

# *Use Cases in Big Data Software and Analytics*

Vol. 1, Fall 2017

---

*Bloomington, Indiana*

Monday 9<sup>th</sup> October, 2017, 09:55

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

# Contents

<b>1 Preface</b>	<b>9</b>
1.1 List of Papers . . . . .	9
<b>2 Biology</b>	<b>12</b>
<b>3 Business</b>	<b>12</b>
2 hid106	Status: 0%
Big Data Analytics in Groceries Stores Qiaoyi Liu . . . . .	12
3 hid218	Status: 10%
Big data's influence on e-commerce and lifestyle Niu, Geng . . . . .	15
4 hid224	Status: 100%
Big Data Applications in the Hospitality Sector Rawat, Neha . . . . .	17
5 hid234	Status: 100%
Big Data Analytics in Tourism Industry Weixuan Wang . . . . .	23
6 hid235	Status: 100%
Big Data in Recommendation System Yujie Wu . . . . .	26
7 hid301	Status: 0%
Big Data Analytics in Finance Industry Gagan Arora . . . . .	29
8 hid302	Status: 100%
Big Data Application in Restaurant Industry Sushant Athaley . . . . .	29
9 hid310	Status: 100%
Big Data Applications in Food Insecurity Kevin Duffy . . . . .	34
10 hid328	Status: 100%
Big data analysis in Finance Sector Dhanya Mathew . . . . .	36
<b>4 Edge Computing</b>	<b>42</b>

11 hid201	Status: 100%	
Big Data analytics and Edge Compting		
Arnav, Arnav . . . . .	42	
12 hid306	Status: 100%	
The Internet of Things and Big Data		
Murali Cheruvu . . . . .	45	
<b>5 Education</b>		<b>48</b>
13 hid236	Status: 0%	
Big Data in MOOC		
Weipeng Yang . . . . .	48	
14 hid329	Status: 100%	
Big Data Analytics in Higher Education Marketing		
Ashley Miller . . . . .	50	
<b>6 Energy</b>		<b>56</b>
15 hid228	Status: 100%	
Big data applications in Electric Power Distribution		
Swargam, Prashanth . . . . .	56	
<b>7 Environment</b>		<b>59</b>
16 hid202	Status: 0%	
Big data analytics in Weather forecasting		
Himani Bhatt . . . . .	59	
17 hid332	Status: 100%	
Big Data Analytics in Agriculture		
Judy Phillips . . . . .	65	
18 hid346	Status: unkown	
Big Data in Oceanography		
Zachary Meier . . . . .	68	
<b>8 Government</b>		<b>68</b>
19 hid305	Status: 100%	
Big Data Analytics for Municipal Waste Management.		
Andres Castro Benavides, Mani Kumar Kagita . . . . .	68	
20 hid319	Status: 100%	
Big Data Analytics for Municipal Waste Management		
Mani Kumar Kagita, Andres Castro Benavides . . . . .	77	
<b>9 Health</b>		<b>86</b>
21 hid210	Status: 0%	
Natual Language Processing of Electronic Health Records		
Hotz, Nicholas . . . . .	86	
22 hid311	Status: 100%	
Big Data and Healthcare		
Matthew Durbin . . . . .	89	

23 hid312	An Overview of Big Data Applications in Mental Health Treatment	Status: 100%
	Neil Eliason . . . . .	90
24 hid320	Big Data Analytics and Applications in Childbirth	Status: 100%
	Elena Kirzhner . . . . .	94
25 hid325	Impact of Big Data on the Privacy of Mental Health Patients	Status: 100%
	J. Robert Langlois . . . . .	101
26 hid326	Bigdadta in Clinical Trails	Status: 100%
	Mohan Mahendrakar . . . . .	104
27 hid327	Using Big Data to minimize Fraud, Waste, and Abuse (FWA) in United States Healthcare	Status: 100%
	Paul Marks . . . . .	107
28 hid330	Big data in Improving Patient Care	Status: 100%
	Janaki Mudvari Khatiwada . . . . .	112
29 hid331	Big Data Applications In Population Health Management	Status: 100%
	Tyler Peterson . . . . .	115
30 hid335	Big Data Analytics, Data Mining, and Public Health Informatics: Using Data Mining of Social Media to Track Epidemics	Status: 100%
	Sean M. Shiverick . . . . .	118
31 hid339	Big data application for treatment of breast cancer	Status: 100%
	Hady Sylla . . . . .	118
<b>10 Lifestyle</b>		<b>118</b>
32 hid347	Sociological Applications of Big Data	Status: 0%
	Jeramy Townsley . . . . .	118
<b>11 Machine Learning</b>		<b>118</b>
33 hid208	This is my paper about Big Data and Deep Learning	Status: 100%
	Jyothi Pranavi,Devineni . . . . .	118
34 hid211	Distributed environment for neural network	Status: 100%
	Khamkar, Ajinkya . . . . .	118
35 hid215	Big Data and Artificial Neural Networks	Status: 100%
	Mallala, Bharat . . . . .	120

36 hid229	Status: 100%
Big Data and Machine Learning	
ZhiCheng Zhu . . . . .	120
<b>12 Media</b>	<b>123</b>
37 hid109	Status: Completed
Big Data in Social Media	
Shiqi Shen . . . . .	123
38 hid209	Status: 100%
Big Data Application in Web Search and Text Mining	
Han, Wenxuan . . . . .	123
39 hid213	Status: 0%
Big Data and Speech Recognition	
Yuchen Liu . . . . .	130
40 hid231	Status: 100%
Using Big Data for Fact Checking	
Vegi, Karthik . . . . .	130
41 hid233	Status: 100%
Big Data Applications in Media and Entertainment Industry	
Wang, Jiaan . . . . .	135
42 hid314	Status: 0%
Big Data analytics in Media industry	
Sarang Fadnavis . . . . .	138
43 hid336	Status: 100%
Recommendation Systems on the Web	
Jordan Simmons . . . . .	140
44 hid340	Status: 100%
Big data analytics for archives and research libraries	
Timothy A. Thompson . . . . .	143
45 hid345	Status: 100%
Big Data Danger: Weaponizing Social Media.	
Ross Wood . . . . .	146
<b>13 Physics</b>	<b>149</b>
46 hid304	Status: 100%
Big Data and Astrophysics	
Ricky Carmickle . . . . .	149
<b>14 Security</b>	<b>151</b>
47 hid111	Status: unkown
Big Data Analytics in Biometric Identity Management	
Robert Gasiewicz . . . . .	151
48 hid205	Status: 0%
Applications of Big Data in Fraud Detection in Insurance	
Chaudhary Mrunal L . . . . .	152

49 hid237	Status: 100%
Big Data Analytics in Cyber Security and Threat Research	
Tousif Ahmed . . . . .	152
50 hid316	Status: 100%
Big Data Analytics in Biometric Identity Management	
Robert Gasiewicz . . . . .	155
51 hid333	Status: 0%
Big Data and Artificial Intelligence solutions for In Home, Community and Territory Security	
Anil Ravi, Ashok Reddy Singam . . . . .	158
52 hid337	Status: 100%
Big Data and Artificial Intelligence Solutions for in Home, Community and Territory Security	
Ashok Reddy Singam, Anil Ravi . . . . .	158
<b>15 Sports</b>	<b>163</b>
53 hid105	Status: unkown
This is my paper about data visualization in sports	
Lipe-Melton, Josh . . . . .	163
54 hid214	Status: 0%
Big Data and Basketball	
Junjie Lu . . . . .	163
55 hid216	Status: 0%
Big Data Analytics in Sports - Track and Field	
Mathew Millard . . . . .	163
56 hid232	Status: 100%
Big Data Analytics in Sports - Soccer	
Rahul velayutham . . . . .	164
57 hid342	Status: 100% done
Big data analytics in college football (NCAA)	
Udoyen, Nsikan . . . . .	167
<b>16 Technology</b>	<b>170</b>
58 hid107	Status: 100%
DevOps in support of Big Data Applications and Analytics	
Ni,Juan . . . . .	170
59 hid203	Status: 99% Completed
Big Data Analytics using Spark	
Chandwani, Nisha . . . . .	172
60 hid204	Status: 100%
Big Data Analytics and High Performance Computing	
Chaturvedi, Dhawal . . . . .	177
61 hid212	Status: Completed
Big Data Analysis using MapReduce	
Kumar, Saurabh . . . . .	180

62 hid308	Status: 100%
Big Data and Data Visualization	
Pravin Deshmukh . . . . .	183
63 hid313	Status: 100%
Big Data Platforms as a Service	
Tiffany Fabianac . . . . .	183
64 hid315	Status: 0%
Roles and Impact on Mobility Network Traffic in Big Data	
Garner, Jeffry . . . . .	186
65 hid323	Status: 100%
This is my paper about NoSQL Databases in support of Big Data Applications and Analytics	
Uma M Kugan . . . . .	187
66 hid334	Status: 100%
AWS in support of Big Data Applications and Analytics	
Peter Russell . . . . .	189
67 hid338	Status: 100%
Docker in support of Big Data Applications and Analytics	
Anand Sriramulu . . . . .	192
68 hid348	Status: 0%
Using Singularity for Big Data	
Budhaditya Roy . . . . .	196
<b>17 Text</b>	<b>197</b>
<b>18 Theory</b>	<b>197</b>
69 hid104	Status: 100%
What Separates Big Data from Lots of Data?	
Jones, Gabriel . . . . .	197
70 hid324	Status: 100%
Big data and Analytics in Blockchain	
Ashok Kuppuraj . . . . .	200
<b>19 Transportation</b>	<b>200</b>
71 hid219	Status: unkown
Big Data Analytics Architecture for Real-Time Traffic Control	
Parampali Sreenath, Syam Sundar Herle . . . . .	200
72 hid225	Status: 50%
Optimizing Mass Transit Bus Routes with Big Data	
Schwartz, Matthew . . . . .	205
73 hid343	Status: 100%
Big Data Applications in Self-Driving Cars	
Borga Usifo . . . . .	207
<b>20 TBD</b>	<b>211</b>

74 hid101		Status: 0%
	Big Data and standardize testing	
	Huiyi Chen . . . . .	211
75 hid102		Status: unkown
	This is my paper about xyz	
	Dianprakasa, Arif . . . . .	212
76 hid318		Status: 0%
	This is my paper about xyz	
	Gregor von Laszewski, Fugang Wang . . . . .	213
77 hid321		Status: unkown
	This is my paper about xyz	
	Knapp, William . . . . .	214

# Chapter 1

## Preface

### 1.1 List of Papers

Name	HID	Title
hid101	Huiyi Chen	Big Data and standardize testing
hid102	Dianprakasa, Arif	This is my paper about xyz
hid104	Jones, Gabriel	What Separates Big Data from Lots of Data?
hid105	Lipe-Melton, Josh	This is my paper about data visualization in sports
hid106	Qiaoyi Liu	Big Data Analytics in Groceries Stores
hid107	Ni,Juan	DevOps in support of Big Data Applications and Analytics
hid109	Shiqi Shen	Big Data in Social Media
hid111	Lewis, Derek	Big Data Analytics in Biometric Identity Management
hid201	Arnav, Arnav	Big Data analytics and Edge Compting
hid202	Himani Bhatt	Big data analytics in Weather forecasting
hid203	Chandwani, Nisha	Big Data Analytics using Spark
hid204	Chaturvedi, Dhawal	Big Data Analytics and High Performance Computing
hid205	Chaudhary, Mrunal L	Applications of Big Data in Fraud Detection in Insurance
hid208	Devineni, Jyothi Pranavi	This is my paper about Big Data and Deep Learning
hid209	Han, Wenxuan	Big Data Application in Web Search and Text Mining
hid210	Hotz, Nicholas	Natual Language Processing of Electronic Health Records
hid211	Ajinkya Khamkar	Distributed environment for neural network
hid212	Kumar, Saurabh	Big Data Analysis using MapReduce
hid213	Liu, Yuchen	Big Data and Speech Recognition
hid214	Lu, Junjie	Big Data and Basketball
hid215	Mallala, Bharat	Big Data and Artificial Neural Networks
hid216	Millard, Mathew	Big Data Analytics in Sports - Track and Field
hid218	Niu, Geng	Big data's influence on e-commerce and lifestyle
hid219	Parampali Sreenath, Syam Sundar Herle	Big Data Analytics Architecture for Real-Time Traffic Control
hid224	Rawat, Neha	Big Data Applications in the Hospitality Sector
hid225	Schwartzter, Matthew	Optimizing Mass Transit Bus Routes with Big Data
hid228	Swargam, Prashanth	Big data applications in Electric Power Distribution
hid229	ZhiCheng Zhu	Big Data and Machine Learning
hid230	YuanMing Huang	Big data with natural language processing
hid231	Vegi, Karthik	Using Big Data for Fact Checking
hid232	Rahul Velayutham	Big Data Analytics in Sports - Soccer
hid233	Wang, Jiaan	Big Data Applications in Media and Entertainment Industry

hid324	Weixuan Wang	Big Data Analytics in Tourism Industry
hid235	Wu, Yujie	Big Data in Recommendation System
hid236	Yang Weipeng	Big Data in MOOC
hid237	Ahmed, Tousif	Big Data Analytics in Cyber Security and Threat Research
hid301	Arora, Gagan	Big Data Analytics in Finance Industry
hid302	Sushant Athaley	Big Data Application in Restaurant Industry
hid304	Ricky Carmickle	Big Data and Astrophysics
hid305	Andres Castro Benavides	Big Data Analytics for Municipal Waste Management.
hid306	Cheruvu, Murali	The Internet of Things and Big Data
hid308	Pravin Deshmukh	Big Data and Data Visualization
hid309	Dubey, Lokesh	BigData Analytics using Apache Spark in Social Media
hid310	Kevin Duffy	Big Data Applications in Food Insecurity
hid311	Durbin, Matthew	Big Data and Healthcare
hid312	Neil Eliason	An Overview of Big Data Applications in Mental Health Treatment
hid313	Tiffany Fabianac	Big Data Platforms as a Service
hid314	Fadnavis, Sarang	Big Data analytics in Media industry
hid315	Garner, Jeffry	Roles and Impact on Mobility Network Traffic in Big Data
hid316	Robert Gasiewicz	Big Data Analytics in Biometric Identity Management
hid318	Irey, Ryan	This is my paper about xyz
hid319	Mani Kumar Kagita	Big Data Analytics for Municipal Waste Management
hid320	Elena Kirzhner	Big Data Analytics and Applications in Childbirth
hid321	Knapp, William	This is my paper about xyz
hid323	Uma M Kugan	This is my paper about NoSQL Databases in support of Big Data Applications and Analytics
hid324	Ashok Kuppuraj	Big data and Analytics in Blockchain
hid325	J. Robert Langlois	Impact of Big Data on the Privacy of Mental Health Patients
hid326	Mahendrakar, Mohan	Bigdadta in Clinical Trails
hid327	Marks, Paul	Using Big Data to minimize Fraud, Waste, and Abuse (FWA) in United States Healthcare
hid328	Dhanya Mathew	Big data analysis in Finance Sector
hid329	Ashley Miller	Big Data Analytics in Higher Education Marketing
hid330	Janaki Mudvari Khatiwada	Big data in Improving Patient Care
hid331	Tyler Peterson	Big Data Applications In Population Health Management
hid332	Judy Phillips	Big Data Analytics in Agriculture
hid333	Anil Ravi	Big Data and Artificial Intelligence solutions for In Home, Community and Territory Security
hid334	Peter Russell	AWS in support of Big Data Applications and Analytics
hid335	Sean Shiverick	Big Data Analytics, Data Mining, and Public Health Informatics: Using Data Mining of Social Media to Track Epidemics
hid336	Jordan Simmons	Recommendation Systems on the Web
hid337	Ashok Reddy Singam	Big Data and Artificial Intelligence Solutions for in Home, Community and Territory Security
hid338	Sriramulu, Anand	Docker in support of Big Data Applications and Analytics
hid339	Hady Sylla	Big data application for treatment of breast cancer
hid340	Tim Thompson	Big data analytics for archives and research libraries
hid341	Tibenkana, Jacob	Big Data Applications for Clinical Trials
hid342	Udoyen, Nsikan	Big data analytics in college football (NCAA)
hid343	Usifo, Borga	Big Data Applications in Self-Driving Cars
hid345	Wood, Ross	Big Data Danger: Weaponizing Social Media.
hid346	Zachary Meier	Big Data in Oceanography

hid347	Jeramy Townsley	Sociological Applications of Big Data
hid348	Budhaditya Roy	Using Singularity for Big Data

# Big Data Analytics in Groceries Stores

Qiaoyi Liu

Indiana University of Bloomington  
3209 E 10th St  
Bloomington, Indiana 47408  
ql30@umail.iu.edu

## ABSTRACT

This paper helps us understanding how big data is working in Groceries store and how Big Data helping their business.

## KEYWORDS

i523, hid106, Data Science, Big Data Analytics, Cloud Computing,customer study

## 1 INTRODUCTION

Today, numerous market chains perform an assessment of their client/customers on a massive set of data, discovering experiences that assist them better includes customers and, thus, drive income. Discerning how to use big data is vital in an industry where profits are razor thin, and waste management is a broad issue. By gathering and evaluating customer data, grocery stores can sharpen their approach to everything from advertising exercises and pricing to product classification and customer's benefit [1, 2]. With the appropriate analytical tool, grocery stores can unite various sources of data and get information progressively in real time, letting them precisely conjecture product demand, improve stock levels and turn-rates, and lessen waste of perishable products. The article will examine the importance of Big Data Analytics in Groceries stores, its relevancy, its use as a competitive advantage tool to attracting customers, in addition to determining customer demand. Grocer Loyalty program databases, rich with a point to point customer information, have been in presence for quite a long time, giving food merchants a clear preferred standpoint (for those that have utilized this information) contrasted with different retailers [4]. Grocers have had a head start beginning on using this information in better understanding shopper behaviors and shopping preference. Nonetheless, with the coming of new technological innovations, new contenders, new channels and the rise of a 'constantly-on' and 'time-starved' purchaser base with a bunch of advantageous shopping choices [5] the grocery industry is presently trailing different retailers in the capacity to use these new 'huge' data sources to advance their investigative abilities from interactions to transaction[3]. Specifically, the development of new types of data sources [5] offers a chance to Small to Medium Size grocer's equal opportunity to compete with big chains of supermarkets. The proceeding section highlights the relevance of the big data.

## 2 RELEVANCY OF BIG DATA ANALYTICS IN GROCERIES STORES

### 2.1 Increases the customer shopping experience

As per a current SHSFoodThink white paper "Are We Chain Obsessed?" 64% of customers said that the previous shopping experience is what makes them keep coming back! not the items themselves [5]. By utilizing bits of knowledge received from the information transaction database, online networking, promotional activity, customers purchasing behavior, and client movement patterns, grocery stores can find a way to guarantee they are engaged with their customers that matter most. For instance, they can investigate customers shopping movement to enhance the layout of their store, or recognize attrition risks for clients who have not as of late bought staple things, similar to milk. In like manner, chains can construct item varieties demonstrated with the customer needs and purchase patterns in certain regions [3–5]. Regardless of whether it is through reconsidering store layout or furnishing store attended with mobile apps to better serve clients, analytics can enable grocers to change consumer's expectations.

### 2.2 Restructure the Supply Chain

Grocery stores can likewise utilize analytic to investigate the production of their products, monitor production processes, and quality control, and improve straightforwardness with buyers about their sustenance production practices of foods [2]. Suppliers remain to profit from the evaluation also, with access to secure, customized content of information identified with performance sales of the product, stock, margins, and marketing effectiveness. Giving supplier an opportune profitable business knowledge that supports joint ventures, drives performance, and decreases waste products

### 2.3 Build Superior Marketing Programs

Loyalty programs furnish grocery merchants with an abundance of data to enable them to distinguish client segments and precisely characterize item preferences. By joining this information with different data sources [5] like healthful patterns, favored technique for accepting marketing promotion, customer movement patterns, and weather-related events [5] grocery merchants can concentrate on enhancing, and derive income from, the general shopping experience [5]. For instance, grocery retailers can utilize analytics to customize the advancements they offer to clients given what they are well on the way to buy. They can likewise time advancements fittingly, and offer codes to customers who often as possible buy certain things.

## 2.4 Improves HR Strategies

Supermarket stores utilize analytics to manage work-related decisions. Information freely accessible through online networking accounts and different means can be examined in conjunction with a grocer's internal information to direct decision identified with selection and recruitment, employee termination, and performance management and advancements [1]. For example, an investigation of late action on LinkedIn can reveal insight into which representatives are destined to leave an organization. Grocery merchants can likewise break down information to control the advancement approaches that will build workforce performance. For example, they could explore different avenues regarding organizing a social gathering for representatives at a subset of their stores, and analyze information on profitability, morale, and turnover in the preceding months [4]. They may find that the gathering information prompted a more positive workplace where workers feel more noteworthy engagement at work, and soon after that, they could roll the strategy out to different stores.

## 2.5 Using big data for competitive advantage and attracting customers

Numerous grocery stores have been utilizing transaction and client information for a considerable length of time, despite the fact that many still have not completely used all that can be proficient with these types of information. For Small to Medium Sized grocery merchants, many have swung to subcontracted point solutions because of an absence of available analytics assets and potential framework investment required [1, 5]. The issue with point solutions recently is that if? they independently work out for a particular business section and the evaluation is cookie cutter. In this way, the 'information' is not coordinated and hard if not difficult to give an all-encompassing picture of client conduct overall touch focuses for instance. Nor are the investigations offering a cross-functional observation that is pertinent to all business partners as far as driving differentiation in the commercial center in promoting, advertising, store operations and supply chain. As far as utilizing 'new' data sources, for example, mobile, social and text, the industry is particularly occupied with a discovery' phase of investigation with an assortment of center sections, testing and figuring out how to extricate an incentive from these rich new sources of information. There are two common paths grocery merchants takes with little respect of the 'size' of the organization: to start with is Strategic Commitment, in which there is C-level (hierarchical) commitment making the venture in the assets to get the majority of the in-house data and evaluated it [4]. Presently like never before, information, analytics, and IP are seen as vital resources and competitive discriminators. The other is Business Discovery; in which grocery merchants outsource to an Analytics as a Service firm to use internal and external information. Performing analytics speeds the construction of business advantages creating new users case and helps catch 'quick wins' before making resource commitment to technological innovation and human capital in advance [1]. In view of progress, and a wit, trusted stakeholder willing to share the techniques and explanatory models, can assist grocery merchants to proceed with an outsourced administrations supplier or relocate the data, analytics in addition to IP in-house.

## 3 RECOMMENDATIONS

### 3.1 Real-time insight on product demand

Nowadays, retailers can get to information on item demand levels instantly on a chain of stores. Nevertheless, numerous merchants are still in the earliest stages in regards to evaluating and monetizing the huge amount accessible data [3]. This prompts stocking deficits, for example, evaluating item demanded based exclusively on past historical information. It can likewise convey about wrong promoting endeavors: If a customer purchased ketchup on Saturday, an email coupon for it on Sunday is not well planned and make little sense to the shopper. This is the place data from store loyalty programs in addition to credit card sales can prove to be useful. Its data can be utilized to define needs of the customers in future. For example, grocery merchants can use data analytics to decide how regularly customers purchase sugar, flavors, or different items, and after that send every family unit coupons given their propensity to buy [5].

### 3.2 Enhancing in-store stock management

Perishable basic supplies, for example, dairy, meat, and fish call for precise stock administration, regularly on an hourly premise. Client analytics and prediction tools can enable grocery merchants to calibrate their inventory levels by assessing buyer purchasing behavior and requested products from various viewpoints and situations [5]. For example, grocery retailers might need to screen cycles like when customers go for particular nourishment, purchasing patterns amid sales deals when storing activity peaks or seasonally inspired buys. As indicated by a report from Manthan, this methodology worked for U.K. food grocery merchant Waitrose: a deeper understanding of buyer purchasing behavior and demand outlines using cutting edge client analytics and predicting tools helped the store [1]. Concurrently, retailers can utilize these systems to all the more deftly change their stock levels and amplify high-buy products.

### 3.3 Leveraging Predictive Analytics

Amazon spearheaded item proposal engine: the "if you purchased that, you may like this" invention. This strategic changing web-based shopping feature mirrors the retailer's profound assessment of buyers' shopping basket. Proposal engine is intended to enable customers to find items they were not sorting out but rather would be interested in purchasing [4]. Today, general grocery merchants are progressively tapping the global innovation behind proposal engine: predictive analytics. This kind of assessment measures future patterns in light of present and past information, and it can enable stores to improve business. Information is driven, all-encompassing assessment of "purchasing triggers, for example, regularity, weather, stock, and advancements, is progressively informing grocery stores' product blend, marketing plans, and sales forecast [5]. Furnished with these information-driven tools, stores can better distinguish what items customers need today and what they will be demanding in future, and this learning will enable them to stay competitive for a considerable length of time to come.

## 4 CONCLUSION

Big data analytics is profound tool assisting grocery merchant establishing insightful information concerning the market structure and sales demand. With the appropriate analytical tool, grocery stores can unite various sources of data and get information progressively in real time, letting them precisely conjecture product demand, improve stock levels and turn-rates, and lessen waste of perishable products. Advancement in information technology is offering new means for Small to Medium Business such as grocery merchant can use to drive the products sales. Big as discussed previously, assist grocery merchant to increase their customer experience, restructure supply chain, create superior market programs, improve HR strategies, and creates them a competitive advantage.

## REFERENCES

- [1] Ban G-Y. 2014. Business analytics in the age of big data. *Business Strategy Review* 25, 3 (2014), 8–9.
- [2] A. Hussain and A. Roy. 2016. The emerging era of Big Data Analytics. *Big Data Analytics* 1, 1 (2016).
- [3] S. Goodarzi J. Aloysijs, H. Hoehle and V. Venkatesh. 2016. Big data initiatives in retail environments: Linking service process perceptions to shopping outcomes. *Annals of Operations Research* (2016).
- [4] M. Lebbah M. Ghemsoun and H. Azzag. 2016. State-of-the-art on clustering data streams. *Big Data Analytics* 1, 1 (2016).
- [5] Eric Siegel. 2013. *Predictive analytics: the power to predict who will click, buy, lie, or die*. Vol. 51. Wiley; 1 edition.

# Big Data's influence on ecommerce and lifestyle

Geng Niu

Indiana University Bloomington

752 Woodbridge Dr

Bloomington, Indiana 47408

gengniu@iu.edu

## ABSTRACT

Big data has become the buzz words in recent years and it exerts huge influence on e-commerce and our lifestyle. However, for the general public big data is still something mysterious. This paper will serve as a review of what ways big data is utilized to improve e-commerce and influence our daily life.

## KEYWORDS

big data, ecommerce

## 1 INTRODUCTION

People were used to get dressed well at weekends and drove or took public transportation to the centers of cities or towns to choose what they like in physical stores. However, this is never necessary with the rapid development of e-commerce driven by internet technologies and better logistics. E-commerce became a buzz word about 15 years ago but it came into being in 1991 when internet started to be used for commercial purposes. “At first, the term e-commerce meant the process of execution of transaction electronically. In 2000, the word e-commerce was redefined as the process of purchase of available goods and services over the internet.” [1]. This paper will focus on big data’s influence on the newer definition of e-commerce instead of the first one which is very broad.

## 2 THE COMING OF THE BIG DATA ERA

In the traditional mode of commerce, consumers need to go to physical stores and take time to look for products they want by walking. Companies manufacturing these products do commercials on TV and newspapers to attract potential consumers. This mode of doing business did not change in the beginning of e-commerce, and the difference is that sellers moved into virtual shops from a real shop. In the web 2.0 era, search engines enabled consumers to look for products in virtual shops and sellers can receive feedback in their website[4].

However, in the mobile and sensor-based era e-commerce is drastically changed. “The number of mobile phones and tablets (about 480 million units) surpassed the number of laptops and PCs (about 380 million units) for the first time in 2011” [4]. The wide spread of mobile devices and other sensor-based devices enables the gathering of huge volume of data which is fresher and more accurate compared with data gathered from surveys and questionnaires. “In most cases, e-commerce firms deal with both structured and unstructured data. Whereas structured data focuses on demographic data including name, age, gender, date of birth, address, and preferences, unstructured data includes clicks, likes, links, tweets, voices, etc.”[2]. With huge and various data available and relevant technologies, the big data era came.

## 3 MONITORING CONSUMERS’ JOURNEY IN ONLINE TRANSACTION

Big data analytics makes more data driven strategies for businesses to reach their consumers. With the use of data generated from Electronic Data Interchange, business runners can gain better understanding of consumer behavior so as to improve customer service and business strategies. Customers can be labeled into different segments or groups according to the patterns of their purchase online with their demographic information. By doing so, customers can be easily targeted especially during campaigns and festival sales because companies invest a lot to attract customers and retain existing base[8]. For example, Amazon is providing more customized offers, advertisements and discounts to consumers because it can identify patterns in consumers’ shopping habit which is enabled by analyzing cookies and clickstream on consumer browsers[5].

There are two technologies associated with the monitoring of consumers’ journey online. One is text mining which relies on the use of text-based content from blogs and social media sites. Based on the information obtained, judgments on relevant issues can be made[5]. Text mining usually involves the process of structuring the input text, deriving patterns within the structured data, and finally evaluation and interpretation of the output[11]. Another technology is sentiment analysis which is based on learning algorithm or artificial intelligence to make clear about attitudes to a particular good or service. The words obtained from the data will be analyzed and tagged and then are interpreted whether the opinion is positive or not[5].

## 4 PERSONALIZED SERVICES

Recommender systems or recommendation systems are also used by e-retailers to provide personalized services. Recommender system is a subclass of information filtering system that seeks to predict the “rating” or “preference” that a user would give to an item. Recommender systems can generate recommendations in two ways. The first way is called collaborative filtering, which means a model from a user’s past shopping behaviors including purchase records and ratings to given items as well as decisions made by other users will be built to generate recommendations. Another approach to build model is the content-based filtering. In this approach, a series of discrete characteristics of an item will be used to recommend additional items with similar properties[7].

Let’s take Amazon as an example. 35% of Amazon’s revenue can be attributed to its recommendation engine. Amazon has on-site recommendations. When users click “your recommendations” link, they will see the products that the system recommends to them. Another way to recommend products is through the “frequently bought together”. For instance, when a user is searching for a laptop

he or she wants to buy, he or she probably sees that a backpack which can hold the laptop is recommended. Some other ways of providing recommendations is “your browsing history”, “related to items you’ve viewed” and personal emails.[6]

## 5 DYNAMIC PRICING

When customers are shopping online, there is an electronic seller bargaining with you. This technology is called dynamic pricing. “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.”[10]. Amazon customers can receive different or customized prices or discounts for the same item. This is set by the resource planning system through the use of data of previous purchase, clickstream, cookies and so on. CNN once reported that for a particular DVD, the price increased by \$ 2.5 after the customer deleted his cookies[5]. Here are some strategies for dynamic pricing. The first one is high-value customer price which means that customers who always pay full price for a certain product or service rarely get information about promotion or discounts. Another strategy is based on demand and supply and the time. For example, a seller could price up the products like a coat in extreme weather because it is possibly very needed by people[3].

Although this function has its benefits such as increasing margin profits, customers may view it as price discrimination. However, there are some differences between dynamic price and price discrimination. Price discrimination happens when a seller changes the price of a product or service according to a consumer’s demographics. In contrast dynamic price more focuses on price fluctuations in demand and competitive landscape[9].

## 6 LIFE CHANGES

Lifestyle changes are caused by a combination of internet, mobile devices and e-commerce. And big data is not possible to apply without the advances made in internet and ecommerce. For business runners, big data provides them more opportunities to gain profits. They are more likely to locate a potential buyer of their products and services. For example, the recommendation system can help them find customers not only in the local area but also in other cities or even countries. A seller who operates his store in Taobao in Shanghai receives a large number of orders from customers all over China in holidays, which is not imaginable. However, they are facing pressure from the increased workload. Since customers do not have to go to a physical store, they may order their goods whenever online. In Taobao, sellers are supposed to be online for most of the day. Even a customer ordered something at 10pm, the seller should send notification of the order and answer questions the customer has. Another example is the way people watch dramas and movies. In the past, one had to wait in front of the TV and found no good dramas. Or he went to the cinema only to find the movie not worth the money for the ticket at all. On with Netflix and Youku, a Chinese video site, one can know millions of other viewers’ rating and choose the types of dramas and movies they

like. It is certain that big data in e-commerce is influencing people’s lifestyle shopping, traveling, eating and entertainment.

## 7 CONCLUSION

With the spread of mobile phones and laptops and affordable high-speed internet, people now have their electronic assistants. Amazon and Taobao will tell you what products that you may be interested in are available. Google will send you notification about news that you have been following. When you are on the street, your mobile phone may tell you what are the good restaurants nearby. It has no doubt that big data has made people’s life more convenient. And big data renders business runners more opportunities to gain profits as well as more competition from other people.

## REFERENCES

- [1] 2008. History of Ecommerce. (2008). <http://www.ecommerce-land.com/history-commerce.html>
- [2] Shahriar Akter and Samuel Fosso Wamba. 2016. Big data analytics in E-commerce: a systematic review and agenda for future research. *Electronic Markets* 26 (2016).
- [3] Matthew Bertulli. 2017. 5 Dynamic Pricing Strategies for eCommerce Growth. (2017). <https://www.demacmedia.com/dynamic-pricing-strategies-e-commerce/>
- [4] Hsinchun Chen, Roger H. L. Chiang, and Veda C. Storey. 2012. BUSINESS INTELLIGENCE AND ANALYTICS: FROM BIG DATA TO BIG IMPACT. (2012).
- [5] Uyoy Zino Edosio. 2014. Big Data Analytics and its application in E-commerce. (2014).
- [6] Tom Krawiec. 2017. The Amazon Recommendations Secret to Selling More Online. (2017). <http://rejoiner.com/resources/amazon-recommendations-secret-selling-online/>
- [7] Greg Linden, Brent Smith, and Jeremy York. 2003. Amazon.com Recommendations Item-to-Item Collaborative Filtering. (2003).
- [8] Durjoy Patranabish. 2016. How Big Data is impacting the e-commerce industry. (2016). <https://yourstory.com/2016/11/big-data-impacting-e-commerce-industry/>
- [9] Brian Smyth. 2015. Dynamic Pricing and Price Discrimination: What is the Difference? (2015). <http://blog.wiser.com/dynamic-pricing-and-price-discrimination-whats-the-difference/>
- [10] Wikipedia. 2017. Dynamic Pricing. (2017). [https://en.wikipedia.org/wiki/Dynamic\\_pricing](https://en.wikipedia.org/wiki/Dynamic_pricing)
- [11] Wikipedia. 2017. Text mining. (2017). [https://en.wikipedia.org/wiki/Text\\_mining](https://en.wikipedia.org/wiki/Text_mining)

# Big Data Applications in the Hospitality Sector

Neha Rawat  
Indiana University  
Bloomington, Indiana  
nrawat@iu.edu

## ABSTRACT

The rise of *Big Data* in the field of Hospitality though recent, is by no means temporary. The hotel industry is one which deals with millions of customers on a day-to-day basis and generates a plethora of customer data through such interactions. It is also the sector which depends the most on customer loyalty, and thus profits greatly through the analytical insights that Big Data has to offer. Keeping this in mind, hotels today, whether they are big chains or small independent establishments, are using data generated internally and on the web to develop strategies for better customer satisfaction, marketing effectiveness, yield management and operational efficiency.

## KEYWORDS

i523, HID224, Marketing, Yield Management, Recommendation Systems, Data Warehousing, Data Mining

## 1 INTRODUCTION

Big data is often defined as “data that exceeds or is beyond the capabilities of the organization to store or analyze for accurate or timely decision making” [11]. It is characterized by features such as its volume, velocity and variety. Two other characteristics that have been recently added to these are veracity and volatility, referring to the uncertainty and dynamic nature of such data [11]. Despite the unstructured nature of such data, it presents us with a variety of opportunities which make it so appealing.

The hospitality sector too generates a huge amount of data in its day-to-day processes about its customers, operational processes such as electricity and water consumption and the daily revenue generated. Some of the questions that can be addressed using this data are - What is the country of origin of the customer? What are his/her particular preferences in terms of food or other amenities? What booking channel did they use? What was the time/season of booking? How is the performance of the hotel relative to the local market? What is the monthly energy consumption and other expenditures? [1].

Using the data generated internally by the administrative units and different departments, gathered externally from the web - from sites of aggregators such as Expedia and Trivago and from social networking sites such as Twitter, hotels can derive quite useful insights into the opportunities they can utilize and the challenges they should overcome.

## 2 THE ADVENT OF BUSINESS INTELLIGENCE

Business Intelligence has been a part of the Hospitality sector for some time now. Earlier though, it was used mainly in traditional revenue management systems to deal with duration of stays and promotional programs [6]. However, it was not developed well

enough to provide additional insights into other areas of hotel management. The emergence of companies which worked as online booking platforms, such as Expedia and Travelocity, led way to a new form of data, which though unstructured, could be leveraged as a window into the customers’ preferences. Few hotels such as Marriott, InterContinental Hotels, Hilton and Hyatt utilized these opportunities presented by business intelligence to get ahead in the game, but were not very successful due to insufficient planning and technical expertise, lack of executive support and wide-spread adoption [6].

## 3 BIG DATA AND HOSPITALITY

With the advancement of technology, the generation of data increased manifold. Researchers from UC Berkeley had estimated that “the world had produced about 1.5 billion gigabytes of information in 1999 and in a 2003 replication of the study found out that amount to have doubled in 3 years” [12].

The Hospitality sector too found data from a variety of sources - social media, review data, data from search engines like Google and other customer data sources [1]. As a result, business intelligence systems were made more structured, driven by advanced IT technologies and machine learning algorithms. Figure 1 gives the structure of a typical hospitality business intelligence system.

[Figure 1 about here.]

The vast amount of data now is used for a variety of tasks in the hotel management field. The most essential ones are - Customer Satisfaction and Marketing, Yield/Revenue Management and Operational Effectiveness.

### 3.1 Customer Satisfaction and Marketing

Customer loyalty is the main driver behind the hospitality business. The use of big data analytics has worked towards providing hoteliers with insights about what their guests want. This information can be used by the hotels to improve existing customer satisfaction as well as develop marketing techniques to attract new customers. This helps convert “high-spending customers to repeat customers” and increases the hotel’s profitability [8].

An excellent example of the use of analytics for customer satisfaction is the new system introduced by the US chain of hotels, Denihan Hospitality [7]. Using IBM analytics technology, they worked towards combining their internal customer and transactional data with the review data found on the web. This was used to implement various data-driven solutions regarding the quality of the rooms, bathrooms and other facilities. They even went ahead to create interactive dashboards and “putting analytics in the hands of the frontline hotel staff” who received real-time updates as to the requirements of their customers [7].

In order to implement the above hotel evaluation structure, one can

use the services of WebCrawlers and cloud computing platforms like Hadoop. A similar system created by Ming-Shen Jian, Yi-Chi Fang, Yu-Kai Wang and Chih Cheng uses cloud technologies coupled with data mining algorithms to create a customer response and evaluation system [4]. The system uses Hadoop to implement a multi-node cluster on the cloud server, programs a WebCrawler to retrieve review data from websites, extracts the informative adjectives using MapReduce and a text segmentation system and gives the word count using Hadoop's WordCount program. Weights are assigned to the different words using a neural network which are then clustered and analyzed for classification using a clustering algorithm. The final results are averaged for all reviews for a particular hotel to determine its score [4]. Figure 2 gives a rough structure for the above system.

[Figure 2 about here.]

Marketing too profits from the availability of such data by using search data generated by aggregators such as Expedia and TripAdvisor to develop discount programs and other offers to attract customers. The data history of customers available with hotels can also be used to analyze the requirements of customers at particular times and seasons of the year to create effective marketing strategies. Loyalty programs can be developed to retain long-term customers which can be identified using this data. Events and important occasions can be kept track of in order to release special offers, promotions and advertisements. Data gathered from social media sites is one which can be used most efficiently, through sentiment analysis techniques, to modify marketing strategies according to the different customer demographics.

### 3.2 Yield Management

Yield or Revenue Management deals with price optimization of the different resources offered by a hotel according to different internal as well as external factors. These factors could be the weather or season, the demand and supply in the local market or any internal pricing strategy being implemented.

As mentioned earlier, revenue management was among the first areas where business intelligence was used. Traditional revenue management tools were improved considerably with the advent of big data. Data available on booking sites and on search engines provided different customer channels, resulting in more sources of revenue but also more complexity in the economic management of a hotel. This data however could be leveraged to gain insights about the different customer channels and types so as to align the revenue system accordingly. One example of the above is the *innRoad* Real-Time Revenue Management System [3]. The *innRoad* system consists of three components - a forecasting module, a network optimizer and a suite of channel-level optimization modules. It uses real-time data to forecast property demand rates according to different segments and dates and then uses these forecasts for economic evaluation and allocation of rooms. The channel optimization modules use these evaluations along with the data they receive from various channels (rankings, reviews, etc.) to generate real-time prices for different channels, thus providing valuable information regarding the demand and supply view for the hotel [3]. Figure 3 gives the architecture for the above revenue management system.

[Figure 3 about here.]

The result of such an optimized system is an increase in revenue and decrease in management time and effort. The variety of data being generated online can be gathered and structured to create a big data warehouse which can be leveraged by such revenue systems to provide fast and useful real-time business analytic solutions.

### 3.3 Operational Effectiveness

There are several internal operations such as energy and water consumption, which can be optimized to ensure effective resource planning in any hospitality industry. Big data can prove to be a major tool in this area too, especially for big chains. Internal data from hotels belonging to a particular chain can be consolidated and analyzed to gain information about the resource utilization by different hotels and in different areas. Necessary strategies can then be devised to ensure optimum use of resources.

As mentioned by Kahn and Liu, the administrative data from a hotel can act as "laboratory" for researching different methods to improve energy efficiency [5]. In their study on a major United States hotel chain, they utilized energy consumption data from all hotels in the chain and used a multivariate linear regression technique to understand the factors that affected consumption rate in different areas. One conclusion that they arrived at was that consumption rates were lower in California, which was explained by the stringent energy efficiency laws in California. Conduction of various randomized control-trials also revealed that strategies such as informing people about the downside of increased energy consumption and offering performance bonuses to hotel managers who reduced consumption along with maintaining customer satisfaction, worked in favor of reducing energy costs [5].

The above case study demonstrates how use of even the regular internal energy consumption data generated by hotels over time can prove an essential source of information about the resource utilization in a hotel. Such data mining strategies to contain energy consumption can help decrease not only the operational costs of the hotel but also improve the eco-friendly aspect of the hotel due to reduction of harmful carbon emissions.

## 4 RECOMMENDATION SYSTEMS

Recommendation systems for travel and hotel sites such as Trivago, Priceline and Expedia are major business intelligence entities in the hospitality sector. These systems deal with huge volumes of data and analyze them to return useful recommendations. The most commonly used recommendation models are - Content-based, Collaborative Filtering and Hybrid. Content-based models provide recommendations based on previous ratings by the user, Collaborative Filtering models provide recommendations based on preferences of similar users and Hybrid models combine the above two i.e. the user's choice as well as the popularity of the recommended hotels [9].

An example of an effective Collaborative Filtering recommendation system is the KASR (Keyword-Aware Service Recommendation) system [9]. The model was implemented by extracting keywords from user comments to generate a list of keywords which were matched with a domain thesaurus (both for the current user and

previous users). Similarity between the current user and any previous user recommendations were calculated using approximate and exact similarity methods. Weights were assigned according to the number of such keywords and personalized ratings were calculated to generate recommendations for the current user. The system was implemented on Hadoop and using MapReduce for better scalability [9].

Similar to above, recommendation systems for the other two models, using the original algorithm and modified, have also been implemented. These recommendation systems provide users with the convenience of searching and booking optimum travel and stay packages in one go. Hopper, a useful travel application, uses its predictive analytics to inform users of the best time to fly to get cheaper rates on airline tickets. Doing so, it raised 16 million in a growth funding round in 2016 [10]. Expedia, a well-known travel application, partners with 231,000 hotels and 400 airlines to provide useful deals to customers [13]. These recommendation systems not only serve as useful tools for their customers but also valuable sources of business data for their client i.e. the hospitality sector.

## 5 CASE STUDIES

Big data analytics has increased tremendously across all service sectors, and the hospitality sector is moving further up the ladder in this era of business intelligence. However, there are some pioneers which must be mentioned as shining examples in this race. Red Roof Inn, a US economy hotel chain, struck upon the idea of having hotels close to the airport in the winter of 2013-14, as the flight cancellation rates were around 3 per cent at that time and travelers searched for hotels nearby to stay. They used data available publicly regarding flights and weather conditions to launch a marketing strategy that resulted in a 10 per cent increase in business in the targeted areas [7]. Starwood Hotels and Resorts, a large chain with around 1,200 hotels around the world, used local and worldwide market data along with seasonal weather data to update their pricing system and launch marketing campaigns. This resulted in a 5 per cent increase in their revenue-per-room [7]. Marriott Hotels, present at over 3,500 locations and generating 12 billion USD in revenue, revealed their success strategy as being “driven by internet availability”. The launch of the *Marriott Reward Program*, based on a business intelligence system which gives real-time information on the member loyalty status, duration of stay, and possible pricing models, has greatly boosted customer satisfaction [6]. InterContinental Hotels in San Francisco gathered data regarding the energy profiles of their hotel buildings and leveraged it to reduce their energy costs by 10-15 per cent [14]. Choice Hotels improved their business intelligence program by incorporating *Business Objects*, a business intelligence focused company, in their process to attain real-time data about revenue and occupancy rates. The dashboards with all the key data was provided to all their executives to assist in their decisions, thus empowering the company from within using big data analytics as a tool [6]. These case studies truly reflect the impact and growth of big data in the hospitality sector.

## 6 CONCLUSIONS

Big Data has revolutionized the field of Travel and Hospitality, and continues to grow as a major factor in all business decisions. What

started as a simple revenue management structure, has grown into an intelligent, sustainable system affecting more than one area in the hotel management arena. Launching marketing campaigns, deciding prices and resource allocations, optimizing energy and water consumption, renovating the IT structure, and improving customer comfort and satisfaction, have all been transformed by the arrival of Big Data and business intelligence. There are challenges still to the smooth integration of business intelligence into the day-to-day processes in the Hospitality Industry - overcoming a silos mentality, improving technical expertise to implement the complex Business Intelligence infrastructures needed, and gathering the resources required to support these structures. However, we have observed how the use of big data analytics and intelligence has reformed the hotels who used them. Integration of Big Data and intelligent systems as part of the decision-making process has the potential to become the next ‘big thing’ for the Hospitality Sector.

## REFERENCES

- [1] Duetto [n. d.]. *Bringing Predictive Analytics to the Hotel Industry*. Duetto.
- [2] Justin Guinn. 2017. Business Intelligence Tools. (2017).
- [3] innRoad [n. d.]. *Big Data Revenue Management for Independent Hotels*. innRoad.
- [4] Ming-Shen Jian, Yi-Chi Fang, Yu-Kai Wang, and Chih Cheng. 2017. Big Data Analysis in Hotel Customer Response and Evaluation based on Cloud. *International Conference on Advanced Communications Technology(ICACT)* (2017). <https://doi.org/10.23919/icact.2017.7890201>
- [5] Matthew E. Kahn and Peng Liu. 2016. Utilizing “Big Data” to Improve the Hotel Sector’s Energy Efficiency: Lessons from Recent Economics Research. *Cornell Hospitality Quarterly* 57, 2 (2016). <https://doi.org/10.1177/1938965515619489>
- [6] Diane Korte, Thilini Ariyachandra, and Mark Frolick. 2013. Business Intelligence in the Hospitality Industry. *International Journal of Innovation, Management and Technology* 4, 4 (2013). <https://doi.org/10.7763/IJIMT.2013.V4.435>
- [7] Bernard Marr. 2016. How Big Data And Analytics Are Changing Hotels And The Hospitality Industry. (2016).
- [8] Mauricio. 2016. The role of big data in the travel and hospitality sector. (2016).
- [9] Shunmei Meng, Wanchun Dou, Xuyun Zhang, and Jinjun Chen. 2014. KASR: A Keyword-Aware Service Recommendation Method on MapReduce for Big Data Applications. *IEEE Transactions on Parallel and Distributed Systems* (2014). <https://doi.org/10.1109/TPDS.2013.2297117>
- [10] Sarah Perez. 2016. Hopper raises 16 million for a travel app that tells you the best time to fly. (2016).
- [11] Gloria Phillips-Wren and Angela Hoskisson. 2014. Decision Support with Big Data: A Case Study in the Hospitality Industry. *Frontiers in Artificial Intelligence and Applications* 261, DSS 2.0 &ndash; Supporting Decision Making with New Technologies (2014). <https://doi.org/10.3233/978-1-61499-399-5-401>
- [12] Gil Press. 2014. 12 Big Data Definitions: What’s Yours? (2014).
- [13] Isabel Thottam. 2017. How Expedia, Hopper and Skyscanner Use Big Data to Find You the Cheapest Airfares. (2017).
- [14] Mark van Rijmenam. 2017. Why Hotels Should Apply Big Data Analytics To Provide a Unique Guest Experience. (2017).

#### LIST OF FIGURES

1	Hospitality Business Intelligence System [2]	5
2	Structure of the Customer Response Evaluation System [4]	5
3	innRoad Real-Time Revenue Management System [3]	6

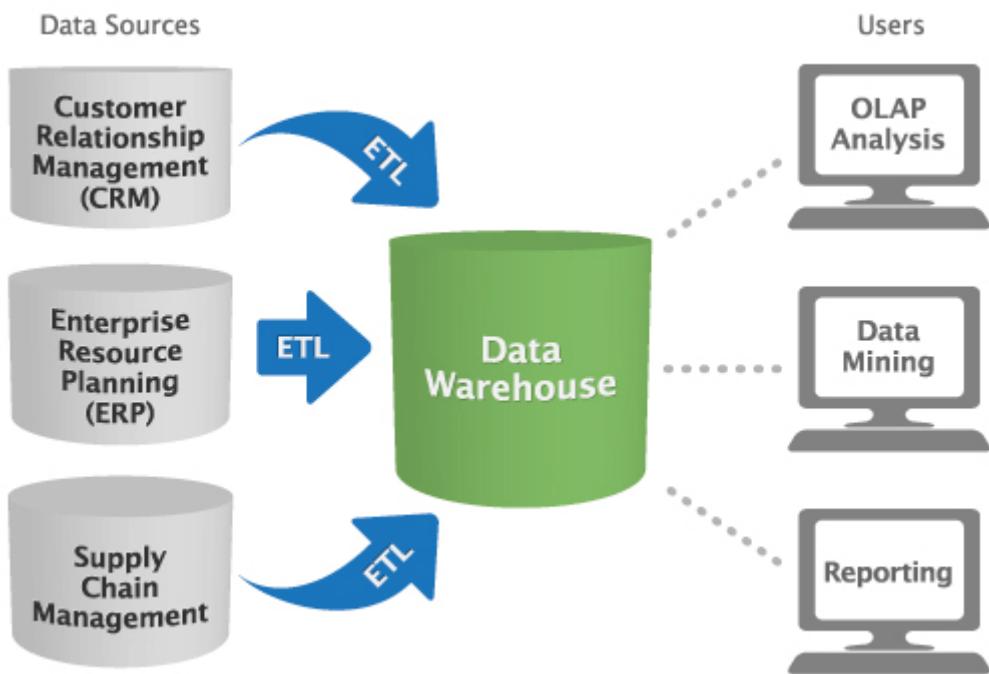


Figure 1: Hospitality Business Intelligence System [2]

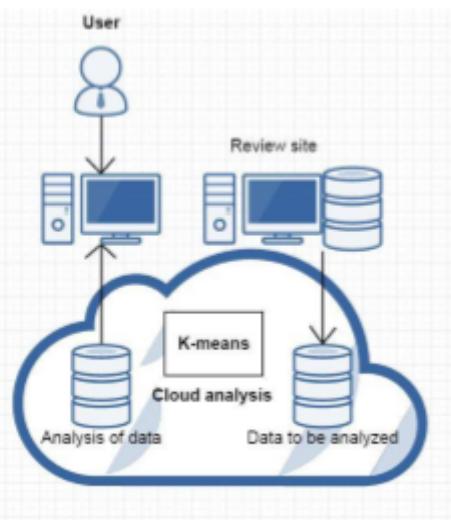


Figure 2: Structure of the Customer Response Evaluation System [4]

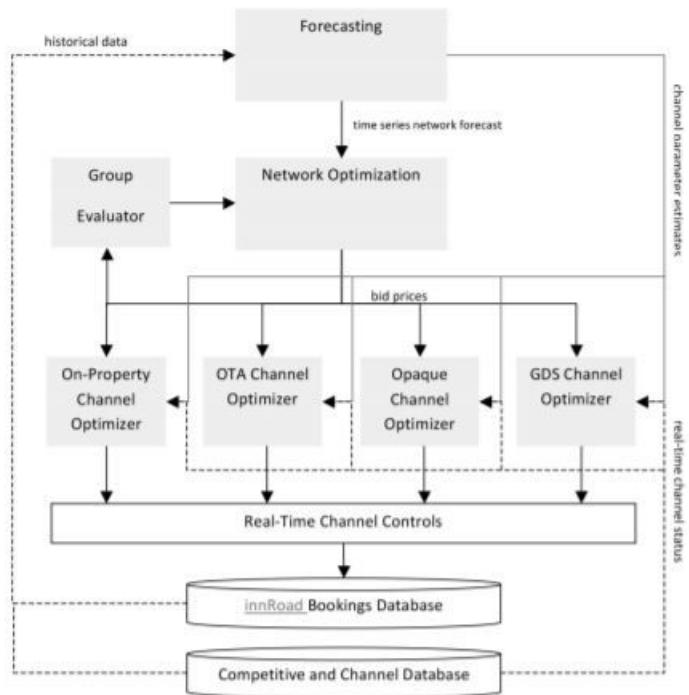


Figure 3: innRoad Real-Time Revenue Management System [3]

# Big Data Analytics in Tourism Industry

Weixuan Wang  
Indiana University Bloomington  
Bloomington, Indiana 47405  
wangweix@indiana.edu

## ABSTRACT

This study focused on how the tourism industry has been impacted by the development of the Internet and improvements in information and communication technologies. This study explored how big data are generated related the tourism industry and how big data analytic has influenced and can further affect tourism research.

## KEYWORDS

I523, HID234, Big data analytic, Tourism,

## 1 INTRODUCTION

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[11]. Developments in search engines, capacity, and speed of networks have influenced the number of tourists around the world that use technologies for planning and experiencing their travels. In addition, ICTs enable travelers to access reliable and accurate information and make reservations faster, cheaper and more convenient than the traditional way [3].

The development of ICTs also enables Internet users to both create and distribute content (multimedia information), which is called user-generated content (UGC) or consumer-generated content (CGC)[3].Platforms for UGC or CGC such as blogs, virtual communities, wikis, social networks, collaborative tagging, and media sharing sites play an increasingly important role as information sources for tourists. Social networks like TripAdvisor, Instagram, Facebook, Yelp, and booking.com are essential for tourists for multiple reasons: for their preparation of trips (booking hotels), during a trip (choose restaurant) and sharing their experience (writing hotel or restaurant reviews). Millions of data records are produced daily in regards to tourism by tourists, businesses an public services [9]. These data can be distinguished from big data by its volume, velocity (the speed it is produced), variety (different formats), variability (diversity of sources) and volatility (different level of production) [8].

Big data has been attracting more and more attention from tourism business and tourism researchers alike [4]. Big data analytics which is the activities of the specification, capture, storage, access, and analysis of such data sets to make sense of its content, provide new opportunities and challenges for tourism practitioners and researchers to understand tourists' behavior [8]. This study explores how big data are generated in the tourism industry and used in tourism research, further explore the implication and influence of big data and big data analytics for future research.

## 2 BIG DATA IN THE TOURISM INDUSTRY

Most activists in tourism industry had been generating a huge amount of data for several years.booking a plane ticket, reserving a hotel room and renting a car all leaves a data trail [9]. These data could add up to more than hundred of terabytes or petabytes structured data in the conventional databases. Discussion of travel arrangement on travel community online, status and post on social media like facebook and twitter, compliments and compliant on review websites like TripAdvisor constructs as more challenging and live unstructured data that arrives at a much faster pace than a conventional database [1]. Tourism practitioners are trying to understand tourists' behavior by accepting and analyzing these big data [9].

Airline and hotel chains have been using their big data which is the large volume of structured information that has been produced internally. Airlines and hotels have employed this tool to analyze of hotels' prices. Moreover, airlines have optimized the details of planning for the crew and routing [2, 9]. The online sector of the tourism industry has also quickly adopted big data to improve internal decisions and understand customers [1]. The online sector of the industry include online travel agencies (like Kayak, Expedia), meta-search engines (like Google) and some information companies that distribute tourism information (TripAdvisor).For example, Amadeus has developed a program for special results and the ability to search for its customers and Kayak has developed a program for predicting the prices [9].

### 2.1 Use of Social Media data in the Tourism Industry

Tourists in the digital age often use a variety of tools to access information that the tourism industry or other users have provided [12]. A tourist produces high volume of data when they are searching for travel websites, reporting data 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 [1, 9]. All these data that are produced constantly can demonstrate tourists' motivation, interests, and their planning patterns and so on.

Previous studies have demonstrated several different usage and formats of big data in the travel and tourism industry [13]. Social media is one of them that has a huge effect on the tourism industry. Social media includes blogs, review sites, media sharing, social networks, and wikis. The remarkable growth of these data sources has inspired new strategies to understand the socio-economic phenomenon in various fields [9]. Discussions on social media are considered as electronic word-of-mouth (eWOM) that has in some degree substituted tradition face-to-face word-of-mouth for information exchange of tourist experience [3]. According to a study

on travelers' counseling with social media for travel planning in the US in 2014, 44 percent in the age group 18-34 years old use information in social media before planning for travel [10].

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 [2, 8]. 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. However, the study also has its own limitation because of the limitation of technology to better exploit the data [2]. 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 [6].

## 2.2 Other Big Data in the Tourism Industry

Beside the use of social media content to analyze tourists behavior, previous studies by Statistics Netherlands has also proposed using other innovative ways to understand tourists behavior by using mobile phone [5]. First method is using log data collected by an app installed on mobile devices, which allowed researchers to track accurate movements of a person or family. This app also can pop up different questions that are triggered by location or change of time, such as purpose of the journey, satisfaction and activities. This innovative design combined the traditional survey with log data from smartphone measurements produced a rich and valuable sets of data [5]. However, this kind of method may be hard to get willing participants, because of privacy concerns and also technical issues such as people may not know how to download and use such application.

Another project from Statistic Netherlands uses aggregated mobile phone meta-data based on call detailed records from 2012 to 2014. This study collaborated with two telecom providers. Call detailed records contained information of the date and time and location where a communication through mobile network is used. The study uses these information and roaming data to identify unique foreign tourists, was able to detect different groups of foreign tourists and what are their favorite touristic sites within Netherlands [5]. The limitation of this research is also restricted because it requires collaboration with telecom providers and its privacy concerns. With the technology development and widespread of WI-FI, when tourists go to another country they may not need to have roaming service in their destination [5].

## 3 BIG DATA IN TOURISM RESEARCH

Although tourism scholar has recognized the importance of UGC data such as travel blogs, online reviews and social media post as a form of eWOM has a huge influence in creating destination image. Tourism scholar has also done content analysis on online reviews and travel blogs, but recognizing big data and using big data in tourism research is still limited [3, 11].

Most tourism research utilizing big data are still 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. They mined their customer review data from TripAdvisor using a web crawler. Through their linguistic analysis of their data and cross-comparing with perceptual mapping of the hotels, they find 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) [4].

Another study also focused on UGC and trying to find out determinants of hotel customer satisfaction by discriminating among customers by language group. This study collected 412,784 reviews on TripAdvisor for 10,149 hotels in China. They have found out that tourists speaking different languages (such as Chinese, English, German, French, Russian etc.) differs substantially in terms of their emphasis on various attributes of hotels, and forming different satisfaction rating for hotels [7].

Both of the two studies mentioned above were from tourism or hospitality journals, were conducted by tourism researchers. Another study from outside of tourism research cohort provided a different study using big data to understand tourist behavior. This study designed and evaluated a big data analytics method using geotagged photos shared by tourists on Flickr to support destination management organization in analyzing and predict tourist behavior patterns at destinations (for this study it is Melbourne, Australia). The study designed a geotagged photo analytic artifact with textual meta-data processing geographical data clustering, representative photo identification and time series data modeling. This study demonstrated how to analyze unstructured big data to enhance strategic decision making in tourism destinations, provided insight on how city tour can be designed to better reflect tourists' interests and enrich their travel experience [8].

## 4 CONCLUSION

This study has explored the literature of big data and its implication in the tourism industry. 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. Therefore, big data presented us opportunities to better understand tourist behavior, their motivations, and interests. However, big data also poses challenges for tourism practitioner and tourism researchers.

Like these two studies from tourism and hospitality journals, they share similarities in terms of data collection methods. Tourism researchers have recognized the importance of user-generated data which was able to provide them the volume of data they need for better generalization. One limitation of this kind of tourism research is that they only focus on hotel reviews, but their method could extend to other tourism sectors such as attraction and event to evaluate or review dimensions of tourist satisfaction. Another limitation they have is that they are only focusing on the text-based data from review website. How to integrating and getting useful information from other unstructured data such as image, video, post on Facebook and Twitter is still challenging for tourism researchers.

However, studies outside of tourism domains can be helpful in helping tourism researchers to utilize other formats of big data to understand tourist behavior. Therefore, collaboration with other fields and utilizing unstructured big data, and big data analytics in relation to tourism are much needed for tourism research.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski and I523.

## REFERENCES

- [1] Rajendra Akerkar. 2012. *Big Data & Tourism*. Technical Report. Technomathematics Research Foundation.
- [2] 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)*, 5–7. <https://doi.org/10.1109/BigData.2014.7004475>
- [3] Jin Chung and Dimitrios Buhalis. 2009. *Virtual travel community: bridging travellers and locals*. IGI Global, Chapter Chapter 8, 130–144.
- [4] Yue Guo, Stuart J. Barnes, and Qiong Jia. 2017. Mining meaning from online ratings and reviews: Tourist satisfactionanalysis using latent dirichletallocation. *Tourism Management* 59, Supplement C (2017), 467 – 483. <https://doi.org/10.1016/j.tourman.2016.09.009>
- [5] Nico Heerschap, Shirley Ortega, Alex Priem, and May Offermans. 2014. *Innovation of tourism statistics through the use of new big data sources*. Technical Report.
- [6] Takeshi Kurashima, Tomoharu Iwata, Go Irie, and Ko Fujimura. 2013. Travel route recommendation using geotagged photos. *Knowledge and information systems* 37, 1 (2013), 37–60.
- [7] Yong Liu, Thorsten Teichert, Matti Rossi, Hongxiu Li, and Feng Hu. 2017. Big data for big insights: Investigating language-specific drivers of hotel satisfaction with 412,784 user-generated reviews. *Tourism Management* 59, Supplement C (2017), 554 – 563. <https://doi.org/10.1016/j.tourman.2016.08.012>
- [8] Shah Jahan Miah, Huy Quan Vu, John Gammack, and Michael McGrath. 2017. A Big Data Analytics Method for Tourist Behaviour Analysis. *Information & Management* 54, 6 (2017), 771 – 785. <https://doi.org/10.1016/j.im.2016.11.011>
- [9] S. Shafiee and A. R. Ghafari. 2016. Big data in tourism industry. In *2016 10th International Conference on e-Commerce in Developing Countries: with focus on e-Tourism (ECDC)*, 1–7. <https://doi.org/10.1109/ECDC.2016.7492979>
- [10] Statista. 2014. Travelers who consult social media when travel planning in the United States as of April 2014, by age group. (2014). <https://www.statista.com/statistics/305150/travelers-using-social-media-for-travel-planning-by-age-us/> accessed 2017.
- [11] 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.
- [12] 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>
- [13] 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>

# Big Data in Recommendation System

Yujie Wu

Indiana University Bloomington

Bloomington, Indiana 47401

yujiwu@iu.edu

## ABSTRACT

This paper will be focused on how the company recommends their products and services to their customers based on the data about customer's preferences through the case of Netflix and Yahoo.

## KEYWORDS

Recommendation system, Netflix, Yahoo

## 1 INTRODUCTION

With the development of web technology and online business, recommender systems are widely used in e-Commercial business platform such as Amazon, eBay, Monster and Netflix. They process a tremendous number of online commercial activities and provide the personalized online business experience, which relies on the recommender system. The recommender system tells the customers what they are looking for, what they want to buy, and so on. With the recommender system, less popular products can attract people's attention and e-Commercial business model works more efficient and profitable.

The basic problem of recommendation system is personalized matching of items (people, products, services, jobs, etc.) to people[3]. The recommendation system takes the data that is produced by people's online activities and some specific criteria such as overall context, user information, community information, properties of items plus the machine learning or data mining algorithms to output some information or suggestion that people may be interested in or related to according to their preferences for some goals[3].

## 2 NETFLIX RECOMMENDER SYSTEM

Netflix recommender system is an industrial-scale and real-world recommender system. Its recommendation is based on personalization. For customers (household), everything that they could see on the front-end webpage containing rows and columns is recommendation. The columns are sorted by the ranking and diversity. The personalized genre rows focus on user interest which is important for user satisfaction. They are generated based on the users' recent activities, ratings, comments, or users' preference settings. The recommender system will filter out the movies if they have been watched before and exclude duplicated tags and genres when providing recommendations and suggestions[3].

Netflix recommender system just takes the user preferences and output the immediate recommendations. How is it highly related to Big Data? According to the statistics from Netflix, last two quarters in 2013 have four million new registered subscribers, which leads to total 29.2 million subscribers were actively using Netflix. There are 4 million ratings, 3 million searches, 30 million plays happening in Netflix website every day. At the end of 2013, Netflix reached 44 million members[3]. A large amount of data is collected each day. Therefore, it becomes reality that Netflix recommender system could use Big data which usually beats better algorithms to provide recommendations.

The algorithms that Netflix recommender system is using are Restricted Boltzmann Machines (RBM) and a form of Matrix Factorization. They are developed as part of the Netflix 2007 Progress Prize which worth several million dollars. Restricted Boltzmann Machine is a neural network. The form of Matrix Factorization is an asymmetric form of SVD which can take implicit information into account[1]. Both algorithms consist of a tremendous number of different machine learning techniques. The algorithms consume a large amount of data as their input. Machine learning techniques form an abstract model which is waiting for data stream to shape it. Once the model reaches convergence or it becomes mature enough, the algorithms output the prediction which is used as the recommendation for Netflix users. More data means more precise the outcome is.

The recommendation algorithms are designed based on the hypothesis that the suggestions will increase the member engagement with Netflix service and ultimately attract more users and more profits. To verify whether the algorithm works as expected, Netflix designed a test, named AB test. AB test is an experimental approach to figure out the changes of webpages which maximize an outcome of interest. The test contains two identical versions with only one different variation which possibly affect customer's behavior[3]. For instance, the A version of a website has some webpages that could be accessed through a category list. The version B of that website is modified from version A that the webpages which can be accessed only through a category list now have their own shortcuts listed on the main page of the website. Once executing the AB test, it is obvious whether the modification on that variation increases the user engagement.

To modify the webpage, it should measure or evaluate all related metrics, which is a data-driven process. Metrics could

be short-term or long-term. Sometimes, short-term metrics do not fit the long-term goals. For example, larger quantity of clicks does not necessarily mean better recommendation. However, long-term metrics such as member retention works better in Netflix[3]. With the choice of metric, Netflix monitors how users interact with different algorithms during the testing.

### 3 YAHOO RECOMMENDER SYSTEM

The main page of Yahoo contains many modules such as advertising module, search queries recommendation, breaking news recommendation, and application recommendation. All recommendations rely on Yahoo recommender system based on the given context such as user data and user preferences. Yahoo recommender system is not merely an algorithm or a piece of code, it is an environment that involves items, context, and metric. Items could be articles, advertisements, movies, songs that users may be interested in. Context could be query keywords, pages, mobile, social media that users provided while surfing online. Metric could be click rate, revenue, engagement that needs to be optimized for achieving some long-term business objectives[4].

Every second, a tremendous amount of data from users and machines is feed to the system. It is a problem that big data matters. Therefore, big data analytics and machine learning algorithms can be applied to improve or optimize the metric and the system while recommendation is on-going.

The data is easy to obtain but its quality is not guaranteed since the nature of data resource. Various factors including the properties of the item, context, feedback, and constraints specifying legitimate matches may affect data quality and eventually the solution. Yahoo recommender system uses collaborative filtering to deal with such problem.

Collaborative filtering assigns each item an individual rating to form a consensus recommendation. To be more specific, collaborative filtering has three branches which are user-based collaborative filtering, item-based collaborative filtering, content-based collaborative filtering. As the name implies, user-based collaborative filtering groups the similar users and find their preferences, then it predicts the interest of current user based on the group of the similar users. Item-based collaborative filtering recommends items to current user based on the rating that is assigned to each individual item. Content based collaborative filtering finds the items with the similar properties that the current user likes[4].

Collaborative filtering is now the most prominent approach to generate recommendations. It presumes that the ratings of the items are given by users. Then it takes a table of data including the users and item ratings to compare the values and return the top-ranked items for the current user[4]. Finally, collaborative filtering outputs a prediction

that describes how much the current user likes or dislikes the item.

As mentioned before, the input is a table which has a set of attributes. Each attribute represents an item and each tuple represents a user. Therefore, the value in each cell means the rating of the item given by corresponding user. Collaborative filtering finds some most similar users and their items to the current user, then remove the items that current user have already seen or purchased. Hence, the input data table only includes similar users and items which will be recommended to the current user.

Here remains a problem that how to define the similarity between users. Let A and B be two different users and let I be the set of items that both user A and B rated. Let  $r_{a,i}$  be the rating of user A for  $i^{th}$  item. Let  $\bar{r}_a$  and  $\bar{r}_b$  be the average value of all items in set I rated by user A. Therefore, the similarity could be calculated as the following function[4]:

$$sim(a, b) = \frac{\sum_{i \in I} (r_{a,i} - \bar{r}_a)(r_{b,i} - \bar{r}_b)}{\sqrt{\sum_{i \in I} (r_{a,i} - \bar{r}_a)^2} \sqrt{\sum_{i \in I} (r_{b,i} - \bar{r}_b)^2}}$$

The similarity function is called cosine similarity. The function assumes each tuple in the table is a vector. Since similarity function uses cosine value, the possible value of similarity is between -1 and 1. If two vector points to the same direction, cosine similarity value equals 1. If two vector points to the opposite direction, cosine similarity value equals -1.

Once the data table is feed to the algorithm, the prediction of the rating value of some random item i which will be recommended to the current user could be calculated as follows[4]:

$$pred(a, i) = \bar{r}_a + \frac{\sum_{b \in N} sim(a, b)(r_{b,i} - \bar{r}_b)}{\sum_{b \in N} sim(a, b)}$$

where a is the current user and b is a random user in the data table. The set N is group of all users in the data table except the current user. The item with highest rating value will be returned by the algorithm as the ultimate suggestions to the current user.

Yahoo recommender system in advertisement module employs machine learning technologies such as singular value decomposition (SVD) and latent semantic indexing (LSI) to provide recommended keywords. SVD and LSI are also used to recommend music and movies[2]. Like the most machine learning algorithms, SVD and LSI train the model based on the numeric data. Since a tremendous amount of data is gathered in a short period of time, the training time will increment exponentially and leads to a delay in response finally. The solution of Yahoo recommender system is partition the data set and develop new method for certain sets. The training time , as a result, increases log-linearly in practical situations[2].

## 4 CONCLUSION

Big data is highly involved in recommendation machines. Both Netflix and Yahoo utilize machine learning algorithms such as Restricted Boltzmann Machines, a form of Matrix Factorization, singular value decomposition, and latent semantic indexing. Yahoo also uses collaborative filtering algorithm for item recommendation. Netflix uses AB testing for validating a new recommender algorithm. In the future, more efficient and more elegant algorithms will be invented. Big data will lead to a more precise recommendation.

## REFERENCES

- [1] Xavier Amatriain. 2014. How does the Netflix movie recommendation algorithm work? Online. (12 2014). <https://www.quora.com/How-does-the-Netflix-movie-recommendation-algorithm-work>
- [2] Dennis Decoste, David Gleich, Tejaswi Kasturi, Sathiya Keerthi, Omid Madani, Seung-Taek Park, David M. Pennock, Corey Porter, Sumit Sanghai, Farial Shahnaz, and Leonid Zhukov. 2005. Recommender Systems Research at Yahoo! Research Labs. Online. (1 2005). <https://www.cs.purdue.edu/homes/dgleich/publications/decoste2005%20-%20yahoo%20recommender%20systems.pdf>
- [3] Geoffrey Fox. 2017. Big Data Applications and Analytics Case Study: e-Commerce and Life Style Infomatics: Recommender Systems I. Online. (9 2017). <https://drive.google.com/file/d/0B6wqDMlyK2P7YklwczVfQJjqVG8/view>
- [4] Geoffrey Fox. 2017. Big Data Applications and Analytics Case Study: e-Commerce and Life Style Infomatics: Recommender Systems II. Online. (9 2017). <https://drive.google.com/file/d/0B6wqDMlyK2P7UVloVElaZ2FXcTg/view>

# Big Data Application in Restaurant Industry

Sushant Athaley  
Indiana University  
sathaley@iu.edu

## ABSTRACT

Big data application is not only getting used in scientific research but it is also getting used commercially. Most of the businesses are using big data to change the way they are operating and getting rewarded. The restaurant business is also currently evaluating how big data can be used. This study focuses on the big data elements for the restaurant industry, gathering of big data, analytics, available big data solutions, current implementations, and challenges faced by restaurant industry in big data application. This study considers information from various sources like articles, books and web to provide this information.

## KEYWORDS

i523, hid302, big data, restaurant, application, analytics

## 1 INTRODUCTION

Big data is revolutionizing the way business is getting conducted in various industries. The retailer like Amazon uses it to provide personalized buying suggestions and social networking site like LinkedIn uses it to connect more people. Question is, do we have big data available for the restaurant industry and how big data application is going to be beneficial? The restaurant industry is facing challenges like shrinking labor pool, moderate economic growth, costly labor, challenging profit margin, high competition, moderate sales growth and growing expectation from the customer on the dining experience, can big data application help overcome these challenges?[5]

The study is structured as follows. Section *Ingredients* captures various data points available in the restaurant industry for the big data analysis. Section *Consume* provides details on how data can be gathered in the restaurant industry. Section *Recipe for Success* captures various big data analytics which can help to solve different problems. Section *Kitchen Tools and Gadgets* provides information on current big data solutions and tools available for the restaurant industry. Section *Flavourful Implementations* provides real-life examples of big data applications in the restaurant industry. Section *Hell's Kitchen* capture various challenges involved in using big data for the restaurant industry. Finally, section *Conclusion* concludes the study.

## 2 INGREDIENTS

To understand how big data analytics will help, we first need to find out what are the data points present in the restaurant industry which can be considered as big data. As one of the V-variety of big data, the restaurant also has structured and unstructured data. Structured data is something which is getting generated inside the restaurant and unstructured data is something which is outside of the restaurant. Refer figure 1.

[Figure 1 about here.]

## 2.1 Structured Data

Structured data is well formatted, easy to understand and analyze. Restaurant POS(point of sale) system shows what's selling, where, and at what time[11]. Food and beverage cost, labor cost, product mix, rent cost are obvious data points. Raw material required for preparation, menu, ingredient consideration, meal preparation, product availability from the supplier, prices of products are the data points which comes from the kitchen of the restaurant. Staffing schedule, table turnover, bar management, wages, salaries, tips, customer feedback is valuable data. The number of time employee coming late, number of times drinks provided as comp due to server error is data.[6]

## 2.2 Unstructured Data

Unstructured data is un-formatted, difficult to gather and analyze. Data shared from social media like trends, retweets, shares, and comments categorize as unstructured data. Customer promotions, customer profile like age, gender, address, email, taste preference, favorite dish, various milestones like birthdate, anniversary, along with family information is also an unstructured data. Weather and traffic information also constitutes as an important data to consider. [6]

## 3 CONSUME

These various data attributes can be collected from the different systems. Most of the data is generated inside the restaurant by the system like POS which captures all sales transactions. POS system can also break down sales by time, size of the party, menu items, and ingredients. The inventory provides information on suppliers, food, beverages, and gas and electricity bill. Payroll provides information on wages, salaries, employee schedule, and time off by the employees. Loyalty program and marketing promotions provides data regarding marketing of the restaurant.

Outside data can be gathered through the various applications like OpenTable, Facebook, Twitter, Yelp, TripAdvisor, Foursquare, Urbanspoon or Instagram, weather and traffic sites. Information can be gathered from customer like his favorite menu/drink item, favorite table, special request, allergies, liking to the presentation, feedback on ambiance, service and food. [6]

## 4 RECIPE FOR SUCCESS

Benjamin Stanley, co-founder of Food Genius, suggests "A restaurant operator shouldn't just jump into big data unless they have a problem they are trying to solve"[9]. Big data analytics can help with various analysis which can solve different issues but it's important to know the problem which needs to be solved. If the goal is to reduce costs, streamline operations or better manage the staff then analysis needs to be done in inventory control, supply chain management or scheduling solutions. If the problem is related to food

trends, menu options and improving the customer experience, then focus probably can be on social media, customer demographics, and dining-out trends. [6]

Menu analysis can help with deciding the cost of the item, popular menu item, how often items are ordered, the time when menu item ordered, ingredient used and if any ingredient needs to be substituted[9].

Labor cost can be managed better by analyzing overtime pay, absenteeism, costs to sales, costs by department and server, tips, amount of time spent at the table, types of entrees sold and whether the server sells the special. This analysis can be used to motivate, train and provide incentives to the servers[6],[9].

Guest check analytics can help determine what sells well, how often somebody orders certain items and detailed pricing analyses[6]. Customer profile analysis gives insight on demographics of the customer, ages, income level, their family information, kind of food they like, allergies, drink habits, places they dine out, special occasions and this analysis can be used to provide the personalized experience to the customer[6]. Servers can use customer profile analysis to suggest menu choices, celebrate birthdays or special occasions, or run specials to drive more business. Reservation system data analysis helps in understanding who all are coming, when they last visited, what they tend to order, are they celebrating any special occasion and accordingly then chef can decide on the menu[12].

Data mining of data from social media like Facebook, Twitter, Instagram, YouTube can help in understanding sentiments of the customer, social news, trending topic, views on self and competitor restaurants, identify brand or restaurant fans[8]. This mining also provides the capability to get feedback real time and respond at the same time. This information can be used to do targeted marketing for the specific audience[8].

## 5 KITCHEN TOOLS AND GADGETS

Fishbowl provides cost-effective data analytics solution to the restaurant industry using Hadoop and other technologies. Fishbowl integrated Hadoop with their marketing platform to provide guest analytics, menu management, media analytics, promotions and mobile platform to provide complete solutions.[7][1]

MyCheck and MarketingVitals.com together provide mobility and data analytics platform for the hospitality industry. [3]

Dickey's Barbecue Pit restaurant has worked with big data and business intelligence service provider iOLAP to develop a proprietary system called as Smoke Stack. Smoke Stack provides real time data analytics to take better decisions. [10]

Upserve, a restaurant management platform, provides payment processing, point of sale, data insights to boost margins and exceed guest expectations.[12][2]

Founding Farmers gathers data together from Swipely, OpenTable and analytics service Avero Slingshot to do the customer profile analytics and builds top 100 customers to reach out to them in a highly personalized way. It also helps in understanding customers food and drink preferences along with how they would like to be served so that their dining experience can be personalized.[9]

## 6 FLAVORFUL IMPLEMENTATIONS

A quickservice chain monitors its drive-thru lanes to determine which items to display on its digital menu board. When lines are longer, the menu features items that can be prepared quickly. When lines are shorter, the menu features higher-margin items that take a bit longer to prepare. Those subtle changes in the menu board wouldn't be possible if the company couldn't tap into a steady stream of data in real time to make instantaneous adjustments.[6]

Haute Dogs and Fries, a two-unit, quickservice restaurant in Alexandria, Va., leverages social media to connect with customers. Being small and community-focused allows the operation to quickly identify market trends and make offers in real-time, says co-owner Lionel Holmes. He monitors social media throughout the day and might post a lunch special at 11 a.m. or a dinner offer at 3 p.m. based on what is trending. Haute Dogs and Fries is on Twitter, Facebook and Instagram and uses email to reach customers and build loyalty.[6]

Fig and Olive, a seven-location New York-based restaurant group, has used guest-management software to track more than 500,000 guests and \$17.5 million in checks. The restaurants have been able to customize the dining experience for individual guests and deliver results with targeted email communications. It's *we miss you campaign* offered complimentary crostini to guests who hadn't dined there in 30 days. The result: Almost 300 visits and more than \$36,000 in sales, translating into a return of more than seven times the cost of the program. Matthew Joseph, who leads technology and information systems for the company, says linking POS data with online reservations, plus monitoring social media mentions on Facebook, Twitter or TripAdvisor, helped Fig and Olive create its brand identity and build loyalty.[6]

Dickey's Barbecue Pit, which operates 514 restaurants across the U.S., uses Smoke Stack system to provide near real-time feedback on sales and other key performance indicators. All of the data is examined every 20 minutes to enable immediate decisions. If the sale is not at certain baseline at a certain store in the region then it enables them to deploy training or operation directly to that store. For example, if there is lower than expected sales one lunchtime, and have an amount of ribs there, then text invitation is sent to people in the local area for ribs special to both equalize the inventory and catch up on sales.[10]

Andy Husbands, chef-owner of Tremont 647 restaurant, uses a management system called Upserve to keep tabs on what his customers like and don't like. The software pulls together streams of information like transaction data, OpenTable reservations, and sales history and displays everything on a dashboard that Husbands can access on his phone, giving him insight into how his food and staff are performing. He can instantly see which server has the highest check average and whether it's because server, for instance, sells more appetizers or drinks than his/her co-workers.[12]

## 7 HELL'S KITCHEN

The restaurant industry is very slow in terms of adopting or spending on new technologies due to small profit margins, high employee turnover and the overall cost of implementation[12]. Most of the restaurants are still using legacy software packages which are inadequate in dealing with the big data. These legacy software packages

are cumbersome to upgrade or integrate with new technologies or data streams which are required for the big data analytics. It can take a lot of times to get data from old restaurant software to the data warehouse. Even if data is centralized, it's difficult for most of the restaurants to hire a data scientist to analyze data due to their costly salaries. Only big restaurant chain can afford such costly labor and tools needed for the big data application[4]. Another major challenge is the variety of big data source and format involved in restaurant industry like structured data in form of POS, inventory systems and unstructured data like social networking site or weather reports. Combining data from such various sources is big deal. There are financial challenges also as technology offered to work with big data is expensive which makes leveraging big data challenging for most of the restaurants.[7] Dealing with customer personal data poses a security risk. This sensitive information if collected need to be protected so that it is not misused for identity theft or some other fraud.[6]

## 8 CONCLUSIONS

Big data application offers ample opportunities to solve the various problems faced by the restaurant industry. It is opening avenues which cannot be imagined earlier but adoption of big data application is a bit slow in restaurant industry compared to other industries like retail due to low-profit margins and high application cost. Currently, big data is mostly used by the large chain and Michelin star restaurants who can afford the big data solutions. Efforts are getting made to provide low-cost solutions so that small and medium restaurant can also embrace the big data. There is no doubt that big data application is going to change the way people dine out and as quickly restaurant adopts it the quicker it's going to provide customers that Umami effect.

## A TRANSLATION

Restaurant related terms used and corresponding translation in terms of usage in this study.

- **INGREDIENTS** - any of the foods or substances that are combined to make a particular dish, this term is used to denote the data attributes in restaurant industry for big data
- **CONSUME** - eat, corresponds to gathering of big data
- **RECIPE FOR SUCCESS** - corresponds to big data analytics
- **KITCHEN TOOLS AND GADGETS** - corresponds to solutions and tools available for big data application in restaurant industry
- **FLAVORFUL IMPLEMENTATIONS** - corresponds to real life big data implementation in the restaurant industry
- **HELL'S KITCHEN** - It's a popular reality television cooking competition show full of challenges, corresponds to challenges of using big data in restaurant industry
- **Umami** - Japanese food term to describe delicious food or taste
- **POS** - point of sales system to capture sales in the restaurant

## ACKNOWLEDGMENTS

The author would like to thank internet fraternity who generously contributes information on the web for others enlightenment. The

author would also like to thank Dr. Gregor von Laszewski for his review and suggestions.

## REFERENCES

- [1] [n. d.]. ([n. d.]). <https://www.fishbowl.com>
- [2] [n. d.]. ([n. d.]). <https://upserve.com>
- [3] 2015. (Sept 2015). <http://www.businesswire.com/news/home/20150916005807/en/MyCheck-Marketing-Vitals-Announce-Integration-Big-Data>
- [4] 2015. Big Data's Last Crusade: Restaurants still slow to embrace smart technology. *FastCasual.com* (May 2015).
- [5] 2016. Restaurant industry to navigate continued challenges in 2016. (02 2016). <http://www.restaurant.org/News-Research/News/Restaurnt-industry-to-navigate-continued-challenges>
- [6] National Restaurant Association. 2014. Big Data and Restaurants: Something to Chew On Web. (11 2014). <https://www.restaurant.org/Downloads/PDFs/BigData>
- [7] Dev Ganeshan. 2015. How Big Data Technologies Are Revolutionizing Restaurant Marketing. (Feb 2015). <https://www.foodnewsfeed.com/fsr/vendor-bylines/how-big-data-technologies-are-revolutionizing-restaurant-marketing>
- [8] LISA JENNINGS. 2015. Making big data small. *Nation's Restaurant News* 49, 7 (May 2015), 22–23.
- [9] Amanda C. Kooser. 2013. BIG DATA. *Restaurant Business* 112, 9 (September 2013), 24–31.
- [10] Bernard Marr. 2015. Big Data At Dickey's Barbecue Pit: How Analytics Drives Restaurant Performance. (Jun 2015). <https://www.forbes.com/sites/bernardmarr/2015/06/02/big-data-at-dickeys-barbecue-pit-how-analytics-drives-restaurant-performance/> Forbes Article.
- [11] John Morell. 2013. Get a Grip on Big Data. (may 2013). <https://www.qsrmagazine.com/operations/get-a-grip-on-big-data>
- [12] Nicole Torres. 2016. How restaurants know what you want to eat before you do. FOOD and DRINK INC. — MAGAZINE. (May 2016). <https://www.bostonglobe.com/magazine/2016/05/26/how-restaurants-know-what-you-want-eat-before-you/hnZHM3xCkL1BhX0PKL3tmM/story.html>

## LIST OF FIGURES

1 Image courtesy restaurant org - Data Sources

5

# WHERE DATA COMES FROM

## Structured

(inside the business)

- **POS** — What's selling, how much does it cost, who's buying it
- **Suppliers** — Product availability, prices
- **Accounting** — Costs, revenue, margins
- **Labor** — Wages, salaries, tips

## Unstructured

(outside the business)

- **Social media** — Likes, trends, retweets, shares, comments
- **Customer profiles and loyalty programs** — Names, addresses, email, preferences
- **Weather and traffic patterns**

## Why you need both

Structured data tells you the “**what**”; unstructured data tells you the “**why**.” Using both gives you a more holistic view of your customer.

Figure 1: Image courtesy restaurant org - Data Sources

# Big Data Applications in Food Insecurity

Kevin Duffy

Graduate Student, Data Science Online Masters Indiana University School of Informatics, Computing, and Engineering  
4014 E. Stop 10 Rd.  
Indianapolis, Indiana 46237  
kevduffy@iu.edu

## ABSTRACT

This paper addresses how big data can be used to identify "food deserts", areas where there is no fresh, healthy food available to the population, to be used for community planning or research purposes.

## KEYWORDS

food deserts, food insecurity, big data

## 1 INTRODUCTION

For many within the United States, ready access to affordable, nutritious food is a constant challenge. Many communities have no grocery store with supplies of various fresh foods, relying instead on convenience stores and fast food restaurants in order to find sustenance. These areas have come to be known as "food deserts".

It is estimated that 23.5 million Americans currently live in a food desert[8], and they have been linked to higher rates of childhood obesity, heart disease, and overall lower quality of life[7].

Up until recently, it has been difficult to define what a food desert actually is, and where to find them. However, researchers armed with big data have been able to make advances in identifying these problem areas and introducing solutions to help the people living there.

This paper will set a common definition with which to identify what a food desert is and where they are found. It will then showcase a few examples of government and private sector solutions to food deserts using big data through information sharing and classification.

## 2 DEFINITIONS

It will be useful to identify a common definition to operate on concerning "food deserts". Since it is a relatively new term, many differing definitions have been floated. For the purposes of this paper, we will use the definition given by the United States Department of Agriculture (USDA). According to the USDA, a food desert is any area that meets two criteria:

- (1) Low income, defined using poverty rate and median family income data. A community defined as "low-income" would have the following characteristics[8]:
  - (a) Poverty rate exceeding 20 percent
  - (b) A median family income being no greater than 80 percent of the median family income of the larger community
- (2) Low access, with at least one of the following characteristics[1]:
  - (a) A. 33 percent of the population of the given area does not have the means (transportation) to reach a store, or

- (b) B. There is no store within their defined area.

## 3 IDENTIFYING PROBLEM AREAS

With the problem defined, the USDA set out to identify where in the United States were the areas that matched this criteria. All of the needed data was publicly available.

The USDA created their Food Access Research Atlas[3] in order to examine more carefully the similarities and differences between these areas. They used a variety of sources to inform the map where these areas existed:

- For general demographics, population, and rural/urban distinction they used data from the 2010 census.
- For income, vehicle availability, and food stamp participation they used data from the 2010-14 American Community Survey[5].
- For a comprehensive list of supermarkets and large grocery stores, they used two sources:
  - (1) A list of stores authorized to receive SNAP benefits (food stamps)
  - (2) A trade list from Trade Dimensions TDlinx[1].

This data was assigned to 1/2 kilometer squares for the most granular look possible at distinct food deserts within our cities and states. Using this information, they mapped out in detail where food deserts exist in the United States.[1]

Isolating the problem is vital, but only part of the solution. There are reasons these communities are without sufficient grocery options. For rural areas, the population density is often too low for companies to find it worthwhile to build a new store. For urban areas, increased crime levels often deter companies from finding a location desirable, even if it is in a densely populated area.[8]

However, unique solutions are emerging through the use of big data. Here are some examples of organizations using data such as that provided by the USDA to leverage solutions to those living in food deserts.

### 3.1 Online delivery

Normally, FreshDirect is used as a web-based produce delivery service catered towards a wealthier demographic. It provides fresh fruits and vegetables right to people's homes. But the company recently started a pilot program to bring online groceries to disadvantaged areas identified as not have ready access to fresh food.[6] The pilot program currently only exists in a few zip codes in New York, but it is proving effective.

The company is able to use card readers at delivery to charge the groceries to the recipients' SNAP benefits card - bringing fresh food to deserts and circumventing the problem of companies avoiding high-crime areas for brick-and-mortar businesses. The company is

compiling data on the impact of the pilot program as they look at possible expansion.[6]

### 3.2 Charity matching

To many who live in food deserts, food pantries are an essential source of fresh food. These organizations used to be scattered and uncoordinated - donors did not know who to donate to, organizations had to rely on whatever foods happened to be dropped off in order to stock their shelves, and shoppers never knew what to expect when getting food.

That has changed with the Matching Excess and Need (MEANS) Database.[2] MEANS connects donors and food distributors algorithmically to find the best match - a fast and local pickup for the donor, and real-time notifications on donation matches for the distributors. The algorithm takes into account factors such as how quickly a charity responds and picks up items, how much and what quantity of foods a donor typically provides, and what items a pantry typically needs.[4] This application has been adopted by restaurants and grocery stores to reduce waste and find a willing recipient for their donation. It has been adopted in virtually every state and by major companies to eliminate waste and give back to the community.

## 4 CONCLUSIONS

Food deserts, and food scarcity in general, continues to be a major problem in our society. However, thanks to scarcity and demographic data being better collected and utilized, new solutions are being introduced to this age-old problem. There may not be simple solutions to bringing brick-and-mortar grocery stores back into underserved areas, but new technology applications powered by big data could be a vital path forward to circumventing the problem.

The path forward seems to be increased data collection, collaboration and information sharing between governments and private organizations (encompassing non-profits and corporations). This can be used to identify at an even more granular level individuals at risk of food scarcity. Organizations can then use this information to create applications and programs to address these needs:

- If companies like FreshDirect are any indication, companies who previously found that potential revenue from establishments in high-crime areas not being worth the risk may reexamine these areas and find profit may still be found using innovative online shopping tools paired with software reading SNAP benefit data.
- If organizations like MEANS are any indication, non-profits may find that a greater utilization of big data to streamline the pairing of donors to pantries may greatly affect their organization's impact on hunger. In addition, this innovation greatly impacts businesses as well, as they can use these services to donate foods that would have otherwise been thrown away. This benefits them from a monetary standpoint (tax write-offs) as well as a PR standpoint.

Big data applications are slowly but surely integrating into government, non-profit, and business functions. As we gain a greater understanding for the new concept of food deserts, hopefully data will continue to find ways to solve this problem.

## REFERENCES

- [1] [n. d.]. ([n. d.]).
- [2] [n. d.]. ([n. d.]).
- [3] [n. d.]. Food Access Research Atlas. ([n. d.]). <https://www.ers.usda.gov/data-products/food-access-research-atlas/>
- [4] [n. d.]. Matching Excess And Need. ([n. d.]). <https://www.meansdatabase.com/>
- [5] =2015. American Community Survey 2010-2014. (December =2015).
- [6] Heather Haddon and Annie Gasparro. 2016. Companies and Government Seek New Answers for Food Deserts. (Oct 2016). <https://www.wsj.com/articles/companies-and-government-seek-new-answers-for-food-deserts-1476670262>
- [7] Latetia V. Moore, Ana V. Diez Roux, Jennifer A. Nettleton, and David R. Jacobs. 2008. Associations of the Local Food Environment with Diet Quality?A Comparison of Assessments based on Surveys and Geographic Information Systems: The Multi-Ethnic Study of Atherosclerosis. (Apr 2008). <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2587217/>
- [8] Michele Ver Ploeg, Vince Breneman, and Tracey Farrigan. 2009. Access to Affordable and Nutritious Food-Measuring and Understanding Food Deserts and Their Consequences: Report to Congress. (Jun 2009). <https://www.ers.usda.gov/publications/pub-details/?pubid=42729>

# Big data analysis in Finance Sector

Dhanya Mathew  
Indiana University  
711 N Park Ave  
Bloomington, Indiana 47408  
dhmathew@iu.edu

## ABSTRACT

Big data as the name implies, refers to large and complex data which continues to grow enormously day by day. The broad proliferation of data and new and efficient technological support has transformed the way industries operate and compete. Industries like financial firms, in particular, have widely adopted big data analytics to obtain better investment decisions with consistent growth. In order to understand what drives profit in an organization or company, we should be able to predict the business trends, challenges, opportunities risks and what profit group (extremely unprofitable, average, extremely profitable etc.) a set of customers falls into based on their data at any given time. Financial firms like banks are storing these data for many decades and the recent technology boom that happened with big data technologies help the firms to uncover the secrets to understand consumer behavior, prevent major disasters and theft. We show the wide possibilities open for financial firms by analyzing big data to improve decision making, productivity, customer satisfaction etc which in turn beneficial for both organizations and customers.

## KEYWORDS

i523, HID328, big data, data-driven, data lakes, Hadoop, Random Forest

## 1 INTRODUCTION

There are 3 fundamental elements to big data - Volume, Variety and Velocity. Velocity is the speed at which data must be stored and analyzed [13]. Data sets grow rapidly because they are increasingly gathered by cheap and numerous information-sensing Internet of things devices such as mobile devices, aerial (remote sensing), software logs, cameras, microphones, radio-frequency identification (RFID) readers and wireless sensor networks[2]. According to 2015 big data info graphic contributed by Ben Walker of Voucher Cloud, around 2.5 quintillion Bytes of data is created every day which would fill 10 million Blu-ray discs. These discs when stacked on one another, would measure the height of 4 Eiffel Towers. Ben suggests that data generation by 2018 will be 50,000 GB per second [5].

According to Gartner Survey, 64 percent of organizations invested or planning to invest in big data technology in 2013(including but not limited to Hadoop, NoSQL, Spark, R and Storm) [14]. 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 [10]. 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[2]. We investigate in particular, how big data is helpful in financial firms in

terms of predictive analysis and profitable growth. The finance sector also contributes to the daily data generation from products and marketing, banking, business, share market etc. Finance 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 terms of finance sector. The key idea behind is how to retrieve the 'signal' of relevant information from the bulk of data. Let us explore the wide range of possibilities of big data analysis that finance sector can come up with including decision making, discovery of new business opportunities, enhanced productivity and efficiency, risk management, fraud detection, innovation possibilities, efficiency and growth and customer segmentation.

### 1.1 Efficient decision making

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. Data driven decision making approach includes data storage, data elaboration, data analysis and decision making[10].

[Figure 1 about here.]

Figure 1 shows data-driven decision making approach and discovery of new business opportunities.

*Data storage:* Even though big data does not define by the size alone, we need the right means to store the huge volume and variety of data. Big data is distributed - stored across many machines and managed with Hadoop File System and distributed DBs like HBase and Apache Cassandra[7].

*Data elaboration:* Generate combined information by eliminating unwanted data using data cleansing methods like grouping, joining, filtering etc.(Spark, R, MapReduce, Storm).

*Data Analysis:* Big data analysis is the process of analyzing the data to derive the semantics of the available data to understand the hidden patterns, correlations, market trends, customer preferences which helps the organizations to take more informed decisions. Visualization tools include- Tableau, Google chart, D3, Fusion chart etc. are used to visualize the results of analysis.

*Decision making:* Data-driven decision making based on the analysis.

There is a feedback analysis done for a bank as part of 2nd International Symposium on Big Data and Cloud Computing. Feedback processes are important for any organization to help and understand the potential areas of improvement and if done on a regular basis, they help to identify gaps in services rendered. This bank also started to collect feedback from their customers over a period

of 3 years and 6 months; from those who visited bank branches as well as from those who used online services. Customers were asked to rate the bank anonymously on a scale of 1 to 5 on the following parameters:

- Is the customer happy with the quality of service?
- Is the customer happy with the speed of service?
- Are customer queries addressed effectively?

The analysis is performed using the pertaining subset of the total data collected, comprising of feedback from around 20,000 customers[15].

[Figure 2 about here.]

As shown in Figure2, the customers rated bank services as average. Hence the concerned bank took some measures to correct the issue, and this resulted in ratings improvements.

## 1.2 Increased productivity and growth

Compared to traditional data warehouses, the big data concept of Data lakes to store raw data offers more flexibility in data access and analysis. Large volumes of data are stored, managed and analyzed in data lakes by using automated and sophisticated analytical tools.

Applications like, Machine learning algorithms, In-memory technologies, fast access DBs, big data queries and real-time analysis methods consume less time to come up with meaningful information and reports by accessing data lakes.

*Data lakes:* Data Lakes can be compared to the actual lakes where rivers or streams that bring water to it. In data lakes, this is called ingestion of data. We collect all the data that we require to analyze to reach our goal irrespective of the source. These 'streams' of data come in several formats: structured data (simply said, data from a traditional relational database or even spreadsheet: rows and columns), unstructured data (social, video, email, text etc.), data from all sorts of logs (weblogs, clickstream analysis etc.), XML, machine-to-machine, IoT and sensor data. Logs and XML are also called semi-structured data. There can be data filters in place based on the requirements[4].

## 1.3 Fraud detection

One of the best ways to fight cybercrime is with early detection. Banks are prime targets for cybercriminals and fraudsters, and any kind of public breach creates a lot of embarrassment, bad publicity, and unwanted scrutiny. Clearly banks have a vested interest in any technology to identify and prevent a data breach or fraud[6].

Banks and financial services firms use analytics to differentiate fraudulent interactions from legitimate business transactions. By applying analytics and machine learning, they are able to define normal activity based on a customer's history and distinguish it from unusual behavior indicating fraud. The analysis systems suggest immediate actions, such as blocking irregular transactions, which stops fraud before it occurs and improves profitability[1].

The security and fraud analysis done by 2nd International Symposium on Big Data and Cloud Computing, clearly shows that, based on historical transactions and consumption capacity of customers, coupled with the behavioral analysis can help us reveal a potential threat to the system, as well as uncover frauds that might have happened in the past[15].

[Figure 3 about here.]

As shown in Figure3 from the analysis, we can observe that net transactions count grows with time and subtly and in the month of May and June 2013, card ending 13 shows spike in number of transaction count. The number of transactions more than doubled during the period for this card holder. Normally this is where the analyst should sound an alarm. If we are to upscale our small dataset to include millions of card holders, such spikes are dangerous and can mean a potential compromise of the system. It clearly indicates a misuse of the Card by miscreants and unauthorized access of funds by unscrupulous agents.

## 1.4 Customer Segmentation and personalized marketing

Banks have been under pressure to change from product-centric to customer-centric businesses. One way to achieve that transformation is to better understand their customers through segmentation. Big data enables them to group customers into distinct segments, which are defined by data sets that may include customer demographics, daily transactions, interactions with online and telephone customer service systems, and external data, such as the value of their homes. Promotions and marketing campaigns are then targeted to customers according to their segments[1].

There are many segmentation identification algorithms available in the Big Data world. Random Forest is one of the prominent algorithm. Apache spark, R are some of the technologies that have good integration with segmentation algorithms

*Personalized Marketing:* One step beyond segment-based marketing is personalized marketing, which targets customers based on understanding of their individual buying habits. While it's supported by big data analysis of merchant records, financial services firms can also incorporate unstructured data from their customer's social media profiles in order to create a fuller picture of the customer's needs through customer sentiment analysis. Once those needs are understood, big data analysis can create a credit risk assessment in order to decide whether or not to go ahead with a transaction[1].

## 1.5 Understand new business opportunities

Big data will fundamentally change the way businesses compete and operate. Companies that invest in and successfully derive value from their data will have a distinct advantage over their competitors. A performance gap that will continue to grow as more relevant data is generated, emerging technologies and digital channels offer better acquisition and delivery mechanisms, and the technologies that enable faster, easier data analysis continue to develop. It is difficult to identify what is most important in the data, which technologies best suits the needs, who the customers are and what they expect. Being more data-driven gives an edge over competitors[9].

Big data is the intersection of business strategy and data science, offering new opportunities to create competitive advantages. It allows companies to use data as a strategic asset, equipping them with pertinent real-time information when making decisions in order to eliminate inefficient operating processes, enhance the customer experience, take advantage of new markets, etc. For many

companies and businesses, big data is already a critical path to develop new products, services and business models[10].

## 1.6 Discovery of innovation possibilities

Data is increasingly becoming a key differentiator between wildly profitable and struggling businesses. Exploring and analyzing data translates information into insight and drives to innovations[3].

Successful firms make decisions based on facts and data rather than intuition and are open to innovation concepts.

## 1.7 Risk Management

Financial firms especially banking sector are facing new regulatory requirements and challenges or risks each year. Big data adoption provides organizations a simplified and data-driven solution to mitigate the risks and helps to convert the data into usable information for regulatory reporting. Using data lakes and stronger analytic tools also helps to foresee the expected impact quickly[8].

## 1.8 Cost effective information gathering

Unlike traditional business intelligence systems, new techniques and technologies used with Big Data allow to gain useful information at a much lower cost. New architectures and the move from data silos to 'data lakes' can provide substantial cost advantages and greater scalability due to flexibility in the data analysis. In fact, having all data sources in a data lake allows users to pull new reports on relatively new data, while in traditional data warehouses (DWHs) users have to extract, transform and load (ETL) new data into a static data model, which is expensive and costly from a time perspective. By using automated and sophisticated analytical tools that can store and analyze data faster and more easily, organizations can reduce the overall cost [10].

## 1.9 Big data - Risks and considerations

Big data plays an increasingly important role in the financial services sector, where it is used for everything from targeting advertisements to optimizing portfolios. While these technologies have many benefits, critics are quick to point out that they can also become a source of discrimination if they are developed and/or used in an improper way[11].

*Data Security:* This risk is obvious and often uppermost in our minds when we are considering the logistics of data collection and analysis. Data theft is a rampant and growing area of crime. And attacks are getting bigger and more damaging[12].

*Data Privacy:* Closely related to the issue of security is privacy. But in addition to ensuring that people's personal data are safe from criminals, you need to be sure that the sensitive information you are storing and collecting is not going to be divulged through misuse by yourself or by people to whom you have delegated responsibility for analyzing and reporting on it[12].

*Bad Analytics:* Aka 'getting it wrong.' Misinterpreting the patterns shown by your data and drawing causal links where there is in fact merely random coincidence is an obvious pitfall. Sales data may show a rise following a major sporting event, prompting you to draw a link between sports fans and your products or services, when in fact the rise is based on there being more people in

town. The rise would be equally dramatic after a large live music event[12].

*Bad Data:* There might be situations where many data projects that start off on the wrong foot by collecting irrelevant, out of date, or erroneous data. This usually comes down to insufficient time being spent on designing the project strategy[12].

## 2 CONCLUSION

The Big Data revolution offers new opportunities for profitable growth and the financial services firms being one of the most risk-laden and dynamic of all business segments globally, are responding to it enthusiastically. It has become their derived knowledge that making sizeable investments in big data is ultimately a gain. Data has become the key element for decision making with the right choice of analytical tools and skill-set. When data from multiple sources combined and analyzed in a smart way, there emerges the insights which derive intelligent decisions and finally drives to profit.

## ACKNOWLEDGMENTS

The author would like to thank the web loaded with information on any subject. The author would also like to thank Prof. Gregor von Laszewski for his review and suggestions.

## REFERENCES

- [1] [n. d.]. 5 Big Data Use Cases in Banking and Financial Services. Web page. ([n. d.]). <http://www.ingrammicroadvisor.com/data-center/5-big-data-use-cases-in-banking-and-financial-services>
- [2] [n. d.]. Big data. Web page. ([n. d.]). [https://en.wikipedia.org/wiki/Big\\_data](https://en.wikipedia.org/wiki/Big_data)
- [3] [n. d.]. Big data. Web page. ([n. d.]). [https://www.tableau.com/solutions/big-data?utm\\_campaign=Prospecting-BGDATA-ALL-ALL&utm\\_medium=Paid-Search&utm\\_source=Bing&utm\\_language=EN&utm\\_country=USCA&kw=%2Bbig%20%2Bdata&adgroup=CTX-Big+Data-Sitelink&adused=%7bcreative%7d&matchtype=p&placement=%7bplacement%7d&gclid=CNGAtcXn09YCFWwifgodDW4Dsw&gclsrc=ds&dclid=CMPCu8Xn09YCFcjVZAodCT4PlQ](https://www.tableau.com/solutions/big-data?utm_campaign=Prospecting-BGDATA-ALL-ALL&utm_medium=Paid-Search&utm_source=Bing&utm_language=EN&utm_country=USCA&kw=%2Bbig%20%2Bdata&adgroup=CTX-Big+Data-Sitelink&adused=%7bcreative%7d&matchtype=p&placement=%7bplacement%7d&gclid=CNGAtcXn09YCFWwifgodDW4Dsw&gclsrc=ds&dclid=CMPCu8Xn09YCFcjVZAodCT4PlQ)
- [4] [n. d.]. Data lakes and big data analytics: the what, why and how of data lakes. Web page. ([n. d.]). <https://www.i-scoop.eu/big-data-action-value-context/data-lakes/>
- [5] [n. d.]. How much data is created daily? Web page. ([n. d.]). <https://storageservers.wordpress.com/2016/02/06/how-much-data-is-created-daily/>
- [6] [n. d.]. The Top 5 Trends for Big Data in Financial Services. Web page. ([n. d.]). <http://www.ingrammicroadvisor.com/data-center/the-top-5-trends-for-big-data-in-financial-services>
- [7] Antony Adshead. [n. d.]. Big data storage: Defining big data and the type of storage it needs. ([n. d.]). <http://www.computerweekly.com/podcast/Big-data-storage-Defining-big-data-and-the-type-of-storage-it-needs>
- [8] Michael Schroeck David Turner and Rebecca Shockley. [n. d.]. Analytics: The real-world use of big data in financial services. ([n. d.]). [https://www-935.ibm.com/services/multimedia/Analytics.The\\_real\\_world\\_use\\_of\\_big\\_data\\_in\\_Financial\\_services\\_Mai\\_2013.pdf](https://www-935.ibm.com/services/multimedia/Analytics.The_real_world_use_of_big_data_in_Financial_services_Mai_2013.pdf)
- [9] EY. 2014. Big data Changing the way businesses compete and operate. (April 2014). [http://www.ey.com/Publication/vwLUAssets/EY\\_-Big\\_data\\_-changing-the-way-businesses-operate/%24FILE/EY-Insights-on-GRC-Big-data.pdf](http://www.ey.com/Publication/vwLUAssets/EY_-Big_data_-changing-the-way-businesses-operate/%24FILE/EY-Insights-on-GRC-Big-data.pdf)
- [10] Gregor Meyer Fabrizio Sarrocco, Vincenzo Morabito. 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)
- [11] Justin Kuepper. 2017. The Problem With Big Data in Financial Services. (January 2017). <http://www.investopedia.com/articles/insights/010517/problem-big-data-financial-services.asp>
- [12] Bernard Marr. 2015. The 5 Biggest Risks of Big Data. (June 2015). <http://data-informed.com/the-5-biggest-risks-of-big-data/>
- [13] Trevor Nath. 2015. (April 2015). <http://www.investopedia.com/articles/active-trading/040915/how-big-data-has-changed-finance.asp>
- [14] STAMFORD. [n. d.]. Web page. ([n. d.]). <http://www.gartner.com/newsroom/id/2593815>

- [15] Santosh Gopalkrishnan Utkarsh Srivastava. [n. d.]. Impact of Big Data Analytics on Banking Sector: Learning for Indian Banks. ([n. d.]). <https://www.sciencedirect.com/science/article/pii/S1877050915005992>

#### LIST OF FIGURES

1	Data-driven decision making approach [10]	6
2	Overall Customer Feedback for provided parameters [15]	6
3	Net credit transactions count (left) and net debit transactions count (right) [15]	6

Figure 1. Data-driven decision making and discovery of new business opportunities

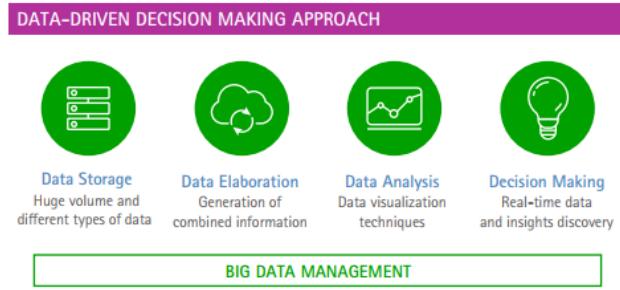


Figure 1: Data-driven decision making approach [10]

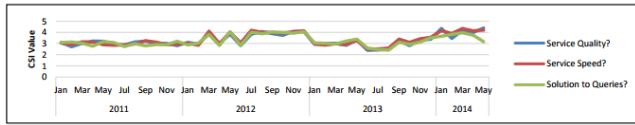


Figure 2: Overall Customer Feedback for provided parameters [15]



Figure 3: Net credit transactions count (left) and net debit transactions count (right) [15]

# Big Data Analytics and Edge Computing

Arnav Arnav

Indiana University, Bloomington

Bloomington, Indiana, USA

aarnav@iu.edu

## ABSTRACT

With the exponential increase in the number of connected IoT devices, the data generated by these devices has grown enormously. Sending this data to a centralized server or cloud results in enormous network traffic and may lead to failures and increased latency. A solution for this problem is to do some processing on the devices closer to the network edge, enabling responsive and real-time analytics. There have been various developments in the field of edge computing some of which are described here.

## KEYWORDS

i523, hid201, Edge Computing, Big Data Analytics

## 1 INTRODUCTION

Internet of things is rapidly gaining importance and Evans Data Corporation's Global Developer Population and Demographics Study reports 6.2 million developers working in the IoT domain[11]. With the rapid increase in the acceptance of Internet of Things (IoT) devices across various fields across the world, ranging from industrial sensors to lifestyle and sports products, and the consequent increase in the data generated by such devices, there is a pressing demand for devices and processes that can analyze this data and provide responsive analytics[13]. Traditionally, IoT applications follow one of the two approaches - cloud-centric approach, where the sensing devices send data to the cloud where the analytics are performed or device-centric approach, where stand-alone devices running proprietary code perform analytics locally[13]. Networks are largely centralized with organizations storing all data, which may not be directly beneficial to them, in their data centers, and data flowing from the edge to the cloud on each operation[2].

With an increase in the number of connected devices, it gets increasingly difficult to perform all analytics on a server in a traditional manner. Thus, edge computing involves pushing a part of this computation closer to the end user of the device, or closer to the network edge[14][2]. This helps reduce the cost incurred in communicating large amounts of data over the network, ensures some level of availability even when the connection to the cloud is broken and reduces the cost of computation and storing data on the cloud[13][2].

## 2 HOW EDGE COMPUTING WORKS

Edge computing emerged with the development of content delivery networks (CDNs) by Akamai which use nodes close to the user to prefetch web content and accelerate web throughput. Edge computing extends this concept with the help of cloud infrastructure to run arbitrary task-specific code at nodes close to the edge, typically

known as cloudlets. These cloudlets usually run on a virtual machine or a light-weight container for ease of isolation and resource management[12].

Proximity to the edge of the network ensures various benefits. It helps to provide highly responsive applications, by using a more powerful computing resource near the edge and minimizing end-to-end latency, which is essential in time-critical applications like virtual reality which require a latency of less than 16ms for the images to appear stable[3][12]. Proximity also increases scalability with the help of edge analytics where cloudlets perform the first level of analytics on the sensor data and only send processed data and metadata to the cloud to reduce bandwidth usage as the number of connected devices increases[12]. Decentralization of data can also provide the owners of data more control over the privacy of their data, and provide ways to safely communicate this data between various entities[2][5].

In industrial applications like aviation where a large amount of data is generated on each flight[12], analyzing this data in a centralized manner becomes impractical. In such cases, fog computing is more useful which adds different elements at various levels of hierarchy between the edge and the cloud[7]. In industrial environments, there are a lot of different systems running new as well as legacy applications which may be proprietary and integrating these applications to provide end-to-end IoT solutions is still a challenge. Linux Foundation's EdgeX platform provides a way to simplify and standardize edge computing architectures and is gaining importance as an industrial IoT solution[7].

## 3 SOME EXAMPLES

Simmhan describes an application that was built using Apache-NiFi, a lightweight dataflow execution engine used for vehicle classification from video streams using a Tensorflow deep neural network encapsulated within a NiFi dataflow executing across multiple raspberry pis. This allows video streams to be analyzed locally and also provides the flexibility to use cloud infrastructure for computation when edge devices are constrained[13].

Yang Zhao et al proposed an occupancy and activity monitoring application with doppler sensing and edge analytics. The application uses low-cost motion sensing and embedded signal processing, detection and machine learning to detect activity in real time, even when multiple people are present in a room. The developers provide a web portal to help ease monitoring activity from a remote location[16].

Analysing video feeds on a large scale in real time is a challenging task. Each of the videos may be very large and a large amount of bandwidth is needed to stream the video feed to a central location which is not feasible especially if the cameras are connected wirelessly. In addition to this, the entire video may not be useful and most parts of it may be discarded depending on the application.

Furthermore, these applications need to provide results with low latency as important decisions often need to be made based on the output in case of surveillance applications[3]. Thus compute abilities available on cameras can be utilized to provide real-time video analysis, processing the video at the camera and only communicating interesting bits to the cloud[12].

A real-time video processing solution is proposed in [3] that focuses on traffic planning and safety and provide high accuracy outputs and detects anomalous traffic patterns to suggest preemptive safety measures and reduce traffic accidents and deaths. Interactive augmented reality applications must rely on object tracking, face detection, and other video analytics to obtain spatial knowledge, and must rely on cloudlet based edge solution to provide users with a smooth interaction experience[3].

Scientists at MIT's Computer Science and Artificial Intelligence Lab (CSAIL) are working on self-folding printed robots and their use in saving lives as an alternative to invasive surgery procedures, which would require a cloud in the proximity as those robots and sensors generate a large amount of data that needs to be processed very fast[4].

Verizon created a universal cloud-in-a-box solution running Linux on a generic x86 architecture, in an OpenStack container that can put compute, storage and networking resources near the edge to support their increasing number of users and power 5G in the future[4][9].

## 4 RECENT DEVELOPMENTS

The need for a holistic data analytics platform to combine various techniques in cloud and edge computing and to ease data management arises in applications like health monitoring where anomalies in a patient's conditions must be immediately reported and an analysis on historical patient data is needed to find out more details about patient's overall condition[10]. The lack of platforms for the edge that allow development and simple deployment in a distributed setting is a key limitation to using edge devices effectively[13].

Taking on these challenges a serverless platform was proposed by Nastic et al that supports real-time analytics across cloud and the edge by optimizing the placement of analytics operations and automatically managing available resources[10].The model takes a top-down approach for control processes combined with a bottom-up approach for data management allowing analytics to be done at various levels of granularity and the results served to the application from either the edge or the cloud depending on the need[10]. The platform provides developers with an API that allows them to easily define analytics functions without worrying about data management and optimization complexities.

Early IoT infrastructures were heavily cloud dependent and all the computation was done in the cloud. This tight coupling with the cloud is however not desirable in many time-critical or data-intensive applications[5]. An edge offloading architecture named FADES (Function virtualizAtion basED System)was proposed by Cozzolino et al that reverses the traditional paradigm and dispatches some computation to the devices close to the edge. How this offloading to the edge should be performed depends on the application, the hardware capabilities, and the software requirements[5]. The multilayer pipeline ensures reduced amount of data to be uploaded

and the MirageOS based unikernel approach provides an additional layer of security by running the deployed tasks inside a virtualization platform, bridging the gap between complex cloud-based applications and edge applications and providing modularity[5].

## 5 AI ON THE EDGE

With the emergence of decentralized applications, smart machines that rely on machine learning and mesh computing to provide local real-time analytics are becoming a reality. MIT's Eyeriss which is an accelerator for deep neural networks uses no wifi and no data transmission. With peer to peer networks gaining importance, edge computing is vital to provide low latency applications that are decentralized[2].

Since many artificial intelligence (AI) applications need a huge amount of processing power and require a large amount of data, traditional AI applications rely on cloud servers to perform their computation. This is a serious limitation in applications where connectivity is not reliable and time-critical decisions are required[6]. iEx.ec is a company that uses Etherium blockchain to create a market for computing resources, in turn, facilitating distributed machine learning[8].

In applications like flying a swarm of drones, a loss of connectivity to the cloud can be fatal and cause disruption of the operation. Thus AI coprocessor chips that can run machine learning algorithms can offer intelligence at the edge devices. Movidius recently announced a deep learning compute stick[1] that can add machine learning capabilities to computers and raspberry pis as a plug and play device[6].

Machine learning algorithms like one-shot learning which require lesser data are rapidly enabling edge devices to perform intelligent tasks easily[15]. Gamalon, backed by Defense Advanced Research Projects Agency (DARPA), is using Bayesian Program Synthesis to reduce the amount of data required for machine learning[6].

## 6 CONCLUSION

With the increase in the number of connected devices and the increase in the demand of real-time and interactive applications, we see that edge computing is a necessity and many industries are rapidly moving towards edge solutions. Although industrial IoT still faces challenges with the integration of legacy applications and proprietary applications with new technology, open source solutions are being widely accepted. Research on various platforms and architectures for edge computing continuously aims to reduce the gap between cloud and edge devices and establish standards for the same. The emergence of decentralized applications and the growing importance of machine learning has driven technologies that provide machine learning capabilities to edge devices which are becoming a fundamental requirement to move towards decentralized AI applications, that can provide results in near real time.

## ACKNOWLEDGMENTS

The author would like to thank Professor Gregor von Laszewski for providing the opportunity to study the topic in detail and for providing all the tutorials and support material needed to write the paper.

The author would also like to thank other associate instructors of the class for helping promptly with queries on piazza which helped everyone a great deal.

## REFERENCES

- [1] [n. d.]. movidius website. ([n. d.]). <https://developer.movidius.com/>
- [2] Scott Amyx. 2016. Ready for the disruption from edge computing? IBM iot blog. (August 2016). <https://www.ibm.com/blogs/internet-of-things/edge-computing/>
- [3] G. Ananthanarayanan, P. Bahl, P. Bodk, K. Chintalapudi, M. Philipose, L. Ravindranath, and S. Sinha. 2017. Real-Time Video Analytics: The Killer App for Edge Computing. *Computer* 50, 10 (2017), 58–67. <https://doi.org/10.1109/MC.2017.3641638>
- [4] Jason Baker. 2017. Why OpenStack is living on the edge. opensource.com blog. (May 2017). <https://opensource.com/article/17/5/openstack-summit-news>
- [5] Vittorio Cozzolino, Aaron Yi Ding, and Jörg Ott. 2017. FADES: Fine-Grained Edge Offloading with Unikernels. In *Proceedings of the Workshop on Hot Topics in Container Networking and Networked Systems (HotConNet '17)*. ACM, New York, NY, USA, 36–41. <https://doi.org/10.1145/3094405.3094412>
- [6] Ben Dickson. 2017. How do you bring artificial intelligence from the cloud to the edge? TNW website. (August 2017). [https://thenextweb.com/contributors/2017/08/21/bring-artificial-intelligence-cloud-edge/#.tnw\\_5VcrJGrz](https://thenextweb.com/contributors/2017/08/21/bring-artificial-intelligence-cloud-edge/#.tnw_5VcrJGrz)
- [7] Andrew Foster. 2017. Why the Industrial IoT Needs an Open-Source Edge Platform. (July 2017). <https://www.rtinsights.com/why-the-industrial-iot-needs-an-open-source-edge-platform/>
- [8] iEx.ec. 2017. *Building a Fully Distributed Cloud for Blockchain based Distributed Applications*. white paper. iEx.ec. <http://iex.ec/wp-content/uploads/2017/04/iExec-WPv2.0-English.pdf>
- [9] Nicole Martinelli. 2017. Pushing the edges with OpenStack. Open Stack Articles. (May 2017). <http://superuser.openstack.org/articles/edge-computing-verizon-openstack/>
- [10] S. Nastic, T. Rausch, O. Seekic, S. Dustdar, M. Gusev, B. Koteska, M. Kostoska, B. Jakimovski, S. Ristov, and R. Prodan. 2017. A Serverless Real-Time Data Analytics Platform for Edge Computing. *IEEE Internet Computing* 21, 4 (2017), 64–71. <https://doi.org/10.1109/MIC.2017.2911430>
- [11] Avi Patwardhan. 2016. Incorporate streaming analytics in the Internet of Things. IBM data and analytics hub blog. (October 2016). <http://www.ibmbigdatahub.com/blog/incorporate-streaming-analytics-internet-things>
- [12] Mahadev Satyanarayanan. 2017. The Emergence of Edge Computing. *Computer, IEEE computer society* (2017). <http://elijah.cs.cmu.edu/DOCS/satya-edge2016.pdf>
- [13] Yogesh Simmhan. 2017. IoT Analytics Across Edge and Cloud Platforms. IEEE IOT Newsletter. (May 2017). <https://iot.ieee.org/newsletter/may-2017/iot-analytics-across-edge-and-cloud-platforms.html>
- [14] Wikipedia. 2017. Edge computing — Wikipedia, The Free Encyclopedia. (2017). [https://en.wikipedia.org/w/index.php?title=Edge\\_computing&oldid=802381553](https://en.wikipedia.org/w/index.php?title=Edge_computing&oldid=802381553) [Online; accessed 7-October-2017 ].
- [15] Wikipedia. 2017. One-shot learning — Wikipedia, The Free Encyclopedia. (2017). [https://en.wikipedia.org/w/index.php?title=One-shot\\_learning&oldid=793877024](https://en.wikipedia.org/w/index.php?title=One-shot_learning&oldid=793877024) [Online; accessed 7-October-2017 ].
- [16] Yang Zhao, Jeff Ashe, David Toledano, Brandon Good, Li Zhang, and Adam McCann. 2016. Occupancy and Activity Monitoring with Doppler Sensing and Edge Analytics: Demo Abstract. In *Proceedings of the 14th ACM Conference on Embedded Network Sensor Systems CD-ROM (SenSys '16)*. ACM, New York, NY, USA, 322–323. <https://doi.org/10.1145/2994551.2996543>

# The Internet of Things and Big Data

Murali Cheruvu  
Indiana University  
3209 E 10th St  
Bloomington, Indiana 47408  
mcheruvu@iu.edu

## ABSTRACT

The Internet of Things, or IoT, is all about data from connected devices. Millions of consumer and industrial devices drive IoT growth and challenge with data volume and variety. Big Data analytics helps combing through these high volumes of complex IoT data into meaningful business insights.

## KEYWORDS

i523, hid306, Data Science, Internet of Things, IoT, Smart Devices, Sensors, Actuators, Big Data Analytics, Cloud Computing

## 1 INTRODUCTION

The Internet of Things (*IoT*) is the network of physical devices, vehicles, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data[6]. Devices of all types - cars, thermostats, implants for radio-frequency identification (RFID), pacemakers and more - have become smarter, opening up the need for their connectivity with the internet. Today, over 50% of IoT activity is centered in manufacturing, transportation, smart environments and consumer applications like wearable gadgets, but within five years all industries will have rolled out IoT initiatives. *Gartner, Inc.* forecasts that 8.4 billion connected things will be in use worldwide by end of 2017 and will reach 20.4 billion by 2020[2].

## 2 IOT INTUITION

The rise of IoT changes everything by enabling *smart* things. Products and environments are becoming smarter. Broadly speaking, two kinds of IoT are emerging: *Consumer IoT* and *Industrial IoT*. Products such as Apple Watch, Fitbit, Smart TV, etc. are considered Consumer IoT. Examples of Industrial IoT are: manufacturing equipment and medical devices. A few more examples of IoT include:

### 2.1 Smartphones

With smartphone's range of sensors (accelerometer, gyro, video, proximity, compass, GPS, etc.) and connectivity options (cell, wi-fi, bluetooth, etc.) user has well equipped IoT device that can automatically monitor movements, location and workouts throughout the day.

### 2.2 Smart Homes

An example of smart home enabled by IoT devices: The user arrives home and his car communicates with the garage to open the door. The thermostat is automatically adjusted to his preferred temperature due to sensing his proximity. He walks through his door as it

unlocks in response to his smartphone or RFID implant. The home lighting is smartly turned on at dark.

### 2.3 Smart Cities

Smart surveillance, safer and automated transportation, smarter energy management systems and environmental monitoring are all examples of IoT applications for smart cities.

### 2.4 Smart Medical Alerts

The Proteus ingestible pill sensor is powered by contact with stomach fluid and communicates a signal that determines the timing of when patient took her medication and the identity of the pill. This information is transferred to a patch worn on the skin to be logged for the patient and her doctor's reference. Heart rate, body position and activity can also be detected accordingly.

### 2.5 Smart Aircrafts

Rolls-Royce is using Azure Cloud Stream Analytics and Power Business Intelligence (BI) to link up sensor data from its engines with more contextual information like air traffic control, route data, weather and fuel usage to get a complete report of the health of its aircraft engines.

## 3 NEED OF BIG DATA

The true value of IoT is not in the internet connected devices themselves; the value lies in making context-aware relevant data and converting the result into enterprise-grade, tangible and *actionable* business insights. The IoT and Big Data are intimately connected: billions of internet-connected things will, by definition, generate massive amounts of data. As the *things* turn more digital, IoT will analyze complex data structures and respond intelligently in real time.

Big Data, meanwhile, is characterized by *four Vs* - volume, variety, velocity and veracity[5]. That is, data come in large amounts (*volume*), with a combination of structured and unstructured data (*variety*), arrive at often real-time speed (*velocity*) and can be of uncertain source (*veracity*). Such information is unsuitable for processing using traditional SQL-queried relational database management systems (RDBMSs), which is why a cluster of alternative tools – notably Apache's open-source *Hadoop* distributed data processing system, various *NoSQL* databases and a range of business intelligence (*BI*) platforms - have evolved to serve such a complex data process.

## 4 IOT BUILDING BLOCKS

To scale the needs of IoT, the strategy should include infrastructure and applications that process and leverage machine and sensor data

accordingly. At the moment, IoT platforms are often custom-built functional architecture. Enterprises that take the first step into this new market should look for interoperability between existing systems and a new IoT operating environment. The building blocks of an ideal IoT platform include:

#### 4.1 Sensors and actuators

A major part of the IoT is not so much about smart things (devices), but about sensors and actuators. Smartphone would not have been smarter if it does not have an array of sensors embedded in it. A typical smartphone is equipped with five to nine sensors, depending on the model. *Sensors* measure physical inputs and transform them into raw data; *actuators* act on the signal from the sensors and convert it into output, which is then digitally storable for access and analysis. These tiny innovations can measure anything ranging from temperature, force, flow, position to even light intensity then can be attached to everything from smartphones to medical devices and then record & send data onto the cloud[3].

#### 4.2 Network Connectivity

Network Connectivity in the devices is achieved through: wireless/wired, wi-fi, bluetooth, zigbee, VPN and cellular - 2G/3G/LTE/4G. Thread technology is emerging as an alternative for home automation applications and Whitespace TV technologies being implemented in major cities for wider area IoT-based use cases. Depending on the application, factors such as range, data requirements, security, power demands and battery life will dictate the choice of one or some form of combination of the technologies. In March 2015, the Internet Architecture Board - a group within the Internet Society that oversees the technical evolution of the internet - released a guide to IoT networking. This outlined four common communication models used by IoT smart devices: Device-to-Device, Device-to-Cloud, Device-to-Gateway, and Back-End Data-Sharing[4].

#### 4.3 Collaboration and Security

Human and organizational behavior is critical in realizing the value of IoT approaches, and it is particularly important in shifting an organization to demonstrate clearly what will change, how it affects people, and what they stand to gain from IoT applications. Tons of collected IoT data could easily contain sensitive information about people and operations, and can even lose the control of critical systems. Beyond protecting personal privacy and business secrets, as more systems become automated, the risk of attacks becomes both more likely and more impactful.

Devices themselves should be secured, as should operating systems, networks and every other exposed piece of technology along the way. The roles of users, administrators and managers should be individually defined with appropriate access and strong authentication embedded in the design. A multi-layered approach to security is essential, and it should have checks and balances to reinforce protection and, if necessary, diagnose any breaches. For the IoT to work effectively, all the challenges around regulatory, legal, privacy and cybersecurity must be addressed; there needs to be a framework within which devices and applications can exchange data securely over wired or wireless networks. To address these challenges and for better IoT interoperability, one key player, *OneM2M*

issued Release 1, a set of 10 specifications covering requirements, architecture, Application Programming Interface (API) specifications, security solutions and mapping them to common industry protocols[1].

#### 4.4 Cloud Computing

The cloud computing brings needed agility, scalability, storage, processing, global reach and reliability to an IoT platform. Flexible scalability can be achieved by using (a) Cloud Centric IoT - Good choice for low-cost things where data can easily be moved, with few ramifications (b) Edge Analytics - Ideal for things producing large volumes of data that are difficult, costly or sensitive to move, and (c) Distributed Mesh Computing - *Future-ready* multi-party devices automatically collaborate with privacy intact.

#### 4.5 Big Data Analytics

Data Analytics involves statistical tools and techniques with business acumen to bring out hidden information from the data. Advanced types of data analytics include data mining, which involves sorting through large data sets to identify trends, patterns and relationships; predictive analytics, which seeks to predict customer behavior, equipment failures and other future events; and machine learning, an artificial intelligence technique that uses automated algorithms to churn through data sets more quickly than data scientists can do via conventional analytical modeling. Text mining provides a means of analyzing documents, emails and other text-based content. Big Data analytics applies data mining, predictive analytics and machine learning tools to volume of data coming from various sources with various types of data formats.

Big Data analytics, in the context of the IoT, refers to sensor analog inputs being converted to digital data, analyzed, and resulting in a response going back to the device. Much of this data is in an unstructured form, making it difficult to put into structured tables with rows and columns. To extract valuable information from this complex data, Big Data applications often rely on cutting edge analytics involving data science. Distributed computers in the cloud running sophisticated algorithms can help enhance the veracity of information by data mining through the noise created by the massive volume, variety, and velocity. Some analytics may need to be performed using edge or mesh computing, some in the data center and some in a cloud environment, depending on the trade-off of speed versus depth. IoT analytics applications can help companies understand the IoT data at their disposal, with an eye toward reducing maintenance costs, avoiding equipment failures and improving business operations.

### 5 CONCLUSION

Internet of Things shaping human life with greater connectivity and ultimate functionality, and all this is happening through ubiquitous networking to the Internet. There is seemingly no limit to what can be connected to the Internet. IoT will become more personal and predictive. The goal of a connected IoT ecosystem is to get the most out of the internet of your things in your context. Industrial IoT side, it is becoming disruptive yet inevitable for companies to welcome it. Creating a connected IoT ecosystem that maximizes

business value, collaboration is need with technologies, data, process, insight, action and people. The *T* of IoT is clearly important, but too often, it is the only area of focus when examining IoT in business. Rest of the systems need to be instrumented to leverage the data: communicating it to the right place for action - whether the cloud, data center, or edge - and then using analytics to understand data patterns and craft a response to fix or optimize. However, security and privacy will be the top considerations for companies developing IoT devices. Innovative organizations are starting to put this to use today.

## REFERENCES

- [1] 2015. IoT Interoperability. (Jan. 2015). <http://www.onem2m.org/images/files/oneM2M-whitepaper-January-2015.pdf>
- [2] 2017. Garner Press Release. (Feb. 2017). <http://www.gartner.com/newsroom/id/3598917>
- [3] Hakim Cassimally Adrian McEwen. 2014. *Designing the Internet of Things*. Wiley.
- [4] Lyman Chapin Karen Rose, Scott Eldridge. 2015. *The Internet of Things: An Overview*. Technical Report. <https://www.internetsociety.org/resources/doc/2015/iot-overview>
- [5] Wikipedia. 2017. Big Data. (2017). [https://en.wikipedia.org/wiki/Big\\_data](https://en.wikipedia.org/wiki/Big_data) [Online; accessed 23-Sept-2017].
- [6] Wikipedia. 2017. Internet of things. (2017). [https://en.wikipedia.org/wiki/Internet\\_of\\_things](https://en.wikipedia.org/wiki/Internet_of_things) [Online; accessed 23-Sept-2017].

# Big Data and Massive Online Open Education

Weipeng Yang

School of Education, Indiana University Bloomington

201 N Rose Ave

Bloomington, Indiana 47405

yang306@umail.iu.edu

## ABSTRACT

Massive Open Online Education(MOOC) often refers to a kind of online course that emphasizes free and unrestricted access via the internet. This paper will focus on how to collect such data as length of study, learning time of the day, preferred courses and other learners' behaviors to analyze and make predictions for future course designers and online teaching platform administrators.

## KEYWORDS

big data, MOOC

## 1 INTRODUCTION

Nowadays people in the field from K-12 to institutions of higher education have witnessed a great shift from traditional classroom teaching to distance learning. These online courses are based on Learning Management Systems (LMSs). The more advanced a learning management system could be, the better they could collect a variety of data from students' activities and performances. With this amount of data, educators and researchers could utilize data mining and data visualization techniques to generate synchronous feedback and to keep-track of students' progress with higher efficiency. The source of the data could be the average time a student is learning a certain course, test score of a quiz, response rate in an online discussion session, etc.

## 2 BIG DATA

Big data are sometimes considered as the amount of data that could be available to an organization, in which contains a gigantic amount of information that would render itself too complex for any household data-processing software to manage. Not only big data emphasizes the amount of data, it also calls for the need of real-time data and a wide source of data. As for the field of education, big data provide more direct evidence-based approach to learning and could allow researchers to see the difference of students nationwide or even worldwide. Analyzing these data could help LMS providers to make strategical improvements or let online teachers provide personalized tutoring to those students in need.

## 3 EDUCATIONAL DATA MINING IN MOOC

Educational Data Mining (EDM) refers to the process of analyzing various kinds of data on diverse levels of education (for instance, data could be collected from online students to decision-makers of the MOOC corporation) via a variety of techniques and tools. What is collected includes time, sequence and context of the course being taught. It could be easily inferred that EDM requires cooperation of various subjects such as statistics, artificial intelligence, machine learning, etc. With these interdisciplinary means data could be

processed. EDM aims to predict the academic performance of a student, evaluate student learning in the context of LMS, improve instructional sequences and evaluate add-on software that could provide additional help with the LMS. Pioneers of this field are researching how to improve the modeling of student performance, teaching domain and LMS properties and characteristics. They are also interested in providing students with diverse needs different track of learning courses accordingly. It is concluded that EDM usually requires five means to analyze educational data: prediction, clustering, relationship mining, distillation of data and discovery via models. Prediction stresses that students' academic performance will be analyzed via their behavior in online learning. Clustering means that by sensing such specific characteristics as preference of learning materials or performance styles, the students will be grouped according to the elements mentioned above. Moreover, these resources could be recommended to learners with similar needs. Relationship mining is the most mentioned method in EDM. It focuses on figuring out hidden relationships with such variables as teaching and learning strategies, students' performance in online environment and students' interactions. Distillation of data for human judgement concentrate on ways to filter out most important data in a cluster so that researcher could figure out structures in the data quickly. Discovery via models, the last method, focuses on utilizing existing model to analyze newly collected data. To better utilize EDM, the MOOC cooperation shall establish a data structure first by determining the need of its users and their learning goals as well as the source of the data. Then they shall start defining certain variables and start creating a model or choose from an existing one. In the end they could start using this model to predict students' preferences and make modification accordingly. It is stated in some research that after using EDM to collect more information, MOOCs' learning outcomes are improved and course tutors could cater to students' needs more efficiently.

## 4 LEARNING ANALYTICS

Other than computer science and statistics, Learning Analytics (LAs) are rooted on a wider spectrum of subjects such as sociology and psychology. Those who apply LAs wish to create a learning environment for teachers in which each student's learning need will be satisfied to the greatest extent and they could also choose their own learning tracks via their own learning habits. LAs could also enable facilitators of MOOC to distribute educational resources with better decision-making mechanism, providing feedback to students and help at-risk students (refer to those who haven't participated in learning activities for a long time or those who do not have ideal performance in quizzes). To reach these goals mentioned above, LAs also involve a vast variety of data, from students' learning habits, assignments collected, social interaction online, threads

on discussion forums to generate students' progress and identify those who might be at-risk. With enough data collected, LAs could also be utilized to determine the overall structure of the course, students' learning objectives and the sequence of learning contents. Decisions are often based on models with multiple dimensions such as students' experience, knowledge, their preferred sequence of learning. LAs consist of three steps: Data collection and processing, analyzing data and action and data post processing. It can be concluded that LAs could be efficient for all level of users, tutors and decision-makers in MOOC however it also face lots of challenges as decision makers will need to determine what kind of data to collect and they need to connect separate collected data together via specific algorithm to gain a holistic view of inner connections between.

## 5 CONCLUSIONS

With the rapid iteration of software and LMSs, learners nowadays could easily gain access to massive amount of learning materials at almost every corner of the world. MOOC brings great flexibility to learners so that they could choose their online instructors, their sequence of learning and their learning materials. It also brought instructors and students closer than ever so that they could interact more frequently, thus enabling a more dynamic atmosphere in learning. Challenges also arises as the numbers of students grow exponentially, it could be more difficult for teachers and managers to keep track of each student's status and provide help accordingly. Thanks to the introduction of big data in this field, decision maker of MOOC could evaluate and investigate students' status more easily and could develop more learning strategies. It can be envisioned that soon big data will relieve more burden on teachers' shoulders.

## REFERENCES

# Big Data Analytics in Higher Education Marketing

Ashley Miller  
Indiana University  
admille@iu.edu

## ABSTRACT

While the collection of vast amounts of data in the world of higher education has occurred for decades, the use of big data applications and analytics is fairly new to this environment. There is a need to understand how the use of big data analytics can help institutions determine student behavior as well as stay relevant in a digital and evolving age of technological advances, tools, and skills. The higher education space is changing as the population of students going to college is on the decline which increases competition and the need for institutions to be more strategic in their efforts for attracting students to their institutions. We will explore at a very high level how higher education could utilize big data analytics to inform marketing initiatives in recruiting and enrolling students as well as what potential challenges and considerations could impact this process.

## KEYWORDS

i523, hid329, big data, higher education, marketing, analytics, data-driven decision making

## 1 INTRODUCTION

Today's colleges and universities are drowning in data. With the emergence of big data, institutions are now faced with providing useful analysis and reports to a variety of stakeholders including administrators, professors, as well as to the students themselves [3]. A variety of challenges lie in the path of institutions using big data effectively such as finding the necessary skill set for staff, technology tools and resources, as well as understanding then what to do with the data collected to better inform decision making. While there is literature that addresses utilizing big data for learning analytics and even course enrollment and development, as Daniel states, there is still "limited research into big data in higher education" [3]. Higher education could benefit from using big data analytics in their marketing efforts for recruiting and enrolling students as well as identifying what gaps may still exist in the quest to understand today's college student in their college search process.

## 2 CURRENT ENVIRONMENT

According to the *Western Interstate Commission for Higher Education (WICHE)*, the projected number of high school graduates will decline over the course of the next decade [2]. Meanwhile, the number of four-year institutions in the United States has increased with more than 3,000 available college options [4]. Increased competition and fewer students have made the higher education marketplace crowded and convoluted. There are a variety of factors that go into a student's decision on where to attend and ultimately what area to study. In their 2013 trends report, the Lawlor group identified a number of aspects that will impact the higher education landscape, among those included are [1]:

- The demographics of today's college student is changing with more women attending college than men in addition to an increase in ethnic and socio-economic diversity as well as first-generation students [2].
- The college search process today happens primarily in the digital space which includes third-party websites, email, social media, and digital advertising [5]. This *Generation Z* grew up in a technology rich and connected environment which means that colleges have to also be constantly on in this space to effectively recruit and enroll students.
- The need to showcase the *value* of going to college, not only through the quality of education received relative to the price paid but also through outcomes-level data, including retention and placement rates and even starting salaries of recent graduates.

With these trends in mind, there is a need for institutions to be more targeted in their marketing efforts. Big data analytics can be used to help assess the impact of these trends as well as how institutions can make better decisions with these techniques.

## 3 BIG DATA ANALYTICS TO SEGMENT BY DEMOGRAPHICS

Big data can be one way to better inform these efforts and also help with the return-on-investment (ROI) for advertising and marketing related efforts. Other universities have capitalized on utilizing big data in attracting students. For instance, St. Louis University described a process of retroactively looking at demographics of students who succeeded at the university and had high satisfaction scores [9]. This information coupled with nearly 100 other data points gave insight to the admissions team when exploring new markets as well as identified clusters of students that may be interested in attending St. Louis University. The university was then able to develop a targeted digital campaign in these areas that they believed included students who would be a good fit for the university. With the reliance on big data, St. Louis University was able to reduce costs as the need to mass market went away and ultimately increased enrollment and retention rates [9].

## 4 BIG DATA ANALYTICS TO UNDERSTAND BEHAVIOR ONLINE

The web environment is common tool in college exploration as a report by Ruffalo Noel Levitz shows that three out of four high school students state utilize an institution's website as their most used resource when exploring colleges [5]. Web analytics provides a wealth of information on users such as how much time is spent on certain pages, bounce rate, paths in website exploration and ultimately conversion rates when various goals are completed such

as scheduling a tour or filling out an application for college [7]. Google Analytics is one tool used to track and evaluate efforts on websites. Higher education institutions could take advantage of this tool by tracking top pages viewed, geography and age of visitors, as well as areas where they may be losing students in the information search process. With this data, institutions can identify opportunities for improvement in ensuring students are finding the information they need in a timely and efficient way as well as develop customized marketing efforts to invite students back into the experience to complete various calls-to-action.

## 5 BIG DATA ANALYTICS TO CONVEY VALUE

Utilizing big data to understand outcomes of current students, and ultimately graduates, can help tell the value story to prospective students. By tracking the experiences among current students during their four (or more) year college career, predictive analytics could be implemented to determine which combination set of experiences best contribute to the success of a student. Temple University utilized predictive analytics to increase graduation rates by sending messages to students who were considered to be "at risk for dropping out" based on financial aid data [12]. This similar type of approach could be utilized in marketing efforts as well. If a profile of student could be created based on existing data and therefore create an ability to predict the future actions of prospective students, then marketing messages could be more tailored based on where that prospective student is in the enrollment funnel.

## 6 CHALLENGES

In order for the use of big data analytics in higher education marketing to be successful, there are basic measures that have to be met. Marsh et. al outlines some key considerations when using big data analytics for effective decision making which include: accessibility, quality, timeliness, and motivation to use [6]. These same factors can be also impact the use of big data analytics in a higher education setting.

### 6.1 Accessibility

Typically, institutional research offices have been the primary house for student data collected over time but that doesn't mean it's the only place where data lives [8]. As Daniel state, there is also data in higher education that lives across a number of areas in a wide variety of formats [3]. With this, accessing data can be a challenge as there is no central system or warehouse. Depending on the type of data needed, the sources can be siloed which means that the data sources are not connected to one another to provide a complete picture. Further, the level of permissions to access data can also vary which can make it difficult for marketers to access.

### 6.2 Quality

Coupled with the fact that data across an institution can live in multiple places, there are issues around the quality of data. The disparity of data sources can lead to quality concerns but also the skill set of those who maintain or utilize the data. If no standard processes exist for data cleaning, integration, reporting, or interpretation, then the risk of having invalid conclusions increases [6].

Decisions made on inaccurate data could potentially be costly for institutions.

### 6.3 Timeliness

There can be issues with timeliness in a variety of ways. Alignment on the objectives for data analysis can require input from multiple stakeholders which takes time. The aspects involved in processing the data itself could involve a significant amount of time, people, and resources. Often times, decision making for marketing purposes needs to happen quickly and there can be a gap between obtaining the needed information and when decisions need to be made.

### 6.4 Motivation

There is also a underlying cultural aspect to using big data analytics in the right way across an institution. With the silos that exist in higher education, collaborating across departments and sharing information overall can help to forge better working relationships. Successful efforts rely on the involvement of multiple departments including information technology (IT) [3]. The importance and message about utilizing big data analytics has to come from leadership for others to be equally motivated.

## 7 POSSIBLE SOLUTIONS

While significant challenges can exist in utilizing big data analytics to inform marketing initiatives in higher education, there are possible solutions to explore. One way to overcome the challenge of accessibility would be to create a central area where data could live. This would also allow the opportunity for others to access data and create consistency across the institution. Having a central system would also help with the data quality aspect if the the format of the data was consistent in the way it was stored, presented, and accessed. Along with creating a central area, a standardized data flow would also be beneficial. In Figure 1, Eduventures outlines a proposed data flow within the area of higher education [11].

[Figure 1 about here.]

## 8 OTHER CONSIDERATIONS

Throughout this process of exploring the use of big data analytics for higher education marketing, there are other factors to consider. With the collection, analysis, and use of big data, what implications does this pose to data security and privacy issues among students? As stated by Slade and Prinsloo, ethical issues can come into play regarding data ownership and governance [10]. Given that higher education institutions are faced with an increased level of scrutiny, what protocols have to be put into place to ensure the safety of students' data? Further, what level of accountability is assigned with the different areas/persons that are in need of the data to inform decision making? There are also policy issues to consider regarding what kind of data can be collected on students and how and where this information should be stored.

## 9 CONCLUSIONS

Competition for today's student will only increase with changing educational needs and offerings, including development of emerging degree programs as well as delivery. For marketers in higher

education, they need to have access to necessary data about current as well as prospective students to better tailor messaging and marketing efforts appropriately. With this, the validity of available data is key as making decisions based on incomplete data can be problematic and costly for an institution. Given the nature of the web environment that is constantly changing, obtaining data in a timely manner is crucial so action can be taken at the right time. Insights around data are only as good as the people that make use of them so creating a culture within an institution that motivates others to make data-driven decisions is imperative for these efforts to be successful.

## REFERENCES

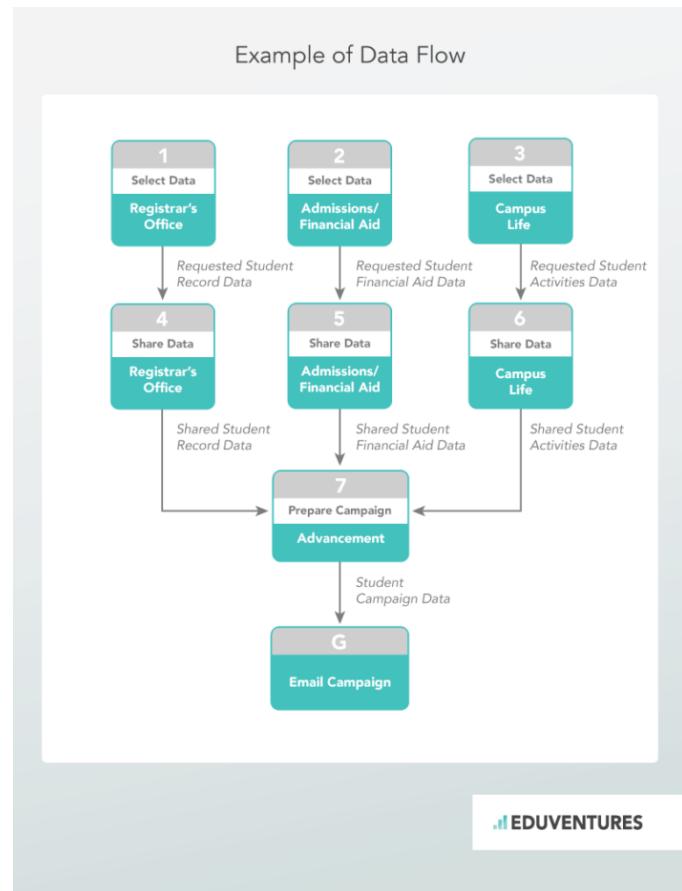
- [1] 2014. Trends in Higher Education Marketing, Recruiting, and Technology. (2014).
- [2] Peace Bransberger. 2017. Impact and Implications: Projections of Male & Female High School Graduates. (2017).
- [3] Ben Daniel. 2015. Big Data and Analytics in Higher Education: Opportunities and Challenges. *British Educational Research Association* (2015).
- [4] National Center for Education Statistics. 2015. Digest of Education Statistics. (2015). <https://nces.ed.gov/fastfacts/display.asp?id=84>
- [5] Stephanie Geyer. 2016. E-Expectations Trend Report. (2016).
- [6] Julie A. Marsh, John F. Pane, and Lara S. Hamilton. 2006. Making Sense of Data-Driven Decision Making in Education. (2006). [www.rand.org](http://www.rand.org)
- [7] Mohammad Amin Omidvar, Vahid Reza Mirabi, and Narjes Shokry. 2011. Analyzing the Impact of Visitors on Page Views with Google Analytics. 2 (2011).
- [8] Anthony G. Picciano. 2012. The Evolution of Big Data and Learning in Analytics in American Higher Education. *Journal of Asynchronous Learning Networks, Volume 13: Issue 3* (2012).
- [9] Jeffrey Selingo (Ed.). 2017. How Colleges Use Big Data to Target the Students They Want. (2017).
- [10] Sharon Slade and Paul Prinsloo. 2013. Learning Analytics: Ethical Issues and Dilemmas. *American Behavioral Scientist* (2013).
- [11] James Wiley. 2016. Do You Know Where Your Data is Going? (2016). <http://www.eduventures.com/2016/09/where-is-your-data-going/>
- [12] Mikhail Zinshteyn. 2016. Big Data Allows for Higher Education Predictive Analytics. (2016).

LIST OF FIGURES

1 Example of a data flow [11]

6





**Figure 1: Example of a data flow [11]**

# Big Data Applications in Electric Power Distribution

Swargam, Prashanth  
Indiana University Bloomington  
107 S Indiana Ave  
Bloomington, Indiana 47408  
pswargam@iu.edu

## ABSTRACT

Now-a-days, the process of storing the power measurements have changed. Conventional meters are replaced by the smart meters. New distribution management systems like SCADA and AMI are implemented to monitor power distribution. These smart meters record the readings and communicate the data to the server. However, these systems are designed to generate the readings very frequently i.e., 15 minutes to an hour. Upon that, smart meters are being deployed at every possible location to improve the accuracy of the data. This advancements in electric power distribution system results in enormous amounts of data which requires advance analytics to process, analyse and store data. This paper discusses about the implementation of Big Data technologies, challenges of implementing Big Data in Electric Power Distribution Systems.

## KEYWORDS

Big Data, Power Distribution,Smart Power

## 1 INTRODUCTION

Volume of data is increasing. According to forbes, it is said that, world's data utilization will increase to 44 zettabytes from the current utilization of 4.4 zettabytes[6]. To process this data, Big Data analytics will be useful. But, instantiating a big data architecture is not easy task.

In electrical Power Distribution industry, data deluge is picking its pace. The data which was recorded for month, is now being noted for very small intervals. This quadruples the amount of data that should be process. There is a lot of potential work to be put in for designing a good Big Data architecture to process and analyse this data. Most of the power generation units are developing their infrastructure to support these designs.

### 1.1 4 v's in Big Data in Power Distribution System

Big Data is mostly described in 4 v's. Each of this V's are considerable factors in a Big Data Solution.[8]

Volume: The data is periodically generated by many data sources like smart meters, machines and other appliances.

Variety: Each data source in electric power distribution system is explicit to each other. Each source has its own frequency of data generation and its own method of data generation. Thus, the data is heterogenous.

Velocity: is the speed at which the data is available for the end user.

Veracity: It deals with the correctness of the data. As all the data collected by sensors, meter tend to have various losses, correction

algorithms should be defined to find the accurate data. Their might be chances for data transfer losses.

## 2 DATA SOURCES

Smart meters which are placed at customer's vicinity will record the consumption of a specific group of customers. This data can be used to analyse the behaviour of customer for certain circumstances of weather and environment.

Distribution systems which manage the distribution of power, generate large amount of data related to voltages and currents at various levels of distribution. This data is very important in analysing the load level and demand for the distribution circle.[7]

Phasor measuring units at generation. This data is used to analyse the behaviour of generator and amount of power generation that will be required to supply enough power. This data will be used to decide the functioning of generators.[11]

Old market data will be used to analyse the pricing and marketing strategies. These data is more focused on users and their behaviour.

## 3 DATA INTEGRATION

### 3.1 Service Oriented Model

This model has a workflow which is defined in Business process Enterprise Language often referred as WS BPEL[1]. WS BPEL is used for is enterprise language used for automating a business process. BPEL files defines the process to be followed by a request from the web services. In this model, All the user requests are handled by services. These services either connect to the storage resources or calls the other services based on the process model defined in BPEL. This modelling ensures data is being utilised in a structural manner and analysed according to the process model.

Interfacing services: This service is used to manage the interfaces with the end user. This services generally initiates calls to a process defined in WS BPEL. After all the other processes which are defined in process model are completed, this service is used to project the analytical data to the user at the end of execution. In this case, this service receives data from one of the process models.[9]

Execution Service: This service is responsible for all the logic involved in modelling the data. For the common requests, these are well documented in BPEL files. These documents specify the set of instructions to be followed to model the data as per the request from the service. This service uses a Information management services to establish a data link to data storages.[9]

Pooling Services: All the data requests coming from Information management services are managed by pooling services. This service help the other services in establishing a dynamic connection to data storages. This service also handles one way communication between the data storages and Information management services.

This is called event-driven approach. All the activities like addition of data, removal of data in data storages are considered as event. These events are communicated to the information management services.

## 4 DATA STORAGE AND PROCESSING

### 4.1 Hadoop and MapReduce

Hadoop and MapReduce are prevalent technologies in storing and processing data. Hadoop has a database in file system called as HDFS. HDFS[2] and MapReduce is an Apache Project which is used to split the data into various segments and store the data in various commodity boxes. These boxes are clustered together to allow the flow of data between them.

As the data is generated at different physical locations, it will be easy to store data at different geographical locations. There will be minimal transmission of data. Changes in electrical grid doesn't require the change in entire data model. On addition or deletion of a electrical node, a new data storage can be added without any intervention to the existing data storages. This distributed model also ensures high availability. Availability of one data source will have minimal or no effect on the availability of the system thus reducing the downtime and business losses.

The data from various sources have different formats. This makes it difficult to store data in traditional relational databases because of type conversions and relational handling. Hadoop overcomes this problem by storing the data in filesystems. Data can be easily pre-processed and stored in the pictorial representations rather than in tables and schemas.

Mapreduce is a programming model. This has two components i.e., Jobtracker and Tasktracker. Jobtracker is a master process which is responsible for scheduling assigning the jobs to Tasktracker. Tasktracker is responsible for execution of the mapreduce jobs. A sample mapreduce[3] task takes has two phases. The first phase is a map phase, where the data is divided into several pieces. The second stage is reduce phase, where the data is processed to produce output. These mapreduce jobs are scheduled and run in batches. This is called Batch Processing.[10] This map and reduce functions are very reliable in analysing the nature and demand of customer from the data available from the most recent processed jobs. Mapreduce jobs run on static data. This will not serve the requests like load analysis, electrical machinery failure, metering failure, power loss which require real time data.

### 4.2 Apache Spark for Realtime data

Apache Spark[14] is a cluster computing model. It has capability to perform real time analysis of data. It is nurtured with more enhanced machine learning algorithm and libraries. Spark SQL, MLlib, Spark streaming, GraphX are some of those. Spark framework contains data in distributed sets. It also has set of working programs on the distributed sets of data. This set of programs are called Resilient Distributed Dataset functions[12].

The dynamics of electrical properties changes in milliseconds. In order, to collect these dynamics, the power measuring systems have evolved. New instruments like phasor measurement units have evolved. These devices collect data at the rate of 20-40 readings per second. However, if there is any delay in processing such huge

amount of data, then the collected data is not useful. Apache spark tackles this issue in two different approaches.

Streaming Approach:[14] Streaming approach reacts to the each and every event that occurs in the data. As soon as new data is injected, all the resilient distributed dataset functions are called. This function processes data and makes them into a usable format and stores them. This kind of approach is used in metering, billing and load management.

Iterative approach:[5] In this approach, spark offers in memory computing. The datasets are accessed in memory instead of the going to the physical database. All the phasor readings which are required by multiple requests to calculate state space estimation use the developed cache data on the servers instead of accessing them from the data storage. This make requests like state space calculation much lighter.

## 5 CHALLENGES IN IMPLEMENTING BIG DATA

### 5.1 Information Security

A large amount of customer electricity usage data is collected. This data must be protected from data leaks. Access control systems must be enhanced to restrict the access to the customer data. Leaked data can be exploited to trace the end user and his/her appliances.[13]

### 5.2 Asset Management

Assets are the power collection units. These are one of the important devices in the architecture. All the assets must be maintained properly to ensure the quality of data. If any of the power measuring unit goes down or malfunctions, there will be discrepancy in analysing data. This will lead to improper decisions.

### 5.3 Adaptability

The amount of data is increasing by many folds. In present world, Data Analytics has become a part of Electrical Industry. Though, Many Power Industries have implemented Big Data solutions, there are many industries which are yet to implement Big Data technologies. Most of the South asian countries still use SCADA for processing electrical Data.[4]

## 6 CONCLUSION

This paper briefly highlights the importance of Big Data Solutions in Power distribution systems. Firstly, Data sources for analytic systems in power distribution like smart meters, Phasor measurement units are briefed. Integration of Data from various sources using service oriented architecture and the important processes in the service oriented architecture are discussed. Later, Implementation of distributed file system i.e., HDFS with processing models like MapReduce and Apache Spark are discussed. At last, challenges like information security, asset management and adaptability of Big Data Technologies are discussed.

## REFERENCES

- [1] [n. d.]. ([n. d.]). <https://managementmania.com/en/ws-bpel-web-services-business-process-execution-language>
- [2] [n. d.]. ([n. d.]). [https://en.wikipedia.org/wiki/Apache\\_Hadoop](https://en.wikipedia.org/wiki/Apache_Hadoop)
- [3] [n. d.]. ([n. d.]). [https://www.tutorialspoint.com/hadoop/hadoop\\_mapreduce.htm](https://www.tutorialspoint.com/hadoop/hadoop_mapreduce.htm)

- [4] 2002. ABB SCADA system to automate power for Hyderabad & Secunderabad and streamline APCPDCL electrical distribution network. (2002).
- [5] 2013. Putting Spark to Use: Fast In-Memory Computing for Your Big Data Applications. (11 2013). <https://blog.cloudera.com/blog/2013/11/putting-spark-to-use-fast-in-memory-computing-for-your-big-data-applications/>
- [6] 2014. The Digital Universe of Opportunities: The Rich Data and Increasing value of Internet of Things. (04 2014). <https://www.emc.com/leadership/digital-universe/2014view/executive-summary.htm>
- [7] A. B. M. Shawkat Ali (Ed.). 2013. *Smart Grids Opportunities,Developments, and Trends*. Springer.
- [8] Amr A.Munshi and Yasser A.-R.I. Mohamed. 2017. Electric Power Research Systems. Elsevier (2017).
- [9] Jyotishman Pathak, Yuan Li, Vasant Honavar, and James McCalley. [n. d.]. A Service-Oriented Architecture for Electric Power Transmission System Asset Management. ([n. d.]).
- [10] Shyam R, Bharathi Ganesh HB, Sachin Kumar S, Prabaharan Poornachandran, and Soman K P. 2015. Apache Spark a Big Data Analytics Platform for Smart Grid. (2015).
- [11] Abu-Rub Shady S. Refaat, Haitham, Rub, and Mohamed Amira. 2016. Big Data Better Energy Management and Control Decisions for Distribution Systems in Smart Grid. (2016).
- [12] Chunning Tu, Xi He, Zhikang Shuai, and Fei Jeing. 2016. Big data issues in smart grid. *Renewable and Sustainable Energy Reviews* (2016).
- [13] Nanpeng Yu, Sunil Shah, Mingguo Hong, and Kenneth Loparo. 2015. Big Data Analytics in Power Distribution Systems. (2015).
- [14] Matei Zaharia. [n. d.]. ([n. d.]). [https://en.wikipedia.org/wiki/Apache\\_Spark](https://en.wikipedia.org/wiki/Apache_Spark)

# Big Data Analytics in Weather Forecasting

Himani Bhatt  
Indiana University  
Bloomington, Indiana  
himbhatt@iu.edu

## ABSTRACT

Daily over 20 terabytes of data get generated of different key weather-related parameters like wind speeds, temperature readings , satellite images, barometric pressure from different locations. Yet the extreme weather events cause huge amount of loss and damage worldwide. For instance, 90 percent of the crop losses are due to weather calamities all over the world. The ability to better predict the weather could slash this by up to 25 percent. The ability to use the big data generated efficiently directly affects the chances to reduce economic loss, environmental damage and fatality. This can be considered as the best motivation to improve and invest in this extremely challenging task.

## KEYWORDS

NWP (Numerical Weather Predictions),Supercomputers.

## 1 INTRODUCTION

Big data analytics applications help data scientists , statisticians to analyze tons of data in order to have useful insights and make predictions based on it.In majority of the cases the data that has been dealt with is unstructured and complex. In case of weather forecasting , data about the current state of atmosphere (that includes wind , humidity , temperature etc) is gathered, and by using concepts of meteorology , the evolution of atmosphere in future is predicted. Weather forecasting is extremely challenging since large number of variables are involved and their interaction is also very complex. The data accumulation is done from the sources like trained observers , weather balloons,weather stations, satellites ,radar, etc. The data is then plugged into super computers which uses numerical forecast equations to create forecast models of the atmosphere and to produce the meteorological analysis. This paper discuss how big data analytics is used in weather forecasting.[8]

## 2 HISTORY OF WEATHER PREDICTION

After the invention of the first electronic computer ENIAC , a group of meteriologists at New Jersey's institute for Advanced Study produced first weather forecast using ENIAC and numeric prediction techniques back in 1950.There forecast was for 24 hours but they took more than 24 hours to complete.This can be marked as the need for the beginning of numerical weather predictions.[9]

### Numerical weather prediction models

Any typical numeric weather prediction model will have complex and multidimensional data.These models divide earth into various atmospheric boxes.For each box they try to apply mathematical equations for the current weather and they try to forecast weather for coming days. These equations are derived from physics and

fluid motion.This data is divided horizontally as latitude longitude and vertically as different pressure levels. And hence it is multidimensional.

The higher the resolution of the data, more is the accuracy of the NWP models. Because of improved resolution, improved data sources, and improved physics processes, enormous advancements are seen in the atmospheric modelling techniques. With the models improving , requirement of high computing powers increase proportionally, and the models now need supercomputers to run operationally.

[Figure 1 about here.]

## 3 WEATHER PREDICTION IN MODERN TIMES

A company named Weather Analytics has been forecasting a week's weather in advance by analyzing US Government's weather service data of past 38 years. It's methodology includes placing global data in a 35km by 35km grid and then extraction of relevant variables from the a generated outputs which are often in range of 650,000 per hour.

The company says:'We then extract pertinent variables and create/calculate numerous others. We store this massive amount of weather information in databases which allows us to: present the data quickly, calculate additional variables, and uniquely package the data.'

[2]

Enhancement of data processing power is clearly exemplified by the supercomputer at UK based firm called Met Office, which has 480,000 cores, two million GB of memory and 17,000TB of storage. This 140 tonnes processing giant is capable of performing over 23,000 trillion operations per second,which has brought the accuracy of modern 4 days forecasts on par with that of 1 day forecasts 30 years ago through improved data model resolution and enabling usage of smaller grid sizes.[2]

## 4 HADOOP FOR CLIMATE ANALYTICS

The NASA center for climate simulation uses Apache Hadoop for performing high performance computing as it combines distributed storage of large datasets with parallel computing and optimizes computer clusters.It has built a new platform with Hadoop for developing new analysis capabilities.Hadoop Bloom filter is utilized that helps to identify rapidly and memory efficiently if an element is present.

### Advantage of using HDFS and MapReduce

- Hadoop is resilient to failure, provide load balancing and parallelization. When the data is sent to an individual node , it is also sent to other nodes in the cluster. So in case of failure their will be a copy of data available.
- Storage nodes and compute nodes are same. It means that tools for the data processing are on the same servers where the data is located , which result in fast data processing. Hadoop is capable of processing terabytes of unstructured data in just minutes and petabytes in hours. Thus is highly used in weather analytics.
- The requested operations are mapped to the appropriate nodes using specified key.[6]

## 5 CURRENT WEATHER FORECASTING MODELS

### 5.1 Deep Thunder' - World's Most Advanced Hyper-Local Weather Forecasting Model

Deep thunder is a research project by IBM and it is headed by Lloyd Treinish. The scientists in IBM developed first parallel processing supercomputers that can be used for weather modelling. This supercomputer is based on IBM RS/6000 SP( it is a family of Reduced instruction set computer based on UNIX servers , supercomputers made by IBM in 1990's).It was first installed at National Weather Service office in Georgia in 1966.

With high accuracy deep thunder can deliver hyper localized weather conditions up to three days in advance, with calculations as fine as every mile and as granular as every 10 minutes. Deep thunder can forecast weather for an 84 hours duration.Rio De Janeiro's city operation center is already using Deep Thunder.[1]

[Figure 2 about here.]

#### Technology Used

Deep thunder uses a 3D telescopic grid where data from one model is fed into another model , that is called coupled models in climatology. This data is then verified with the historical data. They work in collaboration with National Oceanic and Atmospheric Administration(NOAA), and use global models provided by them. In order to decrease the amount of processing required, they zoom in, that exponentially increase the resolution, down to models with resolution as small as 1 meter. This layered model approach shrinks big high performance computing problem to a relatively smaller footprint of parallel processing systems. The data sources of Deep Thunder are public satellite sources, underground personal weather stations, smartphone barometer etc.[4]

### 5.2 Hybrid renewable energy forecasting(HyRef)

Together with focusing on the damages done by weather we can also work on creating renewable resources. Wind and solar energy can be used to produce enormous amount of power. Forecasting the wind and solar availability will help in reducing the uncertainty associated with variable renewable energy generation. Hyref combines big data analytics and weather modeling technology to accurately forecast the availability of wind power and solar energy. This helps the energy providers to optimize the output and integrate

more renewable energy into the power grid.[3]

Hyref has the following key components :

- **Weather modeling capabilities** - The modeling is done at very granular level, from a square kilometer to vertical dimensions like heights where rotors and turbine hubs are located.
- **Advanced imaging technology** - Cloud imaging, advanced cameras.
- **Sensors on the turbines** - Highly perceptive sensors are used to monitor the turbulence, temperature and direction of wind.
- **Analytical capabilities** - Hyref use cloud image analytics and advanced numerical prediction models to calculate weather impacts on solar generation and to forecast cloud movements.SAS is used for this purpose and it is on DB2 platform.[5]

'Applying analytics and harnessing big data will allow utilities to tackle the intermittent nature of renewable energy and forecast power production from solar and wind, in a way that has never been done before,' said Brad Gammons, general manager of IBM's Global Energy and Utilities Industry group, in a statement. 'We have developed an intelligent system that combines weather and power forecasting to increase system availability and optimize power grid performance.'[7]

## 6 CONCLUSION

Ability to better predict the weather can have a dramatic impact on our planet by creating new energy resources and helps us to be better prepared for weather related incidents across all industries. Businesses from retail , production , energy , agriculture, water resource management are all using predictions from weather models to make decisions. 'Weather Analytics ,a company that provide climate data ,estimates that weather impacts more than 33 percent of worldwide GDP'.[1]Thus a better weather forecast will definitely have a positive economic impact.Not only economic impact, it can potentially save thousands of lives and safeguard property in times to come.

Increasing evidence of climate change worldwide is prompting governments and scientists to take action to protect people and property from its effects.One such instance is the upgradation of national weather information system by South Korea , after being hit by Typhoon Sanba and Hwangsa storms. The upgrade resulted in increase in the agency's data capacity by nearly 1000 percent to 9.3 petabytes. And it has now become Korea's most capable storage system. The output comes as the better understanding of the weather patterns and predicting the ferocity and location of the weather events. The technology support is provided by the IBM.[10]

This project of South Korea dramatically illustrates today's big data phenomenon and its impact on weather forecasting.

## REFERENCES

- [1] David Semmelroth Alan Anderson. 2015. BIG DATA AND WEATHER FORECASTING. (2015). <http://www.dummies.com/programming/big-data/data-science/big-data-and-weather-forecasting/>
- [2] Manek Dubash. 2016. Big data and the weather forecast. (2016). <http://www.zdnet.com/article/big-data-and-the-weather-forecast/>
- [3] Rolf Gibbels. 2013. IBM's Hybrid Renewable Energy Forecaster. (2013). [http://www.altenergymag.com/content.php?post\\_type=2129](http://www.altenergymag.com/content.php?post_type=2129)
- [4] IBM. 2012. Deep Thunder. (2012). <http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/deepthunder/>
- [5] IBM. 2013. IBM's HyRef Seeks to Solve Wind's Intermittency Problem. (2013). <http://www.renewableenergyworld.com/articles/2013/08/ibms-hyref-seeks-to-solve-winds-intermittency-problem.html>
- [6] NASA. 2015. Applying Apache Hadoop to NASA's Big Climate Data. (2015). [http://events.linuxfoundation.org/sites/events/files/slides/ApacheCon-NASA\\_Hadoop.pdf](http://events.linuxfoundation.org/sites/events/files/slides/ApacheCon-NASA_Hadoop.pdf)
- [7] Michael Graham Richard. 2013. Better short-time local weather prediction cheaper renewable energy. (2013). <https://www.treehugger.com/renewable-energy/better-short-time-weather-prediction-cheaper-renewable-energy.html>
- [8] L. F. Richardson. 1922. *Weather Prediction by Numerical Process*. Cambridge University Press.
- [9] Chris Robbins. 2015. A Brief History of Weather Forecasting. (2015). <http://www.iweathernet.com/educational/history-weather-forecasting>
- [10] Information Week. 2014. Weather Analytics. (2014). <https://www.informationweek.com/big-data/big-data-analytics/3-ways-big-data-supercomputing-change-weather-forecasting/a/d-id/1269439>

#### LIST OF FIGURES

1	Histogram by NCEP(National Centres for Environmental Prediction) showing trends in computing power and operational model skill over time	5
2	84 hours forecast by predicted by Deep Thunder	6

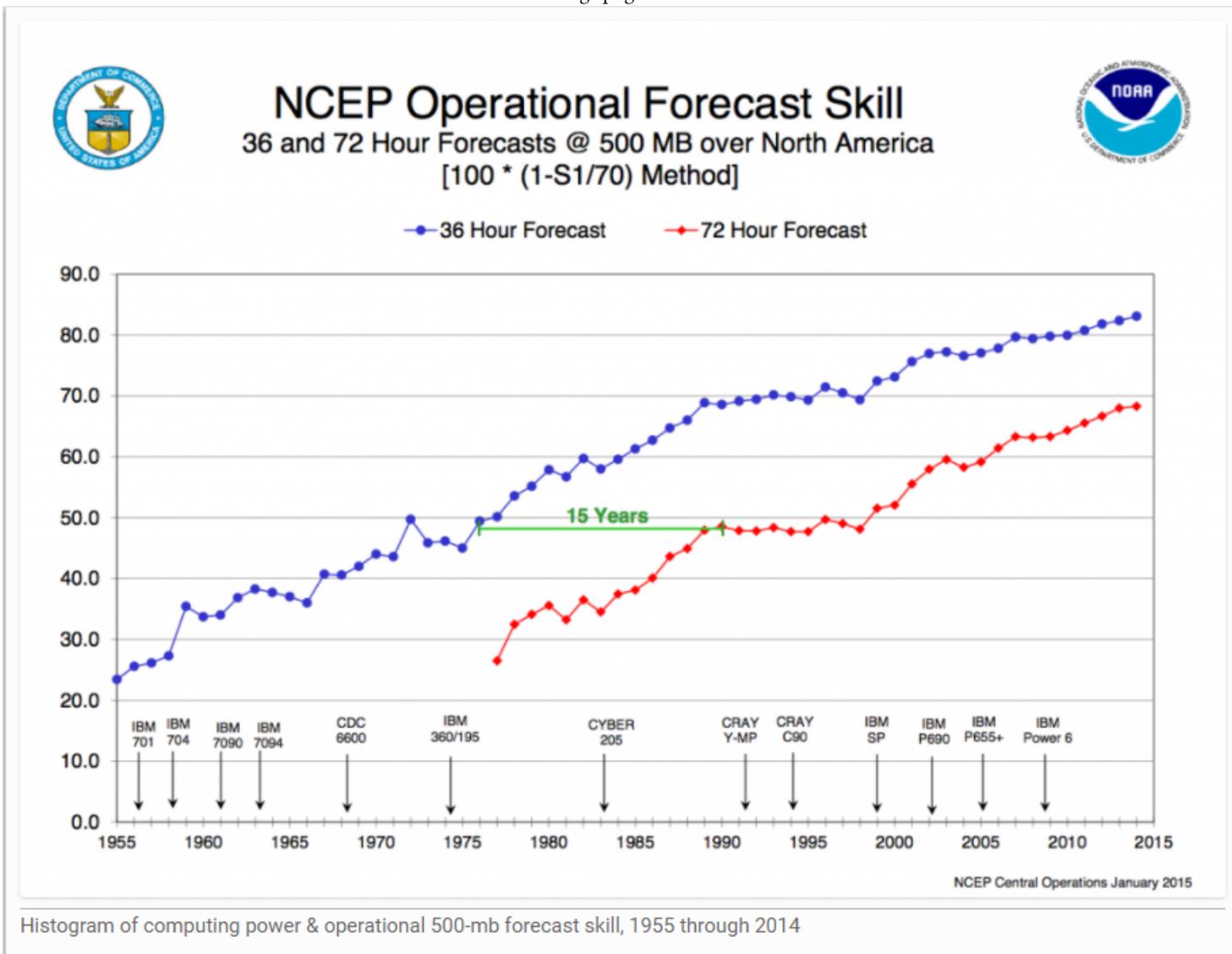


Figure 1: Histogram by NCEP(National Centres for Environmental Prediction) showing trends in computing power and operational model skill over time

thunder.png



Figure 2: 84 hours forecast by predicted by Deep Thunder

# Big Data Analytics in Agriculture

Judy Phillips  
Indiana University  
PO BOX 4822  
Bloomington, Indiana 47408  
judkphil@iu.edu

## ABSTRACT

Big Data and Data Science is significantly impacting the industry of agriculture and food safety in the food supply chain. Big data is a term for datasets that are so large or complex that traditional data processing applications are not inadequate to process them. [7]. The availability the wireless technology, the Internet of Things, smart machines, and sensors are making food production processes increasingly data driven and data enabled [7]. This in turn, is making farming production processes more productive and food delivery systems more reliable.

## KEYWORDS

I523, HID332, precision farming, smart farming, food production, food safety, precision agriculture, big data

## 1 INTRODUCTION

Big Data is revolutionizing the Agricultural Industry. The Internet of things together with the availability of cloud technology is creating a new phenomenon called Smart farming [7]. Large amounts of information is being captured, analyzed, and used to make operational decisions [4]. As a result, farmers are optimizing productivity, reducing costs, reserving resources, and increasing profitability.

Big Data Analytics is also reducing waste and spoilage as food moves through the food supply chain. According to McKinsey and Company, approximately one-third of all food is lost or wasted every year. That equates to a nine hundred forty (940) billion dollar Global impact [6]. Much of this occurs during the food shipment process.

Internet connected devices are becoming common place on farms. Almost all new farm equipment has sensors. Sixty percent of farmers report some type of internet sourced data to make operational decisions [3]. Sensors are becoming common in food packaging. The related software market is growing rapidly. In 2010 the investment in Agricultural Technology was 500 million. In 2015 the investment had grown to 4.2 billion [4].

## 2 BIG DATA

Big data represents information assets characterized by such high volume, velocity and variety as to require a specific set of technology and analytical methods for its transformation [7]. The amount of data and information generated by the food production industry is massive. For example, it is estimated that sensors on harvesting equipment generate about seven gigabytes per acre. There are 93 million acres of corn and 80 acres of soybeans in the United States alone [3]. In India, there are one billion acres. Data is being collected

at the micro-bit level and much of this data is being processed in real time [5].

## 3 THE SMART FARM AND PRECISION AGRICULTURE

### 3.1 Precision Agriculture - Overview

Precision agriculture is a specific farm management technique that uses sensor and analytic technology to measure, observe and respond to crop and livestock management in real time. Precision farming matches farming techniques to the specific crop and livestock needs. The objective of precision farming is to ensure that crops receive that exact inputs that they need, at the correct time, and in precise amounts [2]. Examples of crop inputs include: water, fertilizer, herbicides and pesticides. This strategy enables a farmer to get the most productivity out each and every resource. Solutions are customized to each individual farmers unique needs.

Processes that are typically managed with Precision techniques include: seeding, planting, harvesting, weed control [1], fertilizer management, breeding, disease control, pesticide management, light and energy management [7].

### 3.2 Precision Farming - Benefits

Precision farming techniques give farmers the ability to make operating decisions in real time based upon data and information that is being generated in real time. It also gives farmers the ability to make predictive insights in farming operations [7]. All of this results in significant benefits: Increased yields, reduced costs, greater productivity, immediate disease management [5], improved crop quality, and better cash flow. Big Data makes farms more profitable. Also, when inputs such as herbicides and pesticides are better managed, it helps the environment. Precision farming also has a socioeconomic impact worldwide because efficiency improvements can help to alleviate global food insecurity [7].

### 3.3 Precision Farming - Data Collection

A very common approach to collecting data is sensor technology. Sensor technologies measure and monitor data. Sensors register and report deviations in real time. Sensors include devices that are located locally on the farm and external satellites.

Types of local sensors include: connected farming equipment (tractors, harvesters), chips planted into livestock [4], and drones. Examples of the types of data that may be collected via local sensors include: Rainfall and water measurements, crop health, livestock health, weather information, yield monitoring, and lighting and energy management [7]. Drones can collect aerial images of fields. Aerial field images can help to monitor crop health. [2]. Data is oftentimes collected in very precise detail. For example, information

can be gathered for each square meter of land or for every individual plant [1].

Data collected with local sensors is often supplemented with information from external sources such as satellites and the cloud. Data that may be collected via satellite and available in real time on the cloud includes: Weather and climate data (historical and real time), soil type analysis, market information, and livestock movements. Data collected from orbiting satellites can also be very granular and personalized [4]. For example, soil characteristics such as texture, organic matter, and fertility is collected to the meter at locations throughout the world [4].

### 3.4 Precision Farming - Data Analysis

After the data is collected it must be consolidated and analyzed. A significant amount of this support is being provided by machine supplier companies that have been servicing the farming industry for generations such as John Deere, DuPont Pioneer, and Monsanto [5]. Now, in addition to selling seeds and machinery, these companies are selling decision support and data science services [3].

Most of this support is in the form of software decision support technology. Companies collect information from individual farms, combine this information with data from other sources, including their own databases, and apply statistical models and algorithms. Results and recommendations are delivered to each grower as personalized solutions. Examples of some potential solutions are: how far apart to place seeds based upon the field position, or what to do to better manage nitrogen levels in the soil [5].

These companies have developed and maintain massive databases of their own. DuPont Pioneer has mapped and has collected data on 20 million acres in the United States. Another company, Cropin, which provides support for farmers worldwide, including growers in extremely remote areas, has mapped over one billion acres globally. Cropin can provide data by individual farm, farm clusters, districts, states, and even countries (India) [5].

In addition to big companies, there are also public institutions that are involved with Big Data Applications. These include universities, the USDA, and the American Farm Bureau Federation. Their interest typically involves issues such as food safety, food security, and data privacy regulation [7].

### 3.5 Precision Farming - Infrastructure

After the data is analyzed it is downloaded from the cloud and made available to the farmers, typically through wireless technology devices. It may be downloaded to a farmer's Ipad or computer in a tractor. Other information can be sent to Smart phones. By interacting with the Internet of Things farmers can manage operational activities from anywhere in the world [7]. Other devices are self automated. One such self automated technology is Variable rate technology (VRT). Variable rate technology is built into equipment such as irrigation systems, feeders, and milking devices [2]. These devices automatically operate in such a way as to deliver optimal results with no human intervention.

None of these processes can happen without the appropriate infrastructure to store, transmit, and transform the data. Typical storage vehicles for this data are typically cloud based platforms,

Hadoop Distributed file system, cloud based data warehouses and hybrid systems. Data transfer is accomplished via wireless technology using cloud based platforms. Machine learning algorithms are typically used to transform and cleanse the data [7].

### 3.6 Precision Farming - Decision Making

Below are some examples of ways in which information provided by Big Data Analytics is providing farmers with the information that they need to make more informed decisions concerning their operations.

Following are some examples of technology in the world of crop science: Satellite systems and sensors can monitor the development of crops in detail. Individual plants can be monitored for nutrients, growth rate and health [6]. In this way, disease outbreaks can be recognized and addressed immediately [5]. Entire fields can be mapped with GPS coordinates to collect data concerning soil conditions and elevation. The data is analyzed using Algorithms and the data is sent back to an Ipad on the farmer's tractor. The tablet then communicates with the tractor's planting mechanism telling it exactly where to place every seed [5]. This same technology can even tell if a single seed has been missed [3]. GPS units on tractors, combines, and trucks help determine the optimal usage of equipment [6].

Big Data technology also improves the field of Animal and livestock management. Milk cows are tagged with chips that monitor the health of the animal. Milking machines shut down when the animal is sick. [4]. Sensors indicate when livestock are ready to inseminate or give birth [1]. Smart dairy farms are using robots to complete tasks such as feeding cows, cleaning barns, and milking cows [7].

Consolidated data can offer insights and information that has never before been possible. Big data companies can test and gather information about the effectiveness of different kinds of seeds across many different conditions, soil types, and climates. The origin of crop diseases can be identified quickly and efficiently with web searches similar to the way that flu epidemics are currently identified [3]. This will enable players to take corrective action quickly. Historical analytics can determine the best crops to plant [7].

## 4 FOOD SAFETY AND THE FOOD SUPPLY

Big Data not only impacts primary food production, it helps to improve the entire food supply chain [7]. According to the Food and Drug Administration, food waste equates to approximately 680 billion in industrial countries and 310 billion in developing countries annually [4]. A significant amount of this food waste occurs during food transport. Big Data can help to address this issue in various ways. First, it can help to manage the logistics of transportation. For example, Big Data can help to insure that food is transported in the best weather conditions in developing countries. This helps to avoid issues such as trucks not being able to navigate muddy roads. Big data can also assist coordination needs between supplier, retailer, and consumer. For example, consumer demand can be tracked with customer loyalty cards or retailers data on shopping patterns. Coordinating food delivery with consumer need helps to minimize food waste [4].

Food spoilage can also be monitored during food transport. Inadequate packaging of food often results in food waste and food spoilage that can even result in life threatening food borne illnesses [6]. Packaging sensors can detect gases that is being emitted from food when it starts to spoil. RFID based traceability systems can monitor food as it moves through the supply system. Packaging integrity and freshness can be monitored in real time. Therefore, waste is reduced and food quality issues can be addressed as they occur [6].

## 5 CHALLENGES AND ISSUES

### 5.1 Developing Countries

The challenges in developing countries are unique. In order for Big Data to be successful there must be infrastructure. Technologies such as satellite imagery and weather monitoring may not be fully developed. Small farmers can not always afford specialized machinery. Farmers do not always have access to devices such as computers, tablets, or Ipads [4].

Such issues are starting to be addressed in some countries. For example, in Africa organizations are being formed which pool several farmers resources together. This enables better access to resources as well as educational information. Also, there are establish companies that are starting to invest and develop technologies around the world, such as CropIn and Monsanto.[4]. Mobile devices such as Smart phones are becoming more common and are starting to be used more widely to manage information. For example, in Tanzania 30000 farmers use mobile phones for business purposes such as contracts, loans and payments.[2].

### 5.2 United States

In the United States, machine suppliers in the form of big companies have played a big role in this evolution by developing decision support tools that provide information to better manage farms [5]. When individual farmers share their personal data with big companies such as John Deere and Monsanto it raises some significant unanswered questions and concerns. Is my personal data safe? Is my data secure? Who owns the data? Who will profit from the data? [3]. Even if it is assumed that the original data belongs to the individual farmers, there is still the question of who owns the data after it is consolidated. Furthermore, there is concern that the aggregated data could be used to for malicious intent such as manipulation of commodity markets [7].

For these reasons, there need to be clear and defined standards regarding issues of privacy, security, data ownership, and market speculation. Such standards are only in the beginning stages of development. Organizations who are currently working on the farmers behalf to develop these standards include: The American Farm Bureau Association, The Big Data Coalition and AgGateway. In the interim, farmers need to do their best to fully understand any contracts that they sign in which they agree to share data. [7].

## 6 CONCLUSION

Improvements to agricultural productivity as result of big data technology are beyond substantial. Big data is being referred to as the most significant revolution in farming productivity since mechanization. In 2009, the United Nations estimated that 900

people in the world were undernourished and that 65 countries face alarming food shortages [4]. Big Data is expected to make an impact Food Insecurity throughout the world as farmers throughout the world adopt these techniques. This technology will enable even small holder farmers to make full use of their productive potential. The use of precision farming techniques and digital technologies will enable farmers to maximize the use of every inch of soil and even the production of each individual plant.

Big Data is improving the food delivery system. Information is available to producers and suppliers that in the past has been impossible to obtain [7]. Big data is making the food supply healthier and safer. Big Data in Agriculture is here to stay.

## REFERENCES

- [1] 2017. Farming goes digital - The 3rd Green Revolution. Web page. (Sept. 2017). <https://www.cema-agri.org/page/farming-goes-digital-3rd-green-revolution>
- [2] 2017. Precision Farming. Web page. (Sept. 2017). <https://en.wikipedia.org/wiki/Precisionagriculture>
- [3] Dan Bobloff. 2017. Big Data Comes to the Farm. Web page. (Sept. 2017). <https://www.businessinsider.com/big-data-and-farming-2015-8/>
- [4] Nir Kshetri. 2016. *Big Data's Big Potential in Developing Economies*. CABI.
- [5] Katherine Noyes. 2017. Cropping Up on Every Farm Big Data Technology. Web page. (Sept. 2017). <https://www.fortune.com/2014/05/30/cropping-up-on-every-farm-big-data-technology>
- [6] Sparapani. 2017. How Big Data and Tech Will Improve Agriculture from Farm to Table. Web page. (Sept. 2017). <https://www.forbes.com/sites/timsparapani/2017/03/23/how-big-data-tech-will-improve-agriculture-farm-to-table/>
- [7] Sjaak Wolfert. 2017. Big Data in Smart Farming - A review. *Agricultural Systems* 153 (Feb. 2017), 69–80. <http://sciedirect.com/science/article/pii/S0308521x16303754>

# Big Data Analytics for Municipal Waste Management

Andres Castro Benavides  
Indiana University  
107 S. Indiana Avenue  
Bloomington, Indiana 43017-6221  
acastrob@iu.edu

Mani Kumar Kagita  
Indiana University  
107 S. Indiana Avenue  
Bloomington, Indiana 43017-6221  
mkagita@iu.edu

## ABSTRACT

Waste management is becoming a greater concern for cities and municipalities around the world because of the continual increase in population and waste. Big data analysis has the potential to not only help assess the current waste management strategies but also provide information that can be used to optimize the systems used in various institutions, local governments, and companies, among others.

## KEYWORDS

Waste Management, Big Data, Local Government, HID305, HID319

## 1 INTRODUCTION

In the current fast-paced society, production of goods continues to increase, and new distribution chains continuously change. The generation of waste and the deprecated goods -from now on referred to as solid waste- has increased over the past ten years, rising from approximately 0.64 kg per person per day of solid waste to approximately 1.2 kg per person per day. Projections estimate that this number is expected to increase to about 1.42 kg by 2025. [15] This continual change and increase make waste management a more complex and more intensive endeavor.

While the quantity of waste itself can and should be reduced by conscious use and a discipline in recycling and reusing items, there is much that can be done to reduce waste in the actual collection and disposal by optimizing waste management systems.

Because of this, different local governments and organizations have recognized the need to develop more elaborate regulations to control the different features, segments, processes involved in waste disposal from the moment the material is discarded by the consumer to the moment the material reaches its ultimate destination, such as a recycling plant or landfill. This set of systematic regulations is called solid waste management. Solid waste management has changed over time. What used to be systems designed and implemented based on local needs and convenient disposal as moved into extensively researched and implemented management systems that consider complex multivariable and dynamic sources of data. [1].

Currently, data used in waste management is collected from many sources and varies depending on the types of solid waste and the rate of disposal. Because of the diversity of sources available (including types of waste, weight collected, the location of collection and disposal, etc.), the quality of the data must be continually monitored and assessed. [6]. New management systems that seek to optimize waste management must collect large volumes of data

from each data source on a daily basis. Multivariate data analysis methods provide exploratory data analysis, classification and parameter prediction using this data. [4]

## 2 MUNICIPAL SOLID WASTE MANAGEMENT

There are significant differences between the general composition of the waste generated in rural areas and the waste produced in urban areas. The waste produced in the later is profoundly influenced by the culture and the practices of our modern society. This distinction means that there will inevitably need to be differentiation in waste management practices and systems based on each communities needs, commerce, economy, and practices. [6]

Municipal Solid Waste (MSW), commonly known as garbage or trash, consists of items that residential, commercial, institutional and industrial sites generate. This is much different from the type of waste produced, for example, in an agricultural community. Urban, or municipal, waste can be the result of everyday activities, such as leftover food, plastic bottles, packaging material, wooden furniture, electrical and electronic appliances, glass, medical waste, cardboards, waste tires, office wastes, consumer goods, among others.

The amounts of solid waste and its composition vary depending on the country, place, and activity performed at the site where the waste is generated [6]. For this reason, every process related to waste management-transportation, storing and final disposition, among others- must be engineered and tailored to fit the specific needs of community, organization, or local institution. The data collected for analysis will also be specific to the needs and realities of each individual entity, which is why waste management plans are not universal or easily applied from one community to another.

The ways of handling waste have also changed over the years, affecting the best ways to manage waste. According to EPA statistics from 2014, Americans have generated about 258 million tons of MSW of which more than 89 million tons is recycled and composted. The equivalent to a 34.6% recycling rate compared to 6.4% in 1960. Americans have also used the energy production process to combust approximately 33 million tons of waste, while as much as 136 million tons of waste ended up in landfills during the same year. [9]. Because of this, data on recyclable material, dividing waste and recyclable material, and where materials are sent or how they are disposed of has also become significant. Figures 1,2,3 and 4 [9] represents MSW generation rates, recycling, composition rates and Total MSW generation between 1960 and 2014 [9].

[Figure 1 about here.]

[Figure 2 about here.]

[Figure 3 about here.]

[Figure 4 about here.]

In waste management, decision-makers are and will continue to be forced to make choices. When they develop or implement plans, they have a choice as to what information they will or will not consider for analysis. They have to choose what factors are influential in their jurisdiction. They make choices about routes, resources, and all the details between pick up to disposal. These choices can be classified as fortuitous, good, or optimal. [1].

Fortuitous decision-making has no scientific base; the person who is in charge of making decisions must always try to solve the problem with little or no research or data. On the other hand, good decision-making is primarily based on experience, comparison of elements and trial and error. Optimal decision making, however, requires understanding and analysis of techniques and technologies provided by other fields. [1]

This is where Big Data comes in.

### 3 BIG DATA AND WASTE MANAGEMENT

Big data has the capacity to facilitate analysis of information so that better decisions can be made.

In Big Data, the expert in charge takes many data sets coming from diverse and dynamic data sources and applies technologies to analyze these data sets. Authors of papers and books like "The Fourth Paradigm" state that big data exploration works to find patterns in data by analyzing the trends and outliers found in the datasets mentioned above, to generate knowledge. [14]

Characteristics (such as the large volume of data generated in waste management, how dynamically the data is generated, and the variety of formats in which the data comes) turn the task of producing knowledge an ideal task for Big Data. Scientists can interpret the findings of Big Data in a way that allows individuals and institutions involved in waste management, to make optimal decisions. [21]

### 4 SOLUTIONS FOR EFFECTIVE WASTE MANAGEMENT

#### 4.1 Examples of Big data and waste management

In Manchester, England, the Greater Manchester Waste Disposal Authority, England's most significant waste management institution, has started to use Big Data to better orchestrate the waste management services they provide. To get the most out of their Big Data approach, the Greater Manchester Waste Disposal Authority is working in collaboration with the research done by the University of Manchester. Together, they are creating environmentally sustainable solutions for Manchester, and are finding optimal solutions to the 1.1 million tonnes of waste that Manchester produces every year [19].

Another example of a local government implementing Big Data Solutions is the city of Songdo, South Korea. In said city, every citizen needs to use a chip card while disposing of their garbage. Data collected from these chip cards is being used to analyzing on the quantity of disposed waste and their locations. Each trash bin is incorporated with sensors to provide the height of the garbage accumulated in the reciprocal, temperature, and air pollution levels. These multiple parameters help municipal authorities forecast ideal

times to collect the trash and optimize the routes to save time and expenses [19].

Researchers in Ethiopia are combining socioeconomic data alongside geographic data in order to get a clearer understanding of the patterns of how household waste is being collected and distributed. This study helped local authorities to better manage waste practices in urban areas [19].

A group of researchers from the University of Stockholm is using Big Data to identify how to optimize waste management routes in their city. By using a wide variety of data sets collected from various sources, roughly around half a million entries including trash bin locations, weights, and truck routes, researchers have developed waste generation maps of Stockholm. This research has helped reveal various inefficiencies in the current waste management system and will be integral in helping them improve their local waste management [19]. Figure 5 [18] represents heatmap of all waste aggregated per zip code in Stockholm.

[Figure 5 about here.]

*4.1.1 Vehicle Routing Problem.* Vehicle route optimization is one of the primary concerns in waste management. It is termed as Vehicle Routing Problem (VRP) [7]. While routes may be designed based on geography, merely looking at a map and designing what seems to be practical movement through the city, this is underestimating the extent of the factors involved. There are multiple factors that either directly or indirectly affect waste collection that can also be analyzed and considered while designing routes. Common known factors that influence vehicle routing are the type of vehicle, vehicle capacity, number of collection stops, volume per capita and the route length. Figure 6 represents Vehicle Routing Problem [20] when one dump location is placed between different collection routes.

[Figure 6 about here.]

Two of the most basic VRPs are the Travelling Salesman Problem (TSP) and the Chinese Postman Problem (CPP) [2]. However, when too many constraints and attributes are considered, both of the TSP and CPP become more difficult problems to solve. Many researchers have studied and published articles on waste management vehicle routing problem VRPs, and yet it is a persistent problem. Mathematical models need to be developed to provide city administrators with tools to make effective long-and short-term decisions relating to their municipal disposal system [3].

In addition to the common known factors causing VRP problems, indirect attributes must also be taken into consideration. Time of day, traffic, weather patterns, energy prices, demand fluctuations, vehicle health, dump site inventory also have potential to affect route efficiency.

A research team at OSI came up with a better solution for solving VRP problems using Big Data technologies. Mixed Integer Programming (MIP) formulation was designed to interact with millions of attributes in live environments providing real-time decisions to optimize the VRP. Big Data technologies are being used to enable prediction of travel times and forecast and address demand on a tactical timeline. This approach has helped improve VRP forecasting between 5% to 10% [12]. Any improvement, even less than 5% created on VRP is a significant improvement [13].

Scientists and engineers have designed a system that communicates between waste reciprocals, waste collection vehicles and a central system using sensors that measure how full containers are and can send real-time data. [10].

The data collected can be used to optimize routes and space in the waste collection vehicles. Sensors can identify which containers do not need to be collected, allowing them to shorten routes. In addition, sensors can measure the remaining capacity of collection vehicles, allowing them to extend routes when they still have cargo space, ensuring that they return to the disposal center only when they are carrying a full load. By using these sensors, fewer collection vehicles were needed. It was estimated that in three years, the expense of purchasing and implementing this system would be recovered [18].

In addition to the real-time data collection that helps optimize collection and routes, remote self-diagnostics are also helping optimize vehicle use. By being able to monitor the vehicles use and health, maintenance and repair are more efficiently managed. Through this system, managers are made aware of parts that need to be ordered in advance, limiting the time that the vehicles may be out of service. Handheld devices have been developed for service verification, further helping minimize external providers or assessments, optimizing asset management and costs [11].

[18].

**4.1.2 Problem of Landfill Disposal.** A municipal solid waste landfill (MSWLF) is a individually separated area of land or a trench where the household waste is collected and stored. These landfills are designed to store municipal solid waste as well as other wastes like construction and industrial waste. These landfills can be open-pits or below ground refuse chambers. In recent years, its becoming more expensive to operate and maintain these landfills as to protect the environment from escaping liquid pollutants and causing water and surface contamination. These liquid pollutants are commonly called as leachate. It forms when water originating from rainfall or groundwater dissolves gradually through a porous surface and dissolves the chemicals from the refuse especially if the protective layer of the landfill allows liquid or gases to pass through it.

Leachate contamination problems became more problematic in older landfill sites when they are typically lacked in barriers above or below the landfills which causing pollution and diseases to the citizens residing in areas near to these landfills. In modern days, Governments across the world are in one motive to prevent waste disposal and reduce landfill deposits. Steps are taken to reduce number of landfill areas and extending landfill capacity at current sites. Figure 7 displays the number of landfills in the US, 2009.

[Figure 7 about here.]

Landfill disposal, in itself, has its own set of complex factors including measurement and control of gases, management of wastewater, and precipitation patterns affecting water volume in the geological basin.

Identifying these factors creates an opportunity to develop sensors that could collect meaningful data that would be an asset to optimizing landfill disposal. Sensors could measure gas immission, water volume in disposed waste, and precipitaion. Having this information would allow data scientists to develop systems that would identify when disposal would need to be varied, how water

treatment plants could efficiently manage runoff and basin water and communicate with water treatment plants to use more or less of their mechanical resources based on real-time needs.

Manual calculation would be time-consuming and physical observation opens space for inefficiency and delay. In order to compute these calculations promptly so that the information could contribute to optimization, it would be ideal to develop a computer program to compute the mathematical operations. This would contribute significantly to optimization of water treatment, for example, in landfill disposal [1]

Waste management is already in the process of transforming from using older methodologies to modern Big Data technologies. Big Data has a lot more potential to eradicate most of the problems faced by government in waste disposal. Most of the government organizations are taking a leap to minimize disposal of waste and to achieve "zero disposal" goals [17] . A program in government of District of Columbia called "Zero Waste DC" is being initiated to develop and provide resources that will help its residents move towards zero waste. Its main motive is to divert 80% of MSW to recycling or source of energy where the remaining 20% non recoverable waste will be sent to landfills. By collecting vast amounts of data from all sources, they will analyze it to implement cost-effective strategies for converting waste to re-usable resources, improving environmental conditions, taking measures on human health, reducing greenhouse gas emissions and conservation of natural resources. Obtaining data from the sensors on contamination of air with harmful gases, water purification levels from the nearby lakes, physical properties as well as chemical properties of the soil, Big Data will help to analyze this data and provide solutions to prevent them from making situations worst. [17].

When its considered Big Data as a volume, huge amounts of data is being collected daily from different sources like digital meters, sensors, social media to avoid waste disposals. It is how this data is being turned into knowledge to apply into real-world problems. Cloud based solutions and using IoT sensors becoming more insight technologies for smart cities and municipal waste management authorities to optimize the waste and their recycle operations. Big Data will help in lowering of contamination on the waste and improve consumption habits of residents in urban areas.

Reading information from the sensors placed in recycle bins, it is easier to figure out what type of waste is being disposed in the trash bins and by which resident. If there are hazardous materials located, authorities can detect them before even being collected by the trash collectors. This will help to educate corresponding resident on the importance of waste and their contamination results. Big Data Analysis encourage citizens to understand about food scraps so that it can be reused as fertilizer for many of the organic foods. It is termed as "farm to farm" practice according to Robert Reed, Evangelist at Recology [16].

Using Big Data technology to collect real-time data thought the waste disposal process especially for food wastage allows visibility to organic waste. This shows focus on identifying inefficiencies in food management process which in turn helping them to initial improvement in process and to create immediate effects. Optimizing waste management is a key to find operational efficiencies and to support environmental directives. It enables business to

make effective decisions about purchasing or production of organic waste [5].

Environmental Protection Agency US also using benefits of Big Data in recycling of waste. Big Data Analysis helps in identifying quantities of solid waste being recycled and assessing the residents on the benefits they receive by recycling achievements. MSW Characterization Report shows the data collected on generation and disposal of waste in US past 30 years. This data is being analyzed to measure waste reduction and plan recycling programs across the country [8].

## 4.2 Statistics and Waste Management

Statistics help develop mathematical models to predict behavior based on the data collected. In waste management, these statistics can be used by Big Data professionals to draw conclusions and foresee possible outcomes as related to effective policy making and actual waste production, collection, and disposal patterns.

There are many data analysis methods that are used when studying waste management, but the two most popular are PCA and PLS1. [4]

Lingo is a mathematical modeling language designed particularly for formulating and solving a wide variety of optimization problems including linear programming. Lingo optimization software uses the branch and bound methods to solve problems of this type. [1].

These resources are valuable to the continual analysis of data being collected, continually helping in waste management optimization.

## 4.3 GIS Analytics

When it comes to Geographical Information Systems (From now on GIS), there are multiple software and hardware options in the market. From paid software like ArcGIS to Open and free software like GVSIG, some solutions can help interpret large data sets, apply statistics and algorithms of different kinds and display them in a way that refers to a geographical space.

Two optimal routing algorithms have been used to calculate routes for waste collection; Solomon's insertion algorithm and a clustering algorithm. Data was used to help create more efficient routes by minimizing driving distance while taking into consideration factors like lunch breaks (time windows) that affected the distribution of human resources and time/vehicle management. By adding vehicle depots, by rerouting, and by sharing various routes, they predicted that they would be able to shorten vehicle expenditure by as much as 10,000 km.

An additional routing algorithm was used to present information on the environmental significance for optimizing waste collection routes. The study assessed the use of roll-on/roll-off containers while also considering schedules and lunch breaks. Through the utilization of an adaptive large neighborhood search algorithm, alongside a clustering method, a residential waste collection was analyzed, taking into consideration actual pick up points and employee lunch breaks. Using this information, time windows and starting conditions were adapted alongside the routes to reduce the total distance by as much as forty-five percent. [18].

## 5 CONCLUSION

Waste management has been a growing concern and will continue to be an important area for optimization as both consumer waste and population increase. As institutions, governments, and individuals look to assess and optimize resources, minimize cost and create less of an environmental impact of waste management, Big Data has the potential to continue to help provide the information needed for future advancement.

There are various tools being used to optimize the different waste management practices, and there is space to develop additional tools to continue to the information available to decision makers.

One of the main reasons to use Big data in Municipal Waste Management is to provide local governments with tools that would facilitate the implementation of systems to more efficiently manage how much, where and the growth rate of the material that the community dispossess. Optimizing the waste management systems can help minimize the environmental impact of the community's actions, reduce pollution, increase rates of recycled materials, optimize routes to reduce time and expenses, among others. By using Big data, local governments can also track the number and quantity or weight of disposals at different locations; this information can be mapped to reveal the locations of the most significant waste generators. This information will help entities develop specific strategies to reduce waste and help implement permanent solutions for better environments. Waste Management is not only government issue. Citizens should take the initiative and educate others on how to recycle and reduce waste. With the help of the collected data, governments can notify the different entities (individuals, communities, companies and other organizations) a equip them through education and awareness, and also share valuable information about the importance of waste management through different media, such as mobile phones, email, among others. Local governments have just started to adopt Big Data technologies for solving problems involved in MSW, but there is plenty of room for growth and further use and development. By using Big Data Analytics, large amounts of data sets pertaining to specific communities waste, routes, and disposal can be used to identify trends and patterns that could highlight opportunities for improvement. Big Data can play a significant role in managing cities more efficiently, benifiting not only those managing the systems, but the commuties in which they are implemented as well.

## ACKNOWLEDGMENTS

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

## REFERENCES

- [1] Mohsen Akbarpour Shirazi, Reza Samieifard, Mohammad Ali Abduli, and Babak Omidvar. 2016. Mathematical modeling in municipal solid waste management: case study of Tehran. *Journal of Environmental Health Science and Engineering* 14, 1 (18 May 2016), 8. <https://doi.org/10.1186/s40201-016-0250-2>
- [2] Jeroen Belin, Liesje De Boeck, and Jonas Van Ackere. 2012. Municipal Solid Waste Collection and Management Problems: A Literature Review. *HUB RESEARCH PAPERS 2011/34 ECONOMICS & MANAGEMENT* 48, 34 (11 2012), 1–5.
- [3] V. N. Bhat. 1996. A model for the optimal allocation of trucks for solid waste management. *A model for the optimal allocation of trucks for solid waste management*. 14 (1996), 87–96.
- [4] K. Bofkham, E. Smidt, and J. Tintner. 2013. Application of Multivariate Data Analyses in Waste Management. In *Multivariate Analysis in Management, Engineering*

- and the Sciences*, Leandro Valim de Freitas and Ana Paula Barbosa Rodrigues de Freitas (Eds.). InTech, Rijeka, Chapter 02, 15–16. <https://doi.org/10.5772/53975>
- [5] Frank E. Celli. 2016. Data analytics: The most effective approach for a zero waste solution. WasteDive. (09 2016). <http://www.wastedive.com/news/data-analytics-the-most-effective-approach-for-a-zero-waste-solution/425424/>
  - [6] R. Chandrappa and J. Brown. 2012. *Solid Waste Management: Principles and Practice*. Springer Berlin Heidelberg, Berlin. 47–63 pages. <https://books.google.com/books?id=kUOwuAAACAAJ>
  - [7] G. B. Dantzig and J. H. Ramser. 1959. The Truck Dispatching Problem. *Management Science* 6, 1 (10 1959), 80–91.
  - [8] EPA. 2007. METHODOLOGY FOR ESTIMATING MUNICIPAL SOLID WASTE RECYCLING BENEFITS. epa.gov. (11 2007). <https://www.epa.gov/sites/production/files/2015-09/documents/06benefits.pdf>
  - [9] EPA. 2014. Advancing Sustainable Materials Management: Facts and Figures. U.S. Environmental Protection Agency. (2014). <https://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures#Materials>
  - [10] Maurizio Faccio, Alessandro Persona, and Giorgia Zanin. 2011. Waste collection multi objective model with real time traceability data. *Waste management (New York, N.Y.)* 31, 12 (08 2011), 2391–405. <https://www.ncbi.nlm.nih.gov/pubmed/21821406>
  - [11] Megan Greenwalt. 2017. What the Growth of Big Data Means for Waste & Recycling. FLEETS & TECHNOLOGY. (03 2017). <http://www.waste360.com/fleets-technology/what-growth-big-data-means-waste-recycling>
  - [12] Vijay Hanagandi. 2013. A New Paradigm to Solving Vehicle Routing Problems. (09 2013). <https://osiblogdotcom.wordpress.com/2013/09/23/a-new-paradigm-to-solving-vehicle-routing-problems/>
  - [13] Geir Hasle, Knut-Andreas Lie, and Ewald Quak. 2007. *Geometric modelling, numerical simulation, and optimization: Applied mathematics at SINTEF*. Springer, Berlin, Heidelberg, Oslo,Norway.
  - [14] A.J.G. Hey, S. Tansley, and K.M. Tolle. 2009. *The Fourth Paradigm: Data-intensive Scientific Discovery*. Microsoft Research, REDMOND, WASHINGTON. [https://books.google.com.my/books?id=oGs\\_AQAIAAAJ](https://books.google.com.my/books?id=oGs_AQAIAAAJ)
  - [15] Perinaz Hoornweg, Daniel, Bhada-Tata. 2012. *A Global Review of Solid Waste Management*. Number 15 in Urban Development Series. World Bank, Washington, DC, Urban Development & Local Government Unit World Bank 1818 H Street, NW Washington, DC 20433 USA. <https://openknowledge.worldbank.org/handle/10986/17388>
  - [16] James Kobielsus. 2012. Reuse, Recycle, Compost: A New Level of Insight into Garbage. Robert Reed, Evangelist at Recology, zerowasteIBM. (06 2012). <http://www.ibmbigdatahub.com/blog/reuse-recycle-compost-new-level-insight-garbage>
  - [17] Cole Rosengren. 2017. San Francisco expands recycling list, shrinks refuse carts on 'zero waste' crusade. WasteDIVE. (10 2017). <http://www.wastedive.com/news/san-francisco-expands-recycling-list-shrinks-refuse-carts-on-zero-waste/506700/>
  - [18] Hossein Shahrokni, Bram Van der Heijde, David Lazarevic, and Nils Brandt. 2014. Big data GIS analytics towards efficient waste management in Stockholm. In *Proceedings of the 2014 conference ICT for Sustainability*. Atlantis Press, Proceedings of the 2014 conference ICT for Sustainability, Department of Sustainable Development, Environmental Science and Engineering, Industrial EcologyRoyal Institute of TechnologyStockholm, Sweden, 140–147.
  - [19] Mark van Rijmenam. 2016. *How Big Data Shapes Urban Waste Management Services in Manchester*. techreport. University of Technology, Sydney. <https://datafloq.com/read/how-big-data-shapes-urban-waste-management-service/662>
  - [20] wikipedia. 2017. Vehicle routing problem. wikipedia. (2017). [https://en.wikipedia.org/wiki/Vehicle\\_routing\\_problem](https://en.wikipedia.org/wiki/Vehicle_routing_problem)
  - [21] Vitthal Yenkar and Mahip Bartere. 2014. Review on fData Mining with Big Dataf. *International Journal of Computer Science and Mobile Computing* 3, 4 (2014), 97–102.

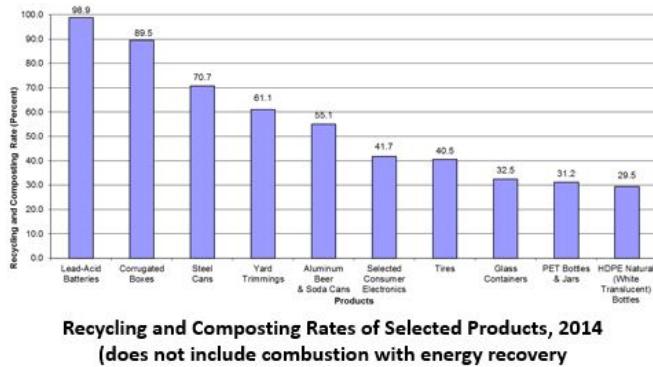
#### LIST OF FIGURES

1	MSW Generation Rates in US from 1960 to 2014	7
2	Recycling and Composting Rates of Selected products in US, 2014	7
3	MSW Recycling and Composting Rates in US from 1960 to 2014	7
4	Total MSW generation in US, 2014	8
5	Choropleth of all waste, aggregated per zip code and normalized to population in Stockholm	8
6	Vehicle Routing Problem	9
7	Number of Landfills in the US 1988-2009	9

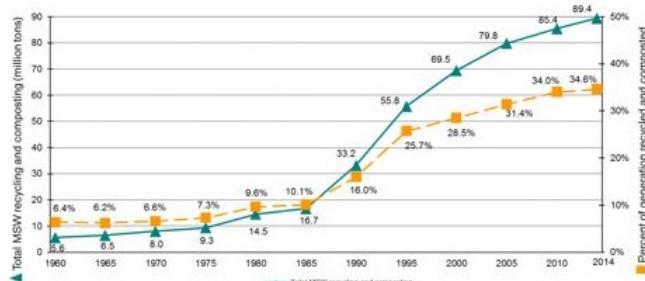


**MSW Generation Rates 1960 to 2014**

**Figure 1: MSW Generation Rates in US from 1960 to 2014**



**Figure 2: Recycling and Composting Rates of Selected products in US, 2014**



**MSW Recycling and Composting Rates, 1960 to 2014**

**Figure 3: MSW Recycling and Composting Rates in US from 1960 to 2014**

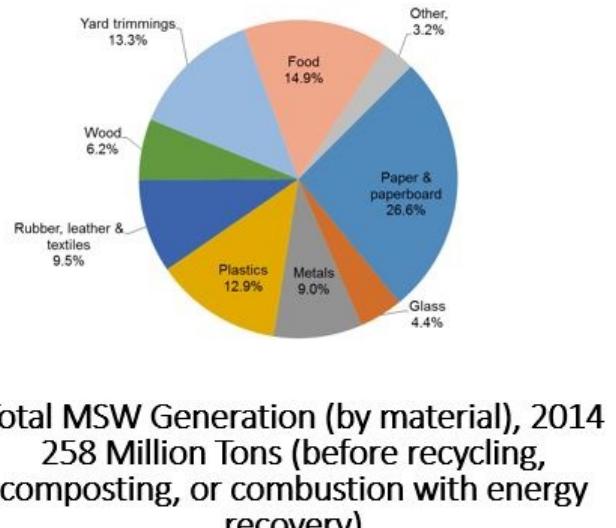


Figure 4: Total MSW generation in US, 2014

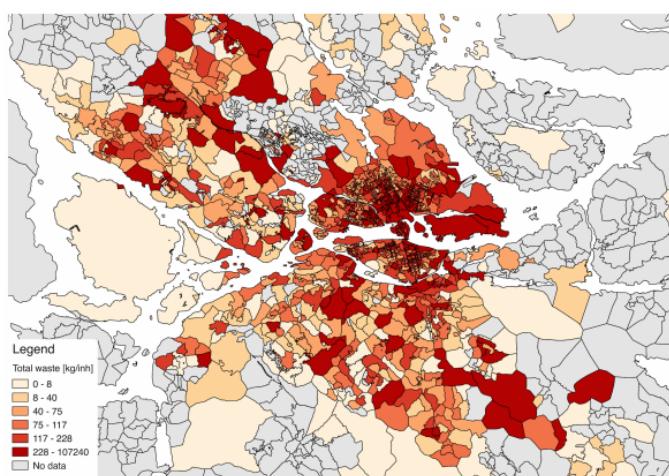
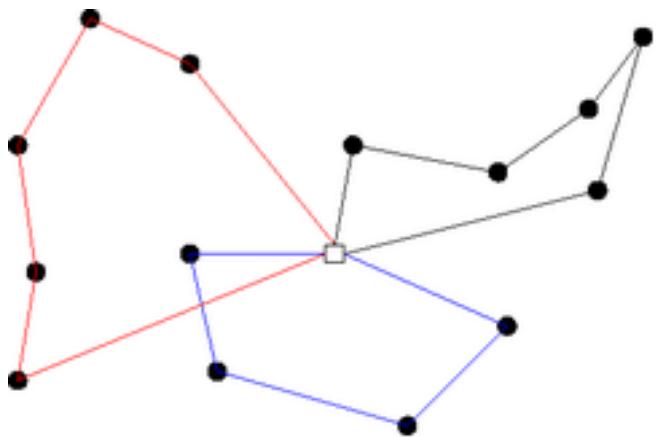
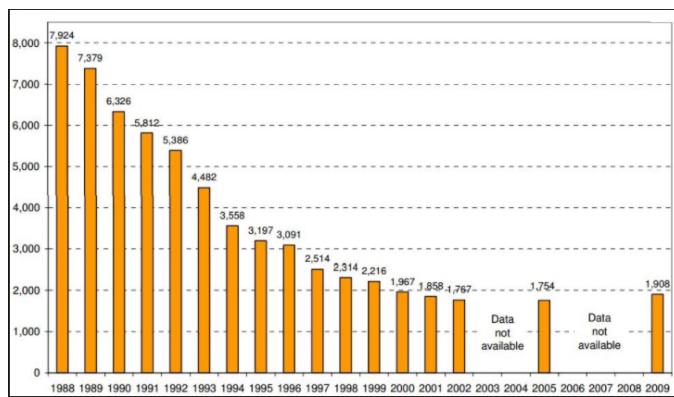


Figure 5: Choropleth of all waste, aggregated per zip code and normalized to population in Stockholm



**Figure represents Vehicle Routing Problem**

**Figure 6: Vehicle Routing Problem**



**Figure 7: Number of Landfills in the US 1988-2009**

# Big Data Analytics for Municipal Waste Management

Andres Castro Benavides  
Indiana University  
107 S. Indiana Avenue  
Bloomington, Indiana 43017-6221  
acastrob@iu.edu

Mani Kumar Kagita  
Indiana University  
107 S. Indiana Avenue  
Bloomington, Indiana 43017-6221  
mkagita@iu.edu

## ABSTRACT

Waste management is becoming a greater concern for cities and municipalities around the world because of the continual increase in population and waste. Big data analysis has the potential to not only help assess the current waste management strategies but also provide information that can be used to optimize the systems used in various institutions, local governments, and companies, among others.

## KEYWORDS

Waste Management, Big Data, Local Government, HID305, HID319

## 1 INTRODUCTION

In the current fast-paced society, production of goods continues to increase, and new distribution chains continuously change. The generation of waste and the deprecated goods -from now on referred to as solid waste- has increased over the past ten years, rising from approximately 0.64 kg per person per day of solid waste to approximately 1.2 kg per person per day. Projections estimate that this number is expected to increase to about 1.42 kg by 2025. [15] This continual change and increase make waste management a more complex and more intensive endeavor.

While the quantity of waste itself can and should be reduced by conscious use and a discipline in recycling and reusing items, there is much that can be done to reduce waste in the actual collection and disposal by optimizing waste management systems.

Because of this, different local governments and organizations have recognized the need to develop more elaborate regulations to control the different features, segments, processes involved in waste disposal from the moment the material is discarded by the consumer to the moment the material reaches its ultimate destination, such as a recycling plant or landfill. This set of systematic regulations is called solid waste management. Solid waste management has changed over time. What used to be systems designed and implemented based on local needs and convenient disposal as moved into extensively researched and implemented management systems that consider complex multivariable and dynamic sources of data. [1].

Currently, data used in waste management is collected from many sources and varies depending on the types of solid waste and the rate of disposal. Because of the diversity of sources available (including types of waste, weight collected, the location of collection and disposal, etc.), the quality of the data must be continually monitored and assessed. [6]. New management systems that seek to optimize waste management must collect large volumes of data

from each data source on a daily basis. Multivariate data analysis methods provide exploratory data analysis, classification and parameter prediction using this data. [4]

## 2 MUNICIPAL SOLID WASTE MANAGEMENT

There are significant differences between the general composition of the waste generated in rural areas and the waste produced in urban areas. The waste produced in the later is profoundly influenced by the culture and the practices of our modern society. This distinction means that there will inevitably need to be differentiation in waste management practices and systems based on each communities needs, commerce, economy, and practices. [6]

Municipal Solid Waste (MSW), commonly known as garbage or trash, consists of items that residential, commercial, institutional and industrial sites generate. This is much different from the type of waste produced, for example, in an agricultural community. Urban, or municipal, waste can be the result of everyday activities, such as leftover food, plastic bottles, packaging material, wooden furniture, electrical and electronic appliances, glass, medical waste, cardboards, waste tires, office wastes, consumer goods, among others.

The amounts of solid waste and its composition vary depending on the country, place, and activity performed at the site where the waste is generated [6]. For this reason, every process related to waste management-transportation, storing and final disposition, among others- must be engineered and tailored to fit the specific needs of community, organization, or local institution. The data collected for analysis will also be specific to the needs and realities of each individual entity, which is why waste management plans are not universal or easily applied from one community to another.

The ways of handling waste have also changed over the years, affecting the best ways to manage waste. According to EPA statistics from 2014, Americans have generated about 258 million tons of MSW of which more than 89 million tons is recycled and composted. The equivalent to a 34.6% recycling rate compared to 6.4% in 1960. Americans have also used the energy production process to combust approximately 33 million tons of waste, while as much as 136 million tons of waste ended up in landfills during the same year. [9]. Because of this, data on recyclable material, dividing waste and recyclable material, and where materials are sent or how they are disposed of has also become significant. Figures 1,2,3 and 4 [9] represents MSW generation rates, recycling, composition rates and Total MSW generation between 1960 and 2014 [9].

[Figure 1 about here.]

[Figure 2 about here.]

[Figure 3 about here.]

[Figure 4 about here.]

In waste management, decision-makers are and will continue to be forced to make choices. When they develop or implement plans, they have a choice as to what information they will or will not consider for analysis. They have to choose what factors are influential in their jurisdiction. They make choices about routes, resources, and all the details between pick up to disposal. These choices can be classified as fortuitous, good, or optimal. [1].

Fortuitous decision-making has no scientific base; the person who is in charge of making decisions must always try to solve the problem with little or no research or data. On the other hand, good decision-making is primarily based on experience, comparison of elements and trial and error. Optimal decision making, however, requires understanding and analysis of techniques and technologies provided by other fields. [1]

This is where Big Data comes in.

### 3 BIG DATA AND WASTE MANAGEMENT

Big data has the capacity to facilitate analysis of information so that better decisions can be made.

In Big Data, the expert in charge takes many data sets coming from diverse and dynamic data sources and applies technologies to analyze these data sets. Authors of papers and books like "The Fourth Paradigm" state that big data exploration works to find patterns in data by analyzing the trends and outliers found in the datasets mentioned above, to generate knowledge. [14]

Characteristics (such as the large volume of data generated in waste management, how dynamically the data is generated, and the variety of formats in which the data comes) turn the task of producing knowledge an ideal task for Big Data. Scientists can interpret the findings of Big Data in a way that allows individuals and institutions involved in waste management, to make optimal decisions. [21]

### 4 SOLUTIONS FOR EFFECTIVE WASTE MANAGEMENT

#### 4.1 Examples of Big data and waste management

In Manchester, England, the Greater Manchester Waste Disposal Authority, England's most significant waste management institution, has started to use Big Data to better orchestrate the waste management services they provide. To get the most out of their Big Data approach, the Greater Manchester Waste Disposal Authority is working in collaboration with the research done by the University of Manchester. Together, they are creating environmentally sustainable solutions for Manchester, and are finding optimal solutions to the 1.1 million tonnes of waste that Manchester produces every year [19].

Another example of a local government implementing Big Data Solutions is the city of Songdo, South Korea. In said city, every citizen needs to use a chip card while disposing of their garbage. Data collected from these chip cards is being used to analyzing on the quantity of disposed waste and their locations. Each trash bin is incorporated with sensors to provide the height of the garbage accumulated in the reciprocal, temperature, and air pollution levels. These multiple parameters help municipal authorities forecast ideal

times to collect the trash and optimize the routes to save time and expenses [19].

Researchers in Ethiopia are combining socioeconomic data alongside geographic data in order to get a clearer understanding of the patterns of how household waste is being collected and distributed. This study helped local authorities to better manage waste practices in urban areas [19].

A group of researchers from the University of Stockholm is using Big Data to identify how to optimize waste management routes in their city. By using a wide variety of data sets collected from various sources, roughly around half a million entries including trash bin locations, weights, and truck routes, researchers have developed waste generation maps of Stockholm. This research has helped reveal various inefficiencies in the current waste management system and will be integral in helping them improve their local waste management [19]. Figure 5 [18] represents heatmap of all waste aggregated per zip code in Stockholm.

[Figure 5 about here.]

*4.1.1 Vehicle Routing Problem.* Vehicle route optimization is one of the primary concerns in waste management. It is termed as Vehicle Routing Problem (VRP) [7]. While routes may be designed based on geography, merely looking at a map and designing what seems to be practical movement through the city, this is underestimating the extent of the factors involved. There are multiple factors that either directly or indirectly affect waste collection that can also be analyzed and considered while designing routes. Common known factors that influence vehicle routing are the type of vehicle, vehicle capacity, number of collection stops, volume per capita and the route length. Figure 6 represents Vehicle Routing Problem [20] when one dump location is placed between different collection routes.

[Figure 6 about here.]

Two of the most basic VRPs are the Travelling Salesman Problem (TSP) and the Chinese Postman Problem (CPP) [2]. However, when too many constraints and attributes are considered, both of the TSP and CPP become more difficult problems to solve. Many researchers have studied and published articles on waste management vehicle routing problem VRPs, and yet it is a persistent problem. Mathematical models need to be developed to provide city administrators with tools to make effective long-and short-term decisions relating to their municipal disposal system [3].

In addition to the common known factors causing VRP problems, indirect attributes must also be taken into consideration. Time of day, traffic, weather patterns, energy prices, demand fluctuations, vehicle health, dump site inventory also have potential to affect route efficiency.

A research team at OSI came up with a better solution for solving VRP problems using Big Data technologies. Mixed Integer Programming (MIP) formulation was designed to interact with millions of attributes in live environments providing real-time decisions to optimize the VRP. Big Data technologies are being used to enable prediction of travel times and forecast and address demand on a tactical timeline. This approach has helped improve VRP forecasting between 5% to 10% [12]. Any improvement, even less than 5% created on VRP is a significant improvement [13].

Scientists and engineers have designed a system that communicates between waste reciprocals, waste collection vehicles and a central system using sensors that measure how full containers are and can send real-time data. [10].

The data collected can be used to optimize routes and space in the waste collection vehicles. Sensors can identify which containers do not need to be collected, allowing them to shorten routes. In addition, sensors can measure the remaining capacity of collection vehicles, allowing them to extend routes when they still have cargo space, ensuring that they return to the disposal center only when they are carrying a full load. By using these sensors, fewer collection vehicles were needed. It was estimated that in three years, the expense of purchasing and implementing this system would be recovered [18].

In addition to the real-time data collection that helps optimize collection and routes, remote self-diagnostics are also helping optimize vehicle use. By being able to monitor the vehicles use and health, maintenance and repair are more efficiently managed. Through this system, managers are made aware of parts that need to be ordered in advance, limiting the time that the vehicles may be out of service. Handheld devices have been developed for service verification, further helping minimize external providers or assessments, optimizing asset management and costs [11].

[18].

**4.1.2 Problem of Landfill Disposal.** A municipal solid waste landfill (MSWLF) is a individually separated area of land or a trench where the household waste is collected and stored. These landfills are designed to store municipal solid waste as well as other wastes like construction and industrial waste. These landfills can be open-pits or below ground refuse chambers. In recent years, its becoming more expensive to operate and maintain these landfills as to protect the environment from escaping liquid pollutants and causing water and surface contamination. These liquid pollutants are commonly called as leachate. It forms when water originating from rainfall or groundwater dissolves gradually through a porous surface and dissolves the chemicals from the refuse especially if the protective layer of the landfill allows liquid or gases to pass through it.

Leachate contamination problems became more problematic in older landfill sites when they are typically lacked in barriers above or below the landfills which causing pollution and diseases to the citizens residing in areas near to these landfills. In modern days, Governments across the world are in one motive to prevent waste disposal and reduce landfill deposits. Steps are taken to reduce number of landfill areas and extending landfill capacity at current sites. Figure 7 displays the number of landfills in the US, 2009.

[Figure 7 about here.]

Landfill disposal, in itself, has its own set of complex factors including measurement and control of gases, management of wastewater, and precipitation patterns affecting water volume in the geological basin.

Identifying these factors creates an opportunity to develop sensors that could collect meaningful data that would be an asset to optimizing landfill disposal. Sensors could measure gas immission, water volume in disposed waste, and precipitaion. Having this information would allow data scientists to develop systems that would identify when disposal would need to be varied, how water

treatment plants could efficiently manage runoff and basin water and communicate with water treatment plants to use more or less of their mechanical resources based on real-time needs.

Manual calculation would be time-consuming and physical observation opens space for inefficiency and delay. In order to compute these calculations promptly so that the information could contribute to optimization, it would be ideal to develop a computer program to compute the mathematical operations. This would contribute significantly to optimization of water treatment, for example, in landfill disposal [1]

Waste management is already in the process of transforming from using older methodologies to modern Big Data technologies. Big Data has a lot more potential to eradicate most of the problems faced by government in waste disposal. Most of the government organizations are taking a leap to minimize disposal of waste and to achieve "zero disposal" goals [17] . A program in government of District of Columbia called "Zero Waste DC" is being initiated to develop and provide resources that will help its residents move towards zero waste. Its main motive is to divert 80% of MSW to recycling or source of energy where the remaining 20% non recoverable waste will be sent to landfills. By collecting vast amounts of data from all sources, they will analyze it to implement cost-effective strategies for converting waste to re-usable resources, improving environmental conditions, taking measures on human health, reducing greenhouse gas emissions and conservation of natural resources. Obtaining data from the sensors on contamination of air with harmful gases, water purification levels from the nearby lakes, physical properties as well as chemical properties of the soil, Big Data will help to analyze this data and provide solutions to prevent them from making situations worst. [17].

When its considered Big Data as a volume, huge amounts of data is being collected daily from different sources like digital meters, sensors, social media to avoid waste disposals. It is how this data is being turned into knowledge to apply into real-world problems. Cloud based solutions and using IoT sensors becoming more insight technologies for smart cities and municipal waste management authorities to optimize the waste and their recycle operations. Big Data will help in lowering of contamination on the waste and improve consumption habits of residents in urban areas.

Reading information from the sensors placed in recycle bins, it is easier to figure out what type of waste is being disposed in the trash bins and by which resident. If there are hazardous materials located, authorities can detect them before even being collected by the trash collectors. This will help to educate corresponding resident on the importance of waste and their contamination results. Big Data Analysis encourage citizens to understand about food scraps so that it can be reused as fertilizer for many of the organic foods. It is termed as "farm to farm" practice according to Robert Reed, Evangelist at Recology [16].

Using Big Data technology to collect real-time data thought the waste disposal process especially for food wastage allows visibility to organic waste. This shows focus on identifying inefficiencies in food management process which in turn helping them to initial improvement in process and to create immediate effects. Optimizing waste management is a key to find operational efficiencies and to support environmental directives. It enables business to

make effective decisions about purchasing or production of organic waste [5].

Environmental Protection Agency US also using benefits of Big Data in recycling of waste. Big Data Analysis helps in identifying quantities of solid waste being recycled and assessing the residents on the benefits they receive by recycling achievements. MSW Characterization Report shows the data collected on generation and disposal of waste in US past 30 years. This data is being analyzed to measure waste reduction and plan recycling programs across the country [8].

## 4.2 Statistics and Waste Management

Statistics help develop mathematical models to predict behavior based on the data collected. In waste management, these statistics can be used by Big Data professionals to draw conclusions and foresee possible outcomes as related to effective policy making and actual waste production, collection, and disposal patterns.

There are many data analysis methods that are used when studying waste management, but the two most popular are PCA and PLS1. [4]

Lingo is a mathematical modeling language designed particularly for formulating and solving a wide variety of optimization problems including linear programming. Lingo optimization software uses the branch and bound methods to solve problems of this type. [1].

These resources are valuable to the continual analysis of data being collected, continually helping in waste management optimization.

## 4.3 GIS Analytics

When it comes to Geographical Information Systems (From now on GIS), there are multiple software and hardware options in the market. From paid software like ArcGIS to Open and free software like GVSIG, some solutions can help interpret large data sets, apply statistics and algorithms of different kinds and display them in a way that refers to a geographical space.

Two optimal routing algorithms have been used to calculate routes for waste collection; Solomon's insertion algorithm and a clustering algorithm. Data was used to help create more efficient routes by minimizing driving distance while taking into consideration factors like lunch breaks (time windows) that affected the distribution of human resources and time/vehicle management. By adding vehicle depots, by rerouting, and by sharing various routes, they predicted that they would be able to shorten vehicle expenditure by as much as 10,000 km.

An additional routing algorithm was used to present information on the environmental significance for optimizing waste collection routes. The study assessed the use of roll-on/roll-off containers while also considering schedules and lunch breaks. Through the utilization of an adaptive large neighborhood search algorithm, alongside a clustering method, a residential waste collection was analyzed, taking into consideration actual pick up points and employee lunch breaks. Using this information, time windows and starting conditions were adapted alongside the routes to reduce the total distance by as much as forty-five percent. [18].

## 5 CONCLUSION

Waste management has been a growing concern and will continue to be an important area for optimization as both consumer waste and population increase. As institutions, governments, and individuals look to assess and optimize resources, minimize cost and create less of an environmental impact of waste management, Big Data has the potential to continue to help provide the information needed for future advancement.

There are various tools being used to optimize the different waste management practices, and there is space to develop additional tools to continue to the information available to decision makers.

One of the main reasons to use Big data in Municipal Waste Management is to provide local governments with tools that would facilitate the implementation of systems to more efficiently manage how much, where and the growth rate of the material that the community dispossess. Optimizing the waste management systems can help minimize the environmental impact of the community's actions, reduce pollution, increase rates of recycled materials, optimize routes to reduce time and expenses, among others. By using Big data, local governments can also track the number and quantity or weight of disposals at different locations; this information can be mapped to reveal the locations of the most significant waste generators. This information will help entities develop specific strategies to reduce waste and help implement permanent solutions for better environments. Waste Management is not only government issue. Citizens should take the initiative and educate others on how to recycle and reduce waste. With the help of the collected data, governments can notify the different entities (individuals, communities, companies and other organizations) a equip them through education and awareness, and also share valuable information about the importance of waste management through different media, such as mobile phones, email, among others. Local governments have just started to adopt Big Data technologies for solving problems involved in MSW, but there is plenty of room for growth and further use and development. By using Big Data Analytics, large amounts of data sets pertaining to specific communities waste, routes, and disposal can be used to identify trends and patterns that could highlight opportunities for improvement. Big Data can play a significant role in managing cities more efficiently, benefiting not only those managing the systems, but the commutes in which they are implemented as well.

## ACKNOWLEDGMENTS

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

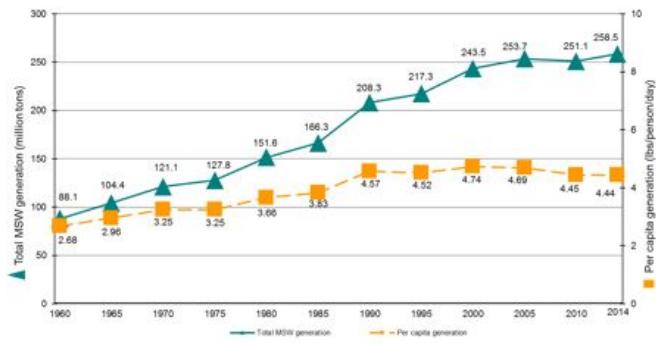
## REFERENCES

- [1] Mohsen Akbarpour Shirazi, Reza Samieifard, Mohammad Ali Abduli, and Babak Omidvar. 2016. Mathematical modeling in municipal solid waste management: case study of Tehran. *Journal of Environmental Health Science and Engineering* 14, 1 (18 May 2016), 8. <https://doi.org/10.1186/s40201-016-0250-2>
- [2] Jeroen Belin, Liesje De Boeck, and Jonas Van Ackere. 2012. Municipal Solid Waste Collection and Management Problems: A Literature Review. *HUB RESEARCH PAPERS 2011/34 ECONOMICS & MANAGEMENT* 48, 34 (11 2012), 1–5.
- [3] V. N. Bhat. 1996. A model for the optimal allocation of trucks for solid waste management. *A model for the optimal allocation of trucks for solid waste management*. 14 (1996), 87–96.
- [4] K. Bofkham, E. Smidt, and J. Tintner. 2013. Application of Multivariate Data Analyses in Waste Management. In *Multivariate Analysis in Management, Engineering*

- and the Sciences*, Leandro Valim de Freitas and Ana Paula Barbosa Rodrigues de Freitas (Eds.). InTech, Rijeka, Chapter 02, 15–16. <https://doi.org/10.5772/53975>
- [5] Frank E. Celli. 2016. Data analytics: The most effective approach for a zero waste solution. WasteDive. (09 2016). <http://www.wastedive.com/news/data-analytics-the-most-effective-approach-for-a-zero-waste-solution/425424/>
  - [6] R. Chandrappa and J. Brown. 2012. *Solid Waste Management: Principles and Practice*. Springer Berlin Heidelberg, Berlin. 47–63 pages. <https://books.google.com/books?id=kUOwuAAACAAJ>
  - [7] G. B. Dantzig and J. H. Ramser. 1959. The Truck Dispatching Problem. *Management Science* 6, 1 (10 1959), 80–91.
  - [8] EPA. 2007. METHODOLOGY FOR ESTIMATING MUNICIPAL SOLID WASTE RECYCLING BENEFITS. epa.gov. (11 2007). <https://www.epa.gov/sites/production/files/2015-09/documents/06benefits.pdf>
  - [9] EPA. 2014. Advancing Sustainable Materials Management: Facts and Figures. U.S. Environmental Protection Agency. (2014). <https://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures#Materials>
  - [10] Maurizio Faccio, Alessandro Persona, and Giorgia Zanin. 2011. Waste collection multi objective model with real time traceability data. *Waste management (New York, N.Y.)* 31, 12 (08 2011), 2391–405. <https://www.ncbi.nlm.nih.gov/pubmed/21821406>
  - [11] Megan Greenwalt. 2017. What the Growth of Big Data Means for Waste & Recycling. FLEETS & TECHNOLOGY. (03 2017). <http://www.waste360.com/fleets-technology/what-growth-big-data-means-waste-recycling>
  - [12] Vijay Hanagandi. 2013. A New Paradigm to Solving Vehicle Routing Problems. (09 2013). <https://osiblogdotcom.wordpress.com/2013/09/23/a-new-paradigm-to-solving-vehicle-routing-problems/>
  - [13] Geir Hasle, Knut-Andreas Lie, and Ewald Quak. 2007. *Geometric modelling, numerical simulation, and optimization: Applied mathematics at SINTEF*. Springer, Berlin, Heidelberg, Oslo,Norway.
  - [14] A.J.G. Hey, S. Tansley, and K.M. Tolle. 2009. *The Fourth Paradigm: Data-intensive Scientific Discovery*. Microsoft Research, REDMOND, WASHINGTON. [https://books.google.com.my/books?id=oGs\\_AQAIAAAJ](https://books.google.com.my/books?id=oGs_AQAIAAAJ)
  - [15] Perinaz Hoornweg, Daniel, Bhada-Tata. 2012. *A Global Review of Solid Waste Management*. Number 15 in Urban Development Series. World Bank, Washington, DC, Urban Development & Local Government Unit World Bank 1818 H Street, NW Washington, DC 20433 USA. <https://openknowledge.worldbank.org/handle/10986/17388>
  - [16] James Kobielsus. 2012. Reuse, Recycle, Compost: A New Level of Insight into Garbage. Robert Reed, Evangelist at Recology, zerowasteIBM. (06 2012). <http://www.ibmbigdatahub.com/blog/reuse-recycle-compost-new-level-insight-garbage>
  - [17] Cole Rosengren. 2017. San Francisco expands recycling list, shrinks refuse carts on 'zero waste' crusade. WasteDIVE. (10 2017). <http://www.wastedive.com/news/san-francisco-expands-recycling-list-shrinks-refuse-carts-on-zero-waste/506700/>
  - [18] Hossein Shahroknii, Bram Van der Heijde, David Lazarevic, and Nils Brandt. 2014. Big data GIS analytics towards efficient waste management in Stockholm. In *Proceedings of the 2014 conference ICT for Sustainability*. Atlantis Press, Proceedings of the 2014 conference ICT for Sustainability, Department of Sustainable Development, Environmental Science and Engineering, Industrial EcologyRoyal Institute of TechnologyStockholm, Sweden, 140–147.
  - [19] Mark van Rijmenam. 2016. *How Big Data Shapes Urban Waste Management Services in Manchester*. techreport. University of Technology, Sydney. <https://datafloq.com/read/how-big-data-shapes-urban-waste-management-service/662>
  - [20] wikipedia. 2017. Vehicle routing problem. wikipedia. (2017). [https://en.wikipedia.org/wiki/Vehicle\\_routing\\_problem](https://en.wikipedia.org/wiki/Vehicle_routing_problem)
  - [21] Vitthal Yenkar and Mahip Bartere. 2014. Review on fData Mining with Big Dataf. *International Journal of Computer Science and Mobile Computing* 3, 4 (2014), 97–102.

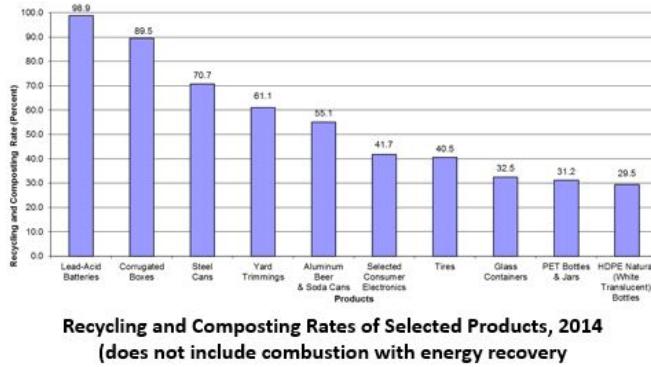
#### LIST OF FIGURES

1	MSW Generation Rates in US from 1960 to 2014	7
2	Recycling and Composting Rates of Selected products in US, 2014	7
3	MSW Recycling and Composting Rates in US from 1960 to 2014	7
4	Total MSW generation in US, 2014	8
5	Choropleth of all waste, aggregated per zip code and normalized to population in Stockholm	8
6	Vehicle Routing Problem	9
7	Number of Landfills in the US 1988-2009	9

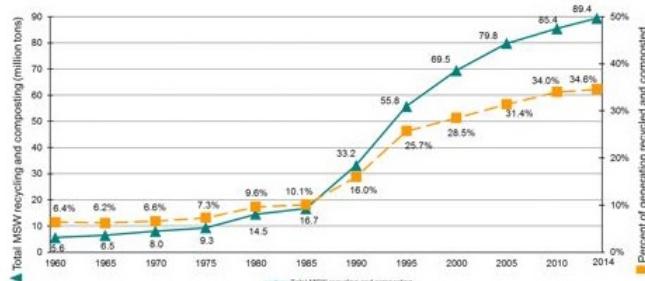


**MSW Generation Rates 1960 to 2014**

**Figure 1: MSW Generation Rates in US from 1960 to 2014**

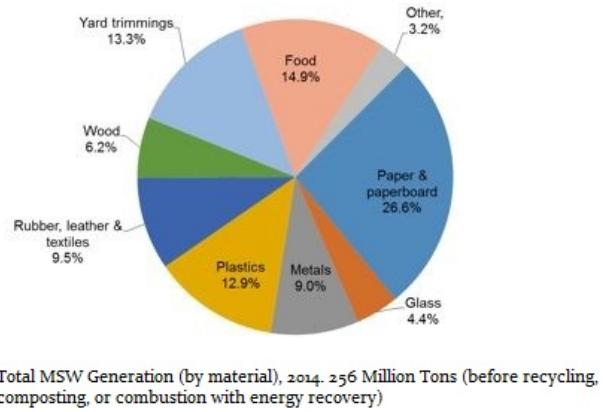


**Figure 2: Recycling and Composting Rates of Selected products in US, 2014**

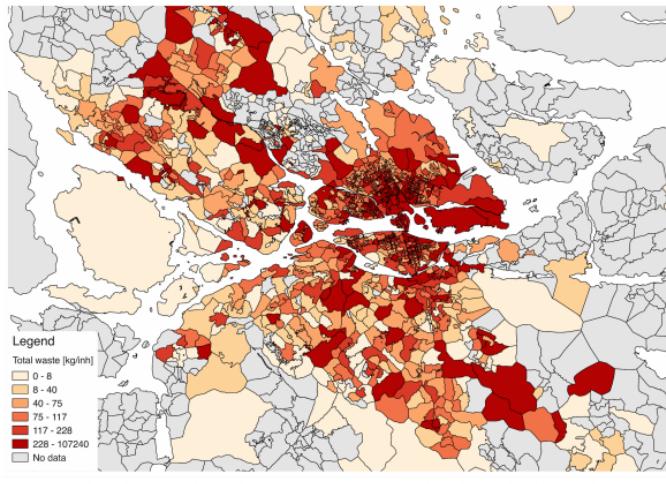


**MSW Recycling and Composting Rates, 1960 to 2014**

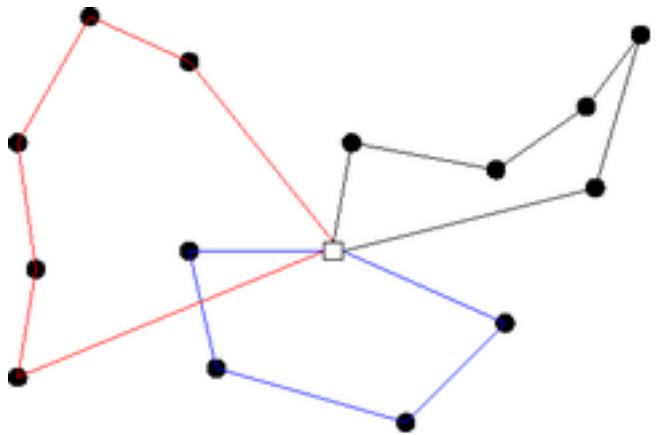
**Figure 3: MSW Recycling and Composting Rates in US from 1960 to 2014**



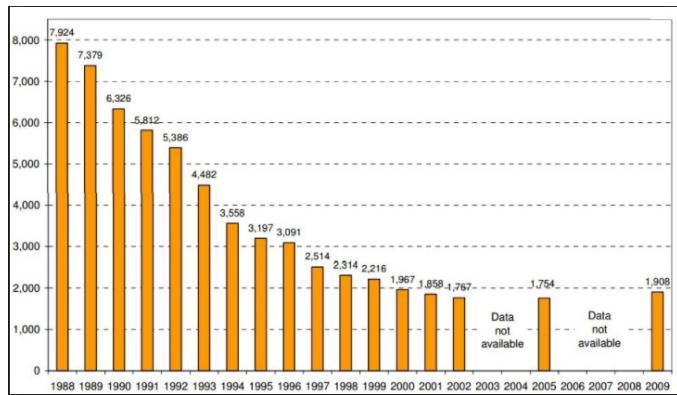
**Figure 4: Total MSW generation in US, 2014**



**Figure 5: Choropleth of all waste, aggregated per zip code and normalized to population in Stockholm**



**Figure 6: Vehicle Routing Problem**



**Figure 7: Number of Landfills in the US 1988-2009**

# Automated Diagnostic Code Extraction in Electronic Medical Records

Nicholas J Hotz  
Indiana University  
nhotz@iu.edu

## ABSTRACT

Electronic medical records (EMRs) play an increasingly important role in healthcare. However, the rapidly growing volume of text in EMRs creates challenges for information extraction (IE). As such, many research institutions are developing computer-based systems to automate EMR structured IE. This paper investigates the processes, the challenges, and the current state of automated IE of EMRs with a specific focus on automated systems that extract ICD9 codes from clinical text. While automated system performance has caught up to the accuracy of manual coding under specific circumstances, automated code extraction remains mostly an academic exercise. To extract value from their work, researchers should shift their focus away from highly specialized algorithms that work in isolation and instead collaborate with industry to develop augmented intelligence systems that help make coding professionals more effective.

## KEYWORDS

Natural Language Processing, Medical NLP, Clinical NLP, Information Extraction, Clinical Coding, Healthcare Big Data

## 1 INTRODUCTION

Demand for structured health data continues to grow [20], and the adoption of electronic health records (EMRs) generates new opportunities to improve clinical care, administrative processes, clinical workflows, and patient outcomes through higher quality, more accurate, more consistent, and more easily accessible documentation [14] [17].

However, the size, growth, and textual nature of EMRs render traditional software and hardware unable to effectively manage healthcare big data [18]. 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 [5]. The volume of healthcare data is doubling every 12-14 months [7], and the diversity of this data further complicates its analysis [10]. Much of it is stored in narrative form which describe patients, their own and their family's medical history, their personal lifestyle, and their current medical conditions [14]. Although convenient for documentation, narrative text is difficult for computer systems to interpret as coded data that can support research, provide clinical knowledge and performance information, and improve patient outcomes [14] [20].

Commonly studied clinical NLP problems include de-identification [23], the development of patient problem summaries [8], and diagnostic code extraction [15]. This paper focuses on diagnostic code extraction which is the process of converting EMR clinical narratives into appropriate medical codes such as ICD9 (the standard medical diagnostic hierarchical taxonomy system in the United

States until September 30, 2015). Perotte et al. describe that both the ICD9 and the more recently adopted ICD10 taxonomies as "organized in a rooted tree structure, with edges representing is-a relationships between parents and children" [15]. Kavauluru et al. explain that the ICD9 and ICD10 leaf nodes are codes that provide specific information used for "billing and reimbursement, quality control, epidemiological studies, and cohort identification for clinical trials" [12].

Currently, coding professionals and clinicians manually extract diagnostic codes from EMRs which is expensive, inefficient, and has become increasingly complex due to various factors including the expansion of payment systems, new reporting requirements, increased oversight and regulation, and the increased volume of EMR data [1] [17] [20] [23]. This complexity limits manual coding accuracy. Manual coders often disagree [16] and are more specific than sensitive in their code assignments [3]. Errors are prevalent; for example, a Swedish study of 4,200 patient records found errors in 20% of the main diagnoses [23]. Over-coding can lead to fraud if healthcare providers bill for services not rendered while under-coding prevents providers from earning reimbursements for valid conditions and services [15].

Since the 1990s, researchers have tried to improve the coding processes through automated coding and classification technologies [11]. Stanfill et al. in their comprehensive literature review in 2010 describe these automated coding systems as "a variety of computer-based approaches that transform narrative text in clinical records into structured text, which may include assignment of codes from standard terminologies, without human interaction". They cite that the American Health Information Management Association asserted in 2004 that, "The industry needs automated solutions to allow the coding process to become more productive, efficient, accurate, and consistent". Yet, Stanfill et al. conclude that the relative performance of automated systems to manual coding is not yet known [20]. As of 2008 and still in 2015, automated systems are still mostly used for research purposes with few applications in use by practitioners [14] [23].

## 2 EMR INFORMATION EXTRACTION CHALLENGES

Several challenges have slowed the development of clinical text NLP applications, which lag behind NLP applications in other fields [4]. Meystre, et al attribute the lack of shareable clinical data as the biggest challenge [14]. Large annotated corpora are needed to develop effective machine learning algorithms that can classify roughly 17,000 possible ICD-9 codes and 68,000 ICD-10 codes whose frequency distributions are highly skewed [2]. However, clinical information needs to be de-identified (which itself is a challenging problem) in order to comply with privacy concerns and regulations

such the USA's Health Information Portability and Protection Act (HIPAA) and the European Union's General Data Protection Regulation (GDPR); as a consequence, large corpora typically remain siloed within individual healthcare systems and are rarely available for outsiders [14] [20].

As a related problem, even when corpora are available, the annotation process is time-consuming, expensive, and traditionally relies on domain experts and linguists [14] [23]. Given the highly specific sublanguages of clinical text, general NLP systems perform poorly on cross-domain clinical texts without these comprehensive annotated corpora. Consequently, much of the development in clinical text NLP occur in siloes and is not used outside of the laboratory in which they were developed [4].

In addition to the lack of shared annotated corpora, Meystre et al. present four challenges that hinder the development of effective clinical text IE. First, clinical narratives contain ungrammatical phrases with short-hand abbreviations and acronyms. About a third of these short-hand texts are overloaded (a single unit may have multiple meanings) which can be challenging for human interpretation and even more challenging for computer interpretation. Second, the rate of misspellings is around 10% [19], which is higher than most texts is difficult for many NLP techniques. Third, clinical texts often contain long series of non-text information, such as laboratory test results, which makes sentence segmentation difficult. Forth, institution-specific pre-formatted templates that appear in clinical texts are difficult for interpretation and their meanings do not transfer to other institutions' information [14]. Chapman et al. discuss additional challenges including the inadequacy of de-identification algorithms, the lack of focus for NLP in non-English clinical texts, and the absence of common clinical standards [4].

Fortunately, recent progress is promising as explained in literature reviews by Delanis et al (2014) and Velupillai et al (2015). These publications praise the clinical NLP community for overcoming many of these hurdles by providing more annotated corpora, developing more advanced NLP tools specific to clinical text, leveraging partially-automated processes to facilitate the annotation of corpora, and focusing on multiple languages [6] [23].

### 3 EMR PRE-PROCESSING

To convert text to medical codes, clinical text flows through various pre-processing and context feature detection techniques. General pre-processing NLP tools are being adopted and specialized for medical texts including:

- **Language Detection:** Multi-lingual studies may start with language detection algorithms, although some might still rely on manual detection [8].
- **Spell checking:** Clinical NLP spell checking uses standard dictionaries and medical-specific tools such as unified medical language system (UMLS) and WordNet [14].
- **Word sense disambiguation:** WSD allows the system to identify the correct meaning of a word that has multiple definitions; however this process is not as accurate with clinical texts as with general English (about 90% for general English and 80% for clinical text) [14].

- **Tokenization and sentence-splitting:** Tokenization is the process for breaking text into tokens such as words, phrases, or symbols [8] [21].
- **Part-of-speech tagging:** Also known as lexical analysis, POS tagging identifies a word's part of speech and its relationship with other words in a sentence [8] [14].
- **Parsers:** Parsers identify the sentence syntax, word dependencies, and expressions of interest [8] [14].

Context feature detection and analysis happen concurrently or following the above steps and identify how words and concepts are used in the context of the sentence. Clinical NLP systems often use a set of regular expressions and algorithms such as NegEx, NegExpander, TimeText, and ConText to define feature context. Notable contexts are negation (e.g. patient *does not* have a condition), speculative (e.g. patient *might have* a condition) temporality (e.g. to identify if the patient *has* or *had* a condition), subject identification (e.g. to identify if the condition belongs to the patient or someone else such as a family member), and severity (such as mild, moderate, or severe conditions) [14] [23].

### 4 REVIEW OF AUTOMATED ICD9 CODE EXTRACTION EFFECTIVENESS

To evaluate the effectiveness of automated systems, studies compare evaluation metrics against standards. Per Stanfill et al.'s literature review of 113 studies, 43% of studies use the gold standard comparison which uses two or more independent reviewers with an adjudication process for disagreements, and 51% use the regular practice standard of one reviewer [20]. Although considered more reliable, gold standards are still prone to error [15]. The most commonly reported metrics include recall or sensitivity (69%), PPV or precision (46%), specificity (43%), and accuracy (25%) [20].

Most studies focus only on a specific subset of clinical texts or diagnoses such as subdomains like radiology [17], for specific diagnoses like congestive heart failure [9] or cancer [13], or to extract only attributes of patients like smoking status [22]. Although many of these studies achieve accuracy metrics comparable or even exceeding gold standards, their results are not generalizable for more comprehensive or practical purposes in the field [20].

However, two recent studies attempt to comprehensively extract ICD9 codes from large EMR sets. In 2013, Perotte et al. attempted to extract ICD9 codes from the clinical text of Multiparameter Intelligent Monitoring in Intensive Care II (MIMIC II), a publicly available database containing de-identified records of 40,000 ICU hospital admissions. They split the 22,815 discharge summaries, which contain 215,826 ICD9 codes (5030 distinct) into 20,533 training documents and 2,282 testing documents. Using a hierarchy support vector machine (SVM) classifier, they achieved an F-measure of 39.5% with a 30.0% recall and 57.7% precision. They also attempted a flat SVM which returned a 27.6% F-measure with 16.4% recall but with a higher precision (86.7%) [15].

Similarly, in 2015 Kavuluru et al. developed automated coding systems with 71,463 in-patient EMRs from the University of Kentucky Medical Center. They conclude that the best-performing automated coding method depends on the size and characteristics of the dataset. For smaller narratives in subdomains such as radiology or pathology, chain classifiers perform best because codes are

highly related to each other. However, feature and data selection methods perform best with more comprehensive in-patient EMRs. Meanwhile, "for large EMR datasets, the binary relevance approach with learning-to-rank based code reranking offers the best performance". They reported a micro F score of 0.48 with codes that occur at least 50 times and a score of 0.54 for codes that occur in at least 1% of records [12].

## 5 OUTLOOK

Researchers are increasingly studying clinical NLP and diagnostic code extraction. However, the output of most research is limited to specific circumstances and has not yet been applied to practical use cases that improve the accuracy and efficiency of medical coding processes. Rather, the research community seems to evaluate its work in terms of algorithm accuracy metrics in their specific strength zones relative to the performance of human coders. Cross-domain medical coding studies are a step in the right direction toward a more practical approach which begins to mimic the reality faced by human coders.

However, the clinical NLP researchers should take this progress further, and collaborate with software engineers, HCI design specialists, business analysts, medical coders, and clinicians to develop practical augmented intelligence systems. These systems, which can include semi-automated recommendation and auditing support software solutions, can aid medical coding professionals in actual workflows to extract diagnostic codes from medical text. A workflow that leverages the strengths of algorithmic systems to shore up areas of human coder weaknesses can optimize medical coding efficiency and accuracy.

## REFERENCES

- [1] 2013. Automated Coding Workflow and CAC Practice Guidance (2013 update). (11 2013). <http://bok.ahima.org/PB/CACGuidance#WchAZMiGOUL>
- [2] Stefan BERNDORFER and Aron Henriksson. 2017. Automated Diagnosis Coding with Combined Text Representations. *Informatics for Health: Connected Citizen-Led Wellness and Population Health* 235 (2017), 201.
- [3] Elena Birman-Deych, Amy D Waterman, Yan Yan, David S Nilasena, Martha J Radford, and Brian F Gage. 2005. Accuracy of ICD-9-CM codes for identifying cardiovascular and stroke risk factors. *Medical care* 43, 5 (2005), 480–485.
- [4] Wendy W Chapman, Prakash M Nadkarni, Lynette Hirschman, Leonard W D'avolio, Guergana K Savova, and Ozlem Uzuner. 2011. Overcoming barriers to NLP for clinical text: the role of shared tasks and the need for additional creative solutions. (2011).
- [5] 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. *Institute for Health Technology Transformation*, <http://ihealthtran.com/big-data-in-healthcare> (2013).
- [6] Hercules Dalianis, Aurélie Névéol, Guergana Savova, and Pierre Zweigenbaum. 2014. Didactic Panel: clinical Natural Language Processing in Languages Other Than English. In *AMIA Annual Symposium 2014*. American Medical Informatics Association, S–84.
- [7] Ivo D Dinov. 2016. Volume and value of big healthcare data. *Journal of medical statistics and informatics* 4 (2016).
- [8] Crescenzo Diomauta, Maria Mercorella, Mario Ciampi, and Giuseppe De Pietro. 2017. A novel system for the automatic extraction of a patient problem summary. In *Computers and Communications (ISCC), 2017 IEEE Symposium on*. IEEE, 182–186.
- [9] Jeff Friedlin and Clement J McDonald. 2006. A natural language processing system to extract and code concepts relating to congestive heart failure from chest radiology reports. In *AMIA annual symposium proceedings*, Vol. 2006. American Medical Informatics Association, 269.
- [10] Sullivan Frost. 2015. Drowning in big data? reducing information technology complexities and costs for healthcare organizations. (2015).
- [11] Ramakanth Kavuluru, Sifei Han, and Daniel Harris. 2013. Unsupervised extraction of diagnosis codes from EMRs using knowledge-based and extractive text summarization techniques. In *Canadian Conference on Artificial Intelligence*. Springer, 77–88.
- [12] Ramakanth Kavuluru, Anthony Rios, and Yuan Lu. 2015. An empirical evaluation of supervised learning approaches in assigning diagnosis codes to electronic medical records. *Artificial intelligence in medicine* 65, 2 (2015), 155–166.
- [13] Burke W Mamlin, Daniel T Heinze, and Clement J McDonald. 2003. Automated extraction and normalization of findings from cancer-related free-text radiology reports. In *AMIA Annual Symposium Proceedings*, Vol. 2003. American Medical Informatics Association, 420.
- [14] Stéphane M Meystre, Guergana K Savova, Karin C Kipper-Schuler, John F Hurdle, et al. 2008. Extracting information from textual documents in the electronic health record: a review of recent research. *Yearb Med Inform* 35, 128 (2008), 44.
- [15] Adler Perotte, Rimma Pivovarov, Karthik Natarajan, Nicole Weiskopf, Frank Wood, and Noémie Elhadad. 2013. Diagnosis code assignment: models and evaluation metrics. *Journal of the American Medical Informatics Association* 21, 2 (2013), 231–237.
- [16] John P Pestian, Christopher Brew, Paweł Matykievicz, Dj J Hovermale, Neil Johnson, K Bretonnel Cohen, and Włodzisław Duch. 2007. A shared task involving multi-label classification of clinical free text. In *Proceedings of the Workshop on BioNLP 2007: Biological, Translational, and Clinical Language Processing*. Association for Computational Linguistics, 97–104.
- [17] Ewoud Pons, Loes MM Braun, MG Myriam Hunink, and Jan A Kors. 2016. Natural language processing in radiology: a systematic review. *Radiology* 279, 2 (2016), 329–343.
- [18] Wullianallur Raghupathi and Viju Raghupathi. 2014. Big data analytics in healthcare: promise and potential. *Health information science and systems* 2, 1 (2014), 3.
- [19] Patrick Ruch, Robert Baud, and Antoine Geissbühler. 2003. Using lexical disambiguation and named-entity recognition to improve spelling correction in the electronic patient record. *Artificial intelligence in medicine* 29, 1 (2003), 169–184.
- [20] Mary H Stanfill, Margaret Williams, Susan H Fenton, Robert A Jenders, and William R Hersh. 2010. A systematic literature review of automated clinical coding and classification systems. *Journal of the American Medical Informatics Association* 17, 6 (2010), 646–651.
- [21] Katrin Tomanek, Joachim Wermter, and Udo Hahn. 2007. Sentence and token splitting based on conditional random fields. In *Proceedings of the 10th Conference of the Pacific Association for Computational Linguistics*. 49–57.
- [22] Özlem Uzuner, Ira Goldstein, Yuan Luo, and Isaac Kohane. 2008. Identifying patient smoking status from medical discharge records. *Journal of the American Medical Informatics Association* 15, 1 (2008), 14–24.
- [23] Sumithra Velupillai, D Mowery, Brett R South, Maria Kvist, and Hercules Dalianis. 2015. Recent advances in clinical natural language processing in support of semantic analysis. *Yearbook of medical informatics* 10, 1 (2015), 183.

# My great Big Dat Paper

Ben Trovato  
Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
trovato@corporation.com

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

i523

## 1 INTRODUCTION

The *proceedings* are the records of a conference. ACM seeks to give these conference by-products a uniform, high-quality appearance. To do this, ACM has some rigid requirements for the format of the proceedings documents: there is a specified format (balanced double columns), a specified set of fonts (Arial or Helvetica and Times Roman) in certain specified sizes, a specified live area, centered on the page, specified size of margins, specified column width and gutter size [? ].

## ACKNOWLEDGMENTS

The authors would like to thank

## REFERENCES

# An Overview of Big Data Applications in Mental Health Treatment

Neil Eliason

Indiana University Online

Anderson, Indiana 46012

nreliaso@iu.edu

## ABSTRACT

Mental health treatment presents with complex informational challenges, which could be effectively tackled with big data techniques. However, as researchers and treatment providers explore these applications, they find a lack of infrastructure and ethical concerns hamper their progress. A unified approach of developing an ethically informed data infrastructure is necessary to proceed.

## KEYWORDS

i523, Mental Health Treatment, Big Data, Data Analytics, Data Infrastructure, Data Ethics

## 1 INTRODUCTION

### 1.1 Big Data

There is no immutable or standardized definition of big data. However, most conceptualizations include data with high volume (amount of data stored), velocity (frequency of data input or update), and/or variety (number of data sources or types), known as the “three v’s”. As these factors increase, they reach the so called “three v tipping point”, where traditional methods of analysis do not meet operational needs. Here, big data analytic techniques are utilized to make these unruly collections of data useful. For example, text mining, audio analytics, video analytics, and social media analytics are specific techniques used to make low value data more organized, condensed, and useful. Then predictive analytics take this processed data, and create data models which can predict future outcomes. These can be divided into regression techniques, which identify ways groups rely on each other, and machine learning techniques, which look for patterns in validated test data and then apply them to an unvalidated sample [3].

### 1.2 Mental Health Treatment

Mental health difficulties are a common problem across the United States, and worldwide. Mental illness of some kind was prevalent among 17.9 % of Americans in 2015, and of that number 4% experienced serious functional impairment as a result [14]. A 2014 meta-analysis study estimated that the worldwide prevalence of mental illness was 17.6% and that 29.2% of the world population would experience mental illness at some point during their life [18]. The effects of these disorders on individuals and societies is costly. The US Center for Disease Control and Prevention estimated that 36,035 people died during a suicide attempt in 2008, and that 666,000 sought emergency room care for self harming behavior [2]. In 2013, the Social Security Administration reported that 1,947,775 persons received social security/disability benefits for either a mood or psychotic disorder, which is around 19% of all recipients [16]. It

is estimated that mental health issues had a \$100 billion cost on the US economy in 2002 [14], and in 2015 there were over 12,000 mental health treatment facilities in the US [20].

Mental health treatment attempts to address these pervasive and complex problems at an individual level. While this by nature results in a system that is heterogeneous and complex, treatment still follows a fairly consistent pattern. First the mental health issue is identified [1], then treatment interventions are assigned [21], and finally treatment progress is monitored [4].

The identification process involves mental health screening and assessment. Screening attempts to identify a person’s primary mental health risks and needs for the purpose of directing them to appropriate sources. They tend to be narrow in focus and brief, which allows them to be easily disseminated to help filter people to the right level of care. Similar to screening, assessment aims to identify a person’s mental health dysfunction, but does so in more clinically robust categories, typically resulting in a diagnosis [1]. Once a person’s mental health issues have been clinically identified, then interventions are assigned. Those traditionally take the form of talk-therapy to develop effective change strategies, medication to reduce symptoms of mental illness, and supportive services such as case management to help coordinate efforts towards the person’s goals [21]. Treatment monitoring is essential to the treatment lifecycle, as this is where clinicians receive feedback regarding the effectiveness of the chosen interventions. While it is natural for clinicians to do this informally, more intentional methods are often overlooked [4]. This process requires an extensive data gathering effort, which traditionally is labor intensive and requires a large team of clinicians.

### 1.3 Thesis

There are large numbers of people struggling with mental illness, and their treatment requires large amounts of frequent data from various sources. This process as traditionally done is inefficient and labor intensive. Big data analytic techniques are designed to target this kind of data, and could greatly increase treatment effectiveness and scope.

## 2 BIG DATA APPLICATIONS IN MENTAL HEALTH TREATMENT

### 2.1 Screening and Diagnosis

Mental health screening is the first chance to direct people in the appropriate direction to meet their mental health needs. Methods that can screen larger amounts of people effectively are critical, as many people with mental illness are not connected with treatment. Several studies explored using social media to identify mental illness in the general population, and demonstrated potential to identify

issues on a large scale. Many attempted to identify depression by analyzing the content of social media posts, and to create a predictive model which would predict variables of interest from dependent variables. By using public data from Twitter or mental health forums large sample sizes were possible, but also resulted in less reliable data. It is estimated that the ability to detect depression by machine driven predictive models running on big social media data was above that of unaided primary care clinicians, but below that of self-report surveys. [5].

Clinical assessment and diagnostic assignment follows screening. There is considerable interest in developing more effective diagnostic assessment using big data analytics. Models were created using techniques such as data mining, machine learning, and natural language processing to group people into diagnostic categories based on data from a variety of sources. [12]. In bipolar research, machine learning algorithms looked for patterns in neuroimaging, genetic analysis, neuropsychological tests, and protein biomarkers. They were able to create predictive models, but their performance was not greater than current diagnostic systems. While this task could not be completely automated via big data analytics any time soon, it may inform clinical diagnosis in the short-term [8].

Predictive models using machine learning techniques are also being constructed from a variety of data sources to estimate patient outcomes, which could be helpful in selection of interventions at the onset of treatment. [12] Predictive risk profiles for patient's with bipolar disorder were created by taking data from Electronic Medical Records and identifying patient characteristics connected to negative outcomes, such as relapse and hospital admission. Studies also explored models which predict patient mood states, based on past monitoring data and how patients will respond to specific interventions. While these examples were fairly accurate (68% to 99%), they were based on relatively small sample sizes [8]. Predictive models show promise of being an effective big data application in mental health treatment, but require further advances in machine learning techniques and validated on larger samples before they can be widely administered [12].

## 2.2 Interventions

Once a person's mental health issues have been clinically identified, then interventions are assigned. Traditional interventions are clinician driven, and are often limited in scope by clinician availability. Web-based interventions, which provide treatment activities via web-browser, have the potential to provide more flexible treatment options for patients. Initial attempts have seen some success, particularly if paired with a human coach. Few estimates of effectiveness exist, as these techniques have not been applied to large groups [10]. While big data approaches are not widely utilized, there is interest in using machine learning to predict content that a particular user would find helpful [11], which is a technique called a recommender system [17]. Also, as interactive interfaces are developed and used by large numbers of online users [10], big data analytics would be beneficial.

## 2.3 Treatment Monitoring

As a person receives treatment, tracking progress towards their goals is critical. Traditionally this is done by patient report via a

tracking log or by clinician inquiry during a session, and is often hindered by a lack of patient engagement. One solution to this is active monitoring utilizing mobile devices. Utilizing text message or application notifications, treatment goal reminders, symptom assessment questions, or encouraging messages are sent to the treatment participant [11]. Feedback from the patient can come in various forms from filling out a survey to voice response, and may be collected multiple times a day. The frequent collection of different types of data make active monitoring an application which could benefit from a big data approach. However, trouble with integrating data into the electronic medical record and a lack of widespread utilization have prevented such approaches from being extensively applied or reliably tested [12].

Another possibility is passive monitoring, which would access information from a mobile device, and connect those to patient behaviors, without any intentional action on the patient's part. This has been done using clinically informed algorithms or machine learning paired with self-report [11]. Devices used were not just smartphones, but including wearables and a sensor which is swallowed to detect medication adherence. Active monitoring has generated considerable research interest, but implementation at a big data level is challenged by lack of client engagement, clinician's ability to use, and difficulties integrating the large quantities and varieties of data [12].

## 3 DISCUSSION

### 3.1 Barriers

Overall, there is considerable interest in developing big data applications at every stage of the mental health process. However, this development has been slow and halting due to a number of issues inherent though not necessarily unique to human services.

For example, the issue of privacy is relevant with many big data applications, but in mental health the sensitive nature of an individual's mental health treatment data creates new difficulties. Typically privacy is preserved through de-identification of the data, but this is not always effective with large-scale data [12]. A specific privacy risk is big data analysis of social media, which captures large amounts of information, which can be used to infer mental health status [5]. When mental health privacy is breached, discrimination regarding employment, insurance, housing, etc. are possible [12]. On the other side of the privacy question, mental health professionals are mandated to report if someone is an imminent risk to themselves or others. Currently, there are no clear guidelines to follow, if this is discovered through public data [5].

Another challenge to capitalizing on big data is the variety of data sources, formats, and storage locations. The vast majority of mobile devices are not run on open source software, as they are sold as commercial products. This hinders collaboration and integration of the data with sources from other companies' products [13]. It is also unclear who owns the data in these situations, causing more disruption [12]. This is not just the case with private data. Large databases and research institutions often struggle to share data, and the decision to do so is often up to the individual researchers. This prevents the collaboration and coordination required to make good use of the available big data opportunities [6].

### 3.2 Future Directions

Considerable attention is being given to big data applications in mental health treatment, and some major initiatives seek to address some of the technical issues mentioned previously. The National Institute of Health's Office of Behavioral and Social Sciences Research has a strong focus on big data in its 2017 to 2021 strategic plan. It specifically called for the development of "data infrastructure that promotes data sharing, harmonization, and integration", and also to develop research methods which are designed for "data-rich" science [15]. There is a related call for treatment to inform research questions, and research questions to inform the structure and collection of big data, as opposed to primarily opportunistic research, which studies data that is most convenient [19]. The integration of private commercial data for big data analytics is also a goal of some researchers [13]. Concerning specific technologies, there is generally great optimism that the big data analytics techniques will continue to be refined, and that wider implementation will result in greater strides in treatment effectiveness.

Most of the research reviewed ended with a short description of ethical concerns in big data use for mental health treatment, and a call for someone to look into this in more detail. The problem is that there is a wide variety of perspectives about this topic. Some operate from the assumption that if data is publicly accessible, that resolves any privacy issues. Others point out cases where individual's privacy was seriously compromised by comparing data from multiple public databases [9]. This is a point where public policy has fallen behind technological innovation. An inter-disciplinary effort from legal, data science, and mental health experts may be required to strike the balance between science and citizen security [7].

## 4 CONCLUSION

At every stage, mental health treatment is a data intensive task. As electronic medical records, social media, and mobile devices continue to increase in data collection and storage capabilities, data relevant to mental health continues to grow larger, faster, and more varied. Many researchers and practitioners are eager to use big data analytics to tap into the potential insights of these data sets.

The first steps of development have already started, and show promise of making a significant positive impact in the field. Predictive analytics are being tested to screen for people with mental illness via social media, and machine learning techniques are being applied to improve the resolution of diagnosis and to inform treatment assignments through outcomes prediction. Though these results need replication with larger samples, they already demonstrate predictive power, which could soon equate with improved treatment in practice.

Applications utilizing mobile devices for active and passive monitoring of treatment participants are generating considerable attention, but are only early in development. As this approach is expanded to larger samples, big data analytics will be critical to managing the velocity and variety of data coming from smartphones and wearables. Integrating big data analytics in web-based mental health interventions, is even earlier in development. The potential to create interactive interfaces, utilizing artificial intelligence and

recommender systems is present, but currently web-based treatments are being tested themselves for viability.

While progress to develop algorithms and programs to process mental health big data continues, it is hindered by the current limitations of data infrastructure and research culture. Though large data sources are available, they are not integrated with one another, and are often prevented from doing so due to preferences of individual researchers or from corporate interest. The National Institute of Health and many researchers are calling for an integrated and open data sharing framework to address this issue.

Also of concern is a variety of ethical questions involved in applying big data analytics to mental health. Ownership of data is not well defined, and often data is sold and studied without the knowledge of its subjects. During this process, an individual's privacy may be compromised, even with de-identified data. This can lead to discrimination and stigma for the individual whose mental health data has been unmasked. While this problem is readily recognized, no major policy or legislative change has adequately addressed it.

As big data analytics continues to mature, mental health treatment should seek to benefit from the unlocking of new knowledge and insights. However, this cannot be done without consideration of how to create an environment that simultaneously encourages practice innovation and patient protection. Treatment seeks to provide effective help to those with mental illness, and big data may help with that aim, but to do this at the expense of the patient rights undermines any help they hoped to gain.

## ACKNOWLEDGMENTS

The researcher would like to thank Professor Gregor von Laszewski, along with Teaching Assistants Juliette Zerick, Saber Sheybani Moghadam, and Miao Jiang, and the anonymous reviewers who helped with the present work.

## REFERENCES

- [1] APA Practice Organization. 2017. Distinguishing Between Screening and Assessment for Mental and Behavioral Health Problems. Webpage. (2017). [www.apapracticecentral.org/reimbursement/billing/assessment-screening.aspx](http://www.apapracticecentral.org/reimbursement/billing/assessment-screening.aspx)
- [2] Alex E Crosby, Beth Han, LaVonne A G Ortega, Sharyn E Parks, and Joseph Gfroerer. 2011. Suicidal thoughts and behaviors among adults aged f18 years—United States, 2008–2009. *Morbidity And Mortality Weekly Report. Surveillance Summaries* (Washington, D.C.: 2002) 60, 13 (2011), 1 – 22. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=22012169&site=eds-live&scope=site>
- [3] Amir Gandomi and Murtaza Haider. 2015. Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management* 35, 2 (2015), 137 – 144. <https://doi.org/10.1016/j.ijinfomgt.2014.10.007>
- [4] Jessica D. Goodman, James R. McKay, and Dominick DePhilippis. 2013. Progress monitoring in mental health and addiction treatment: A means of improving care. *Professional Psychology, Research and Practice* 44, 4 (2013), 231. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edsgo&AN=edsgcl.354463723&site=eds-live&scope=site>
- [5] Sharath Chandra Guntuku, David B Yaden, Margaret L Kern, Lyle H Ungar, and Johannes C Eichstaedt. 2017. Detecting depression and mental illness on social media: an integrative review. *Current Opinion in Behavioral Sciences* 18 (2017), 43 – 49. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com.proxyub.uits.iu.edu/login.aspx?direct=true&db=edselp&AN=S2352154617300384&site=eds-live&scope=site>
- [6] Diego Hidalgo-Mazzei, Andrea Murru, Mara Reinares, Eduard Vieta, and Francesc Colom. 2016. Big Data in mental health: a challenging fragmented future. *World Psychiatry: Official Journal Of The World Psychiatric Association (WPA)* 15, 2 (2016), 186 – 187. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=27265716&site=eds-live&scope=site>

- [7] Sharona Hoffman. 2015. CITIZEN SCIENCE: THE LAW AND ETHICS OF PUBLIC ACCESS TO MEDICAL BIG DATA. *Berkeley Technology Law Journal* 30, 3 (2015), 1741 – 1806. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=115393178&site=eds-live&scope=site>
- [8] Diego Librenza-Garcia, Bruno Jaskulski Kotzian, Jessica Yang, Benson Mwangi, Bo Cao, Luiza Nunes Pereira Lima, Mariane Bagatin Bermudez, Manuela Vianna Boeira, Flvio Kapczinski, and Ives Cavalante Passos. 2017. The impact of machine learning techniques in the study of bipolar disorder: A systematic review. *Neuroscience and Biobehavioral Reviews* 80 (2017), 538 – 554. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edelp&AN=S0149763417300337&site=eds-live&scope=site>
- [9] Jacob Metcalf and Kate Crawford. 2016. Where are human subjects in Big Data research? The emerging ethics divide. *Big Data & Society* 3, 1 (2016). 2053951716650211. <https://doi.org/10.1177/2053951716650211> arXiv:<https://doi.org/10.1177/2053951716650211>
- [10] Thomas D. Meyer, Rebecca Casarez, Satyajit S. Mohite, Nikki La Rosa, and M. Sriram Iyengar. 2018. Novel technology as platform for interventions for caregivers and individuals with severe mental health illnesses: A systematic review. *Journal of Affective Disorders* 226, Supplement C (2018), 169 – 177. <https://doi.org/10.1016/j.jad.2017.09.012>
- [11] David C. Mohr, Michelle Nicole Burns, Stephen M. Schueller, Gregory Clarke, and Michael Klinkman. 2013. Behavioral Intervention Technologies: Evidence review and recommendations for future research in mental health. *General Hospital Psychiatry* 35, 4 (2013), 332 – 338. <https://doi.org/10.1016/j.genhosppsych.2013.03.008>
- [12] Scott Monteith, Tasha Glenn, John Geddes, Peter C. Whybrow, and Michael Bauer. 2016. Big data for bipolar disorder. *International Journal of Bipolar Disorders* 4, 1 (11 Apr 2016), 10. <https://doi.org/10.1186/s40345-016-0051-7>
- [13] Andreu Murru, Eduard Vieta, and Frances Colom. 2016. Big Data in mental health: a challenging fragmented future. *World Psychiatry* 15, 2 (2016), 186. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edsoaf&AN=edsoaf.d1b40726336430fcecd614a54ac6d4b079039a17&site=eds-live&scope=site>
- [14] National Institute of Mental Health. 2017. (2017). <https://www.nimh.nih.gov/health/statistics/index.shtml>
- [15] William T Riley. 2017. Behavioral and social sciences at the National Institutes of Health: Methods, measures, and data infrastructures as a scientific priority. *Health Psychology: Official Journal Of The Division Of Health Psychology, American Psychological Association* 36, 1 (2017), 5 – 7. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=28045300&site=eds-live&scope=site>
- [16] Social Security Administration. 2013. (2013). [https://www.ssa.gov/policy/docs/statcomps/di\\_asr/2013/di\\_asr13.pdf](https://www.ssa.gov/policy/docs/statcomps/di_asr/2013/di_asr13.pdf)
- [17] Stanford Info Lab. 2017. Recommendation Systems. webpage. (2017). <http://infolab.stanford.edu/~ullman/mmds/ch9.pdf>
- [18] Z. Steel, C. Marnane, C. Iranpour, Tien Chey, J. W. Jackson, Patel Vikram, and D. Silove. 2014. The global prevalence of common mental disorders: a systematic review and meta-analysis 1980–2013. *International Journal of Epidemiology* 43, 2 (2014), 476 – 493. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=lhh&AN=20143278163&site=eds-live&scope=site>
- [19] Robert Stewart and Katrina Davis. 2016. 'Big data' in mental health research: current status and emerging possibilities. *Social Psychiatry and Psychiatric Epidemiology* 51, 8 (2016), 1055. <http://proxyub.uits.iu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edsgao&AN=edsgcl.460296829&site=eds-live&scope=site>
- [20] Substance Abuse and Mental Health Services Administration. 2015. (2015). [https://www.samhsa.gov/data/sites/default/files/2015\\_National\\_Mental\\_Health\\_Services\\_Survey.pdf](https://www.samhsa.gov/data/sites/default/files/2015_National_Mental_Health_Services_Survey.pdf)
- [21] Substance Abuse and Mental Health Services Administration. 2017. Behavioral Health Treatments and Services. (2017). <https://www.samhsa.gov/treatment>

# Big Data Applications and Analysis in Maternal Death During Childbirth in United States

Elena Kirzhner

Indiana University Bloomington

3209 E 10th St

Bloomington, Indiana 47408

ekirzhne@iu.edu

## ABSTRACT

Maternal mortality rate in the United States had increased by more than 25 percent from 2000 to 2014. Reducing maternal death during childbirth requires in-depth examination of isolated causes of death. With the major growth of big data and applications, it is possible to collect, analyze and compare specific maternal death causes and contributing factors to predict who's susceptible to fatality and what can be done to prevent it. It will help to develop focused clinical and public health prevention programs.

## KEYWORDS

i523, hid320, Big Data Applications and Analytics, Data Science, Maternal Mortality

## 1 INTRODUCTION

Maternity death is rising for unclear reasons in United States. USA is the only developed nation where that rate is increasing and getting worse.

American women are more likely to die from childbirth than women in any other high developed country. Based on research and analysis by the Center for Disease Control and Prevention [1], maternal death greatly increased from 2000-2014 and more than half of such incidents could have been prevented with the current medical technology.

Most of the cases were result of medical error and unprepared hospitals. Doctor's ability to protect the health of mothers in childbirth is a basic measure of a society's development. Yet every year in the United States 700 to 900 women die from pregnancy or childbirth-related causes, and some 65,000 nearly die. By many measures, the worst record in the developed world [17] and [12].

We have ability to prevent it, by analyzing each cause and predict with monitoring the cases and usage of the Big Data and Analytics.

Statistical research for 2010 put America in the 50th place; the lowest of all developed nations for maternal death during childbirth[2]. Figure 1 shows Maternal Mortality ratio by developed countries per 100,000 live births [14].

[Figure 1 about here.]

From 1990 to 2014 pregnancy related death increased by 1.7 percent while worldwide that rate decreased by 1.3 percent. Thus, proper calculation shows that maternity mortality rate practically doubled in the last decade.

Figure 2 shows percent change in maternal deaths per 100,000 live births, from 1990-2013 [13].

[Figure 2 about here.]

Women giving birth in Asia have lower risk to die than those giving birth in United States [17].

Currently, researches are inconclusive, as to why the rate is rising in USA. Multiple variables are being taken into account, such as race and economic status [5].

### 1.1 Definition

According to the National Center for Health Statistics, Pregnancy Mortality Surveillance System and the International Classification of Disease, to properly analyze data, causes of death during child birth were categorized and defined [3] as follows:

1. Pregnancy related death - death during the first 42 days after giving birth that is directly related to pregnancy and health care. Not related to any accidents outside of the pregnancy.

2. Maternal fatality ratio - death caused by pregnancy for every 100,000 pregnancy occurrences.

### 1.2 Monitoring

The National Center for Health Statistics requires all states on annual basis to provide death certificates with causes of maternal death. This data is analyzed and compared against international statistics [11] and [4].

Additionally, Pregnancy Mortality Surveillance System was implemented in 1896, because of limited pregnancy death related records [10]. This system was created to record and analyze all pregnancy related deaths. Every year, this group sends a request to all 50 states to provide death certificate copies for those who died during childbirth and pregnancy. This data is stored and further analyzed by trained doctors, specialists and data scientists. That group coined a new term "pregnancy-related mortality" [3]. This information is being released in Center for Disease Control and Prevention Morbidity and Mortality Weekly reports and their website [16]. Deaths related to pregnancy from 1998-2010 were published in Obstetrics and Gynecology journal [18]. Furthermore, since launching the program, monitoring and analyzing the data, rate has dramatically increased from 7.2 deaths per 100,000 births in 1987 to 17.8 deaths per 100,000 births in 2011 [16]. Figure 3 shows changes in pregnancy related mortality ratio in United States from 1987-2011 [8].

[Figure 3 about here.]

## 2 BIG DATA USAGE AND HOW IT CAN HELP

The maternity deaths cases are well suited for a big data usage and solution. We have large amount of unstructured data. It could be used on advanced level for further examination. The data could be simplified and accessible to everyone including patients and

doctors. However, there are not enough expertise to use it and limited financial resources. On the other hand, some experts say that it is good to have unstructured or raw data, because it was not modified and could add real value to healthcare analytics. It is fresh and ready to be consumed [6].

The causes of maternity death are not yet identified. We have only limited amount of data that was analyzed [5].

Moving forward, we need to understand and organize pregnancy related deaths and causes. Figure out structure and identify risks by race ethnicity, economic status and age. Professional examination and generated analysis of structured and unstructured data could help with preventing causes of pregnancy related death.

## 2.1 Who Is Already Doing It

Over 200 healthcare applications were developed since 2010. Number of healthcare providers have already benefited from big data by concentrating on the fundamental structure of the big data. Few examples below:

Kaiser Permanente adapted new system called HealthConnect, it communicates new data between collected information about patients and treatments. The implemented system have helped to save more than one billion dollars from lowering patients visits to doctor's office [9].

Blue Shield of California adapted NantHealth and improved outcomes between patients and hospitals by communicating information about the visits, patient health history and hospitals. It helped to provide most effective and cheaper treatments for chronic illness with preventive care and communications between doctors and patients [9].

The Lancet Journal done similar study on October 8, 2016 that called "Global, regional, and national levels of maternal mortality, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015" [13]. They used a standardized process to identify, extract and process all relevant data sources. Uniformed algorithms were applied to identify age category, year category, and location specific patterns of failure and hidden records for vital registration, as well as patterns of deaths misrepresentation [15].

## 2.2 Internet Of Things

Big Data and the Internet Of Things is a growing system that allows convergence of physical equipment that transfers data and communicate with other devices and digital networks tearing down silo walls between operational technology and information technology. In conjunction with big data it allows for extraction of valuable information.

It could be used to monitor patient's health and their pregnancy risks such as diabetes level or blood pressure. It could also track prescribed medicine, it is especially useful for patients without health insurances [13].

## 2.3 Predictive Analytics

Many tools are being utilized for predictive analytics usage, such as data mining, statistics and historical facts. It is being used to analyze given information and generate predictions and outcomes for future and unforeseen events. Stored data could be useful, pregnant women's information could be shared between doctors and

hospitals to be diagnosed in advance, improving number of healthy pregnancies. By being able to analyze relevant data, pregnancy risks could be predicted and provide women with safer and better pregnancy outcomes. The more analyzed data we have, the sooner it will reduce the mortality rates and we'll be able to diagnose each case. Special emergency kits with appropriate medicine could be supplied to each hospital and doctor's office for individual patient.

Huge amount of data is being generated daily and it comes from different sources in variety of shapes and sizes. Pregnancy related issues are being collected through social media, forums, blood tests, pharmaceutical companies, doctor visits, ultrasounds, hospitals, emails and so on. Our life became very digital. Currently, every doctor's visit is being recorded digitally, and electronically health records are being stored at health-care insurance departments and hospital facilities. These records are playing important part of research and scientific analysis.

## 2.4 Crunching Big Data

US government is focusing on research and transforming health-care knowledge. Big data software becoming accessible and being developed for efficiency and made it easier to collect and analyze data from different sources. One of the best options for the data analysis is to input it into Hadoop system to make a more scaleable analysis with that. As of today, it is one of the most popular data management option. Additionally, it is one of the largest systems that is being used by many companies. Its ability to handle multiple amount of data from different sources, makes it productive and provides possibility to get more accurate causes and reasons of any health issues. Hadoop system is an open source software for distributed storage of large datasets on computer clusters and visualization. There are two main features; Hadoop Distributed File System, which responsible for files storage, and MapReduce, which generates and processes the data. The primary function of this programs is the capability to process huge amount of unstructured data and print out analyzed information. This system is all about handling the Big Data [7].

## 3 CONCLUSION

Pregnancy-related mortality findings should be studied and cross analyzed with the latest and advanced technology. It will provide a new view and value, resulting clarification and better health management.

Additionally, it will decrease same errors and doctors faults and prevent maternity death and its causes.

All these years, there was not enough information that was structured for deeper understanding and analysis. It can be improved. Big Data massively grows daily, useful information is everywhere around us; including emails, doctor's notes, lab tests, health insurances, ultrasounds, social media and pharmaceuticals .

Latest and fastest platforms such as Hadoop, have the ability to transform and improve the healthcare, store data and analyze huge mass of information from separate sources.

Doctors, medical staff and patients could use that information to improve and achieve better outcomes for pregnant mothers and prevent death. In addition, it will lower medical costs.

## ACKNOWLEDGMENTS

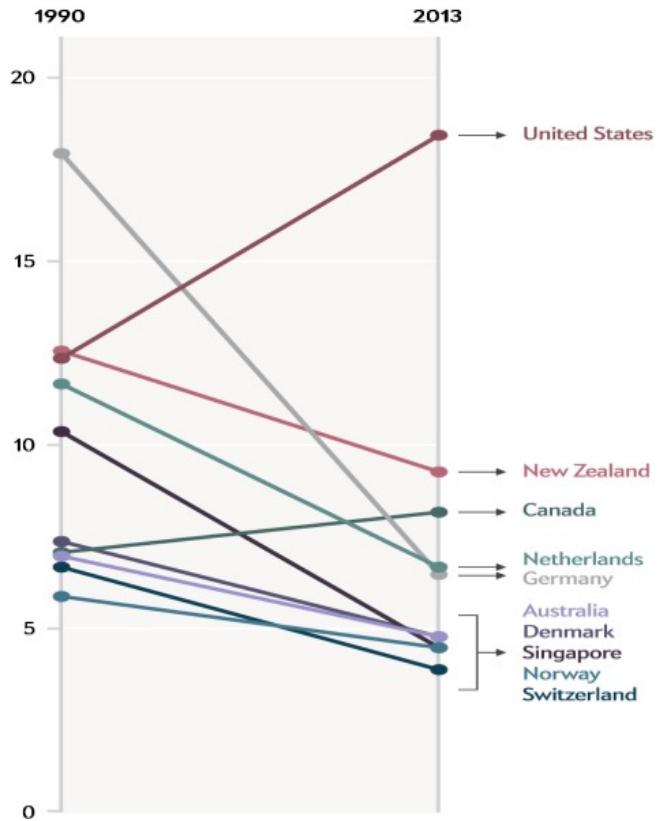
The author would like to thank Dr. Gregor von Laszewski and Miao Jiang for their help, support and suggestions to write this paper.

## REFERENCES

- [1] SJ Bacak, CJ Berg, J Desmarais, E Hutchins, and E Locke. 2006. State maternal mortality review: Accomplishments of nine states. *Atlanta: Centers for Disease Control and Prevention* (2006), 1.
- [2] Debra Bingham, Nan Strauss, and Francine Coeytaux. 2011. Maternal mortality in the United States: a human rights failure. (2011).
- [3] William M Callaghan. 2012. Overview of maternal mortality in the United States. In *Seminars in perinatology*, Vol. 36. Elsevier, 2–6.
- [4] Andreea A Creanga, Cynthia J Berg, Jean Y Ko, Sherry L Farr, Van T Tong, F Carol Bruce, and William M Callaghan. 2014. Maternal mortality and morbidity in the United States: where are we now? *Journal of Women's Health* 23, 1 (2014), 3–9.
- [5] Andreea A Creanga, Cynthia J Berg, Carla Syverson, Kristi Seed, F Carol Bruce, and William M Callaghan. 2012. Race, ethnicity, and nativity differentials in pregnancy-related mortality in the United States: 1993–2006. *Obstetrics & Gynecology* 120, 2, Part 1 (2012), 261–268.
- [6] P Dineshkumar, R SenthilKumar, K Sujatha, RS Ponmagal, and VN Rajavarman. 2016. Big data analytics of IoT based Health care monitoring system. In *Electrical, Computer and Electronics Engineering (UPCON), 2016 IEEE Uttar Pradesh Section International Conference on*. IEEE, 55–60.
- [7] Jens Dittrich and Jorge-Arnulfo Quiané-Ruiz. 2012. Efficient big data processing in Hadoop MapReduce. *Proceedings of the VLDB Endowment* 5, 12 (2012), 2014–2015.
- [8] Centers for Disease Control, Prevention, et al. 2014. Pregnancyrelated mortality surveillance. 2013. (2014).
- [9] Peter Groves, Basel Kayyali, David Knott, and Steve Van Kuiken. 2016. The 'big data' revolution in healthcare: Accelerating value and innovation. (2016).
- [10] Isabelle L Horon and Diana Cheng. 2011. Effectiveness of pregnancy check boxes on death certificates in identifying pregnancy-associated mortality. *Public Health Reports* 126, 2 (2011), 195–200.
- [11] Donna L Hoyert. 2007. Maternal mortality and related concepts. *Vital & health statistics. Series 3, Analytical and epidemiological studies/[US Dept. of Health and Human Services, Public Health Service, National Center for Health Statistics]* 33 (2007), 1–13.
- [12] Amnesty International. 2010. *Deadly Delivery: The Maternal Health Care Crisis In the USA*. Amnesty International Publications.
- [13] Nicholas J Kassebaum, Ryan M Barber, Zulfiqar A Bhutta, Lalit Dandona, Peter W Gething, Simon I Hay, Yohannes Kinfu, Heidi J Larson, Xiaofeng Liang, Stephen S Lim, et al. 2016. Global, regional, and national levels of maternal mortality, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet* 388, 10053 (2016), 1775.
- [14] Dina Fine Maron. 2015. Has maternal mortality really doubled in the US. *Scientific American* (2015).
- [15] J Michael McGinnis, Leigh Stuckhardt, Robert Saunders, Mark Smith, et al. 2013. *Best care at lower cost: the path to continuously learning health care in America*. National Academies Press.
- [16] Yasmin H Neggers. 2016. Trends in maternal mortality in the United States. *Reproductive Toxicology* 64 (2016), 72–76.
- [17] World Health Organization, UNICEF, et al. 2012. Trends in maternal mortality: 1990 to 2010: WHO, UNICEF, UNFPA and The World Bank estimates. (2012).
- [18] Kenneth F Schulz, Iain Chalmers, David A Grimes, and Douglas G Altman. 1994. Assessing the quality of randomization from reports of controlled trials published in obstetrics and gynecology journals. *Jama* 272, 2 (1994), 125–128.

#### LIST OF FIGURES

- |   |  |   |
|---|--|---|
| 1 | A comparison of maternal mortality ratio in the United States with those of some developed countries between 1990 and 2013 [14].             | 5 |
| 2 | Percentage change in Maternal Mortality Rate between 1990 and 2013 in the United States, worldwide, developed and developing countries [13]. | 6 |
| 3 | Changes in pregnancy related mortality ratio in United States from 1987-2011 [8].  | 7 |



**Figure 1:** A comparison of maternal mortality ratio in the United States with those of some developed countries between 1990 and 2013 [14].

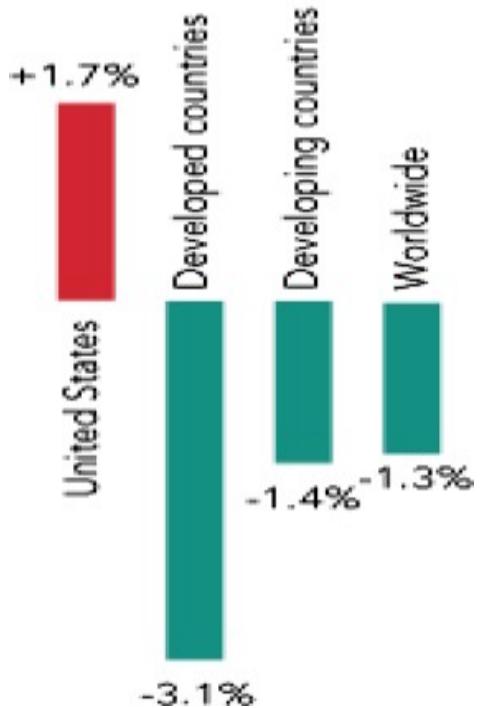


Figure 2: Percentage change in Maternal Mortality Rate between 1990 and 2013 in the United States, worldwide, developed and developing countries [13].

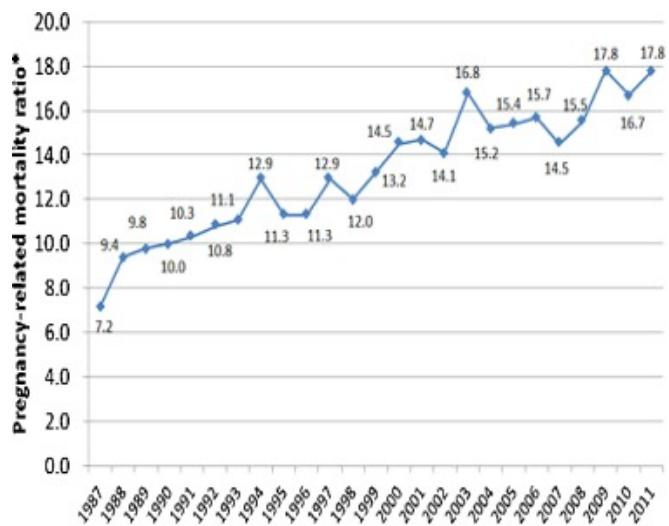


Figure 3: Changes in pregnancy related mortality ratio in United States from 1987-2011 [8].

# **Impact of Big Data on the Privacy of Mental Health Patients**

J. Robert Langlois

Indiana University Bloomington, School of Informatics and Computing

langloir@umail.iu.edu

## **ABSTRACT**

Society has experienced a lot of benefits with the introduction of technology. Today, one of the essential functions of technology is the collection, storage, processing, and transmission of data. The healthcare industry, including mental health services, are huge benefactors of these advances in technology. From birth, medical facilities start collecting information about all individuals; they do so even up to the point of death and all points in between. Over a lifetime, that is an abundance of information about an individual. The question that must be answered is, how is that data be protected to ensure patients' privacy rights? The more information collected on individuals, the more responsibility is assumed by those who collect data; methods for how the data is collected, used and shared must ensure the protection of patients' privacy rights. This challenge is one that needs to be navigated and addressed by medical professionals and facilities, policymakers, and the individuals whose data is collected. Specifically in the mental health field, by resolving patients' privacy concerns, policymakers and researchers can transform the field by introducing more cost effective strategies, ensuring patients' sense of security, and establishing new and more appropriate norms to communicate sensitive health information.

## **KEYWORDS**

Big Data, Mental Health and Privacy i523

## **1 INTRODUCTION**

We live in an era where data is constantly being produced; data exists everywhere in large quantities. The advances in technology have opened the door for businesses to collect inconceivable amounts of information on individuals via emails, smart-phones, sensors, and other technology devices. The 21st century has witnessed a data explosion; many fields have experienced a data deluge that can contribute to boast the economy via data analysis, make new discoveries based on existing data, respond to health problems in a quicker manner, and so forth. While it is worth celebrating the rapid innovations in technology and the presence of huge amounts of data, it is also crucial to consider the number of barriers and risks that come with the increased availability of data; often refers to as big data. One of the barriers that big data faces is privacy. In the healthcare industry, for example, there are protocols to accessing data that can cause financial burdens and can be time-consuming. The cost of collecting, disseminating, and organizing patient information, along with the time it takes to handle the information are some of the challenges. There are also very serious concerns regarding who can have access to what kind of patient information. Policymakers have a very important role in establishing more up-to-date policies and parameters that address the massive amounts of information available and the appropriate ways to collect, share,

and house the data. "When considering the risks that big data poses to individual privacy, policymakers should be mindful of its sizable benefits" [7]. While it is important to address the numerous advantages of big data, it remains relevant to figure out ways to prevent data leakage, and to protect the privacy of individuals. This paper showcases the advantages of big data and the ways to overcome the individual privacy concerns.

## **2 THE ADVANTAGES OF BIG DATA**

Big data analysis presents numerous advantages. For instance, it helps businesses to increase their productivity. This has done through a process of analyzing raw data that produces information that identifies trends and patterns that will help businesses make cost effective decisions. It is also helpful in aiding government agencies to improve public sector administration, and assists global organizations in analyzing information that has wide-reaching impact on the world. The information produced by big data can help medical professionals to detect diseases in earlier stages. Some other advantages of big data analysis is present in many different areas, such as: smart grids, which monitor and control electricity use; traffic management systems, which provide information about transportation infrastructure like roads and highways, mass transit, construction, and traffic congestion; retail by studying customer purchasing behavior to improve store layout and marketing; payment processing by helping to detect fraudulent activity, etc. [7].

Certain research studies have supported the idea that big data allows for real time tracking of diseases and the development, prediction of outbreaks, and facilitates the development of personalized healthcare. Big data can also be used to maximize profits in many disciplines, including healthcare if harnessed properly. [8]. As indicated in [2] "by harnessing big data, businesses gain many advantages, including increased operational efficiency, informed strategic direction, improved customer service, new products, and new customers and markets." While data exists in huge quantities in many fields, including the health care field, individual privacy concerns remain a big problem that policymakers have to tackle to meet current trends in data collection. Improved methods of protecting very personal, private and sensitive health information is needed in order to allow for safe, necessary and adequate access to protected health information within the health care industry. Without proper policies related to data use, access, and protection, this big data potential can not be realized [4]. What are the barriers to big data in healthcare?

## **3 THE BARRIERS TO BIG DATA IN HEALTH-CARE**

One of the barriers faced by big data analysts in healthcare, including mental health services, is privacy. Regardless of the efforts

policymakers try to establish, the different strategies in place to protect individual health information can pose serious challenges that scientists have to wrestle with when it comes to big data analytics. One of the most notable efforts that policymakers have introduced to secure health information, is the creation of the Health Insurance Portability and Accountability Act (HIPAA) in 1996. HIPAA has established norms for data privacy and has mandated security provisions for safeguarding medical and mental health information. Every provider in the healthcare industry must comply with HIPAA privacy laws if they want their practices to remain up and running. The HIPAA laws prohibit providers from sharing patients' information without their consent. The challenge for big data analysts is that a lot of times, patients refuse to share their personal information for research purposes due to fears that the health issue will be the cause of being ostracized, discriminated against, marginalized, etc. "The unintended release of a person's health information into the public realm has huge potential to undermine personal dignity and cause embarrassment and financial harm"[8]. While the healthcare field is faced with a huge increase in health information, individual privacy concern remains a huge conundrum for big data analysis. What can policymakers do to overcome individual privacy concerns, but still allow for the sharing of information that would be for the better good of society at large?

## 4 WAYS TO OVERCOME PRIVACY CONCERN

*4.0.1 Data Anonymization.* One way policymakers can protect individual privacy is by making the data anonymous. Researchers have identified three types of data: personal and proprietary data that is controlled by individuals; government-controlled data, which government agencies can restrict access to; and, open data commons, which means that the data is centrally located and available to all. Big data analysts and researchers have advocated for linking data together that can help to improve health care planning at both the patient and population levels. They also argued for an increase in the amount of information that is available in open data commons. Although the anonymization of data appears to be a great technique that policymakers could espouse to address privacy concerns, other studies have indicated that some data can be traced back to their respective individual; thus, destroying the argument for anonymity.[8]. "Every copy of data increases the risk of unintended disclosure. To reduce this risk, data should be anonymized before transfer; upon receipt, the recipient will have no choice but anonymize it at rest...And re-identification is by design, in order to ensure accountability, reconciliation and audit." If proper norms are established for data analysis, this can potentially contribute to improvements in the health care industry.

Still, there are others that have advocated for data de-identification and data minimization. The term de-identification is the process by which the data is made anonymous. The proponents of this process explain that this protective measure is valid under security and accountability principles, but admonish that policymakers should think about other ways to protect patients' privacy. The term data minimization, describes the extent to which organizations can limit the collection of personal data. It is worth noting that data minimization is contrary to big data analysis because data minimization encourages deleting data that is no longer in use in order to protect

privacy; whereas, big data analysts would prefer to archive the data for ulterior usage. While this technique can help protect privacy, it is antithetical to big data analysis because it contributes to reducing the amount of data collection that could be used in data analysis to make new discoveries, respond to crises, and maximize profits [7].

As found in [1], privacy principles should be introduced during the process of data architecture; privacy should be incorporated into the design and operational procedures. In so doing, personal health care data will be protected against malicious hackers who try to access individuals' personal health information for the purposes of stealing individuals' identity. Another type of data that has been introduced to the healthcare industry is concept quantified self data. It can be understood as the data produced by individuals that engage in self-tracking of personal health information, such as heart rate, weight, energy levels, sleep quality, cognitive performance, etc. These individuals use devices like smart-phones, watches, and wearable technology sensors in the collection of their personal data and biometrics. It has been shown that 60 percent of U.S. adults are tracking their weight, diet or exercise routines, while 33 percent are monitoring their blood sugar, blood pressure, sleep patterns, etc. This indicates that there is a vast amount of health information that has been produced by individuals. What is done with all of this data? This massive supply demonstrates the need to develop policies and protocols that involve individual patient consent to share their collected data; this data can be critical to the advancement of health-care with the support of data analysis. Before that can be done, however, we must first establish the proper norm to use this type of data so that the privacy of individuals can be protected; this ought to be the primary action to take. [6]. In the healthcare industry, Patients often do not want their health information to fall in the hand of other entities without their consent; however, with proper informed consent, patients seemed to become willing to share their personal health information. As agencies work with patients to disclose the purposes of collecting certain, sometimes sensitive, health information, they can empower patients to make informed decisions about their personal health information, thus engaging patients in the process. This can then serve to increase and improve the set of personal health information utilized for clinical research purposes, and subsequently improve people's lives [5]. "Privacy concerns exist wherever personally identifiable information or other sensitive information is collected and stored in any form"[3]. Thus, to protect privacy, other techniques, like encryption, authentication, and data masking may be utilized to ensure that the information is available only to authorized users.

## 5 CONCLUSION

We have seen that healthcare data exists in large quantities; however, privacy concerns are one of the biggest barriers and challenges that scientists face when it comes to utilization of healthcare data. Certain researchers have proposed data anonymization as a solution to privacy concerns, while others have proposed a minimization of the amount of data collected on individual patients, as well as authenticate the data so that it can only be accessed by intended users. Suggestion was also made to involve patients in the collection of health data, so that they can be more willing to share their information that can play a vital role in improving healthcare and mental

health research, reduce health care cost, maximize profits, etc. It is almost certain that scientists will always have to wrestle with privacy concern whenever they are dealing with personal health information; thus the importance for policymakers to continue to encourage dialogue among healthcare providers and patients, and develop policies and regulations on how to utilize healthcare data without compromising patients' privacy rights.

## REFERENCES

- [1] Ann Cavoukian and Jeff Jonas. 2012. *Privacy by design in the age of big data*. Information and Privacy Commissioner of Ontario, Canada.
- [2] Nawsher Khan, Ibrar Yaqoob, Ibrahim Abaker Targio Hashem, Zakira Inayat, Waleed Kamaleldin Mahmoud Ali, Muhammad Alam, Muhammad Shiraz, and Abdullah Gani. 2014. Big data: survey, technologies, opportunities, and challenges. *The Scientific World Journal* 2014 (2014).
- [3] Shahidul Islam Khan and Abu Sayed Md Latiful Hoque. 2016. Digital Health Data: A Comprehensive Review of Privacy and Security Risks and Some Recommendations. *Computer Science Journal of Moldova* 24, 2 (2016).
- [4] Joachim Roski, George W Bo-Linn, and Timothy A Andrews. 2014. Creating value in health care through big data: opportunities and policy implications. *Health affairs* 33, 7 (2014), 1115–1122.
- [5] Robert H Shelton. 2011. Electronic consent channels: preserving patient privacy without handcuffing researchers. *Science translational medicine* 3, 69 (2011), 69cm4–69cm4.
- [6] Melanie Swan. 2013. The quantified self: Fundamental disruption in big data science and biological discovery. *Big Data* 1, 2 (2013), 85–99.
- [7] Omer Tene and Jules Polonetsky. 2012. Big data for all: Privacy and user control in the age of analytics. *Nw. J. Tech. & Intell. Prop.* 11 (2012), xxvii.
- [8] J Van Den Bos, K Rustagi, T Gray, M Halford, E Zeimkiewicz, and J Shreve. 2011. Health affairs: At the intersection of health, health care and policy. *Health Affairs* 30 (2011), 596–603.

# Big data in Clinical Trials

Mohan Mahendrakar

Indiana University

P.O. Box 1212

Bloomington, Indiana 43017-6221

mmahendr@iu.edu

## ABSTRACT

This paper will help us to understand about Clinical Trials and how Big data is impacting Clinical Trials. Oncology (Trials) is undergoing a data-driven metamorphosis. Armed with new and ever more efficient molecular and information technologies, we have entered an era where big data is helping us spearhead the fight against various deceases. This technology driven data explosion, often referred to as "big data". [3]

## KEYWORDS

I523, HID 326, Big data, Clinical, Trials, Health care, Data integration, Analytics

## 1 INTRODUCTION

A primary objective of clinical trials is gaining knowledge from studying a subset of patients which can then be applied to a much wider group of patients to improve care. In routine practice, patient care is delivered within a rich background of intrinsic and endemic confounding factors and biases associated with practices and patients. [2]

The data collected around the world from various patients, deceases form big data (collection of large data sets). Big data is currently being used on a limited basis in the clinical trials arena, but experts believe its widespread use is coming in the near future. Some hail the great promise it holds in furthering drug discovery. Others are skeptical that it will bring much value and say that enthusiasm should be tempered. [5]

According to IBM, 2.3 trillion gigabytes of data are created every day! so much that 90% of the data in the world today has been created in the last two years alone. Digital Universe estimates that by 2020, there will be 5,200 gigabytes of data for every man, woman and child on Earth.

It is predicted that the market for Big Data technology and services will reach \$16.9 billion in 2015, up from \$3.2 billion in 2010. This is an annual growth rate of 40 percent, which is about seven times the rate of the overall information and communications technology market. According to CB insights, health care investments in Big Data totaled \$274.5 million in 2012, and it went to \$371.5 million in 2013. [6]

## 2 BIG DATA & CLINICAL RESEARCH

Discovering clinical trials hidden patterns and associations within the heterogeneous data, uncovering new bio markers and drug targets. Allowing the development of predictive disease progression models. Analyzing Real World Data (RWD) as a complementary instrument to clinical trials, for the rapid development of new personalized medicines. The development of advanced statistical

methods for learning causal relations from large scale observational data is a crucial element for this analysis. [4]

### 2.1 Data Integration

Having access to consistent, reliable, and well linked is one of the biggest challenges facing pharmaceutical clinical trials. The ability to manage and integrate data generated at all phases of the value chain, from discovery to real-world use after regulatory approval, is a fundamental requirement to allow companies to derive maximum benefit from the technology trends. Data are the foundation upon which the value-adding analytics are built. Effective end-to-end data integration establishes an authoritative source for all pieces of information and accurately links disparate data regardless of the source be it internal or external, proprietary or publicly available. Data integration also enables comprehensive searches for subsets of data based on the linkages established rather than on the information itself. "Smart" algorithms linking laboratory and clinical data, for example, could create automatic reports that identify related applications or compounds and raise red flags concerning safety or efficacy. [2]

Implementing end-to-end data integration requires a number of capabilities, including trusted sources of data and documents, the ability to establish cross-linkages between elements, robust quality assurance, workflow management, and role-based access to ensure that specific data elements are visible only to those who are authorized to see it. Pharmaceutical companies generally avoid overhauling their entire data-integration system at once because of the logistical challenges and costs involved, although at least one global pharmaceutical enterprise has employed a "big bang" approach to remaking its clinical IT systems. [2]

Data is being generated by different sources and comes in a variety of formats including unstructured data. All of this data needs to be integrated or ingested into Big Data Repositories or Data Warehouses. This involves at least three steps, namely, Extract, Transform and Load (ETL). With the ETL processes that have to be tailored for medical data have to identify and overcome structural, syntactic, and semantic heterogeneity across the different data sources. The syntactic heterogeneity appears in forms of different data access interfaces, which were mentioned above, and need to be wrapped and mediated. Structural heterogeneity refers to different data models and different data schema models that require integration on schema level. Finally, the process of integration can result in duplication of data that requires consolidation.

The process of data integration can be further enhanced with information extraction, machine learning, and semantic web technologies that enable context based information interpretation. Information extraction will be a mean to obtain data from additional

sources for enrichment, which improves the accuracy of data integration routines, such as duplication and data alignment. Applying an active learning approach ensures that the deployment of automatic data integration routines will meet a required level of data quality. Finally, the semantic web technology can be used to generate graph based knowledge bases and ontologies to represent important concepts and mappings in the data. The use of standardized ontologies will facilitate collaboration, sharing, modelling, and reuse across applications. [4]

## 2.2 Exascale computing

After data integration is completed, the big question is how to process such huge volume of the data? There will be use cases, e.g. precision medicine, where the promises brought by Big Data will only be fulfilled through dramatic improvements in computational performance and capacity, along with advances in software, tools, and algorithms. Exascale computers-machines that perform one billion calculations per second and are over 100 times more powerful than today's fastest systems will be needed to analyses vast stores of clinical and genomic data and develop predictive treatments based on advanced 3D multi-scale simulations with uncertainty quantification. Precision medicine will also require scaling these systems down, so clinicians can incorporate research breakthroughs into everyday practice. [4]

## 2.3 Data-driven metamorphosis

Data collected in clinical trials undergoing a data-driven metamorphosis. Armed with new and ever more efficient molecular and information technologies, we have entered an era where data is helping us spearhead the fight against cancer. This technology driven data explosion, often referred to as "big data", is not only expediting biomedical discovery, but it is also rapidly transforming the practice of oncology into an information science. This evolution is critical, as results to-date have revealed the immense complexity and genetic heterogeneity of patients and their tumors, a sobering reminder of the challenge facing every patient and their oncologist. This can only be addressed through development of clinico-molecular data analytics that provide a deeper understanding of the mechanisms controlling the biological and clinical response to available therapeutic options. Beyond the exciting implications for improved patient care, such advancements in predictive and evidence-based analytics stand to profoundly affect the processes of cancer drug discovery and associated clinical trials. [3]

## 2.4 Big data analytics

Medical research has always been a data-driven science, with randomized clinical trials being a gold standard in many cases. However, due to recent advances in omics-technologies, medical imaging, comprehensive electronic health records, and smart devices, medical research as well as clinical practice are quickly changing into Big Data-driven fields. As such, the healthcare domain as a whole - doctors, patients, management, insurance, and politics - can significantly profit from current advances in Big Data technologies, and from analytics. [4]

## 2.5 Machine Learning

Many healthcare applications would significantly benefit from the processing and analysis of multimodal data - such as images, signals, video, 3D models, genomic sequences, reports, etc. Advanced machine learning systems can be used to learn and relate information from multiple sources and identify hidden correlations not visible when considering only one source of data. For instance, combining features from images (e.g. CT scans, radiographs) and text (e.g. clinical reports) can significantly improve the performance of solutions. [4]

## 3 CHALLENGES

Big pharma companies typically keep their cards close to the vest because it costs so much to develop a drug throughout its lifetime. From discovery to prescription pad, a typical medication can take twelve years and \$4 billion to shepherd through its lifecycle, a significant investment that would be hard to recoup if everyone had the secret to the newest blockbuster pill, especially since only ten percent of drugs ever make it to market. [1]

Although there is already a huge amount of healthcare data around the world and while it is growing at an exponential rate, nearly all the data is stored in individually. Data collected by a clinic or by a hospital is mostly kept within the boundaries of the healthcare provider. Moreover, data stored within a hospital is hardly ever integrated across multiple IT systems. For example, if we consider all the available data at a hospital from a single patient's perspective, information about the patient will exist in the EMR system, laboratory, imaging system and prescription databases. Information describing which doctors and nurses attended to the specific patient will also exist. However, in most of cases, every data source mentioned here is stored in separate silos. Thus, deriving insights and therefore value from the aggregation of these data sets is not possible at this stage. It is also important to realize that in today's world a patient's medical data does not only reside within the boundaries of a healthcare provider. The medical insurance and pharmaceuticals industries also hold information about specific claims and the characteristics of prescribed drugs respectively. Increasingly, patient-generated data from IoT devices such as fitness trackers, blood pressure monitors and weighing scales are also providing critical information about the day-to-day lifestyle characteristics of an individual. Insights derived from such data generated by the linking among EMR data, vital data, laboratory data, medication information, symptoms (to mention some of these) and their aggregation, even more with doctor notes, patient discharge letters, patient diaries, medical publications, namely linking structured with unstructured data, can be crucial to design coaching programs that would help improve people's lifestyles and eventually reduce incidences of chronic disease, medication and hospitalization. [4]

## 4 CONCLUSION

The recent surge in big data initiatives in health care is expected to have a positive impact on clinical trials. Increased standardization of common data elements and nomenclature should assist in streamlined trial design and exchange of data. Standardize between trials and will allow easier multi-study analysis. Standardization

and quality improvement efforts go hand in hand with a maturing big data infrastructure providing collateral benefits to data curation for trials. [3]

## ACKNOWLEDGMENTS

The authors would like to thank to Professor and TAs for guiding in making the better paper.

## REFERENCES

- [1] Jennifer Bresnick. 2014. Big pharma opens up big data for clinical trials, analytics. (July 2014). <https://healthitanalytics.com/news/big-pharma-opens-up-big-data-for-clinical-trials-analytics>
- [2] Jamie Cattell, Sastry Chilukuri, and Michael Levy. 2013. *How big data can revolutionize pharmaceutical R&D*. White Paper. McKinsey Center for Government. [https://www.mckinsey.com/~media/mckinsey/dotcom/client\\_service/public%20sector/regulatory%20excellence/how\\_big\\_data\\_can\\_revolutionize\\_pharmaceutical\\_research.pdf](https://www.mckinsey.com/~media/mckinsey/dotcom/client_service/public%20sector/regulatory%20excellence/how_big_data_can_revolutionize_pharmaceutical_research.pdf)
- [3] Taglang G and Jackson DB. 2016. *Use of "big data" in drug discovery and clinical trials*. Article. Molecular Health GmbH, 69115 Heidelberg, Germany. <https://doi.org/10.1016/j.ygyno.2016.02.022>
- [4] Dr. Adrienne Heinrich, Aizea Lojo, Dr. Alejandro Rodriguez Gonzalez, Dr. Andrejs Vasiljevs, Chiara Garattini, Cristobal Costa-Soria, Dirk Hamelinck, Elvira Narro Artigot, Prof. Ernestina Menasalvas, PD Dr. habil. Feiyu Xu, Dr. Felix Sasaki, Prof. Frank Mller Aarestrup, Gisele Roesems fi?! Kerremans, Jack Thoms, Marga Martin Sanchez, Marija Despenic, Mario Romao, Matteo Melideo, Prof. Dr. Miguel A. Mayer, Prof. Dr. Milan Petkovic, Dr. Nenad Stojanovic, Nozha Boujemaa, Patricia Casla Mag, Paul Czech, Prof. Roel Wuyts, Sergio Consoli, Dr. rer. Nat. Stefan Rping, Stuart Campbell, Dr. Supriyo Chatterjee, Prof. Dr. Ir. Wessel Kraaij, Wilfried Verachtert, Dr. Wouter Spek, and Ziawasch Abedjan. 2016. *Big Data Technologies in Healthcare*. techreport. Big data value association. <http://www.bdva.eu/sites/default/files/Big%20Data%20Technologies%20in%20Healthcare.pdf>
- [5] F. Hoffmann-La Roche Ltd. 2013. *Understanding Clinical Trials*. techreport. GPS Public Affairs, 4070, Basel, Switzerland. [https://www.roche.com/dam/jcr:1d4d1b52-7e01-43ac-862f-17bb59912485/en/understanding\\_clinical\\_trials.pdf](https://www.roche.com/dam/jcr:1d4d1b52-7e01-43ac-862f-17bb59912485/en/understanding_clinical_trials.pdf)
- [6] Dr. Sarika Vanarse. 2014. *BIG DATA BREATHES LIFE INTO NEXT-GEN PHARMA R&D*. techreport. Wipro, DODDAKANNELLI, SARJAPUR ROAD, BANGALORE - 560 035, INDIA. <http://www.wipro.com/documents/big-data-breathes-life-into-next-gen-pharma-RD.pdf>

# Using Big Data to minimize Fraud, Waste, and Abuse (FWA) in United States Healthcare

Paul Marks

Indiana University

Online Student

Shepherdsville, Kentucky 40165

pcmarks@iu.edu

## ABSTRACT

The cost of healthcare includes the loss of billions of dollars due to Fraud, Waste, and Abuse (FWA). Many of the schemes to commit FWA are very intricate and require the analysis of many data sources simultaneously. The question answered here is "How can we use big data analysis to help minimize these costs and thus optimize the money spent on healthcare?"

## KEYWORDS

i523, hid327, fraud, waste, abuse, healthcare, health insurance

## 1 INTRODUCTION

FWA is an issue that affects everyone in the U.S. since healthcare services are leveraged by everyone at some point and the costs for those services include the money lost to FWA. The three components of FWA are varying degrees of culpability. The Centers for Medicare and Medicaid Services (CMS) in part defines fraud as "knowingly and willfully executing, or attempting to execute, a scheme or artifice to defraud any health care benefit program", Waste as "overusing services, or other practices that, directly or indirectly, result in unnecessary costs", and Abuse as "involves payment for items or services when there is not legal entitlement to that payment and the provider has not knowingly and/or intentionally misrepresented facts".[9] While the percentage of cost attributable to FWA can vary from insurer to insurer, Medicare estimates that 11 percent of its payments for Original Medicare are improper primarily due to FWA.[8] In combination these cost the United States healthcare system 80 billion dollars[6] annually.

Advances in big data technology can help reduce these losses. Big data offers the ability to look at data in real time to determine if a claim is legitimate or not. Historically, due to the amount of data involved, this type of analysis would have to happen after the claims have been paid with specific models targeting specific schemes to identify FWA. Big data can help lower the cost of health-care in the United States by identifying FWA claims and stopping payments before they occur.

## 2 HEALTHCARE FRAUD, WASTE, AND ABUSE ENVIRONMENT

It is easy to understand the problem FWA poses. Healthcare funds are of limited quantity. Insurance helps to spread the cost among groups of people, but does not provide limitless funds. As costs increase, so do premiums or direct payments for health-care. In order for as many people to be able to have access to healthcare costs have to be managed. There are many ideas for helping to

provide affordable healthcare, but there is much discussion and disagreement on exactly how to do that. Reducing costs by eliminating as much FWA as possible is one solution that everyone, except for those participating in and profiting from FWA schemes, can agree on.

Data to fight FWA is not just the information gathered by a doctor or other provider while working with a patient. In order to fully utilize advances in technology, multiple sources of information must be brought together. Sources include claims (current and historic), clinical, provider, geospatial, and other sources of information. This allows for data analytics to take a deeper look into not only a single participant, but others who may be related to that participant. "If Provider A is involved in improper billing, it is not uncommon for other providers with which they associate to also be engaged in bad behavior. Thus, many payers will work to analyze connected providers. Information on corporate ownership, billing and management companies, social media interactions of physicians and staff can reveal whether other physicians, pharmacies, radiology centers, home infusion agencies, etc. are engaged in a broader pattern of referral and collusion." [13]

The problem for big data to solve is the size of all this data and how to process it fast enough. Using CMS as an example, being a government entity much of their data is available publicly, it is easy to get an idea of the amount of data. Medicare processed 1.2 billion claims in 2014, covering 53.8 million beneficiaries, with 6,142 hospitals, and 1,173,802 non-institutional providers[7]. In addition payments must be made within a specific timeframe depending on the insurer and their agreement with providers. This time includes all the normal steps to verify and process a claim so the time available to examine the data for FWA is very limited.

It must be noted that when working with this type of data, Protected Health Information (PHI) and Personally Identifiable Information (PII), that there are many regulations about the ability to access and secure it which must be followed. While this makes it more difficult to get access to the data it can be overcome by working cooperatively with the various data owners.

### 2.1 Big Data Techniques for FWA

So how can big data be used to approach this issue? Leveraging big data tools such as Hadoop, analysts could divide the different sources of information into data lakes, looking at each source separately, and then combining the results. Table 1 on page 5 shows sources of information and what level of FWA they are generally related to. The highest level combines sets of data. "Level 7 combines all previous data views and concerns all fraud that is part of criminal networks which involve many different beneficiaries

and/or providers. This much larger data view, spanning billions of claims in the case of Medicaid, is the most rich, delivering the ability to perform complex network analysis that could detect intricate conspiracies. However, performance of analysis here will be much lower than in previous levels.”[14]

While there are simple cases of fraud which follow a typical known pattern, this is only a portion of the problem. Fraud schemes change and can involve many different entities which may not seem to be related on the surface. The more data which can be combined and analyzed, the more fraud that can be found. “Much of the FWA that plague health care payers is the result of organized, sophisticated and collusive activities among providers and between providers and patients. Social network analysis can help identify relationships, links and hidden patterns of information sharing and interactions within potentially fraudulent clusters, including:

- Patient relationships with known perpetrators of health care fraud;
- Links between recipients, businesses, assets and relatives and associates;
- Links between licensed and non-licensed and sanctioned providers; and
- Inappropriate relationships between patients, providers, employees, suppliers and partners”[5]

In order to keep up with organized fraud activities, there must be a dedicated practice of data analytics which is ever evolving.

Traditionally programs have been written to look for specific sets of circumstances. Leveraging existing knowledge about the data and using it to look for specific patterns is known as supervised in big data terms. “There are several supervised fraud detection methods such as: Bayesian Networks, Neural Networks (NNs), Decision Trees, and Fuzzy Logic. NNs and decision trees are the most popular fraud detection methods because of their high tolerance of noisy data and huge data set handling.”[3] There are also unsupervised methods in which data is fed into the system without preexisting notions of what to look for[3]. Unsupervised methods sort through data and find relationships and groupings of related information, find clusters of what could be considered normal, and determine where the outliers are.

Because unsupervised methods only identify outliers, applying unsupervised methods to healthcare data will require that the outliers will then have to be verified as FWA or acceptable patterns. “Patrick McIntyre, SVP of Health Care Analytics at Anthem, one of the country’s biggest payers, credits machine learning and big data with their ability to “identify potentially fraudulent or wasteful claims on a daily basis.” The algorithms are run at the same time as claims are batch processed, so questionable claims are immediately identified, flagged and sent to the clinical coding experts for review.”[4] This greatly increases the ability to fight FWA by having the machine pinpoint where to look in all the data available to the reviewer. Suddenly the task of finding fraud is not as daunting. By leveraging both of these techniques FWA can be discovered at an accelerated pace. The number of models the system knows will grow over time as more data is fed into it and more patterns are discovered and verified.

## 2.2 Current Solutions

Many companies currently offer solutions for detecting FWA in healthcare payment systems. They include the ability to identify FWA claims during the payment cycle so that payment is not made to suspect claims. Truven Health[1], Healthcare Fraud Shield[12], and SAS[10], just to name a few, all have systems they offer based on big data. The specifics of the systems they offer are proprietary in nature so many of the descriptions are generic. Truven Health for instance claims “Our approach to FWA analytics is to infuse our solution with healthcare intelligence. As one example, Truven Health pioneered a ‘medical model’ for the healthcare fraud detection process. A key component of this model is our Medical Episode Grouper (MEG). MEG is an advanced healthcare analytic methodology that groups all the services for a clinically-relevant episode of illness, including inpatient, outpatient, and drug. The MEG episodes are constructed using rigorously defined clinical classifications based on current medical literature. Episodes analysis can expose patterns of clinical and billing abuse that are otherwise difficult to detect such as wasteful or unnecessary services. Using MEG, the analyst can understand the entire range and cost of services provided to a patient during a single episode of illness, which then is aggregated to profile a provider’s entire practice.”[1] SAS materials include “Detect improper payments before the money goes out the door, and get potential savings of hundreds of millions of dollars. Take an enterprise approach to detecting and preventing fraud, waste and abuse with a hybrid analytics solution”[10] and “By making analytical models and rules engines part of the process, you can spot more payment integrity breaches than ever before. Process all data (not just a sample) through rules and analytical models. Use customized models to detect previously unknown schemes. And spot linked entities and crime rings, which can help stem larger losses.”[11]. The U.S. Federal government is also investing heavily into FWA analytics. “The CMS has awarded defense contractor Northrop Grumman Corp. a \$ 91 million contract to develop and implement a second generation of an advanced analytics system, called the Fraud Prevention System, to help identify high-risk claims in Medicaid and Medicare.”[2]

## 2.3 Future uses of Big Data Analytics

Currently there is still a certain amount of honor built into healthcare. “The system’s inherent structure of trust enables both simple billings errors and illicit actors to hide in the shadows of the murky deep as overpayments quietly siphon money away from legitimate care.”[13] If a claim is submitted by a valid entity, using the correct process, and everything is in order then it is most likely paid. For many claims this is done without any specific proof of the services being provided. With more and more healthcare information being digitized this may not be the case in the future. X-rays, lab tests, clinical notes, etc. are all being stored digitally. Computers are now able to interpret images and unstructured text very accurately. By linking this data to claims data the clinical information could be required as part of claims payment. An x-ray of broken bone, notes which support a diagnosis, Magnetic Resonance Imaging files, could all be interpreted automatically. Not only would the data be used to compare to the claims information, but to other images/notes on file to ensure that the same files were not being

submitted with multiple claims. The system could know what one individual medical history looks like compared to another similar to how facial recognition is able to match like images. Requiring and being able to validate more information before services are paid for would help the reduce the ability of perpetrators of FWA to be able to get reimbursed for services they should not. This level of verification would not be possible without the ability to process massive amounts of data quickly.

Historically the payers of most healthcare claims, insurers, have not had the ability to examine actual evidence that a service has taken place on a broad scale. (It is done manually on a specific case or audit basis.) Through the use of advances in big data and combining current and new data stores such as electronic health records into the payment process a difference can be made in the amount of money lost to FWA in healthcare. “By combining identity and entity resolution, rules-based claim and clinical review, complex linking analysis and predictive analytics into a seamless workflow, we will come closer to migrating an integrated pre-pay fraud solution to a real risk control environment with the potential to eliminate billions of dollars in improper payments due to FWA. This is not just a health care imperative, but a national economic imperative that must be addressed immediately. The analytics exist. It is time for those analytics to be implemented and the hard choices that enable that implementation to be made to insure that we remain at the forefront of quality care for all Americans.”[5]

### 3 CONCLUSIONS

While there may be disagreement on many aspects of healthcare in America, everyone should agree that eliminating Fraud, Waste, and Abuse within the system is the right thing to do. FWA costs billions of dollars annually. Just a 1 percent reduction in the estimated 80 billion dollars annually would result in 800 million dollars in savings. With this amount of money at stake significant investments should continue to be made in leveraging advanced big data technologies into solving this problem. Due to the continued rise in the amount of data collected traditional programming cannot keep up with the pace. Advanced techniques must be leveraged which can learn in an unsupervised manner. The future of the best methods for fighting FWA in healthcare will be a combination of this analysis and teams specializing in the rules and regulations of healthcare in the United States. The unsupervised methods will work through massive amounts of structured and unstructured data breaking it down into cases and schemes which are most like FWA. These will be reviewed, confirmed or denied as accurate, and fed back into overall FWA platform. As this cycle continues over and over the ability to fight FWA in United States Healthcare will get better. While Big Data may never eliminate FWA in Healthcare it can help to minimize it and save the country billions of dollars a year.

### ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski for his support and suggestions to write this paper. It has helped to expand my knowledge in how modern data analytics can help to save FWA which has plagued the healthcare system.

### REFERENCES

- [1] Truven Health Analytics. 2017. Program Integrity. Online. (2017). <http://truvnhealth.com/your-healthcare-focus/government/program-integrity>
- [2] Virgil Dickson. 2016. Northrop Grumman wins \$ 91 million CMS contract for fraud detection. Online. (04 2016). <http://www.modernhealthcare.com/article/20160407/NEWS/160409912>
- [3] Namrata Ghuse, Pranali Pawar, and Amol Potgantwar. 2017. An Improved Approach For Fraud Detection In Health Insurance Using Data Mining Techniques. *International Journal of Scientific Research in Network Security and Communication* 5, 3 (06 2017), 27–33.
- [4] Erin Hitchcock. 2017. The Role of Big Data in Preventing Healthcare Fraud, Waste, and Abuse. Online. (09 2017). <https://www.datameer.com/company/datameer-blog/role-big-data-preventing-healthcare-fraud-waste-abuse/>
- [5] Mark Isbitts. 2017. Preventing Health Care Fraud with Big Data and Analytics. Online. (2017). <http://www.lexisnexis.com/risk/insights/health-care-fraud-layered-approach.aspx>
- [6] Vinil Menon and Parikshi Sheth. 2016. Big Data Analytics Can Be a Game Changer for Healthcare Fraud, Waste, and Abuse. Online. (04 2016). <https://www.hfma.org/Content.aspx?id=47523>
- [7] United States Department of Health and Human Services. 2015. 2015 CMS Statistics. Online. (12 2015). <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/CMS-Statistics-Reference-Booklet/Downloads/2015CMSStatistics.pdf>
- [8] United States Department of Health and Human Services. 2016. FY 2016 Agency Financial Report. Online. (11 2016). <https://www.hhs.gov/sites/default/files/fy-2016-hhs-agency-financial-report.pdf>
- [9] United States Department of Health and Human Services. 2017. Combating Medicare Parts C and D Fraud, Waste, and Abuse Web-Based Training Course. Online. (01 2017). <https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/Downloads/CombMedCandDFWAdownload.pdf>
- [10] Inc. SAS Institute. 2017. Health Insurance Get full coverage for your big data challenges. Online. (2017). [https://www.sas.com/en\\_us/industry/health-insurance.html](https://www.sas.com/en_us/industry/health-insurance.html)
- [11] Inc. SAS Institute. 2017. SAS Fraud Framework for Health Care. Online. (2017). [https://www.sas.com/en\\_us/software/fraud-framework-for-health-care.html](https://www.sas.com/en_us/software/fraud-framework-for-health-care.html)
- [12] Healthcare Fraud Shield. 2017. FWAShield A Fully Integrated Fraud, Waste and Abuse Software System. Online. (2017). <http://www.hcfraudshield.com/fwashield.aspx>
- [13] Rodger Smith. 2016. Using Big Data in the Hunt for Healthcare Fraud, Waste, and Abuse Payers must leverage all the big data analytics tools at their disposal to hunt down healthcare fraud, waste, and abuse. Online. (04 2016). <https://recycleintelligence.com/news/using-big-data-in-the-hunt-for-healthcare-fraud-waste-and-abuse>
- [14] Dallas Thornton, Roland M. Mueller, Paulus Schouten, and Jos van Hillegersberg. 2013. Predicting Healthcare Fraud in Medicaid: A Multidimensional Data Model and Analysis Techniques for Fraud Detection. *Procedia Technology* 9, Supplement C (2013), 1252 – 1264. <https://doi.org/10.1016/j.protcy.2013.12.140> CENTERIS 2013 - Conference on ENTERprise Information Systems / ProjMAN 2013 - International Conference on Project MANagement/ HCIST 2013 - International Conference on Health and Social Care Information Systems and Technologies.

[Table 1 about here.]

LIST OF TABLES

1 Types of Fraud and their related Sources[14]

5

**Table 1: Types of Fraud and their related Sources[14]**

		Phantom Billing	Duplicate Billing	Upcoding	Unbundling	Excessive or Unnecessary Services	Kickbacks
Level 1	Single Claim, or Transaction				*	*	
Level 2	Patient / Provider		*		*	*	
Level 3	a. Patient	*	***	*	***	*	
	b. Provider	**		***	*	***	
Level 4	a. Insurer Policy / Provider	**		*	**	**	*
	b. Patient / Provider Group	*	*	*	*	*	
Level 5	Insurer Policy / Provider Group	**		**	**	**	*
Level 6	a. Defined Patient Group	**		*	*	**	**
	b. Provider Group	**		***	**	***	*
Level 7	Multiparty, Criminal Conspiracies	**		**	*	**	***

Usefulness: \* Low \*\* Medium \*\*\* High

# Big Data Applications in Improving Patient Care

Janaki Mudvari Khatiwada

University of Indiana

Bloomington, Indiana 47408

jmudvari@iu.edu

## ABSTRACT

Big data and its applications in providing best service outcome to the patients is a new trend. Patient care is the main objective of healthcare organizations. Getting best possible care in terms of costs and service outcome are patients' expectations. How service providers in health-care industries are using big volume of health related data that are generated when patients provide information about their family history, medical history, food and exercise habit or results from clinical tests? Besides health related data, patients are requested fill out a survey about their overall experiences and even asked to give any recommendations to improve their service.

## KEYWORDS

Big Data, Health Care, Patient care, Electronic health records

## 1 INTRODUCTION

Health care is one of the service sectors where service providers claim to have provided consumers with the best experiences possible, whereas consumers are always researching for the best care facilities that they could possibly get which might save time and money and help them have a quality of life. Health service providers collect high volume of information from the consumers every time when they visit the facilities. The volume of health related informations generated in a high velocity is what consist of big data in health care sector. These informations besides clinical records can be anything related to a person. Such as person's ethnic background, exercise routine and the time he/she spends on it on a weekly or daily basis, general daily meal the person intakes, records on wearable health devices and monitors. In today's world big data has become very impactful in policy making, solving problems and making prediction on whole range of areas. Healthcare industry has become one of the most important sectors to make of use of big data. Big data provides helpful insights for prevention, prediction, diagnosis and identification of best treatment option among all, on the basis of insurance plan a person has. Clinical practitioners acquire, share, compare and analyze big data trend to make their medical diagnosis, treatment recommendation, and prognosis. A richer set of near-real-time information can greatly help physicians determine the best course of action for their patients, discover new treatment options, and potentially save lives [3]. Consumers on the other hand use service provider's websites or web-pages to have an insight of the facilities and available physicians. We look for the ratings and reviews in general based upon which we choose the facility and physician. Big data applications in health care for the purpose of improving patient care is wide; disease prevention and management, health education, research and development, prognosis information sharing, public and individual health management, medical optimization. A goal of modern healthcare systems is to

provide optimal health care through the meaningful use of health information technology in order to improve health care quality and coordination, so that outcomes are consistent with current professional knowledge[7].

## 2 APPLICATIONS

Health data are stored as electronic medical records(EMR),electronic health records(EHR) or any unstructured records, which are analyzed and shared among clinicians. These data are near real time data. The EHR, being adopted in many countries, offers a source of data the depth of which is almost inconceivable. About 500 petabytes of data was generated by the EHR in 2012, and by 2020, the data will reach 25,000 petabytes[2]. One of the trending examples of application of big data in tackling opioid crisis in US. Data scientists at Blue Cross Blue Shield have started working with big data experts at Fuzzy Logix to tackle the problem. Using years of insurance and pharmacy data, Fuzzy Logix analysts have been able to identify 742 risk factors that predict with a high degree of accuracy whether someone is at risk for abusing opioids[5]. ZEO, Inc. is analyzing over a million nights of data to help consumers improve their sleep[2].

In general, applications of big data in health care for improving patient care can be categorized into following categories: Prevention, Prediction, Diagnosis, Disease Management and Research and Development.

### 2.1 Prediction

Analysis of available health records help make prediction which ultimately benefits general population. Making predictions is one of the most useful applications of big data. Researchers use analysis of medical records to make prediction of patients at risk to a disease. The United States National Institutes of Health has a project known as Pillbox, in which big data are used through the National Library of Medicine[4]. Johns Hopkins University (Baltimore, MD, USA) developed a disease prediction system using the social media service Twitter[1] The Seton Healthcare Family (Austin, TX, USA) and IBM Joint Development Program have analyzed and tracked medical information, and have predicted outcomes of two million patients per year[10]. Prediction models are especially useful in explaining epidemics and finding the best approach to deal with it. This helps in population health management. Optum Labs has collected EHRs of over 30 million patients to create a database for predictive analytics tools that will help doctors make big data-informed decisions to improve patients treatment[7]. In another study, Parkland Health and Hospital System in Dallas, Texas, has developed a validated EHR-based algorithm to predict readmission risk in patients with heart failure. Patients deemed at high risk for readmission receive evidence-based interventions, including education by a multidisciplinary team, follow-up telephone support within two days of

discharge to ensure medication adherence, an outpatient follow-up appointment within seven days, and a non-urgent primary-care appointment[8].

## 2.2 Prevention

The mantra, "Prevention is always better than cure" is what everybody wants to follow. Till now physicians have been studying the general pattern of people's lifestyle and make a recommendations on keeping as it is or make a change to prevent their patients from any health problems. Big data help them identify vulnerable population and raise awareness. For example, physicians recommend general public to watch their weight in order to prevent them from diabetes and heart disease. Another such example is, physicians have identified certain population of certain race are more prone to skin cancer when exposed to sun's ultraviolet rays while other race is more prone to have breast cancer. So, they raise awareness and make needed recommendations accordingly. This in totality help make general public's life better and help them live longer and healthy life. Now we have smart-phones and wearables to track our fitness in general, which generate huge volume of data at a high velocity. In the near future, physicians might be using these data to have an understanding of any potential problem and prepare them for necessary remedies. Often by partnerships between medical and data professionals, with the potential to peer into the future and identify problems before they happen[6]. One recently formed example of such a partnership is the Pittsburgh Health Data Alliance - which aims to take data from various sources (such as medical and insurance records, wearable sensors, genetic data and even social media use) to draw a comprehensive picture of the patient as an individual, in order to offer a tailored healthcare package[6]. 100Plus uses public and private data to motivate consumers to take small healthy steps to change daily habits via a mobile application[2].

## 2.3 Diagnosis

Early diagnosis of a disease helps in early intervention of disease management thereby saving lives and reducing costs. Prediction models developed by researchers by using big data help in early diagnosis. Predictive modeling over data derived from electronic health records(EHRs) is being used for early diagnosis and is reducing mortality rates from problems such as congestive heart failure and sepsis[7].

## 2.4 Disease Management

Wearable sensors, monitors and other smart devices help both caregivers and patients to keep track of any changes in factors that is affecting their health. Processing real-time events with machine learning algorithms can provide physicians with insights to help them make lifesaving decisions and allow for effective interventions[7]. Ideally, individual and population data would inform each physician and his or her patient during the decision-making process and help determine the most appropriate treatment option for that particular patient[9].

## 2.5 Research and Development

Big data from past help physicians identity general variables responsible for illnesses. After identifying general trend, they can make

precise recommendation to their patients and thereby help them have a quality of life and save them costs. Research and development is one of the important applications of big data and analytics that helps in finding new tools, more effective medications, drugs and treatment regimen. Data-sharing arrangements between the pharmaceutical giants has led to breakthroughs such as the discovery that desipramine, commonly used as an anti-depressant, has potential uses in curing types of lung cancer[6]. Big data helps Pharmaceuticals reduce cost of research and therefore lowers drugs cost which benefits patients. Data from clinical trials and patients records help identify adverse effects of a drug.

## 3 CHALLENGES

While big healthcare data and applications and analytics provides a huge opportunity in improving patient care, it equally comes with some challenges. Privacy and security of personal information is one of the biggest challenges. In February of 2015, the largest ever healthcare-related data theft took place, when hackers stole records relating to 80 million patients from Anthem, the second largest US health insurer[6]. Since healthcare data are large in volume and are in variety of forms; structured or unstructured, managing this big data of such variety is a challenge. Transforming big volume of unstructured data data which comes in such a velocity, into structured version is another challenge. Data sharing between institutions is another challenge. Maintaining privacy of people's records can be a huge liability for the organizations involving in information sharing.

## 4 CONCLUSION

While big data in healthcare has some challenges, it still has some very important implications. Physicians and analysts are using big data in prevention, prediction, diagnosis and disease management. With the help of big data physicians are able to identify disease risk factors and may predict a problem if those risk factors are not resolved. Thereby making needed recommendations which will ultimately help a patient. Discussions above present few examples of applications of big data for improving patient care. There is an increasing trend in making use of patients' clinical records for analytics. Going through literatures indicates that use of big data in improving patient care is in the beginning phase. Information technology has provided consumers with variety of wearables making people more conscious about their health. In near future physicians might make use of data from the wearables to have an understanding of patients health. Health insurance companies might use big streaming data from wearables to provide incentive such as lowering insurance premium or rewards point to people who are consistent in exercising.

## ACKNOWLEDGMENTS

I would like to thank prof. Gregory Von Laszewski and teaching assistants who helped me throughout my writing.

## REFERENCES

- [1] David A.Broniatowski, Michael J. Paul, and Mark Dredze. 2013. fiNational and Local Influenza Surveillance through Twitter. Online Journal. *PLoS One* 8, 12 (Dec 2013). <https://doi.org/10.1371/journal.pone.0083672>

- [2] B Feldman, E Martin, and T Skotnes. 2012. *Big data in healthcare hype and hope*. Technical Report. GHDonline. [https://www.ghdonline.org/uploads/big-data-in-healthcare\\_B.Kaplan\\_2012.pdf](https://www.ghdonline.org/uploads/big-data-in-healthcare_B.Kaplan_2012.pdf)
- [3] Hewlett Packard. 2014. *Big Data and healthcare*. Business White Paper. HP. <http://h20195.www2.hpe.com/V4/getpdf.aspx/4aa5-2847enw>
- [4] Rae Jesano. 2010. Free Drug Information Sources on the Web: Government Sites. Online Journal. *Journal of Hospital Librarianship* 10, 2 (Apr 2010), 145–151. <https://doi.org/10.1080/15323261003681554> arXiv:<http://dx.doi.org/10.1080/15323261003681554>
- [5] Mona Lebied. 2017. 9 Examples of Big Data Analytics in Healthcare That Can Save People. Web Page. (2017). <http://www.datapine.com/blog/big-data-examples-in-healthcare/>
- [6] Bernard Marr. 2015. *How Big Data is Changing Healthcare*. Blog. Forbes. <https://www.forbes.com/sites/bernardmarr/2015/04/21/how-big-data-is-changing-healthcare/#667047cf140c>
- [7] Carol McDonald. 2017. *5 Big Data Trends in Healthcare for 2017*. Web Page. MAPR Data Technologies. <https://mapr.com/blog/5-big-data-trends-healthcare-2017/>
- [8] Ravi B. Parikh, Ziad Obermeyer, and David Westfall Bates. 2016. *Making Predictive Analytics a Routine Part of Patient Care*. Web Page. Harvard Business Review. <https://hbr.org/2016/04/making-predictive-analytics-a-routine-part-of-patient-care>
- [9] Wullianallur Raghupathi and Viju Raghupathi 3. PMC. Web. 6 Oct. 2017. 2014. Big Data Analytics in Healthcare: Promise and Potential. *Health Information Science and Systems* 2, 3 (February 2014). <https://doi.org/10.1186/2047-2501-2-3>
- [10] S.Feldman, J. Hanover, C. Burghard, and D. Schubmehl. 2012. *Unlocking the power of unstructured data*. White Paper HI235064. IDC Health Insights, 5 Speen Street Framingham, MA 01701 USA. <http://uhcjsc.com/pdf/Unlocking%20the%20Power%20of%20Unstructured%20Data.pdf>

# Big Data Applications In Population Health Management

Tyler Peterson

Indiana University - School of Informatics, Computing, and Engineering

711 N. Park Avenue

Bloomington, Indiana 47408

typeter@iu.edu

## ABSTRACT

Healthcare providers are experiencing pressure to reduce costs while also delivering increasingly high quality care. External forces in the form of alternative reimbursement models and programs offering both incentives and penalties have spurred healthcare organizations to find opportunities for increasing the value of their work. Given the complexity of the healthcare system, the opportunities are vast in number. Preventing hospital admissions, management of chronic conditions and the early detection of potentially deadly conditions are a few of the major initiatives. The shared attribute of these three opportunities is that the solutions are often most effective when directed towards people who are going about their day-to-day lives in the community, as opposed to those who are currently confined to hospital beds or in an exam room. Through these programs, providers are compelled to proactively reach out to all people who make up the population they serve. To understand the needs of a population, healthcare providers must embrace big data. Novel analysis and presentation of massive, heterogenous datasets is essential. Big data applications and analytical tools are appearing at the bed side, in exam rooms and on patients themselves as providers seek to harness the power of big data.

## KEYWORDS

i523, hid331, Population Health, Predictive Analytics, Electronic Medical Records, EMRs

## 1 INTRODUCTION

The United States spent \$3.2 trillion on healthcare in 2015, 5.8 percent higher than the previous year[8]. This amounts to nearly \$10,000 per person living in America[8]. Chronic diseases such as diabetes, cancer and cardiovascular disease contribute to 70 percent of US deaths and incur 75 percent of healthcare expenditures[9]. Despite these high costs, the US lags behind other countries in quality[7]. In other words, we are paying more for less. Healthcare providers are looking to use big data to aid their efforts of reducing costs and increasing the quality of care. The system has a massive amount of data at its disposal, and the rate at which it is accumulating is increasing. In 2011, the US health system possessed 150 exabytes, and the total will soon be counted in zettabytes[14].

The proposed solutions for achieving less expensive, higher quality care are numerous and varied. Several proposals seek to alter the behavior of healthcare providers that have grown accustomed to the fee-for-service reimbursement model. Traditionally, providers are reimbursed for services rendered. Redundant tests, unnecessarily readmitted patients, and frequent emergency room visits generate a profit. This is a financial arrangement that rewards volume without consideration to value[11]. It directs attention to patients who can

be immediately provided with services, namely patients who are either in the hospital or at an outpatient appointment. This fee-for-service reimbursement model does not incentivize healthcare providers to look beyond its immediate customers and take the initiative to provide services to the community at-large.

Alternative payment models are engineered with the intention of changing that behavior. The Medicare Shared Savings Program (MSSP) is a type of Accountable Care Organization (ACO) that provides a framework for healthcare organizations to have a level of accountability for the quality, cost and patient experience of an assigned population. MSSP participants choose one of four financial risk arrangements. One track lets providers avoid any penalty, or risk, in the case that they do not lower their Medicare expenditure growth. The other three tracks offer increasingly higher risks and rewards[4]. In order to receive a share of any cost savings, ACOs must demonstrate the delivery of high quality care by reporting the organization's performance on quality measures that can be categorized into four domains - patient experience, care coordination, preventative health and at-risk population management[2].

Other initiatives penalize providers for delivering sub-standard care. In 2016, the US government penalized 2,597 hospitals for excessive 30-day hospital readmissions[15]. If patients are initially admitted with a heart attack, heart failure, pneumonia, chronic lung disease or for a hip/knee replacement procedure and are subsequently readmitted to a hospital within a month of the initial stay, a hospital is considered responsible. The penalties for those readmissions amounted to \$528 million nationally in 2016, \$108 million higher than 2015[15].

Entire communities stand to benefit from these programs. Providers must proactively engage with patients who are going about their day-to-day lives while also providing high quality care within their hospitals and at their clinics. To understand how to approach each individual that makes up their community, healthcare providers must harness the power of big data. Mitigating a hospital admission before it occurs or discovering and treating a condition before it worsens requires methodical data collection, pinpointed data analysis, and deliberate, compassionate execution of proactive healthcare delivery. Big data applications and analytical tools are essential for accomplishing those demands.

## 2 BIG DATA IN POPULATION HEALTH

Big data applications and analytics are well-suited for approaching the issues and opportunities described above because while health care is often described in macro terms, the meaningful interactions happen at the micro level. High-level, aggregated datasets may describe a population, but don't provide the necessary depth for understanding how one patient's needs and circumstances are unique from all the rest. There are various types of data that help illustrate

a patient's overall health picture. Medical claim data includes diagnoses, procedures, dates, cost and points of care. Electronic medical records (EMRs) also includes diagnoses, procedures and dates, while also cataloging lab values, free-text notes, images and medication lists. Clinical trial data, patient satisfaction survey data, genomics data and medical device data also contributes to the massive amount of healthcare data available to providers[10].

This data can be used to meet the nuanced demands of alternative reimbursement models and avoid readmission-related penalties. These programs have attributes that lends themselves to big data applications. MSSP participants need to attest to 31 measures in 2017. These measures, for example, address diabetics with poor hemoglobin A1c control, all-cause, unplanned admissions for heart failure patients, use of imaging studies for low back pain, and patients' perceived quality of communication with providers[3]. Data is essential for identifying patients who fall within the scope of each metric, determining which patients have already met the goal of the measure, and engineering processes to help make providers aware of the patients who have yet to receive the recommended intervention. For example, a healthcare organization must identify their diabetic patients (typically with ICD-10 diagnosis codes), determine which of those patients had their hemoglobin A1c tested within the measurement period, and had a lab result within the accepted value range. Patients may fail the measure in one of two ways: a patient either has not been tested within the measurement period or the patient has a lab value outside of the acceptable range. Patients in the former category should be contacted by the provider and have an appointment scheduled to have the lab drawn. The patients in the latter category should be treated in a manner that brings the hemoglobin A1c within the acceptable range and followed closely by a care team.

To avoid penalties associated with readmissions, some healthcare providers are employing advanced techniques, such as machine learning, to identify patients who are at high risk of being readmitted within 30 days of the initial hospital stay. Mount Sinai Health System in New York, NY, developed a predictive model to evaluate heart failure patients for risk of readmission. The model building began by analyzing 4,205 attributes, including 1,763 diagnosis codes, 1,028 medications, 846 laboratory measurements, 564 surgical procedures, and 4 types of vital signs[13]. Mount Sinai concluded that their model featured in the research study outperformed the previous models used to assess their heart failure patients, while conceding that the model needs to be updated and recalibrated with several years of data from several different hospital sites[13]. In other words, even more data is needed. In the meantime, this model can still be used to analyze each heart failure patient prior to discharge for the likelihood of readmission. Care teams can then dedicate extra resources to the especially high-risk patients.

Wearable technology has also infiltrated the healthcare space, especially devices that can remotely and wirelessly monitor patients' vitals and symptoms. The data feeds can be used by providers to assess the effectiveness of (and adherence to) medications, observe lifestyle habits, or recommend that a patient schedule a follow-up appointment or go to an emergency room[1]. There are hundreds of thousands of mobile health apps available in app stores, and more than half of these are geared for patients with chronic diseases[1]. This technology has appeared in clinical trials as well. A study

determined that patients with type 2 diabetes who monitored blood glucose with an app achieved greater reduction in hemoglobin A1c results compared to patients who did not use an app[6].

### 3 INFRASTRUCTURE

The infrastructure needed to support these efforts is complex. A cornerstone of enabling big data analysis in healthcare is EMR software. EMRs replace the paper chart as the location for all details related to patient care. These information systems gather a wide variety of information, including patient encounters, lab results, medications, diagnoses, and procedures, as well as demographic and socioeconomic information, among many other data elements. Providers may also add notes by typing or through dictation software. The information is stored in data warehouses that can be queried and analyzed in a way unimaginable in the era of paper charts. EMRs can also be programmed to remind or notify a provider that, for example, a patient meets the criteria for the MSSP colonoscopy screening measure and has not had a colonoscopy in ten years, so an appointment for the procedure should be scheduled. As of May 2016, 96 percent of non-Federal acute care hospitals had adopted a certified EMR[5].

Health care data is growing in such a way that it benefits from big data applications such as Hadoop and MapReduce, which create a framework capable of handling massive amounts of structured data, such as discrete lab values and diagnosis codes, and unstructured data, such as physician notes. Hadoop breaks the large datasets into smaller subsets, MapReduce processes those subsets independently and in parallel, and the processed subsets are combined into a final result[12].

Data visualization tools are also essential for communicating key messages in data. Tools such as Tableau and Qlikview, and open source code libraries such as Plotly and Bokeh (written for Python), allow savvy users to present large, complex data sets in visually compelling ways to quickly communicate important ideas. Dashboards can promote exploratory data analysis, and can engage even those who are not technical through easy to use point-and-click user interfaces.

### 4 CONCLUSION

Big data applications are capable of turning data into insights, and this is critical for aiding healthcare providers in their efforts to evolve the way they practice medicine. EMRs will continue to amass vast amounts of information about patients and their unique characteristics and needs. Programs and policies will continue to foster the mindset that healthcare providers must actively consider all individuals who constitute the population they service, not just the patients actively in a hospital or present in a clinic. Big data applications will continue to be engineered to deliver the right information to the right provider. These tools will promote the most beneficial action for each individual patient.

### ACKNOWLEDGMENTS

The author would like to thank Professor Gregor von Laszewski and his teaching assistant for their help with Github, Latex and JabRef.

## REFERENCES

- [1] Linda Brookes. 2017. Can Technology Transform Chronic Disease Management? (April 2017). <https://www.medicalnewstoday.com/articles/317016.php>
- [2] Centers for Medicare and Medicaid Services. 2017. Accountable Care Organization 2017 Quality Measure Narrative Specifications. (January 2017). <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/sharedsavingsprogram/Downloads/2017-Reporting-Year-Narrative-Specifications.pdf>
- [3] Center for Medicare and Medicaid Services. 2017. Medicare Share Savings Program Quality Measure Benchmarks for 2016 and 2017 Reporting Years. (December 2017). <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/sharedsavingsprogram/Downloads/MSSP-QM-Benchmarks-2016.pdf>
- [4] Centers for Medicare and Medicaid Services. 2017. New Accountable Care Organization Model Opportunity: Medicare ACO Track 1+ Model. (July 2017). <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/sharedsavingsprogram/Downloads/New-Accountable-Care-Organization-Model-Opportunity-Fact-Sheet.pdf>
- [5] JaWanna Henry, Yuriy Pylypchuk, Talisha Searcy, and Vaishali Patel. 2016. Adoption of Electronic Health Record Systems Among U.S. Non-Federal Acute Care Hospitals: 2008–2015. (May 2016). <https://dashboard.healthit.gov/evaluations/data-briefs/non-federal-acute-care-hospital-ehr-adoption-2008-2015.php>
- [6] Can Hou, Ben Carter, Jonathan Hewitt, Trevor Francisa, and Sharon Mayor. 2016. Do Mobile Phone Applications Improve Glycemic Control (HbA1c) in the Self-management of Diabetes? A Systematic Review, Meta-analysis, and GRADE of 14 Randomized Trials. *Diabetes Care* 39, 11 (November 2016), 2089–2095. <http://care.diabetesjournals.org/content/39/11/2089>
- [7] Rabah Kamal and Cynthia Cox. 2017. U.S. Health System is Performing Better, Though Still Lagging Behind Other Countries. (May 2017). <https://www.healthsystemtracker.org/brief/u-s-health-system-performing-better-though-still-lagging-behind-countries/#item-start>
- [8] Anne B. Martin, Micah Hartman, Benjamin Washington, Aaron Catlin, and National Health Expenditure Accounts Team. 2017. National Health Spending: Faster Growth In 2015 As Coverage Expands And Utilization Increases. *Health Affairs* 36, No. 1 (2017), 166–176. <http://content.healthaffairs.org/content/36/1/166>
- [9] Farshad Fani Marvasti and Randall S. Stafford. 2012. From Sick Care to Health Care - Reengineering Prevention Into The U.S. System. *The New England Journal of Medicine* 367, 10 (September 2012), 889–891. <http://www.nejm.org/doi/full/10.1056/NEJMmp1206230#t=article>
- [10] Carol McDonald. 2016. How Big Data Is Reducing Costs And Improving Outcomes In Health Care. (June 2016). <https://mapr.com/blog/reduce-costs-and-improve-health-care-with-big-data/>
- [11] Harold D. Miller. 2009. From Volume To Value: Better Ways To Pay For Health Care. *Health Affairs* 28, 5 (2009), 1418–1428. <http://content.healthaffairs.org/content/28/5/1418.abstract>
- [12] Elizabeth O'Dowd. 2016. How Hadoop Supports Healthcare Data Analytics Infrastructure. (October 2016). <https://hitinfrastructure.com/news/how-hadoop-supports-healthcare-data-analytics-infrastructure>
- [13] Pacific Symposium on Biocomputing (Ed.). 2016. *Predictive Modeling of Hospital Readmission Rates Using Electronic Medical Record-Wide Machine Learning: A Case-Study Using Mount Sinai Heart Failure Cohort*. Vol. 22. Pacific Symposium on Biocomputing. <https://www.ncbi.nlm.nih.gov/pubmed/27896982>
- [14] Wullianallur Raghupathi and Viju Raghupathi. 2014. Big Data Analytics In Healthcare: Promise And Potential. *Health Information Science and Systems* 2, 3 (2014). <https://www.biomedcentral.com/track/pdf/10.1186/2047-2501-2-3?site=hissjournal.biomedcentral.com>
- [15] Jordan Rau. 2016. Medicare's Readmission Penalties Hit New High. (August 2016). <https://khn.org/news/more-than-half-of-hospitals-to-be-penalized-for-excess-readmissions/amp/>

# Distributed Environment For Parallel Neural Networks

Ajinkya Khamkar  
Indiana University  
P.O. Box 1212  
Bloomington, Indiana 47408  
adkhamka@iu.edu

## ABSTRACT

The past decade has seen the rise of Deep Neural Networks. A standard Deep Convolutional Neural Network has an upwards of Million parameters to train[1]. The data required to train these networks typically ranges in Hundred's of Gigabytes, making it inefficient to train these networks on standalone machines. Graphical Processing Units decrease the computation time significantly but suffer from memory constraints. Existing Industrial architectures use a distributed computing paradigm capable of handling parallel computing tasks. I highlight approaches which use cheaper commodity systems integrated in a distributed fashion to handle training such Deep Neural Networks.

## KEYWORDS

I523, Distributed Systems, Convolutional Neural Networks, Parallel Systems, Deep Neural Networks

## 1 INTRODUCTION

The past decade has seen the rise of Deep Neural Networks. Neural Networks have the ability to model complex non-linear functions by efficiently representing the input parameters as a system of linear equations with non-linear activation. They have achieved unparalleled success in the fields of Computer Vision, Natural Language Processing and Artificial Intelligence. Section 2 discusses the number of parameters required to be trained for popular deep architectures. Large amounts of data is required to train these parameters. Section 3 discusses the size of the traditional data sets used to train these networks. Deep Neural Networks are inherently parallel in nature, with weights and gradient updates shared across layers within the network. Section 4 discusses various ways to introduce parallelism while training Deep Neural Networks. Section 5 discusses methodologies to update Model parameters when the data to train is distributed across multiple machines within the network. Section 6 introduces methodologies to train multiple layers of the same network in parallel in a distributed fashion.

## 2 POPULAR ARCHITECTURES

AlexNet[1], which achieved state of the art top 5 error of 19.80 % for the Imagenet Large Scale Image Recognition Challenge in 2012 trained 60 Million parameters. In subsequent years, VGG-16 [2] a 16 layer deep convolutional neural network achieved state of the art top 5 error of 8 % in 2014 trained 138 Million parameters. ResNet [3], used a 152 layer deep architecture and trained 60 Million parameters to achieve top 5 error of 6.16 %. DeepMind's Alpha Go agent ran on 48 CPU's and 8 GPU's.

## 3 DATA SIZE

Youtube 8 Million video data set is one of the most popular datasets to train video classification algorithms. The total size of the dataset is 1.7 terabytes. The Imagenet Large Scale Image Recognition dataset 2012, used to train popular deep learning classification algorithms has a total of 22,000 classes and has a size of 138 gigabytes.

## 4 PARALLEL AND DISTRIBUTED ARCHITECTURES

### 4.1 Convolutional Neural Networks

Convolutional Neural Networks drive modern Computer Vision and Artificial Intelligence based research. The convolution operation involves sliding a filter of a predefined size over the input data and perform element-wise multiplication. They are capable of extracting higher level information from input data and project them to lower level embedding. The patterns identified in the lower level embedding can be used to perform various Machine Learning tasks such as classification, clustering, object recognition and source separation.

**Parallelism of convolution operation.** Every layer of a Convolutional Neural Network has a stacked input of filters. These filters are responsible for extracting higher level information from the input data. The filters operations are independently applied to the input data. This makes it possible to compute these operations in parallel to each other and collate their results. Recent advanced software architectures such as tensorflow and theano are capable of achieving computation in parallel using multiple cores. Additionally Graphical Processing Units can be explicitly programmed for parallel implementation of the convolution operator to achieve state of the art computational results.

### 4.2 Need For distributed approaches

Standard Convolutional Neural Networks have millions of parameters to train and optimize. Additionally the data required to train these systems ranges in Hundred's of Gigabytes. These computational constraints make it inefficient to train deeper networks on stand alone machines.

- Data Parallelism - When the data required to train neural networks exceed the systems storage capacity, it is required to distribute the data across multiple machines and introduce a data pipeline to feed input to the network.
- Model Parallelism - When the model being trained is too large to fit into the main memory. It is required to distribute different layers of the model across different machine and

use distributed variants of Stochastic Gradient Descent to update each layer being processed on different machines.

## 5 DATA PARALLELISM

Data parallelism involves storing the input data required to train our Convolutional Neural Network Model across multiple machines. Each machine runs the same network model. Each model is then trained on an unordered random subset of the data. One of the biggest challenges faced in data parallelism is updation of model parameters. These are broadly classified into 2 categories.

- Synchronous update - In synchronous updates, gradients are computed using the loss generated by each model on a mini-batch of the independent input. Weights are updated using a single gradient generated by averaging the losses of each model.
- Asynchronous update - In asynchronous updates, each model runs independently. Global parameters shared by multiple models are held in a global parameter server. Each model then fetches the updated parameters from the server to process the mini-batch

### 5.1 Synchronous Updates

Zinkevich, Weimer, Smola & Li, 2010 [4] introduced a parallel variant of the traditional Stochastic Gradient Descent algorithm. They designed a simple yet efficient algorithm which averaged the gradients generated by the multiple machines within the network. This method is shown to converge and provide an optimal speedup.

**Algorithm 1** Parallel SGD ( $\{c^1, \dots, c^m\}, T, n, w_o, k$ )

---

```

1: for machine  $\in \{1, \dots, k\}$  in parallel do
2:    $v_i = SGD(\{c^1, \dots, c^m\}, T, n, w_o)$ 
3:    $v = \frac{1}{k} \sum_{i=1}^k v_i$ 
4: Return  $v$ 
```

---

### 5.2 Asynchronous Updates

Dean et. Al, 2012 [5] introduced an asynchronous variant of the traditional Stochastic Gradient. They proposed the use of a centralized communication server which holds parameters used by all models running in parallel. The communication server is distributed across several machines. Each model requests the centralized server for updated parameters before processing the mini-batch. Thus each model requests only those machines which holds parameters relevant to its partition. After computation of the gradient post processing the mini-batch the centralized server is updated with the new gradients. Subsequently the parameters are updated using the newly computed gradient. Asynchronous updates are more robust as compared to Synchronous updates. If a machine within the network fails, other machines are still up and computing their gradients.

**Algorithm 2** Downpour SGD ( $p, d$ )

---

```

1: for machine  $\in \{1, \dots, k\}$  in parallel do
2:   query updated parameters from server
3:    $v_i = SGD(p, d)$ 
4:   Update centralized server with  $v_i$ 
5:    $p = p - \nabla v_i$ 
```

---

## 6 MODEL PARALLELISM

Model parallelism involves training different layers of the Deep Neural Network in a distributed fashion across several machines in a network. In Model parallelism, different layers at the same level within the network are trained on the same input data. Model parallelism is required when the size of the network is too large to fit in main memory. Recent research in Deep Convolutional Networks is focused on the ‘wider’ paradigm instead of the traditional ‘deeper’ paradigm [6]. Wider Convolutional Networks can be viewed as a stack of smaller networks connected in parallel. Each of these smaller networks is designed and optimized to extract complex relationships in the input data at different depth levels. Wider Networks are computationally efficient than deeper networks. These smaller networks can be trained in parallel across multiple cores as these networks do not suffer from resource sharing. Each network in a layer gets its own copy of the output from the previous layer. A master layer is required to collate the results of the smaller networks to be passed to the next layer of the Network.

## 7 CONCLUSION

The number of parameters to train a neural network optimally have been increasing in the last few years. The data required to train these networks efficiently is continuously increasing. Standalone architectures are quickly being replaced with distributed architectures designed to handle training of these networks. Existing Industrial architectures can be tuned to train deep neural networks. They are optimal for training such networks with little to no additional cost of setup and expertise. With the techniques presented above, deeper architectures can be trained efficiently and optimally to achieve state of the art results.

## REFERENCES

- [1] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E Hinton. Imagenet classification with deep convolutional neural networks. In *Advances in Neural Information Processing Systems 25*. 2012.
- [2] Karen Simonyan and Andrew Zisserman. Very deep convolutional networks for large-scale image recognition. *CoRR*, abs/1409.1556, 2014. URL <http://arxiv.org/abs/1409.1556>.
- [3] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. *CoRR*, abs/1512.03385, 2015. URL <http://arxiv.org/abs/1512.03385>.
- [4] Martin Zinkevich, Markus Weimer, Lihong Li, and Alex J. Smola. Parallelized stochastic gradient descent. In *Advances in Neural Information Processing Systems 23*, pages 2595–2603. 2010. URL <http://papers.nips.cc/paper/4006-parallelized-stochastic-gradient-descent.pdf>.
- [5] Jeffrey Dean, Greg S. Corrado, Rajat Monga, Kai Chen, and Matthieu et al Devin. Large scale distributed deep networks. *NIPS’12*, 2012.
- [6] Christian Szegedy, Wei Liu, Yangqing Jia, Pierre Sermanet, Scott E. Reed, Dragomir Anguelov, Dumitru Erhan, Vincent Vanhoucke, and Andrew Rabinovich. Going deeper with convolutions. *CoRR*, abs/1409.4842, 2014. URL <http://arxiv.org/abs/1409.4842>.

# Big Data in Machine Learning

ZhiCheng Zhu

Indiana University Bloomington

936 S Clarizz Blvd

Bloomington, Indiana 47401

zhuzhic@iu.edu

## ABSTRACT

With the development of IT technology, the world will enter the information age. People also called this “the era of third industrial revolution”. Given the continuous development of the process of the third industrial revolution, all aspects of the traditional way of human society are changing. It can be said that every minute on the internet, have large amounts of new information be produced. With the increasing use of the internet and the increase of network bandwidth. People are making data every moment. It makes the information increasing quite quickly at a phenomenal rate. With so much data becoming available, getting data is not a problem for us anymore but find the right resource from the expanding information becoming a problem for most of the researchers. Because the data collected and stored at enormous speeds and human analysts may take weeks to discover useful information, traditional techniques are unfeasible for big data area. Therefore, we need to find new techniques to meet the challenge.

## KEYWORDS

i523, hid229, Big data, Machine Learning, Technology

## 1 INTRODUCTION

The word “Machine Learning” first raised by Arthur Samuel, an American pioneer in the computer gaming and artificial intelligence areas [1]. In a broad sense, machine learning is a way to give the machine the ability to learn so that it can complete some task which not done directly by programming. It is a way of using Data to produce a model and then using the model to do prediction. Traditionally, if we want the computer to work, we will give it a series of computer instructions, and then the computer will follow this instruction step by step. The consequence always results by the code which you input before. And you can predict the result. But this way does not work in machine learning. Machine learning does not accept the instructions you entered at all, instead, it will accept the data you entered and applications of machine learning methods to these data sets and finally get produce a result. The core of big data is finding the value from the massive data sets, machine learning is a key technique that can effectively use the data value, for big data, the machine learning is indispensable. On the contrary, for machine learning, the more data will be more likely to improve the accuracy of the model. Therefore, the rise of machine learning is also inseparable from the help of big data. Big data and machine learning are mutually reinforcing and dependent.

## 2 CHALLENGES IN MACHINE LEARNING

Compared with the traditional machine learning, machine learning in big data can greatly expand the number of samples, the classification of many problems have a rich sample as support, this is the advantage of big data, but also caused many problems. Now, with the continuous optimization of hardware and programming algorithms, data collection and magnitude are no longer the major problems hindering the big data research. The relationship between different data sets, what kind of data is useful, which date is redundant and even cause interference to other data, how to reduce noise and make the model more accurate will be a challenge facing by machine learning when it mixes with big data. Big data has great potential value in all aspects of our society, it is not a simple task to obtain valuable information from big data. The core target of machine learning in big data is to excavate the data value which hidden in the data sets and find the information we need so as to maximize the value of data from the huge volume and structure of the data.

### 2.1 CHALLENGES IN PAST, NOW, AND FUTURE

Machine Learning has made extraordinary progress in the last 30 years. There have been significant advances in some area such as “Data Security, Finance, Marketing Personalization, Recommendations, and Smart Cars”. But there are still a lot of obstacles for machine learning to go a step further. for example, lack of available data sets will be a problem whatever the past, the present, or the future. It has always been a problem. In the past, it is hard for a data scientist to find a tool to collect intensive data for researching. Nowadays, most of the data are collected by the big Internet company. the key problem of machine learning becomes to how people can get permission to access the data sets which owned by these big internet company. In the future, as the machine learning develop, the safety will become increasingly become the focus of attention. The Machine learning can be broken down into the following categories:

- “Supervised learning is a type of machine learning algorithm that uses a known data set (called the training data set) to make predictions. The training data set includes input data and response values. From it, the supervised learning algorithm seeks to build a model that can make predictions of the response values for a new data set. A test data set is often used to validate the model. Using larger training data sets often yield models with higher predictive power that can generalize well for new data sets.” [3].

- “Unsupervised learning is a type of machine learning algorithm used to draw inferences from data sets consisting of input data without labeled responses” [4].
- Semi-Supervised Learning: A learning method combining supervised learning with unsupervised learning. Recognition is done using a large amount of unlabeled data and also using labeled data at the same time.

For example, one of the most common problem in Machine learning is Catastrophic forgetting, as we all know the machine learning need learning from the enormity of data and create a model. Catastrophic forgetting means the model will completely and abruptly forget previously learned information upon learning from some new data sets. If we want to achieve artificial general intelligence, then machine learning must be able to be used to perform multiple tasks. Even we can use representation learning and transfer learning to help us solve this problem to a certain extent but still has significant performance degradation. Another problem for machine learning is the safety. If we want to apply machine learning in people's daily life. The security will be a question which the Data scientist unable to avoid. For example, in an image recognition test, “starting with an image of a panda, the attacker adds a small perturbation that has been calculated to make the image be recognized as a gibbon with high confidence”[6]. Another problem might raise because of the type of data sets. There are several different types of data in the Big Data area. The original unlabeled data and labeled data. the labeled will highly increase the efficiency of the process when the model starts to learning. Also, it will make the model more accurate when they do recognition. But the fact is even though the data increasing quite quickly at a phenomenal rate, with 2.5 quintillion bytes a day. but most of these data are unlabeled, which means these data are useless for supervised learning. and it also not suitable for deep learning which is the subset of machine learning.

### 3 APPLICATIONS IN MACHINE LEARNING

With the development expands and skills improved, machine learning becoming more popular and accepted by a lot of areas. Machine learning has been widely applied in data mining, computer vision, Natural Language Processing, biometrics, search engines, medical diagnosis and detection of credit card fraud, securities market analysis, DNA sequencing, speech and handwriting recognition, strategy games and robotics areas.

#### 3.1 Machine learning in data mining

Data mining has been influenced by many disciplines, including database, machine learning, and statistics. To put it crudely, databases provide data management techniques, machine learning and statistics provide data analysis techniques. Many techniques provided by the statistical areas usually need further develop in the machine learning field, and then become effective machine learning algorithms before they can enter the field of data mining[5]. Statistics affects data mining through machine learning, while machine learning and database are two major supporting technologies of data mining.

#### 3.2 Machine learning in recommendation system

One of most common application in machine learning area is the recommendation system which running on the different Big internet company. Amazon may be taken as a typical example of the recommendation system. Based on a user's shopping record and a lengthy wish list, identifies which of the products the user is really interested in and willing to buy. Such a decision model can help the company to provide advice to customers and boost product consumption. for example, when you Log on to Facebook or GooglePlus, and they recommend the user who might be associated with you or you might know[2].

#### 3.3 Machine learning in Marketing Personalization

According to the behavior pattern of the user during the free trial and the behavior in the past, which users might change to be a premium user, and which will not?. Such a decision model can help the company intervene in the program to convince users to pay sooner or better participate in product trials. For example, most of the video website and streaming media provider are willing to give user a free trial which can collect the user information and produce more attractive video or series to increase the user base[2].

### 4 CONCLUSION

Big data and machine learning are the two most popular fields in the Information Technology area. From the middle evil times' blocking of information to the explosion of data now, the amount of data in various fields and the scale of data sets have been increased at a phenomenal rate. The huge volume of data has brought huge potential opportunities and changes. With the proper use of the machine learning in big data can produce a lot of advantage. such as improve the efficiency. we can use the advantage of these data to help us make a better decision in different fields. one of a good example in scientific research is the data-driven research. In the scientific research, we can use the big data of the search engine to predict the ability widely used in the fields of medicine, astronomy and so on

### 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] R. Kohavi and F. Provost. 1998. *Machine Learning*. Vol. 30. 271–274 pages.
- [2] Bernard Marr. 2016. The Top 10 AI And Machine Learning Use Cases Everyone Should Know About. (2016). Retrieved October 09, 2017 from <https://www.forbes.com/sites/bernardmarr/2016/09/30/what-are-the-top-10-use-cases-for-machine-learning-and-ai/#d4886ea94e9>
- [3] Mathworks. 2016. Introducing Machine Learning. (2016). Retrieved October 09, 2017 from <https://www.mathworks.com/discovery/unsupervised-learning.html>
- [4] Mathworks. 2016. Introducing Machine Learning. (2016). Retrieved October 09, 2017 from <https://www.mathworks.com/discovery/supervised-learning.html>
- [5] Margaret Rouse. 2017. data mining. (2017). Retrieved October 09, 2017 from <http://searchsqlserver.techtarget.com/definition/data-mining>
- [6] Ophir Tanz and Cambron Carter. 2017. Why the future of deep learning depends on finding good data. (2017). Retrieved October 09, 2017 from <https://techcrunch.com/2017/07/21/>

[why-the-future-of-deep-learningdepends-on-finding-good-data/](https://www.tensorflow.org/tutorials/images/data_augmentation)

# Big Data Application in Web Search and Text Mining

Wenxuan Han

Indiana University Bloomingtonn

1150 S Clarizz Blvd

Bloomington, Indiana 47401-4294

wenxhan@iu.edu

## ABSTRACT

Because of the rapid development of social media, there are gigantic amount of data generated in every second on the web. And those data could be stored in any forms like text, videos, images or their combinations. The more complicated forms of data, the more space it will take up and will cost more time to read it. Although most of today's personal computers have a very high performance, it is extremely difficult to process and analyze useful text information from those huge amount of unstructured data by using traditional single computer methods without the help of big data tools or text mining techniques. Fortunately, the improvements in big data application are also increasing fast in order to support those difficult works on web search and text mining. This paper first studies the knowledge of web search technique and its data analytic steps, then introduces the link structure with a broad analysis of some web page structures (Hubs and PageRank), and at last, discusses their applications in this field of big data.

## KEYWORDS

I523, HID209, Big Data, Social Media, Web Search, Text Mining, PageRank, Hubs

## 1 INTRODUCTION

In recent years, social media has become more and more popular as a new way of communication and knowledge transfer. People could use it to create, share, exchange information and create their own network. Social media usage has been boosted from 2005 to 2015. Users between 18 and 29 ages are the mainly part of social media users [7]. Today 90% of young adults are active on social media. This proportion was 12% in 2005 [1]. And since the development of mobile products, social media has also been offered a better platform for users to share data faster and more convenient. Thus, this proportion could be keep stable or still increase during the next few years.

Nowadays, a growing number of people prefer to express their opinion and feelings through tweeting, sharing images, commenting on social sites [7]. Since the amount of such data become extremely large, it is significant to extract and analyze useful information through them by using text analysis methods. Therefore, some applications which based on these information have been developed, such as recommendation system and search engine.

However, as the big data began to appear in the website, there are some problems that people must face for web search which include the longer search queries (key words) requirement, support the huge number of searches and multiple languages. And these problems cause the progress of web search and text mining technologies.

Web search is similar to information retrieval (IR) which is used to search for information on the World Wide Web [10]. The information may be a mix of web pages, images, and other types of files. Since web search is applying on web which has the huge amount of data, it has a much larger scale than many IR systems. Although web search is a complex technique, it has the capability to understand how to crawl internet to get and update information.

Text mining (also known as knowledge discovery in text database [4]) is semi-automatic process of discovering information, meaningful contents, topics, word, relations and patterns from a large amount of text data [7], which is also a branch of data mining. The text data could be extracted by web search at first.

## 2 WEB SEARCH TECHNIQUE

### 2.1 Key Fundamental Principles

DIKW hierarchical model is the most basic model in the information management, information systems and knowledge management disciplines. Thus, it also used behind web search technique. It contains four main components: data, information, knowledge and wisdom. Since this paper only considers this model in web search area, these four components have the following conception.

- Data: raw web pages or “documents viewed as a bag of words”.
- Information: result of query or “documents viewed as a collection of insights”.
- Knowledge: result of processing query results by user.
- Wisdom: synthesis of many such actions by a set of users.

Figure 1 shows the hierarchical framework of DIKW model. It shows a pyramid contructure with wisdom in the top level and data in the bottom level.

[Figure 1 about here.]

### 2.2 Search Engines

A web search engine is a software system for searching information on the Internet. The search results are generally presented in a line which are often referred to as search engine results pages. And some search engines also have the capability to mine data from databases or other open directories. Unlike web directories, which are maintained only by human editors, search engines also maintain web crawling, indexing and searching processes in real-time [10]. Table 1 displays the development of search engines and some searching technologies in recent years.

[Table 1 about here.]

### 2.3 Boolean and Vector Space Models

After discussed the basic principles and the application of web search, here introduce a model that used to define the search technique. Boolean model and vector model are both retrieval model that can be a description of either the computational process or the human process of retrieval. For a retrieval model, it specifies the details of [6]:

- Document representation.
- Query representation.
- Retrieval function (how to find relevant results).
- Determines a notion of relevance.

In boolean model, keywords are considered to be either present or absent in a document and to provide equal evidence with respect to information needs. Queries are boolean expressions of keywords, which connected by AND ( $\wedge$ ), OR ( $\vee$ ), and NOT ( $\neg$ ), including the use of brackets to indicate scope [6]. Thus, for the output of this model, the result document should be either relevant or not, and could not give partial matches or a ranking. Although this model is easy to understand and offers a clean formalism, it might become extremely complicated for most of web users in big data.

For vector space model, documents and queries are vectors in a high-dimensional space. Assume  $t$  distinct terms remain after preprocessing. Each term ( $i$ ) in a document or query ( $j$ ) is given a real valued weight  $w_{ij}$ . Therefore, both documents and queries are expressed as  $t$ -dimensional vectors [6]:

$$d_j = (w_{1j}, w_{2j}, \dots, w_{tj})$$

There are some patterns to represent term weight. One is the Term Frequency, which assume that important terms have the higher frequency of occurrence in a document. The following equation define the vector space model.

$$tf(t, d) = \begin{cases} 0, & freq(d, t) = 0 \\ 1 + \log freq(d, t), & \text{otherwise} \end{cases}$$

While  $t$  refers to terms, and  $d$  refers to documents. This model straightforward to map everything to a vector and compare their angles. But it is hard to find a good set of basis vectors, a good weighting scheme for terms and a comparison function.

### 2.4 Web Crawling

It is not difficult to extract data from web with the help of algorithms. The input of the algorithm could be a list of URL's visited already and a list of new URL's to visit. Then executes the following steps in a loop:

- (1) Fetch URL off list and check if done.
- (2) If not done, go to web and continue collect.
- (3) Hand document to document analyser.
- (4) Extract all URL's and add to list of new URL's to visit.

The result could be lots of detail of course. Then after fetching from the web, it should do the following steps:

- (1) Convert document from HTML, PDF, Word, ... to a text document.
- (2) Tokenization: remove formatting, punctuation, capitals and convert to common form which makes document become a set of canonical tokens.
- (3) Filtration: remove "stop words" (e.g. the, is, a, etc.).

- (4) Stemming and Normalization: remove inflections and cope with non trivial synonyms.

Then the output are contents in bag of words and final terms are those used to define each dimension of vector space model.

## 3 WEB DATA (TEXT) MINING

### 3.1 Web Data Analytics Steps

For the big data which people search from web, it could be very difficult to extract or analyze useful information behind them. Thus, it is necessary to define the following steps to make those data structured or orderly so that people could easily applying other techniques like text mining to analyze them.

- (1) Get the digital data from web.
- (2) Preprocess data into searchable data like words or positions.
- (3) Form Inverted Index in order to map words to documents.
- (4) Use algorithm like PageRank to rank relevance of documents.
- (5) Apply some technologies (e.g. reverse engineering, preventing reverse engineering, etc.) for web advertising.
- (6) Build the structure of the Internet and its people and pages.
- (7) Clustering documents into topics.
- (8) Might utilize Bayes to convert Mathematics of frequency into Mathematics of belief.

### 3.2 Link Structure Analysis

Since link structure has the significant impact to Search Engine Rankings, the PageRank flow and the number of pages that get indexed, it became one of the important factors of SEO (Search Engine Optimization) [2].

Link structure explores the connectivity patterns between web pages that contain the useful information and makes the huge of websites statistics meaningful. That is to say, mining these big data could help us understand what kind of things that users looking for, what are the hottest categories of a website and which pages are the most popular. Continuous optimization of link structure can eliminate duplicate content and promote popular pages in order to get more pageviews and higher rankings on Search Engine results [2].

An idea of the link structure for web pages is Hubs, which is known as Hubs and Authorities. The concept of this idea is simple: certain web pages served as large directories that were not actually authoritative in the information for users, but have links that led users direct to other authoritative pages [5]. Figure 2 shows the structure of Hubs.

[Figure 2 about here.]

As it shows in this figure, a good hub represented a page that pointed to many other pages and a good authority represented a page that was linked by many different hubs.

After defined the link structure of web pages, it comes to a link analysis algorithm named PageRank used by Google Search to rank websites in their search engine results. It is a way of measuring the importance of website pages. PageRank assigns a numerical weighting to each element of a hyperlinked set of documents with the purpose of "measuring" its relative importance within the set.

The numerical weight that it assigns to any given element  $E$  is referred to as the PageRank of  $E$  and denoted by  $PR(E)$  [9]. The output of PageRank is a probability distribution that a page will be visited by a person who has the same probability to click each link on this page. This probability could be calculated iteratively with each page getting a contribution at each iteration equal to its page rank divided by the sum of links on page:

$$PR(\text{page } i) = \sum_{\text{page } j \text{ pointing at } i} \frac{PR(\text{page } j)}{\text{number of pages linked on page } j}$$

For example, a PageRank of 0.5 means there is a 50% chance that a person clicking on a random link will be directed to the document with the 0.5 PageRank [9]. PageRank could be used in ranking academic doctoral programs, recommendation systems and many other searching areas.

### 3.3 Clustering and Topic Models

After obtained results through a search query, it is important to classify them by groups for the further analysis. Clustering, also known as grouping document together, is the responses to a search query which give a group of documents. Suppose documents are the points in a space, the task of clustering is to identify regions. There are several ways to do this task:

- Clustering: Nearby regions of points.
- Support Vector Machine (SVM): Chop space up into parts.
- Gaussian Mixture Models (GMMs): A type of fuzzy clustering.
- K-Nearest Neighbors.

Alternatively, some “hidden meaning” can be determined with a topic model. It used to discover the abstract “topics” that occur in a collection of documents so that people could group documents by those topics. Topic modeling is a frequently used text-mining tool for discovery of hidden semantic structures in a text body [3]. Assume each document is a set of topics and each topic is a bag of words, a topic model aims to find the best set of topics and best set of words in topics through a mathematical framework. That is to say, it allows people to examine a set of documents and discover what the topics might be and what each document’s balance of topics is [3].

## 4 CONCLUSION

The aim of this paper is to demonstrate the core contents and the technique background of web search and text mining in big data area. Since the growth amount of data generate on web everyday cause the traditional computing methods and algorithms inefficiency, it is essential to make innovations in web search aspect. In the recent twenty years, search engines developed quickly and DIKW model, which was known as a popular model used in information system before, has applied in web for building its basic principles as well. As the vector space model appeared, the simple boolean model has been replaced in order to define the search query model more completely. And with the help of web crawling algorithm, multiple types of text data extracted from website have become normalized before mining (analysis) the useful information.

Since webs page could seem as link structure, there must exists some patterns between linked pages. PageRank which found by

Google is still widely applied in many different big data systems today, it has the ability to find the most relevant page for the content that the user searches for. After obtained pages of data information, we could utilize clustering to group documents together by topics.

## ACKNOWLEDGMENTS

The author would like to thank Professor Gregor von Laszewski and all TAs for providing the resource, tutorials and other related materials to write this paper.

## REFERENCES

- [1] Perrin A. 2015. Social Networking Usage: 2005-2015. (October 2015).
- [2] Bbriniotis. 2016. Link Structure: Analyzing the most important methods. (October 2016). <http://www.webseoanalytics.com/blog/link-structure-analyzing-the-most-important-methods/>
- [3] David Blei. 2012. Probabilistic Topic Models. *Commun. ACM* (2012).
- [4] Emir and Almir. 2016. Application of Big Data and Text Mining Methods and Technologies in Modern Business Analyzing Social Networks Data about Traffic Tracking. *IEEE* (October 2016).
- [5] Christopher D. Manning and Prabhakar Raghavan. 2008. Introduction to Information Retrieval. *Cambridge University Press* (2008).
- [6] R.Mooney, J. Ghosh, and D. Lee. 2017. Boolean and Vector Space Retrieval Models. (2017). <http://www.cs.ucsb.edu/~tyang/class/293S17/slides/Topic2IRModels.pdf>
- [7] Mehmet U. and Seeren G. 2016. Text Mining Analysis in Turkish Language Using Big Data Tools. *IEEE Computer Society* (2016).
- [8] Wikipedia. 2017. DIKW pyramid. (September 2017). [https://en.wikipedia.org/wiki/DIKW\\_pyramid#cite\\_note-Rowley-1](https://en.wikipedia.org/wiki/DIKW_pyramid#cite_note-Rowley-1)
- [9] Wikipedia. 2017. PageRank. (September 2017). <https://en.wikipedia.org/wiki/PageRank>
- [10] Wikipedia. 2017. Web search engine. (October 2017). [https://en.wikipedia.org/wiki/Web\\_search\\_engine](https://en.wikipedia.org/wiki/Web_search_engine)

#### LIST OF FIGURES

1	DIKW hierarchical model [8].	5
2	Hubs structure for web pages.	5



Figure 1: DIKW hierarchical model [8].

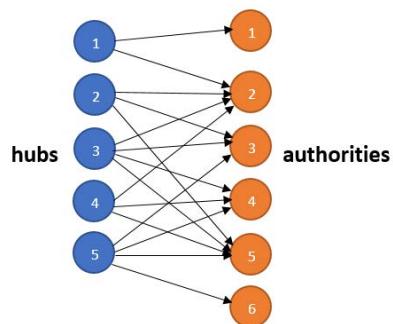


Figure 2: Hubs structure for web pages.

LIST OF TABLES

1 Search engines development.

7

Year	Events
1990	First engine “Archie” appeared.
1994	Original Yahoo was human created catalog.
1995-2000	The classic information retrieval techniques adapted to HTML.
1998	Google founded with its link structure by using the PageRank algorithm.
2000-2005	Add context, spell check, suggestions, multiple sources.
2005-	Add optimization of complete results, topic analysis of documents, social search.

**Table 1: Search engines development.**

# Using Big Data For Fact Checking

Karthik Vegi

Indiana University Bloomington  
2619 East 2nd Street, Apt 11  
Bloomington, IN 47401, USA  
kvegi@iu.edu

## ABSTRACT

Big Data is no more the elephant in the room it once used to be. Since John Mashey coined the term in 1998, it has come a long way. It is often described as the three Vs: Volume, Velocity, and Variety of the data. Of late, a new dimension, *Veracity* has been gaining importance which describes the quality and accuracy of the data. We show how Big Data can be used to spot fake news, bad data used by politicians, advertisers, and scientists.

## KEYWORDS

i523, hid231, big data, veracity, fact check, data accuracy

## 1 INTRODUCTION

Big Data is playing a crucial role in building a smarter planet. Each and every action that we take leaves a digital footprint. Big Data is lending a great helping hand to crunch this data to make smarter decisions. “Big Data is at the heart of the smart revolution. It is already completely transforming the way we live, find love, cure cancer, conduct science, improve performance, run cities and countries and operate business [5].”

“Large scale searches and analyses over multiple sources involves extracting data from highly heterogeneous structures, semantics, and qualities. One of the fundamental issues is that the extracted information can be biased, noisy, outdated, incorrect, misleading, and thus unreliable. To add to the problem, available data sources can provide conflicting information, leaving the users in doubt with respect to the accuracy [3].”

“The impact of fake news on the recent election has focused public attention on this multi-tentacled and growing problem. Vast swaths of the population fall prey to such misinformation, while others struggle to discern unbiased truth from the morass of lies and distortions that surrounds us [1].” With so many data sources like media, internet, newspaper, and many more, it is not easy to spot fake news and fact check the data. We need to take the help of the technological advances like Big Data and Artificial Intelligence to handle this problem.

“Fake news and fact checking is clearly a data veracity problem. Veracity refers to several quality dimensions related to repairing data inconsistencies and fixing other data quality problems such as duplicates, missing or incomplete data. Data veracity can be attributed to the following:

**Ambiguity:** Data can be inconsistent from one source to another, leading to misinterpretation.

**Staleness:** The data is obsolete and no longer relevant.

**Falsification:** False or distorted information can be intentionally propagated by one source or a coalition of sources. Information can

be manipulated or presented selectively to influence the audience and encourage a particular conclusion [3].”

## 2 FACT CHECKING AS A BIG DATA PROBLEM

Often veracity is not just about data quality, it is about data *understandability*. But fake news is understandable and we can make great sense out of it by careful analysis. We should therefore strive to achieve *truthfulness* [1]. “Misinformation dynamics, in fact, is where the big data concept of data veracity and the problem of fake news connect. We are not simply talking about the accidental inaccuracies that make up the bulk of enterprise data quality efforts. On the contrary, fake news is intentional misinformation, and furthermore, it is dynamic [1].”

“A common strategy to evaluate the reliability of the sources is to take advantage of data redundancy, and rely on majority voting heuristic, which simply assigns a true label to data that are claimed by the majority of the sources. But this strategy is known to be error-prone, because it counts all the sources equally and does not consider source dependence [2].”

The social networking giants like Facebook and Twitter faced this problem and a lot of fingers were pointed at them for acting as a medium for spreading fake news. Facebook took the initiative to tackle the problem head on by implementing an option where the users can flag the story as false. The more false votes it garners, the less likely it is for it to appear on the news feed. It also displays a warning to the users mentioning that a lot of users have reported the story as false. But the problem here is that we are giving people a chance to alter truth. It also makes everyone believe that anything that is not flagged is true which might not always be the case [1]. “To solve these problems, a combination of big data and AI methodologies are being developed that rely less on human-generated input, which can be swayed by opinion or a lack of facts. Google published a paper in 2015 about a new method of scoring web pages based on the accuracy of the facts presented. The algorithm assigns documents a trust score, which would then presumably be used as part of Google’s overall scoring to determine search rank. The technology is important, because it is attempting to understand a page’s context without the use of third-party signals, like links [2].”

“The news media and social media cannot be solely responsible for preventing fake news. Each one of us has equal responsibility to discern the accuracy. Tools already exist that can help individual users spot fake news sites. *Hoaxy* is an online tool that helps people visualize the spread of claims and fact-checking online, and is available to anyone to use. Many Chrome extensions have been created that can alert and help filter fake news. Even popular websites like

*Snopes* and *FactCheck.org* can help identify the most egregious fake stories [1].”

### 3 BIG DATA TECHNIQUES FOR FACT CHECKING

#### 3.1 Recommendation Based Approaches

Recommendation based approaches take the help of the community to determine the accuracy and quality of the sources. The reputation of the sources increases as more people agree that the source is reliable. These methods clearly have their shortcomings as people can be influenced by third party agencies to improve the trustworthiness of certain sources [3].

#### 3.2 Content Based Approaches

“Content based approaches work by computing a trustworthiness score of a source as a function of the belief in its claims, and then the belief score of each claimed data as a function of trustworthiness of the sources asserting it [3].” The source quality is initialized and iteratively updated based on the content belief. Various probabilistic methods have been used to tackle other aspects beyond trustworthiness and data belief [3].

In one such methodology, the truth discovery problem is transformed into a probabilistic inference model. An iterative algorithm is proposed which computes the posterior distribution of all the values of the sources and finds the one with the maximum probability. The model derives all the possible values reported by the sources and the conflicting values in the data streams and then calculates a score [7].

**Figure 1** illustrates the content based approach for truth discovery in data streams. As there can be heterogeneous sources, first a semantic mapping is employed for the values provided by various sources, such that the values for truth discovery are consistent [7]. “For example, the meaning of the weather conditions ***rainy*** and ***wet*** are considered to be the same in weather forecast truth discovery. Also ***partly sunny*** and ***mostly cloudy*** are grouped and considered to be the same as ***clear*** [7].”

“At each time  $t$ , the system collects a set of conflicting values for entity  $i$  as  $V = \{v_1, v_2, \dots, v_k\}$  from multiple data sources. Next, the system resolves the conflicts and discovers the true value  $v$  in  $V$  based on the current data uncertainty and source quality. Then, the system updates the data uncertainty and source quality based on the inferred value  $v$  and conflicting values  $V$ . [7]”

[Figure 1 about here.]

#### 3.3 Evidence Based Approaches

Evidence based approaches augment the content based approaches by relying on evidence, context and priori knowledge about the data sources [3]. Data provenance information may be used in truth discovery computation, as well as external information about the context, the sources, the data or user network [3]. This involves checking the dynamics of information in the network and recomputing the truth discovery accordingly [3]. “The problem with evidence based practice is that outside of areas like health care and aviation is that most people in organizations do not care about having research evidence for almost anything they do. That does

not mean they are not interesting in research but they are just not that interested in using the research to change how they do things [6]”

### 4 AUTOMATING FACT CHECKING

In this digital age, fact checking makes more sense when it is done in real time. “Politicians and media figures make claims about *facts* all the time, but the new army of fact-checkers can often expose claims that are false, exaggerated or half-truths. The number of active fact-checking websites has grown from 44 a year ago to 64 in 2015, according the Duke Reportersis Lab [4].”

The delay window between the time when a claim is made and the time when the claim is checked for truth has to be as less as possible. Fact checking takes longer time than traditional journalism. This gives enough time for the politicians and other people to make a claim and get away with it [4]

#### 4.1 Computational Challenges

**4.1.1 Finding claims to check:** This constitutes converting raw data to natural language and extracting contextual information such as speaker, time, and occasion [4].

**4.1.2 Getting data to check claims:** This involves evaluating the quality and completeness of sources and mapping them back to the data sources. Integrating multiple sources and cleansing data is an integral part of this step [4].

#### 4.2 Claimbuster

**Claimbuster** is an online tool to check for facts in real time. “For every sentence spoken by the participants of a presidential debate, Claimbuster determines whether the sentence has a factual claim and whether its truthfulness is important to the public. The calculation is based on machine learning models built from thousands of sentences from past debates labeled by humans. The ranking scores help journalists prioritize their efforts in assessing the veracity of claims. Claimbuster can be expanded to other discourses such as interviews and speeches and also adapted for use with social media [4].”

Claimbuster makes use of a supervised learning approach and breaks the sentences into three categories namely *Non Factual Sentences*, *Unimportant Factual Sentences*, and *Check-worthy Factual Sentences* [4]. “Given a sentence, the objective of Claimbuster is to derive a score that reflects the degree by which the sentence belongs to *Check-worthy Factual Sentences*. Many widely-used classification methods support ranking naturally. For instance, consider a Support Vector Machine (SVM). *Check-worthy Factual Sentences* are treated as positive examples and both *Non Factual Sentences* and *Unimportant Factual Sentences* as negative examples. SVM finds a decision boundary between the two types of training examples and calculates the posterior probability using a decision function. The probability scores of all sentences are used to rank them. This clearly will help the journalists and fact checkers to free up time to focus on more important things like reporting and writing [4].”

## 5 CONCLUSION

Big Data coupled with Artificial Intelligence and Machine Learning can tackle the fact checking problem. Rather than working in silos, the social networking giants and the search engine giant could work together with researchers to come up with a more effective solution. This ensures that there are no loose ends with respect to the accuracy of the data. This is important because there is a disconnect between data sources at times and not everybody has control and access to data that somebody else owns.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski and the teaching assistants for their support and suggestions in writing this paper.

## REFERENCES

- [1] 2017. Fake news: Big Data and AI to the rescue. Webpage. (Jan. 2017). <https://www.forbes.com/sites/jasonbloomberg/2017/01/08/fake-news-big-data-and-artificial-intelligence-to-the-rescue/#69e474df4a30>
- [2] 2017. Fake news: How Big Data can help. Webpage. (March 2017). <https://www.forbes.com/sites/bernardmarr/2017/03/01/fake-news-how-big-data-and-ai-can-help/2/#7ea468b92039>
- [3] Laure Berti-équille and Javier Borge-Holthoefer. 2016. *Veracity of Data*. Morgan & Claypool.
- [4] Naeemul Hassan, Bill Adair, James Hamilton, Chengkai Li, Mark Tremayne, Jun Yang, and Cong Yu. 2015. The Quest to Automate Fact-Checking. (10 2015).
- [5] Bernard Marr. 2015. *Big Data*. John Wiley & Sons Ltd.
- [6] Oxford. 2018. Evidence based practice problem. Webpage. (2018). <https://www.oxford-review.com/blog-research-problem-evidence-based/>
- [7] Zhou Zhao, James Cheng, and Wilfred Ng. 2014. Truth Discovery in Data Streams: A Single-Pass Probabilistic Approach. In *Proceedings of the 23rd ACM International Conference on Conference on Information and Knowledge Management (CIKM '14)*. ACM, New York, NY, USA, 1589–1598. <https://doi.org/10.1145/2661829.2661892>

LIST OF FIGURES

1 Truth Discovery In Data Streams [7]

5

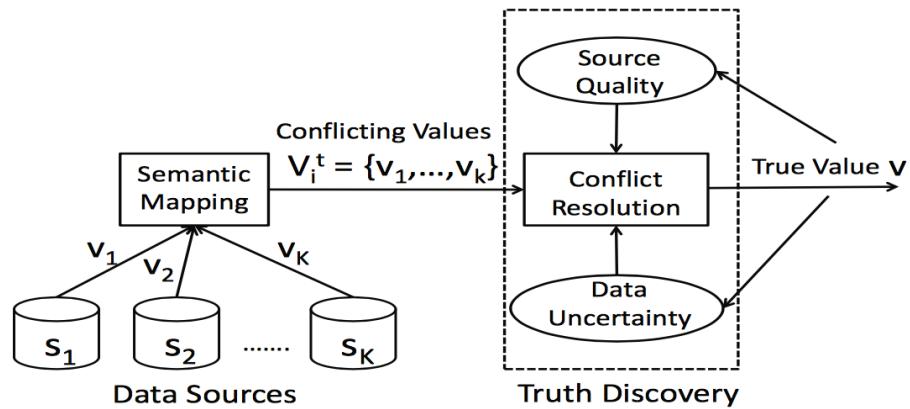


Figure 1: Truth Discovery In Data Streams [7]

# Big Data Applications in Media and Entertainment Industry

Jiaan Wang

Indiana University Bloomington

3209 E 10th St

Bloomington, Indiana 47408

jervwang@indiana.edu

## ABSTRACT

The growth of big data and its various applications in media and entertainment industry has been swift in recent years as well as the rapid surge of big data and the increasing need for big data technologies. We describe the problems that come with big data and its challenges in the industry. We then present various utilization of big data and why big data is important to the advancement of media and entertainment industry.

## KEYWORDS

i523, hid233, Big data, Media, Entertainment industry, Technology, Recommendation

## 1 INTRODUCTION

The amount of data being generated is increasing exponentially every year. Currently, we don't have the resources to process or analyze all the data. For example, giant tech companies like Google process over 20 petabytes of data daily [6]. "The rate at which we are generating data is rapidly outpacing our ability to analyze it and the trick here is to turn these massive data streams from a liability into a strength" [2]. Despite that, the technologies used to collect, analyze and interpret data are continuously improving [6].

IDC, the International Data Corporation, believes that "organizations that are best able to make real-time business decisions using big data streams will thrive, while those that are unable to embrace and make use of this shift will increasingly find themselves at a competitive disadvantage in the market and face potential failure. This will be particularly true in industries experiencing high rates of business change and aggressive consolidation" [7].

But what is big data? Wanda Group, a multinational conglomerate company based in China, defines big data as a DIKW hierarchical model, which stands for Data, Information, Knowledge and Wisdom [9]. "Big data is about the growing challenge that organizations face as they deal with large and fast-growing sources of data or information that also present a complex range of analysis and use problems. Big data technologies describe a new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery, and analysis" [7].

Emerging sources for big data include industries that are preparing to digitize their content. Particularly, "the media and entertainment industry moved to digital recording, production, and delivery in the past five years and is now collecting large amounts of rich content and user viewing behaviors" [7].

## 2 CHALLENGES IN MEDIA AND ENTERTAINMENT INDUSTRY

"The problem with the massive data collection and distribution system created is: big data is a big mess. Most of the data captured in our daily lives just sits around, cluttering up storage space on devices and slowing down connections" [6].

"Media and entertainment industry has frequently been at the forefront of adopting new technologies. The key business problems that are driving media companies to look at big data capabilities are the need to reduce the costs of operating in an increasingly competitive landscape and at the same time, the need to generate revenue from delivering content and data through diverse platforms and products" [4].

Traditional TV media are facing challenges as its data is scattered. "It has internal data from set-top boxes, network management systems, BOSS systems, etc. as well as external data from online user behaviors. Data integration is the primary challenge in big data applications of traditional TV media" [9]. In China, the overall economy of traditional TV media does not look promising. The amount of time user spent on traditional TV has declined while more time is spent on Internet TV. "Studies have shown that, in 2012, Internet TV user base has reached 26.1 million while traditional TV user base is only 600 million. In addition, traditional TV operation rate has decreased from 70 percent in 2009 to 30 percent in 2012" [9].

These are the main challenges media and entertainment industry needs to deal with in order to better utilize big data to make a difference:

- "Making sense of data streams, whether text, image, video, sensors, and so on. Sophisticated products and services can be developed by extracting value from heterogeneous sources" [4].
- "Exploiting big data step changes in the ability to ingest and process raw data, so as to minimize risks in bringing new data-driven offerings to market" [4].
- "Curating quality information out of vast data streams, using algorithmic scalable approaches and blending them with human knowledge through curation platforms" [4].
- "Accelerating business adoption of big data. Consumer awareness is growing and technical improvements continue to reduce the cost of storage and analytics tools among other things. Therefore, it is more important than ever that businesses have confidence that they understand what they want from big data and that the non-technical aspects such as human resources and regulation are in place" [4].

### 3 APPLICATIONS IN MEDIA AND ENTERTAINMENT INDUSTRY

“Massive quantities of data are already being captured about entertainment. For example, *Supernatural*, an American horror series, created by Eric Kripke in 2005. Now in its seventh season, it has generated roughly 112 hours of footage. We have a lot of pixels and we also have every action of every character; every line of dialogue; a history of when, where, and how often everyone dies. Because all of that information is data, what we actually have, in and around those 112 hours of pixels, is a map to the world of *Supernatural*, and the characters inside it. Today, all of that footage and all of that information is locked away in old style data collections: fixed and unwieldy. But if we can store all that information in a system, modeled more on biology than books, and apply our significant and increasing processing power to analyze and respond to the world, rather than just move it around mechanically, then we have the possibility of generating and interacting with the world and the characters of *Supernatural*” [6].

“Hollywood also uses big data big time” [5]. “IBM worked with a media company and ran its predictive models on social media buzz for the movie Ram Leela. According to the reports, IBM predicted a 73 percent success for the movie based on right selection of cities. Such rich analysis of social media data was conducted for Barfi and Ek Tha Tiger. All these movies had a runaway success at the box office. Shah Rukh Khan’s Chennai Express, one of the biggest box office grosses in 2013, used big data and analytic solutions to drive social media and digital marketing campaigns. IT services company *Persistent Systems* helped Chennai Express team with the right strategic inputs. Chennai Express related tweets generated over 1 billion cumulative impressions and the total number of tweets across all hash tags was more than 750 thousand over the 90-day campaign period. Singapore based big data analytic firm Crayon has worked with leading Hindi film industry producers to understand the kind of music to release in order to create the right buzz for movies. In addition, Lady Gaga and her team browse through listening preferences and sequences to optimize the play list for maximum impact at live events” [3].

“Sports is another area where big data is making big impacts. Germany, FIFA 2014 champion, has been using SAP’s Match Insights software to analyze team performance which made a big difference for the team. It analyzes data such as player positions, touch maps, passing abilities, ball retention and even metrics such as aggressive play. In addition, Kolkata Knight Riders, an Indian Premier League team, used Match Insights to determine the consistency of its players which helped in auction as well as in ongoing training” [3].

“By using big data to understand why the customers subscribe and unsubscribe, entertainment organizations could develop the best product and promotional strategies to attract and retain clients. Unstructured sources best handled by big data apps like email, call detail records and social media sentiment reveal factors that are often overlooked for driving customer interest. Big data makes possible the understanding of consumption of digital media and entertainment and behavior that could be used together with traditional data demographic for personalized advertising in the right context at the right time, in the right place” [5].

“Recommendation engines are very powerful personalization tools because it’s a great way to show people items they will like. A lot of Amazon’s fantastic revenue growth has been built on successfully integrating recommendations across the buying experience from product discovery to checkout” [1].

“Amazon is investing a large amount of talent and resources on getting better artificial intelligence, specifically deep learning technology to make recommendation engines which learn and scale even more efficiently. In May 2016, Amazon opened up its sophisticated artificial intelligence technology as a cloud platform. The company unveiled DSSTNE, an open source artificial intelligence framework that Amazon developed to power its own product recommendation system” [1].

“Amazon says it releases pilots at Amazon Studios periodically for customers to watch and review. Their feedback is taken into account when executives decide which pilots will become a full series. One product of that system is the comedy series *Transparent*, based on a Los Angeles family whose patriarch is transgender. Its debut in 2014 coincided with greater social awareness about transgender issues and was rewarded the following year with the Golden Globe for best TV series, musical or comedy” [8].

Another big media company who uses recommendation engines big time is Netflix. “No one understands the idea of content discovery better than Netflix, because the on-demand streaming video is probably the world’s biggest market for digital consumption of content. Netflix has worked hard to ensure its recommendation algorithms can highlight as much of its content library as possible. In December 2015, Netflix revamped the technology behind its content recommendation engine, deciding to do away with region based preferences in light of their ongoing global expansion” [1].

“Netflix, which distributes shows such as *House of Cards* and *Orange Is the New Black*, pioneered the use of mathematical equations to promote titles that a subscriber might enjoy. That is based on variables such as previously downloaded content, the subscriber’s location and the show’s broader popularity” [8].

“A typical Netflix user may lose interest unless something interesting is found within 60 seconds, two employees of the Los Gatos, California-based company wrote in a paper published in a scholarly journal last year. Netflix’s system for coming up with personalized viewing recommendations helps save more than 1 billion dollar a year by reducing the number of subscription cancellations” [8].

### 4 CONCLUSION

The rapid growth of big data has given media and entertainment industry an unique opportunity to utilize resources in order to benefit from big data applications and technologies. However, there are still some key challenges media companies are facing such as how to quickly adapt to the big data era, how to deal with and analyze immense amount of data pouring in every minute and how to make cost-effective products and consumer experiences. Examples of current effective big data applications and technologies such as Match Insights from SAP and personalized recommendation engines from Amazon and Netflix are provided. In summary, big data applications and technologies are crucial in the success of media and entertainment companies.

## ACKNOWLEDGMENTS

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

## REFERENCES

- [1] Shabana Arora. 2016. Recommendation Engines: How Amazon and Netflix Are Winning the Personalization Battle. Web Page. (June 2016). <https://www.martechadvisor.com/articles/customer-experience/recommendation-engines-how-amazon-and-netflix-are-winning-the-personalization-battle/> HID: 233, Accessed: 2017-10-06.
- [2] Lauren Browning. 2015. We sent men to the moon in 1969 on a tiny fraction of the data that's in the average laptop. Web Page. (June 2015). <http://www.businessinsider.com/mind-blowing-growth-and-power-of-big-data-2015-6> HID: 233, Accessed: 2017-10-07.
- [3] Ashok Karanja. 2014. How Big Data Is Changing The Entertainment Industry! Web Page. (July 2014). <https://www.linkedin.com/pulse/20140730194648-8949539-how-big-data-is-changing-the-entertainment-industry> HID: 233, Accessed: 2017-10-03.
- [4] Helen Lippell. 2016. *Big Data in the Media and Entertainment Sectors* (1 ed.). Springer International Publishing, Gewerbestrasse 11 CH-6330 Cham (ZG) Switzerland, Chapter 14, 245–259. [https://doi.org/10.1007/978-3-319-21569-3\\_14](https://doi.org/10.1007/978-3-319-21569-3_14) HID: 233, Accessed: 2017-10-03.
- [5] Ritesh Mehta. 2017. Big Data in the Field of Entertainment. Web Page. (Aug. 2017). <https://insidebigdata.com/2017/08/20/big-data-field-entertainment/> HID: 233, Accessed: 2017-10-03.
- [6] Tawny Schlieski and Brian David Johnson. 2012. Entertainment in the Age of Big Data. *Proc. IEEE* 100, Special Centennial Issue (May 2012), 1404–1408. <https://doi.org/10.1109/JPROC.2012.2189918> HID: 233, Accessed: 2017-09-20.
- [7] Richard L. Villars, Carl W. Olofson, and Matthew Eastwood. 2011. Big data: What it is and why you should care. *White Paper, IDC* 14 (June 2011). [www.tracemyflows.com/uploads/big\\_data/idc\\_amd\\_big\\_data\\_whitepaper.pdf](http://tracemyflows.com/uploads/big_data/idc_amd_big_data_whitepaper.pdf) HID: 233, Accessed: 2017-09-20.
- [8] Angus Whitley. 2016. How Entertainment Companies Use Big Data. Web Page. (July 2016). <https://www.comstocksmag.com/bloomberg/how-entertainment-companies-use-big-data> HID: 233, Accessed: 2017-10-03.
- [9] Chunjie Zhang, Wenqian Shang, Weiguo Lin, Yongan Li, and Rui Tan. 2017. Opportunities and challenges of TV media in the big data era. In *2017 IEEE/ACIS 16th International Conference on Computer and Information Science (ICIS)*. IEEE, Wuhan, China, 551–553. <https://doi.org/10.1109/ICIS.2017.7960053> HID: 233, Accessed: 2017-09-20.

# Big Data in Media(Content) Industry

Sarang Fadnavis  
INDIANA UNIVERSITY BLOOMINGTON  
P.O. Box 1212  
Bloomington, INDIANA 47405  
sfadnavi@iu.edu

## ABSTRACT

Media industry has evolved from the traditional business model which was Television, Print Media (like Newspaper, articles, magazine) providing most of the revenues from it to new world of digital media. Digital media is the new era of content sharing on social networking or Internet. The rate at which internet is accessible to everyone as per IDC estimates, till 2020 it will reach 450 Billion per day which reflect true business need and strategies can be planned as per market analysis

## KEYWORDS

TRP = Television Rating Points,

## 1 INTRODUCTION

News, TV, market analysis, Movies or Video on demand, etc were part of content distribution by specific organization / Production house to sell it to broadcaster to further use the content. All these distribution was one way communication and hardly possible to get exact Television Rating point (TRP) or feedback about article. Internet has given us flexibility to get feedback on the good / bad videos, Photos to reach 50million user Radio took 38 years, TV almost 13 years, Internet just 3years and facebook added 200 million user in less than a year. Such a heavy internet usage has raised a concern over data (content) availability and analysis to make it effective for marketing and strategic business as most of the data available is unstructured form. size [1].

## 2 ISSUES FACED BY MEDIA INDUSTRY

- Audience Measurement methodologies and standardization of individual and multimedia channel planning
  - Tracking ROI and attribution across media channels proving effectiveness of media campaign activity
  - Keeping up to date with constantly evolving market trends, initiatives and opportunities
  - Business costs of continually evolving marketing technology and media research
  - Managing an increasingly diverse and Sliped agency roster
  - Fragmenting market and increased competition from other media and channels ie social, owned and earned media
  - Procurement and agency margins finding an effective and sustainable business model
  - Disconnect and Mis-communication between client, agency and media
  - Limited scope for outside the square and new opportunities
- size [2]

## 3 BIG DATA IN MEDIA INDUSTRY

Internet has changed the world in terms of interaction and communication we do. Media contents are available on youtube, Netflix, chromecast for free or low cost .Also on social networking sites like facebook, twitter, Instagram and WhatsApp. 16 zettabytes unique data was created in 2106. Such an enormous amount of data can be analyzed to get some answers to the change in pattern and product marketing

We do not have a choice on whether we do social media the question is how well we do it if Erik Qualman

50 percent of world's population is under 30 years and 96 percent of millennial are on social media, Facebook and Google tops highest weekly traffic on internet size [4]

### 3.1 Benefits of big data and Internet

Understand customer content preferences

- Increase the relevance in FTfs communication to customers
- Personalize content
- Deploy intelligence to customer touchpoints, including customer service, website, mobile apps and third parties, such as advertisers, in order to target campaigns

### 3.2 statistics from 2017

- 3.8 Billion people uses internet
- 20.8 Billion devices will be using internet by 2020
- 24 hrs of video is uploaded to youtube every minute
- 300 million photos uploaded to facebook everyday
- 2 Billion active users in facebook

size [4]

## 4 SOCIAL MEDIA ANALYTICS PLATFORM

Comprehensive social media platform that combines data feed, data mining and data analysis tool size [3]

### 4.1 News Platform

News analytics uses Natural language processing, technique to score news items and to confirm Author sentiments, Relevance, Volume Analysis, Uniqueness, and Headline Analysis

### 4.2 Social Network media Platform

Bandwidth, salesforce Marketing Cloud and Media Analysis Platform

- Item type! stage of the story: Alert, Article, Updates or Corrections.
- Item genref! classification of the story, i.e., interview, exclusive and wrap-up.

- Headlinefi!?alert or headline text.
- Relevancefi!?varies from 0 to 1.0.
- Prevailing sentimentfi!?can be 1, 0 or fk??1.
- Positive, neutral, negativefi!?more detailed sentiment indication.
- Broker actionfi!?denotes broker actions: upgrade, down-grade, maintain, and undefined or whether it is the broker itself

## 5 CONCLUSION

Content Media has exploded in terms of data generated with both structured and unstructured. There is a need to use Big data and this need will be increasing day by day in order to work towards marketing and strategic planning new product companies will need the analytics for improving their product by understanding market and current trends.

## ACKNOWLEDGMENTS

I would like to thank Prof Gregor von Laszewski for the opportunity and Mani Kumar to help me with Git hub tool

## REFERENCES

- [1] Scott Anthony. 2011. *What the Media Industry Can Teach Us About Digital Business Models*. Technical Report 4. Jack Myers Media Business Report.
- [2] Jack Myers. 2011. *The Media Industry's Greatest Failures of the Past Two Decades*. Technical Report 2. Jack Myers Media Business Report.
- [3] ANDREW PERRIN SHANNON GREENWOOD and MAEVE DUGGAN. 2016. *Social Media Update 2016*. Technical Report 4. Pew Research Center Internet & Technology.
- [4] Statista. 2017. *Distribution of global social content sharing activities as of 2nd quarter 2016, by social network*. Technical Report 1. Statista.

# Recommendation Systems on the Web

Jordan Simmons  
Indiana University Bloomington  
jomsimm@iu.edu

## ABSTRACT

Recommendation Systems are being used all over the web. There are different popular techniques that are being used in modern systems. Some of the larger well known companies are using this technology very well. This material is an overview of some techniques, state of the art systems, and challenges and limitations of Recommendation Systems.

## KEYWORDS

i523, hid336, Recommendation Systems, Big Data

## 1 INTRODUCTION

Recommendation systems (RS) leverage big data in order to create value for both businesses and customers. “The goal of a recommender system is to generate meaningful recommendations to a collection of users for items or products that might interest them.” [7]. RS are effective for a variety of industries and products which can range from a product in a store, a news article on a site, or a search query. RS is beneficial to businesses and customers by increasing metrics such as revenue and customer satisfaction [2]. Many online platforms are starting to use RS to analyze their data. In order to gain a better understanding of RS, general analysis of modern techniques, companies currently using RS, and challenges and limitations within the field will be covered.

## 2 RECOMMENDATION TECHNIQUES

Three common RS techniques would include content-based, collaborative, and hybrid recommendations [1]. Other techniques exist, but these three are the most widely used today. In order to determine which technique is best depends on the recommendations to be made, and the data used to make them. Many times, the hybrid approach is used because there can be limitations with other approaches [1]. Overall, it is best to understand a little bit about each technique before choosing which is best.

### 2.1 Content-Based

Content-Based RS recommend items to users by using descriptions of items and how the user is profiled based on their interest [8]. Items are classified by different characteristics, attributes, or variables [8]. Once items are classified, they can be grouped together based on the classifications. Users are classified by data they provide to the system, and/or the data collected by interacting with the system.

Content-Based RS are commonly seen on web applications and E-commerce sites. These types of systems readily track and monitor almost all user activities. Typically a user has an account with the system, which is where data was voluntarily provided. With this data, users can be classified easier compared to a customer walking into a brick and mortar business.

### 2.2 Collaborative Filtering

“Collaborative Filtering is the process of filtering or evaluating items using the opinions of other people” [10]. This type of RS is commonly seen on systems where an item can be rated by a user. With this technique, user rating are collected and stored from a user for an item that they have used or purchased. The ratings from the user are then compared to other users that have rated the same item. For example, person A buys items 1 and 2 and rates each item highly. Then, person B buys item 1 and rates it highly. Since person A and B both bought and rated item 1 highly, the system would likely recommend item 2 to person B. On the contrary, if person B gave item 1 a low rating, the system would not likely recommend item 2 to person B. This concept uses the assumption that “people with similar tastes will rate things similarly” [10]. This assumption may not be true in all cases, but it is a good base for RS to start learning users interests, and recommend items based on those interest. With this technique, the more ratings that the systems has collected per item, and the more ratings given by the user, the easier it is for that system to make recommendations to that specific user.

### 2.3 Hybrid

Hybrid RS takes two or more techniques and combines them to improve performance and reduce limitations that a single technique might have [3]. In most cases, collaborative filtering is used with one or more of the other techniques to improve performance. Other techniques that are used and not discussed include Demographic, Utility-Based, and Knowledge-based recommendations [3]. The hybrid approach narrows down items with one technique, and then uses another technique on that subset of items to make a more accurate recommendation. Determining the best hybrid system depends on the specific business case, and the data used to make the recommendation.

An example of a hybrid approach would use collaborative filtering and the content-based methods described above. For example, if User A is interested in baseball. The system would use the content-based approach to narrow down all items that are classified as baseball items. From this subset of baseball items, the system could then use the collaborative-filtering approach to find the items with ratings from other users which will be user group B. The system would then find all item ratings from user group B and compare those item ratings to person A. If there are any users in group B that have similar likes to person A, the system would likely recommend the baseball items to person A that person B has previously rated highly. This is a high-level example of how a hybrid RS would work. Real world examples are more complex than this example, and use large amounts of data.

### 3 MODERN SYSTEMS

Two well known companies that are currently using RS are Netflix and Amazon. These two companies have huge customer bases, in which they collect data on. The data collected within these sites and how they utilize it to generate suggestions to their users is what makes these companies have successful advanced recommendation systems.

#### 3.1 Netflix

Netflix is an internet based company that offers a variety of movies and television shows. Netflix had a problem of customers sorting through its large selection of movies and shows, and eventually losing interest which resulted in abandonment of their services [5]. Over the years, Netflix has created and continually developed new RS algorithms which they claim saves them more than one billion dollars per year and a monthly turnover in the low double digits [5].

Netflix does very well at recommending movies and shows to its users. They have incorporated different strategies to collect data from users which is the base of their RS. Data is collected in the form of customized search, video ratings, continue watching feature, amount of time spent watching and other user activities [5]. Using the data collected from these features, Netflix can recommend top rated, now trending, and videos based on user interest, which is very appealing to the user when there are so many selections to choose from.

#### 3.2 Amazon

Amazon is an online store that sell a large variety of products. Amazons RS provides recommendations for millions of customers from a catalog that has millions of products. [11]. Instead of comparing customers to customers, amazon uses an item-based collaborative filtering approach. This process finds items that were bought together with unusually high frequencies, and uses these relationships to recommend products to customers based on what they have purchased in the past [11]. With this algorithm, Amazon is providing a unique experience to every user and helping them find products they may not have found. Since the initial launch of this algorithm, it has "been tweaked to help people find videos to watch or news to read, been challenged by other algorithms and other techniques, and been adapted to improve diversity and discovery, recency, time-sensitive or sequential items, and many other problems." [11]

## 4 CHALLENGES AND LIMITATIONS

As with most technologies, RS has its challenges and limitations. It is hard to speak of this topic without speaking about the questions "more data usually beats better algorithms" [9]. This quote has raised controversy about which of the two actually produce better results. In most cases, there are many different variables to consider when answering this question.

#### 4.1 Limitations

With complex systems, there can be many variables that cause issues that limit full capabilities of that system. Specifically, in RS, some of these limitations include cold start problems,data sparsity,

limited content analysis, and latency problems [6]. These limitations seem to be more data related rather than the actual techniques and approaches of the technology being used to analyze that data. When there is no data for a new user, it is hard for RS to create suggestions for this user. The system has no data on the users activities or what interests that user has. When a new item is added to a system, there are no reviews and no data collected with the interaction of user for this particular item. On the other hand, too much data can become redundant. At this point gathering more data will have limited gains.

## 4.2 Cross-Domain Recommendations

Cross-Domain recommendations aim to "leverage all the available user data provided in various systems and domains, in order to generate more encompassing user models and better recommendations" [4]. Every day the amount of data being collected increases. This data is being collected from different sources. Cross-Domain RS could use data from different sources, which could make up for some of the data caused problems. An example of a Cross-Domain recommendation would be Netflix using data from Facebook to help recommend movies to a new user. Using data from various systems like this would bring up new issues like privacy and security, but if systems started working together and sharing data there could be benefits for both systems.

Cross-Domain Recommendations help with domain specific data issues. Two different systems may have different ways of collecting and organizing data. If system 1 collects variables A ,B and C, and system 2 collects variables A, B, and D, each system has information that the other system does not have. This is where sharing the data between systems could have benefits for both systems. In doing this, each system is not only benefiting from more data, but different and perhaps better data. This would also require using better algorithms to analyze the different sets of data. Depending on the system, more data can be more beneficial than better algorithms. In terms of scalability, gathering more data that is different from what is currently being collected, and using better algorithms along with the different data could potentially maximize recommendations for that system.

## 5 CONCLUSION

With a base understanding of RS, it is easy to see how this technology can be very beneficial in online platforms. RS has different techniques that can be used in a variety of online systems. Many large companies are creating custom RS and are benefiting greatly from them. As the massive amount of data grows from day to day, the ways in which RS is used will continue to evolve. It will be interesting to see how Cross-Domain Recommendations are used in the future, and if companies start to adopt this concept of sharing data. Data being analyzed from various systems could unlock hidden information that a single system may not be capable of producing.

## ACKNOWLEDGMENTS

The author would like to thank course instructors for organizing setup of the latex format used in this paper.

## REFERENCES

- [1] Gediminas Adomavicius and Alexander Tuzhilin. 2005. Toward the Next Generation of Recommender Systems: A Survey of the State-of-the-Art and Possible Extensions. *IEEE Trans. on Knowl. and Data Eng.* 17, 6 (June 2005), 734–749. <https://doi.org/10.1109/TKDE.2005.99>
- [2] Xavier Amatriain and Justin Basilico. 2016. Past, Present, and Future of Recommender Systems: An Industry Perspective. In *Proceedings of the 10th ACM Conference on Recommender Systems (RecSys '16)*. ACM, New York, NY, USA, 211–214. <https://doi.org/10.1145/2959100.2959144>
- [3] Robin Burke. 2002. Hybrid Recommender Systems: Survey and Experiments. *User Modeling and User-Adapted Interaction* 12, 4 (01 Nov 2002), 331–370. <https://doi.org/10.1023/A:1021240730564>
- [4] Iván Cantador, Ignacio Fernández-Tobías, Shlomo Berkovsky, and Paolo Cremonesi. 2015. *Cross-Domain Recommender Systems*. Springer US, Boston, MA, 919–959. [https://doi.org/10.1007/978-1-4899-7637-6\\_27](https://doi.org/10.1007/978-1-4899-7637-6_27)
- [5] Carlos A. Gomez-Uribe and Neil Hunt. 2015. The Netflix Recommender System: Algorithms, Business Value, and Innovation. *ACM Trans. Manage. Inf. Syst.* 6, 4, Article 13 (Dec. 2015), 19 pages. <https://doi.org/10.1145/2843948>
- [6] Shah Khusro, Zafar Ali, and Irfan Ullah. 2016. *Recommender Systems: Issues, Challenges, and Research Opportunities*. Springer Singapore, Singapore, 1179–1189. [https://doi.org/10.1007/978-981-10-0557-2\\_112](https://doi.org/10.1007/978-981-10-0557-2_112)
- [7] Prem Melville and Vikas Sindhwani. 2010. *Recommender Systems*. Springer US, Boston, MA, 829–838. [https://doi.org/10.1007/978-0-387-30164-8\\_705](https://doi.org/10.1007/978-0-387-30164-8_705)
- [8] Michael J. Pazzani and Daniel Billsus. 2007. *Content-Based Recommendation Systems*. Springer Berlin Heidelberg, Berlin, Heidelberg, 325–341. [https://doi.org/10.1007/978-3-540-72079-9\\_10](https://doi.org/10.1007/978-3-540-72079-9_10)
- [9] Anand Rajaraman. 2008. More Data Usually Beats Better Algorithms. (03 2008). <http://anand.typepad.com/datawocky/2008/03/more-data-usual.html>
- [10] J. Ben Schafer, Dan Frankowski, Jon Herlocker, and Shilad Sen. 2007. *Collaborative Filtering Recommender Systems*. Springer Berlin Heidelberg, Berlin, Heidelberg, 291–324. [https://doi.org/10.1007/978-3-540-72079-9\\_9](https://doi.org/10.1007/978-3-540-72079-9_9)
- [11] Brent Smith and Greg Linden. 2017. Two Decades of Recommender Systems at Amazon.Com. *IEEE Internet Computing* 21, 3 (May 2017), 12–18. <https://doi.org/10.1109/MIC.2017.72>

# Big Data Analytics for Research Libraries and Archives

Timothy A. Thompson  
Indiana University Bloomington  
School of Informatics, Computing, and Engineering  
Bloomington, Indiana 47408  
timathom@indiana.edu

## ABSTRACT

Research libraries and archives have played a longstanding role in information management and access. In the second half of the twentieth century, libraries were at the forefront of automation and networked access to information. Since the advent of the internet, however, they have failed to keep pace with technological advances and currently face serious challenges in serving the evolving needs of researchers, whose information-seeking strategies are now shaped by internet search engines and online social media applications. To remain relevant in the current information landscape, libraries and archives must implement new strategies for converting legacy metadata to new formats that can add value to the research process. Although the data and metadata produced by libraries and archives may not always qualify, *prima facie*, as big data, an awareness among information professionals of the tools, techniques, and affordances of big data can help make library services more relevant to researchers.

## KEYWORDS

i523, hid340, Library Metadata, Archival Metadata, Linked Open Data, Data Conversion

## 1 INTRODUCTION

Cultural heritage institutions such as libraries and archives have a longstanding tradition of producing structured data—in the form of catalog records or finding aids—to describe their collections. In the twentieth century, library card catalogs were gradually replaced by machine-readable formats, the foremost of which were the Machine Readable Cataloging (MARC) formats for bibliographic and authority data (standardized as ISO 2709 and ANSI/NISO Z39.2)[3].

Initial development of the core MARC format, commissioned by the Library of Congress, was finalized in 1968, when the first electronic catalog records were distributed[3]. Originally, MARC records were used to facilitate the automated creation of card catalogs, which remained the primary method of information retrieval in libraries until the 1980s, when online public access catalogs (OPACs) became available and the pace of automation began to accelerate[9]. It was not until 2004 that the MARC record format (stored as a binary file) was mapped to an XML schema, making it more amenable to computation and transformation[7]. Notwithstanding, the MARC format has now become increasingly archaic and hinders data sharing and interoperability between libraries and contemporary platforms for research and information retrieval, such as the World Wide Web.

## 2 IS LIBRARY METADATA BIG DATA?

Although libraries and other cultural heritage institutions have created millions of metadata records over time, even the largest catalogs fall short of the scale typically associated with big data. The entire catalog of the Library of Congress, an institution that holds over 13 million physical volumes, totals less than 100 gigabytes. By comparison, Twitter produces approximately 12 terabytes of data on a daily basis[2, p. 1527]. According to Teets and Goldner, “If you consider just the metadata representing the collection of printed and electronic works held by libraries, it really cannot be considered big data in its current meaning”[9]. However, if big data is defined more broadly as a set of methodologies for analysis and an ecosystem for data aggregation, then libraries clearly stand to benefit from adopting its tools and techniques.

Ekbia et al., for example, propose a view of big data as a “social movement” that has been shaped by alliances “among heterogeneous players in business, academia, and government”[2, p. 1527]. By undertaking projects focused on data modeling and mass conversion and migration of legacy data, libraries can position themselves to partner with other players and provide enhanced information retrieval services, exposing their metadata in contexts that are more relevant to the current needs of researchers. In addition, by adopting graph-based models that are native to the World Wide Web, libraries can merge their data more seamlessly with the wider universe of online data in order to “generate massive collections of new relationship assertions”[9].

By leveraging universal standards such as the Resource Description Framework (RDF), libraries, archives, and other cultural heritage institutions can uncover latent relationships that are currently buried in catalog records, connecting them to data from disparate sources and providing a “training set for all human knowledge”[9, p. 430]. Teets and Goldner suggest that the process of splitting catalog records into discrete, linkable statements could vastly expand the size and scope of library-created metadata: “From a single [record], we can extract relationships from co-authors, citations, geo-locations, dates, named entities, subject classification, institution affiliations, publishers and historical circulation information. From these relationships, we can connect to other works, people, patents, events, etc. Creating, processing and making available this graph of new assertions at scale is big data”[9, p. 431].

## 3 TOWARD BIG DATA

Both libraries and archives face particular challenges in attempting to embrace the ethos of big and complex data. The rules and instructions used by catalogers and archivists to describe information-bearing resources are still reflective of the card catalog environment and do not support the kind of data-centric granularity needed to

enable effective data integration and interoperability[10]. One of the primary obstacles in converting and migrating legacy data is the problem of entity resolution and name disambiguation. A second obstacle, one that is by turns social, legal, and technical in nature, involves libraries' ability to publish and preserve digitized content.

### 3.1 Entity Resolution

Two recent projects exemplify the large-scale effort in libraries and archives to remediate legacy data and merge information from multiple sources. In the archival community, researchers are often faced with scenarios in which a person's papers are scattered among geographically distant repositories, but there is no master index that links the relevant collections together. One initiative, the Social Networks and Archival Context Project (SNAC), is working to develop algorithms and routines for entity resolution in order to address this problem. Researchers in the SNAC Project have focused on developing supervised machine learning algorithms for matching names across records that have been collected from multiple archival repositories[6]. Experiments with methods based on Naive Bayes Classification have yielded promising results, particularly when data from name strings is combined with contextual information (such as birth and death dates) that has been extracted from related records, with an accuracy rate of approximately 80%[6].

The task of entity resolution is made particularly difficult by the approach to data creation that has been traditionally employed by libraries and archives. In catalog records describing a book or archival collection, for example, creators are identified by name strings rather than unique identifiers. Catalogers must follow detailed rules for ensuring that each name string—known as an “authorized heading”—is unique, but because these strings are hand-crafted by humans rather than generated by machines, they are particularly vulnerable to error and inconsistency.

In the Wikidata database, by contrast, which was originally compiled from structured data templates on Wikipedia pages, the American author Mark Twain is represented by a unique identifier that can be dereferenced as an HTTP URI: <https://www.wikidata.org/wiki/Q7245>. Wikipedia pages about Twain, regardless of the language they are written in, are able to link to this single identifier. In the Library of Congress Name Authority File, however, Twain is identified instead by the string “Twain, Mark, 1835-1910”.

The Library of Congress maintains the “authorized” list of names for U.S. libraries, but many other national libraries maintain their own authority files. In the case of a well-known author such as Twain, there may be substantial agreement across institutions from Roman-script language communities as to the format of the authorized heading. For libraries and archives whose official languages are expressed in other character sets, the process of entity resolution may be more difficult.

To address the problem of string-based identification, the OCLC Online Computer Library Center, a global data provider for the library industry, has developed an initiative called the Virtual International Authority File (VIAF). VIAF is a data aggregation portal that attempts to resolve named entities across “more than 130 million authority and bibliographic records expressed in multiple languages, scripts, and formats”[4, p. 1]. MARC authority records are contributed to VIAF from nearly 50 contributing partners, most

of which are national libraries[4]. References to named entities are clustered and merged using a 300+ core Hadoop cluster in a monthly batch process that takes approximately “12 hours of cluster compute time to complete”[4, p. 2]. In a multistep algorithm, named entities in VIAF are progressively grouped into identity clusters, and pair-wise matching is performed between datasets from each institutional contributor. Because it is able to draw on a wider range of sources for disambiguation and entity resolution, VIAF has, to date, achieved a higher degree of accuracy in matching entities than has the SNAC Project, with success rates of over 90%[4].

### 3.2 HathiTrust

In the library domain, the project that perhaps comes closest to the scale and scope of “big data” is the HathiTrust Digital Library and the related HathiTrust Research Center. In large part, the HathiTrust initiative grew out of the response of major research libraries to the Google Books mass digitization enterprise[1, 8, 11]. Libraries were particularly concerned about the issues of long-term digital preservation and open access to research data. With the favorable settlement of a high-profile lawsuit brought by the Authors Guild and other plaintiffs against both Google and HathiTrust, the latter has moved ahead with research projects to publish curated datasets extracted from the full text of both public domain and in-copyright titles. HathiTrust is committed to providing “non-consumptive” access to its data, and it has developed an approach that provides access through “data capsules”; this approach gives researchers as much flexibility as possible while simultaneously protecting against the unlawful “leakage” of full-text content onto the open web[11].

Researchers are now able to perform data mining on an extracted features dataset that contains page-level data features from all of the nearly 14-million volumes in the HathiTrust corpus. Although this dataset is substantially larger than the largest catalog of library metadata, its current size of 4 terabytes is still comparatively small by big data standards[5]. Nonetheless, HathiTrust’s methodological sophistication and principled approach to data use and access provide a model for other projects in the library domain to follow.

## 4 CONCLUSION

For libraries, archives, and other cultural heritage institutions, the most significant paradigm shift that could be attributed to the big data phenomenon is a new view of descriptive metadata *as data* in its own right. As libraries in particular move away from legacy formats and domain-specific idiosyncrasies, they will be better equipped to serve the evolving needs and interests of researchers, who may themselves be struggling to come to grips with the scale of data in the age of the internet. Once libraries gain a more sophisticated understanding of their own data models and formats, they will be better positioned to assist researchers in managing, storing, and sharing their data—which is likely to be much bigger than anything produced by libraries themselves.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski and the i523 teaching assistants for their support and suggestions in writing this paper.

## REFERENCES

- [1] H. Christenson. 2010. HathiTrust: A Research Library at Web Scale. *LRTS* 55, 2 (2010), 93–102.
- [2] H. Ekbja, M. Mattioli, I. Kouper, G. Arave, A. Ghazinejad, T. Bowman, V. R. Suri, A. Tsou, S. Weingart, and C. R. Sugimoto. 2015. Big Data, Bigger Dilemmas: A Critical Review. *Journal of the Association for Information Science and Technology* 66, 8 (2015), 1523–1545.
- [3] K. M. Ford. 2012. LC's Bibliographic Framework Initiative and the Attractiveness of Linked Data. *ISQ: Information Standards Quarterly* 24, 2/3 (2012), 46–50. <http://www.niso.org/publications/isq/2012/v24no2-3/ford/>
- [4] T. B. Hickey and J. A. Toves. 2014. Managing Ambiguity in VIAF. *D-Lib Magazine* 20, 7/8 (2014), 1–12.
- [5] A. Kinnaman and E. Dickson. 2017. HTRC Docs: Extracted Features Dataset. (Sept. 2017). <https://wiki.htrc.illinois.edu/display/COM/Extracted+Features+Dataset> accessed 2017.
- [6] R. R. Larson and K. Janakiraman. 2011. Connecting Archival Collections: The Social Networks and Archival Context Project. In *Research and Advanced Technology for Digital Libraries, TPDL 2011*. 3–14. [https://doi.org/10.1007/978-3-642-24469-8\\_3](https://doi.org/10.1007/978-3-642-24469-8_3)
- [7] Library of Congress. 2004. MARC XML Design Considerations. (Dec. 2004). <http://www.loc.gov/standards/marcxml/marcxml-design.html> accessed 2017.
- [8] B. Plale, R. McDonald, Y. Sun, I. Kouper, R. Cobine, J. S. Downie, B. Sandore-Namachchivaya, and J. Unsworth. 2013. HathiTrust Research Center: Computational Access for Digital Humanities Research and Beyond. In *JCDL'13*.
- [9] M. Teets and M. Goldner. 2013. Libraries' Role in Curating and Exposing Big Data. *Future Internet* 5 (2013), 429–438. <https://doi.org/10.3390/fi5030429>
- [10] R. Tennant. 2002. MARC Must Die. (Oct. 2002). <http://lj.libraryjournal.com/2002/10/ljarchives/marc-must-die/> accessed 2017.
- [11] J. Zeng, G. Ruan, A. Crowell, A. Prakash, and B. Plale. 2014. Cloud Computing Data Capsules for Non-Consumptive Use of Texts. In *ScienceCloud 2014*.

# Big Data Dangers: Weaponizing Social Media

Ross Wood

rmw@indiana.edu

HID 345

## ABSTRACT

Social media has changed the way people get information, disseminate information, communicate, and stay in touch with others, both online and in the real world. As more and more people from different age groups and socioeconomic backgrounds begin adopting social media and becoming active users, data is being created at a geometric rate. The analysis of all this data being generated can be used in a myriad of different ways, including nefarious ones. It is possible to analyze the digital footprint of social media users in order to accurately target enormous swaths of a population with propaganda, misinformation, and deception which have been created to cater to the specific population's social or political bias.

## KEYWORDS

i523, HID345, Social Media, Social Media Mining, Big Data, Social Media Scraping

## 1 INTRODUCTION

The rise of social media among all tiers of society, not just the tech savvy portion, has created interesting opportunities in the field of big data and social media mining. The decrease in costs and size of computing tools is also helping to fuel a technological explosion among different societies, with more and more people having access to social media than ever before. This increase in users creates a tremendous amount of data, all of which can be analyzed to reveal information about the users and real world populations. This information can be used to inform, educate, and improve the lives and systems we use daily. However, in the wrong hands, this kind of information can also be used to influence and manipulate citizens into supporting things that are against their self-interest, and against the interests of their society. If an informed citizenry is essential to maintaining freedoms, then in effect, social media can be weaponized and used to curtail freedoms for some by misinforming and radicalizing its user bases.

## 2 USER BASE EXPLOSION

The increase in population of social media user bases is helping lead the way in 21st century social engineering, for better or worse, and this increase is causing data to be created at a scale that has never before been seen. Indeed, a report found that the population of adults in the United States who use social media rose from 7% in 2005, to 65% in 2015 [6]. Furthermore, the report found that "there continues to be growth in social media usages among some groups that were not among the earliest adopters, including older Americans" [6]. The ability to scrape massive amounts of user data from social media sites allows for an analysis of a user's individual digital footprint. When all these footprints are put together and analyzed, conclusions about an individual's taste in entertainment, political, and social leanings can be drawn, as well as information about

an individual's personality and socioeconomic background. When these conclusions are combined with user location and network structure data, a situation is created where an organization or group could manipulate an entire segment of a country's population. The success of this method depends largely on how accurate all the accumulated user data is. The more accurate the data, the better job a machine does at making these demographic predictions. But just how accurate can a machine be at predicting a human's personality and sociopolitical leanings based on digital information alone?

### 2.1 Accuracy

The accuracy of a machine's prediction about individual personality and demographics is improved as it accumulates more user data to work with. In essence, the more a person uses social media and creates information about themselves, the easier it is going to be for a machine to look at this information and predict certain things about the person. One study found that to a certain point, humans are better than machines at making personality judgments on other humans. However, once a machine has, in this example as little as 100 Facebook likes, the machine's ability to make accurate personality judgments starts to outperform the predictive ability of humans [9]. The study found that with even a small amount of data, machines can predict a person's personality better than that same person's close acquaintance. The study's findings also "highlight that people's personalities can be predicted automatically and without involving human social-cognitive skills" [9]. This automated process makes it easy for people and organizations to gather large amounts of user data for analysis, that can then be used however these people or organizations see fit.

## 3 NEFARIOUS DEMOGRAPHIC INFORMATION ANALYSIS

An individual's personality traits are not the only information that machines can glean from peoples' social media footprints. Indeed, there are a number of different methods of analysis that can be used when approaching this problem. One would use different methods for trying to figure out different kinds of population information during analysis. It is possible to infer user data, such as age, race, and socioeconomic background, based only on concepts as simple as word use and assigning emotional feelings to different words [7]. All of this demographic information would be quite valuable to individuals or organizations wanting to understand or influence various populations and subsets of populations, or even just to understand user bases for marketing purposes. This user population information that has been generated could then be used to target these various population segments with misinformation and propaganda that appeals to their specific confirmation bias. If the misinformed user were to then share the misinformation or propaganda with their like minded friends online, this could create a self-sustaining cycle of misinformation that reinforces the

misinformed beliefs of users. This is known as an echo chamber and they can be quite pervasive in social media [2].

### 3.1 Using Demographic Data

There are recent examples of these techniques having been used on populations. A post electoral analysis of various elections in Russia found that not only are governments using this approach to their benefit, but also that it works best in regions that exhibit large amounts of racial, social, religious, or socioeconomic tension [4]. Using this data to spread misinformation works by causing both sides of any argument to seem radical, even the rational side. The misinformation does this by working off the confirmation bias of the reader, which was acquired by analyzing their digital footprint. The example of Russian election use found that this approach worked best in areas that were particularly volatile in regards to racial prejudice and struggle [4]. So in other words, someone with a racial bias towards a certain group would have their beliefs reinforced through social media use. This effect is only further reinforced by social media users whose experience on social media is limited primarily to echo chambers, which further distort their view of society while simultaneously widening the societal divide and radicalizing users [2].

### 3.2 Bots

Misinformation and propaganda, which add fuel to the fire of discussions in these so called echo chambers, can also be spread by the insidious use of bots, which are programs that do automated tasks. These tasks range from simple jobs like retweeting something, to complex tasks like conversing with a human and tricking them into thinking the bot is real. Whatever the case, that task is often one that helps convince people of an agenda that the bots have been told to push. As of March 2017, there are almost 48 million active twitter bots. These bots can push any information their masters want, while also serving the purpose of inflating the popularity of people, tweets, and points of view that are more aligned with the bots' agenda [1]. Bots are key to the successful spread and propagation of misinformation and their campaigns. They are now capable of even greater insidiousness by being able to target specific groups using user data generated by social media users. This misinformation technique is taken to another level with bots sophisticated enough to engage in limited conversations with real people over social media [8]. Chat rooms, message boards, and social media sites are flooded with bots, all pushing different agendas. The more resources and effort an organization can put behind an misinformation push of this manner, the more effective it will be.

### 3.3 Social Polarization

Irregardless of who uses these techniques and for what purposes, one outcome that always arises from their use in this way is social polarization. The focal point of the polarization depends on which social struggle is being exploited to manipulate the common social media user. Protests, economic inequality, racial discrimination: there are any number of current social problems to draw from if one wanted to fan the flames of social unrest on a large scale in order to push a political or corporate agenda. This effect is beginning to have

a visible influence on societies around the world as misinformation campaigns are causing more and more people to be misinformed on current events. A misinformed voter does not make good choices, and enough of them together has the potential to throw the entire democratic process out of whack [3]. Social polarization leads to instability and unrest, which can be profitable to certain members of society who might take advantage of these techniques.

## 4 DISCUSSION

Social media use has become so ingrained into everyday life that, at this point, it would be almost impossible to get people to stop using it, even if it was demonstrated to them that it has a potential negative effect on society. Indeed, this abstinence approach should not be advocated, as social media and the data it produces can be used to benefit society at large in a multitude of ways. That being said, it would be wise to continue to monitor and study different ways social media can harm society by being used to benefit the few at the expense of the many [5]. If processes and protections aren't put into place in the near future, the entire democratic process could continue to destabilize and become polarized to the point where it is so consumed by corruption that it cannot be salvaged.

One possible solution is to examine your network and establish who the key peddlers of misinformation are and to block or delete their accounts. This approach would be effective since "successful sources of false and biased claims are heavily supported by social bots" [8]. Another approach is to fight fire with fire and create bots that are sophisticated enough to detect misinformation as it begins to trend and then counter this trend with the truth [1]. Whatever solution to this problem takes shape, the exponential growth of social media users and the unprotected data they generate [6] make it imperative that a solution is found and implemented. Until that happens, huge portions of social media users are going to continue to be tricked into believing misinformation and propaganda through data analysis and manipulation.

## 5 CONCLUSION

The rising population of social media users is beginning to pose a threat in regards to a population's ability to stay accurately informed. As this population of users grows and creates more and more data, so to does the ability to use sophisticated techniques to deceive the users. The growth of social media grows hand in hand with new dangers. As more people get their news through social media, it becomes easier to misinform them. In essence, the more information that is known about someone, the easier it is to take advantage of them. And if you are trying to dupe someone, the modern world makes it easy to accumulate information on people by analyzing their social media digital footprint.

We are starting to see real world effects of these techniques in the form of population destabilization and user manipulation through propaganda and misinformation campaigns. At present there are no safeguards in place to protect users from attempts to deceive them, no matter where the attacks come from or what agenda they have. Until safeguards are developed and put into place to protect users and the enormous amounts of data that they generate from those who would use it against them, the problem is only going to continue to grow and get worse.

## ACKNOWLEDGMENTS

The author would like to thank Dr. Gregor von Laszewski, Miao Jiang, and Juliette Zerick for assistance with this assignment and using github.

## REFERENCES

- [1] Ceren Budak, Divyakant Agrawal, and Amr El Abbadi. 2011. Limiting the Spread of Misinformation in Social Networks. In *Proceedings of the 20th International Conference on World Wide Web (WWW '11)*. ACM, New York, NY, USA, 665–674. <https://doi.org/10.1145/1963405.1963499>
  - [2] Siying Du and Steve Gregory. 2017. The Echo Chamber Effect in Twitter: does community polarization increase?, Vol. 693. 373–378.
  - [3] Robert Epstein. 2016. *Subtle New Forms of Internet Influence Are Putting Democracy at Risk Worldwide*. Springer New York, New York, NY, 253–259. [https://doi.org/10.1007/978-1-4939-6415-4\\_9](https://doi.org/10.1007/978-1-4939-6415-4_9)
  - [4] Regina Goodnow, Robert Moser, and Tony Smith. 2014. Ethnicity and Electoral Manipulation in Russia. 36 (12 2014).
  - [5] Rodrigo Ochigame and James Holston. 2016. Filtering Dissent Social Media and Land Struggles in Brazil. *New Left Review* 99 (Jan. 2016), 85 – 100. <https://newleftreview.org/II/99/rodrigo-ochigame-james-holston-filtering-dissent>
  - [6] A. Perrin. 2015. *Social Media Usage: 2005-2015: 65% of Adults Now Use Social Networking Sites—a Nearly Tenfold Jump in the Past Decade*. <https://books.google.com/books?id=OupAnQAACAAJ>
  - [7] Daniel Preoțiu-Pietro, Svitlana Volkova, Vasileios Lampos, Yoram Bachrach, and Nikolaos Aletras. 2015. Studying User Income through Language, Behaviour and Affect in Social Media. *PLOS ONE* 10, 9 (sep 2015), e0138717. <https://doi.org/10.1371/journal.pone.0138717>
  - [8] Chengcheng Shao, Giovanni Luca Ciampaglia, Onur Varol, Alessandro Flammini, and Filippo Menczer. 2017. The spread of fake news by social bots. (07 2017).
  - [9] Wu Youyou, Michal Kosinski, and David Stillwell. 2015. Computer-based personality judgments are more accurate than those made by humans. *Proceedings of the National Academy of Sciences* 112, 4 (jan 2015), 1036–1040. <https://doi.org/10.1073/pnas.1418680112>
- [6] [9] [7] [4] [2] [1] [3] [5] [8]

# Big Data and Astrophysics

Ricky Carmickle  
Indiana University  
TBD  
TBD, TBD TBD, USA  
TBD@iu.edu

## 1 INTRODUCTION

The volume of data generated by astrophysics and astronomical platforms rivals the output of other data sources. Astrophysics and astronomy are considered a primary domain generating 'Big Data', alongside Twitter, YouTube, and Genomics research. [18].

Astrophysics and astronomy data is generated by relatively few sources [18][22] but each of these sources generates data at a high volume, with high variety, and at high velocity[12]. The emergence of Big Data methods has changed the way astronomical data is gathered and has allowed for rapid growth in the scope and design of astronomical and astrophysical research[3].

## 2 BIG DATA CHALLENGES IN ASTROPHYSICS

Astronomic data requires perpetual development of data cleaning, storage, processing, searching, mining, and analysis tools. [3]. The data collection tools used for the most data-intensive sky surveys are primarily telescopes, which observe astronomical objects in high definition over a wide range of the electromagnetic spectrum from gamma rays, to visible light, to extremely-low frequency radio waves. [23]. The largest astronomic and astrophysics research projects have created databases of hundreds of terabytes, and projects in development are expected to capture data in the exabytes[13][21][22].

The Large Synoptic Survey Telescope (LSST), the highest volume astronomical data project currently under construction, is expected to generate 15TB of data per day with over 200 dimensions of data per astronomical object [25]. This 3.2 gigapixel telescope camera is located in Cerro Pachn, Chile and is expected to generate 30 terabytes of data each night of operation for a total of 150 petabytes over the predicted 10-year operational window [24].

The highest-volume astronomical data project currently in the planning stages is the Square Kilometer Array (SKA), which is set to be constructed with portions of the array located in South Africa, Australia, and New Zealand; construction is expected to be completed in 2024. The data collection would consist of multiple radio telescopes in an array design spread over thousands of kilometers. This project would gather 14 exabytes of data each day of operation and store about 1 petabyte of that daily data[10]. Transmission of this data would match the entire data output of the internet in 2013[1].

Making use of this data has challenged almost every part of the Big Data field. In the most basic sense, the processing of data from astronomical and astrophysics platforms is a process of recording

high-definition images of the sky, comparing all parts of this image to preceding and successive images to determine the movement of individual objects, then directing the most likely candidates for real astronomical changes to human experts for classification [big data revolution in astrophysics]. The depth and detail of images varies depending on the project goals and wavelength of light being observed.

For ground-based observation projects, the most common source of noise in data which requires cleaning are satellites, 'junk' in earth orbit, and defects in the telescope lens which can create artifacts[20]. Two of the most effective methods of cleaning astronomical datasets are the Hough Transform method and the Renewal String Approach[2][19][20]. Data curation and storage must be handled in a decentralized way, with researchers and space agencies across the globe contributing to archiving this flow of data to different cloud storage and open source storage systems[9][17]. The mining of astronomical data has created an entirely new field of 'Astroinformatics[4]' which focuses on efficient management of computing resources. Data mining of astrophysical and astronomical data requires search and selection features which can quickly return data relevant to a researcher's needs[11][16]. Different query solutions, including SQL, Map-Reduce tools, XtreemFS, and new tools constantly in development[7][15]. The ability to analyze astronomical data is ultimately a problem of identifying significant events, new attributes for astronomical objects, and interesting "front-page-news" outliers through the "petascale"[5] data containing high levels of noise as well as less significant data.

## 3 HOW BIG DATA HAS CHANGED ASTROPHYSICS

Astronomical and astrophysical data is growing rapidly in size, and researchers are able to gather increasingly large volumes of data as Big Data tool develop alongside the observational technology.

Many of the leading Big Data tools in Astrophysics and Astronomy were developed around the Sloan Digital Sky Survey (SDSS)[6]. SDSS began observations in 1998 and gathered astronomical data as images until 2009. SDSS ultimately gathered 140 terabytes of data which quickly dwarfed the amount of data gathered in the entire history of astronomy. The fields of Astroinformatics and Astrostatistics emerged as data science caught up to this flow of data. The machine learning, data processing, data storage, and data querying were developed concurrent to SDSS and smaller sky surveys like the Palomar Digital Sky Survey, and the SkyMapper Southern Sky Survey[6][8][14].

The LSST and SKA are examples of research platforms designed with Big Data tools and methods in mind following the development of these tools with prior surveys. There is little indication that

Astrophysics and Astronomy will become less data intensive in the future.

# My great Big Dat Paper

Ben Trovato

Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
trovato@corporation.com

G.K.M. Tobin

Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
webmaster@marysville-ohio.com

Lars Thørväld

The Thørväld Group  
1 Thørväld Circle  
Hekla, Iceland  
larst@affiliation.org

Valerie Béranger

Inria Paris-Rocquencourt  
Rocquencourt, France

Aparna Patel

Rajiv Gandhi University  
Rono-Hills  
Doimukh, Arunachal Pradesh, India

Huifen Chan

Tsinghua University  
30 Shuangqing Rd  
Haidian Qu, Beijing Shi, China

Charles Palmer

Palmer Research Laboratories  
8600 Datapoint Drive  
San Antonio, Texas 78229  
cpalmer@prl.com

John Smith

The Thørväld Group  
jsmith@affiliation.org

Julius P. Kumquat

The Kumquat Consortium  
jpkumquat@consortium.net

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

ACM proceedings, L<sup>A</sup>T<sub>E</sub>X, text tagging

## 1 INTRODUCTION

The *proceedings* are the records of a conference. ACM seeks to give these conference by-products a uniform, high-quality appearance. To do this, ACM has some rigid requirements for the format of the proceedings documents: there is a specified format (balanced double columns), a specified set of fonts (Arial or Helvetica and Times Roman) in certain specified sizes, a specified live area, centered on the page, specified size of margins, specified column width and gutter size [1].

## ACKNOWLEDGMENTS

The authors would like to thank

## REFERENCES

- [1] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. <https://doi.org/10.1007/3-540-09237-4>

# **Big Data Analytics in Cyber Security and Threat Research**

Tousif Ahmed

HID 237

Paper 1

Big Data Application and Analytics, Fall 2017

touahmed@indiana.edu

## **ABSTRACT**

The introduction of big data poses new security threats for the organizations and the consequences can cause catastrophic damages for organizations. Newer threats are sophisticated enough that the existing security mechanisms might be ineffective to thwart the attacks. However, big data analytics and tools can help the organizations to detect the threats and take protective measures. Moreover, big data analytics and machine learning together can detect newer threats which was not possible before. In this paper, we discuss some new cybersecurity threats and challenges that has been bolstered by big data and then we discuss some new big data related security mechanisms which can help the organizations to protect their resources.

## **KEYWORDS**

Big Data, Cyber Security, Threat Intelligence

## **INTRODUCTION**

With the rapid growth of consumer based services, artificial intelligence, and social medias, the number security and privacy threats are also increasing. Emerging cyberattacks are not only a threat for industries, end-users are at more risk than ever. A recent stat published by MalwareBytes suggests that there are a rapid proliferation of number of security threats recently and more than 1 billion malwares were detected in their collected data of six month time span [6]. The consequence of the cyberattacks can be catastrophic to the Organization and the security of the consumers. Therefore, proper defensive mechanism and security controls need to be placed to impede cyber threats. However, newer threats have become so sophisticated that now it's extremely difficult detect and mitigate newer threats. Existing security mechanisms are ineffective due to the large volume of traffic on the internet and lack of resources.

To accommodate and protect from new line cyber attacks, industries now rely on big data analytics. These new big data analytics shows promises for these new sophisticated cyberattacks and a new area of research has established which studies newer threats and explore defensive mechanisms. Advanced analytics and a combination of machine learning can improve the cyber security and provide a new defensive mechanisms. For example, with the large number of traffic on websites big data analytics enables the security administrators to detect intruders effectively and prevent them from compromising the system. Moreover, the big data analytics can also provide newer lines of defense against consumer's security threat. For example, financial industries can analyze the user's financial behavior and detect anomalies which may help users to mitigate the consequence of stolen credit card or identity theft. The introduction big data analytics poses interesting conundrum for security and privacy, on one hand it creates new security and privacy risks and on

the other hand big data analytics provides newer tools for mitigating security threats.

In this paper, we first discuss the cyber security and privacy threats of big data analytics on organizations and consumers, then we discuss some potential applications that can be used to mitigate cyber security risks.

## **CYBER SECURITY THREATS AND CHALLENGES**

In this section, we briefly discuss various security threats that is posed by the introduction of big data analytics:

### **Increased potential for security breaches**

Now, organizations are collecting more data which increased the motivation of the attackers to exploit the organization's vulnerabilities and breach their security. The main objective of the attackers are accessing and downloading consumer's data and that data can be sold to other companies or those information can be used to infiltrate more sensitive data [3]. For example, if the user's email and birth date can be revealed from one system, that data can be used to infer other sensitive information like banking information. The availability of the data motivates the attacker to attack a system and gain access. Recent series of security breaches on high profile companies like Yahoo [10] and Equifax [13] provides examples of increased potential, and the number of affected users provides an example of the consequences.

### **Threats to consumers privacy**

With more data and available tools, consumer's privacy is at more risk than ever. Users share bits of their personal information on various websites and the combined information from various websites poses new security and privacy threats to the consumers. Consumer's privacy threat is a big risk for an organization as the security of the user's data is correlated with the reputation of the organization. Therefore, thwarting the security attacks have become an important issue for the organizations.

### **Sophisticated vulnerabilities**

With sophisticated big data tools, attackers are now implementing more intelligent spams, malware, and website threats [5]. By using machine learning tools, newer generation of spams have been proliferated which is now hard to detect. The rise of chatbots and automated text generating tools have enabled creating spams extremely easy. Moreover, social medias have made spam distribution extremely easy. Besides spams and malwares, increasing number of device usages (smartphone, IoT devices) have increased the number

of BotNets. Using analytics tools, now botnet distribution and management has become pretty easy [4, 11]. The emergence of deep learning has also motivated newer types of security threats.

## Complex security management and monitoring

With high volume of data, now security management is extremely complex. It is very difficult to correctly assess the risks of a system and monitor the networks. With millions of users accessing websites, now it is almost impossible to scrutinize the network traffics. The high volume of data creates additional security risks for organizations. Existing signature based intrusion detection has become irrelevant with higher number of traffics and unpredictable nature of the users.

## BIG DATA ANALYTICS FOR CYBER DEFENCE AND THREAT RESEARCH

In response to newer security threats, big data analytics have been used to provide newer set of tools to the security administrators. Based on the existing researches and news, in this section we discuss some newer techniques for cyber defence:

### Scalable Anomaly detection

The most widely used big data tools for cyber defense is the anomaly detection. Now, with the help of numerous data it has become extremely easy to detect anomalies. Anomaly or abnormal behaviour detection is pretty easy to detect with large volume of data, as most user's exhibits common behavior or patterns. Illegal or bad actors act differently while accessing a system and using clusters it has become very easy to detect anomalies. Nowadays, anomaly detection systems have been incorporated to detect scammers, credit card thieves, hackers, and potential intruders. Network monitoring schemes have become extremely scalable and efficient, so that it can easily raise an alert once an abnormal behavior exhibits [8, 9].

### Effective Malware Analysis

The existing ways to detect malwares are highly inefficient as it highly relies on the previously seen malwares and signatures. Once a software behaves in an inappropriate way (e.g., accessing files that the software does not suppose to, creating multiple copies, logging keys), then the antivirus generates an alert and then the software is matched with the virus database. With the new attack mechanisms, the malware analysis and reverse engineering of the softwares are highly time consuming and inefficient. Moreover, they do not always help to prevent a security breach. With the help of big data analytics tool, now it's become extremely easy to analyze high volume of software behaviors, network traffics, file-system modification. Therefore, big data analytics shows promises of a more intelligent antivirus with more effective malware analysis [7].

### Fake user detection and prevention at scale

With the growing number of services, one problem that the organizations regularly face is that the number of fake users. Often fake users create profiles in various platforms and websites. These fake users often create problems on the platforms ecology and exhibits abusive behaviors towards legitimate users. Identifying fake users often extremely difficult with the large number of legitimate users. Now, big

data analytics provides various tools to analyze networks effectively which allowed the platforms to detect fake users by analyzing their behaviors. Often these fake user's creates a large networks and by clustering algorithms it has become pretty easy to isolate the group of fake users.

### Spam fighting and detect Botnets at scale

Spam and Botnet are one of the major security problem for organizations. They cost useful resources and the underground economy of spam suggests that spam accounts have high benefits [12]. Everyday hundreds of users falls into phishing attack which cost the users monetary loss. The proliferation of social medias and crowd sourced systems have increased the spam distribution. However, now organizations are extremely effective on detecting spams and botnets. Various data analytics are helping organizations to prevent spammers and protect naive users [11].

### Automated security management

As mentioned earlier, security management has become extremely complex with higher volumes of traffic and data. However, big data management tools provide better security management and new data analytics and visualization tools provide automated approach of security management. Now, it's not necessary to manually investigate the behaviors and generate rules. Using the tools and machine learning, now it is possible to predict threats and automate the security and risk management.

### Better surveillance and cyber safety

Since 9/11, we have seen an increasing usage of communication technology by terrorists or malicious users. However, with the variety of platforms it has become hard to identify these malicious actors. Big data analytics tools provide a better tool for government surveillance. Although such massive surveillance compromises public privacy, still such surveillance has become effective to thwart dangerous national attacks and so far more than 50 terror plots have been thwarted [14]. Such massive surveillance have become possible due to the big data tools and analytics. They have been successful detecting anomalous behaviors and identifying the bad actors. Similar to the terrorists, these new tools are helpful for detecting social menaces like pedophiles online and keep people safe online.

## CONCLUSION

Although big data tools and analytics has created cyber threats, it is also helping defending the threats and shown promises on successful defending in the future. According to recent stats, security breaches are declining with the help of big data analytics [2]. However, with the apparent benefits still companies have not widely adopted big data tools for security, only one in five companies are using big data security at this moment [1]. The main reason for not adopting big data analytics is the high cost and lack of human resources. However, it is expected that the cost will be reduced and more people will be interested on big data related tools which may influence widespread use of big data analytics. With the increasing usage and better tools, threats will be more sophisticated and defensive mechanisms need to be advanced on parallel.

## ACKNOWLEDGMENTS

The authors would like to thank Professor Gregor von Laszewski for helping us with the instruction and resources that was required to complete this paper. We would also like to thank the associate instructors for being available on the course website all the time and helping us with their answers.

## REFERENCES

- [1] Bi-survey.com. 2016. Big Data Security Analytics: A Weapon Against Rising Cyber Security Attacks? . <https://bi-survey.com/big-data-security-analytics>. (2016). Online; accessed Sept 30, 2017.
- [2] CSO Online. 2016. How Big Data is Improving Cyber Security. <https://www.csionline.com/article/3139923/security/how-big-data-is-improving-cyber-security.html>. (2016). Online; accessed Sept 29, 2017.
- [3] Hervais Simo Phom. 2015. Big Data: Opportunities and Privacy Challenges. *CoRR* abs/1502.00823 (2015). <http://arxiv.org/abs/1502.00823>
- [4] Y. Gahi, M. Guennoun, and H. T. Moutah. 2016. Big Data Analytics: Security and privacy challenges. In *2016 IEEE Symposium on Computers and Communication (ISCC)*, 952–957. <https://doi.org/10.1109/ISCC.2016.7543859>
- [5] T. Mahmood and U. Afzal. 2013. Security Analytics: Big Data Analytics for cybersecurity: A review of trends, techniques and tools. In *2013 2nd National Conference on Information Assurance (NCIA)*. 129–134. <https://doi.org/10.1109/NCIA.2013.6725337>
- [6] MalwareBytes. 2017. Malwarebytes Releases Global State of Malware Report, Finds 2016 as Year Threat Reality Catches Up to Threat Hype. <https://press.malwarebytes.com/2017/01/31/malwarebytes-releases-global-state-of-malware-report-finds-2016-as-year-threat-reality-caughts-up-to-threat-hype/>. (2017). Online; accessed Sept 27, 2017.
- [7] Rahul Dasgupta. 2015. Big data analytics leads the way for next-gen malware protection. <http://techspective.net/2015/04/27/big-data-analytics-leads-the-way-for-next-gen-malware-protection/>. (2015). Online; accessed Sept 27, 2017.
- [8] A. Razaq, H. Tianfield, and P. Barrie. 2016. A Big Data Analytics Based Approach to Anomaly Detection. In *2016 IEEE/ACM 3rd International Conference on Big Data Computing Applications and Technologies (BDCAT)*. 187–193.
- [9] L. Rettig, M. Khayati, P. CudrĂl-Mauroux, and M. PiĂşrkowski. 2015. Online anomaly detection over Big Data streams. In *2015 IEEE International Conference on Big Data (Big Data)*. 1113–1122. <https://doi.org/10.1109/BigData.2015.7363865>
- [10] Selena Larson.CNN. 2017. Every single Yahoo account was hacked - 3 billion in all. <http://money.cnn.com/2017/10/03/technology/business/yahoo-breach-3-billion-accounts/index.html>. (2017). Online; accessed Sept 27, 2017.
- [11] Kamaldeep Singh, Sharath Chandra Guntuku, Abhishek Thakur, and Chittaranjan Hota. 2014. Big Data Analytics framework for Peer-to-Peer Botnet detection using Random Forests. *Information Sciences* 278, Supplement C (2014), 488 – 497. <https://doi.org/10.1016/j.ins.2014.03.066>
- [12] Brett Stone-Gross, Thorsten Holz, Gianluca Stringhini, and Giovanni Vigna. 2011. The Underground Economy of Spam: A Botmaster's Perspective of Coordinating Large-scale Spam Campaigns. In *Proceedings of the 4th USENIX Conference on Large-scale Exploits and Emergent Threats (LEET'11)*. USENIX Association, Berkeley, CA, USA, 4–4. <http://dl.acm.org/citation.cfm?id=1972441.1972447>
- [13] Tara Bernard and Tiffany Hsu and Nicole Perlroth and Ron Lieber. 2017. Equifax Says Cyberattack May Have Affected 143 Million in the U.S. <http://money.cnn.com/2017/10/03/technology/business/yahoo-breach-3-billion-accounts/index.html>. (2017). Online; accessed Sept 27, 2017.
- [14] The Washington Post. 2013. NSA head: Surveillance helped thwart more than 50 terror plots. [https://www.washingtonpost.com/news/post-politics/wp/2013/06/18/nsa-head-surveillance-helped-thwart-more-than-50-terror-attempts/?utm\\_term=.784e59848c4f](https://www.washingtonpost.com/news/post-politics/wp/2013/06/18/nsa-head-surveillance-helped-thwart-more-than-50-terror-attempts/?utm_term=.784e59848c4f). (2013). Online; accessed Sept 29, 2017.

# Big Data Analytics in Biometric Identity Management

Robert W. Gasiewicz

Indiana University

711 N. Park Avenue

Bloomington, IN 47408

rgasiewi@iu.edu

## ABSTRACT

The United States Government, through its collection and use of biometric data, has leveraged big data in order to protect its citizens and keep our country safe. The speed and accuracy with which this biometric data can be effectively matched to an identity can mean the difference between life and death, as well as the integrity of our institutions. This paper predominantly focuses on how the United States Government, collects, stores, and uses big data to facilitate solving crimes and to enhance national security.

## KEYWORDS

i523, HID316, Big Data, Biometrics, Fingerprinting, 2-Print, 10-Print, Matchers, Matching Algorithms, DHS, Homeland Security, Border Security, National Security, Immigration, Terrorism, FBI, AFIS

## 1 INTRODUCTION

Across the spectrum, big data is rapidly changing the way we do business, the way we live, and the way governments around the world do everything they can to keep us safe in the face of an increasingly dangerous world. Long before the advent of big data, fingerprints were used as a means of forensic identification, but it wasn't until technology had progressed to the point to which these prints could be converted and stored in digital format, organized, and then matched against other stored data and even other databases, that this data truly became useful on the large scale that it is today.

Biometrics technology is changing rapidly, and with it, both the size and scope of data being collected. From 2-print to 10-print, iris to facial recognition, the demand for both data intensive processes and rapid matching have grown exponentially, and understanding how the United States Government uses biometrics is a case study in big data if there ever was one.

## 2 HISTORY OF FINGERPRINTING: THE ANALOG ERA

In 1858, a man by the name of Sir William James Herschel began using fingerprints as a means of identification [4] near Calcutta, India. This started as a means of not solving crimes, but preventing them; Sir William's aim was to thwart attempts at forging signatures - something that had begun to occur at epidemic proportions. Herschel also used fingerprinting to prevent the collection of pension benefits by relatives after the pensioner had deceased.

It wasn't until 1886 that Scottish surgeon, Dr. Henry Faulds, proposed the concept of using fingerprints to identify criminals to London's Metropolitan Police [3]. Incredibly, they dismissed his proposal.

By 1906, the concept of identifying criminals using fingerprints had made its way to the United States, first in New York City and then elsewhere throughout the country. In 1924, the United States Congress created the Identification Division of the Federal Bureau of Investigation (FBI) and 22 years later, they had processed over 100 million fingerprint cards. By 1971, this number had more than doubled [5].

## 3 BIOMETRICS ENTERS THE DIGITAL AGE

Before the 1960s and 1970s, fingerprints were stored on cards and expert examiners studied fingerprint features, or minutiae, such as ridges, enclosures, and bifurcations. Fingerprints were then filed according to the Henry classification system [1]. Processing was slow, taking weeks or even months and everything had to be done at one central processing facility. Big Data was perfect solution to this problem.

By the dawn of the 1980s, the completely analog system transitioned toward a more digital platform by storing filing codes on early computer systems. It wasn't until 1986 that the Automated Fingerprint Identification System was released commercially to agencies across the United States Government.

## 4 AUTOMATED FINGERPRINT IDENTIFICATION SYSTEM (AFIS)

In July of 1999, the AFIS or IAFIS system became a fully automated, nationalized computer system intended for enhanced and rapidly expedited matching capabilities. The AFIS system is not only a criminal and civilian database for fingerprints, photographs, as well as military and civilian data, it is also a matching system, providing either positive or negative identification of prints submitted against its cache of stored records. In addition to biometric identification, AFIS also serves as a means of biographic identification based on pieces of data such as name, date of birth, tattoos, various ID numbers, and other relevant personally identifiable information (PII).

As Simon A. Cole explains in his 2002 book, *Suspect Identities: A History of Fingerprinting and Criminal Identification* [1], AFIS can work in four of the following ways:

1) 2-print (left and right index finger) and 10-print (all ten of a person's digits) taken from a crime scene, body, or border checkpoint and can be checked against a database of other fingerprints

2) A single latent, or partial trace print can also be checked against a database of other fingerprints

3) A complete 2-print or 10-print image can be checked against other stored latent prints

4) So-called "unsolved" prints, both latent and complete 2-print and 10-print images can be stored in the database and checked against any new subsequent additions.

Today AFIS is the largest biometric database in the world.

## 5 INITIAL ACHIEVEMENTS OF DIGITIZATION

With AFIS, the original intent of digitizing several hundred million fingerprint cards was to make it easier to do a job that was already being performed manually. As outlined above, it met two requirements: identify fingerprints and serve as a central reporting system on criminal history for the United States Government.

As time went on, AFIS began to earn additional credibility in other areas as well. It not only helped to improve the collection and identification process with regard to latent fingerprints, but it also forced the standardization process by which all fingerprints are collected, stored, and matched against. These standards are known as uniform biometric standards and were essential in enabling various government agencies to share data they collect.

In addition to saving the government and the environment an enormous amount of ink and paper by doing away with fingerprint cards, AFIS has also helped to expedite the pace at which criminals are able to be identified as well as how quickly cases are able to be adjudicated. Lastly, an additional immediately recognized benefit of digitization of fingerprint records has been the rapid improvement of digital image quality needed to more accurately match fingerprints.

## 6 BIOMETRICS AND BIG DATA

The ever-present question in the world of burgeoning big data is always: "how is this useful?" Often large swaths of data are collected as a part of standard business processes, or, in this case, as a part of criminal investigations and only later are new uses found for the data that's been gathered. As technology evolves new possibilities emerge and stewards of the data find new ways in which it can be used.

There are times, however, in which there are catalysts in addition to the steady march of technological advancement that force us to change the way we look not only our data, but at the world around us. After September 11th, 2001, the United States Congress passed the "Homeland Security Information Act" which with the understanding that information systems for collecting biometric and biographical data were already in existence, must be efficient and should not be duplicated throughout the federal, state, and local governments. The U.S Department of Homeland Security was created in 2002, consolidating many disparate agencies under one roof and one new cabinet level position, reporting directly to the President of the United States.

Subsequent to this, it was incumbent upon the United States Department of Justice (DOJ) to use any means necessary to protect the United States from being subjected to any additional acts of terrorism. To accomplish this the DOJ would need to have other United States Government agencies working together to share information, but foreign law enforcement agencies as well.

## 7 ENHANCED BIOMETRIC DATA COLLECTION

Biometric Big Data got even bigger in 2003 when the recently formed U.S. Department of Homeland Security created the United States Visitor and Immigrant Status Indicator Technology (US-VISIT) program. In order to meet the ever-increasing demands to preserve and secure our national security, additional measures and enhanced collection at border crossings and at airports was undertaken. Prior to US-VISIT, as had been observed for hundreds of years, paper travel documents and biographical information could be easily forged, various systems were scattered across the U.S. Government and were not well-coordinated, and partner countries did not abide by the same sets of guidelines.

With the creation of the US-VISIT program, the digitization of both biometric and biographic details of individuals coming in and out of the U.S. ensured that these details could not be easily forged or altered. Specifically, the use of fingerprints, and moreover the ability to match them against the largest biometric database in the world in around 10 seconds, prevents untold hundreds of thousands of attempts by dangerous criminals and terrorists from obtaining visas or gaining entrance to the U.S.

By working closely with other agencies across the U.S. Department of Homeland Security, US-VISIT has the same access to crucial fingerprint data as:

- 1) Immigration and Customs Enforcement (ICE)
- 2) Customs and Border Protection (CBP)
- 3) FBI
- 4) Department of State (DOS)
- 5) U.S. Citizenship and Immigration Services (USCIS)
- 6) U.S. Coast Guard (USCG)
- 7) Department of Justice (DOJ), State, and Local Law Enforcement
- 8) Department of Defense (DOD) and Intelligence Community

This level of cooperation was solidified even further on October 25, 2005 with U.S. Presidential Executive Order 13388 [2]:

To the maximum extent consistent with applicable law, agencies shall, in the design and use of information systems and in the dissemination of information among agencies:

- (a) give the highest priority to
  - (i) the detection, prevention, disruption, preemption, and mitigation of the effects of terrorist activities against the territory, people, and interests of the United States of America; (ii) the interchange of terrorism information among agencies; (iii) the interchange of terrorism information between agencies and appropriate authorities of state, local, and tribal governments, and between agencies and appropriate private sector entities; and (iv) the protection of the ability of agencies to acquire additional such information; and

(b) protect the freedom, information privacy, and other legal rights of Americans in the conduct of activities implementing subsection (a).

This E.O spelled out the sweeping changes that the U.S. Department of Homeland Security had already made to the way data was collected, processed, standardized, and matched against.

## 8 THE FUTURE OF BIOMETRICS AND BIG DATA

The future of biometrics and big data is bright. In the past decade, the U.S. Government has moved from 2-print to 10-print, with plans to begin using iris and facial recognition, as well as gait, to identify and neutralize threats. The move from 2-print to 10-print alone represented five fold increase in data storage needs. Storing detailed images of a person's eyes, their face, and the way they walk will require even more data storage capacity and the raw computing power to analyze it. Such advances are necessary to keep us safe in an increasingly dangerous world.

## REFERENCES

- [1] Simon A. Cole. 2002. *Suspect Identities: A History of Fingerprinting and Criminal Identification*. Academic Trade. (book).
- [2] Information Sharing Environment. [n. d.]. Executive Order 13388. ([n. d.]). Retrieved October 4th, 2017 from <https://www.ise.gov/resources/document-library/executive-order-13388-further-strengthening-sharing-terrorism-information-protect-americans>
- [3] Henry Faulds. 1880. *On the skin-furrows of the hand*. Oxford University Press. <https://doi.org/10.1038/022605a0> (book).
- [4] William J. Herschel. 1916. *The Origin of Finger-printing*. Number ISBN 978-1-104-66225-7 in Fundamental Algorithms. Oxford University Press. (book).
- [5] U.S. Marshals Service Website. [n. d.]. Fingerprint History. ([n. d.]). Retrieved October 3rd, 2017 from <https://www.usmarshals.gov/usmsforkids/fingerprint-history.htm>

# **Big Data and Artificial Intelligence Solutions for in Home, Community and Territory Security**

**Ashok Reddy Singam**

Indiana University

711 N Park Ave

Bloomington, Indiana 47408

asingam@iu.edu

**Anil Ravi**

Indiana University

711 N Park Ave

Bloomington, Indiana 47408

anilravi@iu.edu

## **ABSTRACT**

Anti-social activities became the most significant threat to national security because of their potential to bring massive damage to our homes, public infrastructure, economy, and people. The existing systems and methods haven't reached the level of sophistication to be able to consolidate the large volumes of relevant data from variety of sources and demographics. The present video surveillance systems use static cameras at fixed locations inside/outside the house to provide alerts when any event detected. However, they are not intelligent enough to understand the context, recognizing the people faces and voices, and differentiate between family members and strangers etc. The limitations of data collection, data mining and adoption of artificial intelligence led to ineffective systems which are not as predictive as they should be.

The concept of having an intelligent "ear-and-eye" monitoring at the home to constantly observe the surroundings both inside and outside can protect the house and personnel much more safer way. By extending this capability to the neighborhood and city through collaboration would create safe cities across the world. The key differentiating capability from existing systems is to use a micro drone with integrated video and voice with environment sensors to process the voice and facial data with machine learning algorithms. The limited range micro drones can freely move around the house based on the voice and video analytics while learning the friends, family members and strangers.

The technology advancement allows integrating the video, audio and social media data of targeted regions (homes, public places and extended areas) for comprehensive security analysis. Such systems can use advanced statistical methods, image classification and machine learning algorithms to predict and prevent the threats based on the severity probability.

## **KEYWORDS**

i523, HID333, HID337, Artificial Intelligence, Neural Networks, Machine Learning, Micro Drone

## **1 INTRODUCTION**

It is widely believed that information technology will play an indispensable role in making the world safer by supporting intelligence and knowledge discovery through collecting, processing, analyzing, and utilizing terrorism and crime related data[3]. Social network analysis (SNA) has been widely explored to support intelligence and law enforcement agencies in investigating the terrorist and criminal social networks. It is valuable in identifying terrorists, suspect subgroups, and their communication patterns.

However, in the present world, the systems are disparately processing the data and the decisions/conclusions are being made without considering multiple dimensions of the context. The large corporations, nations, and intelligence agencies are using their individual systems in isolation but not taking integrated approach to solve the problems in their entirety due to their political and economic interests.

Analyzing the individual human behaviors, interactions, transactions, and actions is the key element in identifying the potential threat in advance. Generating and analyzing such data from individual homes and extending the concept to larger groups is the idea behind this discussion.

The current technologies allow to collect the data from individual homes and roll up to the communities, cities and then to the nations across the world. Since this involves with the personal data from people directly, it is required to follow privacy-preservation policies and methods enforced by local/national government agencies. By accessing the household level data of individuals video, voice, social media and other business transactional data would allow to characterize, analyze and assess the people behaviors and motives which can be maintained and processed as needed by Big Data systems. These systems are very complex in nature due to the variety, volume and velocity of the data, where the Big Data technologies will play a significant role in realizing them. In addition to data collection and mining, if artificial intelligence is applied to analyze and evaluate the data then the crime prediction and prevention would be feasible.

In order to realize such systems, one would need several technologies and sub-systems in various layers to effectively collect, transfer, mining, learning and analyze the data. In the following sections some of the technologies/sub-systems that can be used to achieve the objectives of proposed conceptual model are described. The discussion here consists of reviewing the available papers/systems related to security informatics and understanding the technologies and methods used. The gaps perceived in the review are attempted to solve by proposing a new concept.

## **2 HOME SECURITY CONCEPT**

This section describes a proposed scalable security system concept, which can be extended to community, city and beyond. The conceptual model has multiple sub-systems coordinate with each other to establish a robust home security system. In this model, a micro-drone integrated with video and audio will continuously monitor the house both inside and outside. An autonomous dual micro-drone model will have capability to view the surrounding

with high resolution frame rates and transfer the data to edge processing unit and/or cloud based HDFS server. The social media data of housemates (e.g., E-mail, Facebook, Twitter, WhatsApp, and other web/mobile applications) gets integrated in to HDFS server.

This will establish a known context with complete information of individuals residing in the house by analyzing the contacts, communication exchange (phone calls, SMS, E-mails), trade transactions, and family/friends/foe information. With the combination of video, voice and social network data a comprehensive home security system can be achieved which not only protects the house but also individuals by having superior knowledge about all the activities. This will require Big Data infrastructure along with machine learning algorithms in various sub-systems.

This conceptual model can be realized with available technologies and can be architected such that it will become a basic building block for scalable system.

Some of the existing technology companies making us to believe realization of proposed concept:

- *Squadrone System*: A Pioneer in producing intelligent deep learning drones for real-time surveillance
- *Neurala*: A leader in deep learning and neural network software for drones
- *Nvidia*: The world leader in visual computing technologies and leading GPU manufacturer

## 2.1 Dual Micro-Drones with Video and Audio

The prevailing drone technology is reaching higher levels of sophistication allowing newer concepts to be realized in surveillance applications. In this proposed concept a micro-drone with integrated video, voice and environmental sensors (temperature, humidity, and accelerometers) can be designed along with learning algorithms to add intelligence. In the basic system, there will be two micro-drones to cover both in-side and out-side of the house (can consider adding more depending on the size of the house/facility) monitoring activities all the time. The drone hardware and software detects and recognize all moving objects through deep learning algorithms such as Regional Convolution Neural Networks (R-CNN). Li Wand and Dennis Sng[8] have reviewed the recent progress of deep learning in object detection, object tracking, face recognition, image classification and scene labeling. The deep models have significantly improved the performance in these areas, often approaching human capabilities. The reasons for this success are two-folded. First, big training data are becoming increasingly available (e.g. data streams from a multitude of sensors) for building up large deep neural networks. Second, new advanced hardware (e.g. GPU) has largely reduced the training time for deep networks.

The concept of micro-drone video and audio sub-system is to recognize human face and voice and establish the association. After the human object is created with face-voice association, the human characteristics, behaviors, social contacts, social media accounts, family/friends contact database and personal identification will be mapped. This person object (one of the housemate) will be constantly trained with large set of data during the learning period. Once the person object is matured with enough intelligence then the system will be ready for monitoring and analyzing the data of the person he/she actually mapped to. Multiple person objects will

be created to map all the persons live in that house. The duo micro-drones are intelligent enough to recognize all the persons in the house and understand their behaviors, motives, actions, schedules, plans and their complete activities as time progresses.

These micro-drones freely move around the house to monitor the family, friends, foes, strangers, and people who ever happen to be in the house surroundings and visit to meet housemates. Micro-drones are smart enough to sense the people emotions based on the expressions, conversations and actions to predict the future consequences and get ready for protective actions (e.g., alerting appropriate people and agencies). Also, micro-drones are equipped with sensors to detect environment conditions (temperatures, wind, rain and humidity etc...) to take good care of themselves by reaching back to dock/home stations while ensuring that security precautions are addressed.

Since micro-drones are autonomous with self-manuevering and self-diagnostics capabilities, they will take care of self-charging, protecting themselves from being damaged by staying away from objects and people.

The technologies available to realize such a micro-drone consists of: autonomous multicopters, high resolution built-in 360 degree video cameras, high speed network link, high speed GPUs, environment sensors, software with machine learning algorithms for various capabilities discussed above.

## 2.2 Big Data Infrastructure for Data Handling

Big data can be acquired, stored, processed, and analyzed in many ways. The big data source has different characteristics, including the frequency, volume, velocity, type, and veracity of the data. In the proposed conceptual model, multiple sub-systems generate the big data from variety of sources such as video, voice, environment sensors (temperature, humidity, wind etc.). Also big data will be generated from all major social media accounts of individual house mates such as Twitter, Facebook, YouTube, Instagram, E-mails and WhatsApp in addition to GPS location, mobile phone calls and text messages.

The Big Data infrastructure would organize the data through multiple data layers such as collection hub, staging hub and Data Lake. Apache Hadoop has emerged as the de facto standard way of storing all of this *Big Data*, mostly in the form of commercial implementations from HortonWorks, Cloudera and MAPR. Associated technologies such as Flume, HBAsE, Hive, Kafka, MapReduce, Spark and Storm offer different ways to get information into and out of Hadoop Distributed File Systems (HDFS) so it can be shared with analytics engines, enterprise applications and user interfaces.

## 2.3 Data Privacy Preservation Models

In the proposed conceptual system, multiple layers of sub-systems collect the individual home level information and uses anonymization models to preserve the privacy of individuals. The objective is hiding the sensitive personal information such as personal identities but publishing the rest of the data, an anonymized version of relational data. The data that will be sent out to be used for next level (community/region) fed to privacy preservation algorithms such as k-anonymity protection models which are being used in real-world systems known as "Datafly", "-Argus" and "k-Similar".

The k-anonymity methods ensure that at least k records with respect to every set of quasi-identifier attributes are indistinguishable. There are other alternative methods such as l-diversity and m-invariance can be applied as well to apply different constraints on anonymity. For social network integration in to proposed system, models can use subgraph generalization approach to preserve the privacy, which has been discussed in the paper "Privacy-Preserved Social Network Integration and Analysis for Security Informatics"

## 2.4 Video Data Integration and Analysis

The high quality video image frames will be processed to analyze the situational awareness. Learning hierarchical representation of video image data by using deep architecture models is the key component of video analytics. By using the deep learning algorithms to perform object detection, object tracking, face recognition, image classification and scene labeling would enable to establish a comprehensive situational awareness in the home security context. For example, facial expressions manifest not only emotions but also allied actions, behavioral patterns and give a lot of useful data when it comes to helping law enforcement and forensics agencies. Video analytics can be achieved based on data curation, sentiment analysis, and other advanced solutions. Expressions like "happy", "sad", "angry", "scared", "surprised" or "neutral" form the basis of video analytics.

This method and approach can be extended to city and region levels by rolling up the data from individual homes. In the context of city and regional security, video analytics would help in people management, vehicle management, behavior monitoring. For example, in the public events deep learning enabled systems can perform crowd detection, queue management, people counting, people scattering, people tracking; in the vehicle management, systems can perform vehicle classification, traffic monitoring, license plate recognition, road data gathering. Also, behavior monitoring can be achieved through motion detection, vandalism detection, face detection, privacy masking, and suspicious activity detection. With the advent of new technologies in computing speed there are several Graphics Processing Units (GPU) integrated with high quality image sensors introduced by technology companies such as NVidia can be used in the conceptual model.

## 2.5 Voice Data Integration and Analysis

The live voice recording integrated with video analysis provides better and accurate insight in to situation awareness for predicting and preventing the potential threats much faster. Traditional voice analytics tools rely on keywords and phonetics. These solutions are not well enough in deriving context and relevancy. With big data and AI advancements, now it is even possible to analyze for things like stress levels, lies, emotional content and more from audio data. Deep learning is becoming a mainstream technology for speech recognition and has successfully replaced Gaussian mixtures for speech recognition and feature coding at an increasingly larger scale. Google's Speech Recognition API built using deep learning neural network algorithms is one of the voice analytics software available in the market, which can be used in the proposed conceptual model.

In the proposed conceptual model, the complete characterization of housemates can be performed using deep learning algorithms. This will help to recognize the voice of the persons within the house and build the context. Also, the learning algorithms continue refining the voice characterization of the persons and extend the voice database to other family members and friends. This key aspect of associating voice to the person would help resolving the contextual issues if any arises during behavior assessment.

## 2.6 Social Media Data Integration

In the conceptual model, along with the video and voice association, if the individual social media activity is monitored his/her behavior can be predicted to assess the motivations and potential actions. The social media accounts can be integrated in to big data system to collect the data from applications such as Facebook, Twitter, Instagram, WhatsApp, E-mails, and SMS etc.

By analyzing behaviors observed on social media, we can categorize these behaviors into individual and collective behavior. User activities on social media generate behavioral data, which is massive, expansive, and indicative of individual preferences, interests, opinions, and relationships. This behavioral data provides a new lens through which we can observe and analyze individual and collective behaviors of people.

Natural language processing (NLP) algorithms along with reasonable quantity of training data can lead to understand sentimental behavior, which is one of the key elements for security informatics. This capability can be applied to proposed conceptual model to ensure that system is analyzing the social network data.

## 2.7 Learning Algorithms and Predictive Analysis

The two critical machine learning algorithms needed to realize the proposed concept are for the face and voice recognition. Deep learning models are potential candidates for these two tasks. Deep learning architectures have different variants such as Deep Belief Networks (DBN)[2], Convolutional Neural Networks (CNN)[4], Deep Boltzmann Machines (DBM)[5] and Stacked Denoising Auto-Encoders (SDAE)[7], etc. The most attractive model is Convolutional Neural Networks which have achieved very promising results in both computer vision and speech recognition.

The ability to estimate the occurrence of future events using expertise, observation and intuition is critical to the human decision-making process. From a biophysical perspective, there is strong evidence that the neocortex provides a basic framework for memory and prediction in which human intelligence emerges as a process of pattern storage, recognition and projection rooted in our experience of the world and driven by perception and creativity. There is increasing consensus among cognitive psychologists that human decision making can be seen as a situation-action matching process which is context-bound and driven by experiential knowledge and intuition. Significant advances have been made in the integration of predictive modeling with social and behavioral factors, in both equation-based approaches, and probabilistic evidentiary reasoning approaches[6].

### 3 COMMUNITY DRONE NETWORK

The intelligent drone home security system would enable to provide comprehensive situational awareness at home level. The proposed drones are limited in their coverage area which is strictly enforced by regulatory/intelligence/government agencies. Since this intel-drone is scalable to extend the coverage by just adding another device, it can be conceivable to create a network of intel-drone to cover a given community. The community drone network is collection of security drones covering a specific region within a city which will ensure that relevant data is delivered to law enforcement and intelligence agencies. This would require one of the drones in the network to be nominated as *Gateway Drone* to communicate with law enforcement/intelligence agencies. Each drone will have the capability to become a *Gateway Drone* as needed. When the new drone is installed it will automatically look for existing *Gateway Drone* in that community, which if exists then it will join the network and gets registered. If no *Gateway Drone* is recognized, the new drone claims or becomes *Gateway Drone*.

#### 3.1 Gateway Drone

The *Gateway Drone* represents a specific community, which will maintain all the home addresses within that community along with associated personnel per the privacy preservation policies set forth by the regulatory/intelligence agencies. The *Gateway Drone* performs dual function (1) ensure that constantly communicates with *Police Drone* or *City Drone* and (2) monitor its own house security aspects.

The *Gateway Drone* is critical drone in the regional/city security context as it will provide all sensitive information timely to alert the agencies with potential threat.

The *Gateway Drone* will discharge or transfer its role when it is no longer capable of doing so due to any technical and/or any other issues. When existing *Gateway Drone* is dropped off from its role then all the drones within the network will be alerted and one of the drones that is closer to the *Police Drone* or *City Drone* will become the *Gateway Drone*.

### 4 CITY/EXTENDED REGIONAL DRONE NETWORK

The proposed conceptual model defines city level security network as a combination of multiple *Community Drone Networks* together. In a given city there can be 'n' number of *Community Drone Networks* based on the households, public places, and commercial entities. A network of *Gateway Drones* forms as a *City Drone Network* with one of the drones nominated as *City Gateway Drone*.

Developing a fully autonomous and cooperative multi-drone system requires robust inter-drone communication. There has not been enough research to say with conviction what design would work best. The reliability and bandwidth requirements from the drone networks are diverse. The drone networks, therefore, have all the requirements of mobile wireless networks and more. Node mobility, network partitioning, intermittent links, limited resources and varying QoS requirements make routing in drone a challenging research task[1].

In the proposed conceptual model, since each drone will use WLAN infrastructure mode in addition to Adhoc mode, there will

always be a reliable network available to exchange the information. The security drones will switch between Adhoc and infrastructure modes based on the network availability to pass on the information to *Gateway Drones*.

#### 4.1 Drone Networking Challenges

The main challenges that drone networks facing are routing, seamless handover and energy efficiency. Routing has unique requirements - finding the most efficient route, allowing the network to scale, controlling latency, ensuring reliability, taking care of mobility and ensuring the required quality of service. In drone networks, additional requirements of dynamic topology (with node mobility in 2-D and 3-D), frequent node addition and removal, robustness to intermittent links, bandwidth and energy constraints make the design of a suitable protocol one of the most challenging tasks[1].

The handover latency and the packet loss during handover process may cause serious degradation of system performance and QoS perceived by the users. IEEE has standardized Media Independent Handover (MIH) services through their standard IEEE 802.21. These services can be used for handovers and interoperability between IEEE-802 and non-IEEE-802 networks, e.g., cellular, 3GPP, 4G. MIH, however, does not provide intra-technology handover, handover policies, security and enhancements to link layer technologies. However, MIH is a nascent technology that has not been widely deployed and evaluated[1].

Energy efficiency is a very important requirement in drone networks. Reducing the energy consumption helps in increase in network lifetime and useful payload that can be carried. Energy consumption can be reduced through transmission power control; load distribution or making nodes sleep[1].

### 5 CONCLUSION

In this discussion it has been perceived that existing security informatics systems are disparately implemented and consolidation of data and analysis at various layers hasn't been done efficiently. Considering that big data technologies are robust enough to collect the large volumes of data from variety of sources, a conceptual model is proposed to discuss the feasibility of integrated video, voice, and social media data of individuals to be collected and analyzed for applying the machine learning algorithms. With the technologies such as high speed computing and big data infrastructure, learning algorithms can be applied to solve face and voice recognition. The combination of video, voice, and social network data the proposed conceptual system can address some of the prevailing home, community and territory security challenges and issues.

### ACKNOWLEDGMENTS

The authors would like to thank professor Gregor von Laszewski and his team for providing *LaTex* templates and assistance with *JabRef* tool to organize references.

### REFERENCES

- [1] Lav Gupta, Raj Jain, and Gabor Vaszkun. 2015. Survey of Important Issues in UAV Communication Networks. *CoRR* 18 (11 2015), 1–1.
- [2] G. E. Hinton. 2009. Deep Belief Networks. *Scholarpedia* 4, 5 (2009), 5947.
- [3] Paul Kantor, Gheorghe Muresan, Fred Roberts, Daniel Zeng, Frei-Yue Wang, Hsinchun Chen, and Ralph Merkle. 2005. *Intelligence and Security Informatics* (1 ed.). Vol. 3495. Springer-Verlag Berlin Heidelberg.

- [4] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E Hinton. 2012. ImageNet Classification with Deep Convolutional Neural Networks. In *Advances in Neural Information Processing Systems 25*, F. Pereira, C. J. C. Burges, L. Bottou, and K. Q. Weinberger (Eds.). Curran Associates, Inc., 1097–1105. <http://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf>
- [5] Ruslan Salakhutdinov and Hugo Larochelle. 2010. Efficient Learning of Deep Boltzmann Machines. In *Proceedings of the Thirteenth International Conference on Artificial Intelligence and Statistics (Proceedings of Machine Learning Research)*, Yee Whye Teh and Mike Titterington (Eds.), Vol. 9. PMLR, Chia Laguna Resort, Sardinia, Italy, 693–700. <http://proceedings.mlr.press/v9/salakhutdinov10a.html>
- [6] Antonia Sanfilippo, Nigel Gilbert, and Mark Greaves. 2012. Technosocial predictive analytics for security informatics. *Security Informatics* 1, 1 (22 Aug 2012), 8. <https://doi.org/10.1186/2190-8532-1-8>
- [7] Pascal Vincent, Hugo Larochelle, Isabelle Lajoie, Yoshua Bengio, and Pierre-Antoine Manzagol. 2010. Stacked Denoising Autoencoders: Learning Useful Representations in a Deep Network with a Local Denoising Criterion. *J. Mach. Learn. Res.* 11 (Dec. 2010), 3371–3408. <http://dl.acm.org/citation.cfm?id=1756006.1953039>
- [8] Li Wang and Dennis Sng. 2015. Deep Learning Algorithms with Applications to Video Analytics for A Smart City: A Survey. *CoRR* abs/1512.03131 (2015).

## A WORK BREAKDOWN

### A.1 HID 333:Anil Ravi

- Identified Paper1 topic
- New Security System conceptual model
- Literature study
- Created Abstract and Introduction Sections
- Created Home Security Concept section
- Created Community Drone Network section
- Reviewed the draft paper

### A.2 HID 337:Ashok Reddy Singam

- Editing Latex template using ShareLatex online tool
- Managed JabRef entries
- Created Video Data Integration and Analysis Section
- Created Voice Data Integration and Analysis Section
- Reviewed articles on Machine learning
- Created Learning Algorithms Section
- Reviewed the draft paper

# **Big Data Analytics in Sports - Track and Field**

Mathew Millard  
Indiana University Bloomington  
938 N Walnut St. Apt. G  
Bloomington, Indiana 47404  
mdmillar@indiana.edu

## **ABSTRACT**

This paper covers the impact that Big Data has and could have on the sport of track and field.

## **KEYWORDS**

i523

## **1 INTRODUCTION**

This is my introduction

## **2 THE BODY OF THE PAPER**

This is the body of my paper

## **3 CONCLUSIONS**

This is my conclusion

## **ACKNOWLEDGMENTS**

Acknowledgments

## **REFERENCES**

# Big Data Analytics in Sports - Soccer

Rahul Velayutham

Indiana University Bloomington

2661 E 7th Street Apt H

Bloomington, Indiana 47408

rahul.vela@gmail.com.com

## 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. The impact of Big data in the field of sports, in particular, soccer and how they have helped football clubs evolve their business models and operations from a more hands-on approach to applying complex software and ML models to improve tactics, scouting, and training practices. This study takes a look at the technologies that have been used like MiCoach, Tracab and a look at the leading players like Opta and how the data generated from these companies could be put to use. It is hoped that this study will help demonstrate the importance of Big data in sports, its applications, and avenues for improvement in the field.

## KEYWORDS

Big Data, Soccer , Scouting

## 1 INTRODUCTION

## 2 BIG DATA IN SOCCER

Big Data has become a crucial part of soccer. Data obtained from big data technologies is used to chart training sessions, shape tactics, predict odds for betting and suggest line ups for fantasy premier leagues. Journalists are increasingly using facts obtained from big data to corroborate their stories and often create new stories when normally none could have existed, for example stats may show a player's ineffective performance could be masked by the good form of the team mates around him. We will now go into a little detail of how all this is done.

### 2.1 Big Data in Scouting

**2.1.1 Introduction.** Two of the biggest commodities in soccer are the clubs and its players. As mentioned previously transfers are now some of the biggest sources of revenue for clubs. Players fetch for as high as 200 million pounds these days[13]. Also, the quest to find the next big star / the hidden gem against proven expensive players is now a mark of success. Clubs cannot freely go and sign whoever they feel are data monsters, restrictions on the number of players they can sign while at the same time the potential costs that may be involved in the transfer force clubs to make sure the investment they make are the right one. It is recommended to have a look at this article to understand what happens behind the scenes at football clubs when it comes to scouting[4].

**2.1.2 Data collection.** Most clubs either have acquired specific companies for scouting for example Arsenal FC acquired paid over

2 million pounds for the US company StatDNA, whose data has since been used to advise their signings. [8], and or have scouts who obtain the data themselves. As to how clubs obtain the data, most do not divulge such details to protect their strategies but consensus is that popular sites like opta which analyze matches at real time and release statistics for others to make use of[7]. Alternatively, clubs send performance analysts to feeder clubs and they track matches of prospective candidates and create data for themselves. It is also worth noting that big data has led to only to software development but as well as hardware, for example the Adidas MiCoach a device that tracks metrics and displays it to coaches is used during training and potential scouting sessions. The article mentioned provides an example of how the device was used to realize a gem among a batch of superstars.[6]

**2.1.3 Data Processing.** Most articles only explain in theory how they go on about processing the data and even fewer talk about the technical aspect behind it. Corroborating from different sources [10][5][8] a general theoretical summary can be given, In the case of obtaining data from say the internet i.e., mine data from free sites like squawka, whoscored, opta. Data warehousing technologies like pig, Hadoop etc, can be used. Parsing the XML, one can store this data and applying meaningful ML algorithms with defined parameters to filter players. For example, we can mine the data for fields like chances created, distance covered etc for a league and then filter out say midfielders and chances created in order to find the next best attacking midfielder.

For clubs generating their own data, real time analysis of videos using advanced image processing technologies in tandem with their own hands on analysis they could generate data and store it again or say CSV files. These files then could be uploaded to a private databank. From these banks data warehousing can be once again performed and the previous process can be repeated.

### 2.2 Big Data in Training and Tactics

In today's world which is being driven more and more by capitalistic gains, even the world's most famous sport i.e., soccer cannot be spared. Sports players command huge transfer fees, MNCs are pumping billions [ millions are soon becoming a thing of the past][2], and as such the even the tiniest mistake can lead to millions lost. Hence, now there is a need to augment daily operations from scouting to coaching level with technology. One of the technologies which are fast invading the world of soccer is big data. One can never have enough data, data guides tactics, training session, betting, scouting and so much more. Gone are the archaic days of notes and papers and specialists [ these specialists do have a very important role to play but with the advancing times they may soon become a thing of the past]. The study looks at two crucial aspects

in soccer scouting and training, tactics. In tactics, we look at the new sensation known as fantasy leagues.

**2.2.1 Introduction.** Before the advent of big data, coaching was a more personalized hands-on affair, that doesn't mean it is any less now but the amount is a lot less than before. Preparing for match involved sending scouts and making them watch the match live and relying on their notes or analyzing videos for hours in hopes of trying to find a weak link. Coaches do spend hours in front of a TV screen but they augment it with software and now look at games from a data-sided point of view, an example of this is the former coach of Everton Roberto Martinez [4]. Aside from tactics big data also is slowly invading the field of training sessions big data are being used to create customized training sessions as well as to analyze and mitigate potential injuries.

**2.2.2 Data Collection.** Data collection here has two aspects to its hardware and software in the previous section the software component was already discussed to a good extent. Now we will shift focus towards the hardware components and their impact/ role in data collection. Below are excerpts from the article [11] which provide excellent insight as to how data is gathered. Athletes are not only monitored by cameras in stadiums, but also by many quirky devices such as accelerometers, heart rate sensors and even local GPS-like systems. for example, the Germans in the world cup held previously in Brazil wore Adidas miCoach elite team system during training sessions before and during the competition.[11].The device collects and transmits information directly from the athletes' bodies, including heart rate, distance, speed, acceleration and power, and then display those metrics live on an iPad. All this information is made available live on an iPad to coaches and trainers on the sideline during training, as well as post-session for in-depth analysis. Analysis of the data can help identify the fit players from those who could use a rest.

**2.2.3 Data Processing.** The article [10] gives a great insight into how data obtained from devices is processed. Big data is characterized using the so-called three V's: (1) Volume, (2) Variety and (3) Velocity. With respect to tactical analytics in soccer these concepts can be mapped in the following way:

(1) Volume refers to the size of datasets in soccer. For example, a current dataset for positional data typically encoded using Extensible Markup Language (XML) ranges between 86 and 300 megabytes (MB). Thus, storing position, event and video data from a single complete Bundesliga season results in 400 gigabytes of tracking data[10].

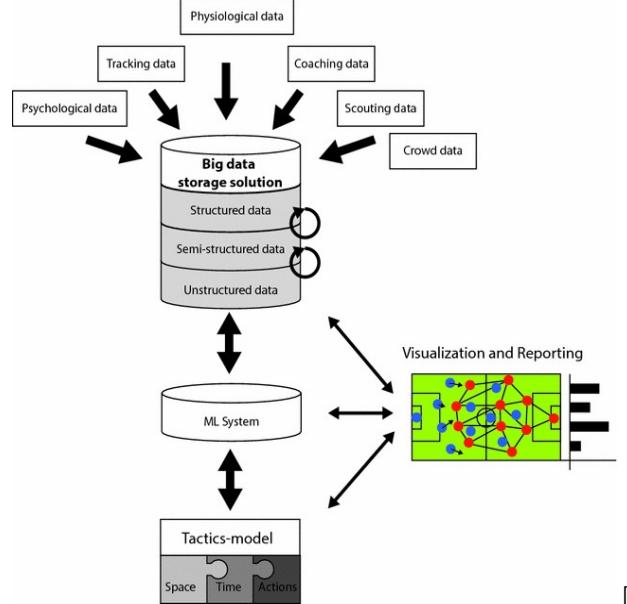
(2) Variety refers to different data formats and data sources. Variety can be further distinguished into (a) structured, (b) semi-structured, and (c) unstructured data. Structured data has a clearly predefined schema describing the data. In contrast, unstructured data lacks a definite schema with video data and text messages being typical examples. Semi-structured data falls in between these two extremes and consists of data which lacks a pre-defined structure but may have a variable schema[10].

(3) Velocity describes the speed with which novel data is being generated. In soccer, the velocity varies widely from real-time analysis like in the case of opta to delayed statistics released by journalists

etc[10]. From this data generated Machine learning models can be applied to look for anomalies and spot out a weakness in opponents and as well as gauge areas in which the own team requires improvements.

### 2.3 Tools

In this section, the technological stack and possible tools for implementation are discussed. A candidate big data soccer technological stack for soccer tactics analyses should be organized along several levels.



[10]

First, the necessary infrastructure to collect the data is required. Second, a storage system is required allowing efficient data storage and access. Finally, a processing pipeline has to be established to extract relevant information from the data and to subsequently merge the information to build an explanatory and/or predictive model[10]. An in-depth discussion of specific technological solutions is beyond the scope of the present study. A few useful technologies are however discussed, note we will only be discussing the software aspect since the hardware aspects have been discussed in great detail in the previous sections.

It has previously been stressed upon how difficult it is to obtain the details of technologies clubs use to run their daily operations. However, after dissecting it is not all that difficult to make an educated guess on which tools could possibly be used for the above purposes. Let's start with obtaining data in the previous sections we have already seen how opta obtains its data using live analysis[1]. Now we shall explore a new tool called Twitter Heron, which can be used to obtain information from tweets.

One of the problems with opta is that it may not cover leagues/tiers which are not profitable for it. However, football clubs generally have very enthusiastic fan bases and with Twitter being a very convenient social media tool we can try to mine data from tweets to generate our data. Twitter heron is a real-time analytics platform developed by Twitter. It is the direct successor of Apache Storm, built to be backward compatible with Storm's topology API but with a wide array of architectural improvements. Heron supports

Seamless support for different processing semantics, is efficient and scales extremely well. A good blog on why Twitter heron is ideal can be found here.[9]

Previously we touched on the subject of how scouts could use data from opta for analysis, from the internet the best way to obtain such data is to extract from XML. For this many different ways can be used. Some of the most popular manners are using Map Reduce, LogParser and even PIG.

MapReduce is a processing technique and a program model for distributed computing based on java. The MapReduce algorithm contains two important tasks, namely Map and Reduce. The map takes a set of data and converts it into another set of data, where individual elements are broken down into tuples (key/value pairs). Secondly, reduce task, which takes the output from a map as an input and combines those data tuples into a smaller set of tuples. As the sequence of the name MapReduce implies, the reduce task is always performed after the map job.

The major advantage of MapReduce is that it is easy to scale data processing over multiple computing nodes. Under the MapReduce model, the data processing primitives are called mappers and reducers. Decomposing a data processing application into mappers and reducers is sometimes nontrivial. But, once we write an application in the MapReduce form, scaling the application to run over hundreds, thousands, or even tens of thousands of machines in a cluster is merely a configuration change. This simple scalability is what has attracted many programmers to use the MapReduce model.[12]

Log Parser is a free command line utility for Windows that allows you to perform queries against a variety of file types including things like log files, CSV files, and XML files. This utility can even parse data sources such as the Active Directory or the Windows Event Logs. Log Parser is extremely flexible, but it is not a utility for novices. Using Log Parser requires experience with custom queries as well as with working from the command line. An example of PIG XML parsing can be found in this blog [3]. We can Use Spark SQL for querying data from DBs so that it can be used to extract features and clean up data.

## REFERENCES

- [1] Carl Bialik. 2014. The People Tracking Every Touch, Pass And Tackle in the World Cup. *online* (2014). <https://fivethirtyeight.com/features/the-people-tracking-every-touch-pass-and-tackle-in-the-world-cup/>
- [2] Julie Cooling. na. Investing in Soccer. *na* (na). <https://www.forbes.com/sites/juliecooling/2017/03/23/investing-in-soccer/#8b404ce2ec97>
- [3] learnbigdataanalytics. 2000. Pig XML parsing. *online* (2000). <https://learnbigdataanalytics.wordpress.com/hadoop-eco-systems/pig/practice/xml-parsing/>
- [4] Tim lewis. 2012. How computer analysts took over britains top clubs. *guardian* (2012). <https://www.theguardian.com/football/2014/mar/09/premier-league-football-clubs-computer-analysts-managers-data-winning>
- [5] Will Luca. 20000. Data Driven Football. *online* (20000). <http://data-speaks.luca-d3.com/2017/10/data-driven-football.html>
- [6] Wired micoach. 2000. Big Data devices in football. *online article* (2000). <https://www.wired.com/2012/09/major-league-soccer-micoach/>
- [7] Optasports. 2000. generating live time data. *video* (2000). <http://www.optasports.com/about/how-we-do-it/how-we-package-the-data.aspx>
- [8] Outsideoftheboot. 2000. An insight into the data analysis of football. *newspaper article* (2000). <http://outsideoftheboot.com/2015/09/24/insight-into-data-analysis-in-football/>
- [9] Karthik Ramasamy. 2000. Why Heron? *online* (2000). <https://streamli.io/blog/why-heron>
- [10] Robert Rein and Daniel Memert. 2016. Big data and tactical analysis in elite soccer: future challenges and opportunities for sports science. *PMC* (2016). <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4996805/>
- [11] Jure Rejec. 2000s. How Big Data is Changing the World of Football. *online* (2000s). <https://datafloq.com/read/how-big-data-is-changing-the-world-of-football/1796>
- [12] Tutorialspoint. 2000. map reduce definition. *online* (2000). [https://www.tutorialspoint.com/hadoop/hadoop\\_mapreduce.htm](https://www.tutorialspoint.com/hadoop/hadoop_mapreduce.htm)
- [13] Wikipedia. na. Expensive transfers. *na* (na). [https://en.wikipedia.org/wiki/List\\_of\\_most\\_expensive\\_association\\_football\\_transfers](https://en.wikipedia.org/wiki/List_of_most_expensive_association_football_transfers)

## 3 CONCLUSIONS

It can be seen the huge impact Big Data has in soccer. It has become a multi-million business. The acquisition of StatDNA by Arsenal for 2 million is proof of that. Also nowadays more and more clubs are being run entirely on big data proof of this is FC Midtjylland (Denmark) and also Brentford FC (England). Matthew Benham and Rasmus Ankersen are the pioneers in data analysis and have completely revolutionized their scouting departments. OPTA is the global leader in stats generation and is rated above 60 Million plus. Aside from just scouting potentials, it is used to shape tactics and also understand the strengths and weakness of players. While it may appear that the industry seems to have less scope of development this is only true for the top-ranked clubs. Most of the mid-table and lower league clubs still make use of traditional methods. The scope for open source software which provides a detailed scouting analysis has a huge market potential.

# Big Data Analytics in NCAA Football

Nsikan Udojen

School of Informatics and Computing, Indiana University

P.O. Box 1212

Dublin, Indiana 43017-6221

nudoyen@iu.edu

## ABSTRACT

This paper provides an overview of applications of big data in NCAA football by surveying current research and development work that supports the increased application of big data analytics to various aspects of NCAA football. The focus of current research is support for player performance management, injury prevention, and the use of predictive analysis to predict outcomes of games. However, the nature of interactions between players in football limit the efficacy of big data techniques in other areas such as strategy.

## KEYWORDS

i523,hid342, big data, analytics, NCAA football

## 1 INTRODUCTION

National Collegiate Athletics Association (NCAA) football is one of the most widely watched sports in the United States. The size of the fan base and the profits that can be derived from televised games incentivize universities and other interested parties to invest in the application of big data analytics and data science methods in general to improve on-field outcomes by enabling better management of player well-being and performance. The purpose of this paper is to provide an overview of the use of data science in National Collegiate Athletics Association (NCAA) football. Recent research on the use of data science to improve various aspects of NCAA football will be surveyed, while current trends and their implications will be discussed.

## 2 BIG DATA ANALYTICS IN NCAA FOOTBALL

### 2.1 Predictive Analytics

NCAA football analysts invest a significant amount of time trying to forecast performance of various teams throughout the season. Their analysis fuels sports talk shows and other mass media programs that target dedicated fan bases, giving them a deeper understanding of the game and allowing them to learn more about their teams. Data used to support NCAA football analysts' predictions is drawn from a mix of sources such as coaches' polls, and detailed and routinely updated data on players' performance. Some of this data is combined to create composite indexes, such as ESPN's Football Power Index (FPI)[1], which are used to rank teams based on thousands of simulations of their game outcomes, and updated weekly, based on available data. Composite indexes such as the FPI support broader discussion of matchups every week, and encourage analysts to ask broader questions in previewing games, but typically are not used in any systematic way to predict outcomes.

Several researchers have applied data mining methods towards the prediction of NCAA football scores[4],[2]. Various research

efforts have focused on the scope of relevant data, and how to model such data. In their paper comparing NCAA football game outcome prediction methods, Delen et al. used data on NCAA teams from 244 bowl games between 2002 and 2009 to generate and compare several predictive models[2]. They compared the performance of the models by using them to predict 2010-11 bowl game scores and found that classification-based models were better than regression-based classification methods at predicting game outcomes.

### 2.2 Performance Management & Player Safety

Several data mining methods have been developed to monitor athletes' performance and enable coaches to make data-driven decisions to improve results and avoid injuries. Platforms such as Microsoft's Sports Performance Platform [3] enable the collection and aggregation of biometric and other data that can be used to monitor performance. The use of wearable technology devices such as Fitbit to monitor NCAA football players has been proposed. Most efforts to apply data analytics to performance management in NCAA football focus on the evaluation and management of individual players, rather than the use of data mining to drive strategic decisions for teams during games.

In support of performance management, groups such as the NCAA Sports Science Institute gather data on injuries to college athletes and have used findings from their studies based on that data to advise the NCAA on issues such as the optimal frequency of football practices[7]. By analyzing data from the Big 12 conference, scientists at the NCAA Sports Science Institute were able to determine that the majority of injuries (and 58% of concussions) occurred during preseason practice. Their suggested guidelines, which were endorsed by 16 medical organizations, called for a reduction in the frequency of preseason practice sessions and less full-contact practice sessions.

In their paper, Ofoghi et al. describe how performance analysis requirements influence data gathering in their presentation of a general framework that applies data mining methods to sports [5]. The authors attempt to describe in their framework the most important features needed to categorize sports to enable data mining. Through their framework, Ofoghi et al. discuss the types of data that can be collected, depending on the nature of the sport being studied, and list important considerations.

Schumaker et al., list several standard data-driven metrics used to assess football teams and individual players[6]. The listed metrics include:

- *Defense-Adjusted Value Over Average (DVOA)*, which measures the success of a particular play against a defense and compares it to the average.

- *Defense-Adjusted Points Above Replacement (DPAR)*, which evaluates individual players by assessing their contribution (in points) compared to a replacement player.
- *Adjusted Line Yards (ALY)*, which assigns credit to an offensive line based on how far the ball is carried

While abundant data exists to compute the listed metrics and compare teams using them, their subjective nature makes them unreliable. DVOA, for instance, accounts for variables such as time remaining in the game, field position, and the quality of the opponent. There is no guidance on how such variables are computed or the weights assigned to each one. The ALY measures the contribution of the offensive line and the running back by rewarding the running back's individual effort for successful carries and punishing the offensive line for failed attempts. The ALY is adjusted based on league averages, which do not account for issues such as weather or bad officiating, which may have impacted a team's performance.

When used together, these metrics give a detailed view of a team's past performances. There is however, no evidence of successful use of such detailed assessments of a team's past performances to support strategic decisions during a game. The metrics are more suitable for highlighting areas of concern than predicting how well one team will fare against another before they play.

### 3 DISCUSSION

Research on predictive models that predict outcomes of NCAA football games illustrates the difficulty involved in capturing the nuances and complexity of the sport in a model. It also illustrates problems with the use of historical data for predictive purposes in NCAA football. For example, the data mined for the study by Delen et al., which was used to predict 2010-11 bowl games, included data points from as early as 2002, when none of the players in the 2010-11 bowl games were even eligible to play college football. It is difficult to determine how much data is sufficient to produce accurate predictions, and current data alone may not be sufficient, since some NCAA football teams may play as few as eleven games in a season.

Several features of the metrics used to describe and rate NCAA football players and teams make it difficult to use them for predictive purposes, despite the abundance of data to be collected. These include

- *The subjective nature of the metrics*

To account for the context-specific nature of the data being gathered to describe individual and team performances, some metrics are weighted to reflect factors such as the quality of the opponent. Such subjective factors are usually not evenly considered by different evaluators, and may change as the season progresses.

- *Focus on outcome-based metrics, such as ALY*

By relying on metrics that report only the outcomes of individual plays, data that reflects the tactics used and other technical aspects of the game are overlooked. Such metrics also ignore an opponents ability to learn and improve after a football game.

- *Inability to aggregate metrics*

No single metric effectively describes a football team's performance well enough to enable comparison to other teams. When different metrics are combined to describe a football team's performance, the manner in which they are combined is subjective. When the metrics are combined to create a composite index used to compare teams and predict outcomes, they do not provide a complete picture of potential interactions and mismatches between teams that could influence the outcome of the game between them. A prime example of this is the Bowl College Series (BCS) formula used to select the teams that would play for the NCAA Football National Championship from 1998 to 2013.

- *Lack of context*

When metrics are used to rate individual players, they often do not account for teammates' inputs. An example is yards-after-catch (YAC), often used by scouts to rate wide receivers. YAC reports the amount of additional yards a player gains after catching a pass from the quarterback, and should measure individual effort of the player that catches the ball. However, additional yards gained by a player after catching the ball may be due to defensive errors or assistance from teammates who block players on the opposing team. Likewise, other metrics used to rate receivers such as yard-per-catch or total yards are computed without considering the quality of the quarterback's decision-making or the defensive schemes employed by the opponent.

The use of data mining to manage player performance raises concerns over privacy and the ownership and potential misuse of the data collected[8]. The scope and amount of data collected about players has increased with the proliferation of the use of data mining methods to study player performance. In some cases, the harvesting of data collected by wearable technology devices by sportswear companies is permitted under the terms of the agreements between universities and the sportswear companies that sponsor their football teams. While companies such as Nike have stated that they have not yet begun harvesting players' biometric data, at least some of the data they could collect would not be covered by United States federal HIPA (Health Information Portability and Accountability Act) laws[9].

### 4 CONCLUSION

The use of data mining and analytics in NCAA football is increasing, as it has in other sports. However, due to the complexity of the game, practical uses of data analytics currently available and under exploration are in individual and team performance management and prevention of injuries. Research on data analytics, and current applications of technology to NCAA football have focused on techniques to extract meaningful information from gathered data, rather than the explanation and use of such information for predictive purposes.

The inability to account for context in data makes the use of data science to predict outcomes and influence strategy in NCAA football games difficult. The use of data primarily to compile metrics that describe past outcomes and average individual and team performance levels does not enable an understanding of their true

capabilities. There is thus a need to continue to rely on qualitative assessments by experts when making predictions or scouting individual players, and use data analytics as a supporting tool to provide relevant information to guide the discussion.

## REFERENCES

- [1] 2017. ESPN Football Power Index - 2017. ESPN Online. (Oct. 2017). <http://www.espn.com/college-football/statistics/teamratings>
- [2] Dursun Delen, Douglas Cogdell, and Nihat Kasap. 2012. A comparative analysis of data mining methods in predicting NCAA bowl outcomes. *International Journal of Forecasting* 28 (2012), 543–552. <https://doi.org/10.1016/j.ijforecast.2011.05.002>
- [3] Jeff Hansen. 2017. Sports Performance Platform puts data into play fit? and action fit? for athletes and teams. Official Microsoft Blog. (June 2017). <https://blogs.microsoft.com/blog/2017/06/27/sports-performance-platform-puts-data-play-action-athletes-teams/>
- [4] Carson K. Leung and Kyle W. Joseph. 2014. Sports data mining: predicting results for the college football games. *Procedia Computer Science* 35, special issue of KES 2014 (2014), 710–719.
- [5] Bahadorreza Ofoghi and John Zelezniakow. 2013. Data Mining in Elite Sports: A Review and a Framework. *Measurement in Physical Education and Exercise Science* (July 2013), 171–186. <http://dx.doi.org/10.1080/1091367X.2013.805137>
- [6] Robert P. Shumaker, Osama K. Solieman, and Hsinchun Chen. 2010. *Sports Data Mining*. Springer.
- [7] Jon Solomon. 2017. NCAA recommends ending two-a-day football practices and reducing tackling. CBS Sports Online. (Jan. 2017). <https://www.cbssports.com/college-football/news/ncaa-recommends-ending-two-a-day-football-practices-and-reducing-tackling/>
- [8] Tom Taylor. 2017. Footballfis Next Frontier: The Battle Over Big Data. (June 2017). <https://www.si.com/2017/06/27/nfl-football-next-frontier-battle-big-data-whoop-nflpa>
- [9] Mark Tracy. 2016. With Wearable Tech Deals, New Player Data Is Up for Grabs. The New York Times. (Sept. 2016). <https://nyti.ms/2creZ4t>

# DevOps in support of Big Data Applications and Analytics

Juan Ni

Bloomington, Indiana 47401

nijuan@iu.edu

## ABSTRACT

This paper discuss the relationship between devops and big data applications and analytic. The investigation will focus on cloud platform devops , because the carrier for most of big data application and analytic is cloud platform. Also, define the difficulty of implement devops is important for designing a big data application.

## KEYWORDS

big data,devops, cloud platform

## 1 INTRODUCTION

Following with cloud computing and big data analytic prosperous, devops began getting more and more attention. In the traditional development group, we usually have six processes which are "Analyze", "Design", "Code", "Test", "Deploy", and "Maintain". And each of the traditional process is isolate with other, once a group finish their part, they will shift the work to next group for the next level processing. But once the client change their needs, it will take really long time to track back the work and making adjustment at traditional development team. Especially for big data application, due to the complex of big data application, the development period will be longer than usual, therefore, we need devops to help us satisfy our client needs at long period development and keep efficiency processing speed. Devops is not a set of tool, it is a methodology that include basic principle and practical. According to the devops concept, the processes of devops are "Code", "Build", "Test", "Package", "Release", "Configure", and "Monitor" [3]. Unlike the traditional development processes, all processes of devops are connecting inside a loop. So devops is the integration of Development and Operations,

## 2 THE NEED OF DEVOPS FOR BIG DATA APPLICATION

The gap of communication between development and operations on big data application is the main issue. In big data application and analytic project, analyst change their algorithm ceaselessly, and the change of analytically model will make the infrastructure and resource demeaned become much different with the original one. In the traditional development team, developers are not involve into the analyst activity, because the big data analyst and application developer is isolated. Once the developer get the changing requirement from analytic team, they need to take time to understand the adjustment and reorganized the manpower inside the group. This communication delay will lower the entire processing speed, decreasing the competitiveness of big data analysis. Big data is timeliness, if the processing take to much time, the outcome will be less value, so big data application need devops to prevent data losing value by fall behind.

## 3 THE VALUES OF DEVOPS

The main value of devops is to break down the "Wall of confusion" between developer and operator. According to Jerome's idea, devops have two main values which are "Continuous Delivery" and "Benefits". [2] The "Benefits" of devops include but not limit to "Repeatability and Reliability", "Productivity", "Time to recovery", "Guarantee that infrastructure is homogeneous", "Make sure standards are respected", and "Allow developer to do lots of tasks themselves". Those benefit allow developer and operator working better as a team, and understand each others work. "Continuous Delivery" help project team decrease the application delivery period by having faster application development, high frequency update can reduce the risk and cost of changing demand during the delivery. This is extremely useful for big data application because it always requirement lot of change during delivery. The increasing of delivery frequency can let the project team more familiar with the processes of application deployment, also will getting more feedback from the user.

IBM organizes the values of devops into three domains, "increase customer experience", "improve innovation ability", and "faster achieve value". [1]. Devops is not the goal of application development, but it can let development team reach their goal. It increase customer experience via faster update, and having faster response to customer's feedback. Then we using devops to avoid rework cause by misunderstanding the demand, so the project team have time and energy to investigate new technology. Finally, once the delivery period is shorter and shorter, user can actually use the application early before the content inside the application are out date, this is important for big data application because the replacement of big data analysis algorithm is changing all the time. Devops is endless, it will continually develop the entire project team include the technology, processes flow, teamwork, and team culture.

## 4 CLOUD PLATFORM AND DEVOPS

The expectation of cloud platform is change the capital cost to operate cost, but the true value of using cloud platform is decrease the barrier which slow down the development speed and developer time. Most of work on the cloud platform can be automatic, so development team can be free from the heavy lifting of daily work such as management hardware and patch installing. So using cloud platform mean company from providing product change to providing service, which fit the big data application concept. Customer don't buy the application if the content doesn't make sense, so let cloud platform as the big data application carrier is good for the project team focus on the content inside the application and provide better service.

The SaaS significance is mixing operation and function, so user experience on SaaS will feel like they are integral. So user expect having high quality function and continuous update in the same

time. Unlike the traditional devilmnt team provide "Waterfall methodology" rare release event, devops provide frequent release events can satisfy customer need and maximize utilize the automation of cloud platform. Devops make operate and development keep almost the same speed and flexibility which is suitable for big data business need in cloud platform.

## 5 THE WEAKNESS OF DEVOPS

The difficulty of implement is the biggest weakness of devops. Each company have their own development tool and process, they all have their own feature, so it is really hard to have a temple that fit to every company and situation. For team leader, they only able to organized team and develop processes under limit source. So it is hard to having a optimal plan at most of time, for example to let each member inside the team have same understand ing and sense of duty is really hard. The implement of devops having many requirements, clarify the current situation and set up phased goal is basic requirement for early devops.

## 6 CONCLUSIONS

The main purpose of doing devops in big data applications and analytic is to eliminate the isolate situation between Solution Architect(big data analyst) and programmer. This can be achieve by cross education training for both architect and programmer, so they can understand the basic concept and terminology from both domain. Once they finish the training, they will suppose to have a better understanding of each others' idea, and prevent the process off track. Furthermore, devops can let those two group testing the application environment and adjusting the foundation framework to meet the new needs, it represent faster fixing and update capacity.

## REFERENCES

- [1] Gina Poole. 2017. DevOps delivers real value and successful business outcomes. (2017). [https://www.ibm.com/developerworks/community/blogs/invisiblethread/entry/devops\\_delivers\\_real\\_value?lang=en](https://www.ibm.com/developerworks/community/blogs/invisiblethread/entry/devops_delivers_real_value?lang=en) [Online; accessed 08-October-2017].
- [2] Jerome Kehrli. 2017. DevOps explained. (2017). <https://www.niceideas.ch/roller2/badtrash/entry/devops-explained> [Online; accessed 08-October-2017].
- [3] Wikipedia. 2017. Devops – Wikipedia, The Free Encyclopedia. (2017). <https://en.wikipedia.org/wiki/DevOps> [Online; accessed 08-October-2017].

# Big Data Analytics using Spark

Nisha Chandwani

Indiana University Bloomington

Bloomington, Indiana 47405

nchandwa@iu.edu

## ABSTRACT

With Petabytes of data being generated every second, big data analytics has become one of the most talked about terms in the technological world. Many organizations are trying to use big data for deriving useful business insights in order to improve decision making. However, we need special tools and frameworks to analyze such large amounts of data. We discuss how big data can be efficiently analyzed using Apache Spark which is a memory based computing framework. We discuss the core components and the architecture of Spark along with its ecosystem that extends the capabilities of Hadoop MapReduce.

## KEYWORDS

i523, HID203, Apache Spark, RDD, Big Data Analytics, Hadoop, MapReduce

## 1 INTRODUCTION

The growth of data has been following an exponential rate with huge amounts of data being generated every second. In today's world, having Terabytes or even Petabytes of data to deal with is not uncommon. The challenge lies not only in the volume of data but also in the large variance of the kind of data that has to be dealt with. This has led to the birth of one of the most talked about terms in today's technological world, i.e., Big Data. Most of the organizations today are collecting big data with the goal of extracting *value* from the exploratory analysis of this data and using this information to make business decisions. However, analyzing such enormous data is in itself a huge challenge and this is where big data analytics frameworks like Spark come to rescue. Spark is a general distributed computing framework that is optimized for in-memory processing. We show how Spark supports faster data analysis and is proving to be one of the most successful frameworks for Big Data Analytics.

## 2 SPARK

Spark is a general distributed computing framework which is based on Hadoop MapReduce algorithms[4]. However, using Hadoop MapReduce for complex tasks requires frequent disk I/O which make Hadoop less suited for low-latency tasks. To overcome this, Spark extends the capability of MapReduce by providing in-memory computing which enables it to query data much faster than disk-based engines like Hadoop[9]. Due to its memory computing capabilities, Spark is often used for iterative applications, such as Data Mining and Machine Learning[4].

Apache Spark has a well-defined architecture which is based on two main abstractions[3]:

- Resilient Distributed Datasets (RDD)
- Directed Acyclic Graph (DAG)

### 2.1 Resilient Distributed Datasets (RDD)

The entire framework of Spark is centered around RDD as it supports in-memory processing computation. This means it stores the state of memory in the form of an object across multiple jobs and the object is shared between these jobs[5]. RDD is a collection of data items that can be operated in parallel and is stored in memory or on disk. This parallel data computing structure is read-only and is distributed over a cluster of machines offering a restricted form of distributed shared memory. RDDs are maintained in a fault-tolerant way and can cache intermediate data across a set of nodes. Thus, RDDs enable Spark to efficiently support iterative algorithms[7].

RDD supports two types of operations[2]:

- Transformation: Operations like join, union, filter or map on existing RDDs which produce a new RDD as a result of the operation, are referred to as transformations.
- Action: Operations like count, first and reduce which evaluate an existing RDD and return values after computations are referred to as Actions.

### 2.2 Directed Acyclic Graph (DAG)

Spark consists of an advanced Directed Acyclic Graph (DAG) engine which allows programmers to develop complex, multi-step data pipeline[8]. Each Spark job creates a DAG of task stages to be executed on the cluster where each node in the DAG is an RDD partition and each edge represents a transformation to be applied on the data. This allows simple tasks to complete in a single stage whereas more complex tasks are completed in a single run of multiple stages, rather than splitting them into multiple jobs[10]. Thus, DAG abstraction eliminates the Hadoop MapReduce multi-stage execution model resulting in better performance[3].

## 3 SPARK ARCHITECTURE AND HARDWARE INTRODUCTION

Spark is built in programming language Scala and is run on Java Virtual Machine (JVM). In addition to Scala, it provides API for Java and Python as well. For running an application, Spark provides the following two options[10]:

- Interpreter in the Scala language distribution allows users to execute their queries on large data sets through Spark engine.
- Users can write their applications as Scala programs called driver programs. These driver programs can be then compiled and submitted to the cluster's master node.

Apache Spark uses a master/worker architecture as shown in Figure 1. It mainly consists of a driver program (SparkContext), workers (executors) and a cluster manager which are described below[3]:

[Figure 1 about here.]

- Driver Program: This program runs the main function of the Spark application. It is also responsible for the creation of the SparkContext object which basically coordinates the independent sets of processes running for an application on the cluster. The main components of the driver program are - DAGScheduler, TaskScheduler, BackendScheduler and BlockManager that translate the user code into Spark jobs that are executed on the cluster.
- Executor: These are the worker processes that are responsible for the execution of tasks sent by the SparkContext object. Some of these tasks include processing the data, reading from and writing data to external sources, performing computations and storing the results in in-memory cache or on hard disk drives.
- Cluster Manager: This is an external service that is responsible for acquiring resources on the Spark cluster and allocating them to the Spark jobs.

Being a memory-based computing platform, one of the most important factors of the Spark cluster is the memory. All the nodes, i.e., the driver and the executor nodes, should be equipped with at least 8 GB of memory for Spark to run well. For the cluster manager, Spark currently supports the below three deployments[4]:

- Standalone: It is a simple cluster manager included with Spark. Since Spark Standalone is available in the default configuration, it is the easiest way to set up a cluster and run applications on Spark.
- Apache Mesos: It is a general cluster manager that provides API for resource management and task scheduling across multiple nodes
- Hadoop YARN: It is the resource manager in Hadoop 2 which was added to Spark in version 0.6.

## 4 SPARK FOR BIG DATA ANALYTICS

With a large number of companies now looking to expand their advanced analytics capabilities, the ecosystem of Spark is right out of the box, making advanced analytics a reality. This ecosystem, as shown in Figure 2, provides an impressive set of high-level tools which include - Spark SQL for SQL, MLlib for machine learning, GraphX for graph processing and Spark Streaming[4]. Each of these components is-

[Figure 2 about here.]

- Spark Core API is the foundation of the overall ecosystem that provides task scheduling, dispatching and basic I/O functionalities. It is available through API in languages like Java, Python, Scala and R.
- Spark SQL is Apache's Spark module for supporting SQL implementation. It provides seamless integration of SQL queries with Spark programs. It provides a common way to connect to a variety of data sources such as Hive, JSON, JDBC, etc.
- Spark Streaming is an extension to the core Spark API which provides the capability to process streaming jobs along with batch jobs. The languages supported are Java, Python and Scala.

- MLlib is Spark's scalable Machine Learning library which is usable in Java, Python, Scala and R. MLlib supports high-quality algorithms such as classification, regression, clustering, recommendation, dimensionality reduction, etc. MLlib leverages Spark's excellence in iterative computing enabling it to run faster than MapReduce on huge datasets.
- GraphX is Spark's parallel computation API used for charts and graphs processing[4]. GraphX extends the capabilities of Spark RDD by introducing RDD graph which is a directed multi-graph with properties connected to each node and the edge[8].

One of the challenges of analyzing big data is that it can come in any shape or size. Thus, whether big data is to be processed offline (Spark Core) or on the fly (Spark Streaming), whether it is structured (Spark SQL) or connected in nature (GraphX), Spark ecosystem is a framework that can be widely used in big data analytics.

## 5 SPARK VERSUS HADOOP MAPREDUCE

Both Spark and Hadoop MapReduce are widely used in big data analytics, however, Spark has some major use cases over Hadoop[10]:

- Unlike Hadoop, Spark supports interactive data mining and data processing
- Spark outperforms Hadoop when it comes to iterative algorithms in machine learning as it keeps working sets in memory for efficient reuse
- Spark supports efficient stream processing which is one of the major advantages over Hadoop
- Spark is faster than MapReduce in execution

Though Spark has many advantages, Hadoop MapReduce can prove to be more efficient when it comes to batch processing for data with size greater than the available memory.

## 6 CONCLUSION

With the increasing volume of data, big data analytics is only going to become more critical for businesses decisions. Analyzing data at a huge scale presents many challenges and as we showed, Apache Spark can be very useful in overcoming these challenges. Over past few years, though Hadoop MapReduce has been one of the prime big data analytics framework, we showed how Spark has some major use cases over Hadoop. Though Apache Spark is a relatively young data project, it has already been adopted by a wide range of industries for big data analytics. We provided an introduction to Spark and discussed its architecture and the core components. As future work, we can discuss a case study and show how Spark processes big data in a more efficient manner than Hadoop MapReduce.

## ACKNOWLEDGMENTS

We would like to thank Prof. Gregor von Laszewski and the teaching assistants for their helpful suggestions.

## REFERENCES

- [1] Apache Spark. [n. d.]. Cluster Mode Overview. ([n. d.]). <http://spark.apache.org/docs/1.3.0/cluster-overview.html>
- [2] DeZyre. 2016. Apache Spark Ecosystem and Spark Components. (02 2016). <https://www.dezyre.com/article/apache-spark-ecosystem-and-spark-components/219>

- [3] DeZyre. 2017. Apache Spark Architecture Explained in Detail. (03 2017). <https://www.dezyre.com/article/apache-spark-architecture-explained-in-detail/338>
- [4] Jian Fu, Junwei Sun, and Kaiyuan Wang. 2016. SPARK—A Big Data Processing Platform for Machine Learning. In *Industrial Informatics-Computing Technology, Intelligent Technology, Industrial Information Integration (ICIICII), 2016 International Conference on*. IEEE, 48–51.
- [5] V Srinivas Jonnalagadda, P Srikanth, Krishnamachari Thumati, and Sri Hari Nallamala. [n. d.]. A Review Study of Apache Spark in Big Data Processing. ([n. d.]).
- [6] KDnuggets. 2016. Top Spark Ecosystem Projects. (03 2016). <http://www.kdnuggets.com/2016/03/top-spark-ecosystem-projects.html>
- [7] Ovidiu-Cristian Marcu, Alexandru Costan, Gabriel Antoniu, and María S Pérez-Hernández. 2016. Spark versus flink: Understanding performance in big data analytics frameworks. In *Cluster Computing (CLUSTER), 2016 IEEE International Conference on*. IEEE, 433–442.
- [8] Sriniv Penchikala. 2015. Big Data Processing with Apache Spark - Part 1. (01 2015). <https://www.infoq.com/articles/apache-spark-introduction>
- [9] Abdul Ghaffar Shoro and Tariq Rahim Soomro. 2015. Big data analysis: Apache spark perspective. *Global Journal of Computer Science and Technology* 15, 1 (2015).
- [10] Ankush Verma, Ashik Hussain Mansuri, and Neelesh Jain. 2016. Big data management processing with Hadoop MapReduce and spark technology: A comparison. In *Colossal Data Analysis and Networking (CDAN), Symposium on*. IEEE, 1–4.

#### LIST OF FIGURES

1	Spark Architecture[1]	5
2	Spark Ecosystem[6]	5

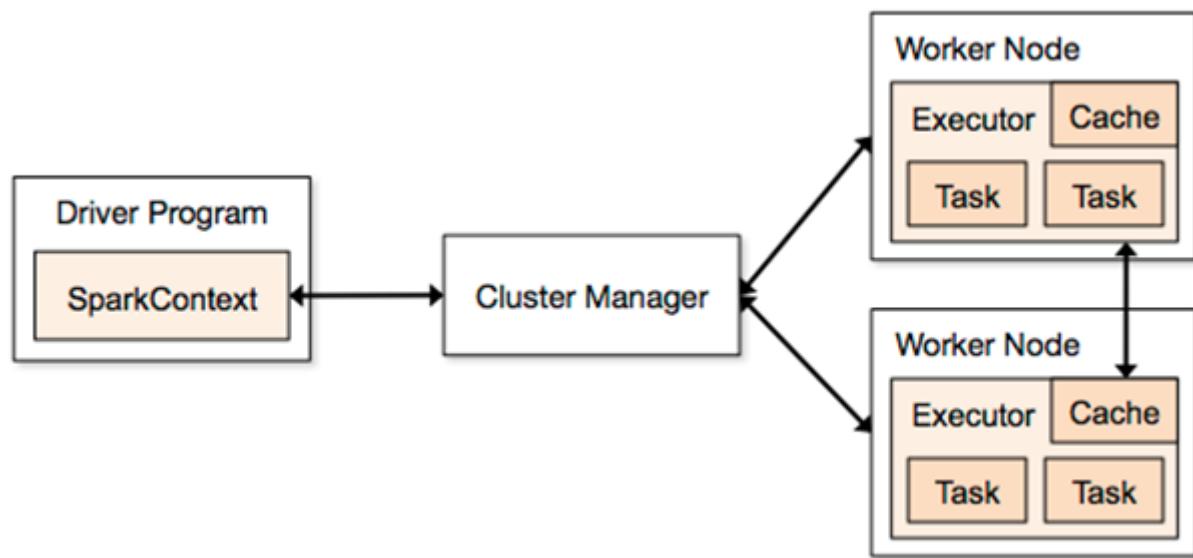


Figure 1: Spark Architecture[1]

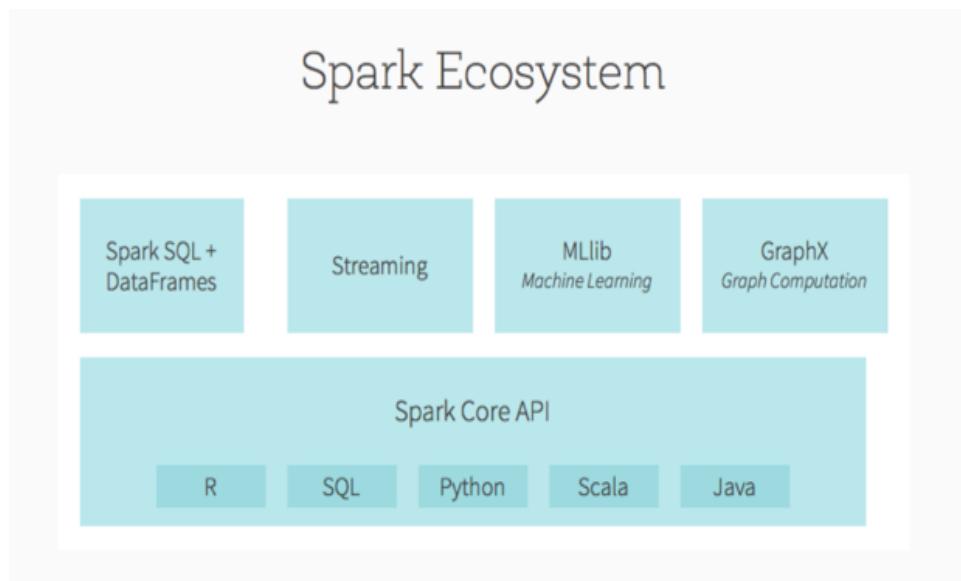


Figure 2: Spark Ecosystem[6]

# Big Data Analytics and High Performance Computing

Dhawal Chaturvedi

Indiana University

2679 E. 7th St, Apt. C

Bloomington, IN 47408, USA

dhchat@iu.edu

## ABSTRACT

This paper provides an introduction to Big Data and High Performance Computing and tries to find how they are related to each other. We describe what exactly is Big Data and High Performance Computing. We then describe what technologies are in use in these respective fields and technology that can be used to combine them.

## KEYWORDS

i523, hid204, Big data, High Performance Computing, SPIDAL

## 1 INTRODUCTION

Data is growing faster than ever, and at the same time, it is becoming obsolete faster than ever. The challenge is to how quickly and effectively one can analyze the data and gain insights that can be useful to solve problems. High Performance Computing plays an important role in running predictive analytics, especially when time is of crucial importance. In this paper, we analyze the ecosystem of the two data-intensive applications. We discuss the important features of the two fields, and then compare the functionality of the two paradigms.

## 2 BIG DATA

The quantity of computer data generated is growing exponentially in this world for many reasons. Retailers are building vast databases of recorded customer activities. Organizations working in logistics, financial services and health-care are also capturing more data. Social media is creating vast quantities of digital material. Big data is a term used for a combination of structured and unstructured data which has a potential to be mined for information.[6] It is often characterized by 3Vs : the enormous **Volume** of data, the **Variety** of data and the **Velocity** at which data is processed.

Here, Volume poses both the greatest challenge and the greatest opportunity as big data could help many organizations to understand people better and allocate resources more effectively. Big Data velocity also raises a number of issues as the rate at which data is flowing into many organizations is exceeding the capacity of their IT systems. In addition, user increasingly demand data to be streamed to them in real-time and delivering this can prove quite a challenge. Finally, the variety of data-types to be processed are becoming increasingly diverse. Today not only text documents, but audio, video , photographs are all equally important source of data.[6]

Recently Big data has been connected with terms such as data analytics, predictive analytics or any other kind of analytics which helps an organization to predict the user behavior so that they can improve their business. Data sets have been growing so rapidly mainly due to increasing number of ways data can be collected

such as smartphones, your internet history or even your search history on a website.

## 3 HIGH PERFORMANCE COMPUTING

High-Performance Computing (HPC) is the use of parallel processing for running applications efficiently and quickly.[7] This term is especially used for computing architecture having capacity of more than a teraflop operations per second. It involves a lot of distinct computer processors working together on a complex problem. The complex problem is divided into smaller parts and distributed among the processors which are inter-connected using an architecture which is either massive centralized parallelism, massive distributed parallelism or something else entirely.

Massive Centralized Parallel computing refers to a computer architecture in which several high processing nodes are connected via a fast local area network. All these pseudo independent nodes are coordinated by a central scheduler. All the processors are connected to a single piece of memory. It is essentially a bigger version of a multi-core processor. It used to be the most common type of HPC architecture 15 years ago, but we don't see much of them anymore. This type of architecture is quite expensive and doesn't really scale. [7]

Massive Distributed Parallel computing refers to a computer architecture in which several high processing nodes are interconnected but with a more diverse administrative domain. It is a more opportunity based architecture in which the resources are allocated on the basis of their availability instead of having a centralized scheduler. The way these different nodes communicate with each other is standardized through a library called Message Passing Interface(MPI).[7]

Almost every Super Computer these days is a hybrid of Distributed and Shared memory in some way. Each node will be a shared-memory system. The network connecting these nodes will be some sort of topology. Along with the architecture, the way code is written needs to get optimized as well. Parallel computing is the key to increase the performance of Super Computing. Ideally, if you have T processors, you would like your program to be T times faster. But that's not the case. This is because not all parts of a program can be successfully split into T parts which can be processed in parallel. Splitting up the program might even cause additional overheads such as communication.

HPC is typically used for scientific research or simulation and analysis of an environment through computer modelling. HPC brings together several computer technologies such as Computer Architecture, algorithms together to solve these high process demanding problems.

## **4 BIG DATA AND HIGH PERFORMANCE COMPUTING SOLUTIONS**

### **4.1 Amazon Web Services**

Amazon Web Services(AWS) provides a variety of tools which are not only capable of handling huge amount of data but also provides technology and techniques for working productively with data at any scale. Another advantage of using AWS for big data analytics is the low cost at which amazon provides these tools. There is no capital investment required, no subscription requirements. Along with this, the ease with which you can configure these services is incredible. Anyone with a basic knowledge of command line can configure these tools with ease. Some of the major analytics tools provided by AWS are Amazon S3, Amazon Kinesis, Amazon DynamoDB, Amazon RedShift and Amazon Elastic MapReduce. Amazon S3 is an object storage built to store and retrieve any amount of data from anywhere such as web sites and mobile apps, corporate applications etc. It is the only cloud storage solution with query-in-place functionality, allowing you to run powerful analytics directly on your data at rest in S3.[1] Amazon Kinesis is real-time streaming and processing for BigData. It is a highly-durable buffer that can handle all that work-load on the front-end as well as on the back-end with the help of series of EMR nodes which can give you an almost realtime analytics.[2]

Amazon DynamoDB is a NoSQL Database with high throughput and low latency for both read and write operations. It is a fully managed cloud database and supports both document and key-value store models. Amazon RedShift is a petabyte scale data warehouse which is massively parallel with over 1000 nodes running at a time.

### **4.2 Apache Hadoop Framework**

The most widely known technology that helps to handle large-data would be a distribution data process framework is Apache Hadoop. It is an open-source framework used for processing huge datasets using a Map-Reduce model. It is based on a master-slave architecture where low-end commodity hardware is interconnected using ethernet. The framework broadly consists of 2 components, the storage part known as Hadoop Distributed File System(HDFS), and the processing part known as Map-Reduce.[8] The Master node split large files into smaller parts and distributes them across the slave nodes. After this, it sends the same code to every node which is used to process the data.

In the Map step, the slave nodes applies the map function to the data and stores the output temporarily. In the Shuffle step, slave nodes reshuffle data between them on the basis of key-values pairs such that data belonging to particular key is located on the same node. After this, slave nodes work process the respective keys in parallel. This results in increased efficiency as all the nodes are working in parallel independently. In the end, the MapReduce system collects the Reduce output from each node and combines it to produce final result.

MapReduce is useful in a wide range of applications, including distributed pattern-based searching, distributed sorting, web link-graph reversal, Singular Value Decomposition(SVD) and other Machine Learning algorithms.[8]

### **4.3 Hybrid of Hadoop and HPC**

There has been convergence at many levels between HPC and Hadoop even though they were originally created to fulfill completely different purpose. HPC was designed for high-end, parallel computing jobs whereas hadoop was designed for cheap data storage and computing jobs.

There has been research going on offering a scale of comparison for different data-intensive computing fields, including blending the best of both computing paradigms using a hybrid of MPI and Hadoop. "The goal is to successfully bring the two data-intensive computing paradigms together to share the developments versus "reinvent the wheel" on either side"[4]. Machine Learning is another area which will have a lot to gain by this hybrid of HPC and Big Data as most of the ML algorithms are based on Linear Algebra which is a common HPC problem. if we run K-Means on MPI and Hadoop, MPI gave out better results than Hadoop. But the second generation Hadoop frameworks such as Spark gave out significantly better performance as they are adopting techniques such as effective collective operations which were previously only found in HPC architecture [5].

Another approach that has been proposed to converge these 2 systems is running Hadoop on top of HPC. However, a lot positives of Hadoop such as higher cluster Utilization are lost in this approach. Furthermore, Hadoop2(YARN) is capable of implementing both HPC applications and data- intensive applications but it still needs work [4].

### **4.4 Scalable Parallel Interoperable Data-Analytics Library (SPIDAL)**

Many of the currently available commercial environments are more shifted towards the data-intensive paradigm. To make these environments work with HPC, there is need for HPC to look towards JAVA to run its codes as most of these commercial environments use JAVA whereas HPC has traditionally preferred C,C++. In the last few years, development has been done in this domain and SPIDAL JAVA has demonstrated significant performance gains when running on clusters upto 3072 cores[3].The developer friendly Java interface in SPIDAL Java will help to integrate it with other big data platforms such as Apache Hadoop, Spark, and Storm in future.[3]

## **5 CONCLUSIONS**

Big Data Analytics and High Performance Computing are quite similar paradigms even though they were built for completely different purpose. In the next few years, its not unrealistic to believe that hadoop jobs to be processed on high end super computers instead of low end commodity infrastructure it presently runs on. This will not only help the Big Data industry but also other fields such as Machine Learning which certainly requires high end computing architecture.

## **ACKNOWLEDGMENTS**

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

The author would also like to thank Mr. Aditya Tandon for proof reading this paper.

## REFERENCES

- [1] Amazon. 2017. Big Data Analytics and High Performance Computing. Web Page. (Oct. 2017). <https://aws.amazon.com/S3/> HID: 204.
- [2] Amazon. 2017. Big Data Analytics and High Performance Computing. Web Page. (Oct. 2017). <https://aws.amazon.com/kinesis/> HID: 204.
- [3] Saliya Ekanayake, Supun Kamburugamuve, and Geoffrey Fox. 2016. SPIDAL Java: high performance data analytics with Java and MPI on large multicore HPC clusters. (04 2016), 3 pages.
- [4] Shantenu Jha, Judy Qiu, André Luckow, Pradeep Kumar Mantha, and Geoffrey Charles Fox. 2014. A Tale of Two Data-Intensive Paradigms: Applications, Abstractions, and Architectures. *CoRR* abs/1403.1528 (2014). <http://arxiv.org/abs/1403.1528>
- [5] André Luckow, Mark Santcroos, Ole Weidner, Ashley Zebrowski, and Shantenu Jha. 2013. Pilot-Data: An Abstraction for Distributed Data. *CoRR* abs/1301.6228 (2013). <http://arxiv.org/abs/1301.6228>
- [6] Wikipedia. 2016. Big Data Analytics and High Performance Computing. Web Page. (June 2016). [https://en.wikipedia.org/wiki/Big\\_data](https://en.wikipedia.org/wiki/Big_data) HID: 204.
- [7] Wikipedia. 2016. Big Data Analytics and High Performance Computing. Web Page. (June 2016). <https://en.wikipedia.org/wiki/HPC> HID: 204.
- [8] Wikipedia. 2016. Big Data Analytics and High Performance Computing. Web Page. (June 2016). [https://en.wikipedia.org/wiki/Apache\\_Hadoop](https://en.wikipedia.org/wiki/Apache_Hadoop) HID: 204.

# Big Data Analysis using MapReduce

Saurabh Kumar  
Indiana University  
Bloomington, Indiana 47408  
kumarsau@iu.edu

## ABSTRACT

With the amount of data created everyday reaching exorbitant limits and a push for analysis across all major fields gaining traction, we need an advanced framework to analyze the large data. Hadoop is such a framework for developing distribution applications. MapReduce is an application model for Hadoop and other distributed file systems. Word count is a small analysis that can be done using MapReduce. It can also be used for complex tasks like implementing search functionality. The main implementation of MapReduce is processing and generating large data sets. A key value pair is processed by the user created map function, which produces intermediate key value pair. The reduce function merges all intermediate values for the same key. Codes written in this programming model are automatically parallelized and executed on a cluster of machines.

## KEYWORDS

MapReduce, distributed, fault tolerance, master, big data

## 1 INTRODUCTION

Many MapReduce models are developed for handling big data. Google distributed file system is one of them[1]. Hadoop is the most popular open source framework for handling big data. Google's MapReduce framework has allowed the search for million of pages and delivering the results in milliseconds[2]. The input data to be processed is large and the computation times have to be lowered. Therefore the data and the computations have to be distributed across thousands of machines to achieve the goal of low computation time while handling large data. The main problems that such a programming model should handle are data distribution, handling failures, parallelizing computation and fast execution. MapReduce handles all these complexities by providing an abstraction which in turn is done by hiding the details of data distribution, error handling, parallelization and load balancing[3].

The map and reduce functions help to parallelize the computations and re-execution is used for fault tolerance. The map function is applied to every record in input. This creates an intermediate key value pair to which a reduce function is applied. All the intermediate values with same key go to the same reducer. The number of mapper depends on the number of distributed file system blocks and the amount of data. Usually there are 10 to 100 mappers for each data node. The execution time on each machine should not be very high or low, as the task setup takes a while. The number reducer depends on the requirement of final data output and the number of unique keys in the intermediate data. The number of reducers should not be too high as it would slow down the computation by generating stragglers. We will see this later. The number

should also not be too low so that parallelization cannot take its effect.

## 2 MODEL

The computation is divided as two functions: Map and Reduce. The user defined Map function produces an intermediate key value pair. These values are grouped together according to their keys by the MapReduce library and then passed to the Reduce function. The user defined Reduce function receives an intermediate key and list of all the values associated with that key. These values are merged together by the reduce function and the values are supplied to the function in different iterations. So that when there are large list of values, the memory does not get full[2].

To better understand this procedure we take the example of word frequency in a document. The Map function produces an intermediate key value pair of a word and its respective count of occurrences. The reduce function then groups by each word and sum up all the counts of occurrences. The final result is every word and its respective frequency in the document. This procedure can also be shown by the help of the two equations below:

$$\begin{aligned} \text{map } & (k1,v1) \rightarrow \text{list}(k2,v2) \\ \text{reduce } & (k2,\text{list}(v2)) \rightarrow \text{sum}(v2) \end{aligned}$$

There can other applications of MapReduce. For a URL access frequency count problem, the map function produces web page requests and the respective output as the key value pair. The reduce function sums up all the counts for a specific page and returns a final output of the pair(URL, total count)[2].

In case of a reverse web link graph example, the map function produces a target and source pair for each link of a target URL in a source page. The reduce function produces the same key, target, and the value as a concatenated list of all the sources that belong to the same target. The output pair is (target, list(source))[4].

Another example can be inverted index. The map function parses each document and produces a word as a key and the document id as the value. The reduce function takes this as an input and outputs a sorted list of document for every word.

## 3 IMPLEMENTATION

The type of implementation of MapReduce depends on the environment. The implementation is different from a small shared memory machine to a large cluster of machines. A cluster consists of hundreds of machines. When a job is submitted to a scheduler, it assigns each task in the job to an available machine in the cluster.

### 3.1 Overview

Different machines in the cluster act as a mapper ie implement the map function. The data is partitioned into sets of M splits, where M is the number of mappers. Each split of data is fed to an individual

mapper and thus all splits can be processed in parallel. There are few machines that implement the reduce function. They are called reducers. The intermediate key space is split into R partitions, where R is the number of reducers. The number of partitions is provided by the user.

The user calls the MapReduce function. The MapReduce library splits the data into M partitions, where each partition size ranges from 16 megabytes to 64 megabytes. This size can be specified by the user through a parameter. Then the library starts many copies of the program on the cluster of machines. One copy of the program acts as a master. The rest are workers or slaves which assigned tasks by the master[5].

The worker who is assigned a map function is a mapper. A mapper reads the contents of an input split. The intermediate key value pair, produced by the mapper, is buffered in memory. The buffered data is periodically written to the local disk and partitioned into R splits. Location of this data is passed back to the master. The master in turns passes the location to the workers who are assigned reduce functions.

When a reducer is notified about a location by the master, it uses remote procedure call to read the data from the local disk in the respective mapper. The intermediate data read by the reducer is sorted and groups together data from each key. The reducer iterates over each unique key and passes the set of values to the reduce function. The output is appended to a final output file. After all map and reduce tasks are completed, the master wakes up the user program.

After the completion of this process the final output is available in R files. Each file comes from one reduce task and the names are specified by the user. These files can be combined to a single file or can be passed as input to another MapReduce function.

The master stores some metadata. It has the state information for every map and reduce task. The states are idle, in progress or completed. It also has the location of the buffered files to be read by the reduce tasks.

### 3.2 Fault Tolerance

Since the MapReduce library is designed to handle large amounts of data and work over a distributed platform, it must tolerate machine failure smoothly.

The master pings every worker after a specific interval. If the worker does not respond to the master then the worker is marked as failed by the master. If a mapper completes its task, then it is reset back to idle state and is available for rescheduling. The same happens when a mapper or reducer has failed. They are reset to idle and available for rescheduling. In case of a failed machine, the completed tasks are re-executed as the output is saved in the local disk, which would have otherwise been incomplete or inaccessible. The output for completed tasks is passed to the global file system ie their locations are passed to the master which handles the data from then on.

When a mapper A has failed and its map task is re-executed by mapper B, then all reducers are notified of this re-execution. Any reducer that has not already read data from mapper A will read the date from mapper B.[2]

Master can write periodic checkpoints of the metadata it maintains. This helps when the master dies, re-execution can be started from the last checkpoint. When there is only one master, the chances that it dies are slim. User can check the state of master and retry the MapReduce operation when the master fails.

While handling large chunks of data, network bandwidth can be the scarce resource in the distributed environment. If not handled properly it will bottleneck the entire operation. Therefore input data is stored in the local disks of the machines in the cluster. As we have seen earlier that the entire file is divided into chunks of 16 to 64 megabytes. Several copies of each block is stored in different machines. This information is also provided to the master node, which oversees the entire operation. When the MapReduce operation is in process, the input data is read locally and the network bandwidth is not consumed. A worker performs different tasks and this helps in load balancing and also speeds up the recovery in case of a failure.

## 4 PERFORMANCE

The total execution time for the MapReduce operation can be increased mainly due to straggler. Straggler is a machine that takes large time to complete a simple map or reduce task. This generally happens during the end of the MapReduce operation, when the reading of input data is slowest. To handle this situation, the master schedules backup executions for the remaining tasks. The task is deemed completed when the primary or backup machine has completed the task.

The arrangement of clusters and the specification of machines used also affect the performance. In the idle state the memory for the machines should be freed for better results. In case of a 1 terabyte file the data is split into 64 megabyte blocks. Therefore there will be 15000 map tasks and reducer can be user decided.

The performance can also be affected by the type of operation we choose. In case of a normal execution where backup tasks are used in case of stragglers, the performance is good. The run time is increased when the backup tasks are not executed. This is when stragglers push the run-time further. In the third scenario when few tasks are killed towards the end the performance is good and similar to the normal execution. In some cases it can be better than the normal execution.

## 5 CONCLUSION

The use MapReduce programming model has propelled a new phase better usage of Big Data. The processing of such large amount of data usually required high end machines with large memories and top of the line processors. This can now be done using common machine but in a distributed environment. This model has also improved the fault tolerance as well as the run time for processing such large data. Such a model has also helped in usage of large machine learning algorithms, clustering problems, large scale graph computation and extraction of large web content. Google uses this model for large scale indexing by creating inverted index. The computation from MapReduce model is efficient so we need not look into the complex internal workings and can create better abstracted programs. It also provides parallelization, load optimization and

load balancing. Such a model can also be re scaled to thousands of machine, thus making it future ready.

## 6 REFERENCES

### REFERENCES

- [1] Sanjay Ghemawat, Howard Gobioff, and Shun-Tak Leung. The Google File System. In 19th Symposium on Operating Systems Principles, pages 29-43, Lake George, New York, 2003.
- [2] Jeffery Dean and Sanjay Ghemawat. MapReduce: Simplified Data Processing on Large Clusters. Google Inc, OSDI, 2004
- [3] Seema Maitreya and C.K. Jhab. MapReduce: Simplified Data Analysis of Big Data. Procedia Computer Science 57, Elsevier, 2015
- [4] Maitrey S, Jha. An Integrated Approach for CURE Clustering using Map-Reduce Technique. In Proceedings of Elsevier, ISBN 978-81- 910691-6-3,2nd August 2013
- [5] Jeffrey Dean et al. Mapreduce: Simplified data processing on large clusters. In Proceedings of the 6th USENIX OSDI, pages 137-150, 2004.

# Big Data Platforms as a Service

Tiffany Fabianac

Indiana University

Bloomington, Indiana

tifabi@iu.edu

## ABSTRACT

Big Data platform solutions allow data producers to use data to the fullest potential by combining processing engines with storage solutions and analytic technologies. Pharmaceutical clients are looking into platform solutions to safely store, analyze, and use clinical trial data, experimental data, drug development studies, drug production, regulation, and a number of other outlets. Just a few of the benefits of using a platform solution to manage these data outlets are possibly not having to change current work processes, that management and other research groups can access and use data without needing special access to systems, and scalability of storage and analytic components is seamless. The problems faced to implementing big data platform solutions include the selection of a platform vendor, the design of appropriate data architecture, and establishing effective user interfaces.

## KEYWORDS

i523, HID313, Big Data, Platform, Cloud Architecture

## 1 INTRODUCTION

Most pharmaceutical companies have adopted one or many Laboratory Information Management Systems (LIMS) and/or Electronic Laboratory Notebooks (ELN). These systems are often implemented as standalone systems within a single Research and Development (R&D) group or even within a single laboratory. A problem seen in large- or mid-sized pharmaceutical companies is that different research groups within the same organization often implement isolated LIMS or ELN. This severely restricts data sharing and reuse between groups which leads to many problems such as the same experiment being run multiple times between different groups, regulatory inefficiencies in tracking sample use and storage, and bottlenecked development cycles due to missing data.

One of the emerging strategies to combat the problems arising from isolated systems is to combine systems using cloud computing. Platform as a Service (PaaS) provides an environment for the development and execution of applications and software tools. The platform is the heart of a cloud computing infrastructure that enables software on-top as well as data created from such software to be accessed and used by a multitude of users[8].

## 2 IMPORTANCE OF PLATFORMS

Many organizations struggle to share data and processing tools among researchers. PaaS provides a method of better resource utilization while reducing maintenance costs[7]. As pharmaceutical companies collect larger and larger masses of data through LIMS, ELN, and other systems the need for scaleable storage becomes inescapable. Cloud storage available with the implementation of a PaaS solves current and predictable future data storage needs as

clinical trial data becomes truly digital and full genome analysis becomes more available. The surge of stored data requires access to tools with the capability of pulling insights from the data. These analytic tools are available in familiar formats that statisticians know and love such as SAS but new analytic tools have been built into platform environments as well as pushed the development of new market players like Tabaco and Spotfire[10].

A pharmaceutical company's R&D group is made up of several diverse units such as analytical chemistry, oncology, genomics, etc. Each of these groups has their own set of unique requirements and thus require multiple solutions to be implemented across the R&D organization. A problem arises now when an FDA regulator enters the lab space and requires an audit trail for a single sample. The sample was aliquoted and distributed across several groups and R&D management needs to be able to prove to the FDA regulator that the sample has been used only for its designated purpose and has been properly destroyed. The sample's use is recorded in several different LIMS and an ELN which the R&D manager does not have access to. With a properly implemented PaaS the manager can print the usage audit trail from each system without accessing them individually. The manager can pull destruction records and storage locations from current inventory and deliver these records to the FDA regulator without directly contacting any of the lab groups.

## 3 IMPLEMENTING PLATFORMS

Implementing a platform raises a number of concerns around security, selecting the right solution, designing the data architecture and associated relationships, and planning the user interface. All of the large platform providers have invested enormous amounts of resources into assuring the security of their data storage solutions. The right solution might be based on available applications, the storage solution's design, the cost, the learning curve for use, or a number of other client based requirements. Data architecture has the overarching purpose to design the data warehouse solution without limitations to growth, analysis tools, or query speed. User interface depends mostly on the user requirements, it could be driven by how much visibility is needed and how read and write privileges are designated.

The overarching concern with storing data outside of the organization is security. Numerous methods have been developed to assure cloud security such as integrated stacks used by Google and Microsoft Azure and Service Level Agreements (SLAs)[5]. Cloud companies are required to maintain high security at all levels. Google runs various vulnerability reward programs that pay developers, hackers, and security experts for finding security bugs. In addition to the product bugs, Google also maintains high security at their

data centers which includes laser beam intrusion detection, multi-factor access control, and biometrics to a limited population of less than 1% of Googlers[3].

#### 4 IDENTIFYING THE RIGHT PAAS

Every organization has a unique set of user requirements and every organization shares a certain number of user requirements. Something as simple as requiring a username and password to access content is a requirement shared across the great majority of systems while the need to create complex animal breeding plans that produce offspring with genetic content for 20 specific alleles may be a requirement for one unique client. A market analysis weighing a platform's capabilities against the organization's requirements will often help to narrow down this expanding market. Some of the largest PaaS providers are Microsoft, Amazon, and Google.

Microsoft big data solutions have taken advantage of open source technologies by setting Hadoop as the center of their big data platform. Hadoop is implemented through Hortonworks Data Platform (HDP) which has been developed as a open source solution with Apache and other open source components. Microsoft allows cloud and on-premise implementation, but generally local environments are only used as proof of concept testing. Microsoft platform solutions allow for data to be manipulated and used in Microsoft tools such as Sharepoint and Excel while big data analysis, visualization, and mining can be performed using SQL Server Analysis Services or HDInsight. The Hadoop-based platform has no limitations with structured or unstructured data, a number of additional tools are available for data storage, and efficient queries provide a potential boost to discovery. Microsoft Azure storage runs \$40 a month per 1TB and employs a pay for use plan to resource use within the platform's toolbox[4].

Amazon Web Services (AWS) offers data storage solutions in NoSQL and Relational Database models. Interactions with these data engines can be done using Hadoop, Interactive Query Service, or Elasticsearch. Amazon has designed their storage sources in such a way that clients can use any preferred open source application, but Amazon has also developed a toolbox of analytic tools. Amazon offers data warehousing through Amazon Redshift which allows for management, query, and analysis at the petabyte-scale. Amazon storage runs around \$80 a month per 1TB. AWS offers Business Intelligence, Artificial Intelligence, Machine Learning, Internet of Things, Serverless Computing, and a number of data interface tools available in a pay-as-you-use billing form[1].

Google Cloud Platform (GCP) offers a complete end-to-end data storage solution which allows the use of GCP developed systems and open source tools. BigQuery is Google's data warehouse tool which is serverless and requires no infrastructure management with the assist of Google Cloud Dataflow. Dataflow eliminates the need for resource management and performance optimization. GCP storage runs \$10 a month per 1TB. GCP has a number of applications for data manipulation. Dataproc allows dataset management through Hadoop and Spark, data visualization can be generated through Datalab, Data Studio, and Dataprep which are all Google developed applications[2].

#### 5 DESIGNING THE DATA ARCHITECTURE

All data storage solutions from relational databases to noSQL data stores to cloud data warehouses have to start with a defined architecture. The data architecture model will illustrate how data components will be organized and connected. The mindset of a data architect should be focused on reducing complexity of the data model while maintaining the highest level on utilization. This can be a fine line to walk as a designer. Complexity can be reduced by breaking user requirements down to the most basic and generalized principles to define the simplest data modules. An example of this might be a system that requires a number of different requests and instead of designing a component for vendor requests, user requests, and management requests the component is designed for request and request type. This generality allows for easy future scaling or additional system requirements not yet defined. Cloud systems maintain high utilization by manipulating data using strategic layering. One layer for storage, one layer for defining storage keys, another for combining query tools, another for consolidating query results and so on. With the more established cloud offerings a lot of these layers have already been supplied, but the transitions and interconnections still have to be outlined by a designer[9].

#### 6 DESIGNING THE USER INTERFACE

A system's user interface (UI) must be laid out in a simple and intuitive manner that allows users to perform the tasks required while exploring new insights provided by generated data. There are a number of influences leading to the development of user interfaces such as familiarity; users are familiar and comfortable performing a search in Google or Amazon interfaces and maintain the same high expectation with their working environment. If a user requires sample tracking or auditing they may relate the need to how a package is tracked with FedEx or UPS and expect the same level of access and insight to sample tracking within their working environment. Users may even have an information management system that they use and are comfortable with so switching to a new UI can be daunting as it requires additional training and most likely new work processes.

UI developers have the challenging job of creating the face of an application. A poorly designed face may not attract as many customers as something with a higher graphical output. Even a strong performing system can be downgraded or completely ignored by users if its front end is poorly laid out. Considerations for a UI design include font-size, space between elements, interactive space, and line-width which can all differ across devices such as between a tablet, desktop, or smartphone[6].

#### 7 CONCLUSION

As more and more companies realize the value of their data, platforms and associated tools become more and more vital to organizational success. The pharmaceutical industry knows that data is king, but is experiencing major bottlenecks in deploying platform solutions for the reasons discussed: the cost and complexity of implementation, the concern over security, the frustration of changing or creating new work processes. Current information management systems help scientists and researchers work exponentially faster than they ever could on paper, but current systems are not designed

to facilitate sharing of ideas. This is where platforms come in. A regulatory supervisor should not need training on every information management system to effectively regulate the use and disposal of clinical samples. A laboratory technician should not need to wait for specific system privileges to access a study that the organization did in a different lab space, whether it's in the same building or on the other side of the globe. Platform services are allowing scientists and managers to share ideas more efficiently than they ever have before and the pharmaceutical industry has the potential to exploit this new technology to improve life expectancy, make drugs safer, and research smarter.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Gregor Von Laszewski and Teaching Assistants Hyungro Lee, Juliette Zerick, Saber Sheybani Moghadam, and Miao Jiang.

## REFERENCES

- [1] 2017. Big Data on AWS. Website. (Oct. 2017). <https://aws.amazon.com/big-data/>
- [2] 2017. Big Data Solutions. Website. (Oct. 2017). <https://cloud.google.com/products/big-data/>
- [3] 2017. Google Security Whitepaper. Website. (Oct. 2017). [https://cloud.google.com/security/whitepaper#state-of-the-art\\_data.centers](https://cloud.google.com/security/whitepaper#state-of-the-art_data.centers)
- [4] 2017. Understanding Microsoft big data solutions. Website. (Oct. 2017). <https://msdn.microsoft.com/en-us/library/dn749804.aspx>
- [5] Valentina Casola, Alessandra De Benedictis, Massimiliano Rak, and Villano Umberto. 2014. Preliminary design of a platform-as-a-service to provide security in cloud. *ResearchGate* (01 2014), 752–757. <https://www.researchgate.net/publication/289573602>
- [6] Miroslav Macik, Tomas Cerny, and Pavel Slavik. 2014. Context-sensitive, cross-platform user interface generation. *Journal on Multimodal User Interfaces* 8, 2 (01 Jun 2014), 217–229. <https://doi.org/10.1007/s12193-013-0141-0>
- [7] Sungyoung Oh, Jieun Cha, Myungkyu Ji, Hyekyung Kang, Seok Kim, Eunyoung Heo, Jong Soo Han, Hyunggoo Kang, Hoseok Chae, Hee Hwang, and Sooyoung Yoo. 2015. Architecture Design of Healthcare Software-as-a-Service Platform for Cloud-Based Clinical Decision Support Service. *Healthcare Informatics Research* 21, 2 (April 2015), 102–110. <https://doi.org/10.4258/hir.2015.21.2.102>
- [8] Arto Ojala and Nina Helander. 2014. Value creation and evolution of a value network: A longitudinal case study on a Platform-as-a-Service provider. In *47th Hawaii International Conference on System Science*, Vol. 47. 975–984.
- [9] Jerome H. Saltzer and M. Frans Kaashoek. 2009. *Principles of Computer System Design: An Introduction*. Morgan Kaufmann. <https://doi.org/10.1016/B978-0-12-374957-4.00010-4>
- [10] Domenico Talia. 2013. Clouds for scalable big data analytics. *Computer* 46, 5 (2013), 98–101.

# STUDENT HAS ISSUES WITH MANAGING UPLOAD

Garner  
Indiana University  
Smith Research Center  
Bloomington, IN 47408, USA  
laszewski@gmail.com

## ABSTRACT

This paper provides a sample of a  $\text{\LaTeX}$  document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

Big Data, Edge Computing i523

## 1 INTRODUCTION

Put here an introduction about your topic. We just need one sample reference so the paper compiles in  $\text{\LaTeX}$  so we put it here [? ].

## 2 CONCLUSION

Put here an conclusion. Conlcusions and abstracts must not have any citations in the section.

## ACKNOWLEDGMENTS

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

## REFERENCES

# NoSQL Databases in support of Big Data and Analytics

Uma M Kugan  
Indiana University  
711 N Park Ave  
Bloomington, IN 47408, USA  
umakugan@iu.edu

## ABSTRACT

This paper will help us identify how NoSQL is efficient and cost effective in handling big data and also will highlight on why Big Data can't be handled in traditional RDBMS.

## KEYWORDS

i523, hid323, NoSQL

## 1 INTRODUCTION

RDBMS have always been the preferred method of storage for many years and its powerful Query language made it very user friendly. Data has grown exponentially in a past decade due to the growth of social media, e-commerce and web applications which posed a big challenge for the traditional databases. Need of the hour is not just to limit the data within the structure, but also ability and flexibility to read and store data from all sources and types, with or without structure. Organizations that collect large amounts of unstructured data are increasingly turning to non relational databases, now frequently called NoSQL databases.[?] There are lot of limiting factors in these databases for Big Data especially Structured schema which was one of the main reason for RDBMS to scale it for larger databases[6].

## 2 WHY NOSQL

The term NoSQL was first used by Carlo Strozzi to name a database management system (DBMS) he developed. This system explicitly avoided SQL as querying language, while it was still based on a relational model[3]. The term NoSQL means that the database doesn't follow the relational model espoused by E.F Codd in his 1970 paper A Relational Model of Data for Large Shared Data Banks[5] which would become the basis for all modern RDBMS. NoSQL doesn't mean NO to SQL. It means Not Only SQL. NoSQL means storage is just nonvolatile object store with no maintenance concerns. Most NOSQL DB's are open source which allows everyone to evaluate the tool of their choice at low cost.

## 3 NOSQL TYPES

In [1] Edlich et al. identify four classes of NoSQL systems as 'Core-NoSQL' systems: Key-Value stores, Wide column stores, Graph databases and Document stores.

**Key-Value Stores** : It is a very basic type of non-relational database where every item (value) is stored as an attribute name (key), with its value. e.g. Redis

**Wide Column Stores** : Every record in the stores may differ in the number of columns. This is very important factor for analytics because it needs very low I/O and also reduces

the volume of data that are read to the disk. e.g. HBase and Cassandra

**Graph Database** : As the name indicates, it uses graph structures nodes and edges to represent the data. This is very useful in depicting social relationship, network topology. e.g. Neo4J

**Document Stores** : It stores the data as document typically in Jason or XML format. It is widely used due to its flexibility and ability to query the data. e.g. MongoDB and CouchDB.

## 4 NOSQL FOR BIGDATA

Following factors have to be considered while evaluating NoSQL for Big Data Projects:

### Solution Based on the project Requirements :

Real time Updates for Data Analytics - NoSQL is the solution for applications that receives large volume of data in a real time and where data insights are generated using real time data that was fed.

Publish/Subscribe - NoSQL is the best fit where the enterprise doesn't require complex messaging features for publishing/subscribing.

Document based - Application where data structure is not restricted by schema, NoSQL comes in hand in such places.

### Limitation of traditional Databases :

Scalability - RDBMS are designed for scaling up meaning if storage needs to be increased, we need to upgrade other resources in the existing machine whereas in NoSQL we just have add additional nodes in the existing cluster.

Acid compliance - RDBMS are always acid compliant i.e. Atomicity, Consistency, Integrity and Durability and which of course is its strength to process transactional data while the drawback is it can't handle larger volume of data without impacting the performance. If there are use cases where we don't require ACID compliance and where it has to handle huge volume of data in significantly very less time, then NoSQL is the solution.

Complexity - RDBMS stores the data in defined, structured schema in tables and columns. If the data can't be converted to store in tables, it becomes cumbersome to handle such situations.

## 5 HOW TO HANDLE RELATIONAL DATA IN NOSQL

NoSQL database in general can't perform joins between data structures and hence the schema has to be designed in such a way so

that it can support joins. Below are the key things that needs to be considered to handle relational data in a NoSQL.

**Avoid Sub Queries** : Instead of using complex sub queries or nested joins to retrieve the data, break into multiple queries. NoSQL performances are very high when compared to traditional RDBMS Queries.

**Denormalize the data** : For faster retrieval of data, it is essential to compromise on denormalizing the data rather than storing only foreign keys.

## 6 RDBMS TO NOSQL MIGRATION

Database Migrations are always cumbersome and it is better to plan well ahead and take an iterative approach. Based on the need of application, one have to choose which NoSQL DB's we are going to migrate to. [4]

### 6.1 Planning

The goal of any migration should be better performance at the reduced cost with the newest technology. While migrating from RDBMS, we have to consider volume and source of data that's going to be migrated to NoSQL. All the details should be documented well so that we don't have to face unplanned surprises at the end.

### 6.2 Data Analysis

This is very critical and will help in understanding the nature of the data and how that data is accessed within the application. Based on the analysis of data usage, we will be able to define how data will be read/written which will help us in building a better data model.

### 6.3 Data Modeling

When migrating from any RDBMS, depending on the need of application, we may have to sometimes denormalize the data. In this phase, based on the data analysis and the tech-stream, we have to define keys and values.

### 6.4 Testing

Testing is always very critical and crucial for any migration projects. All aspects of testing from unit testing, functional testing, load testing, integration testing, user acceptance testing etc., have to be carried out and outputs have to be clearly documented.

### 6.5 Data Migration

Once all the above steps are successfully tested and implemented, next final act is to migrate all data from RDBMS to NoSQL. Post implementation validation has to be carried out to make sure everything went well as per the plan and it has to be monitored for few days until the process is stabilized. If there are any issues with the migration, rollback to original state and root cause analysis have to be performed to identify and fix the issue. Once issue has been fixed, data migration has to be scheduled and this step goes in cyclic unless migration was completely successful.

## 7 ADVANTAGES AND DISADVANTAGES OF NOSQL

NoSQL databases differ from traditional databases in features and functionality. There is no common query language, high I/O performance, horizontal scalability and don't enforce schema. It is very flexible and let the users to decide to use the data the way they want.

NoSQL databases have the ability to distribute the database across multiple geographic regions to withstand regional failures and enable data localization. Unlike relational databases, NoSQL databases generally have no requirement for separate applications or expensive add-ons to implement replication.[2]

Since NOSQL doesn't enforce atomicity and hence it is not reliable where data accuracy is very critical. RDBMS are much more matured and the best technical support is available. So there is always fear of unknown until the technology gets widely accepted and used.

## 8 CONCLUSION

With the explosion of the data in the recent years, have paved the big way for the growth of Big Data and everyone wants to move their applications and data into Big Data. Building a big data environment is relatively very cheap when compared to migrating the existing data in RDBMS to NoSQL. We have to carefully weigh in, understand the data and how the data will be used in the use case to enjoy the full benefit of migrating into No SQL.

## ACKNOWLEDGMENTS

My sincere thanks to my mentor and leader Vishal Baijal and to my colleague Michael Macal for their support and suggestions to write this paper and also to my fellow classmate Andres Castro Benavides for his support.

## REFERENCES

- [1] S. Edlich, A. Friedland, J. Hampe, and B.Brauer. Oct 2012. NoSQL: Einstieg in die Welt nichtrelationaler Web 2.0 Datenbanken. Hanser Fachbuchverlag. 6 (Oct 2012).
- [2] MongoDB. 2016. *Top 5 Considerations When Evaluating NoSQL Databases*. Technical Report. MongoDB. <https://www.mongodb.com/nosql-explained>
- [3] Editor P. BAXENDALE. June 1970. (June 1970). <http://www.seas.upenn.edu/~zives/03f/cis550/codd.pdf>
- [4] Nathaniel Slater. March 2015. Best Practices for Migrating from RDBMS to Amazon DynamoDB- Leverage the Power of NoSQL for Suitable Workloads. (March 2015). <https://d0.awsstatic.com/whitepapers/migration-best-practices-rdbms-to-dynamodb.pdf>
- [5] C. Strozzi. July 2012. Nosql relational database management system. (July 2012). [http://www.strozzi.it/cgi-bin/CSA/tw7/l/en\\_US/NoSQL/HomePage](http://www.strozzi.it/cgi-bin/CSA/tw7/l/en_US/NoSQL/HomePage)
- [6] Aspire System. 2014. *BigData with NoSQL*. Technical Report. Aspire System. [http://www.aspiresys.com/WhitePapers/BigData.with\\_NoSQL.Whitepaper.pdf?pdf=nosql-whitepaper](http://www.aspiresys.com/WhitePapers/BigData.with_NoSQL.Whitepaper.pdf?pdf=nosql-whitepaper)

# Amazon Web Services in Support of Big Data and Analytics

Peter Russell  
Indiana University  
petrusse@iu.edu

## ABSTRACT

Executives are constantly looking for ways to find the pulse of their competitive landscape along with ways to gauge the sentiment among their customers. The emergence of the Big Data movement has given businesses the unique opportunity to gain perspective on these fronts, in addition to many others. Amazon Web Services has placed itself at the epicenter of this data movement and now offers tools that allows decision makers to quantify their businesses in ways that were previously computationally impossible or were prohibitively expensive. As a result, with Amazon Web Services, companies now have the ability to gain deep insights into customer activity, which can be used as real-time feedback or guidance to make future experiences more personalized.

## KEYWORDS

Big Data, Cloud Computing, AWS, Big Data Analytics

## 1 INTRODUCTION

Amazon Web Services (AWS), the cloud service arm of Amazon, is currently the most dominant company in the cloud computing marketplace. With a market share of 31%, AWS holds a larger share than the next three closest competitors (Google, Microsoft and IBM) and contributes \$10 billion a year to Amazon[16]. Aside from its financial importance to Amazon though, AWS has become critical for businesses that are looking to gain insights from the data they have at their disposal, especially as this data becomes more abundant [15].

With this business need in mind, AWS offers several products under their ‘Analytics’ platform of services. This is just one of their 18 categories or platforms used to classify their 108 different products. This platform is a particularly interesting area because it is allowing companies to perceive their competitive landscape through an analytical lenses on a scale and frequency not previously seen. Namely, vast data sets in real-time if desired [25].

Our particular focus will be on a high-level description of the products offered in this ‘Analytics’ category, their current utilization by businesses, recent developments in this platform and how it impacts Big Data.

## 2 ANALYTICAL PRODUCTS

To discuss the impact AWS is having on modern businesses, it’s necessary to give a concise description of each analytical service offered. Subsequent sections will then be able to mention these services by name with a basic understanding of that service’s function.

### 2.1 Amazon Athena

Amazon Athena that allows users to analyze data in Amazon Simple Storage Service (S3) as an SQL query. S3 is Amazon’s web interfaced data storage and retrieval service, which can be accessed from

anywhere, and can be more broadly be described as an Infrastructure as a Service (IaaS). This was designed for queries that may be unique and one-off. Athena remains one of the newest products introduced on the Analytics platform as it was released in late 2016 [1].

### 2.2 Amazon Elasticsearch Service

Amazon Elasticsearch Service (ES) is a managed service that implements Elasticsearch, which is an open source engine that allows for the indexing of large data sets. This indexing allows for analysis to better understand the events generating the data, such as with a user of an application [3].

### 2.3 Amazon Elastic MapReduce

Amazon Elastic MapReduce (EMR) is aimed at analysis of large data sets as it allows users to take advantage of a managed Hadoop framework without the traditional setup costs. Hadoop is advantageous over traditional database models because it parses the large data sets over several nodes, allowing for parallel computing and greatly increased efficiency. EMR allows for the iteration over a massive amount of text files while ES is concerned with indexing these files[4].

### 2.4 Amazon Quicksight

Amazon Quicksight is the data visualization tool that allows for seamless charting and integrating with AWS databases. It also recognizes data types and suggests the best type of visualization for a given analysis [6].

### 2.5 AWS CloudSearch

AWS CloudSearch is a managed search engine service that can be integrated into an application for a company’s users. This allows an easier experience for the user without the company having to dedicate the resource costs that historically came with developing and maintaining the search feature [2]. In fact, AWS CloudSearch uses the same logic and intelligence for search queries that is used on Amazon.com. As one might suspect, AWS CloudSearch is similar to Amazon Elasticsearch Service. However, AWS CloudSearch is fully managed while Amazon Elasticsearch remains the more flexible and popular of the two.

### 2.6 AWS Data Pipeline

AWS Data Pipeline is designed to ease the maintenance of regular data sets by allowing users to schedule or automate changes to files along with the movement of that data set to other AWS services [8].

## 2.7 AWS Glue

Broadly speaking, AWS Glue is similar to AWS Data Pipeline in terms of automated transfer and modification of data. However, AWS Glue automates much of this data transformation whereas AWS Data Pipeline offers more flexibility for those who desire it [9].

## 2.8 AWS Kinesis

The work of AWS Kinesis is likely the most known product of AWS to the common consumer as it is responsible for the processing of real-time data for analysis or alert triggering. A dashboard that displays trending topics on social media or fraud detection at a bank is likely fed by an AWS Kinesis setup [5].

## 2.9 AWS Redshift

AWS Redshift was created to meet the database storage and maintenance needs of businesses. With Redshift, companies are able to reduce their capital expenditure and time to implementation, both of which could especially critical for nascent companies [7]. This line of business should prove to be increasingly important as data collection by businesses continues to grow. In 2012, it was already estimated that the cost of storage on AWS Redshift was just 10% the cost of traditional database costs [19].

## 3 RELEVANCE TO BIG DATA: USE CASES

Amazon has stated that they currently have one million active users, which is defined as using their services at least once a month [13]. In exploring current uses it becomes clear that the users are rarely consumers of just one product, opting instead to take advantage of the AWS ecosystem through multiple services. This section will touch upon the most popular AWS products and their interesting uses in the business environment.

### 3.1 Yelp

Yelp is a search based website that allows users to find different types of businesses while also showing user contributed reviews for these businesses. Started in 2004, Yelp's website now averages 28 million unique mobile users and 83 million unique desktop users per month. These users have contributed 135 million reviews in aggregate [26].

The impact of AWS on Yelp's business planning came when the company was trying to decide how to optimize its advertising revenue [11]. Specifically, Yelp stores log data daily on attributes, such as user location, user query, user clicks and displayed ads. This is all in an effort to better formulate search results given the available data and display ads that are most relevant to users [24].

Of the services discussed earlier, Yelp adopted AWS EMR and AWS Redshift to meet its analytical needs. EMR was implemented to allow multiple teams to analyze the data simultaneously and Redshift was used for easy retrieval. EMR is also used to enhance the user's search experience by returning useful results in the case of misspellings, auto-completion or features such as 'People Who Viewed This Also Viewed.' [21] As stated earlier, EMR allows this retrieval of information from the stored in nearly real-time. In all, the utilization of these services allows Yelp to be more dynamic as

its data analysis time is dramatically reduced while also improving the customer experience and ultimately, retention [14].

### 3.2 Zillow

Zillow is an online real estate listing marketplace where users can find homes for sale, recently sold homes or foreclosures. One of the largest draws to the site though, is the modeling of a specific property value through a feature they refer to as a "Zestimate." Through the use of AWS Kinesis for data collection and AWS EMR for data processing, Zillow is able to generate home value estimations in virtual real-time for 100 million properties across the United States, which is said to be a function of over 100 input variables [12]. Some of these inputs need to be as real-time as possible, such as recent sales data, for the most accurate estimate, which made Kinesis so impactful [18]. This integration of technologies has dramatically improved their calculation time for these estimates from hours to seconds [12]. Once again, this enhanced user experience through the utilization of Big Data analytics keeps the website relevant and best suited to meet customer needs.

### 3.3 Netflix

Netflix is a worldwide media provider, offering on-demand movies and shows along with a DVD rental service. Currently, the company has nearly \$9 billion in annual revenue with 104 million subscribers [20]. Incredibly, users in aggregate are watching one billion hours of content *a week* and during peak times, Netflix can be servicing over ten thousand streams a second [22]. Perhaps as impressive as the company's success with its user base is the foresight the company had in early as 2008 to begin moving operations to AWS as it began rolling out its internet streaming services. By 2016, they moved their entire infrastructure to the cloud and can have up to a hundred thousand AWS instances running during peak hours [17].

As likely one of the largest AWS users by market capitalization, Netflix casts a wide net across the use of AWS services. By their own admission, insights gleaned from the data they collect play a pivotal role on business and product decisions. Through the AWS Elasticsearch Service, Netflix is able to properly classify its 1.3 PB of data per day (24 GB per second) across different indices, such as viewing activities, error logs and diagnostics [23]. Similarly, Netflix uses AWS Kinesis as the pipeline used to stream this log data and the real-time functionality allows them to identify potential issues immediately [10]. Whether for business or troubleshooting purposes, this data on AWS can be easily visualized through AWS Quicksight for inferences.

Netflix is perhaps the best example of how a company can leverage AWS to outsource the burdens of data management as the volume of data grows. This allows them to focus on the core competencies and customer experience, which like the other examples, maintains or advances their position in the marketplace.

## 4 RECENT ADVANCEMENTS IN AWS

The most recent advancements in AWS as it relates to Analytics platform have come directly from the introduction of Athena in 2016 and Glue in 2017. Indirectly, AWS has been developing a new product line that is complementary to the Analytics category. In 2016, AWS launched its "Artificial Intelligence" platform, which

is now comprised of seven new services and is clearly an area of growth and focus for Amazon.

Of these new services, Amazon Machine Learning will likely be the most attractive new offering for businesses. This service will allow business users to discover underlying trends in their data and formulate more accurate forecasts.

## 5 CONCLUSIONS

In these use cases, we've seen that AWS has had a positive impact on Big Data for two reasons. First, businesses are better able to embrace the Big Data movement by making data collection and analysis a priority without the major cost that has historically been associated with such an initiative. Second, we would expect that the successful implementation of cloud analytics will help businesses be more successful, in turn incentivizing them to collect more data and therefore, further expanding the Big Data universe.

## REFERENCES

- [1] Amazon. 2017. Amazon Athena. Website. (2017). <https://aws.amazon.com/athena/>
- [2] Amazon. 2017. Amazon CloudSearch. (2017). <https://aws.amazon.com/cloudsearch/>
- [3] Amazon. 2017. Amazon Elasticsearch Service. Website. (2017). <https://aws.amazon.com/elasticsearch-service/>
- [4] Amazon. 2017. Amazon EMR. Website. (2017). <https://aws.amazon.com/emr/>
- [5] Amazon. 2017. Amazon Kinesis. Website. (2017). <https://aws.amazon.com/kinesis/>
- [6] Amazon. 2017. Amazon QuickSight. Website. (2017). <https://quicksight.aws/>
- [7] Amazon. 2017. Amazon Redshift. Website. (2017). <https://aws.amazon.com/redshift/>
- [8] Amazon. 2017. AWS Data Pipeline. (2017). <https://aws.amazon.com/datapipeline/>
- [9] Amazon. 2017. AWS Glue. Website. (2017). <https://aws.amazon.com/glue/>
- [10] Amazon. 2017. Netflix and Amazon Kinesis Streams Case Study. Website. (2017). <https://aws.amazon.com/solutions/case-studies/netflix-kinesis-streams/>
- [11] Amazon. 2017. Yelp Data Analytics Case Study. Website. (2017). <https://aws.amazon.com/solutions/case-studies/yelp-data-analytics/>
- [12] Amazon. 2017. Zillow Provides Near-Real-Time Home-Value Estimates Using Amazon Kinesis. Website. (2017). <https://aws.amazon.com/solutions/case-studies/zillow-zestimate/>
- [13] Jeffrey P. Bezos. 2015. Annual Letter to Shareholders. Press Release. (April 2015).
- [14] Niraj Dawar. 2016. Use Big Data to Create Value for Customers, Not Just Target Them. Website. (Aug. 2016). <https://hbr.org/2016/08/use-big-data-to-create-value-for-customers-not-just-target-them>
- [15] The Economist. 2017. Data is giving rise to a new economy. Website. (May 2017). <https://www.economist.com/news/briefing/21721634-how-it-shaping-up-data-giving-rise-new-economy>
- [16] Synergy Research Group. 2016. AWS Remains Dominant Despite Microsoft and Google Growth Surges. Website. (Feb. 2016).
- [17] Neil Hunt. 2016. Website. (2016). <https://aws.amazon.com/solutions/case-studies/netflix/> Conference Presentation at AWS re:Invent 2016.
- [18] Eric Knorr. 2016. Hot property: How Zillow became the real estate data hub. Website. (April 2016). <https://www.infoworld.com/article/3060773/big-data/hot-property-how-zillow-became-the-real-estate-data-hub.html>
- [19] Ingrid Lunden. 2013. Amazon Takes Redshift, Its Cloud-Based Data Warehouse Killer, Global. Website. (Feb. 2013). <https://techcrunch.com/2013/02/15/amazon-takes-redshift-its-cloud-based-data-warehouse-killer-global/>
- [20] Netflix. 2017. Investor Relations - Financial Statements. Website. (Sept. 2017). <https://ir.netflix.com/>
- [21] David M. Search. 2010. mrjob: Distributed Computing for Everybody. Website. (Oct. 2010). <https://engineeringblog.yelp.com/2010/10/mrjob-distributed-computing-for-everybody.html>
- [22] Softpedia. 2017. Netflix Users Spend 1 Billion Hours per Week Watching Movies. Website. (April 2017). <http://news.softpedia.com/news/netflix-users-spend-1-billion-hours-per-week-watching-movies-514989.shtml>
- [23] Monal Daxini Manas Alekar Zhenzhong Xu Jigish Patel Nagarjun Guraja Jonathan Bond Matt Zimmer Peter Bakas Steven Wu, Allen Wang. 2016. Evolution of the Netflix Data Pipeline. Website. (Feb. 2016). <https://medium.com/netflix-techblog/evolution-of-the-netflix-data-pipeline-da246ca36905>
- [24] Jeremy Stoppelman. 2013. Fast Company Innovation Uncensored. Panel Discussion. (Nov. 2013). <http://blog.fastcompany.com/post/66283564254/>
- [25] Laura Winig. 2016. GE's Big Bet on Data and Analytics. Website. (Feb. 2016). <https://sloanreview.mit.edu/case-study/ge-big-bet-on-data-and-analytics/> Case Study.
- [26] Yelp. 2017. Fact Sheet. Website. (June 2017). <https://www.yelp.com/factsheet>

# Docker in support of Big Data Applications and Analytics

Anand Sriramulu

Indiana University

107 S Indiana Ave

Bloomington, Indiana, USA 47405

asriram@iu.edu

## ABSTRACT

Different uses cases on how docker can improve the performance of Big Data applications.

## KEYWORDS

i523, hid338, Data Science, Docker, Containers, Big Data Analytics, Cloud Computing

## 1 INTRODUCTION

The rapid acquisition of big data and development of computationally intensive analysis has led to need for novel approaches to software deployment. Containers are a solution that allow software to run from one computing environment to another, whether it be from a developer's computer to a test environment or a physical machine in data center to a virtual machine (VM) in a private or public cloud.

Docker is a newer type of container technology and an open source platform for developers and sysadmins to build, ship, and run applications.

Docker has the same concept as a container used for cargo ships: a standard container that is loaded with virtually any goods, and stays sealed until it reaches final delivery. In between, containers can be loaded and unloaded, stacked, transported efficiently over long distances, and transferred from one mode of transport to another. [9]

Docker enables any payload to be encapsulated as a lightweight, portable, self-sufficient container that can be manipulated using standard operations and run consistently on different systems.

Docker containers are isolated, but share the Linux OS kernel, and where appropriate, bins/libraries. This results in significantly faster deployment, much less overhead, easier migration and faster performance. You share the host OS services, so unlike a Virtual Machine, you're not replicating the OS

## 2 DOCKER BENEFITS

In a seemingly constant state of maturation, the benefits of using Docker increase on a regular basis. Here, I'll outline the top five benefits of using the ever-growing platform. [4]

### 2.1 Continuous Deployment and Testing

Docker is gaining a lot of traction in the development and devops world for its consistency across environments. There are always minor differences between environments in development and release lifecycles, unless you have your own private repository environment with tight checks in place. These differences may be because of different package versions or dependencies. Nevertheless, Docker can address that gap by ensuring consistent environments from

development to production. Docker containers are configured to maintain all configurations and dependencies internally. As a result, you can use the same container from development to production making sure there are no discrepancies or manual intervention.

With Docker containers, you can also ensure that developers don't need an identical production environment set up. Instead, they can use their own system to run Docker containers on VirtualBox. If you need to perform an upgrade during a product's release cycle, you can easily make the necessary changes to Docker containers, test them, and implement the same changes to your existing containers. This sort of flexibility is a key advantage of using Docker. Just like standard deployment and integration processes, Docker allows you to build, test and release images that can be deployed across multiple servers. Even if a new security patch is available, the process remains the same. You can apply the patch, test it and release it to production.

### 2.2 Multi-Cloud Platforms

One of Docker's greatest benefits is portability. Over last few years, all major cloud computing providers, including Amazon Web Services (AWS) and Google Compute Platform (GCP), have embraced Docker's availability and added individual support. Docker containers can be run inside an Amazon EC2 instance, Google Compute Engine instance, Rackspace server or VirtualBox, provided that the host OS supports Docker. If this is the case, a container running on an Amazon EC2 instance can easily be ported between environments, say to VirtualBox, achieving similar consistency and functionality. This grants you a level of abstraction from your infrastructure layer. In addition to AWS and GCP, Docker works very well with various other IaaS providers like Microsoft Azure, and OpenStack. [7]

### 2.3 Environment Standardization and Version Control

As discussed above, Docker containers ensure consistency across multiple development and release cycles, standardizing your environment. On top of that, Docker containers work just like GIT repositories, allowing you to commit changes to your Docker images and version control them. Suppose you perform a component upgrade that breaks your whole environment. It is very easy to rollback to a previous version of your Docker image. This whole process can be tested in a few minutes. When compared to VM backup and image creation processes, Docker is fast, allowing you to quickly make replications and achieve redundancy. Additionally, launching Docker images is as fast as running a machine process.

## 2.4 Isolation

Docker ensures your applications and resources are isolated and segregated. Docker containers are as good as VM hypervisors when it comes to isolating resources, but there is still work to be done in terms of management and administration. [3]

Consider a scenario where you are running multiple applications on your VM. These applications can be team collaboration software (e.g., Confluence), issue tracking software (e.g., JIRA), centralized identity management systems (e.g., Crowd) and so on. Seeing as all of these applications run on different ports, you would have to leverage them on Apache and Nginx as a reverse proxy. So far, everything is in good shape, but as your environment moves forward, you will also need to configure a content management system (e.g., Alfresco) into your existing environment. Bear in mind that it requires a different version of Apache Tomcat, which will cause a problem. In order to fix this, you can either move your existing applications to another version of Tomcat or run your content management system (Alfresco) on your currently deployed version.

Fortunately, with Docker, you don't have to do this. Docker makes sure each container has its own resources that are isolated from other containers. You can have various containers for separate applications running completely different stacks. Aside from this, effectively removing applications from your server is quite difficult and may cause conflicts with dependencies. However, Docker helps you ensure clean app removal since each application runs on its own container. If you no longer need an application, you can simply delete its container. It won't leave any temporary or configuration files on your host OS.

On top of these benefits, Docker also ensures that each application only uses resources (CPU, memory and disk space) that have been assigned to them. A particular application won't hog all of your available resources, which would normally lead to performance degradation or complete downtime for other applications.

## 2.5 Security

Docker is evolving at a fast pace, which Gartner even acknowledges, as mentioned above. From a security standpoint, Docker ensures that applications that are running on containers are completely segregated and isolated from each other, granting you complete control over traffic flow and management. No Docker container can look into processes running inside another container. From an architectural standpoint, each container gets its own set of resources ranging from processing to network stacks.[5]

As a means of tightening security, Docker uses host OS sensitive mount points (e.g., '/proc' and '/sys') as read-only mount points and uses a copy-on-write filesystem to make sure containers can't read each other's data. It also limits system calls to your host OS and works well with SELinux and AppArmor. Additionally, Docker images that are available on Docker Hub are digitally signed to ensure authenticity. Since Docker containers are isolated and resources are limited, even if one of your applications is hacked, it won't affect applications that are running on other Docker containers.

## 3 BIGDATA AND DOCKER

Big Data is one of the big trends in IT of recent years. The vast majority of CIOs are collecting and managing more business information than they did two years ago.

CIOs and IT Operations have a common goal: prepping their IT infrastructure to manage the data deluge and growing revenue by making better use of the data they collect.

They also share some common frustrations. Often the right systems are not in place to gather the information they need, and many struggle to give their business managers access to pertinent information.

Arming an organization with the appropriate technology, staff, and systems/processes needed to optimize information for true business intelligence can help manage the data deluge. The following approaches can be applied to increase the chances of a successful outcome.

### 3.1 Use Docker To Avoid Dependency Issues

Each developer might have different set of big data tools and not to mention all the dependencies required, which then must be distributed to each machine in a cluster.

Companies assume this situation is manageable, but get enough developers on the same cluster and it doesn't take long for one tools requirements to break another. This will cause all the dependencies issues.

In this situation, there are two choices - get an entire development team to standardize on a common toolset, or use Docker. Docker allows each tool to be self contained, along with all of its dependencies. This means that a application can have different jobs use different versions of the same tool without a conflict.

This frees up your DevOps team to use the best tools for the data processing job, or set up entirely new systems and drive incredible scale and efficiency.

### 3.2 Reduce Reliance On MapReduce Experts With Pachyderm

For sysadmins that have a large amount of data to analyze, the go-to method has typically been to run MapReduce queries on Hadoop. This typically requires specialist programmers who specialize in writing MapReduce jobs, or hiring a third party such as Cloudera.

This typically means that Big Data initiatives require a lot of co-ordination internally and require resources that are beyond the reach of even large enterprises who do not have that kind of expertise on tap.

Alternatively, Pachyderm is a tool that allows programmers to implement a http server inside a Docker container, then use Pachyderm to distribute the job. This has the potential to allow sysadmins to run large scale MapReduce jobs quickly and easily to make product level decisions, without knowing anything about MapReduce.[8]

Pachyderm has the ambition of replacing Hadoop entirely - whether it achieves that remains to be seen, but it certainly looks like it will be a significant player in the next generation of data processing

### 3.3 Run Scheduled Analytics Using Containers With Chronos

By reading the above section, it's evident that the containers are a great way of deploying services at scale and giving isolation to services that run on the same host and improving utilization, but Docker can also be used for batch processing as well.

The latest release of the Chronos job scheduler for Mesos allows you to launch Docker instances into a Mesos cluster. This provides developers and sysadmins with the ability to run scheduled analytics jobs using containers.[1]

Chronos allows you to schedule Docker containers to run ETL, batch and analytics applications without manual setup on your cluster nodes. One of the neat features of Chronos is that it will also produce a dependency graph between scheduled jobs that depend on each other, so they only run if the previous job is successful.

Chronos and Marathon combine really nicely to provide orchestration for a container infrastructure.

### 3.4 Provision A Big Data Dev Environment Using Ferry

Ferry allows you to create big data clusters on the local machine (and AWS). The beauty of Ferry is that it allows anyone to define a big data stack using YAML, and then share it with other developers using a Dockerfile.[6] Setting up a Hadoop cluster is as simple as:

```
backend:  
- storage  
personality: "hadoop"  
instances: 2  
layers:  
- "hive"  
Connectors:  
- personality: "hadoop-client"
```

Get started by typing

```
ferry start hadoop
```

This will create a two node Hadoop cluster and a single Linux client. This can be customized at runtime or defined using a Dockerfile. Ferry is great for developers who want to get up and running with a big data environment using a test AWS box, developers that need a local big data dev environment, or users that want to share Big Data applications.

Running Ferry on AWS also has several advantages over something like Elastic MapReduce, such as not tying you to a single cluster of a single type (such as Hadoop).

### 3.5 Run Big Data As Microservices With Coho

When we talk to enterprise customers about Big Data processing, there are one or two recurring themes. For example, in healthcare, there are frequent workflows where new data triggers a new action.

Taking transcoding as an example. When a new image is pushed to the storage system, a transcoding workflow will take place, reading the data back to a client machine or VM, transcoding it, and then writing the results back to storage. This can mean that the data has to cross the network three times!

In Big Data environments, data might be pushed out to a separate HDFS-based analytics system, only to be pushed back to the enterprise system when the job has been run.[2]

Coho has worked on a storage-integrated tool that allows developers and DevOps teams to think specifically about workflows as operations on data, and for them to be embedded in the storage system.

These resulting extensions can then run efficiently and transparently at scale as the system grows. This theoretically allows presentation layers to be built on top of existing data, for the system to be extended with audit and compliance functionality and for complex, environment based access controls to be built.

## 4 CONCLUSIONS

The complex nature of big data and the tools used to analyze these data sets makes efficient processing difficult with standard environments. As noted above, the use of emerging technologies such as Docker in combination with automated workflows may significantly improve the efficiency of data processing in data analytics. With the growing number of open data projects, use of these techniques will be necessary to take advantage of available computational resources.

While performance and pipeline efficiency were key components of this implementation, Docker containers also allow for application isolation from the host operating system. Since many big data tools have complex sets of dependencies and are difficult to build from source, the ability to deploy containers with different operating systems and dependency versions to the same host decreases the amount of effort needed to being analysis. For example, the cgDownload utility is distributed as a compiled binary for use on CentOS 6.7, but can only be deployed on CentOS 7 when built from source, which requires a significant amount of manual configuration. With the use of containers allowed the deployment of each utility on its natively supported operating system, which improves stability and decreases the potential for dependency conflicts among software applications.

Several other tools exist for the orchestration of containerized applications, such as Kubernetes and Docker Swarm. For complex platforms, these tools can be used to deploy containers across hardware clusters and to integrate networking and storage resources between containers. However, these applications work strictly at the container level and do not inherently provide application-level workflows as presented here. Additional implementation experience about the use of these tools within high-performance clusters may provide valuable insights about the scalability of these tools within data analytics workflows.

Because of the subsequent increase in analysis throughput, use of these tools means that big data analyses can be done even with limited local computational capacity. Finally, use of container technology can improve pipeline and experimental reproducibility since preconfigured applications can be readily deployed to nearly any host system. While many factors can impact reproducibility, the use of containers limits variability due to differences in software environment or application configuration when appropriately deployed. The continued use of emerging technology and novel approaches

to software architecture has the potential to increase the efficiency of computational analysis in big data.

## REFERENCES

- [1] [n. d.]. Chronos. ([n. d.]). <https://mesosphere.com/blog/docker-on-mesos-with-chronos/>
- [2] [n. d.]. Coho. ([n. d.]). <http://www.cohodata.com/blog/2015/04/09/docker-data-services-microservices/>
- [3] [n. d.]. Container VM. ([n. d.]). <https://blog.netapp.com/blogs/containers-vs-vms/>
- [4] [n. d.]. Docker Benefits. ([n. d.]). <https://opensource.com/resources/what-docker>
- [5] [n. d.]. Docker Security. ([n. d.]). <https://blog.docker.com/2016/08/software-security-docker-containers/>
- [6] [n. d.]. Ferry. ([n. d.]). <http://drydock.readthedocs.io/en/latest/>
- [7] [n. d.]. Multi Cloud Platform. ([n. d.]). <https://boxboat.com/2016/10/21/maintaining-docker-portability-multi-cloud-world/>
- [8] [n. d.]. Pachyderm. ([n. d.]). [http://www.pachyderm.io/open\\_source.html](http://www.pachyderm.io/open_source.html)
- [9] About Docker. [n. d.]. Technical Report. <https://www.docker.com/>

# My great Big Dat Paper

Ben Trovato  
Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
trovato@corporation.com

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

i523

## 1 INTRODUCTION

The *proceedings* are the records of a conference. ACM seeks to give these conference by-products a uniform, high-quality appearance. To do this, ACM has some rigid requirements for the format of the proceedings documents: there is a specified format (balanced double columns), a specified set of fonts (Arial or Helvetica and Times Roman) in certain specified sizes, a specified live area, centered on the page, specified size of margins, specified column width and gutter size [1].

## ACKNOWLEDGMENTS

The authors would like to thank

## REFERENCES

- [1] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. <https://doi.org/10.1007/3-540-09237-4>

# What Separates Big Data from Lots of Data

Gabriel Jones  
Indiana University  
107 S Indiana Ave  
Bloomington, Indiana, USA 47405  
gabejone@indiana.edu

## ABSTRACT

We briefly analyze the history of data to show how having *Lots of Data* hardly differs from data storage and analysis in the early days of SQL, or even before computers. We then explain how *Big Data* represents a paradigmatic shift from conventional data analysis. We then begin to look at the potential limits of *Big Data* to assert that this paradigmatic shift does not mean the end of science. We conclude that misunderstanding *Big Data* prevents organizations from capitalizing on its potential and can lead them to spurious answers.

## KEYWORDS

i523, hid104, Big Data, Lots of Data, Data Science, Data History, Sociotechnical

## 1 INTRODUCTION

In 2008, Wired.com published an article titled "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete." They tried to assert that *Big Data*, at that point still a relatively new term, was such a revolutionary change that the scientific method would no longer exist.<sup>[1]</sup> Since at least 2008, professionals, scientists, and the public have flocked to the idea of *Big Data*, but many still struggle to understand both its grand potential and its realistic limits.<sup>[5]</sup> On one extreme, boasting terabytes of storage, they claim to be *Big Data* experts but only utilize *Lots of Data*, high quantities of traditional data. On the other extreme, they hyperbolize about how *Big Data* will change the world because it eliminates the need for educated hypothesizing, based on the fallacious assumption that *Big Data* is synonymous with *All Data*, implied by Wired.com and by some academics.<sup>[3]</sup>

To avoid the common data deluge delusions, we borrow from a 2014 article written by Professor Carl Logoze, "Big Data, Data Integrity, and the Fracturing of the Control Zone," that defines *Big Data* as "data that disrupt fundamental notions of integrity and force new ways of thinking and doing to reestablish it."<sup>[3]</sup> This definition both breaks the boundaries of *Lots of Data* and reins in the assumed panacea that leads people to believe they have *All Data*. Taking a brief look at the history of data clarifies what it means to have *Lots of Data*. A case study of the 1880s US Census Bureau demonstrates that mostly just volume and efficiency mark the difference between today's use of *Lots of Data* and the historical use of data in general, and how this differs from the definition and possibilities of *Big Data*. Having separated *Big Data* from an incorrectly limiting category, we then make the case for investigating what are the limits of *Big Data*. We briefly examine the basis for the argument that *Big Data* is not *All Data*, but a more rigorous analysis is beyond our current scope. We break down the first extreme, the synonymizing of *Big*

*Data with Lots of Data*, by succinctly explaining how it represents a paradigmatic shift. We also hope to foster additional sociotechnical scholarly discussion and case studies of its limits, which would help break down the hyperbolic synonymizing of *Big Data* with *All Data*.

## 2 A BRIEF LOOK AT THE HISTORY OF DATA

The human ability to store and analyze data has evolved gradually over millennia. Although digital computer technology greatly accelerated this evolution, most mainstream uses of data still show signs of their historical roots. The formation of early libraries over 4,000 years ago signifies an important moment in methods of amassing data to be organized and processed by humans into knowledge.<sup>[4]</sup> Libraries still have prominence today both in the traditional sense, brick and mortar sites where one can study texts, and in a broader context, digital archives of algorithmically curated information. In either case, libraries are literal representations of information. If one wants to access a text, they can obtain a copy of it, physical or digital, and read the actual words of the text.<sup>[3]</sup> In contrast, another ancient technology, the abacus, demonstrates one of the first symbolic representations of data. The abacus uses an arrangement of beads to represent other numbers and calculations. The numbers themselves did not exist but were symbolically represented. This is an important early prerequisite to the emergence of statistics, which seeks to make accurate claims about a population based only on a sample.<sup>[4]</sup>

One of the first uses of the term business intelligence, a feature of statistical analysis, was used in the 1865 *Encyclopaedia of Commercial and Business Anecdotes*. The book described how a banker, Henry Furnese, gained an advantage over competitors by applying a structured method to collect and analyze information relevant to his business activities. Furnese's data analysis is considered one of the first of its kind for commercial purposes. It builds from the fundamental idea that the real world can be represented and analyzed symbolically, as a sample, to produce insights.<sup>[4]</sup> This is the same idea that allows, for instance, modern companies to provide performance bonuses to employees based on how well they meet certain criteria called Key Performance Indicators. It would be impossibly inefficient to have supervisors accurately observe every activity of every employee and objectively judge who made the most contributions, so instead, companies define metrics of good employee behavior and use these metrics to symbolically represent who adds the most value.

While being able to store and analyze data increased in importance near the end of the 19th century, the physical limits of storage and analysis, paper documents and human eyes, created a problem of *Lots of Data*. The US Census Bureau found themselves faced with this problem. As the US population skyrocketed, they estimated

that with late 19th century methods, it would take an estimated 8 years to process the data collected in the 1880 census. Processing the 1890s census data, they predicted, would take over 10 years, so it would not be ready to study until becoming outdated by the 1900 census. The solution came from a young engineer named Herman Hollerith, eventual founder of IBM and creator of the Hollerith Tabulating Machine. His machine mechanically processed punch cards so efficiently it that reduced 10 years of work to three months.[4] Thus, he effectively solved the problem of volume, processing data for the entire US population, and of efficiency, since a few machines successfully completed what would have taken countless human hours.

Overcoming the Census Bureau challenge marks a key moment in the history of dealing with *Lots of Data*. With the advent of digital computing and languages like SQL, technologies have continually risen to the ever-greater demands for volume and efficiency.[2] But armed with new technologies like web and mobile, society has created new types of relatively easily accessible data.[4] The inherently messy, unstructured, rapidly changing nature of this new data goes beyond what an abacus, a library, a Hollerith Machine, or a simple SQL database can handle. In addition to data volume and efficiency, *Big Data* introduces challenges of velocity, the unstable, constantly changing nature, and variety, the unification of datasets as distinct as website-eye mapping and social media network analysis.[6] This distinguishes itself from *Lots of Data*, a term whose significance depends mostly on perspective. Processing the census data used to be a challenge of *Lots of Data*, but with modern computing technology, storing and analyzing simple demographic data is relatively straightforward. *Big Data* offers no such historical asymmetry. Even as technology improves its capability of dealing with volume, the other factors that comprise *Big Data* will still pose challenges. In other words, a *Big Data* problem of yesterday is still a *Big Data* problem of today.

### 3 THE BEGINNING OF A NEW ERA, BUT NOT THE END OF SCIENCE

As the history of data shows, *Big Data* is not just a buzz word. It has real meaning that separates it from past notions of data; it represents a paradigmatic shift in the way we approach the representation and analysis of information, so much so that notions of integrity have been revisited. But this realization can easily be taken too far. In their book, titled *Big Data*, Mayer-Schonberger and Cukier go as far as providing an omniscient mathematical formula for *Big Data*, ( $n = all$ ), where  $n$  is the sample size and all is the population. They claim that *Big Data* represents all the data possibly available, with no limits on time, size, or variety, and therefore represents objective, absolute truth. The correlations we derive from *Big Data* therefore do not need proof of causation; the existence of a relationship or pattern in Big Data must be true of reality because *Big Data* is *All Data*.[3]

While *Big Data* certainly does change the norms of what it means to prove causation, the ( $n = all$ ) proposition falls short in theory and in practice. Numerous scholars argue that data, no matter what its size and complexity, is a sample, "with bias implicit due to choice of instrumentation, span of observation, units of measurement, and numerous other factors. In essence,  $n$  never equals all; all is

a limit in mathematical terms that can be approached but never attained." [3] Ignoring the implicit uncertainty of dealing with a data sample can provide misleading conclusions. "A well-known example of the foibles of the reliance on informally collected data and algorithmic projection is the Google Flu Trends (GFT), which raised huge scientific optimism about the predictive utility of informally collected data when first published in *Nature* in 2009 (Ginsberg et al., 2009). This optimism suffered a serious setback in 2013 when the GFT predictions for that year were shown to be seriously exaggerated (Butler, 2013; Lazer et al., 2014). A complete accounting for this setback is beyond the scope of this paper. However, one acknowledged factor is an overconfidence in the veracity of the data as a true sample of reality, rather than a random snapshot in time and the result of algorithmic dynamics." [3] The grand miscalculations of GFT should not have come as a surprise. Researchers have long-since understood the fallibility of data samples. *Big Data*, while opening up new possibilities for discovery of new questions, still must be held to standards of methodological credibility. Despite the hyperbolic optimism of the 2008 *Wired.com* article, scientific methods, theories, and ways of thinking will still play an important role in discovery.

### 4 CONCLUSIONS

As the latest development in the long history of data, *Big Data* represents a paradigmatic shift. *Big Data* clearly distinguishes itself from its predecessors in definition and in possibility. But, despite its tremendous, paradigm-shifting potential, *Big Data* is still an evolution on the long history of symbolic representation. Like any such representation, it shows but a small sample of the real world, viewed through the distorted lens of various biases. Adding the aspects of velocity and variety expand our avenues of discovery, but they do not eliminate the need for establishing some sense of scientific integrity, even if the norms of integrity must adapt. To be fair, the argument against the ( $n = all$ ) proposition comes mostly from the scientific community, whose entire existence relies on integrity. The business world offers a different context. Often, decision-makers must take actions while relying on nothing more than structured but easily fallible methods of analysis.[3] They try their best to produce reasonable insights with methods such as SWOT Analysis or Porter's Five Forces, because delivering timely, logical arguments often matters more than taking the time to find answers validated through scientific levels of scrutiny. In business, quickly finding reasonable answers often takes priority to slowly finding proven ones. Given their different priorities, businesses can perhaps afford to relax their standards of information integrity with *Big Data*, as long as they are cognizant of its inherent uncertainty. But it is this lack of cognizance that can lead people into the dangerous territory of making ill-advised decisions based on misleading data. In addition to clarifying what it means to go beyond *Lots of Data* to help people capitalize on the vast potential of *Big Data*, we hope to foster more sociotechnical research into what the dangerous territory of being incognizant looks like and how it can be avoided.

### REFERENCES

- [1] Chris Anderson. 2007. The End of Theory: The Data Deluge Makes the Scientific Method Obsolete. Website. (June 2007). <https://www.wired.com/2008/06/>

- pb-theory/
- [2] G. Groner and M. Rockwell. 1977. *Computer-Based Information Systems for a Hospital Emergency Department*. Technical Report. Rand Corporation, Santa Monica, Ca.
  - [3] Carl Lagoze. 2014. Big Data, data integrity, and the fracturing of the control zone. *Big Data and Society* (NO 2014). <https://doi.org/10.1177/2053951714558281>
  - [4] Bernard Marr. 2015. A Brief History of Big Data Everyone Should Read. Website. (Feb. 2015). <https://www.linkedin.com/pulse/brief-history-big-data-everyone-should-read-bernard-marr/>
  - [5] Bernard Marr. 2015. The Difference Between Big Data and a Lot of Data. Website. (Sept. 2015). <http://data-informed.com/the-difference-between-big-data-and-a-lot-of-data/>
  - [6] Svetlana Sicular. 2013. Gartner's Big Data Definition Consists of Three Parts, Not to Be Confused with Three "V"s. Website. (March 2013). <https://www.forbes.com/sites/gartnergroup/2013/03/27/gartners-big-data-definition-consists-of-three-parts-not-to-be-confused-with-three-vs/#2826c61d42f6>

# Big Data Analytics Architecture for Real-Time Traffic Control

Syam Sundar Herle

School of Informatics and Computing, IN 47408, U.S.A.

P.O. Box 1212

Bloomington, Indiana 47408

syampara@umail.iu.edu

## ABSTRACT

The advent of Big Data has triggered disruptive changes in many fields including Intelligent Transportation Systems (ITS). The emerging digital devices have opened unique opportunities to enhance the performance of the ITS. There is crucial need to develop new tools and system to keep up with the Big Data advent. In this paper we will discuss how integrating Big Data with ITS will help in Real-Time traffic control and we will explore some of the existing system which helps in real-time traffic control. Furthermore, we will propose a flexible architecture based on distributed computing platform for real-time traffic control. We will use Kafka, a state-of-the-art Big Data tool for building data pipelines and stream processing.

## KEYWORDS

i523, hid219, Big Data, kafka, Real-Time traffic control, Intelligent Transportation System

## 1 INTRODUCTION

According to [11] "the volume and speed at which data are generated, processed and stored is unprecedented". Big Data is the process of gathering management and analysis of data to reveal hidden patterns. The advent of Big Data have changed many fields ranging from urban planning to vehicle safety. In Big data approaches, the challenge is not alone confined to collecting data but also to exploit the collected data to draw valuable information. Given the magnitude of massive stream of real-time data push the limits of the current storage and processing capabilities. The current statistical model cannot be applied on the crowding data streams, as some these unstructured data [7] are context-based from the internet.

Most of the current system rely on ad hoc architecture solutions [2] [6], which are focused on satisfying predefined goals like predicting traffic flow and are hard to extend to different application. In response, this paper proposes a comprehensive architecture for Big Data for real-time traffic control, which is flexible in ways that it can accommodate diverse set of data sources and different ITS applications, particularly decision support for real-time traffic control. The proposed architecture is based on Kafka, as the data analysis using Kafka is reliable and scalable.

## 2 BACKGROUND

Real-time traffic control systems are composed of two main components: observation of the situation and implementation of the selected control strategy. A local system analyzes the real-time input data where they are integrated and process to identify the

situation. Once a threshold is exceeded, one of the predefined strategies is implemented to optimize the controller objective function. Feedback loop and Model Predictive Control (MPC)[8] are the most common traffic control approaches which are mainly single objective and require purposely-sensed data. Data driven approaches for Big Data in ITS can be divided in three main category,

- Urban planning : Planning public transportation network using studies on travel demand and mobility pattern estimation using mobile location data[8] or call details records [9].
- Transportation operation : services in this domain either focus on decision-making support systems for traffic operations. For example travel time prediction[3], traffic incident and anomaly detection[13].
- Safety : exploring the critical situations arising from the design of the infrastructure has been studied by analyzing trajectories extracted from video data[12].

Big Data analytics approaches scale with respect to the amount and speed of data that needs to be analyzed by relying on a set of storage and computing machines called cluster [10]. Each cluster operates on its own, locally stored, set of data (map function) the results from individual machines are then aggregated (reduce function). Different Big Data analytics tools have emerged like Hadoop Distributed File System (HDFS) or a NoSQL database, which are for batch analytics. On the other side lie tools applying stream analytics, which is preferable when low-latency [5] data-driven decisions are needed. Important tools in this category include Flink, Kafka, and Spark Streaming.

## 3 RELATED WORK

Some of the research study on developed architecture for Big Data analytics in ITS are "Sipresk" created by Khazaei et al. [4] which is a cluster based platform that is built on Godzillla conceptual framework [10] and validated to estimate the average speed and the congested sections of a highway. And another study, by Xia et al. [2] have employed Hadoop distributed computing platform with MapReduce parallel processing to forecast near-future traffic flow.

From both the studies, we can see that there is scarce literature in applying Big Data approach in ITS and none of the approaches focus on Big Data stream processing.

## 4 PROPOSED BIG DATA ANALYTICS ARCHITECTURE FOR REAL-TIME TRAFFIC CONTROL

When developing a platform for data analytics in transport system we need to address many queries some of the nature of queries are,

- Descriptive and predictive queries
- Periodic and non-periodic
- Real-time and non-real time
- single and multiple user

## 4.1 REQUIREMENTS

In order to address above queries, an architecture for traffic control that relies on Big Data analytics has a number of requirements namely,

- Support analysis of data in streaming mode and analysis of historical data in batch mode.
- Provide an easy way to specify a data analytics query and its triggering policy.
- Provide an easy way to plug-in the analysis of different data sources, even as they become available.
- Provide intuitive mechanisms to considering multiple data sources in answering a single query.
- Provide an easy way to plug-in advanced data analysis (Machine learning algorithm).
- Large number of data sources and consumers and scale linearly with these numbers.
- Hardware faults by continuous operation and without loss of data.

## 4.2 Overall Architecture

In order to satisfy the above requirements, we came up with the overall architecture depicted in Fig. 1 In it, the different ITS actors (i.e. drivers, detectors, actuators, operators, etc.) act either as publishers or subscribers to Kafka topics. Kafka is used as the layer that decouples publishers and subscribers from the analytics engine.

[Figure 1 about here.]

Once a publisher publishes a new data item, this gets sent to Kafka and also saved in a Hadoop Distributed File System (HDFS) data warehouse for posterior analysis. The analytics engine gets input from all the publishing topics and performs data analysis. The results of the data analysis may trigger changes that are (i) published to one or more subscriber topics, and (ii) logged in a NoSQL database for posterior analysis of the findings (e.g. in order to determine the accuracy/recall of a predictive model mined from the incoming data). Once a change is published, it is picked up by the ITS actors that listen to the particular subscriber topic; they are ultimately responsible for enacting the change in the ITS.

## 4.3 Prototype of Big Data platform for traffic control

In the described platform, Kafka has the role of the communication medium between the traffic system with its sensors, like loop detectors and actuators like traffic lights and the data analysis module. A number of Kafka topics represent the different types of incoming data from the traffic system like mean speed from loop detectors, vehicle speed and position data from on-board GPS devices. There are no assumption on the format of the data, but in prototype platform the paper have used JSON format. A special Kafka topic, represented as change provider in the platform is responsible for delivering the changes in the form of Kafka messages that should be enacted in

the traffic actors. Such changes are the results of data analytics engine.

The data analytics engine performs the analysis and control logic's defined by each consumer into vary from simple feedback loop to sophisticated machine-learning algorithms. Moreover, users can customize the time intervals for receiving the outcome of the analytics engine. As data come in, they are being processed via user-specified reducer functions. These functions are specific to each topic.

## 5 SIMULATION CASE STUDY

In the traffic control problem, the controller receives the average density from loop detectors on a cross section of a three-lane freeway and decides whether the hard shoulder should be opened or closed. Due to safety reasons, an operator observes the section via Surveillance camera to detect obstacles or stopping vehicles on the hard shoulder. The paper studies the hard shoulder opening system on a 3 km segment of A9 freeway in the north of Munich. This section of the freeway has been used as a digital test bed to assess the performance different types of sensors e.g. camera, which fits to Big Data definition in term of volume, velocity and variety suitable the characteristics of a Big Data analytics.

[Figure 2 about here.]

[Figure 3 about here.]

Since we are interested in high-level ITS architecture and proof of concept for smooth operation of the proposed platform, without losing generality, we have modeled this section in SUMO [1], a microscopic traffic simulation. In order to achieve a realistic representation of the reality, we use virtual detectors in SUMO, each corresponding to an existing sensor. An area detector is placed over the hard shoulder to represent the surveillance camera, virtual loop detectors that measure mean speed and occupancy and floating car data that provide momentary speed and position as well as travel time along the section. Fig. 2 depicts a comparison of the real-world with the SUMO experiment and Fig. 3 illustrates the Kafka publishers and subscribers together with the corresponding published topics.

## 6 CONCLUSION

In this work, we proposed a comprehensive and flexible architecture for real-time traffic control based on Big Data analytics. The architecture is based on systematic analysis of the requirements of the domain. The proposed architecture has been partly reified in a platform employing Kafka. It has been put to action in operating a feedback control loop to open or close hard shoulder of a freeway. The main limitation of the study was lack of access to real-world data. Although using simulation in traffic studies is common, data generated in SUMO are well-structured, valid and do not require data quality and plausibility checks. We recommend to consider these essential issues in future research.

## ACKNOWLEDGEMENTS

This work was done as part of the course "I523: Big Data Applications and Analytic" at Indiana University during Spring 2017. Many thanks to Professor Gregor von Laszewski at Indiana University Bloomington for their academic as well as professional guidance.

We would also like to thank Associate Instructors for their help and support during the course.

## REFERENCES

- [1] D. Krajzewicz, J. Erdmann, M. Behrisch, and L. Bieker. 2012. "Recent Development and Applications of SUMO - Simulation of Urban MOBility". (2012), 128–132 pages.
- [2] D. Xia, B. Wang, H. Li, Y. Li, and Z. Zhang. 2016. "A distributed spatial-temporal weighted model on MapReduce for short-term traffic flow forecasting". (2016), 246–263 pages.
- [3] H. Chen and H. A. Rakha. 2014. "Real-time travel time prediction using particle filtering with a non-explicit state-transition model". (2014), 112–126 pages.
- [4] H. Khazaei, S. Zareian, R. Veleda, and M. Litoiu. 2016. "Sipresk: a big data analytic platform for smart transportation". (2016), 419–430 pages.
- [5] J. Kreps, N. Narkhede, J. Rao, and others. 2011. "A distributed messaging system for log processing". (2011), 7 pages.
- [6] J. Yu, F. Jiang, and T. Zhu. 2013. "RTIC-C: A big data system for massive traffic information mining". (2013), 246–263 pages.
- [7] J. Zhang, F.-Y. Wang, K. Wang, W.-H. Lin, X. Xu, and C. Chen. 2011. "Datadriven intelligent transportation systems: A survey". (2011), 1624–1639 pages.
- [8] L. D. Baskar, B. De Schutter, and H. Hellendoorn. 2016. "Model-based predictive traffic control for intelligent vehicles: Dynamic speed limits and dynamic lane allocation". (2016), 246–263 pages.
- [9] M. S. Iqbal, C. F. Choudhury, P. Wang, and M. C. Gonzlez. 2014. "Development of origin-destination matrices using mobile phone call data". (2014), 63–74 pages.
- [10] M. Shtern, R. Mian, M. Litoiu, S. Zareian, H. Abdeltawab, and A. Tizghadam. 2014. "Towards a multi-cluster analytical engine for transportation data". (2014), 249–257 pages.
- [11] OECD/ITF 2015. "Big Data and Transport: Understanding and assessing options". OECD/ITF. Available at [http://www.itfoecd.org/sites/default/files/docs/15cpb-bigdata\\_0.pdf](http://www.itfoecd.org/sites/default/files/docs/15cpb-bigdata_0.pdf). Accessed: 2017-3-26.
- [12] P. St-Aubin, N. Saunier, and L. Miranda-Moreno. 2015. "Large-scale automated proactive road safety analysis using video data". (2015), 363–379 pages.
- [13] S. Chawla, Y. Zheng, and J. Hu. 2012. "Inferring the root cause in road traffic anomalies, in Data Mining (ICDM)". (2012), 141–150 pages.

#### LIST OF FIGURES

1	Architecture of the proposed platform.	5
2	Cross-comparison of SUMO experiment with real-world situation.	5
3	Topics from Kafka publishers in SUMO experiment.	5

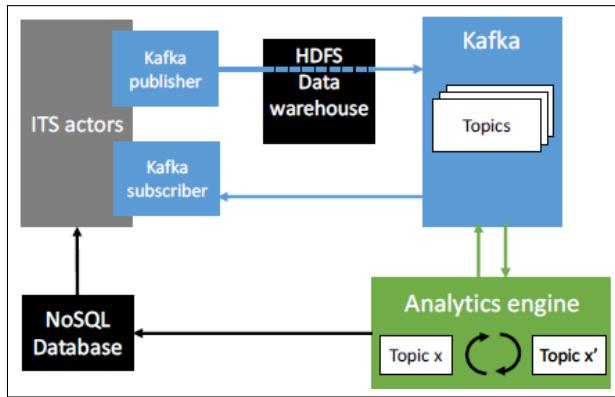


Figure 1: Architecture of the proposed platform.

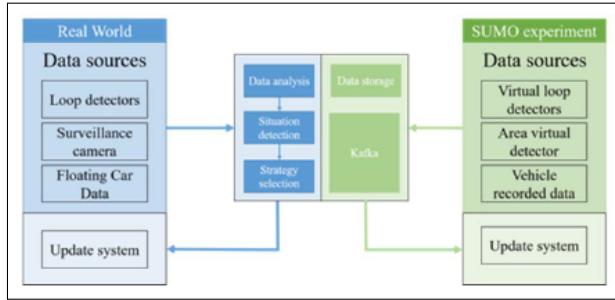


Figure 2: Cross-comparison of SUMO experiment with real-world situation.

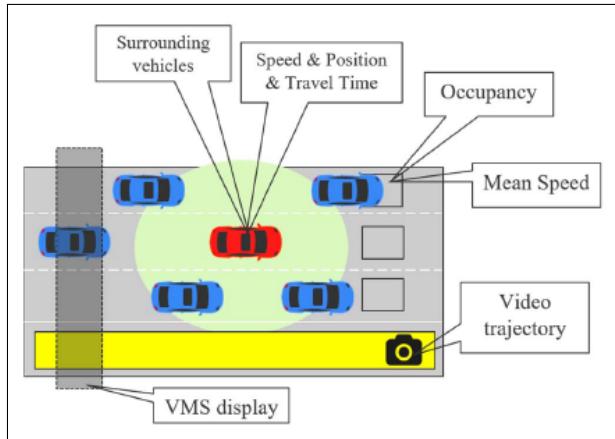


Figure 3: Topics from Kafka publishers in SUMO experiment.

# Optimizing Mass Transit Bus Routes with Big Data

Matthew Schwartz

Indiana University, School of Informatics, Computing, & Engineering

919 E 10th St

Bloomington, Indiana 47408

mabschwa@indiana.edu

## ABSTRACT

Big data analytics is important in the public bus transportation domain because optimized public bus systems can reduce congestion and greenhouse gas emissions, while offering a safe, affordable, and convenient way to travel; however, in many cities people prefer to take private transportation over public buses. Big data can help bridge this gap by optimizing the three pillars of public bus transportation: routes, schedules and infrastructure.

## KEYWORDS

i523, hid225, L<sup>A</sup>T<sub>E</sub>X, big data, bus route optimization

## 1 INTRODUCTION

Optimized public bus transit, is one of the keys to bring sustainable development and a better quality of life to small and medium sized urban areas. Route optimization techniques like human mobility mining & clustering, ant colony and genetic algorithms, and Monte Carlo simulations are only possible through the collection and analysis of big data. Currently "traditional public transportation planning methods have relied on human surveys to understand people's transportation needs. Despite the substantial time and cost spent on the survey process, the macroscopic analysis based on surveys is too static to reflect the fast development of urban areas[5]."

Optimized public bus systems vastly improve residents quality of life (QOL) through four dimensions including improved physical, psychological, social, and economic well-being[4]. Consequently, poor transit experiences can have the exact opposite effect on residents QOL. In a competitive environment to attract and retain residents, cities must prioritize a well optimized public bus system. In addition, a transportation systems needs flexibility to adapt to new points of interest due to American's continual urban migration. Approximately 82% of Americans currently live in urban areas compared to just 64% in 1950. This trend is expected to continue as the United Nations expects 87% of Americans to live in urban environments by 2050[1]. Optimized transportations systems are more important than ever due to millennial's tendencies to delay car ownership[2]. Cities should work to prioritize non-car owners with mass bus transit options over less efficient, safe, and environmentally friendly private transportation alternatives.

One major downfall of urbanization is frequent and intense traffic congestion due to more human activities within limited space, and consequently unnecessary energy consumption during traffic congestionLiu01. The rise of global warming is putting pressure on urban planners to reduce greenhouse emissions. "The Nobel Prize winning 2007 Intergovernmental Panel on Climate Change report concluded that greenhouse gas emissions must be reduced

by 50% to 85% by 2050 in order to limit global warming to four degrees Fahrenheit[3]." Compared to single occupancy vehicle (SOV) travel, average bus transit occupancy reduces CO<sub>2</sub> emissions per passenger mile by 33.33%. When bus transit is fully occupied, CO<sub>2</sub> emissions per passenger mile are reduced by 81.25% compared with SOV travel[3].

Although current mass transit bus systems offer various QOL, environmental, and safety benefits, the current public bus system is far from perfect. Fortunately, new technology makes it easier to collect bus trip data such as velocity, position, heading, and number of riders and locale data such as traffic patterns, road networks, and points of interest. Applying this data to machine learning techniques gives urban planners the knowledge to optimize public transit systems with the end goal of converting private transportation users to public bus transit.

## 2 ROUTE & SCHEDULE OPTIMIZATION TECHNIQUES

### 2.1 Human Mobility Mining & Clustering

### 2.2 Ant Colony and Genetic Algorithms

### 2.3 Monte Carlo Simulations

## 3 INFRASTRUCTURE IMPROVEMENTS

### 3.1 Digital Signage

### 3.2 Roundabouts

## 4 CONCLUSION

Amid a major disruption in the transportation industry due to the introduction of self driving vehicles, public bus systems must adapt. For instance, public bus systems can leverage this new technology and create a network of smaller self driving buses that are highly optimized to local human mobility patterns. Using live traffic data, the Internet of Things, and fast computing big data algorithms, this system of public transportation could eliminate the need for private vehicle ownership all together. For several reasons, creating a highly optimized public bus system is good for QOL standards, sustainability, and safety.

## ACKNOWLEDGMENTS

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

## REFERENCES

- [1] Bret Boyd. 2017. Urbanization And The Mass Movement Of People To Cities. Internet. (01 2017). <https://graylinegroup.com/urbanization-catalyst-overview/>
- [2] Melissa Etehad and Rob Nikolewski. 2016. Millennials And Car Ownership? It's Complicated. Newspaper. (12 2016). <http://www.latimes.com/business/autos/la-fi-hy-millennials-cars-20161223-story.html>

- [3] Tina Hodges. 2010. *Public Transportation's Role in Responding to Climate Change*. Technical Report. U.S. Department of Transportation Federal Transit Administration. <https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/PublicTransportationsRoleInRespondingToClimateChange2010.pdf> Editing/Design: Jarrett Stoltzfus.
- [4] Richard J. Lee and Ipek N. Sener. 2016. Transportation planning and quality of life: Where do they intersect? *Transport Policy* 48, Supplement C (2016), 146 – 155. <https://doi.org/10.1016/j.tranpol.2016.03.004>
- [5] Yanchi Liu, Chuanren Liu, Nicholas Jing Yuan, Lian Duan, Yanjie Fu, Hui Xiong, Songhua Xu, and Junjie Wu. 2017. Intelligent Bus Routing with Heterogeneous Human Mobility Patterns. *Knowl. Inf. Syst.* 50, 2 (Feb. 2017), 383–415. <https://doi.org/10.1007/s10115-016-0948-6>

# I523: Project/Report: 343: Big Data Applications and Autonomous Vehicles

[https://gitlab.com/cloudmesh\\_fall2016/project-343/](https://gitlab.com/cloudmesh_fall2016/project-343/)

Borga Edionse Usifo  
HID 1  
Indiana University  
Bloomington, IN  
busifo@iu.edu

## ABSTRACT

This paper will explain the importance of autonomous vehicles, Big Data applications used on these vehicles, and several computational methods used for achieving successful autonomy.

## 1. INTRODUCTION

The way of life is changing every day with the help of technological advancements. We keep hearing more and more by companies how they are trying to make the computers to think and react like human beings. Autonomous vehicles are one of the products of these advancements.

The main difference of learning between humans and computer is the way of gathering experience. Humans learn from experience but computers learn from the data. This is why data is the most fundamental aspect for the computer to do given task. In this paper, we will learn about how computers process data what kind of analytic used for processing and learning from data and importance of big data.

## 2. IMPORTANCE OF AUTONOMOUS VEHICLES

Autonomous vehicles are essential, and it is the future of driving method to going A to B. There are several reasons for it which will change the future of driving. Before we go into detail about autonomous vehicles we need to learn types of autonomous vehicles which are listed below:

- **Level 0(no automation):** The driver responsible for all aspects of vehicle instruments while monitoring road conditions.[1]
- **Level 1(function-specific automation):** “Automation at this level involves one or more specific control functions; if multiple functions are automated, they operate independently of each other.”[1]
- **Level 2(combined-function automation):** “This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of controlling those functions.”[1]
- **Level 3(limited self-driving automation):** “Vehicles at this level of automation enable the driver

to have full control of all safety-critical functions under certain traffic or environmental conditions, and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. “[1]

- **Level 4(full self-driving automation):** “The vehicle designed to perform all safety-critical driving functions and monitor road-way conditions for an entire trip”[1]

### 2.1 Safety Aspect

Increasing safety features in motor vehicles is decreasing the number of crashes, if we look at the data from U.S. Census Bureau we can see that from 1980 to 2009 we have decreased in accidents. We can not tie all these decreases into technology because road structure and personal education also increased. According to the National Highway Traffic Safety Administration(NHTSA)

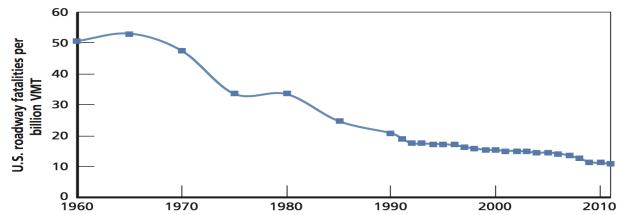
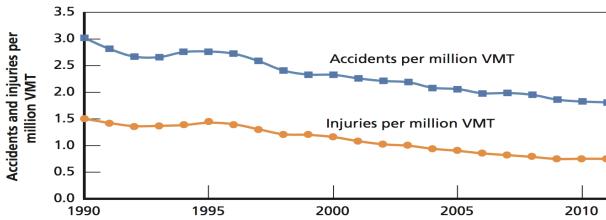


Figure 1: Note: Data from BTS(2013) includes all highway transportation modes: passenger car, light truck, motorcycle, large truck, and bus. Fatalities include vehicle occupants for all highway modes, as well as pedestrians and cyclists

- “The economic cost of motor vehicle crashes that occurred in 2010 totaled 242 billion. This is equivalent to approximately 784 for every person living in the United States and 1.6 percent of the U.S Gross Domestic Product.”[2]
- “Some 3.9 million people were injured in 13.6 million crashes in 2010, including 32,999 deaths. Twenty-four percent of these injuries occurred in crashes that were not reported to police.”[2]



**Figure 2: Note:** Data from the Bureau of Transportation Statistics(BTS,2013) includes all highway transportation modes: passenger car, light truck, motorcycle, large truck, and bus. Crashes involving two or more motor vehicles are counted as one “crash” by the U.S. DOT, so total crashes shown here are fewer than the sum of individual vehicles involved. Injuries include vehicle occupants for all highway modes as well as pedestrians and cyclists.

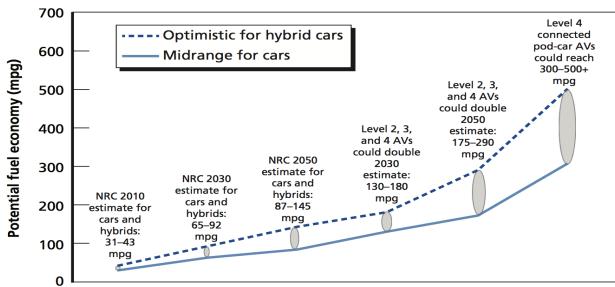
## 2.2 Economic Aspect

Beside from saving money from increasing the safety while decreasing the economic cost of motor vehicles, autonomous vehicles can improve many aspects of business and government supply chain industry, gas usage, time of commuting, and productivity.

“Our research finds that the social benefits of autonomous vehicles including decreased crashes, increased mobility and increases in fuel economy will outweigh the likely disadvantages.”[3]

### 2.2.1 Fuel Consumption

As technology improves every day, we see live traffic events in our navigation apps, and optimally its steering individuals to go to different directions based on traffic events to eliminate any waste from commuting. With the help of autonomous vehicles, this live data directly go to intelligent vehicle systems and an autonomous car will steer their directions without the need of human interaction. An intelligent system like this improve the fuel consumption and decrease the commuting time from point A to B.



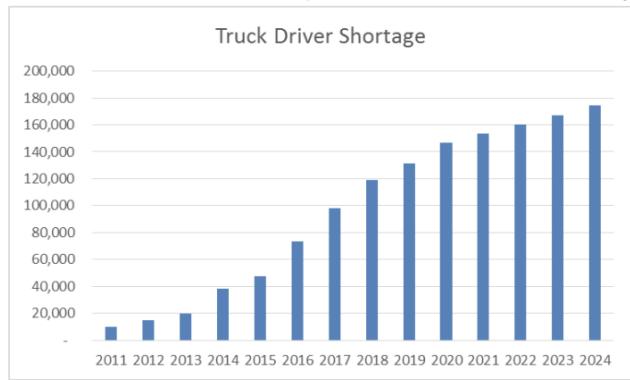
**Figure 3: Range of Fuel Economy Improvements for Conventional, Hybrid, and Autonomous Cars**

### 2.2.2 Supply Chain

As of year, 2017 majority of companies essential success to stay in competitive is the supply chain. Autonomous vehicles will have a high impact on supply chain distributions

because of ability to operate 24/7 in right circumstances, and faster travel times. Self-driving vehicles will also help the current driver shortage situation in supply chain businesses.

“In 2014 trucking industry was short 38,000 drivers. The shortage expected to reach nearly 48,000 in 2015 and if the current trend holds, shortage may balloon to almost 175,000 by 2024”[4]



**Figure 4: Forecast of Truck Driver Shortage**

### 2.2.3 Productivity

Autonomous vehicle will also give people to do multitasking abilities for productivity improvements. Individuals will have more free time to do other tasks.

“Currently, in the U.S., the average occupant of a light-duty vehicle spends about an hour a day traveling time that could potentially be put to more productive use. Indeed, increased productivity is one of the expected benefits of self-driving vehicles.”[5]

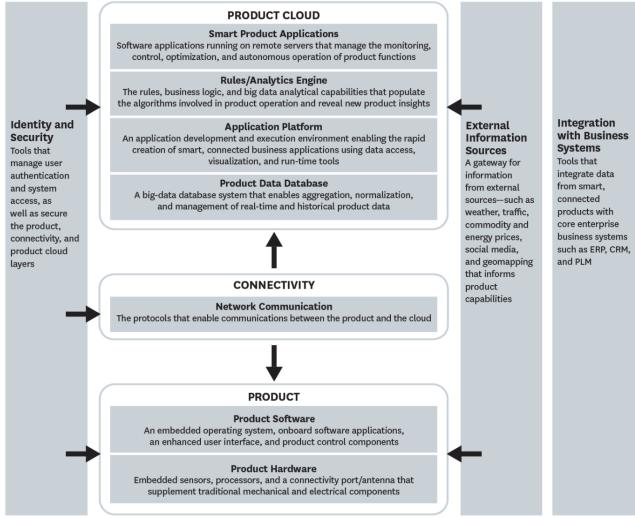
## 3. HOW IT RELATED TO BIG DATA AND WHAT DOES BIG MEAN?

Data can come from all types of resources. In our case, it is sensors, signals, cameras, customer behaviors and many others resources. This data can be structured and unstructured dependent on where it is coming from while the term BIG refers to the volume of data it may also refer to techniques and tools that have been used to process this significant amount of data this tools can vary from cloud computing, visualization techniques to artificial intelligence procedures for analyzing.[6]

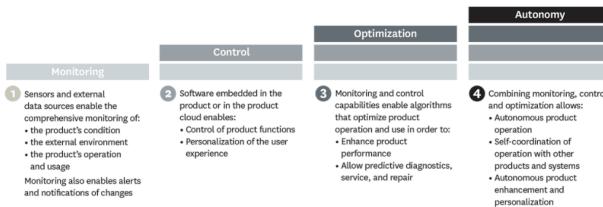
The essential success of autonomous vehicles depends on data. The more data they have the correct decision can the autonomous vehicles do. As we stayed before this data comes from the variety of places some of them are sensors, GPS signals, cameras, internet connectivity. All this data helps the car to make intelligent decisions while analyzing those data, without the data it will never successfully reach to the destination.[7]

Additionally, companies are using “big data to optimize customer experience and operational safety ultimately laying

the groundwork for the fully autonomous vehicles".[6] Companies can get collect data about customer driving habits by integrating additional sensors to its cars.[8] This connectivity to Big Data platform can give companies advantages over deploying new features to their cars. One another importance of Big Data connectivity for autonomous cars is the ability to transfer learning experience to other autonomous vehicles in other words when one autonomous vehicle learns from data and road conditions then that data can be transferable millions of other autonomous vehicles in contrast to individual experience which stays with the person. [8]



**Figure 5: How Big Data and Connectivity Works**



**Figure 6: Process of Connectivity**

## 4. ANALYTICS USED ON AUTONOMOUS VEHICLES

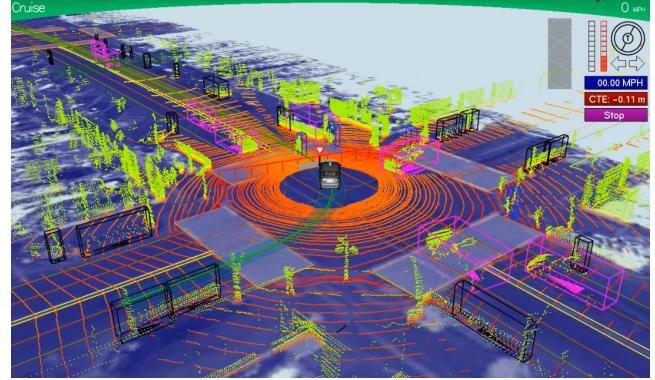
In this topic we will examine some of the methods that used in autonomous vehicles and these will include Machine Learning, Deep Learning, Artificial Intelligence.

### 4.1 Machine Learning

Machine learning widely used for many applications. Some of this applications include image and voice recognition, spam detection, fraud detection, the stock market, teaching a computer how to play chess, and, off course self-driving cars.

Machine learning is teaching computers to learn to perform a task from past experiences this experience comes from

data. Self-driving cars equipped with ECU (Electronic Control Units). These ECUs process data from sensors like Li-dar, radars, cameras or the IoT(Internet of Things) and they are equipped with machine learning algorithms to make decisions in different conditions.[7] These decisions vary from adjusting the speed with different driving conditions to recognizing the pedestrian movement on the road.



**Figure 7: World from an Eye of Autonomous Vehicle**

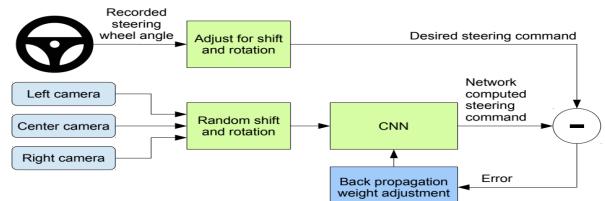
#### 4.1.1 Should we store this data in someplace or analyze it simultaneously

Current technology and Big Data methods allows self-driving or any other autonomous vehicles to analyze data on the go.[9]

"Analyze it on the fly. Rather than bringing data to the storage and analytics, bring the analytics to the data"[9]

## 4.2 Conventional Neural Networks

Conventional Neural Networks (CNN)[10] used in pattern recognition applications. The significant advantage of CNN is that it can automatically learn features of the data from training examples. [10] This gives the significant advantage over learning features from image recognition. The image comes from camera system mounted on a car, after capturing images they will go through CNN, and after recognizing the features on the road, it will give the vehicle to steer itself based on computed steering command.[10]



**Figure 8: CNN Process Steps**

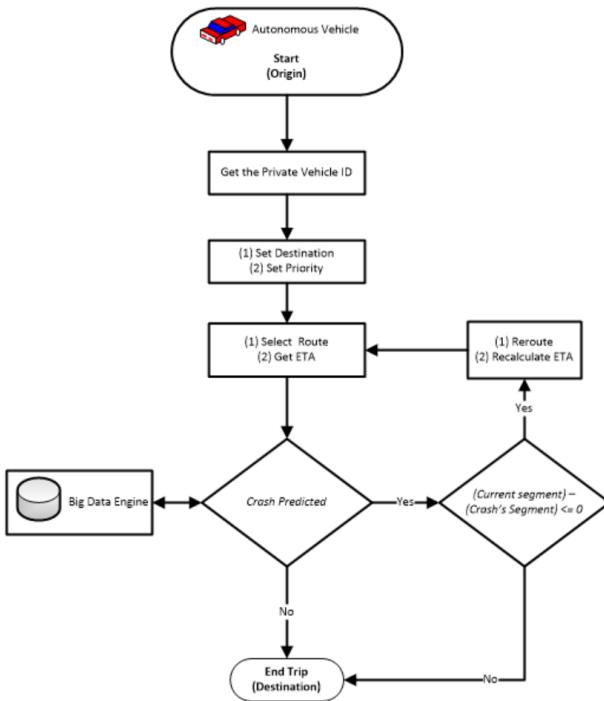
### 4.3 Big Data for Predicting Safety Road Passage

Big data can help to maximize safety aspects in self-driving cars by using Big Data mining and analytics. This kind of analytics will require vehicle and analytics to connect in

cloud-based systems also this will require an entirely automated car, in this case, it is Level 4 which is a fully integrated self-driving car. This autonomy will give the vehicle to the ability to choose the safe passage at all times automatically. Below graph show how this architecture system works. [1]

The system still requires a driver to turn on the car and put the car id. After that, it requires the driver to put the destination. When Big Data engine receives all the required input, it will start predictions for road segments based on real-time Big Data analysis. If the cloud system does not predict any accidents in that road segments than vehicle continuous it is the destination as usual if the cloud system predicts any accidents then it reroutes the vehicle path to the destination.[1]

This kind of cloud system will also give the user to ability choose between fastest route or the best fuel consumption, but the safety is always going to be the first priority. (Below Fig) shows the pseudo-code for implementing in Big Data Engine.



**Figure 9: Big Data Road Passage Safety Process Steps**

## 5. CONCLUSION

In this paper importance of autonomous vehicle and Big Data based applications on an autonomous vehicle is presented. Insights about advantages of autonomous vehicles had given. Several analytical approaches while using Big Data applications had shown.

## 6. REFERENCES

- [1] *Autonomous Vehicles Safe-Optimal Trajectory Selection Based on Big Data Analysis and Predefined*

---

### Algorithm 1: Check the Predicted Accident Location

---

```

initialization;
if (CurrentSegment#) - (CrashSegment#)
    ≤ 0
then
    (1) Reroute;
    (2) Recalculate ETA;
    (3) Recalculate Distance;
    (4) Recalculate Fuel Consumption;
else
    | Keep using the current trajectory ;
end
  
```

---

**Figure 10: Pseudo-code for Road Passage Safety**

*User Preferences.* Florida State University, Dec.

2016. [Online]. Available:

<http://ieeexplore.ieee.org/document/7777922/>

- [2] L. Blincoe, T. Miller, E. Zaloshnja, and B. Lawrence, “The economic and societal impact of motor vehicle crashes, 2010,” National Highway Traffic Safety Administration, techreport DOT HS 812 013, 2010(Revised).
- [3] M. J. Anderson, K. N., K. Stanley, D., P. Sorensen, C. Samaras, and O. Oluwatola, A., “Autonomous vehicle technology,” RAND Corporation, Tech. Rep., 2016. [Online]. Available: [www.rand.org/t/rr443-2](http://www.rand.org/t/rr443-2)
- [4] B. Costello and R. Suarez, “Truck driver shortage analysis,” *American Trucking Associations*, Oct. 2015.
- [5] M. Sivak and B. Schoettle, “Would self-driving vehicles increase occupant productivity?” University of Michigan, The University of MichiganSustainable Worldwide Transportation 2901 Baxter RoadAnn Arbor, Michigan 48109-2150 U.S.A., techreport SWT-2016-11, Sep. 2016.
- [6] V. Beal, “Big data,” Online. [Online]. Available: [http://www.webopedia.com/TERM/B/big\\_data.html](http://www.webopedia.com/TERM/B/big_data.html)
- [7] S. Ravindra, “The machine learning algorithm used in self-driving cars.” [Online]. Available: <http://www.kdnuggets.com/2017/06/machine-learning-algorithms-used-self-driving-cars.html>
- [8] M. E. Porter and J. E. Heppelmann, “How smart, connected products are transforming competition,” Web Page, Nov. 2014. [Online]. Available: <https://hbr.org/2014/11/how-smart-connected-products-are-transforming-competition>
- [9] S. A. System, “The connected vehicle: Big data, big opportunities.”
- [10] M. Bojarski, D. Testa, D., D. Dworakowski, B. Firner, B. Flepp, P. Goyal, D. Jackel, L., M. Monfort, U. Muller, J. Zhang, X. Zhang, and J. Zhao, “End to end learning for self-driving cars,” Nvidia Corporation, NVIDIA Corporation Holmdel, NJ 07735, techreport, Apr. 2016. [Online]. Available: <https://arxiv.org/pdf/1604.07316v1.pdf>

# My great Big Dat Paper

Huiyi Chen  
Institute for Clarity in Documentation  
2451 E. 10TH ST., 612  
Bloomington, Indiana 47408  
huiyichen@indiana.edu

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

ACM proceedings, L<sup>A</sup>T<sub>E</sub>X, text tagging

## 1 INTRODUCTION

This is my Intro

## 2 THE BODY OF THE PAPER

## 3 CONCLUSIONS

This is my conclusion.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Yuhua Li for providing the matlab code of the *BEPS* method.

## REFERENCES

# My great Big Dat Paper

Ben Trovato

Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
trovato@corporation.com

G.K.M. Tobin

Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
webmaster@marysville-ohio.com

Lars Thørväld

The Thørväld Group  
1 Thørväld Circle  
Hekla, Iceland  
larst@affiliation.org

Valerie Béranger

Inria Paris-Rocquencourt  
Rocquencourt, France

Aparna Patel

Rajiv Gandhi University  
Rono-Hills  
Doimukh, Arunachal Pradesh, India

Huifen Chan

Tsinghua University  
30 Shuangqing Rd  
Haidian Qu, Beijing Shi, China

Charles Palmer

Palmer Research Laboratories  
8600 Datapoint Drive  
San Antonio, Texas 78229  
cpalmer@prl.com

John Smith

The Thørväld Group  
jsmith@affiliation.org

Julius P. Kumquat

The Kumquat Consortium  
jpkumquat@consortium.net

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

ACM proceedings, L<sup>A</sup>T<sub>E</sub>X, text tagging

## 1 INTRODUCTION

The *proceedings* are the records of a conference. ACM seeks to give these conference by-products a uniform, high-quality appearance. To do this, ACM has some rigid requirements for the format of the proceedings documents: there is a specified format (balanced double columns), a specified set of fonts (Arial or Helvetica and Times Roman) in certain specified sizes, a specified live area, centered on the page, specified size of margins, specified column width and gutter size [1].

## ACKNOWLEDGMENTS

The authors would like to thank

## REFERENCES

- [1] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. <https://doi.org/10.1007/3-540-09237-4>

# My great Big Dat Paper

Ben Trovato  
Institute for Clarity in Documentation  
P.O. Box 1212  
Dublin, Ohio 43017-6221  
trovato@corporation.com

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

i523

## 1 INTRODUCTION

The *proceedings* are the records of a conference. ACM seeks to give these conference by-products a uniform, high-quality appearance. To do this, ACM has some rigid requirements for the format of the proceedings documents: there is a specified format (balanced double columns), a specified set of fonts (Arial or Helvetica and Times Roman) in certain specified sizes, a specified live area, centered on the page, specified size of margins, specified column width and gutter size [1].

## ACKNOWLEDGMENTS

The authors would like to thank

## REFERENCES

- [1] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. <https://doi.org/10.1007/3-540-09237-4>

# My great Big Dat Paper

Ben Trovato

Institute for Clarity in Documentation

P.O. Box 1212

Dublin, Ohio 43017-6221

trovato@corporation.com

## ABSTRACT

This paper provides a sample of a L<sup>A</sup>T<sub>E</sub>X document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings.

## KEYWORDS

i523

## 1 INTRODUCTION

The *proceedings* are the records of a conference. ACM seeks to give these conference by-products a uniform, high-quality appearance. To do this, ACM has some rigid requirements for the format of the proceedings documents: there is a specified format (balanced double columns), a specified set of fonts (Arial or Helvetica and Times Roman) in certain specified sizes, a specified live area, centered on the page, specified size of margins, specified column width and gutter size [1].

## ACKNOWLEDGMENTS

The authors would like to thank

## REFERENCES

- [1] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. <https://doi.org/10.1007/3-540-09237-4>