of the blur detection algorithm can be attributed to poorly taken images and inconsistent image sizes. We tried to change the size of the images, however, it did not improve the accuracy of the results. Probably using new deep learning based methods will be more effective.

### 3.4 Privacy implications of VizWiz

In the analysis of VizWiz, we have seen various issues of people with visual impairment. Definitely, such applications are helping the users, making them more independent. However, there are privacy risks. We have seen people share their medical health information, often they share their address web workers. The authors of VizWiz data set did not share 5000 photos due to privacy reason. However, people often share their credit card information which can have severe consequences. The information given to unfamiliar people can be exploited. Therefore, additional care is required for such data. Based on the analysis, we have seen multiple times that it is not always possible to automatically answering the questions. We need human intelligence for some challenges. If the data requires human intelligence, then instead of sending the complete data the system can send partial data so that the privacy implication can be reduced.

Another potential privacy threat can be arose from the inability to know what is in the picture. The user can mistakenly capture sensitive photos and share it with the web workers. The bystanders of such devices are also in risk, because they can also inadvertently captured by the user and shared with the crowd workers. One such example is shown in Figure 13. If we check the figure, we can see that a bystander is present in the picture. The question asked for this question was ‘What is this?’. We can assume that the user probably was trying to detect an object but took a photo of nearby person. Similar privacy leakage can happen with credit cards, and other sensitive information. Photos can be shared in error. Therefore, such systems should consider such implications and should take extra precaution to reduce such incidents.

[Figure 13 about here.]

## 4 CONCLUSION

People with visual impairments faces different challenges and by analyzing the VizWiz data set we identified and explored some challenges. Although some challenges could be identified by analyzing portions of the data, big data analytics helps us to get a better exploration of the challenges. Moreover, big data analytics also helps to discover some solution space. In future, if other such services similar analysis it would be possible to reduce the human effort that is required to operate such services. Moreover, with more data

it would be possible to early detect the risks. By early detecting the risks, the system would be more helpful for people with visual impairments. Only in that way, they can enjoy the similar quality like other sighted people.

## ACKNOWLEDGMENTS

The authors would like to thank Professor Gregor von Laszewski for helping us with the instruction and resources that were required to complete this paper. We would also to like to thank the associate instructors for being available on the course website all the time and helping us with their answers.

## REFERENCES

- [1] Tousif Ahmed, Patrick Shaffer, Kay Connelly, David Crandall, and Apu Kapadia. 2016. Addressing Physical Safety, Security, and Privacy for People with Visual Impairments. In *Twelfth Symposium on Usable Privacy and Security (SOUPS 2016)*. USENIX Association, Denver, CO, 341–354. <https://www.usenix.org/conference/soups2016/technical-sessions/presentation/ahmed>
- [2] Aipoly. 2017. Vision through artificial intelligence. <http://aipoly.com/>. (2017).
- [3] Jeffrey P. Bigham, Chandrika Jayant, Hanjie Ji, Greg Little, Andrew Miller, Robert C. Miller, Robin Miller, Aubrey Tatarowicz, Brandyn White, Samuel White, and Tom Yeh. 2010. VizWiz: Nearly Real-time Answers to Visual Questions. In *Proceedings of the 23Nd Annual ACM Symposium on User Interface Software and Technology (UIST '10)*. ACM, New York, NY, USA, 333–342. <https://doi.org/10.1145/1866029.1866080>
- [4] Erin Brady, Meredith Ringel Morris, Yu Zhong, Samuel White, and Jeffrey P. Bigham. 2013. Visual Challenges in the Everyday Lives of Blind People. In *Proceedings of CHI 2013*. <https://www.microsoft.com/en-us/research/publication/visual-challenges-in-the-everyday-lives-of-blind-people/>
- [5] Susumu Harada, Daisuke Sato, Dustin W. Adams, Sri Kurniawan, Hironobu Takagi, and Chieko Asakawa. 2013. Accessible Photo Album: Enhancing the Photo Sharing Experience for People with Visual Impairment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 2127–2136. <https://doi.org/10.1145/2470654.2481292>
- [6] Chandrika Jayant, Hanjie Ji, Samuel White, and Jeffrey P. Bigham. 2011. Supporting Blind Photography. In *The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '11)*. ACM, New York, NY, USA, 203–210. <https://doi.org/10.1145/2049536.2049573>
- [7] Microsoft. 2017. Seeing AI: Turning the visual world into an audible experience. <https://www.microsoft.com/en-us/seeing-ai/>. (2017).
- [8] Michelle Naranjo. 2016 (accessed Sep 1, 2017). Toyota’s Project BLAID Is an Empowering Mobility Device for the Visually Impaired. <https://www.consumerreports.org/car-safety/toyota-project-blaid/>. (2016 (accessed Sep 1, 2017)).
- [9] Looktel Recognizer. 2017. Instantly recognize everyday objects. <http://www.loktel.com/recognizer>. (2017).
- [10] Adrian Rosebrock. 2015. Blur detection with OpenCV. <https://www.pyimagesearch.com/2015/09/07/blur-detection-with-opencv/>. (2015).
- [11] VizWiz. 2017. VizWiz DataSet. <http://www.vizwiz.org/data/>. (2017).

## A APPENDIX

[Figure 14 about here.]

[Figure 15 about here.]

[Figure 16 about here.]

#### LIST OF FIGURES

1	Seeing AI providing various information about people nearby [7].	8
2	Distribution of the number of responses	9
3	Most frequently used words in the questions asked	10
4	Most frequently used interesting words	11
5	Object Detection Questions	11
6	Color Detection images	12
7	Screen Reading images	12
8	Reading problems related images	13
9	Questions asked containing ‘look’ and ‘like’	13
10	Various health related questions	14
11	Poorly captured images	14
12	Accuracy of Laplacian blur detection	15
13	Privacy Implications of VizWiz	16
14	figure	17
15	figure	17
16	Most frequently used interesting words	18

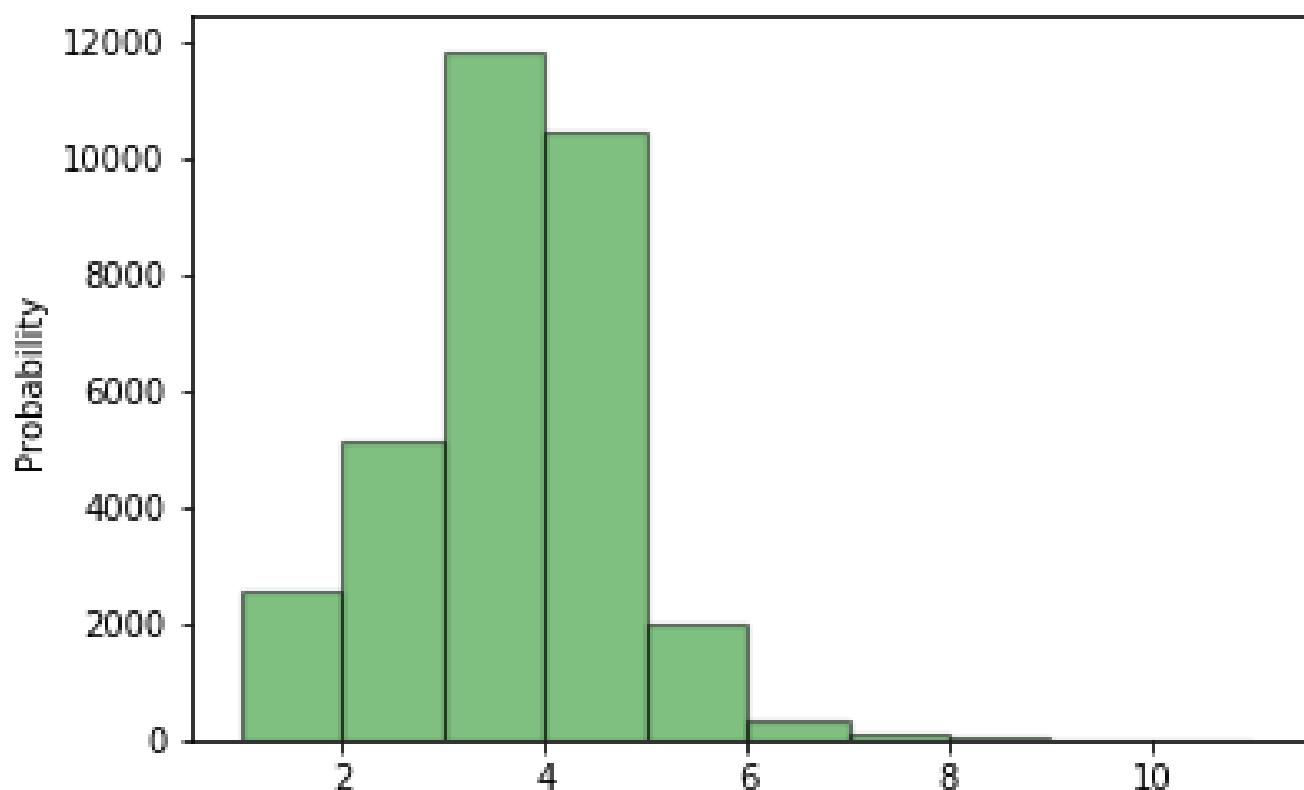


(a) Age, gender, appearance, and facial expression

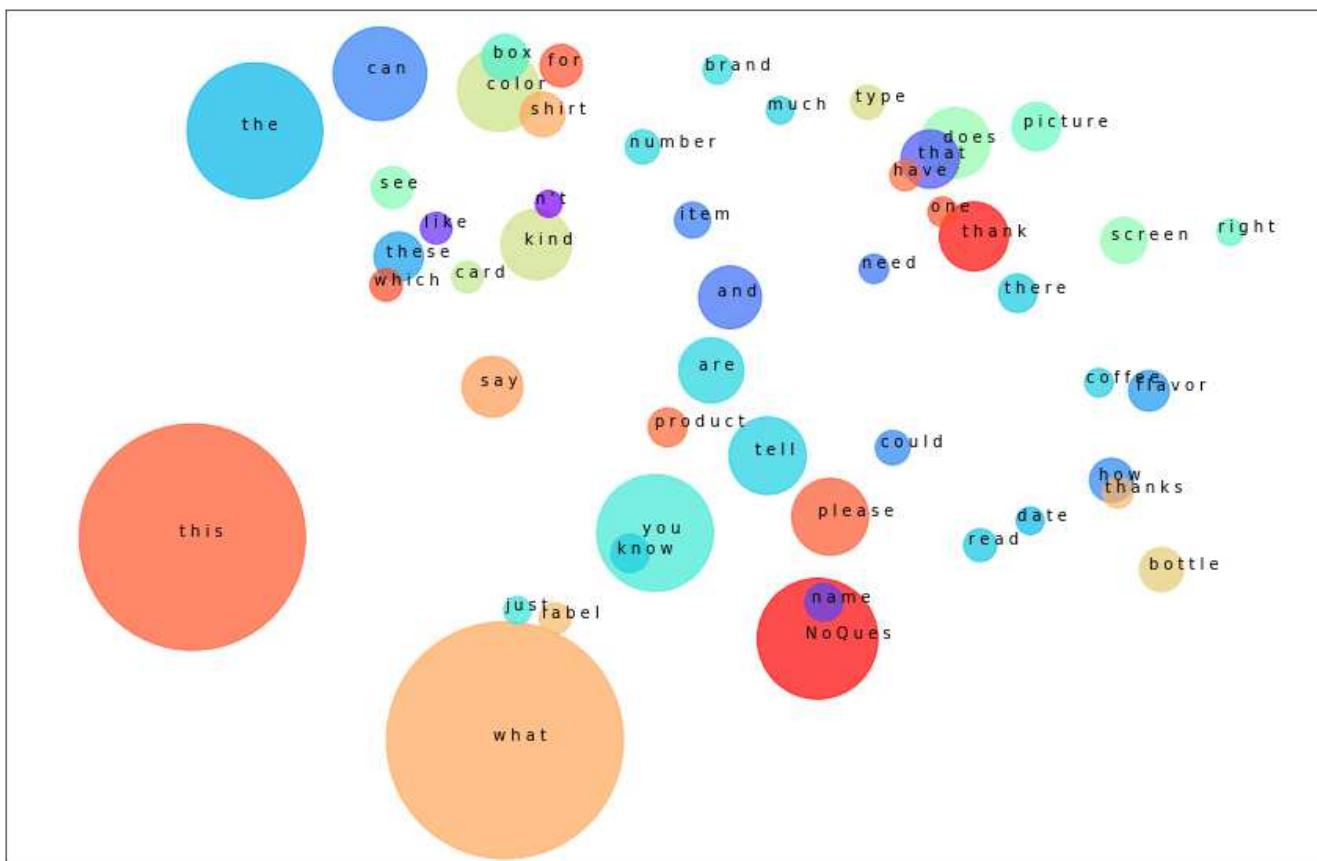


(b) Age, gender, and activity of a nearby person

Figure 1: Seeing AI providing various information about people nearby [7].



**Figure 2: Distribution of the number of responses**



**Figure 3: Most frequently used words in the questions asked**

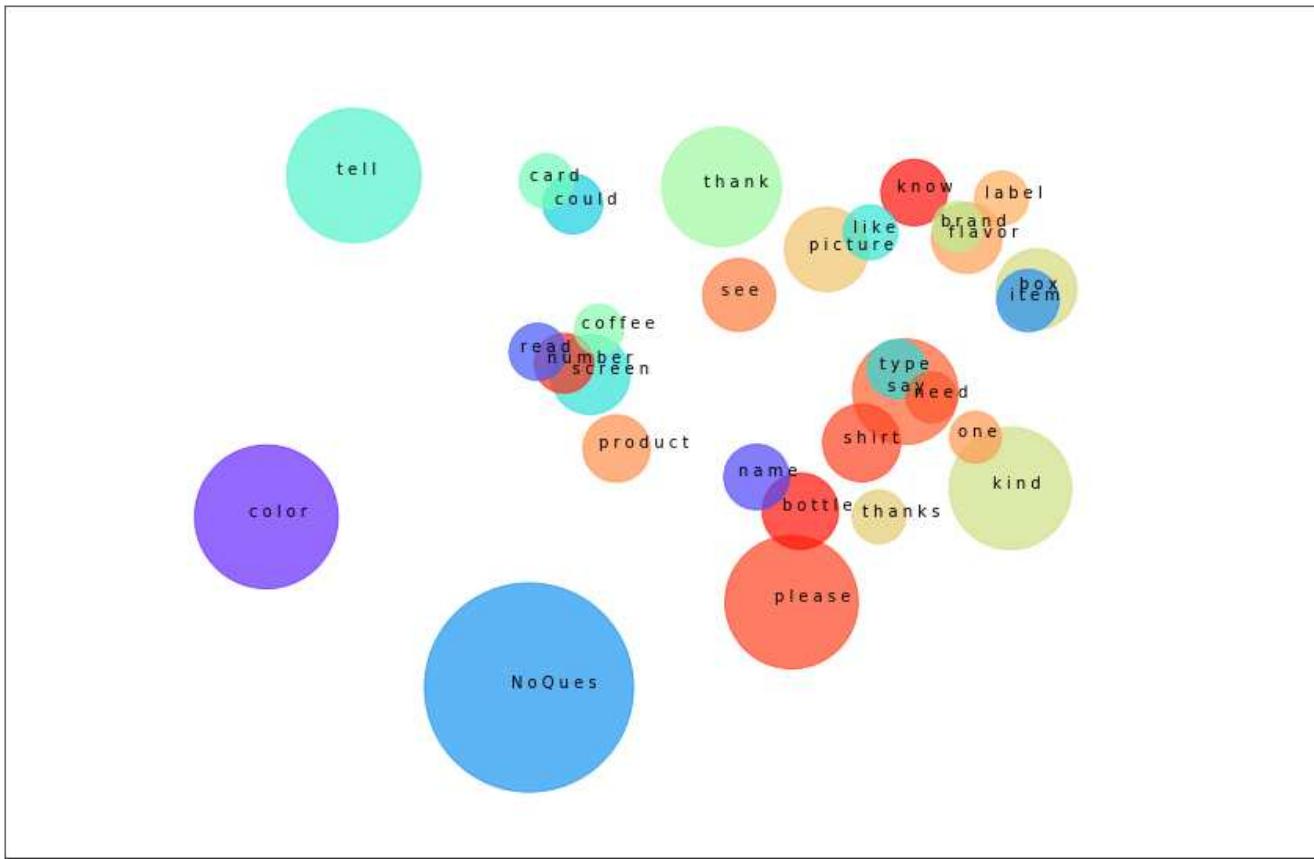


Figure 4: Most frequently used interesting words



Figure 5: Object Detection Questions

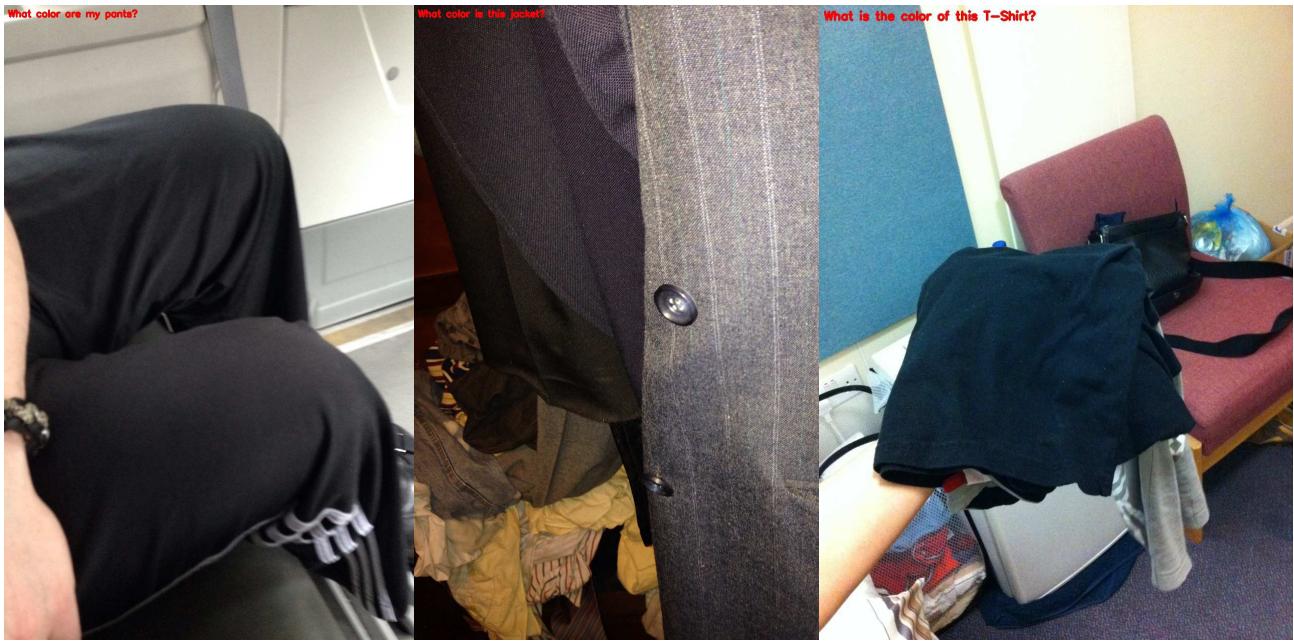


Figure 6: Color Detection images

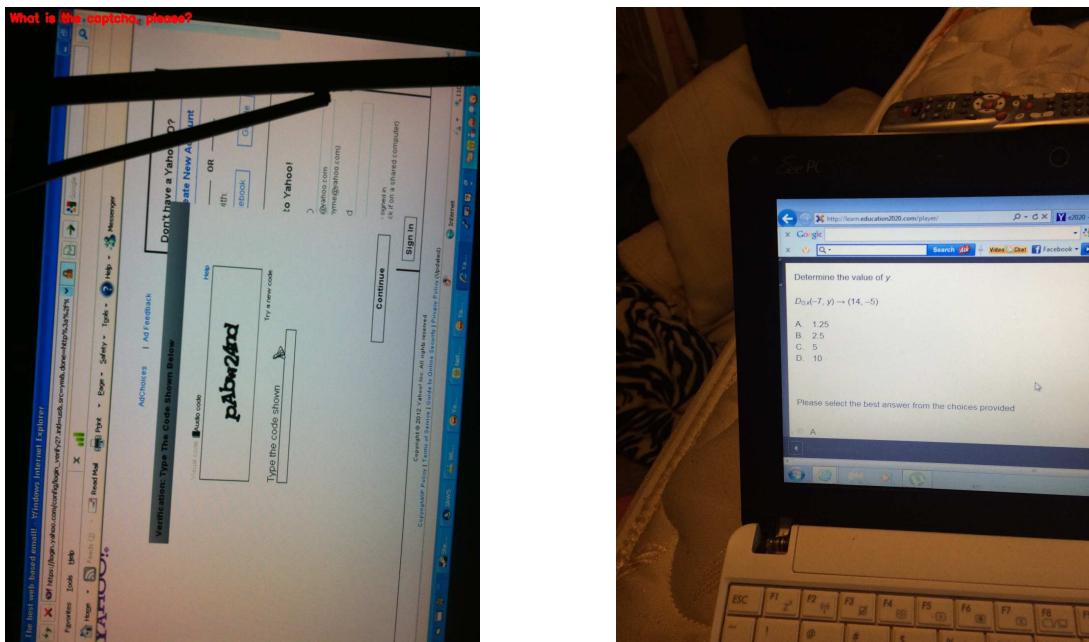


Figure 7: Screen Reading images



Figure 8: Reading problems related images

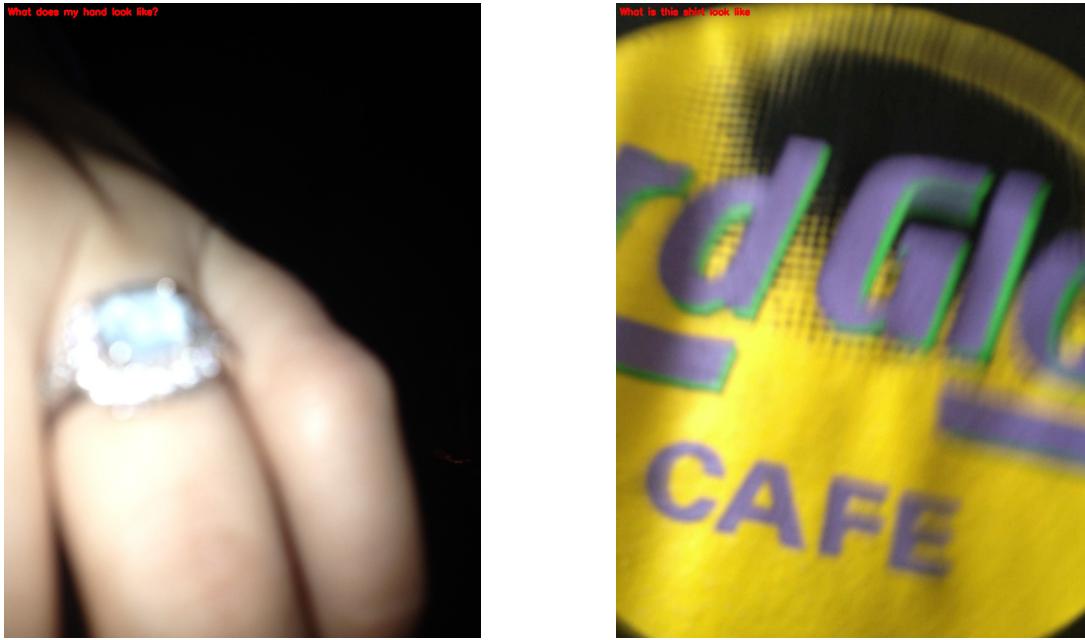
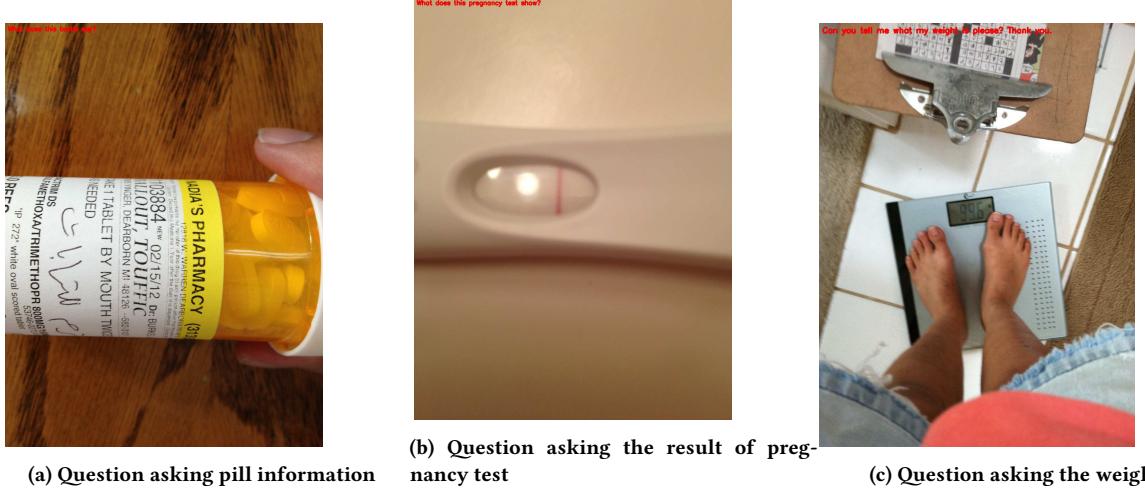


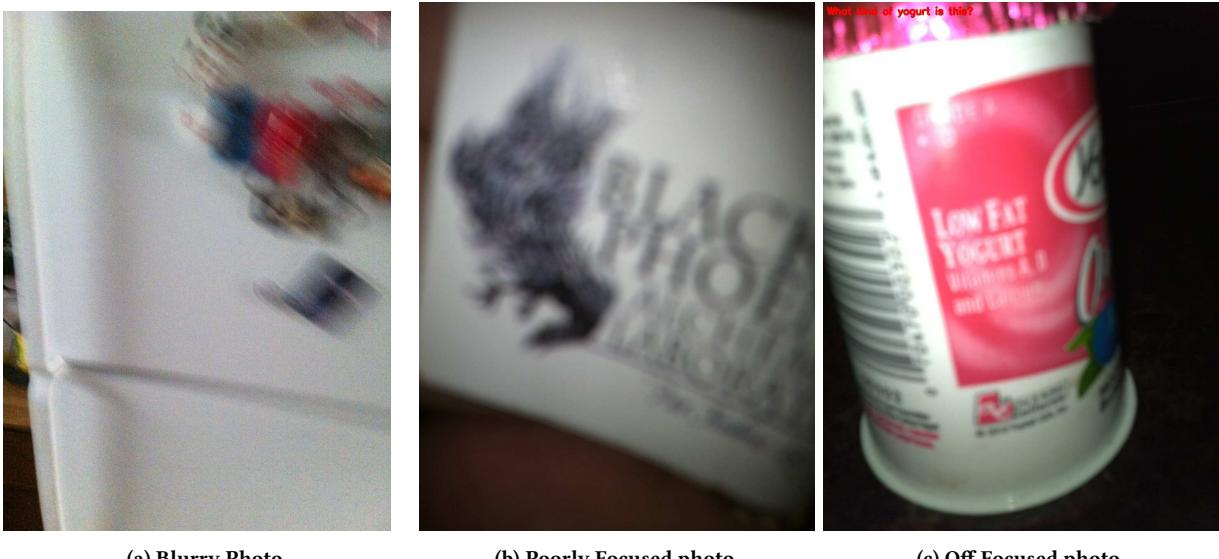
Figure 9: Questions asked containing 'look' and 'like'



(b) Question asking the result of pregnancy test

(c) Question asking the weight

Figure 10: Various health related questions

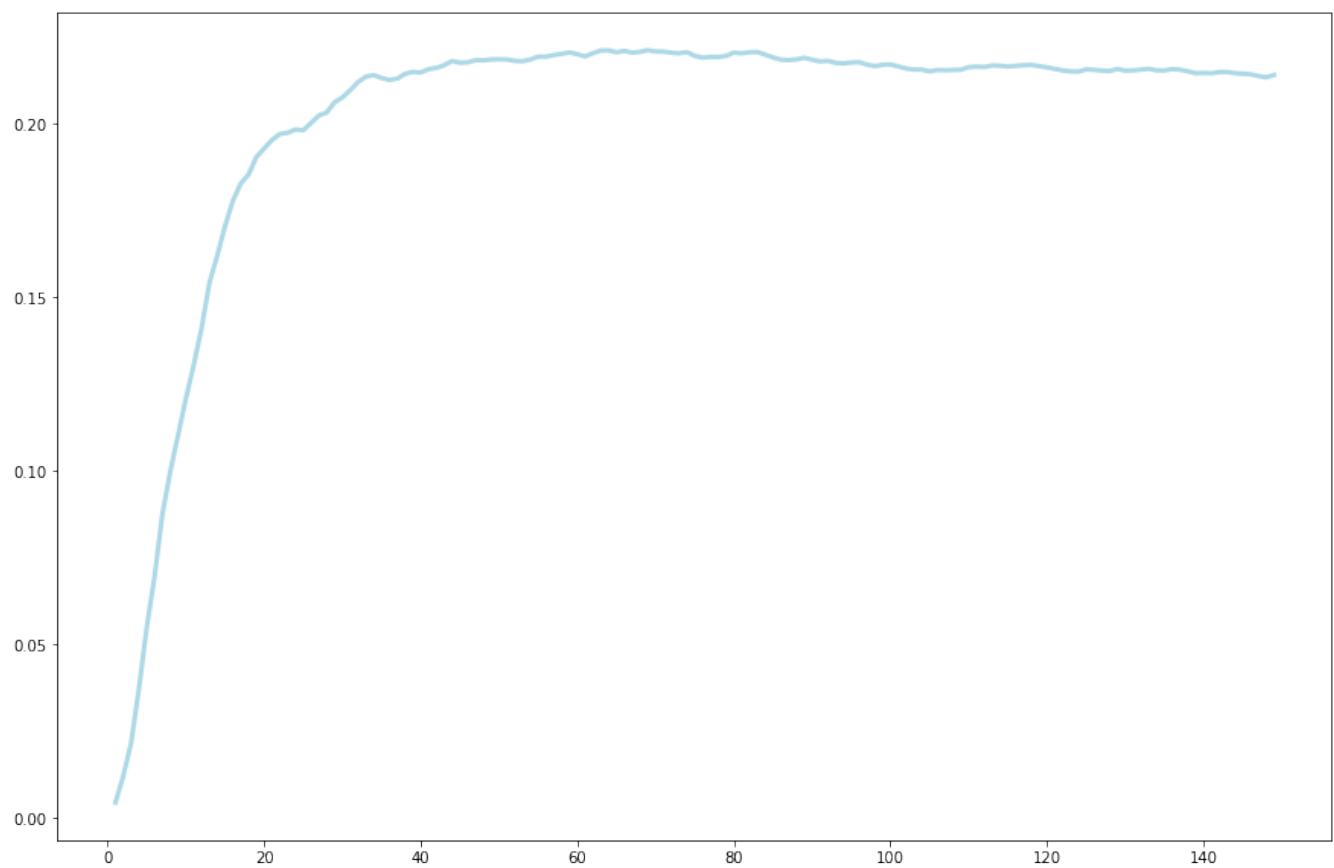


(a) Blurry Photo

(b) Poorly Focused photo

(c) Off Focused photo

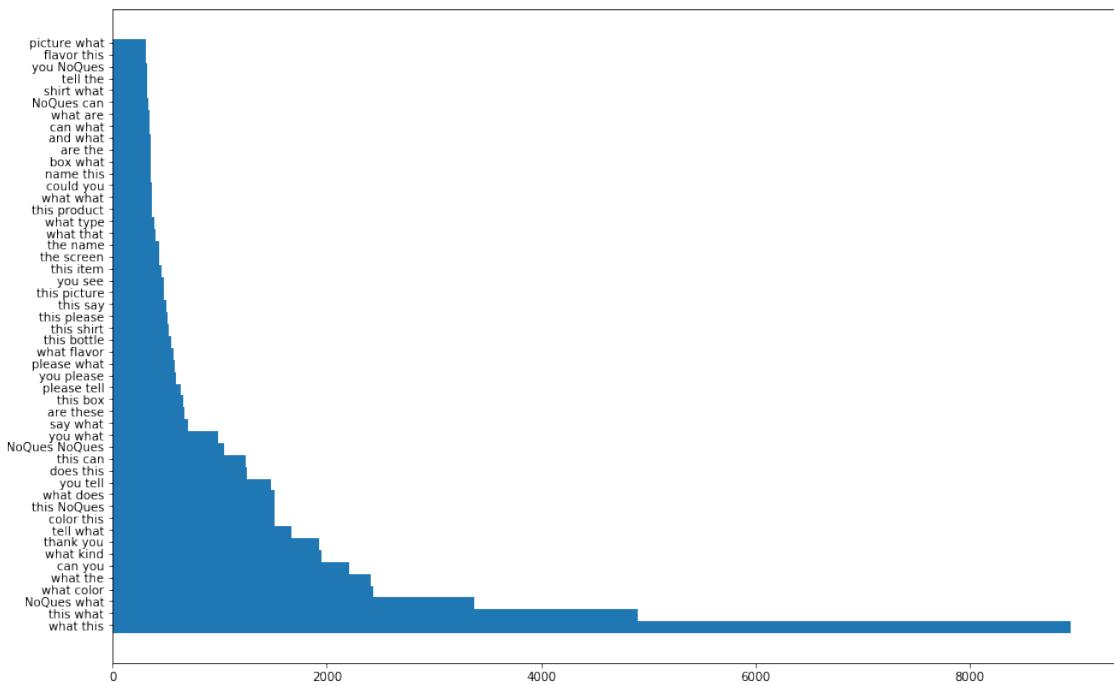
Figure 11: Poorly captured images



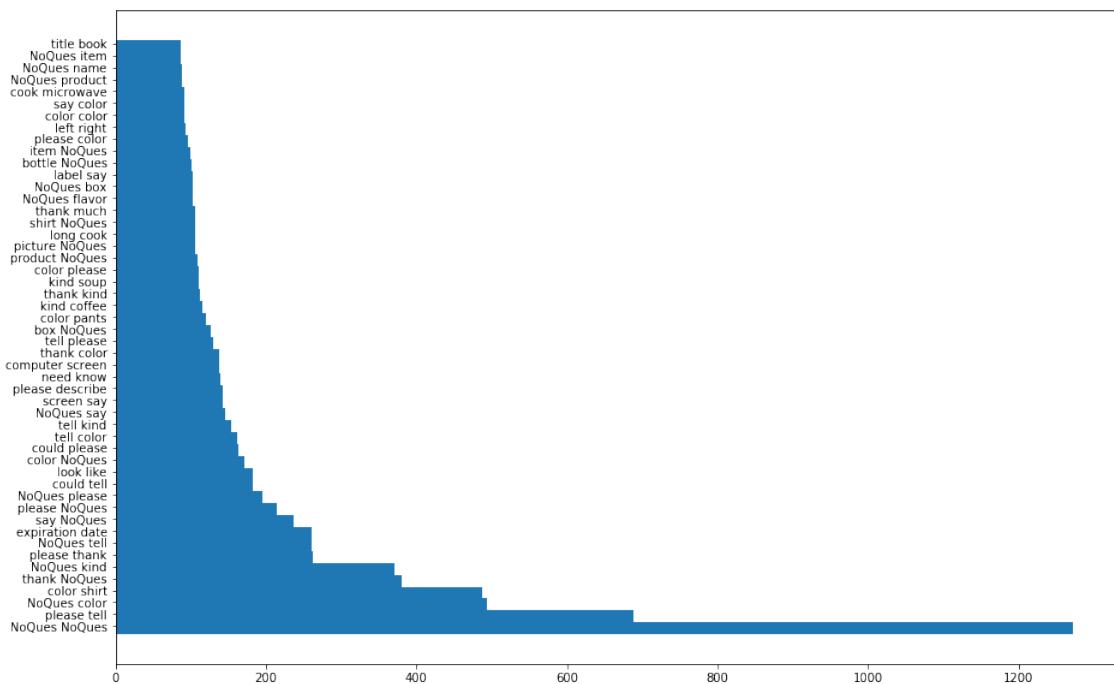
**Figure 12: Accuracy of Laplacian blur detection**



Figure 13: Privacy Implications of VizWiz  
482



**Figure 14: figure**  
Most frequently used pair of word



**Figure 15: figure**  
Most frequently used pair of interesting words

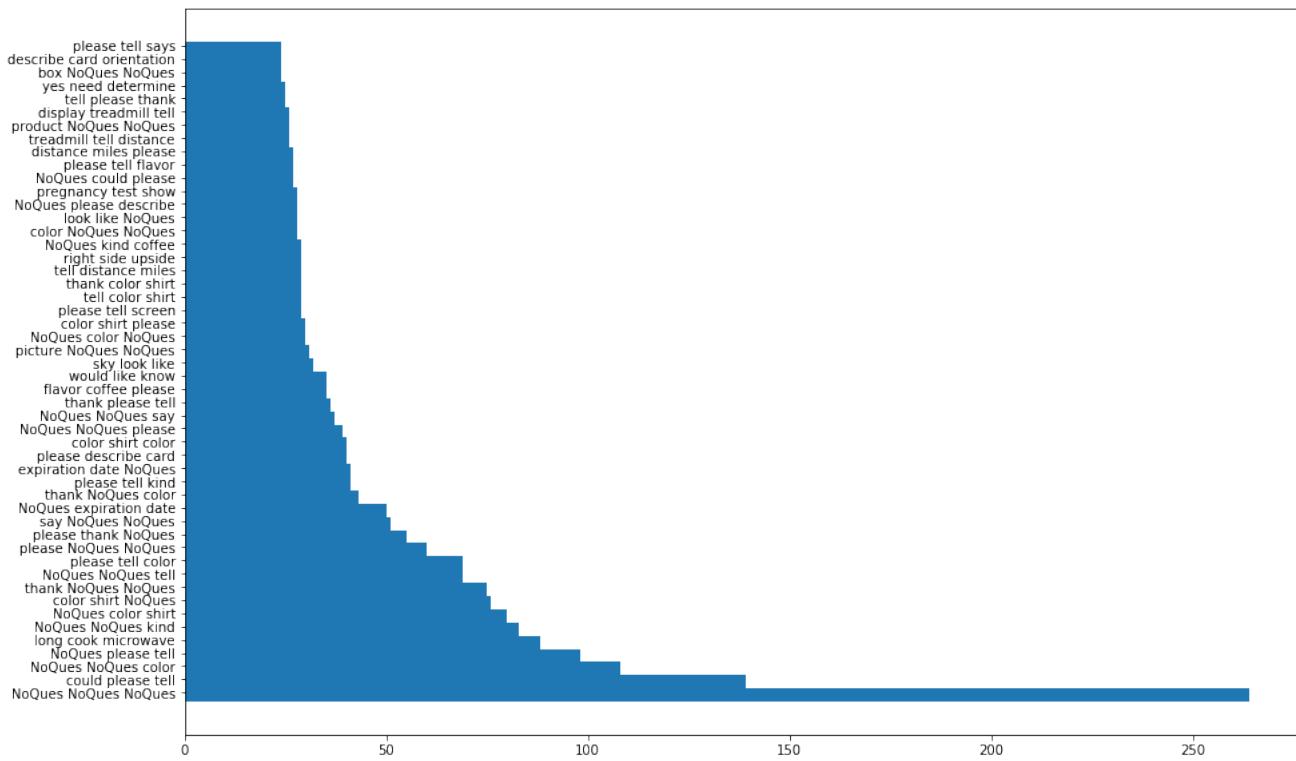


Figure 16: Most frequently used interesting words

```
bibtext report
```

---

```
This is BibTeX, Version 0.99d (TeX Live 2016)
The top-level auxiliary file: report.aux
The style file: ACM-Reference-Format.bst
Database file #1: report.bib
Warning--numpages field, but no articleno or eid field, in Bigham:2010
Warning--no journal in Brady:2013
Warning--no number and no volume in Brady:2013
Warning--numpages field, but no articleno or eid field, in Harada:2013
Warning--numpages field, but no articleno or eid field, in Jayant:2011
(There were 5 warnings)
```

```
bibtext _ label error
```

---

```
bibtext space label error
```

---

```
report.bib:108:@inproceedings {Ahmed:2016,
```

```
bibtext comma label error
```

---

```
latex report
```

---

```
[2017-12-12 20.00.00] pdflatex report.tex
This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex)
bookmark level for unknown defaults to 0.
The anchor of a bookmark and its parent's must not be the same. Added a new anchor.
Float too large for page by 51.24545pt.
Typesetting of "report.tex" completed in 1.6s.
```

---

```
Compliance Report
```

---

```
name: Ahmed, Tousif
hid: 237
paper1: 100%, October 27, 2017
```

```
paper2: 100%, Nov 6, 2017  
project: 100%, Dec 7, 2017
```

```
yamlcheck
```

---

```
wordcount
```

---

```
18  
wc 237 project 18 4961 report.tex  
wc 237 project 18 4849 report.pdf  
wc 237 project 18 598 report.bib
```

```
find "
```

---

```
passed: True
```

```
find footnote
```

---

```
passed: True
```

```
find input{format/i523}
```

---

```
4: \input{format/i523}
```

```
passed: True
```

```
find input{format/final}
```

---

```
passed: False
```

```
floats
```

---

```
43: Big data analytics could be a potential alternative. To understand  
how big data can help people with visual impairments, we need to  
understand the background first. Nowadays, people with visual  
impairments use different technologies for their problems. A wide  
range of technologies such as talking watch, braille reader,  
navigation helper are available in the market to help the visually
```

impaired in their daily tasks. Since the introduction of smartphone, smartphone based applications gained huge popularities among people with visual impairments. Now, mobile and smartphone applications like Seeing AI<sup>[1]</sup>, AiPoly<sup>[2]</sup>, LookTel<sup>[3]</sup>, and other such camera based applications are helping people with visual impairments in object recognition, face recognition, color detection, human emotion detection, activity recognition, and other such tasks that was not possible before. Figure <sup>[4]</sup> depicts an example from Seeing AI which shows that how camera based applications are helping people with visual impairments by describing nearby person's activity (Figure <sup>[5]</sup>) and their facial emotions (Figure <sup>[6]</sup>) .

```

44: \begin{figure}[tbp]
47: \includegraphics[scale=0.3]{images/facial.pdf}
49: \label{fig:facial}
53: \includegraphics[scale=0.3]{images/activity2.pdf}
55: \label{fig:ios}
59: \label{fig:seeingai}
83: \item \textbf{response}: Each question can have multiple responses. As mentioned earlier, some questions were tried to answer using the IQ engine and some questions were sent to the web workers. For each question, there can be one to 11 responses. However, on average three responses were received. The distribution of the responses shown in Figure[7]. From the figure, we can see that most of the questions either received three or four responses.
84: \begin{figure}![ht]
85: \centering\includegraphics[width=\columnwidth]{images/r_count.png}
87: \label{f:response count}
105: \begin{figure}[hbp]
108: \includegraphics[width=\columnwidth]{images/uni_all.png}
110: \label{fig:uni_all}
114: To understand the challenges, we first calculated the frequency of the words. There are around 4500 unique words in the questions. The most frequent 50 words is shown in Figure[8]. If we closely examine the words, we can see that the most frequently used word is \emph{'what'}. \emph{'What'} appeared 22793 times which is approximately 70\% of all of the worlds. The second and third most frequent words are 'this' and 'the'. Since, this is a set of questions, therefore, all the above words are justifiable. Although, 'what' is somewhat giving us an indication that users are asking about objects or subjective questions mostly, 'this and 'the' is not adding that much value. Next, we performed the same analysis by removing the most commonly used words in English. That unigrams

```

gave us some additional insights. The list of most frequently used interesting words can be found in Figure `\ref{fig:uni_int}`. If we remove the commonly used words, then for the majority of the questions had no questions. Those questions were asked by just uploading the photos. We assume that the users thought that the app could automatically answer those questions. Other three most frequently used words are 'color', 'tell', and 'please'. Among these three the most interesting is 'color'. Combination of 'what' and 'color' indicates that people with visual impairments faces issues with color detection, and often they ask the workers about the color of the objects and items. Therefore, we found `\textbf{color detection}` problem of people with visual impairments from the analysis. If we just consider the nouns and pronouns from the 30 most frequently used words, we find 'box', 'picture', 'color', 'screen', 'shirt', 'bottle', 'flavor', 'brand', 'coffee', 'label', and 'product'. From this keywords, we can safely assume three other problems: they face issues with screens (screen), there are issues with objects (brand), and the users face issues with reading labels. Therefore, from the initial analysis we found four problems that people with visual impairments regularly face: `\textbf{color detection}`, `\textbf{object detection}`, `\textbf{reading screens (mobile/computer)}`, and `\textbf{reading labels}`.

```

116: \begin{figure}[hbp]
119: \includegraphics[width=\columnwidth]{images/int_count.png}
121: \label{fig:uni_int}

126: After checking the most frequently used words, we explored the most interesting pairs of words. If we check the bigrams (Figure \ref{fig:bi_all} and \ref{fig:bi_int} in Appendix), it gives confidence of our identified problems. The most frequently used two words are 'what' and 'this' which suggests that most questions were asked to identify the object. Therefore, people with visual impairments definitely face problems with detecting objects. 'What' and 'color' also suggests that users face color detection problem frequently. If we check the bigrams of most frequently used interesting words (Figure \ref{fig:bi_int}), we find some additional insights. If we ignore 'NoQues', then we again see color detection and computer screen reading problem. However, now we can find another interesting pairs of words 'look' and 'like'. This pair indicates a subjective question, where the user is asking how the user is looking like. This identifies another challenges of people with visual impairments \textbf{Impression Management}. Another interesting common pair of words are 'long' and 'cook' which indicates reading label issues, however this can be a household activity issue. The trigrams also gave us some new interesting insights (Figure

```

`~\ref{fig:tri_int}).` Most of the trigrams confirms above mentioned challenges, however, there are some new issues. One interesting trigram is ‘display’, ‘treadmill’, and ‘tell’ which indicates the health fitness related issues or `\textbf{Health Management}` Issue. Due to the accessibility issues in health monitoring and fitness monitoring issues, they can not manage health effective. Therefore, the users often seek help for reading the display. Another interesting three words are ‘pregnancy’, ‘test’, ‘show’ which can also be put into health Management category. However, this seems a private information, but still people with visual impairments have to share this information due to their visual challenges.

- 132: `\subsubsection{Object Detection:}` The most frequently asked question in VizWiz is ‘What is this’ or ‘What is that’. ‘What’ appeared more than 22,000 questions. Among those 22,000 questions around 7,000 questions are ‘What is this?’ and ‘What is that?’. People asks variety of object detection questions ranging from everyday objects to personal objects. Some examples of object detection problem is shown in Figure `~\ref{fig:object}`. By manually analyzing some photos, it seems most of them are related to household activities. Therefore, with better tools it is possible to detect the objects.
- 133: `\begin{figure}[hbp]`
- 136: `\includegraphics[scale=0.3]{images/object_1.pdf}`
- 140: `\includegraphics[scale=0.3]{images/object_2.pdf}`
- 144: `\label{fig:object}`
- 149: `\subsubsection{Color Detection:}` Another most frequent problem that people with visual impairments face is to detect colors. Most of the time they use VizWiz to identify colors of their cloths, items, foods, and others. Some examples of color detection is shown in Figure `~\ref{fig:color}`. Based on the images, automatically detecting the colors seems a challenging task. Because, if we examine figure `~\ref{fig:color}` we can see in the image there can be other objects. Automatically detecting the object of interest will be difficult. For example, in the right most photo the user is asking about the color of the dress in hand, however, there are other objects visible in the photo. Therefore, identifying the color automatically will be challenging.
- 150: `\begin{figure}[hbp]`
- 153: `\includegraphics[scale=0.3]{images/color_1.pdf}`
- 157: `\includegraphics[scale=0.3]{images/color_2.pdf}`
- 160: `\includegraphics[scale=0.3]{images/color_3.pdf}`
- 164: `\label{fig:color}`
- 167: `\subsubsection{Reading Screens:}` Nowadays, people with visual impairments use smartphones and computers. They use screen

reading software which generates synthesized speech to relay the information from screen. However, some times these software fail and visually impaired need to seek help from crowd workers.

Another issue is the accessibility issues of CAPTCHA, people with visual impairments struggles with CAPTCHA. Therefore, they seek people who can read the CAPTCHA for them. Some examples of reading screen problems are shown in Figure~\ref{fig:screen}.

```
168: \begin{figure}[hbp]
171: \includegraphics[scale=0.3]{images/screen_1.pdf}
175: \includegraphics[scale=0.3]{images/screen_2.pdf}
180: \label{fig:screen}
183: \subsubsection{Reading documents or labels:} Another obvious challenges of people with visual impairments is reading documents. The paper documents are not often accessible and people need help from others to read that. People might use scanners to read documents, however, scanning documents can be time consuming. Especially, for scanning food or medicine labels can be difficult. Therefore, participants seek help to read labels for them. Figure~\ref{fig:reading} shows some examples of reading issues. However, there can be potential score for technology for this types of problem. If the user is asking for reading helps, a simple OCR can help. However, OCR might not work well with food labels. One suggestion could be for food related reading question, the system could look for barcode and identify necessary information.
184: \begin{figure}[hbp]
187: \includegraphics[scale=0.3]{images/reading_1.pdf}
191: \includegraphics[scale=0.3]{images/reading_2.pdf}
194: \includegraphics[scale=0.3]{images/reading_3.pdf}
199: \label{fig:reading}
202: \subsubsection{Impression Management:} Based on the analysis, we explored that managing impressions can be challenging. As a social norm, we often present our better selves to others by wearing consistent dresses. For example, we do not want to present ourselves in social places in such way that may misrepresent ourselves. Some words that we found in the questions are ‘look’, ‘like’ which we assume that users are asking to understand their appearance. Therefore, impression management for people could be challenging. Sometimes, the questions can be appearance related. Some examples of impression management challenges is shown in Figure~\ref{fig:impression}.
203: \begin{figure}[hbp]
206: \includegraphics[scale=0.3]{images/impression_1.pdf}
210: \includegraphics[scale=0.3]{images/impression_2.pdf}
215: \label{fig:impression}
218: \subsubsection{Health Management:} Health management is important
```

for everyone. However, people with visual impairments face lot of challenges to maintain healthy behavior. They struggles to cook, therefore, they need to eat outside or eat packaged foods. They can not read the package's well, so miss the nutrition info.

Managing medicine can be issue. Some other issues can be attributed to visual representation of results. For examples, weight scales show visual weights, pregnancy scales convey visual feedback, health monitoring instruments like treadmill convey visual information. All these visual information makes it difficult for managing health issues. Therefore, health management can be challenging. For that reasons, people with visual impairments often ask such applications to help them with various visual indicators in health and fitness. Figure `\ref{fig:health}` shows three different health realted issues of people with visual impairments. Figure `\ref{fig:pill}` depicts the issues of medicine management, users often can not identify the required medicine. Figure `\ref{fig:preg}` shows asking the result of pregnancy test, which can be sensitive.

Figure `\ref{fig:weight}` asking questions about the weight of the user. Since, such applications can forward these questions to friends and family members all these images can be sensitive. However, technology can potentially address this issue by automating the responses.

```
219: \begin{figure}[hbp]
222: \includegraphics[scale=0.2]{images/health_1.pdf}
224: \label{fig:pill}
228: \includegraphics[scale=0.2]{images/health_2.pdf}
230: \label{fig:preg}
233: \includegraphics[scale=0.2]{images/health_3.pdf}
235: \label{fig:weight}
239: \label{fig:health}
244: \begin{figure}[hbp]
247: \includegraphics[scale=0.15]{images/blurry.jpg}
249: \label{fig:blur}
253: \includegraphics[scale=0.25]{images/poor_f.pdf}
255: \label{fig:pf}
258: \includegraphics[scale=0.25]{images/off_focus.pdf}
260: \label{fig:off}
264: \label{fig:photo}
266: Figure \ref{fig:photo} depicts the some not understandable photos taken by people with visual impairments. However, such images takes resources and often cost money. If the system can early detect such images and prevent those images from sending then it can save resources. Misplaced or blurry photos can be early detected. Another potential scope of technology is to automatically fix the blurry images.
```

```

281: \subsubsection{Identifying a good threshold} We run the algorithm
      with various thresholds. The F1 score graph against various
      thresholds did not improve the accuracy. Figure
      \ref{fig:accuracy} shows the accuracy of blur detection.
282: \begin{figure}[hbp]
285: \includegraphics[width=\columnwidth]{images/f1.png}
287: \label{fig:accuracy}
297: Another potential privacy threat can be arose from the inability
      to know what is in the picture. The user can mistakenly capture
      sensitive photos and share it with the web workers. The
      bystanders of such devices are also in risk, because they can
      also inadvertently captured by the user and shared with the crowd
      workers. One such example is shown in Figure \ref{fig:privacy}. If
      we check the figure, we can see that a bystander is present in
      the picture. The question asked for this question was ‘What is
      this?’. We can assume that the user probably was trying to detect
      an object but took a photo of nearby person. Similar privacy
      leakage can happen with credit cards, and other sensitive
      information. Photos can be shared in error. Therefore, such
      systems should consider such implications and should take extra
      precaution to reduce such incidents.
298: \begin{figure}[tbp]
301: \includegraphics[width=\columnwidth]{images/private_1.pdf}
303: \label{fig:privacy}
327: \includegraphics[scale=0.45]{images/bigram_all.png}
329: \label{fig:bi_all}
336: \includegraphics[scale=0.45]{images/bigram_interesting.png}
338: \label{fig:bi_int}
346: \includegraphics[scale=0.5]{images/trigram_interesting.png}
348: \label{fig:tri_int}

```

```

figures 13
tables 0
\includegraphics 28
labels 24
refs 13
floats 13

```

```

True : ref check passed: (refs >= figures + tables)
False : label check passed: (refs >= figures + tables)
False : include graphics passed: (figures >= \includegraphics)
False : check if all figures are referred to: (refs >= labels)

```

```

Label/ref check
passed: True

```

```
When using figures use columnwidth  
[width=1.0\columnwidth]  
do not change the number to a smaller fraction
```

```
find textwidth
```

---

```
passed: True
```

```
below_check
```

---

```
bibtex
```

---

```
label errors
```

```
bibtex errors
```

```
This is BibTeX, Version 0.99d (TeX Live 2016)  
The top-level auxiliary file: report.aux  
The style file: ACM-Reference-Format.bst  
Database file #1: report.bib  
Warning--numpages field, but no articleno or eid field, in Bigham:2010  
Warning--no journal in Brady:2013  
Warning--no number and no volume in Brady:2013  
Warning--numpages field, but no articleno or eid field, in Harada:2013  
Warning--numpages field, but no articleno or eid field, in Jayant:2011  
(There were 5 warnings)
```

```
bibtex_empty_fields
```

---

```
entries in general should not be empty in bibtex
```

```
find ""
```

---

```
passed: True
```

ascii

---

---

=====  
The following tests are optional  
=====

Tip: newlines can often be replaced just by an empty line

find newline

---

passed: True  
cites should have a space before \cite{} but not before the {

find cite {

---

passed: True

# Big Data in Genomics and Medicine

Matthew Durbin, MD FAAP

Indiana University School of Medicine Department of Pediatrics

Division of Neonatology Riley Hospital for Children

699 Riley Hospital Drive

Indianapolis, Indiana 46202

mddurbin@iu.edu

## ABSTRACT

The entirety of the human genome was sequenced in 2003, ushering in a new era of molecular biology, genetics and medicine. Since that time, technologies have advanced significantly, and next generation sequencing allows increasingly rapid and affordable sequencing of the entire human genome. Beyond the human genome, we can also sequence the entire RNA transcriptome, proteome, and metabolome. We can compare these entities in health and disease, and across populations. These new technologies produce massive datasets. Big Data applications and analytics allow interpretation and utilization of these data sets. However, analyzing and interpreting these datasets lags behind sequencing technology, as the rate limiting step. Still these technologies hold great potential for advancing medicine and human health. Combining this omics data with the electronic health record, wearable technology, pharmaceuticals and procedures, moves us towards personalized, precision, medicine.

## KEYWORDS

i523, hid311, Big Data, genomics, genetics, species reintroduction, environment, conservation

## 1 INTRODUCTION

### 1.1 Health and Genomics

The current state of healthcare system in the United States is often described as a crisis. The term comes with good reason, as spending accounts for 17-18% of GDP, dwarfing other nations, and is exponentially rising at an unsustainable rate. For all of our spending, we have poorer health than most developed and many developing nations. The healthcare industry is behind in technology, with recent adoption of an electronic medical record, and prior reliance on paper charting. Communication is most often by decades old technology including phone or fax. Internet communication between healthcare providers, and with patients, is a recent novelty. We have the poorest health, including obesity due to poor diet, lack of exercise, and substance abuse. We pay more for pharmaceuticals than any other country, and most pharmaceutical budget goes to marketing as opposed to research and development. To determine a familial or genetic risk for disease we mostly rely on patient interview.

Big Data has major potential to impact health. Massive data sets related to human health and genomics are compiled by insurance companies, pharmaceutical companies, public health institutions and research institutions. [6] Healthcare is making strides and big data collection is visible everywhere. The electronic medical record EMR is close to universal and is improving constantly. Medical

resources are accessible around the world through smartphones. Wearable technology and fitness tracking apps, nutrition apps are improving personal health. One of the biggest potential impacts to health comes with the advances in next generation sequencing and genomics. These new technologies allow us to determine genetic disease risk, determine prognosis, and predict response to pharmacology and other treatment, all by measuring the genetic code. The most powerful application will be to combine genomic data with the data generated from the EMR, wearable technology, model systems, etc. to develop personalized medicine strategies.

### 1.2 The Genetic Code

For centuries we have known much disease is heritable. Taking a thorough family health history via patient has been a mainstay of medical interview. Previously the medical provider merely noted ailments that ran in families and maintained vigilance in subsequent generations. All of that changed in 1953 when James Watson and Francis Crick reported the molecular structure of Deoxyribonucleic acid, or DNA [27]. DNA is a relatively simple structure is made up of four nucleotides, adenine, guanine, cytosine and uracil on a carbohydrate background. Different triplicate combinations of these four nucleotides, code for 20 amino acids, and these 20 amino acids make up every protein in all living things. This relative simple system is called the genetic code. Much like the 0's and 1's in computer code, giving rise to the complexity of the internet, the genetic code gives rise to the complexity of all living things. Each organism has a unique genetic code, and this molecular blueprint is utilized to create their protein, carbohydrate, lipid structure. Furthermore this DNA code is replicated, blended through reproduction, and passed to future generations. This genetic code is often interrupted in disease such as cancer. Differences in the genetic code lead to differences in disease susceptibility, and treatment response. The human genome refers to humans over 3 billion nucleotides. We have the ability to sequence the human genome, or determine the order of these nucleotide bases.

### 1.3 The Human Genome

The first human genome was sequenced in 2003 [3]. This colossal global effort took over 10 years and thousands of scientists working at great expense. In the end, a private and public group collectively sequenced the first genome. Initially, the technology was extremely expensive and took great deal of time. Through technological advancements including sequencing cores and big data, the cost of the genome has plummeted. The 1000-dollar genome project is an attempt to make sequencing more affordable [6]. We are a long way away from being able to utilize the genome to deliver care.

Bioinformatics expertise has lagged behind sequencing technology. Groups still do not agree on a standard way to process the information. Still this technology improves rapidly, and recently a group published 24-hour genome sequencing for intended use in clinical decision making [19]. Soon it may be a reality for physicians to utilize genomic information, whether about drug susceptibility, or prognosis, to guide medical care. Here we review the methods to assess genetic changes. We discuss issues that present with each method.

## 2 GENOME ANALYSIS

### 2.1 Chromosome Analysis

Historical mainstays to assess changes in the human genome include a method known as a karyotype analysis. A karyotype visualizes the 23 chromosomes that contain our genetic information. Aneuploidy is duplication of a chromosome. Trisomy 21 is a well known syndrome characterized by duplication of the 21st chromosome. Duplication or deletion of all other chromosomes is not compatible with life. However, portions of chromosomes can be duplicated or deleted, giving rise to well known syndromes. Karyotype analysis is capable of visualizing large deletions and duplication in chromosomes, generally greater than 10Mb. Chromosome analysis has been largely surpassed by newer technologies. Given established use and accessibility, it may have a clinical role in rapidly confirming a suspected aneuploidy.

### 2.2 Fluorescent In Situ Hybridization

Fluorescent In Situ Hybridization utilizes fluorescent labeled probes to identify portions of DNA which match the probe sites. In this way the chromosomal material can be visualized. Fluorescent In Situ Hybridization can identify chromosomal duplication and deletions up to 2MB. This is helpful, to identify large duplication's and deletions leading to disease. However we know even single nucleotide changes lead to disease. Therefore Fluorescent In Situ Hybridization has been replaced by other technologies [2].

### 2.3 Genome Wide Association Studies

Historically research has focused on aneuploidy and syndromes representing large duplication or deletion of genetic material, or on single gene mutations leading to disease. However pathogenesis likely involves multiple common and rare single nucleotide variants (Single nucleotide variation) in parallel leading to most disease. Genome Wide Association Studies emerged to study common variants on large scale, and studies have showed multiple susceptibility loci. However, Genome Wide Association Studies failed to identify all forms of genetic disease [24].

### 2.4 Copy Number Variation

A large part of the human genome consists of repetitive sequence, including both long and short repeated segments. There are distinct regions that vary in the number of repeats between individuals, and this variation leads to phenotypic differences between these individuals. This variation is referred to as copy number variation (Copy Number Variation). It is thought that up to 10% of the genome consists of Copy Number Variation. Most Copy Number Variation is inherited but it can also occur de-novo. Copy Number

Variation is increasingly understood as contributing to disease, where varying amounts, or doses, of a particular gene and therefore protein lead to disease [32].

### 2.5 Chromosomal Microarray

Chromosomal microarray is the baseline genetic testing for individuals with disease. Chromosomal Microarray is a technology that detects the presence or absence of patient DNA by measuring hybridization of patient sample to small segments of DNA attached to a surface. Chromosomal Microarray detects deletions and duplications of chromosomal material much smaller than FISH and karyotype. As technology improves, Chromosomal Microarray is able to detect increasingly small changes down to, but excluding, Single nucleotide variation. As many common diseases are due to Single nucleotide variation, sequencing is often necessary. [26]

### 2.6 Sanger Sequencing

In 1977 a paper was published entitled "A rapid method for determining sequences in DNA by primed synthesis with DNA polymerase". This technique, now known as Sanger sequencing, revolutionized molecular biology. Using termination of sequence and dye detection, it provided a fast and easy way to determine the DNA sequence of living organisms. It is still extensively utilized. Many newer technologies have been developed and are known as "next generation sequencing." [20]

### 2.7 Next Generation Sequencing

Next Generation Sequencing refers to a variety of technologies and a number of different methods for high throughput sequencing of DNA samples [16]. The technology utilizes massive number of parallel sequencers to copy short fragments of DNA and assemble transcripts utilizing big data and bioinformatics techniques. According to the illumina website "With its unprecedented throughput, scalability, and speed, next-generation sequencing enables researchers to study biological systems at a level never before possible."

### 2.8 Targeted Gene or Gene Panel Sequencing

Disease is often due to Single nucleotide variation necessitating sequencing for diagnosis. Targeted sequencing is commercially available to detect Single nucleotide variation in a specific gene, or an entire panel of genes, often depending on the disease. Gene panels are available for particular syndromes. Commercial panels utilize both traditional sanger sequencing and NGS technology. Targeted sequencing often provides better coverage of specific genes than does Whole Exome Sequencing. This targeted sequencing circumvents the significant burden of analyzing thousands of variants of unknown significance, a problem inherent to Whole Exome Sequencing, but misses variants in genes outside of the panel, or in novel genes.

### 3 NEXT GENERATION SEQUENCING

#### 3.1 Whole Exome Sequencing

With advancements in technology, exome sequencing is approaching the affordability and efficiency of targeted gene panel sequencing. Whole exome sequencing involves sequencing the entire coding region, or exome, of the genome. This consists of around 20,000 genes and over 30 million nucleotides. The exome, though massive, consists of only 1% of the total genomic DNA. Most genetic diseases involve alteration of this coding exome. Sequencing only 1% of the genomic material is a fraction of the time, cost, and burden of analysis, compared with Whole Genome Sequencing. Due to errors in Whole Exome Sequencing, a portion, (up to 1%), of the coding exome is missed. Coverage varies by gene and by region, with particular genes of interest, such as the HRAS gene implicated in Costello Syndrome, difficult to capture by Whole Exome Sequencing at all. Copy Number Variation, insertions, and deletions are also difficult to detect. Targeted sequencing is often advantageous, but Whole Exome Sequencing is improving and is increasingly accessible to clinicians [30].

#### 3.2 Whole Genome Sequencing

Despite the massive amount of information produced in Whole Exome Sequencing, it represents only 1% of the total genome. Transcription enhancers and promoters, often involved in disease pathogenesis, are outside of the exon and missed by Whole Exome Sequencing. In addition, Whole Genome Sequencing better captures Copy Number Variation, insertions and deletions, frequently involved in disease. Whole Genome Sequencing adds significantly to expense, data storage, analysis, and the burden of determining variant significance. For this reason Whole Genome Sequencing is predominantly used in the research setting, but this is changing. In 2012 a group used rapid Whole Genome Sequencing in the newborn ICU to identifying disease causing pathologic variants. The process, from sample collection to automated bioinformatics analysis, was complete within in 48 hours. This rapid turnaround was intended as a model for utilization of Whole Genome Sequencing in clinical decision making. As technology improves Whole Genome Sequencing will likely become a useful clinical tool [13].

#### 3.3 Variants of Unknown Significance(VUS)

Whole Exome Sequencing produces tens of thousands of variants, and Whole Genome Sequencing exponentially more. Another major hurdle is determining significance. Each variant must be assessed for disease pathogenesis, distinguishing it from a previously unreported polymorphism. Variants can be filtered for pathogenic nature based on conservation across populations and location in a protein. It is often necessary to obtain parents samples and perform sequencing on patient-parent trios to determine novelty. When a novel variant is identified, ideally biologic mechanism is investigated through animal and cell culture models. Genetic variation can now be introduced into animal and cell culture models with greater ease and efficiency utilizing the CRISPR-Cas9 system. Variants are often damaging only in conjunction with other variants. In some cases it is impossible to narrow down a single candidate when a

disease with incomplete penetrance and variable expressivity affects a small family. Efforts are ongoing to improve and streamline variant analysis for clinical utilization [14].

### 4 BEYOND DNA

Initial estimates placed the number of genes at  $\approx 100,000$  [1]. Looking at the massive amount of diversity and the billions of unique human beings on this earth, this was an appropriate estimate. The current number is estimated somewhere around 20,000. The question is what accounts for the rest of phenotypic diversity and disease. The picture of development is complex with networks of genes turned on and off at different locations and timepoints. Regulation of this process occurs to some extent outside of the coding region, through promoters and enhancers, epigenetic alterations, splicing variation, and noncoding RNA. Altered noncoding sequence is increasingly implicated in disease. The human genome project utilized whole exome sequencing. The exome, though massive, consists of only 1% of the total genomic DNA. Many genetic diseases involve alteration of this coding exome but we are discovering that many diseases are due to problems outside of this coding region. Whole genome captures this noncoding region, although with far greater cost, burden of analysis, etc. We have also come to realize that splicing and other post transactional regulation introduces much diversity. We have the technology to sequence the entire RNA transcriptome and the proteome as well. This produces a data set which dwarfs the genome and genomic DNA sequence information. These technologies are currently only utilized in the research setting. Despite our advanced technology, we have very little idea of how to interpret the data in a clinical setting. Again the bioinformatics expertise lags behind. There is amazing potential to advance knowledge and study human disease and a tremendous amount of big data analytics along the way.

#### 4.1 RNA Sequencing

Splicing variation leads to multiple different proteins resulting from a single gene due to differential splicing during transcription. Non-coding RNA also influences expression and modifies proteins after translation. Technologies to examine the elements, include Whole Genome Sequencing to measure DNA outside of the exome, RNA sequencing to measure the splice variants and the transcriptome, and ChIPSeq to measure DNA methylation. These noncoding regulatory elements have important clinical implications, and need further exploration. [25]

#### 4.2 Epigenetic Sequencing

Mutations in transcription factors are well established in pathogenesis and regulation is often through enhancers and promoters outside of the coding sequence. The term epigenetics refers to alterations outside of, or on top of, the genetic material or DNA, that influence phenotype. Common epigenetic factors include DNA methylation, where methylation of DNA bases represses DNA expression, and also histone modification, where the degree to which DNA is wrapped around histones influences its expression. Epigenetic factors are heritable, and also influenced by the environment. [11]

### 4.3 Proteome

Ultimately DNA codes for RNA and RNA is translated into proteins. Proteins are the building blocks of all living things. The proteome is the term for the entire protein content of an organism. New technologies allow us to measure the proteome. The proteome is generally measured through tandem mass spectroscopy or finger-printing. Tandem mass spectroscopy breaks proteins into smaller portions and measures a signature and electrophoresis techniques involve separating proteins on a gel and measuring their fingerprint. These techniques require sophisticated chemistry and data analysis techniques and produce massive datasets. [8]

### 4.4 Metabolome

The Metabolome involves the entire set of small molecules within an organism. Analyzing the metabolome involves measuring every amino acid, organic acid, vitamin and mineral in a cell, tissue or organism. Measurement is usually by mass spectroscopy or nuclear magnetic resonance spectroscopy. requires extensive data analysis.

## 5 OTHER GENOMICS TOOLS

Sequencing technology is not the only factor revolutionizing personalized medicine. There is a separate and equally exciting revolution in cell culture technology integral to personalized medicine. All of these technologies rely on genomics measurements that produce massive datasets and rely on Big Data for analysis.

### 5.1 Model Systems

The optimal diagnosis and treatment of pediatric disease requires an understanding of physiology and pathophysiology. Throughout medical research history animal and cell culture models have been critical to this process. Mouse models, in particular, are extensively utilized because they are relatively convenient, and similar to humans at the chemical, molecular, cellular, and some anatomic levels. Furthermore, the use of transgenic mice allows for genetic manipulation to help elucidate molecular mechanisms. However, given that mice and humans diverged millions of years ago, there are critical physiological differences between the two species. Human diseases often lack a mice ortholog. The equivalent disease in mice may be fatal or benign, and we cannot model some high level human organ functions or late onset diseases. Even non-human primates, despite being our closest ancestors, have important phenotypic differences. For example, because of these differences, it is particularly difficult to develop animal models for neurodegenerative or neurodevelopmental disorders. Differences in mouse disease morphogenesis have led difficulty modeling human congenital heart disease. These limitations drive the need for human cell, tissue, and organ systems models. Many human diseases involve terminally differentiated cell types, such as neurons and cardiomyocytes. These cell types are nearly impossible to sample, culture, and maintain. Even after generating primary cell lines from diseased tissues, ability to derive meaningful conclusions is often hampered by inconsistent replicability, dedifferentiation, and variability due to culture conditions. In this light, tissues derived from human induced pluripotent stem cells (h induced pluripotent stem cellss) has the potential to overcome many inherent limitations of animal and cell culture models

and provide an unprecedented new paradigm to model human diseases.

### 5.2 Pluripotent Stem Cells

During human embryogenesis, the ovum and spermatozoa fuse at fertilization, begin to divide, and differentiate into all cell lineages and tissue types in the human body. During development, these cells lose their pluripotency as they terminally differentiate into specific cell types. Embryonic stem cells (ESC) were first isolated from the blastocyst of developing mouse embryos in 1981, and from human embryos in 1998 [17]. These cells have the remarkable ability to retain pluripotency. The ESC discovery generated great excitement over their potential applicability in human disease modeling and regenerative therapies. However, limitations and controversies soon emerged. The isolation of ESCs from human embryos is ethically controversial. Disease models utilizing ESC are limited to diseases identified through preimplantation genetic diagnosis. Genome editing ECSs provides an opportunity to generate particular mutations of interest, but technique remains largely limited to monogenic diseases. In this light, recent breakthroughs in induced pluripotent stem cell ( induced pluripotent stem cells) technology circumvent many of these drawbacks.

### 5.3 Induced Pluripotent Stem Cells

In 2006, Shinya Yamanaka identified four transcription factors, (OCT4, SOX2, KLF4, and c-MYC), that were capable for reprogramming somatic mouse cells into a pluripotent state [22]. This extraordinary feat was recapitulated one year later in human cells. These induced pluripotent stem cells ( induced pluripotent stem cellss) behave like ESCs with capability to differentiate to most other cell types, and circumvent the ethical controversy and sample limitations. As opposed to human embryos, induced pluripotent stem cellss can be generated from readily accessible tissue samples, such as peripheral blood mononucleated cells (PBMCs). Patient samples can be reprogrammed to induced pluripotent stem cellss, serving as an autologous, continuously renewing supply of pluripotent cells. This has resulted in the dramatic expansion of the stem cell field, with development and improvements in reprogramming protocols, and directed cellular differentiation. Patient-specific induced pluripotent stem cellss can be generated from wide variety of patient samples, including PBMCs from blood samples, to dermal fibroblasts from punch biopsies, and epithelial cells from urine samples. induced pluripotent stem cellss can then be differentiated to most other cell types including cardiomyocytes, neurons, and hepatocytes. Because the lines are patient-specific, they are expected to recapitulate features of many disease phenotypes, whether due to simple monogenic mutations or complex polygenic disease susceptibilities. The patient-specific induced pluripotent stem cellss hold potential for disease modeling, predicting drug response, assessing environmental triggers of diseases, and regenerative tissue engineering. Thus, they provide great potential for research and clinical applications in personalized medicine.

## 5.4 Gene Editing induced pluripotent stem cellss

Mouse models allow genetic alteration using transgenesis and gene knock-outs. Measuring the resulting phenotype is extremely valuable in the study of genetics and development. induced pluripotent stem cellss allow us to utilize these same genetic approaches using human cell lines. The past decade has seen tremendous advances in gene editing technology, including ZFNs (zinc finger nucleases), TALENs (transcription activator like effector nucleases), and CRISPRf?Cas9 (clustered regularly interspaced short palindromic repeat) [21] [10]. The common mechanism of these genomic editing approaches is that they create double stranded breaks (DSBs) at desired locations in the genome, which then can be repaired by either nonhomologous end-joining (NHEJ) that can result in insertion/deletions (indels) or homology directed repair (HDR), which results in precise gene modifications. Of these, the CRISPR-Cas9 technology, which appropriates the prokaryote defense mechanism, has quickly become dominant due to ease with which it can be adapted to precisely edit virtually any region in the host genome. Genome editing, coupled with the induced pluripotent stem cells technology, allow us to study disease mechanism like never before. These technologies allow us to precisely correct mutations, and insert reporters under the endogenous regulatory control. They have also been used to demonstrate feasibility of genomic editing as a therapeutic modality. Recently, a group corrected a pathogenic mutation in preimplantation human embryos, demonstrating the feasibility of gene correction therapy. While still a long way from clinical applications, many disease phenotypes have been corrected in cell culture. These studies show the potential of these powerful technologies for disease modeling, and for therapeutic genome engineering.

## 5.5 Organoid Models

Sometimes a simple, two-dimensional induced pluripotent stem cells-derived tissue culture model cannot fully recapitulate complex organ systems involving three dimensional (3D) architecture; such cases necessitate organoid modeling. In vitro organogenesis, the exciting new frontier in in vitro disease modeling, aims to organize induced pluripotent stem cellss into 3D structures that better recapitulate in vivo physiology. Previous attempts at organoid modeling utilized primary tissue cells, but primary cells are difficult to obtain and often fails to propagate in vitro. In principle, induced pluripotent stem cellss are an ideal cell source to make tissue organoids. The most comprehensive organoid model to date involves a fully vascularized and functional human liver. A 3D gastric organoid was created that progresses through developmental stages adopts similar architecture to the stomach. This organoid provided valuable insights into the gut development, as well as H. Pylori infection. Human induced pluripotent stem cellss were grown also on rat intestinal matrix, to engineer a humanized intestinal graft for nutrient absorption in patients with short bowel syndrome. The established protocol for generating 3D cerebral organoids from induced pluripotent stem cellss, replicates brain developmental stages. The organoid reproduces a variety of brain structures, including the cerebral cortex, ventral telencephalon, choroid plexus

and retina. Manipulating specific developmental signaling pathways in ventral-anterior foregut spheroids recently generated an induced pluripotent stem cells-based human lung model. Lastly, an induced pluripotent stem cells-based human kidney organoid model was recently developed displaying glomerulus-like structures and renal tubules. Future in vitro organogenesis effort must address the need for chemically defined synthetic extracellular matrices, and incorporation of support cell types such as interspersed neurons, immune cells, and other regulatory cells. While the regenerative medicine field is still in infancy, transplantation of functional tissues derived from patient's own cells could profoundly improve the health of patients with end-organ failure. [15]

## 6 BIOINFORMATICS

Each of the steps in analyzing disease models relies heavily on bioinformatics and big data analytic. Bioinformatics is the field combining computer science, biology, mathematics, medicine, engineering, etc. [18] When Watson and Crick first identified the DNA structure, discover quickly led to the DNA coding mechanism and the interpretation of sequencing information. The interpretation and analysis of sequencing data was very amendable to computer science. We began to sequence and interpret larger datasets including entire genes, entire chromosomes, the entire human exome, the entire human genome, and now the entire transcriptome and metabolome. Further we need to compare these large datasets to one another. Bioinformatics has gone far beyond sequence analysis to involve image analysis, mass spectroscopy, and countless other integration between biology and computer science. there are also distinct field of Biomedical informatics, which refers more specifically to the integration of computer science and medicine. This often involves running multiple subsequent computer programs in established pipelines. Projects like the Galaxy project work to streamline these pipelines for ease of use. We will discuss some common applications of bioinformatics.

### 6.1 Sequence Assembly

Sequencing technologies produce millions of fragments of DNA. Sequence assembly is the process of identifying overlapping sequence, aligning the overlapping portion and combining into a complete genome. Once the genome is assembled it is possible to compare a sample of DNA to a known sequence in a database. One of the most popular tools involves the program Basic Local Alignment Search Tool(BLAST.) Scientists can input any obtained sequence and check for matching to a known sequence in the database.

### 6.2 Sequence Annotation

Sequence annotation involves identifying the important regions in a sequence. It includes identifying the regions that code for proteins, regulatory regions, and other biologically significance sequence. It is performed by popular programs such as

### 6.3 Comparison of two states

Another set of software tools involves the comparison of two datasets. This includes the comparison of two disease states, two individuals, or any other two datasets that need comparison and analysis.

## 6.4 Examples of a Popular Bioinformatics Pipelines

The programs utilized for RNA Sequencing analysis include the Tuxedo Suite open source software package which includes Tophat, Bowtie, Cufflink, CuffCompare and CuffDiff [23]. The compressed BAM file type is utilized by these programs. Tophat aligns sequencing reads to the human genome using the high output short read aligner Bowtie and then analyzes the results to identify splice junctions. Cufflinks assembles transcripts, mapping segments of transcripts to genes and individual transcripts of a reference genome. Cufflinks uses fragment counts as a measure of relative abundance, which are reported as Fragments Per Kilobase of exon per Million fragments mapped (FPKM). Assembled transcripts from can be compared using Cuffcompare. CuffDiff to compare transcript expression level, splicing and promoter use. Cuffdiff uses the Cufflinks to compare transcript expression levels in two data sets. It allows the user to find differentially expressed and regulated genes at the transcriptional and post-transcriptional level by reporting the log-fold-change in expression.

## 7 COST OF HEALTHCARE

### 7.1 The Current State

One of the most troubling issues facing the United States, and the world, is the increasing cost of healthcare. The problems are different around the globe. Much of the developing world lacks access to adequate healthcare, which is a serious problem. This paper focuses on a different problem, in the crisis facing the United States. Current healthcare spending is greater than 3 trillion dollars [5]. This makes up 17 percent of GDP. This number grows every year and is unsustainable. This number affects citizens deeply, and currently healthcare costs are responsible for 50% of bankruptcy claims in the United States [6]. All of this extra spending does not equal better health. In most measures of health, from infant mortality to life expectancy, the United States find itself far from the top. There are major issues at play ranging from a massive bureaucracy, to the poor health and obesity of participants.

### 7.2 The Future

It is projected that the average family will spend over 25% of income on to healthcare [6]. The problem is not projected to improve. As the *baby-boomers* age, the population over 60 with high cost chronic healthcare problems, increases exponentially. In Medical School, we were taught about this *silver tsunami* approaching the US healthcare system (prompting me to go into Pediatrics.) Many individuals, including myself, look to Big Data to uncover these problems and help fix them. Before it is too late. There are technology solutions including the electronic health record, medical reference technology, genomic medicine, telemedicine, wearable health technology, and personalized medicine.

## 8 ELECTRONIC HEALTH RECORD

### 8.1 Electronic Medical Record and Genomics (eMerge)

There is currently a massive effort undertaken by multiple companies and branches of government to combine genomics data and the

electronic health record. According to the website: "eMERGE is a national network organized and funded by the National Human Genome Research Institute (NHGRI) that combines DNA biorepositories with electronic medical record (EMR) systems for large scale, high-throughput genetic research in support of implementing genomic medicine." This method of combining genomics data and electronic health information holds great potential.

### 8.2 Adoption of and EMR

Throughout history, medical records were taken on paper, but after 2000 the slow transition to electronic records began [12]. The handwritten records were kept in large file cabinets, and when records needed to be shared between physicians or institutions (across the country or across the street), the paper records were faxed over a telephone line. This technology is decades old. As technology raced forward with supercomputers and the worldwide web, medicine continued to use these antiquated forms of communication. Finally, government mandating forced healthcare systems into the modern era and electronic records went online. Currently over 84% of health records are online [6].

### 8.3 The Current State

A majority of healthcare systems around the world are under a government regulated socialized medical system which comes with a universal health record. The healthcare system in the United States is privatized, therefore the transition to EHR came with individual health entities purchasing a multitude of different EHRs. The problem comes in that a patient presenting to two different healthcare facilities, even if across the street or within the same building, will have two different medical charts that do not communicate with one another. The other problem comes with accessing this information. The two largest companies Epic and Cerner have a commercial interest, with a primary goal to increase revenue to the shareholder. It is exceedingly difficult for the nonprofit entities including academic centers and hospitals to access the patient information within the EHR. There is tremendous potential within the EHR. Beyond data collection, storage, data retrieval, and analysis, we should move towards real time guidance and guidelines for medical decision making to improve health.

### 8.4 Phenome-wide association studies ]

The first established linkage of the electronic health record and genomics datasets took place at Vanderbilt University. Vanderbilt Medical Center began to collecting biospecimens from patients (using an ethically controversial opt-out consent process.) They performed Whole Exome Sequencing on the specimens. They then linked the specimens to the electronic health record and compiled the data in a database called BioVUE. Phenome-wide association studies is the name of a method used to measure the number of phenotypes or diseases reported in the electronic health record, in relation to single nucleotide changes in the human genome [4]. Researchers can assess whether each variant is related to any disease state. The database started in 2012 and is growing rapidly. As the dataset grows, so will its power to predict disease based on single nucleotide variants. An early version of the catalog is currently available online to all individuals.