Lecture 1: Introduction

Pilsung Kang

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Course Information

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- Course homepage
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Set status

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multivariate-data-analysis
Multivariate data analysis @Korea University (Undergraduate)
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Jupyter Notebook ★77 46

Business-Analytics-IME654-
Course homepage for "Business Analytics (IME654)" @Korea University
Jupyter Notebook ★21 28

Business-Analytics-ITS504-
Course homepage for "Business Analytics (ITS504)" @Korea University
★1

R-for-Data-Analytics
Course homepage of "Programming Language for Data Analytics" @Korea University
HTML ★3 3

machine-learning-with-R
Machine Learning with R @FASTCAMPUS
R ★15 20

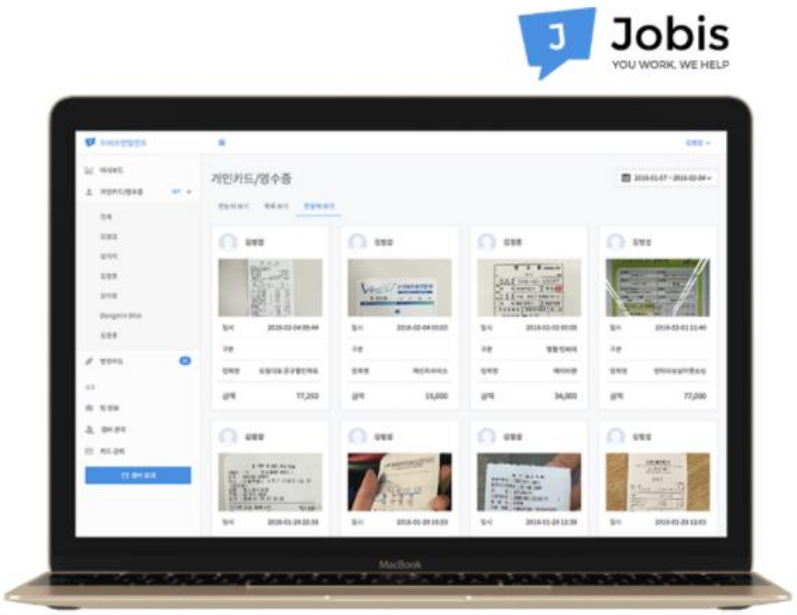
169 contributions in the last year — Contribution settings

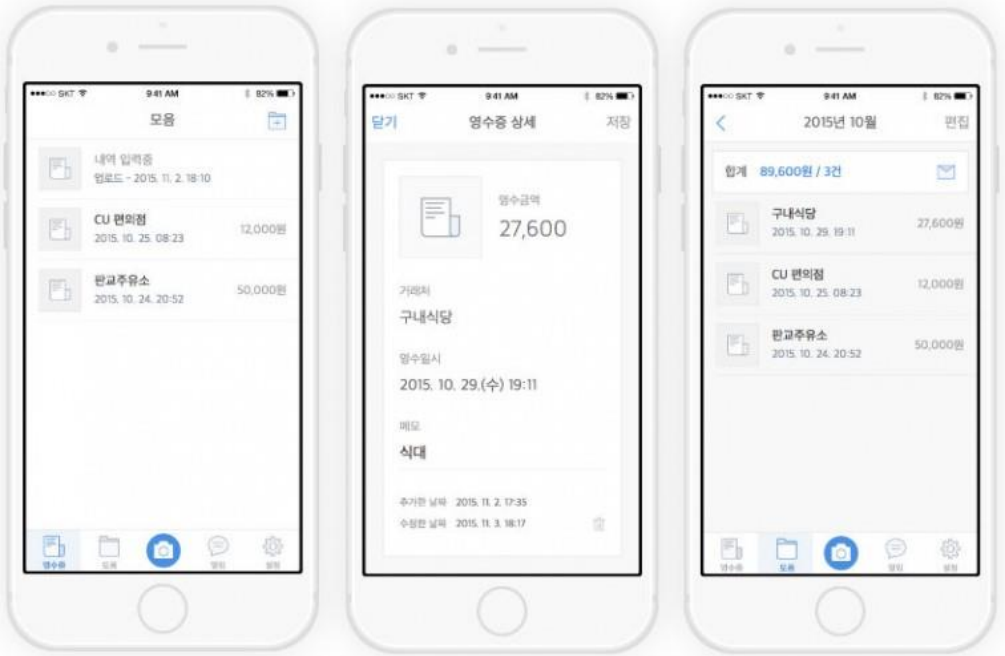
AGENDA

Amazon: Anticipated Shipping

landing.ai: What is defective product and where?

Is Data a Tool or Purpose of Business?



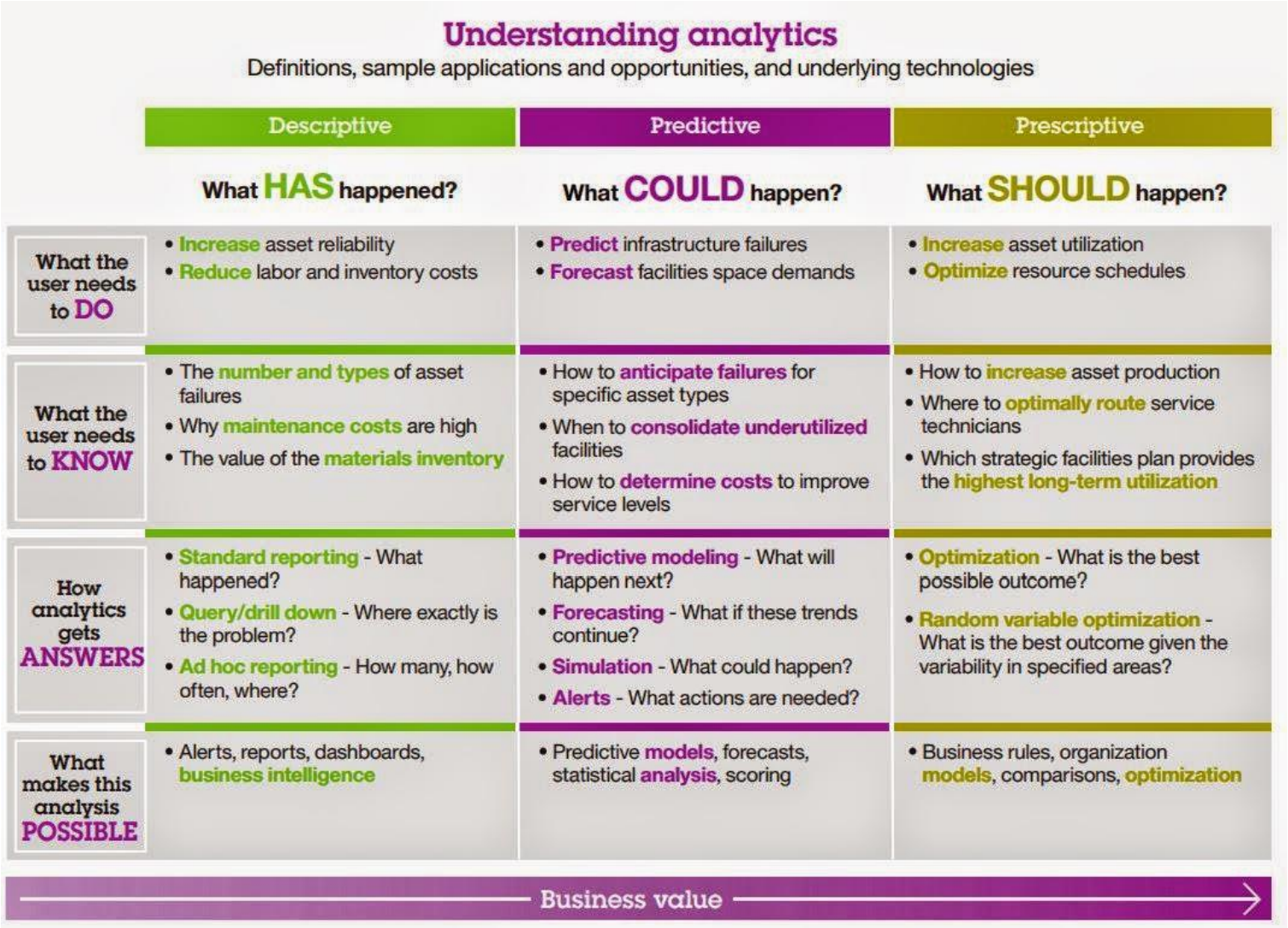


Data-driven Decision Making

- What we want to know

Data-driven Decision Making

- Descriptive vs. Predictive vs. Prescriptive Analytics



Understanding analytics

Definitions, sample applications and opportunities, and underlying technologies

	Descriptive	Predictive	Prescriptive
	What **HAS** happened?	What **COULD** happen?	What **SHOULD** happen?
What the user needs to **DO**	• **Increase** asset reliability • **Reduce** labor and inventory costs	• **Predict** infrastructure failures • **Forecast** facilities space demands	• **Increase** asset utilization • **Optimize** resource schedules
What the user needs to **KNOW**	• The **number and types** of asset failures • Why **maintenance costs** are high • The value of the **materials inventory**	• How to **anticipate failures** for specific asset types • When to **consolidate underutilized** facilities • How to **determine costs** to improve service levels	• How to **increase** asset production • Where to **optimally route** service technicians • Which strategic facilities plan provides the **highest long-term utilization**
How analytics gets **ANSWERS**	• **Standard reporting** - What happened? • **Query/drill down** - Where exactly is the problem? • **Ad hoc reporting** - How many, how often, where?	• **Predictive modeling** - What will happen next? • **Forecasting** - What if these trends continue? • **Simulation** - What could happen? • **Alerts** - What actions are needed?	• **Optimization** - What is the best possible outcome? • **Random variable optimization** - What is the best outcome given the variability in specified areas?
What makes this analysis **POSSIBLE**	• Alerts, reports, dashboards, **business intelligence**	• Predictive **models**, forecasts, statistical **analysis**, scoring	• Business rules, organization **models**, comparisons, **optimization**

Business value

Machine Learning

- Definition
  - ✓ A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at task in T, as measured by P, improves with experience E," – Mitchell (1997)

Supervised Learning

- Predict a single "target" or "outcome" variable
- Finds relations between X and Y.
- Train (learn) data where target value is known
- Score data where target value is not known

Unsupervised Learning

- Explores intrinsic characteristics.
- Estimates underlying distribution
- Segment data into meaningful groups or detect patterns
- There is no target (outcome) variable to predict or classify

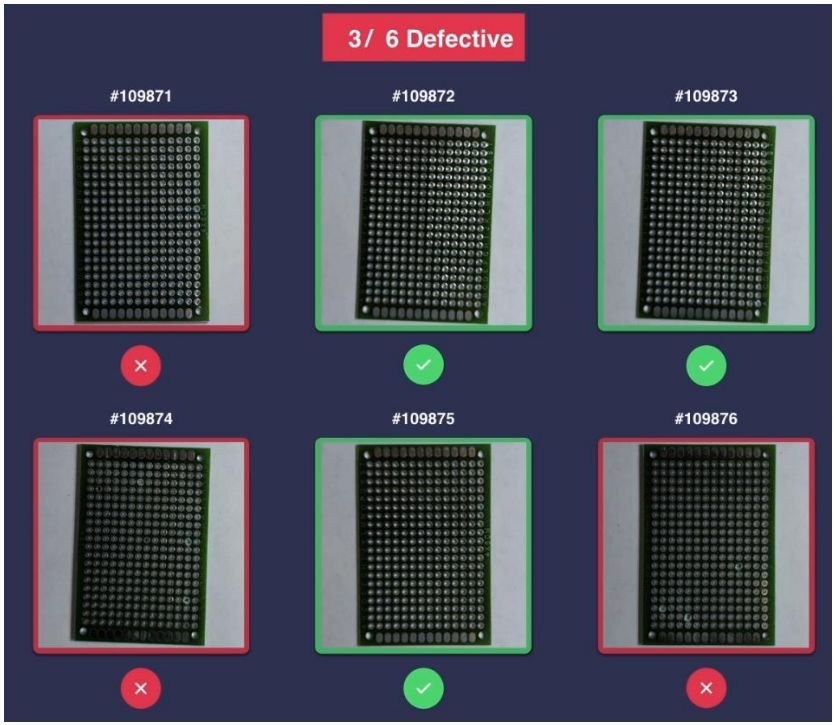
Machine Learning

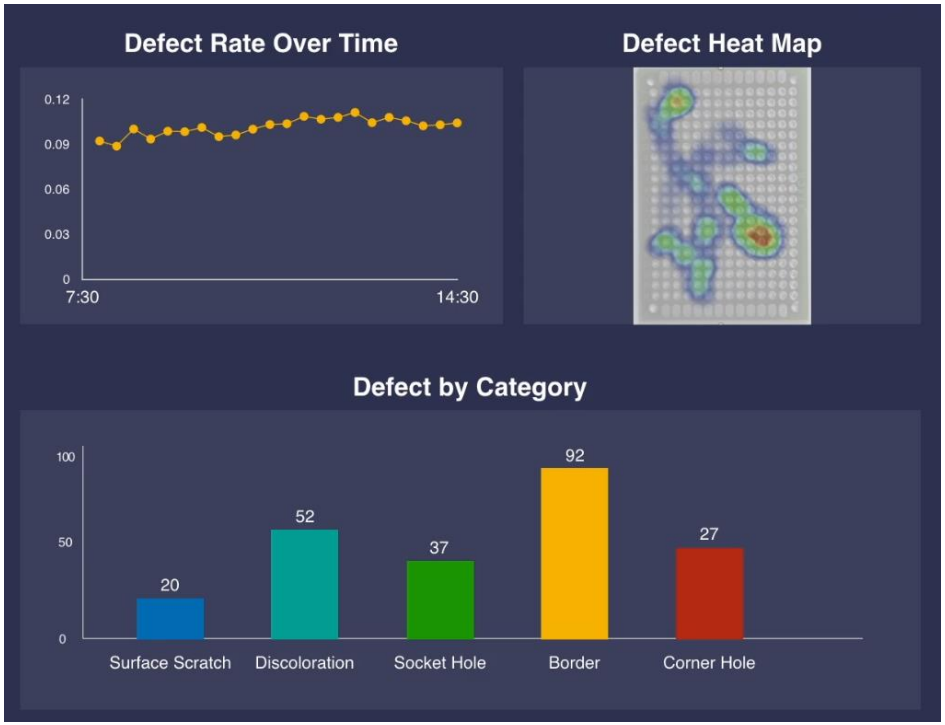
- Definition
  - ✓ A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at task in T, as measured by P, improves with experience E," – Mitchell (1997)

Machine learning models in Self-driving cars

Machine Learning

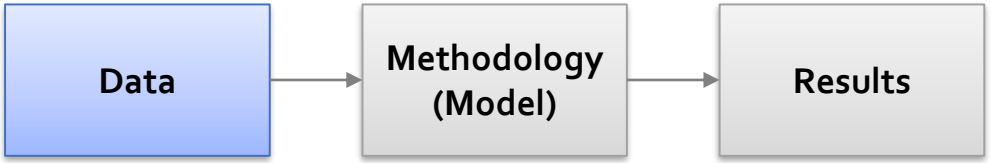
- Machine learning in manufacturing industry
  - ✓ Based on product images and class labels (good/bad),
  - ✓ Models are trained to correctly predict which product are defective and where suspicious areas are

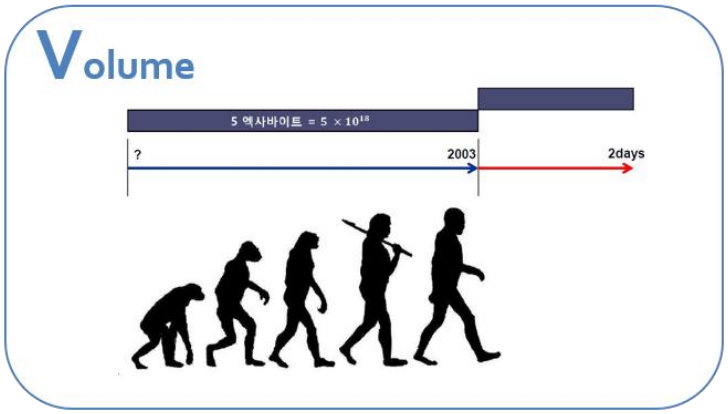


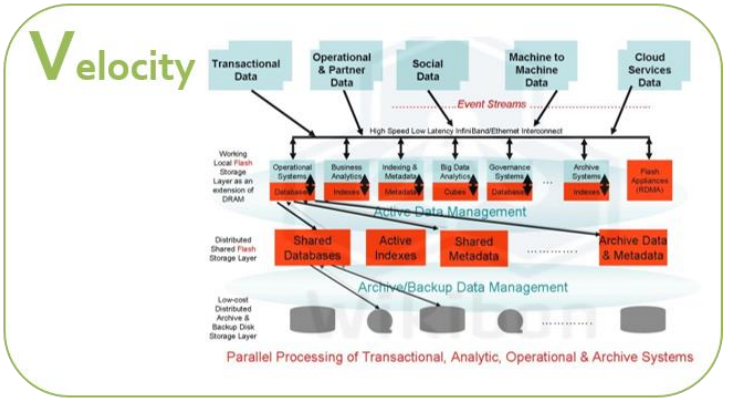


Big Data

- 4Vs in Big Data
  - ✓ Volume, Velocity, Variety, Value







Big Data

- Big Data itself is valuable without any complicated analytics methods

Type	Institution	Forecast
Economic Feasibility in Industries	Economist (2010)	☐ " Data are becoming the new raw material of business: an economic input almost on a par with capital and labour."
	Gartner (2011)	☐ "Intelligence about Information is the Oil of the 21st Century." Future competitive advantage depends on data. ☐ Winning organizations understand the stage of the data economy and overcome information silos through effective information sharing.
	McKinsey (2011)	☐ Big Data is the next frontier for innovation, competitiveness and productivity ☐ Big Data will create values worth more than $600 billion in 5 areas including medicine and public administration
National Competitiveness	US PCAST	☐ Advisors emphasize that US government organizations should focus on the strategy for transformation of data into knowledge, and of knowledge into action.
	Singapore	☐ Singapore looks to evaluate threatening risks and detect environmental changes based on data

Big Data

- Case Study: Navigation system

VS

Data Mining

- Definitions

✓Extracting useful information from large datasets. (Hand et al., 2001)

✓The process of exploration and analysis, by automatic or semi-automatic means, of large quantities of data in order to discover meaningful patterns and rules. (Berry and Linoff, 1997, 2000)

✓The process of discovering meaningful new correlations, patterns and trends by sifting through large amount data stored in repositories, using pattern recognition technologies as well as statistical and mathematical techniques. (Gartner Group, 2004)

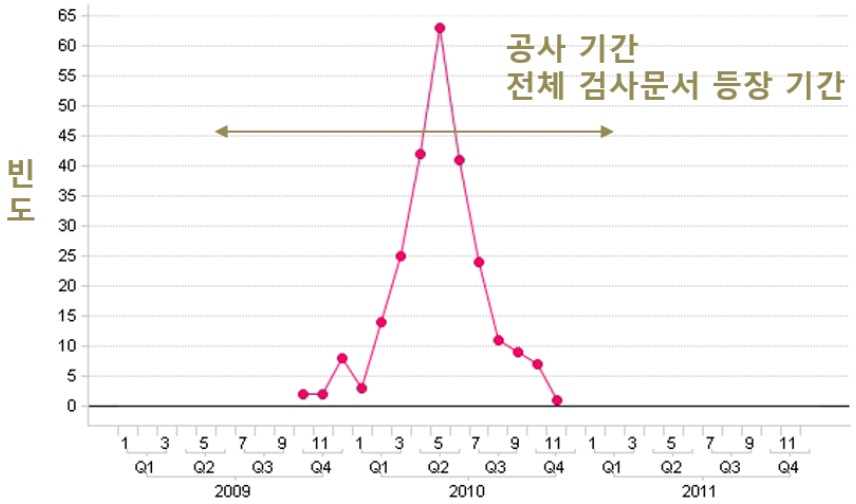
Data Mining

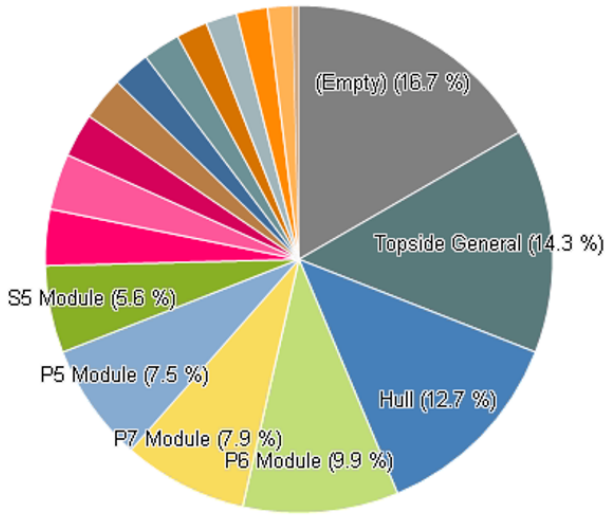
- Definitions

"파이프(pipe)가 흔들리니(shake), 지주(support)를 추가(add)하라"

언제, 어디서?

"공사 중반, Topside General, Hull, P5,6,7 Module 등에서 주로 발생한다"

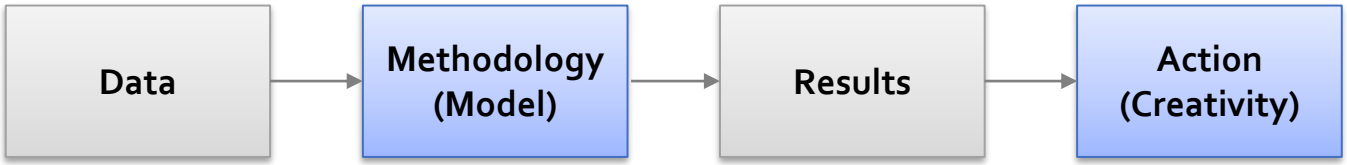




발생하는 장소

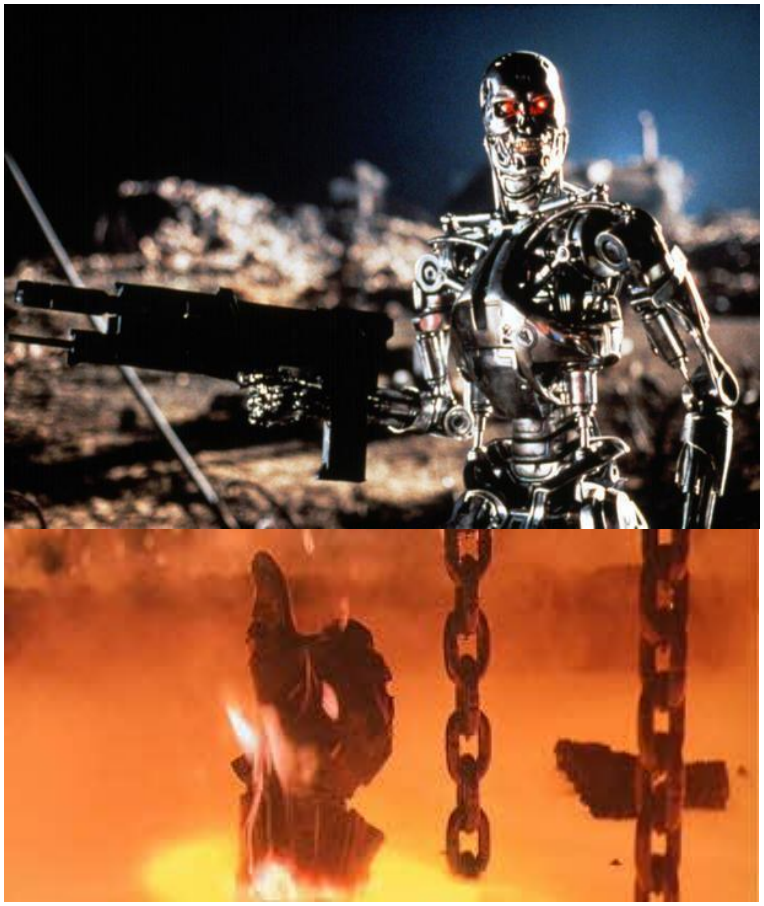
Artificial Intelligence

- Definition
  - ✓ Computers and computer software that are capable of intelligent behavior
  - ✓ Intelligent agent perceives its environment and takes actions that maximize its chance of success



Artificial Intelligence

- AI should be…



Artificial Intelligence

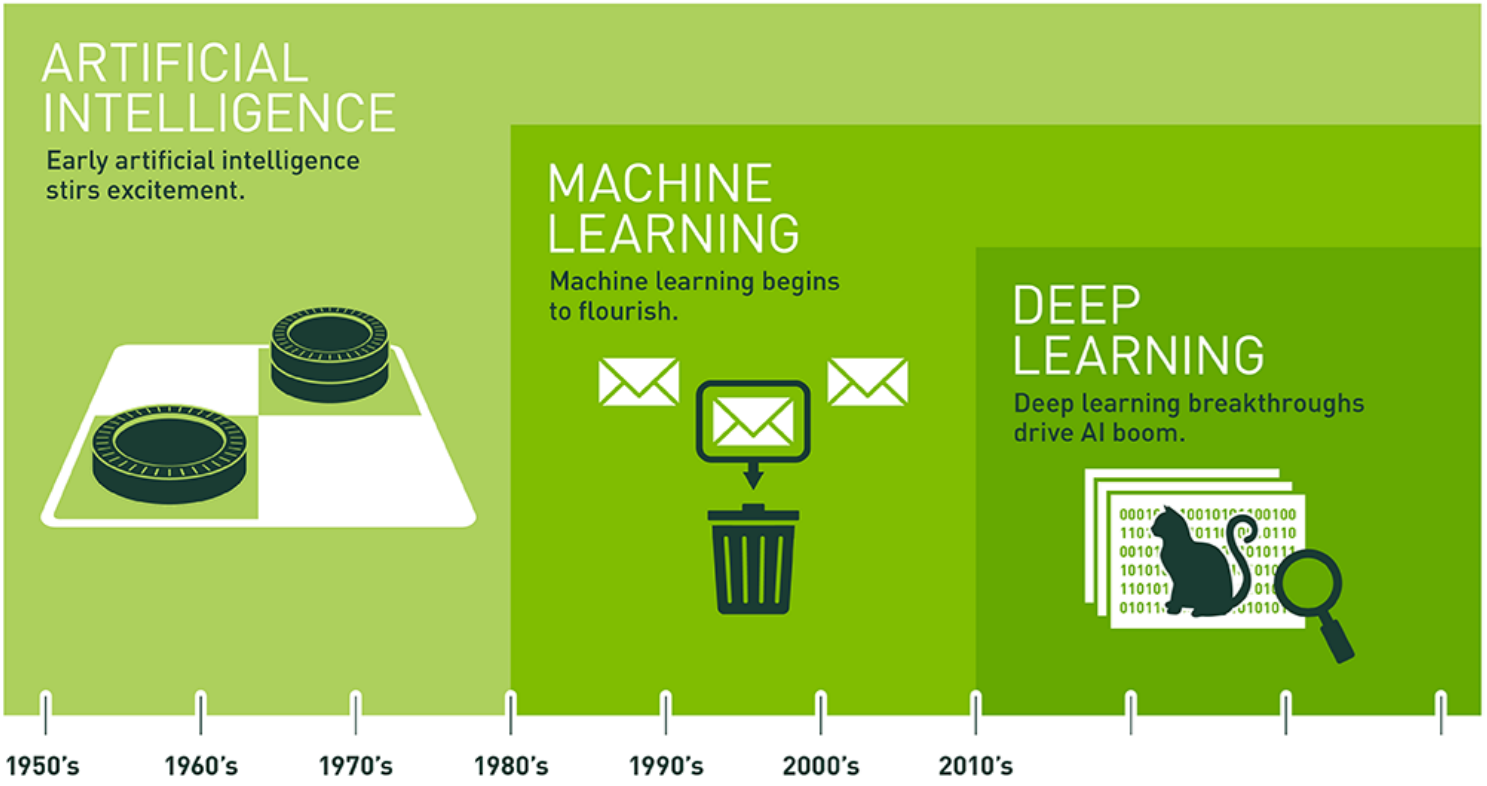
- AI in nowadays…

Artificial Intelligence

- AI in nowadays…

Artificial Intelligence

- AI vs. Machine Learning vs. Deep Learning



Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

AGENDA

Data Science Applications

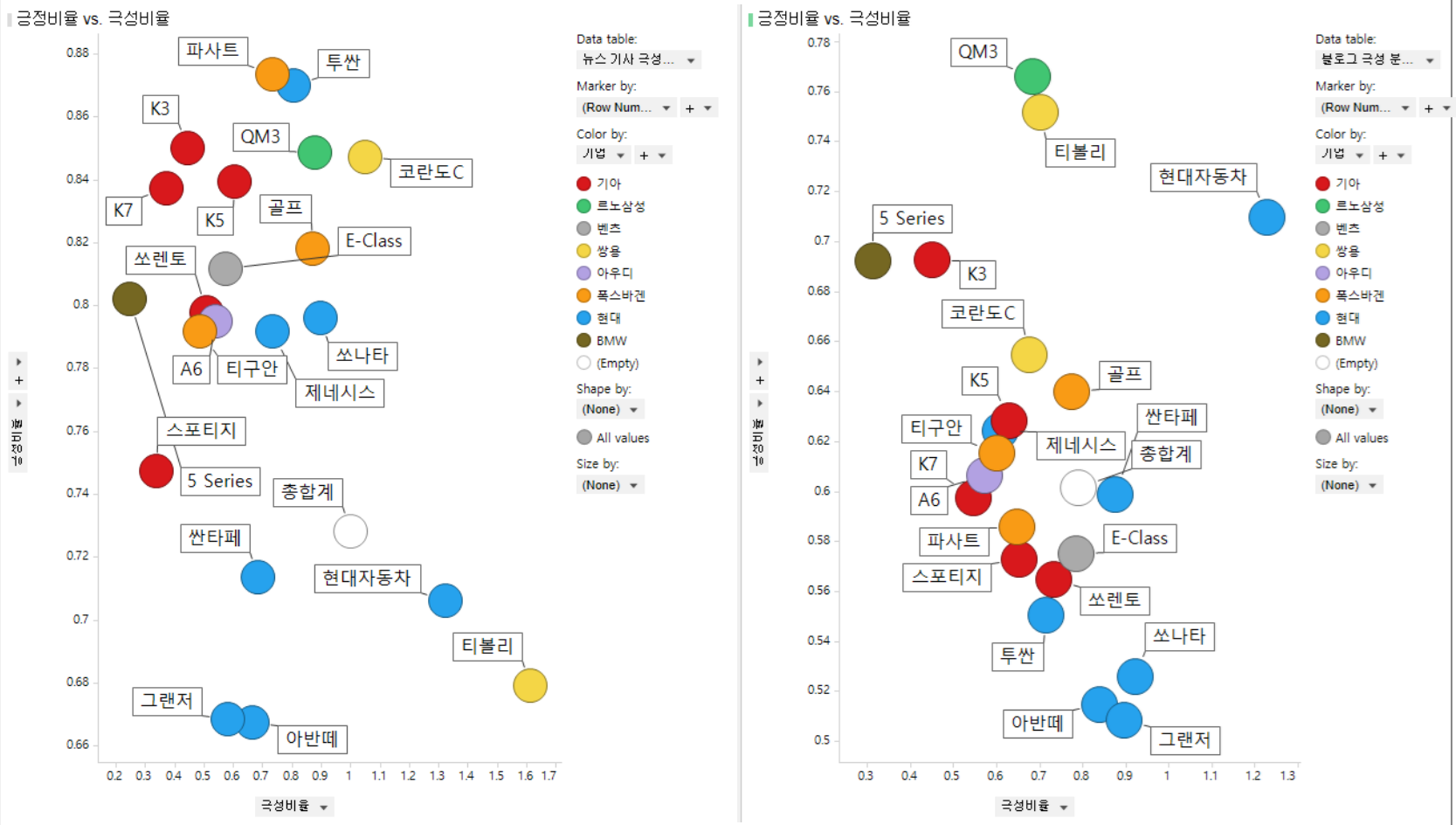
1

Visualization for intuitive understanding

Data Science Applications

1

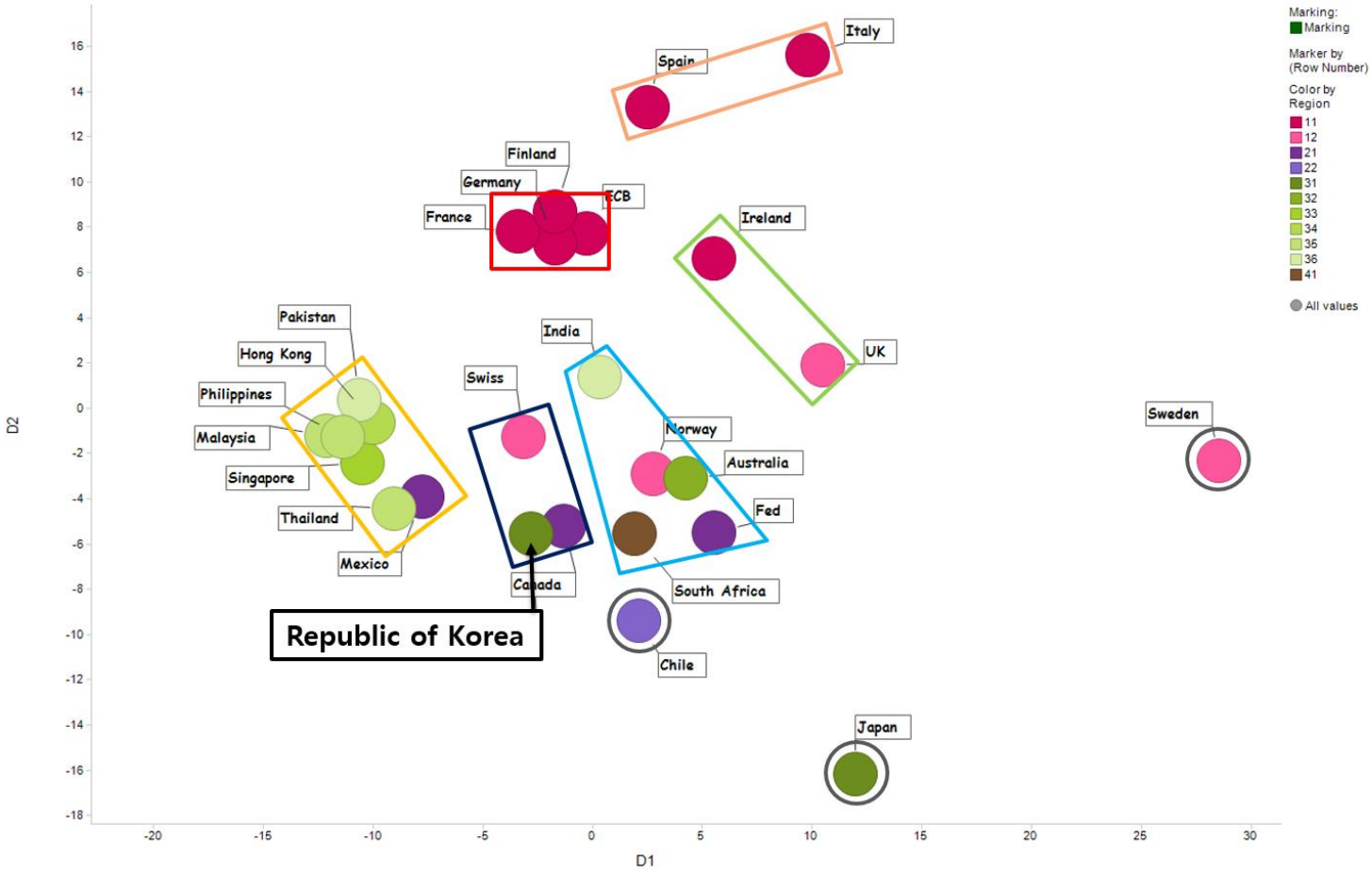
Visualization for intuitive understanding



Data Science Applications

1

Visualization for intuitive understanding



Data Science Applications

1

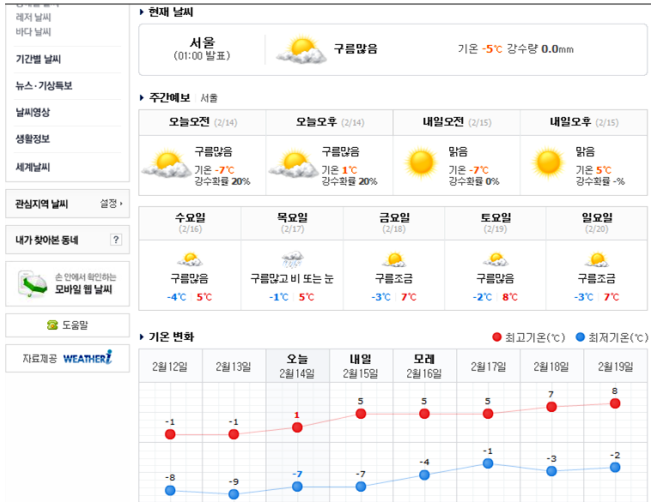
Visualization for intuitive understanding

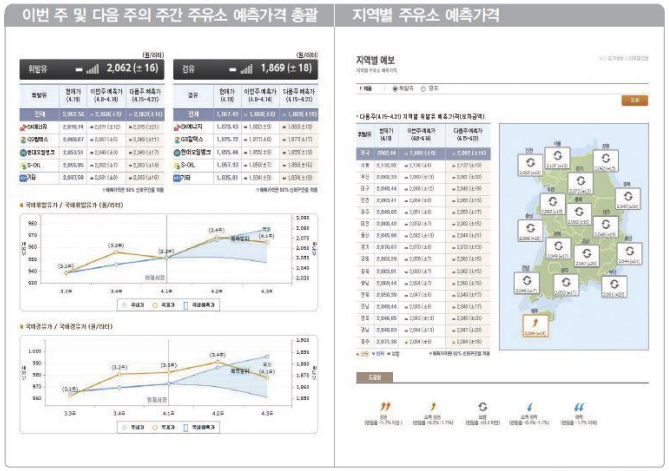
Year	Common Concern	Federal Reserve System	European Central Bank	Deutsche Bundesbank	Bank of England	Bank of Japan
2004	Sustainability Credibility	Expansion Imports	Parliaments Cooperation	Retirement Ages Working Hours	Household-Spending	QE Deflation
2005	China Inflation	Deficits Competitive	Financial Integration	Global Imbalance	Households Future Inflation	QE Recession
2006	Competitive Global Imbalance	Incentives Risk Taking	Administered Price Indirect Taxes	Inflation	China / India Commodities	Domestic and-External Demand
2007	Subprime-Mortgage	Subprime-Mortgage	Price Stability Turmoil	Banking Supervision Disclosure	Credit	Subprime-Mortgage
2008	Financial Turmoil Commodity Prices	Financial Turmoil Funding Markets	Financial Turmoil Liquidity	Financial Turmoil Subprime	Commodity Prices Housing Market	Securitized Product
2009	Financial Crisis Lehman Brothers	Financial Crisis ABS	Non-standard-Measure	Financial Crisis Rescue	Asset Purchase Recovery	Credit Bubble Financial Crisis
2010	Recovery Reform	Recovery Recession	ESRB/ FSB Deficits	Microprudential Macroprudential	Recovery/ QE VAT/ TAX	Deflation
2011	Sovereign Debt Basel III	Dodd-Franc Act Recovery	Sovereign Debt EFSF	Debt Crisis Basel III	Commodity Prices Basel III	Asset Purchase ETFs / REITs
2012	Europe Deleveraging	Recovery (has been) Labor Market	OMT/ ESM/ SSM Fragmentation	Banking Union Taxpayer	Investment-Banking	European Debt Deleveraging
2013	Real Economy Price Stability	(At least as long as) Unemployment	SRM/ SSM/ OMT	SRM / SSM Banking Union	Prudential-Regulation	Price Stability QE

Data Science Applications

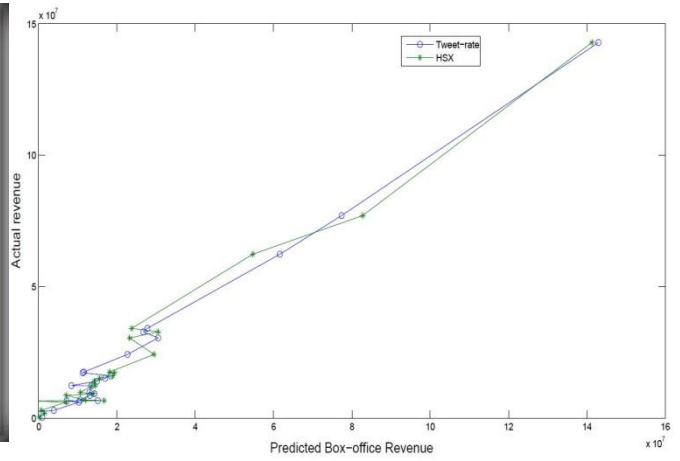
2

Predict, Diagnosis, and Detection





자료 : Opinet 유가정보서비스



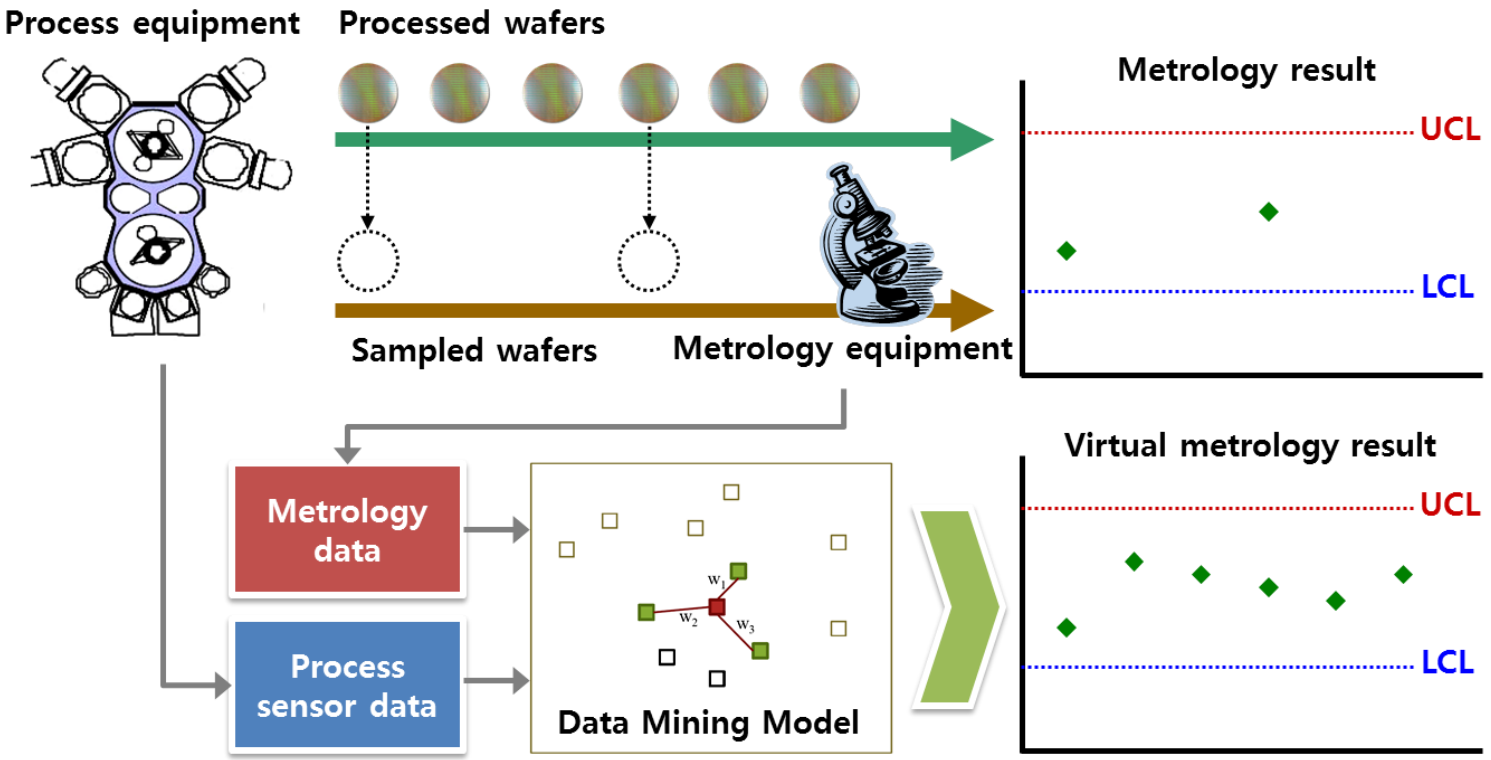
Asur and Huberman (2010) Predicting the Future with Social Media, WI-IAT10: 492-499

Data Science Applications

2

Predict, Diagnosis, and Detection

Virtual Metrology in Semiconductor Manufacturing



Kang et. al. (2009) A virtual metrology system for semiconductor manufacturing, ***Expert Systems with Applications*** **36**(10): 12554-12561.

Data Science Applications

3

Support decision making in everyday life (recommendation system)

Roll over image to zoom in

Apple iPad Pro (11-inch, Wi-Fi, 64GB) - Space Gray (Latest Model)

by Apple

4.5 stars 129 customer reviews | 141 answered questions

List Price: $799.00
Price: $699.99
You Save: $99.01 (12%)

In Stock.

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Ships from and sold by Amazon.com.

Style: **Wi-Fi**

Wi-Fi | Wi-Fi + Cellular

Color: **Space Gray**

Size: **64GB**

1TB | 64GB | 256GB | 512GB

- 11-Inch edge-to-edge Liquid Retina display with Promotion, true Tone, and wide Color
- A12X Bionic chip with Neural Engine
- Face ID for secure authentication and Apple Pay
- 12MP back camera, 7MP True Depth front camera
- Four speaker Audio with wider Stereo sound
- 802. 11AC Wi-Fi and gigabit-class LTE cellular data
- Up to 10 hours of battery life

Show more

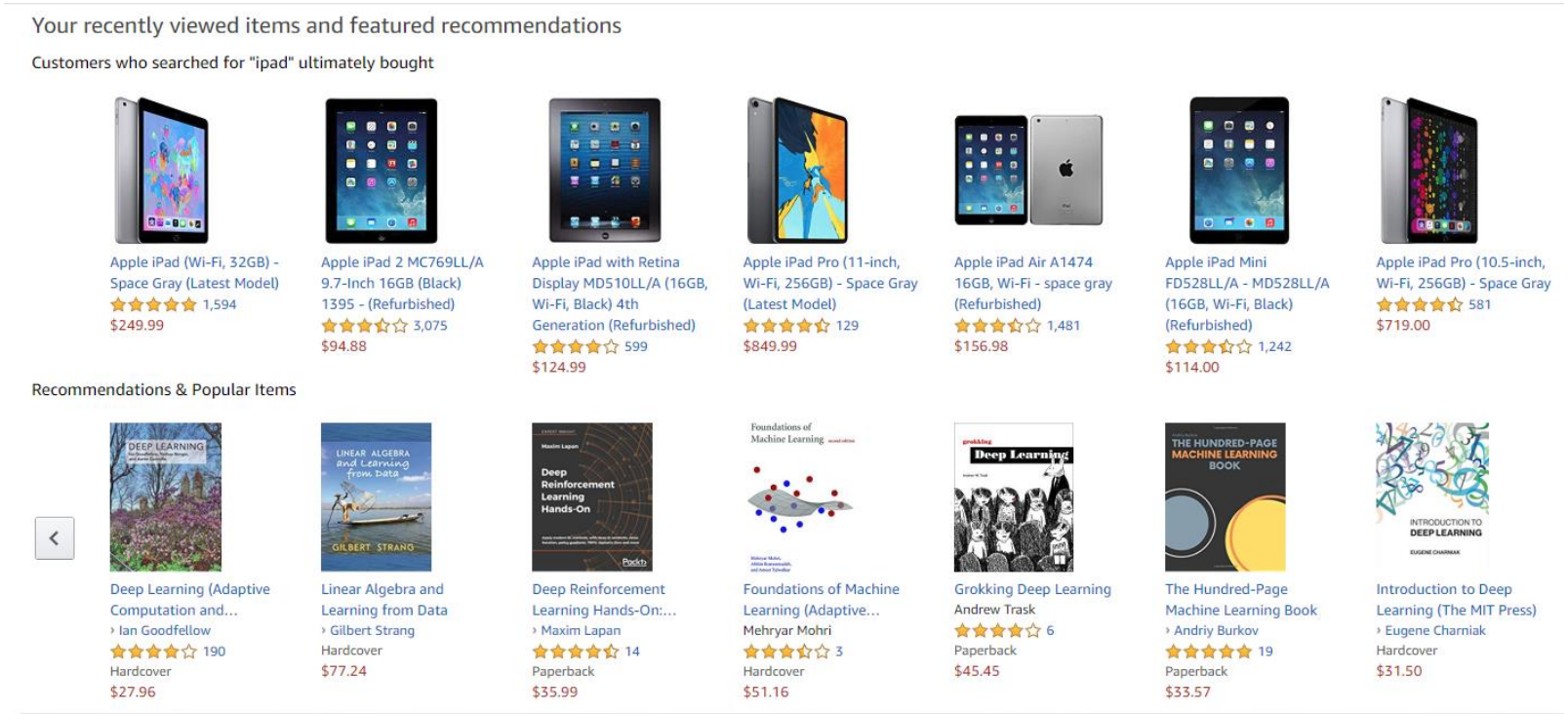
Jump to: Compare devices | Technical details

This product has a serial number that uniquely identifies the item. Should your order go missing before it arrives, Amazon may register the serial number with loss and theft databases to prevent fraudulent use or resale of the item.

Data Science Applications

3

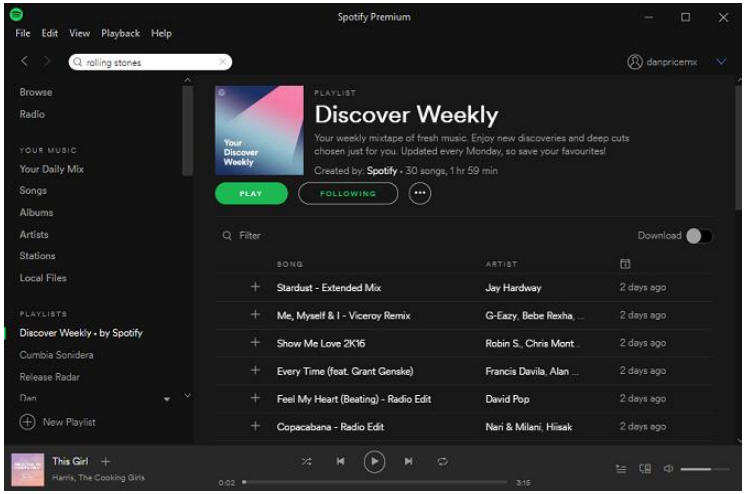
Support decision making in everyday life (recommendation system)

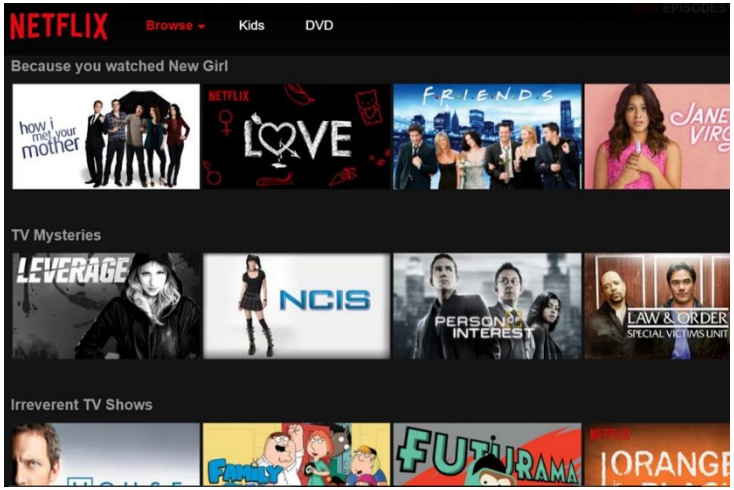


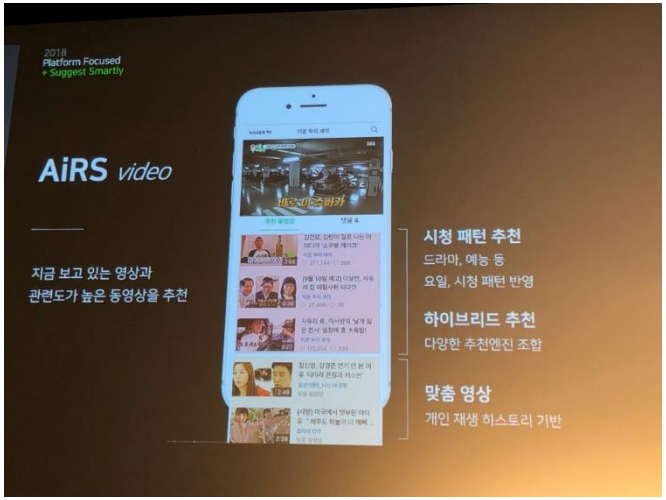
Data Science Applications

3

Support decision making in everyday life (recommendation system)







AGENDA

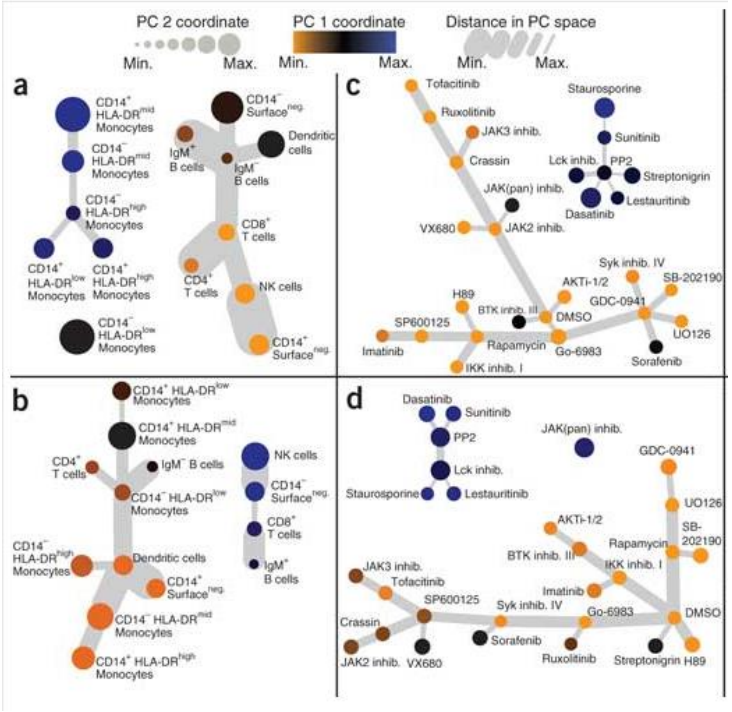
Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	Investigation of the dependence among variables	Prediction	Hypothesis construction and testing

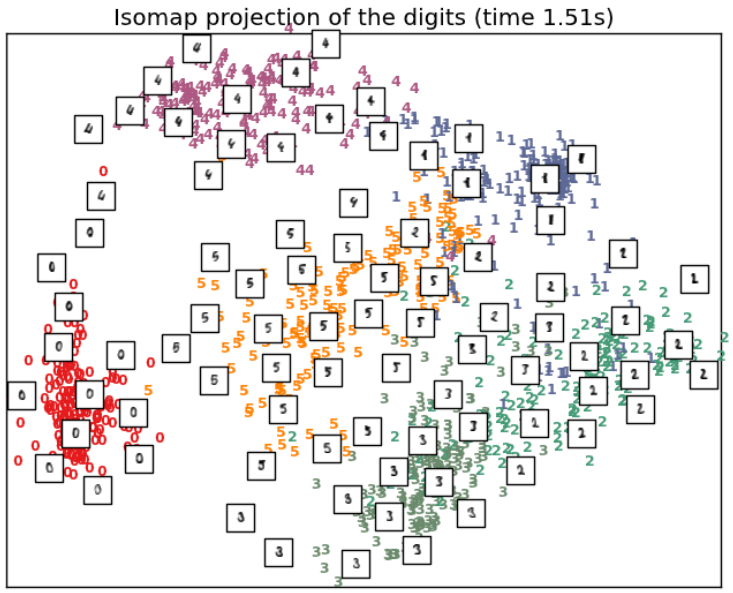
The phenomenon being studied is represented as simply as possible without sacrificing valuable information.

It is hoped that this will make interpretation easier.

Principal Component Analysis



Variable Reduction



http://www.nature.com/nbt/journal/v30/n9/fig_tab/nbt.2317_F6.html

Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	Investigation of the dependence among variables	Prediction	Hypothesis construction and testing

The phenomenon being studied is represented as simply as possible without sacrificing valuable information.

It is hoped that this will make interpretation easier.

- Applications
  - ✓ Using data on several variables related to cancer patient responses to radio-therapy, a simple measure of patient response to radiotherapy was constructed
  - ✓ Track records from many nations were used to develop an index of performance for both male and female athletes
  - ✓ Multispectral image data collected by a high-altitude scanner were reduced to a form that could be viewed as images (pictures) of a shoreline in two dimensions
  - ✓ Data on several variables relating to yield and protein content were used to create an index to select parents of subsequent generations of improved bean plants

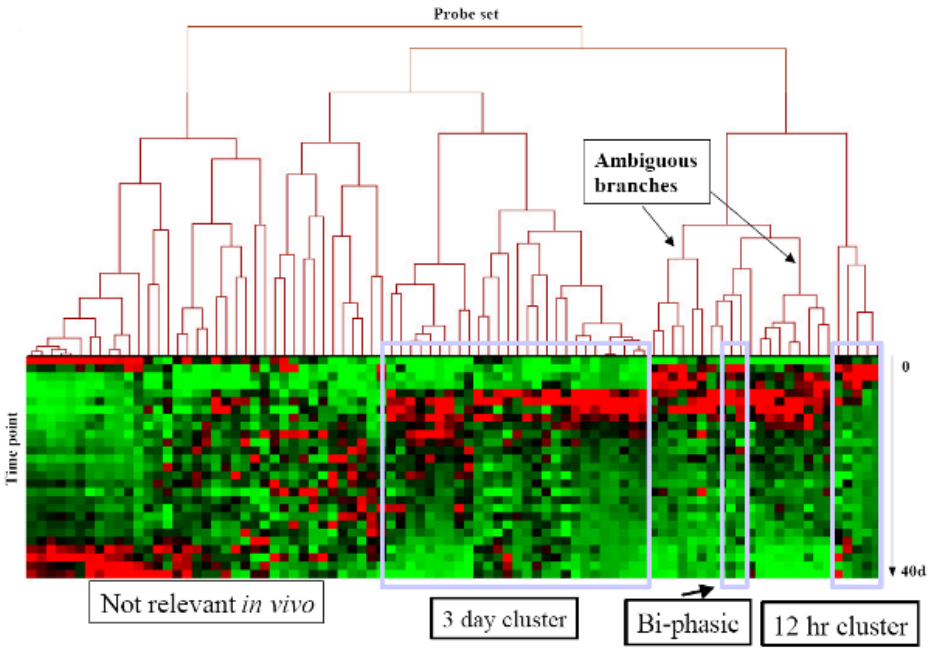
Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	**Sorting and Grouping**	Investigation of the dependence among variables	Prediction	Hypothesis construction and testing

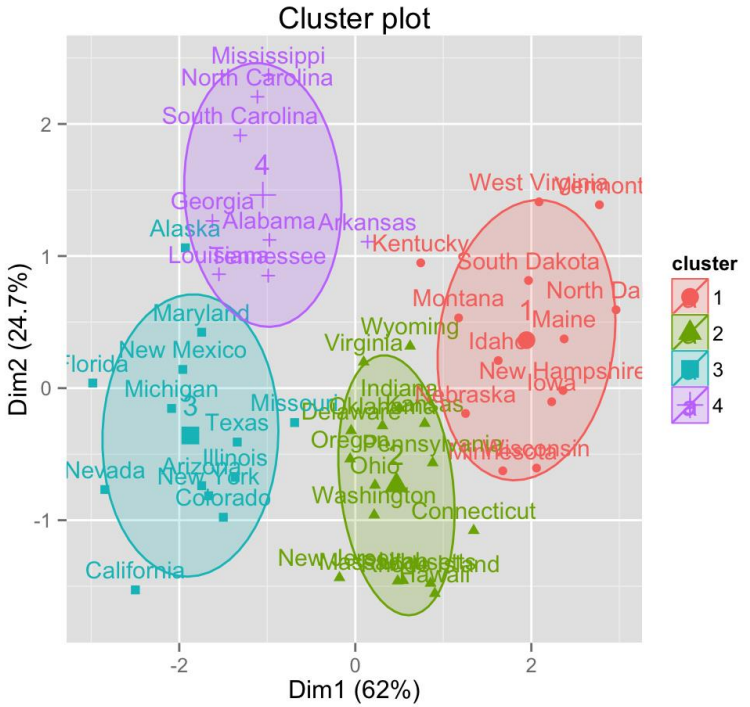
Groups of "similar" objects or variables are created, based upon measured characteristics.

Alternatively, rules for classifying objects into well-defined groups may be required.

Clustering: Hierarchical Clustering



Clustering: K-Means Clustering



Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	**Sorting and Grouping**	Investigation of the dependence among variables	Prediction	Hypothesis construction and testing

Groups of "similar" objects or variables are created, based upon measured characteristics.

Alternatively, rules for classifying objects into well-defined groups may be required.

- Applications
  - ✓ Data in several variables related to computer use were employed to create clusters of categories of computer jobs that allow a better determination of existing computer utilization
  - ✓ Measurements of several physiological variables were used to develop a screening procedure that discriminates alcoholics from nonalcoholics
  - ✓ Data related to responses to visual stimuli were used to develop a rule for separating people suffering from a multiple-sclerosis-caused visual pathology from those not suffering from the disease

Multivariate Data Analysis for Data Science

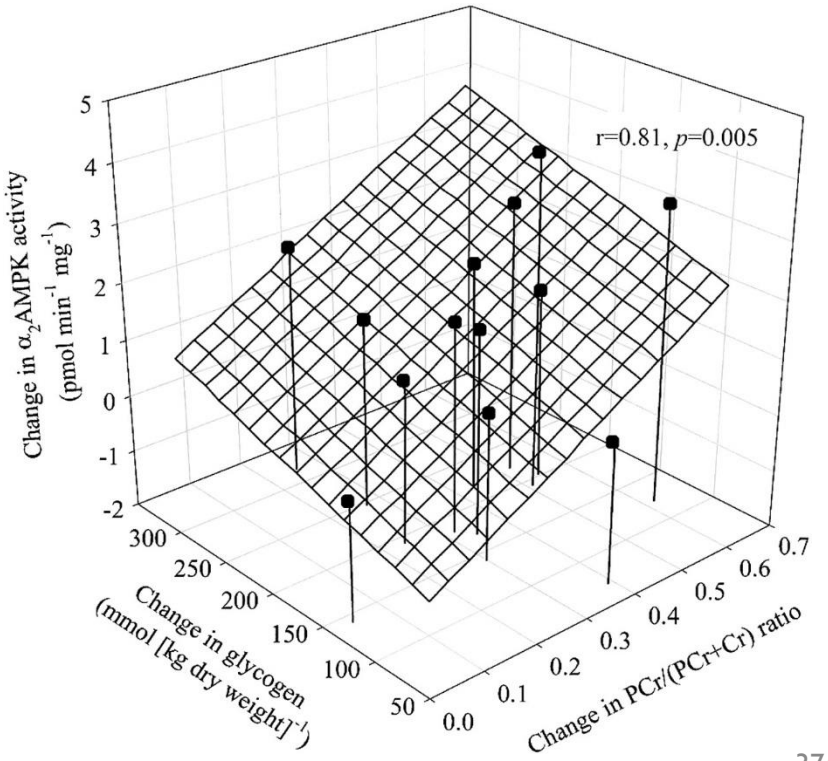
Data Reduction/ Structural Simplification	Sorting and Grouping	**Investigation of the dependence among variables**	Prediction	Hypothesis construction and testing

The nature of the relationships among variables is of interest

Are all the variables mutually independent or are one or more variables dependent on the others? If so, how?

Association Rule Mining

Factor Analysis



Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	**Investigation of the dependence among variables**	Prediction	Hypothesis construction and testing

The nature of the relationships among variables is of interest

Are all the variables mutually independent or are one or more variables dependent on the others? If so, how?

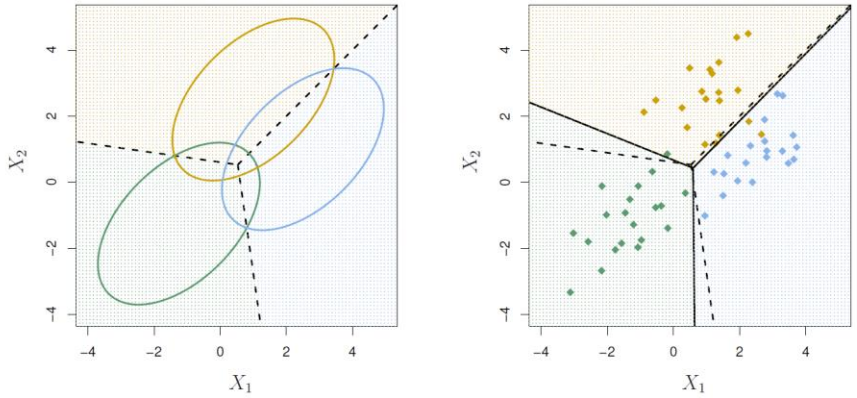
- Applications
  - ✓ Data on several variables were used to identify factors that were responsible for client success in hiring external consultants.
  - ✓ Measurements of variables related to innovation, on the on hand, and variables related to the business environment and business organization, on the other hand, were used to discover why some firms are product innovators and some firms are not.
  - ✓ The associations between measures of risk-taking propensity and measures of socioeconomic characteristics for top-level business executives were used to asses the relation between risk-taking behavior and performance

Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	Investigation of the dependence among variables	**Prediction**	Hypothesis construction and testing

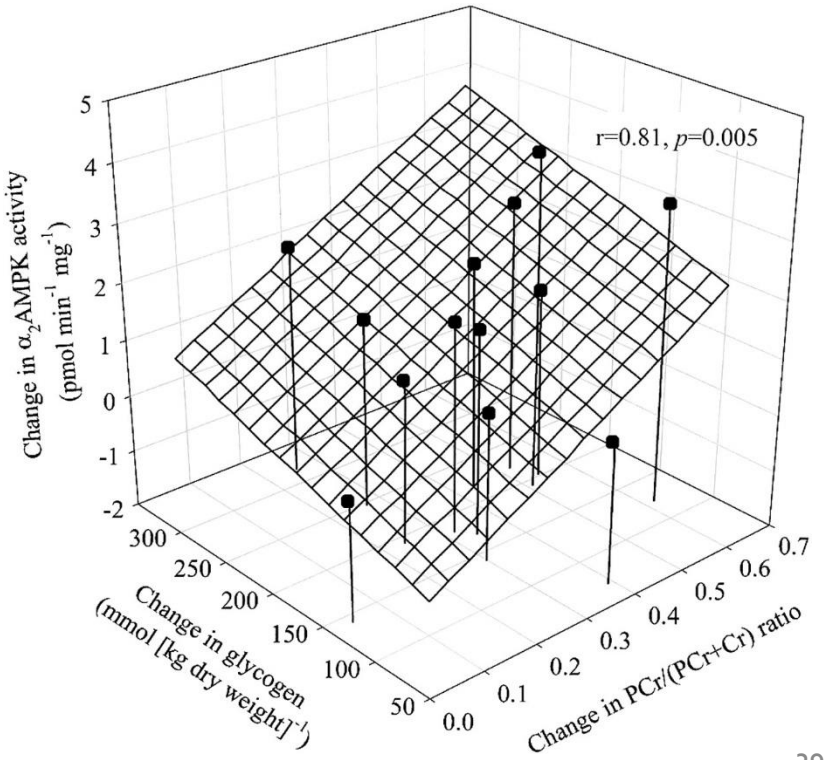
Relationships between variables must be determined for the purpose of predicting the value of one or more variables on the basis of observations on the other variables.

Discrimination and Classification



Here $\pi_1 = \pi_2 = \pi_3 = 1/3$.
The dashed lines are known as the *Bayes decision boundaries*.
Were they known, they would yield the fewest misclassification errors, among all possible classifiers.

Multivariate Linear Regression



Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	Investigation of the dependence among variables	**Prediction**	Hypothesis construction and testing

Relationships between variables must be determined for the purpose of predicting the value of one or more variables on the basis of observations on the other variables.

- Applications
  - ✓ The associations between test scores, and several high school performance variables, and several college performance variables were used to develop predictors of success in college
  - ✓ Data on several variables related to the size distribution of sediments were used to develop rules for predicting different depositional environments
  - ✓ Measurements on several accounting and financial variables were used to develop a method for identifying potentially insolvent property-liability insurers

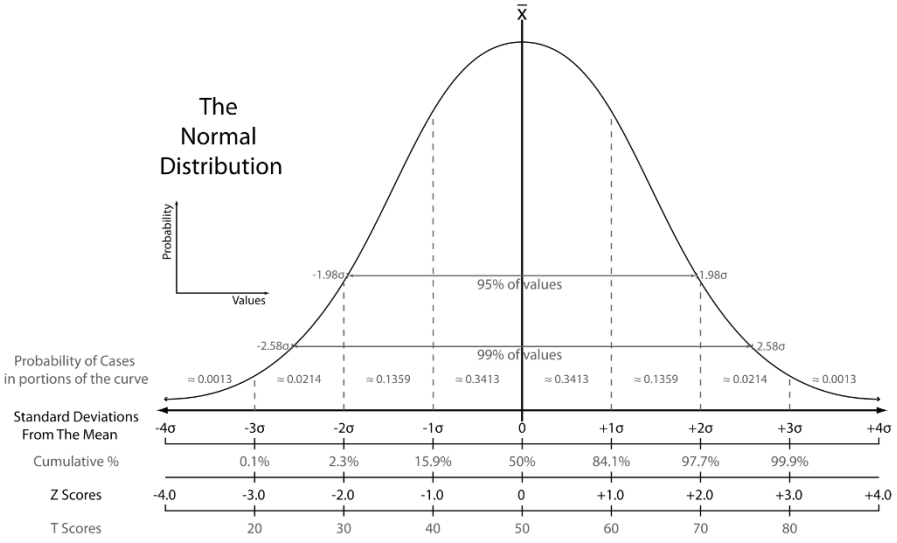
Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	Investigation of the dependence among variables	Prediction	Hypothesis construction and testing

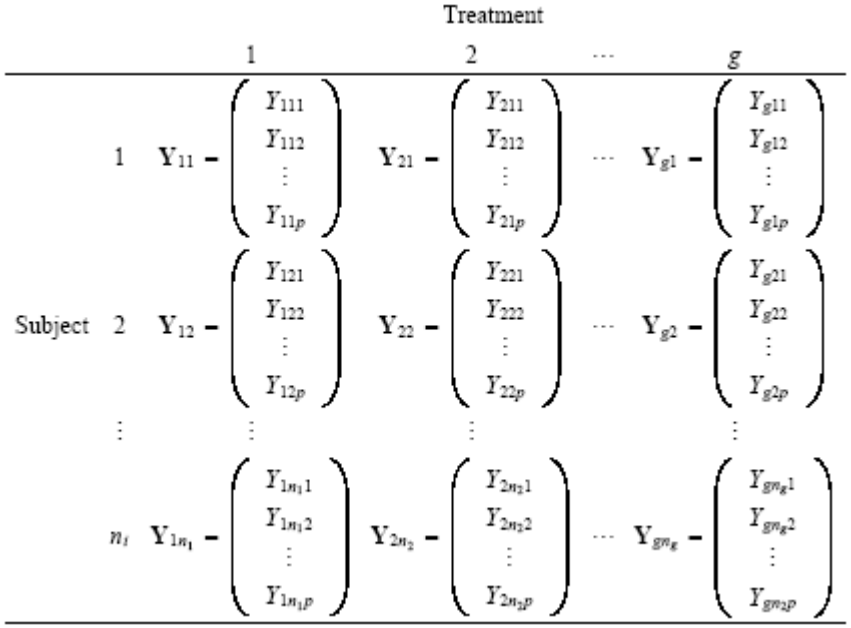
Specific statistical hypotheses, formulated in terms of the parameters of multivariate populations, are tested.

This may be don to validate assumptions or to reinforce prior convictions.

Inferences about a Mean Vector



Comparisons of Several Multivariate Means



Multivariate Data Analysis for Data Science

Data Reduction/ Structural Simplification	Sorting and Grouping	Investigation of the dependence among variables	Prediction	**Hypothesis construction and testing**

Specific statistical hypotheses, formulated in terms of the parameters of multivariate populations, are tested.

This may be don to validate assumptions or to reinforce prior convictions.

- Applications
  - ✓ Several pollution-related variables were measured to determine whether levels for a large metropolitan area were roughly constant throughout the week, or whether there was a noticeable difference between weekdays and weekends
  - ✓ Experimental data on several variables were used to see whether the nature of the instructions makes any difference in perceived risks, as quantified by test scores
  - ✓ Data on many variables were used to investigate the differences in structure of American occupations to determine the support for one of two competing sociological theories

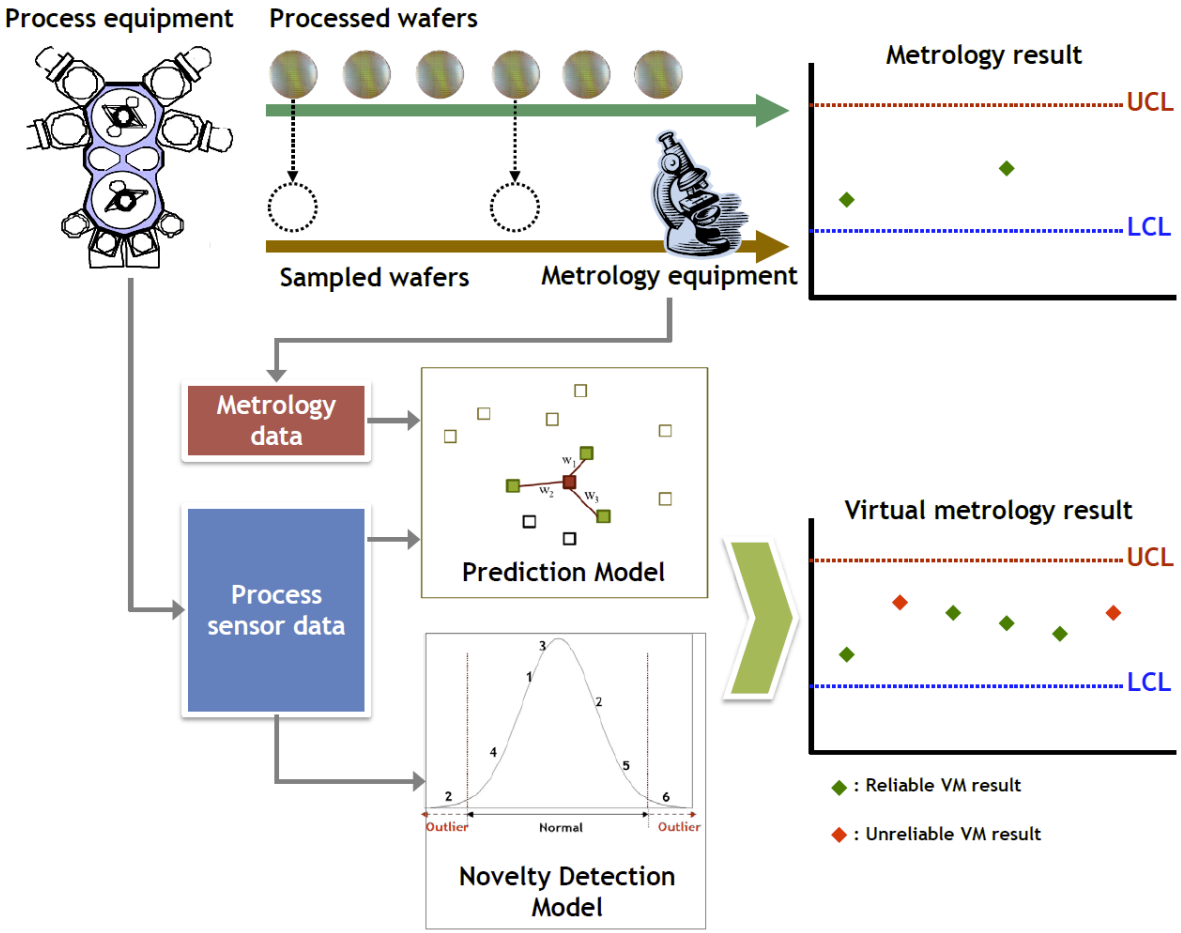
AGENDA

Data Science Procedure

Ask an interesting question	Get the data	Explore the data	Model the data	Communicate and visualize the results
▸ 풀고자 하는 문제가 무엇인가?	▸ 데이터는 어떻게 샘플링할 것인가?	▸ 데이터를 그려보며 데이터의 속성과 구조를 알아보기	▸ 모델 수립	▸ 결과 요약 및 시사점 분석
▸ 만약 관련해 모든 데이터를 보유하고 있다면 무엇을 할 것인가?	▸ 어떤 데이터와 정보가 우리 목표와 관련이 있는가?	▸ 데이터에서 이상한 점은 없는가?	▸ 모델 적합화	▸ 결과가 타당한가?
▸ 무엇을 예측하고 추정하기를 원하는가?	▸ 프라이버시나 개인정보 이슈는 없는가?	▸ 데이터에 어떠한 패턴이 존재하는가?	▸ 모델 검증	▸ 스토리를 말할 수 있는가? (전략 수립)

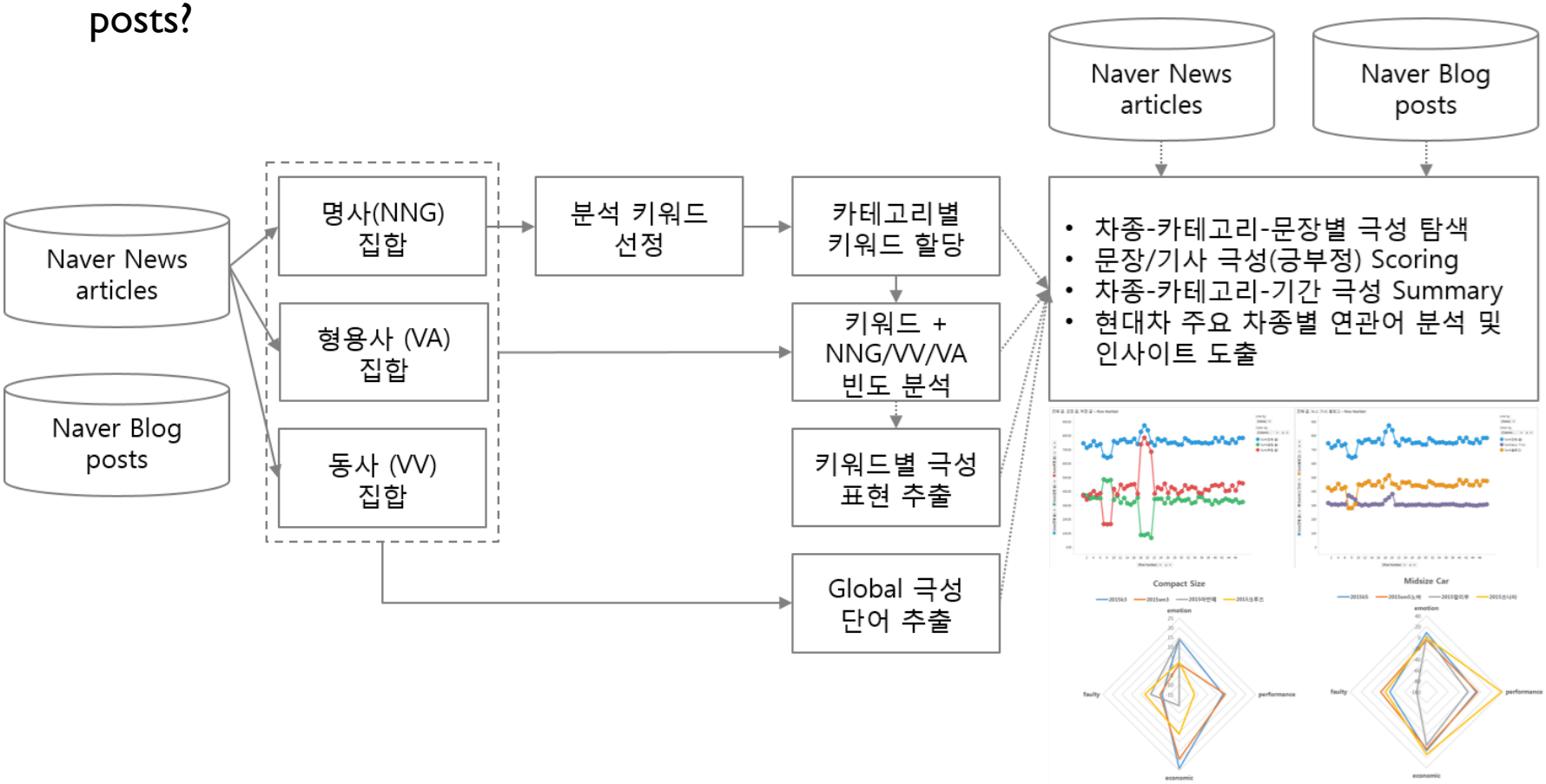
Ask an Interesting Question

- Step 1: Ask an interesting question
  - ✓ Can we predict the product quality based on the sensor data collected from equipment?



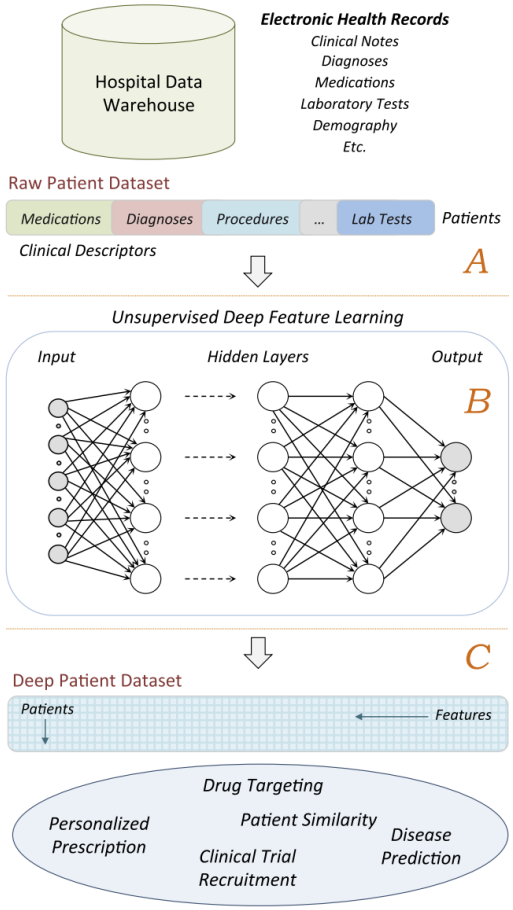
Ask an Interesting Question

- Step 1: Ask an interesting question
  - ✓ Is it possible to understand customers' preference based on news articles and blog posts?



Ask an Interesting Question

- Step 1: Ask an interesting question
  - ✓ Can we predict various diseases based on the electric health records (EHR)?

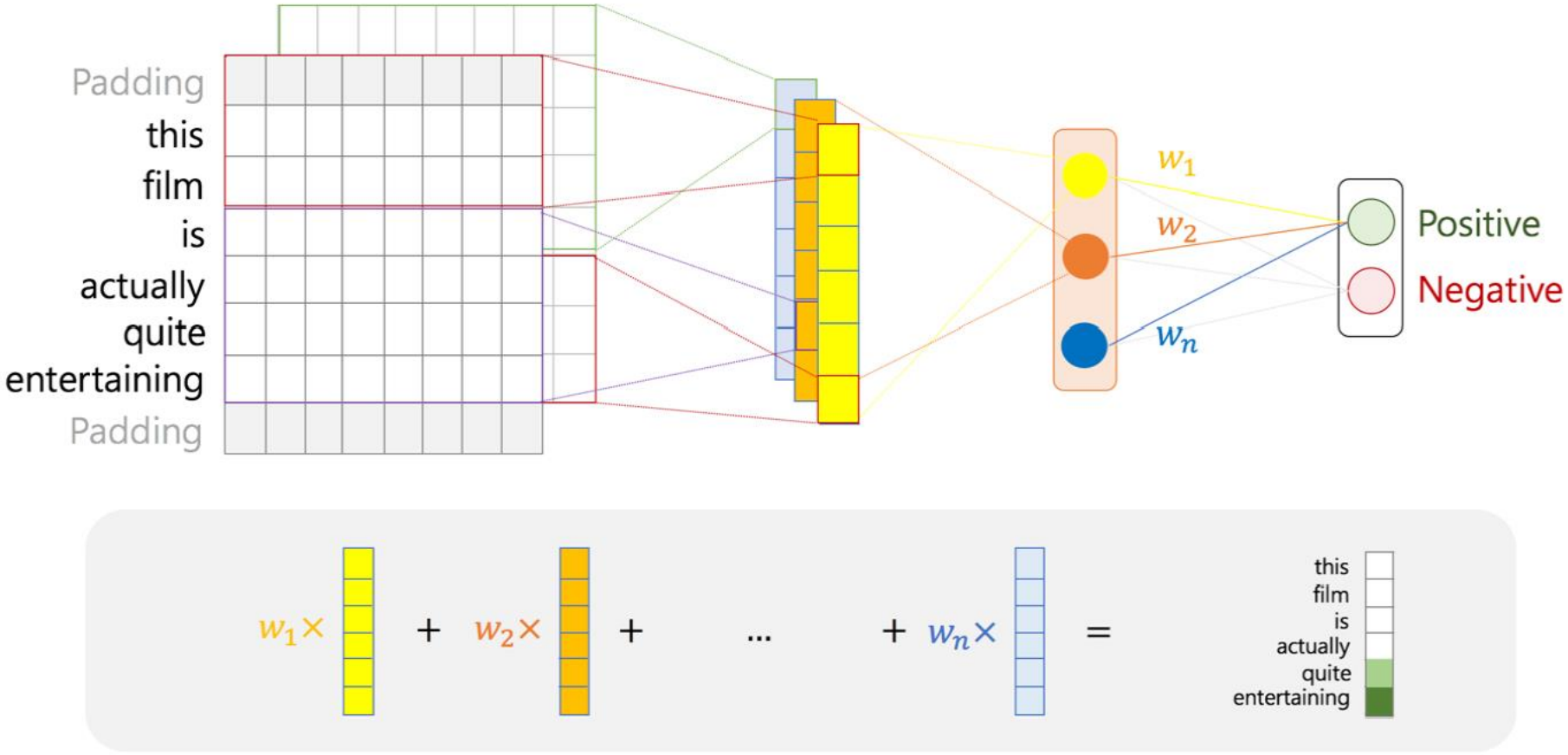


	Area under the ROC curve		
Disease	**RawFeat**	**PCA**	**DeepPatient**
Diabetes mellitus with complications	0.794	0.861	**0.907**
Cancer of rectum and anus	0.863	0.821	**0.887**
Cancer of liver and intrahepatic bile duct	0.830	0.867	**0.886**
Regional enteritis and ulcerative colitis	0.814	0.843	**0.870**
Congestive heart failure (non-hypertensive)	0.808	0.808	**0.865**
Attention-deficit and disruptive behavior disorders	0.730	0.797	**0.863**
Cancer of prostate	0.692	0.820	**0.859**
Schizophrenia	0.791	0.788	**0.853**
Multiple myeloma	0.783	0.739	**0.849**
Acute myocardial infarction	0.771	0.775	**0.847**
Personality disorders	0.787	0.788	**0.846**
Inflammatory conditions of male genital organs	0.659	0.825	**0.841**
Endometriosis	0.697	0.765	**0.839**
Inflammatory diseases of female pelvic organs	0.714	0.799	**0.830**
Cancer of ovary	0.646	0.788	**0.824**
Sickle cell anemia	0.567	0.689	**0.822**
Nephritis, nephrosis and renal sclerosis	0.763	0.775	**0.821**
Cancer of bladder	0.711	0.744	**0.818**
Chronic kidney disease	0.764	0.758	**0.814**
Cancer of testis	0.508	0.771	**0.811**
Menopausal disorders	0.681	0.772	**0.808**
Delirium, dementia and amnestic (and other) cognitive disorders	0.728	0.720	**0.803**
Peritonitis and intestinal abscess	0.689	0.747	**0.801**
Cardiac arrest and ventricular fibrillation	0.711	0.747	**0.799**
Developmental disorders	0.705	0.737	**0.798**

Miotto, R., Li, L., Kidd, B. A., & Dudley, J. T. (2016). Deep patient: An unsupervised representation to predict the future of patients from the electronic health records. Scientific reports, 6.

Ask an Interesting Question

- Step 1: Ask an interesting question
  - ✓ Can we find the emotional expressions automatically from review texts?



Ask an Interesting Question

- Step 1: Ask an interesting question
  - ✓ Can we find the emotional expressions automatically from review texts?

Method	Sentence
Raw text	One of the funniest most romantic and most musical movies ever; definitely worth renting/buying especially if you have a taste for older style of cinematography. The animals and the songs alone will make you smile while watching the movie. A definite must for Madonna fans. :o) *(10 / 10 points)*
Rand	One of the **the funniest most romantic** and musical movies ever definitely worth renting buying especially if you have a taste for older style cinematography The animals songs alone will make smile while watching movie A definite must Madonna **fans** **Positive**
Static	One of the **funniest most romantic and** musical movies ever definitely worth renting buying especially if yo u have a taste for older style cinematography The animals songs alone will make smile while watching movi e **A** definite must Madonna fans **Positive**
NStatic	One **of the funniest most** romantic and musical movies ever definitely worth renting buying especially if yo u have a taste for older style cinematography The animals songs alone will make smile while watching movi e A definite must Madonna **fans** **Positive**
2ch	One **of the funniest most** romantic and musical movies ever definitely worth renting buying especially if yo u have a taste for older style cinematography The animals songs alone will make smile while watching movi e A definite must Madonna **fans** **Positive**

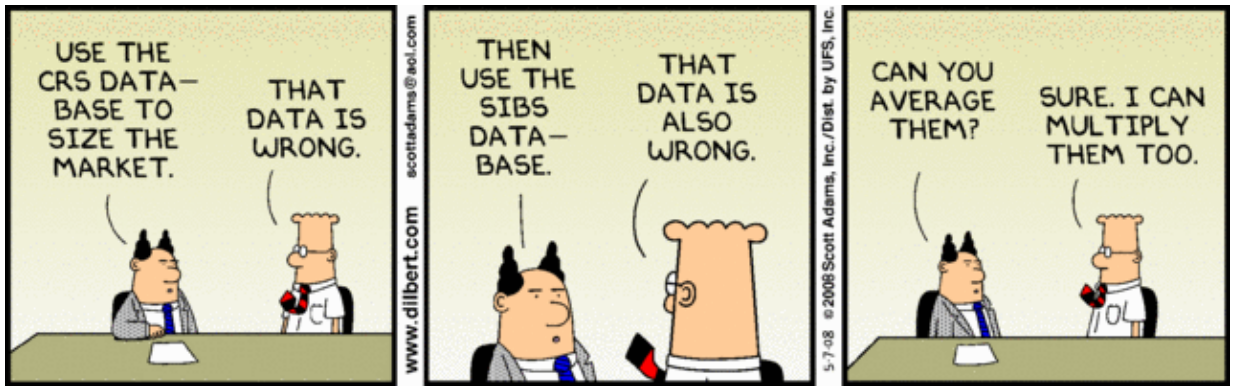
Ask an Interesting Question

- Step 1: Ask an interesting question
  - ✓ Can we find the emotional expressions automatically from review texts?

Method	Sentence
Raw text	This is one of the most boring films I've ever seen. The three main cast members just didn't seem to click well. Giovanni Ribisi's character was quite annoying. For some reason he seems to like repeating what he says. If he was the Rain Man it would've been fine but he's not. *(3 / 10 points)*
Rand	This is one of the most boring films I ve ever seen The three main cast members just didn t seem to click w ell Giovanni Ribisi s character was quite annoing For some reason he seems like repeating what says If Rain Man it **would been fine but he s** not **Negative**
Static	This is one of the **most** boring **films** I ve ever seen The three main cast members just didn t seem to click w ell Giovanni Ribisi s character **was quite annoying For** some reason he seems like repeating what says If Rai n Man it would been fine but he s not **Negative**
NStatic	This is one of **the most boring films** I ve ever seen The three main cast members just didn t seem to click w ell Giovanni Ribisi s character was quite **annoying For** some reason he seems like repeating what says If Rai n Man it wouldbeen fine but not **Negative**
2ch	This is one of the **most boring films** I ve ever seen The three main cast members just didn t seem to click w ell Giovanni Ribisi s character was **quite annoying For** some reason he seems like repeating what says If Rai n Man it would beenfine but not **Negative**
4ch	This is one of the **most boring films** I ve ever seen The three main cast members just didn t seem to click w ell Giovanni Ribisi s character was **quite annoying For** some reason he seems like repeating what says If Rai n Man it would been fine but not **Negative**

Get the Data

- Step 2: Get the Data
  - ✓ Garbage in, garbage out

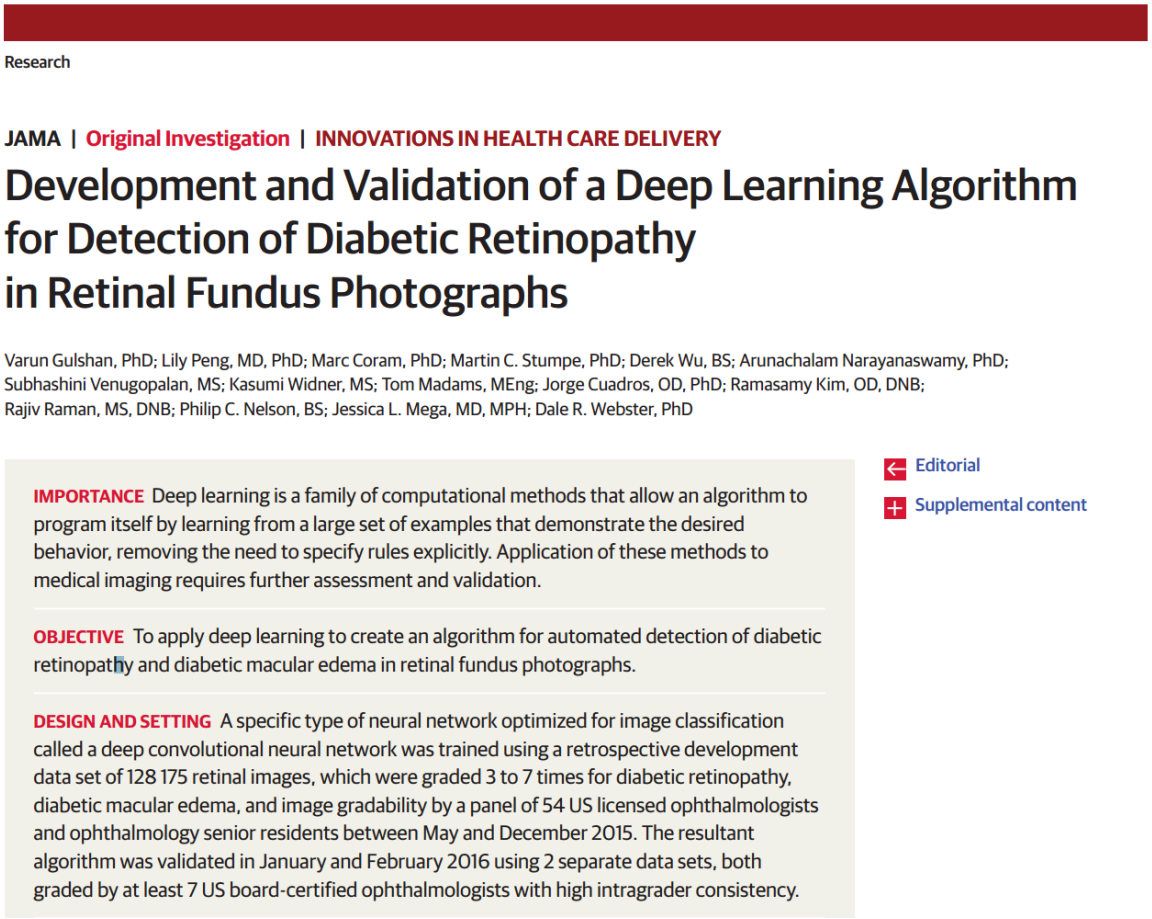


  - ✓ The larger, the better

"We don't have better algorithms than anyone else. We just have more data."

Get the Data

- Step 2: Get the Data
  - ✓ Use domain knowledge from experts (especially when making answer sets)



Research

JAMA | Original Investigation | INNOVATIONS IN HEALTH CARE DELIVERY

Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs

Varun Gulshan, PhD; Lily Peng, MD, PhD; Marc Coram, PhD; Martin C. Stumpe, PhD; Derek Wu, BS; Arunachalam Narayanaswamy, PhD; Subhashini Venugopalan, MS; Kasumi Widner, MS; Tom Madams, MEng; Jorge Cuadros, OD, PhD; Ramasamy Kim, OD, DNB; Rajiv Raman, MS, DNB; Philip C. Nelson, BS; Jessica L. Mega, MD, MPH; Dale R. Webster, PhD

IMPORTANCE Deep learning is a family of computational methods that allow an algorithm to program itself by learning from a large set of examples that demonstrate the desired behavior, removing the need to specify rules explicitly. Application of these methods to medical imaging requires further assessment and validation.

OBJECTIVE To apply deep learning to create an algorithm for automated detection of diabetic retinopathy and diabetic macular edema in retinal fundus photographs.

DESIGN AND SETTING A specific type of neural network optimized for image classification called a deep convolutional neural network was trained using a retrospective development data set of 128 175 retinal images, which were graded 3 to 7 times for diabetic retinopathy, diabetic macular edema, and image gradability by a panel of 54 US licensed ophthalmologists and ophthalmology senior residents between May and December 2015. The resultant algorithm was validated in January and February 2016 using 2 separate data sets, both graded by at least 7 US board-certified ophthalmologists with high intragrader consistency.

Editorial

Supplemental content

Get the Data

Table. Baseline Characteristics[a]

Characteristics	Development Data Set	EyePACS-1 Validation Data Set	Messidor-2 Validation Data Set
No. of images	128 175	9963	1748
No. of ophthalmologists	54	8	7
No. of grades per image	3-7	8	7
Grades per ophthalmologist, median (interquartile range)	2021 (304-8366)	8906 (8744-9360)	1745 (1742-1748)
Patient demographics			

[a] Summary of image characteristics and available demographic information in the development and clinical validation data sets (EyePACS-1 and Messidor-2). Abnormal images were oversampled for the development set for algorithm training. The clinical validation sets were not enriched for abnormal images.

[b] Unique patient codes (deidentified) were available for 89.3% of the development set (n = 114 398 images).

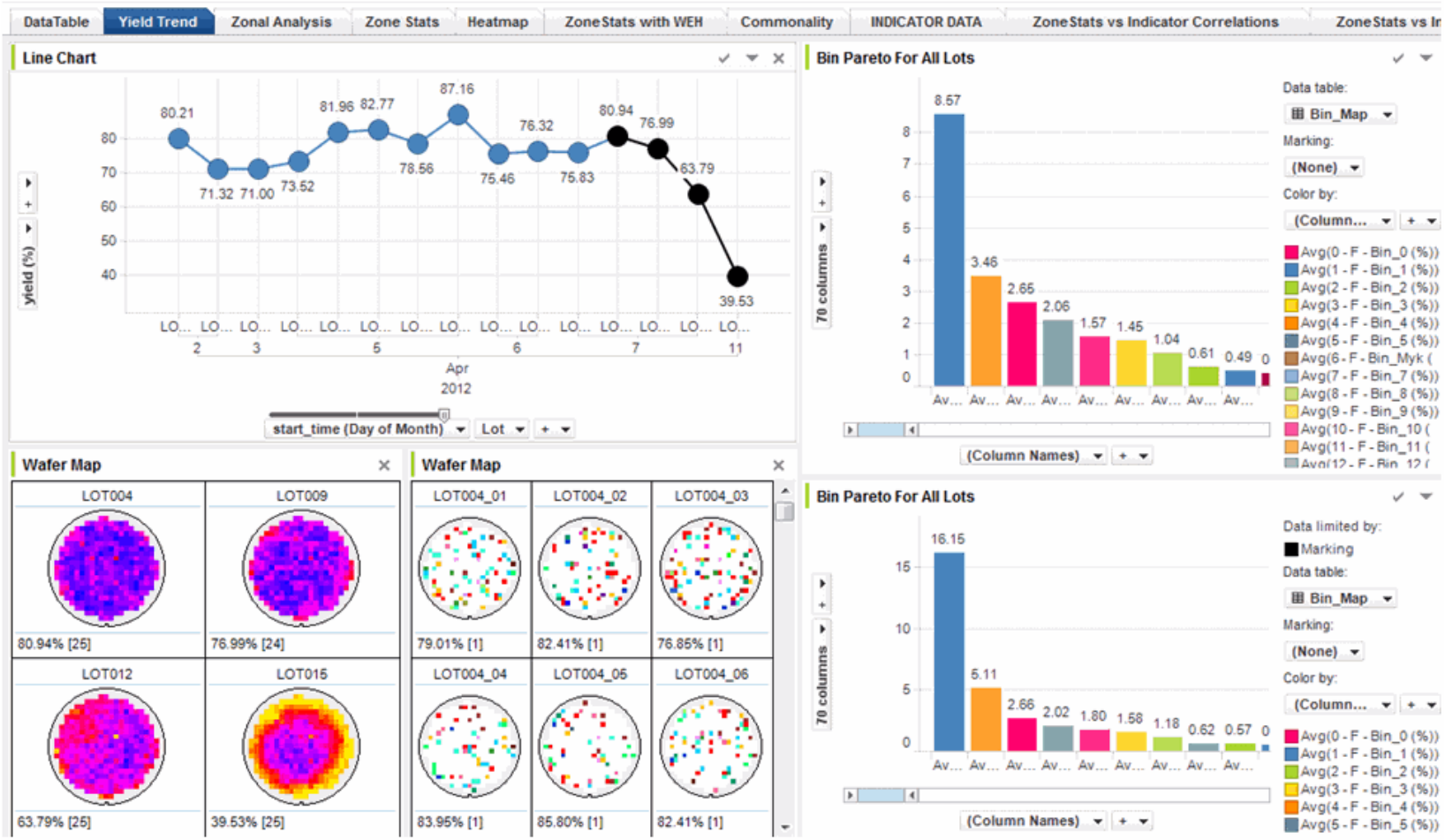
[c] Individual-level data including age and sex were available for 66.1% of the development set (n = 84 734 images).

[d] Image quality was assessed for a subset of the development set.

[e] Referable diabetic retinopathy, defined as the presence of moderate and worse diabetic retinopathy and/or referable diabetic macular edema according to the International Clinical Diabetic Retinopathy Scale,[14] was calculated for each ophthalmologist before combining them using a majority decision. The 5-point grades represent the grade that received the highest number of votes for diabetic retinopathy alone. Hence, the sum of moderate, severe, and proliferative diabetic retinopathy for the 5-point grade differs slightly from the count of referable diabetic retinopathy images.

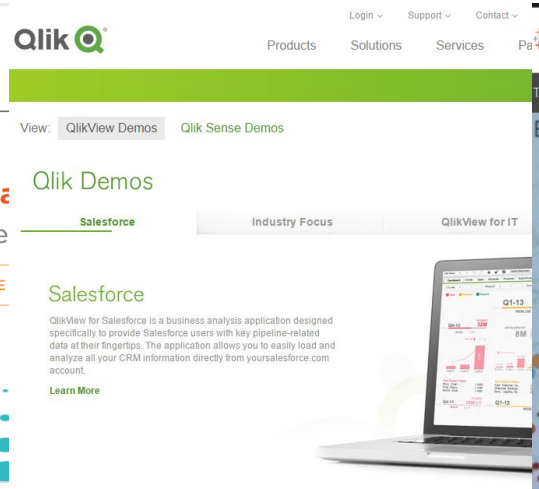
Explore the Data

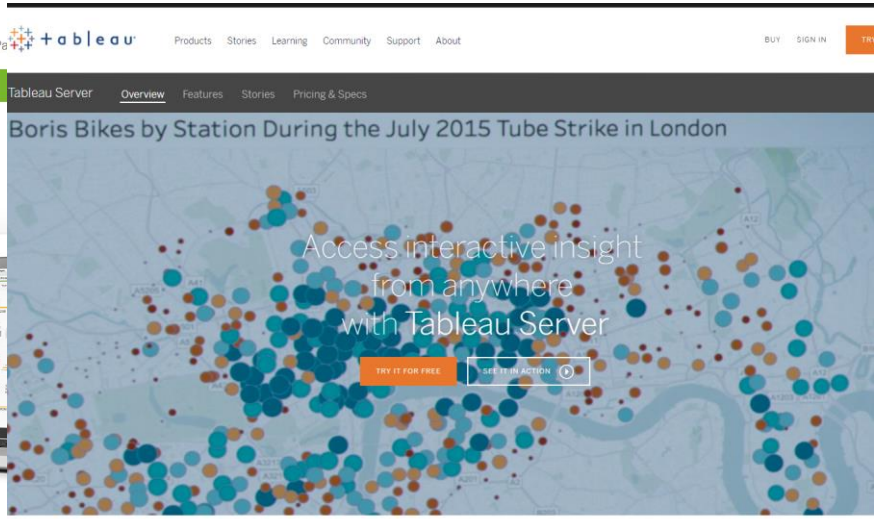
- Step 3: Explore the data before modeling

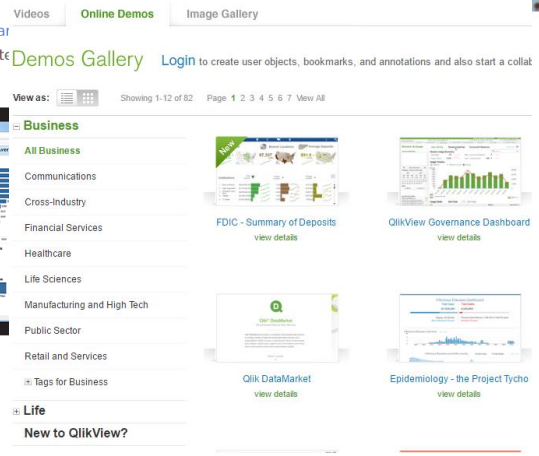


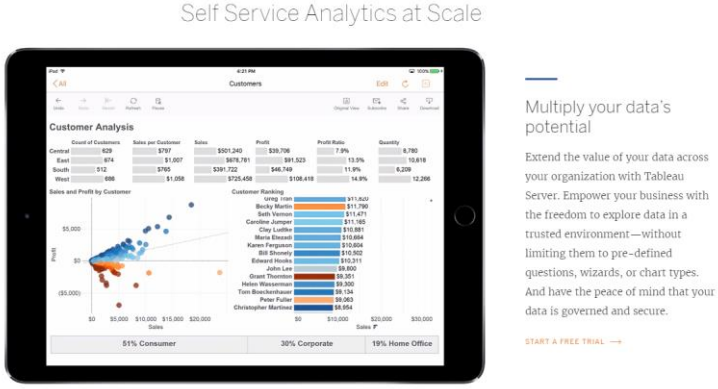
Explore the Data

- Step 3: Explore the data before modeling
  - ✓ Data visualization software can be helpful



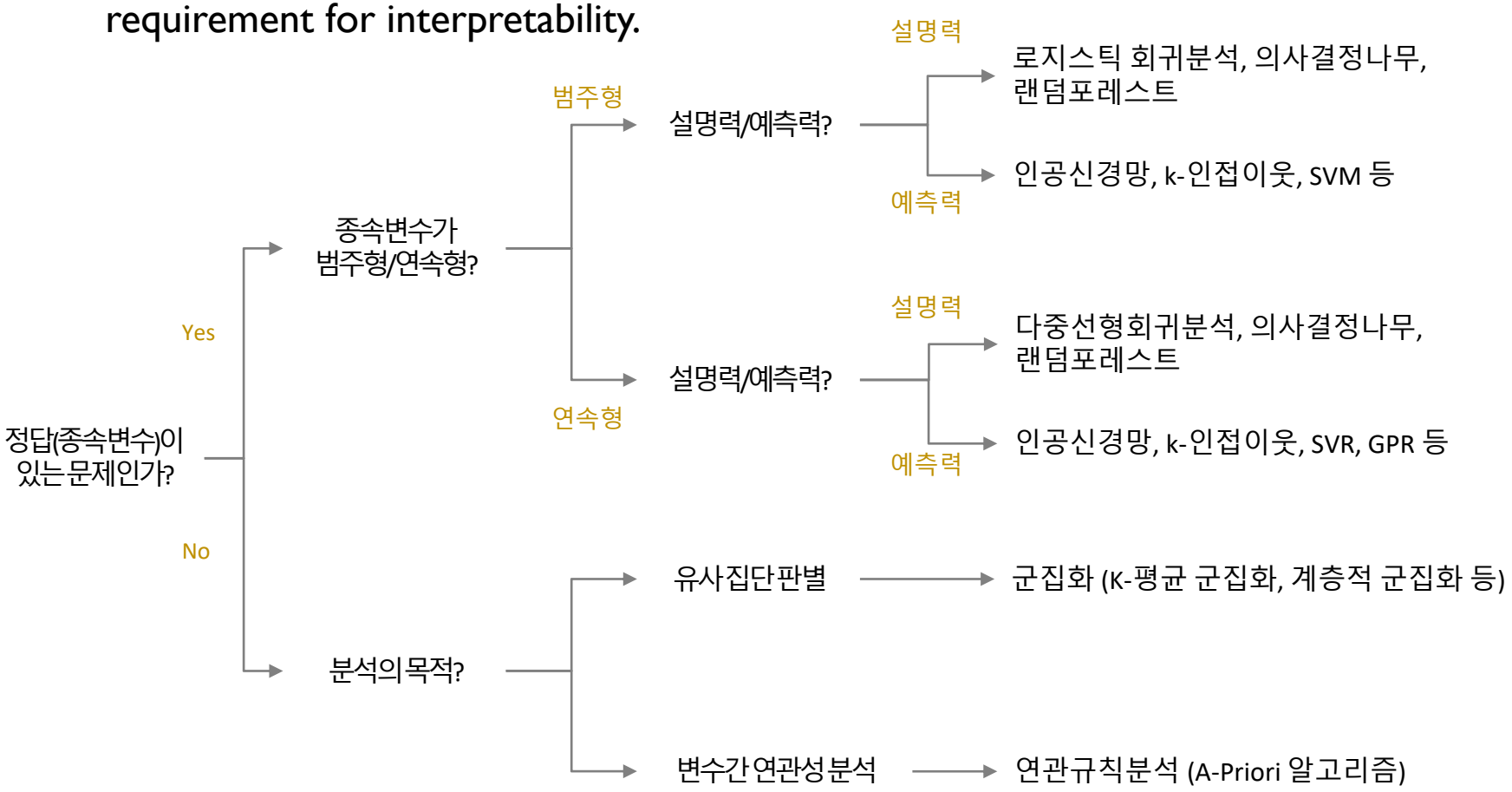






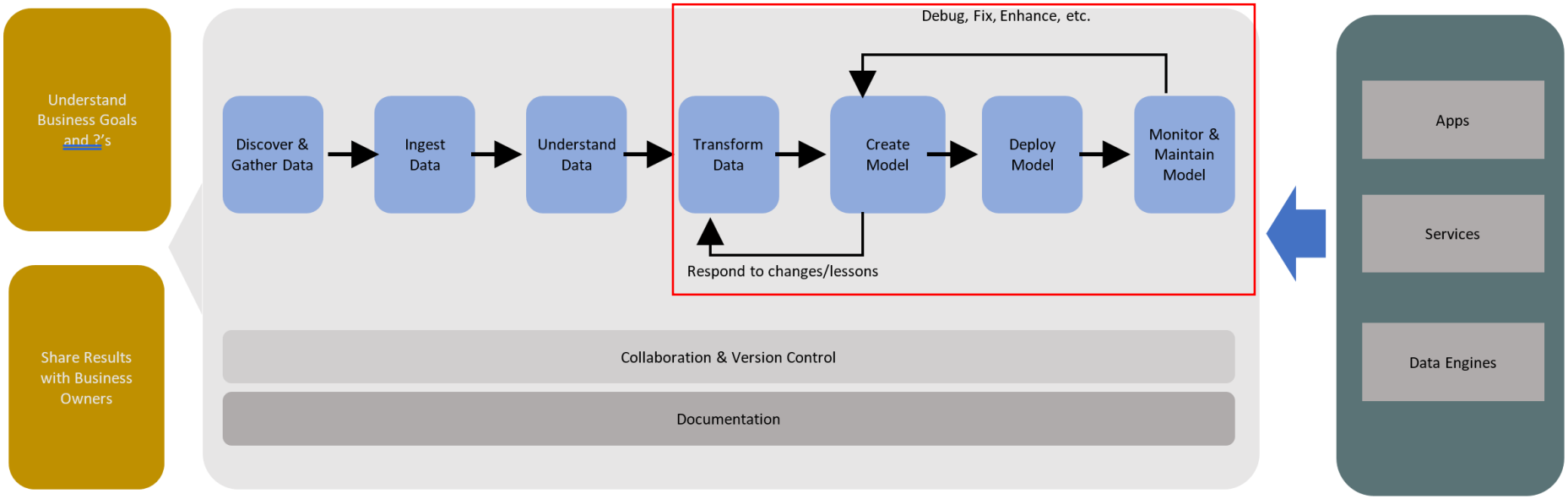
Model the Data

- Step 4: Model the data
  - ✓ Select an appropriate algorithm based on the purpose of task, data characteristics, requirement for interpretability.



Communicate and Visualize the Results

- Step 5: Communicate and Visualize the Results
  - ✓ System implementation, A/B test, model updates, etc.




ANY
questions?