



Lecture I: Introduction

Pilsung Kang

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Korea University

Course Information

- Lecturer

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- Course homepage

- ✓ <http://github.com/pilsung-kang/multivariate-data-analysis>

The screenshot shows the GitHub profile page for Pilsung Kang. At the top, there's a header with a search bar, navigation links for Pull requests, Issues, Marketplace, and Explore, and user stats: 13 repositories, 8 stars, 29 followers, and 3 following. Below the header is a large profile picture of Pilsung Kang. His name, "Pilsung Kang", and GitHub handle, "pilsung-kang", are displayed. A bio states he is an Associate Professor at the School of Industrial Management Engineering, Korea University. Below his profile are sections for pinned repositories: "text-mining", "multivariate-data-analysis" (which is highlighted with a red box), "machine-learning-with-R", "R-for-Data-Analytics", "Business-Analytics", and a note about pinning up to 6 repositories. At the bottom, a grid shows his contribution history from January to December of the previous year, with a legend indicating the volume of contributions.

AGENDA

01 **Introduction to Data Science**

02 Data Science Applications

03 Multivariate Data Analysis in Data Science

04 Data Science Procedure

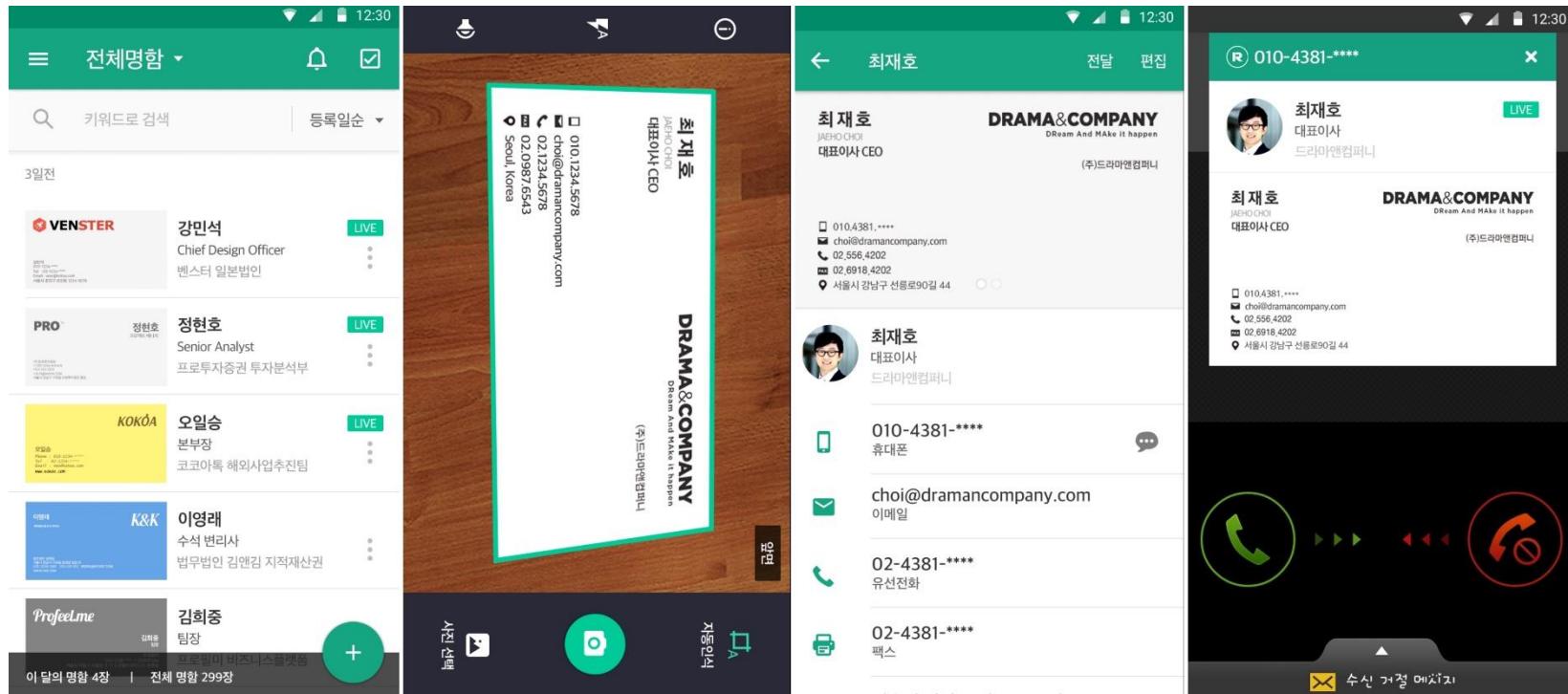
Amazon:Anticipated Shipping

landing.ai: What is defective product and where?

Is Data a Tool or Purpose of Business?

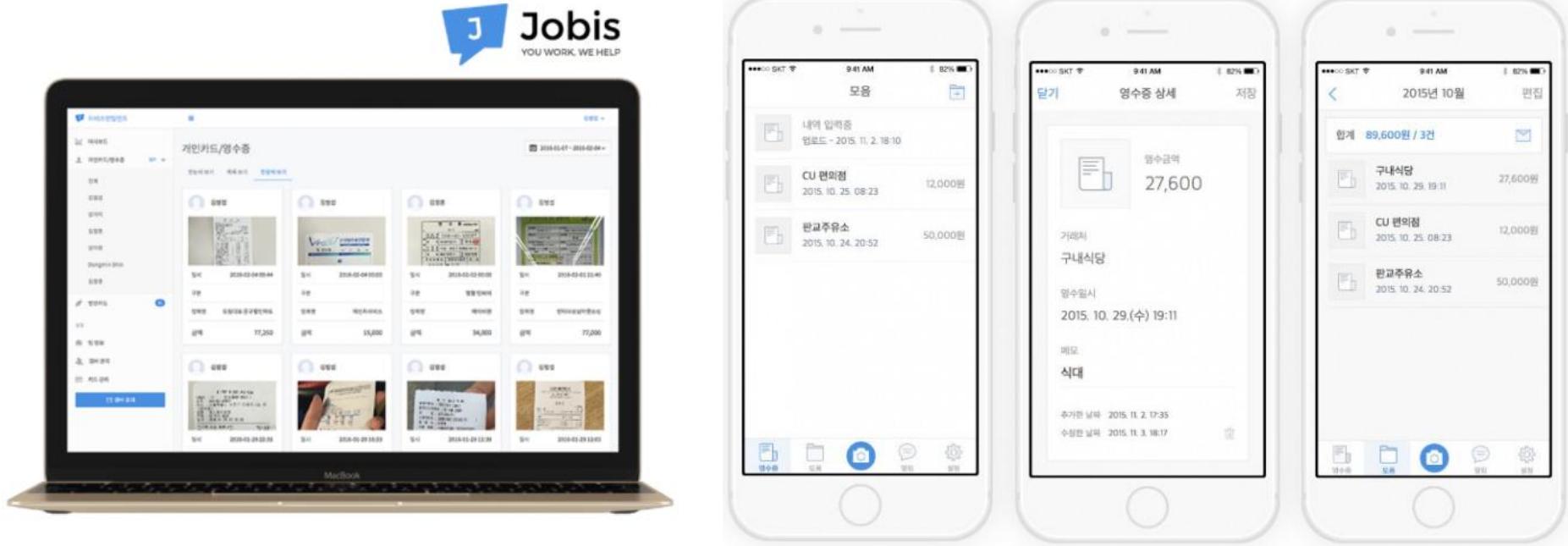
- Sell products or services to collect data?

✓ Alpha Go? No! Alba-Go!



✓ Acquired by Line+ and NAVER on 2017-12-21

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			
	Descriptive	Predictive	Prescriptive
What the user needs to DO	What HAS happened?	What COULD happen?	What SHOULD happen?
What the user needs to DO	<ul style="list-style-type: none">Increase asset reliabilityReduce labor and inventory costs	<ul style="list-style-type: none">Predict infrastructure failuresForecast facilities space demands	<ul style="list-style-type: none">Increase asset utilizationOptimize resource schedules
What the user needs to KNOW	<ul style="list-style-type: none">The number and types of asset failuresWhy maintenance costs are highThe value of the materials inventory	<ul style="list-style-type: none">How to anticipate failures for specific asset typesWhen to consolidate underutilized facilitiesHow to determine costs to improve service levels	<ul style="list-style-type: none">How to increase asset productionWhere to optimally route service techniciansWhich strategic facilities plan provides the highest long-term utilization
How analytics gets ANSWERS	<ul style="list-style-type: none">Standard reporting - What happened?Query/drill down - Where exactly is the problem?Ad hoc reporting - How many, how often, where?	<ul style="list-style-type: none">Predictive modeling - What will happen next?Forecasting - What if these trends continue?Simulation - What could happen?Alerts - What actions are needed?	<ul style="list-style-type: none">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	<ul style="list-style-type: none">Alerts, reports, dashboards, business intelligence	<ul style="list-style-type: none">Predictive models, forecasts, statistical analysis, scoring	<ul style="list-style-type: none">Business rules, organization models, comparisons, optimization

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

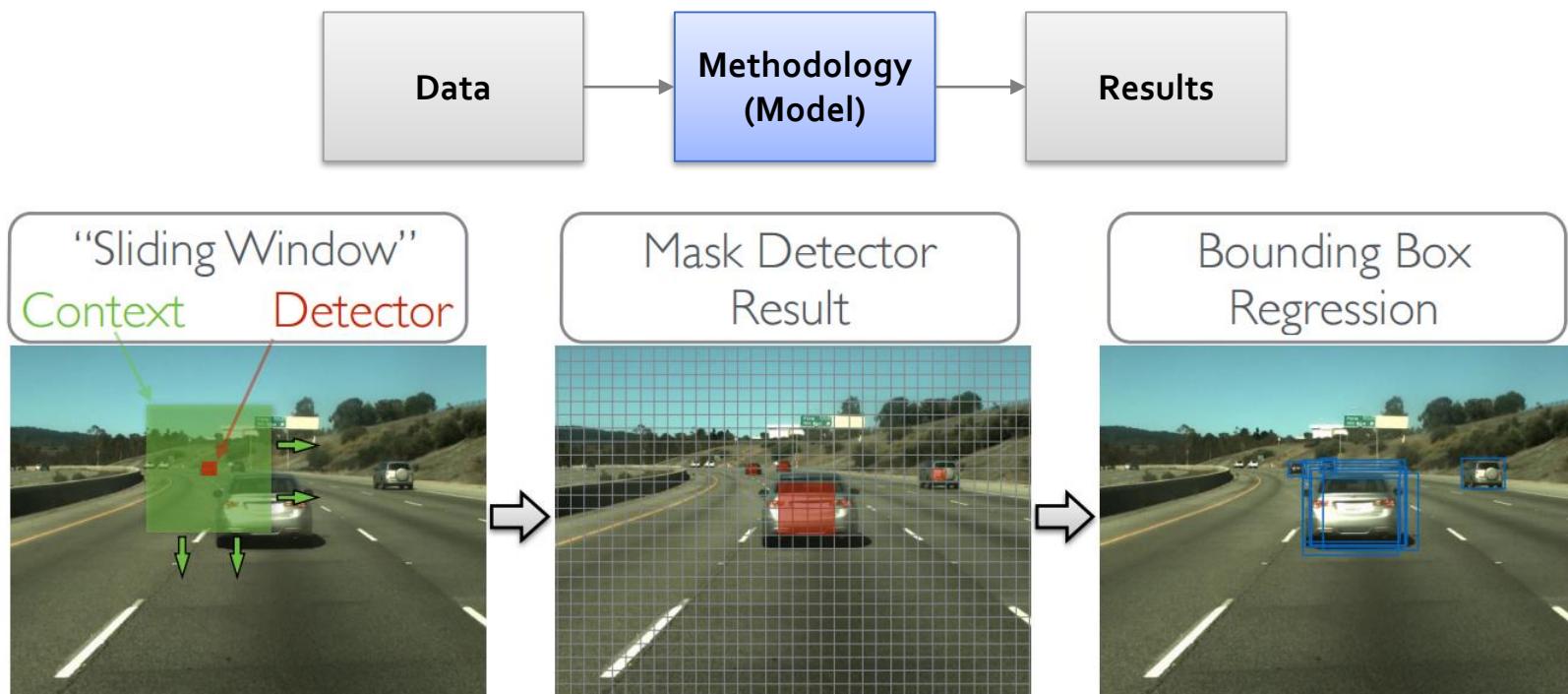
Unsupervised Learning

- 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

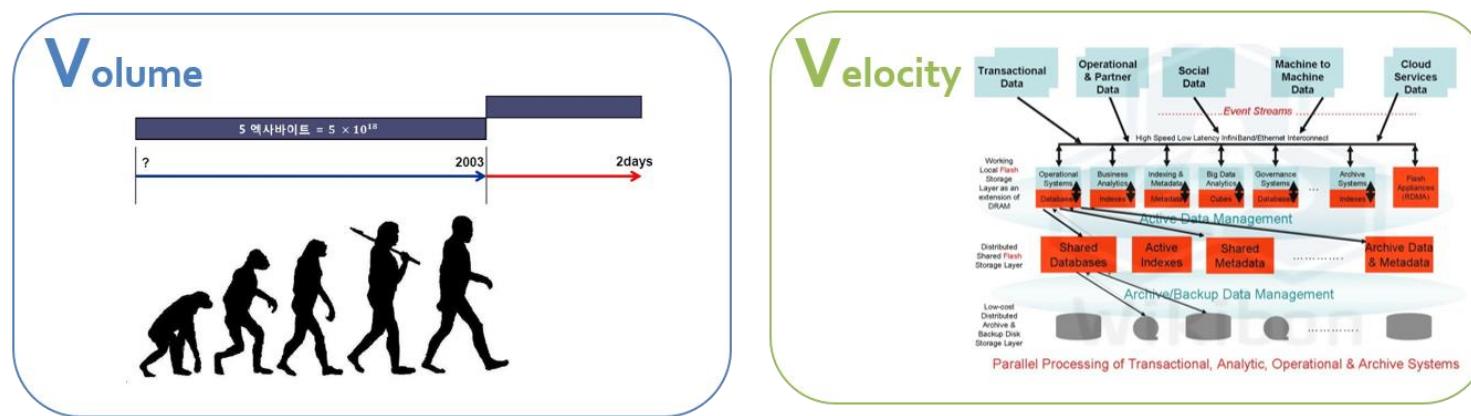
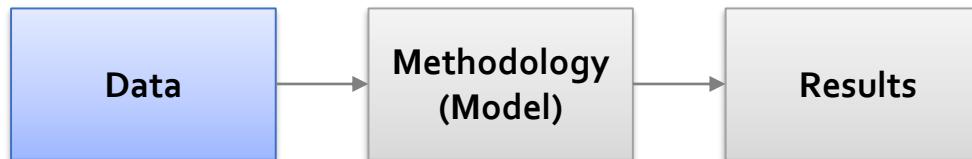
- Machine learning in manufacturing industry
 - ✓ Based on product images and class labels (good/bad),
 - ✓ Models are trained to correctly predict which product are defective and where suspicious areas are



Big Data

- 4Vs in Big Data

✓ Volume, Velocity, Variety, Value



자료: McKinsey (2011.05)

Big Data

- Big Data itself is valuable without any complicated analytics methods

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

Big Data

- Case Study: Navigation system

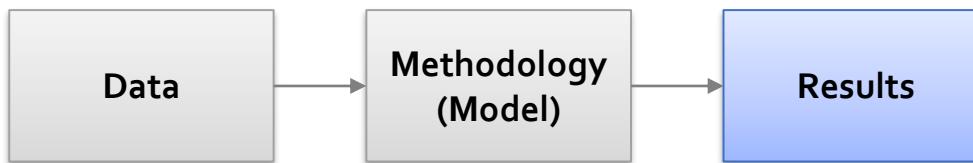


VS



Data Mining

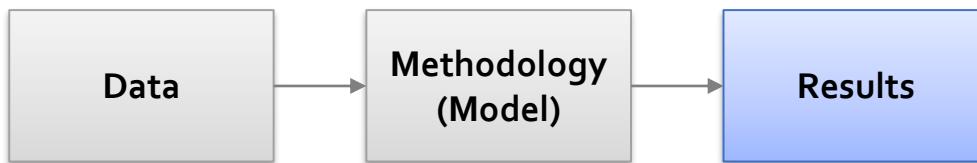
- Definitions



- ✓ 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

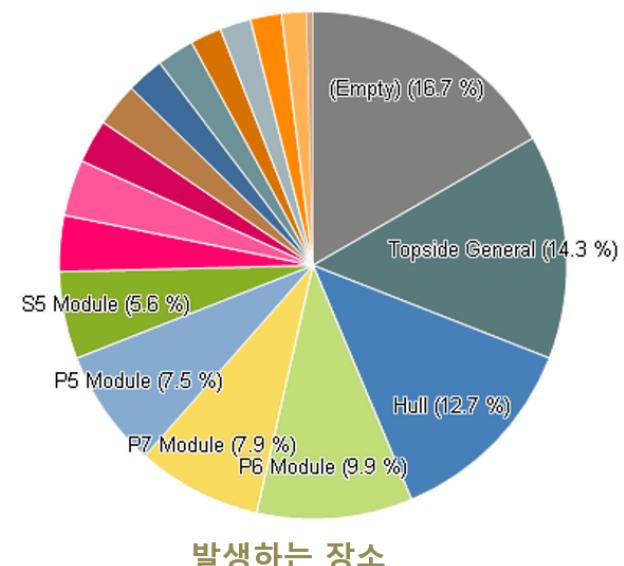
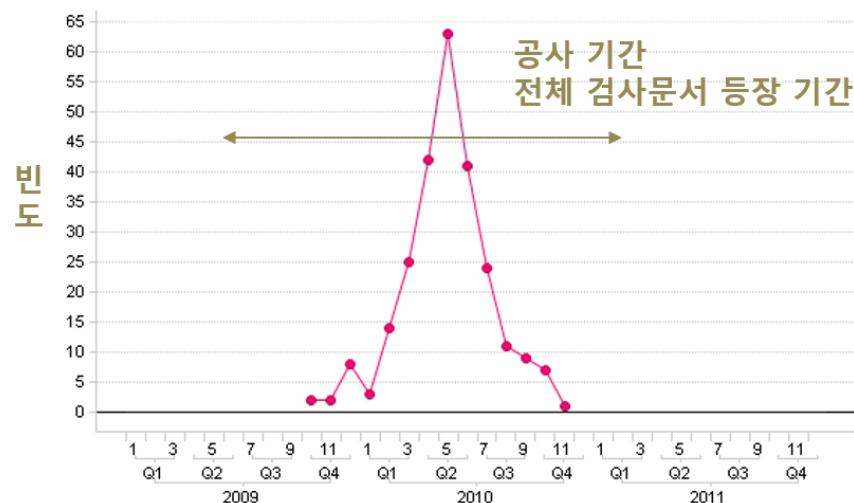
- Definitions



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

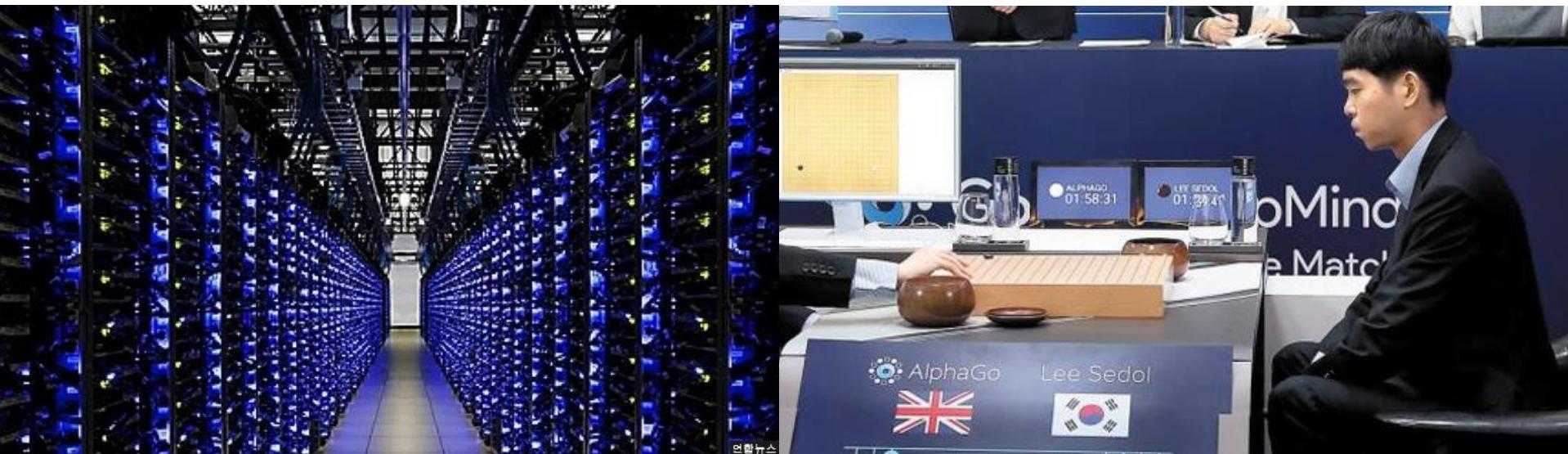
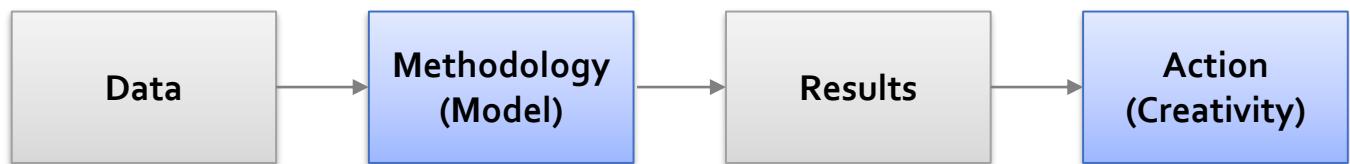
언제, 어디서?

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



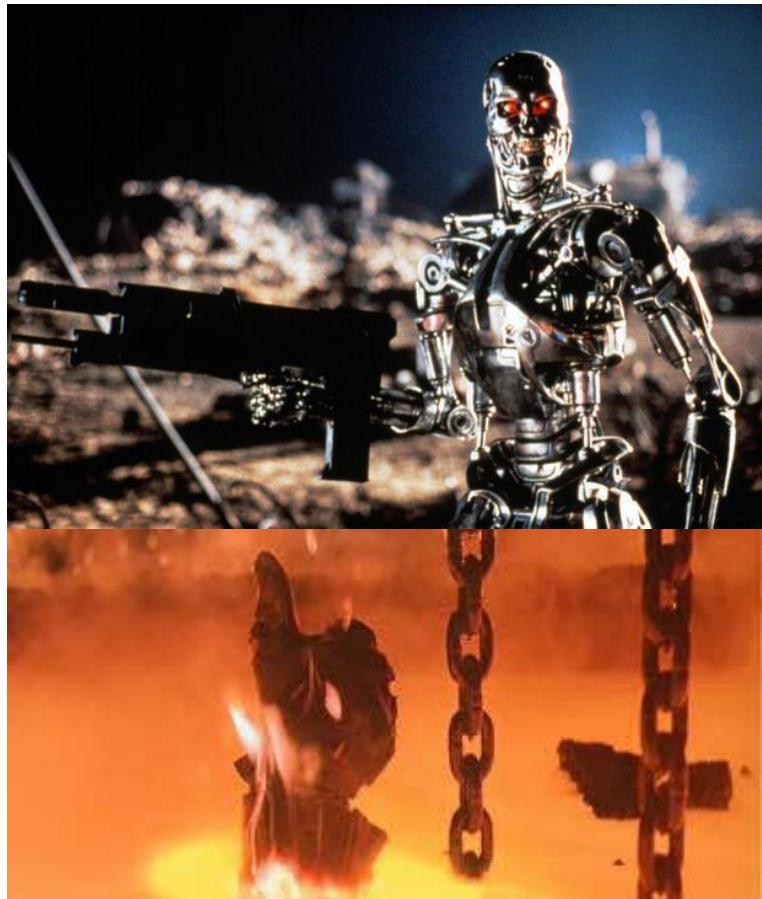
Artificial Intelligence

- 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

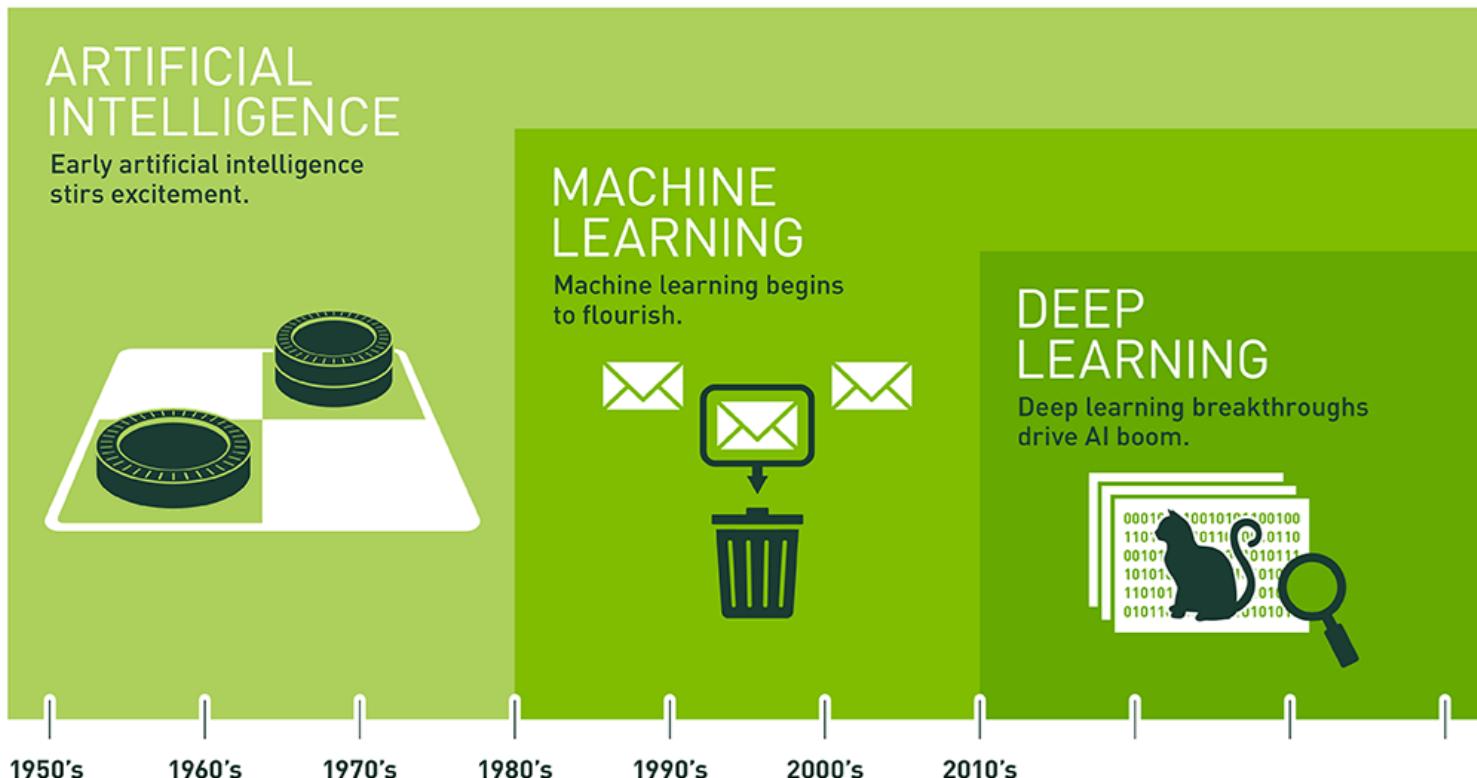
- AI in nowadays...

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/>

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Data Science Applications

1

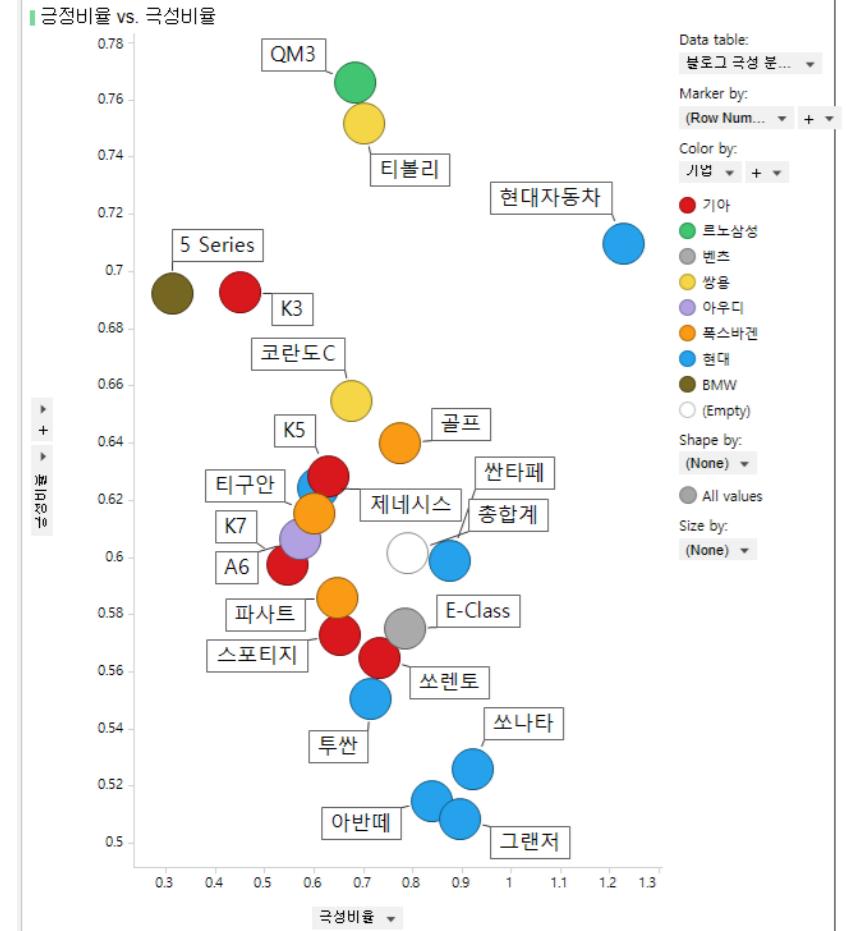
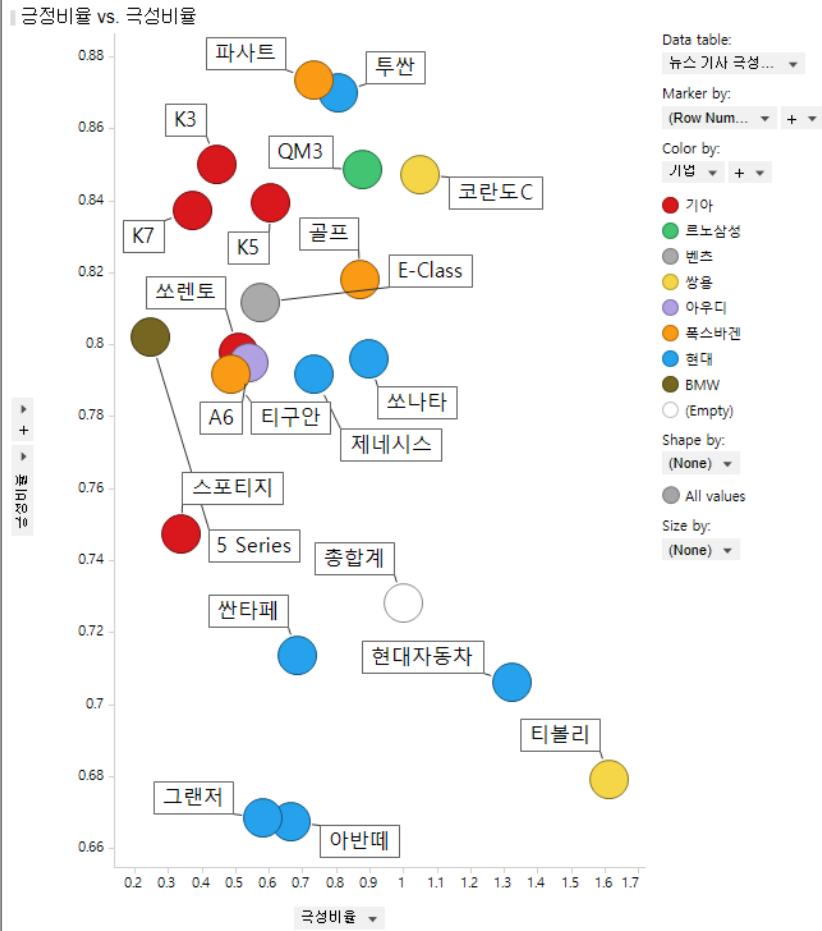
Visualization for intuitive understanding



Data Science Applications

1

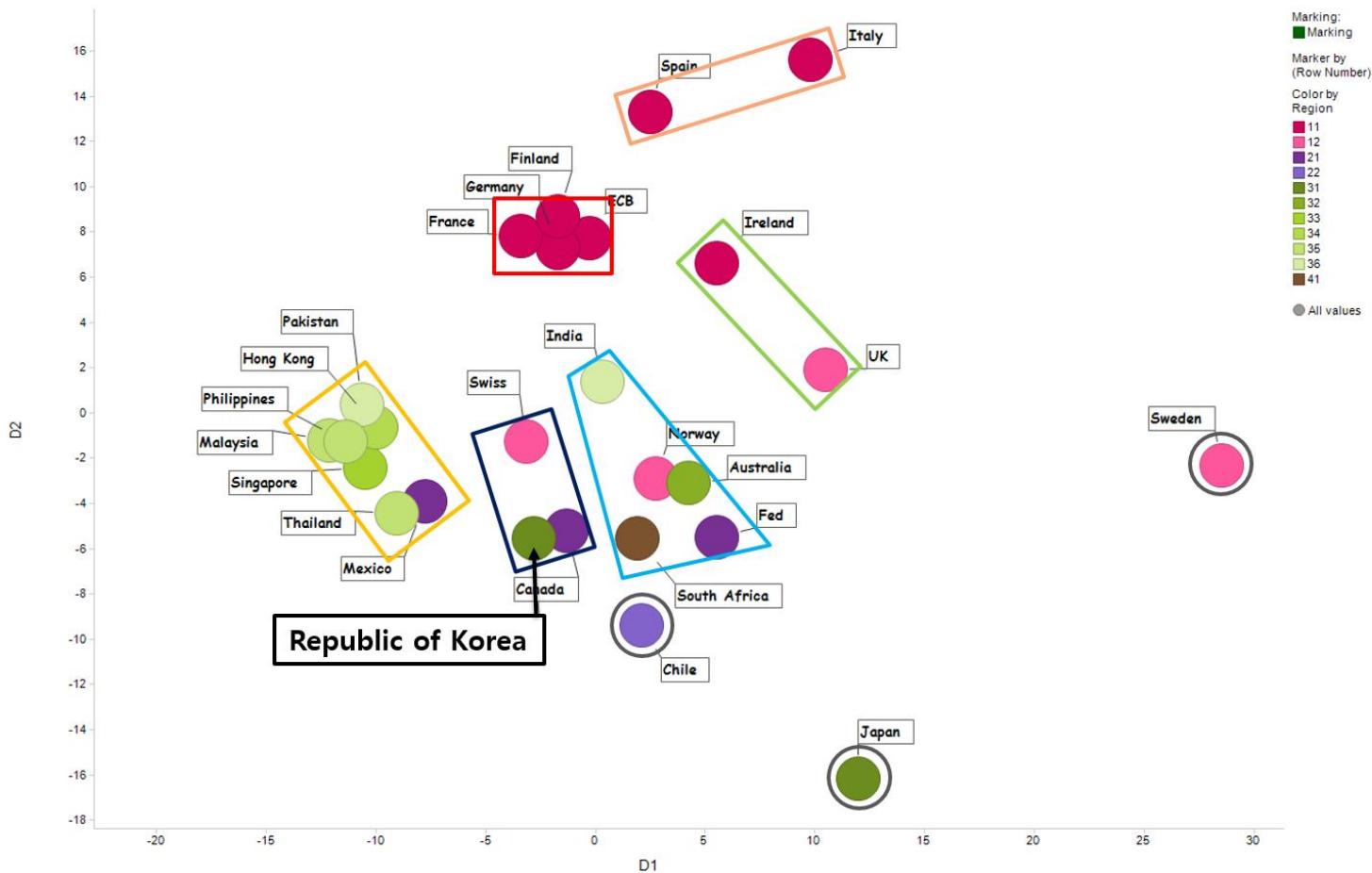
Visualization for intuitive understanding



Data Science Applications

1

Visualization for intuitive understanding



Data Science Applications

1

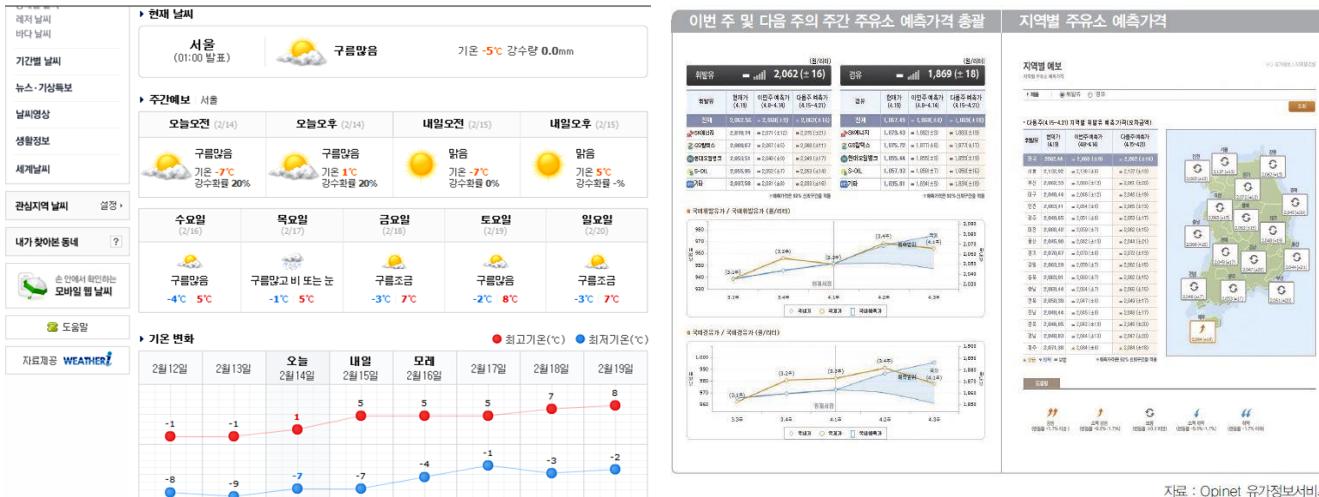
Visualization for intuitive understanding

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

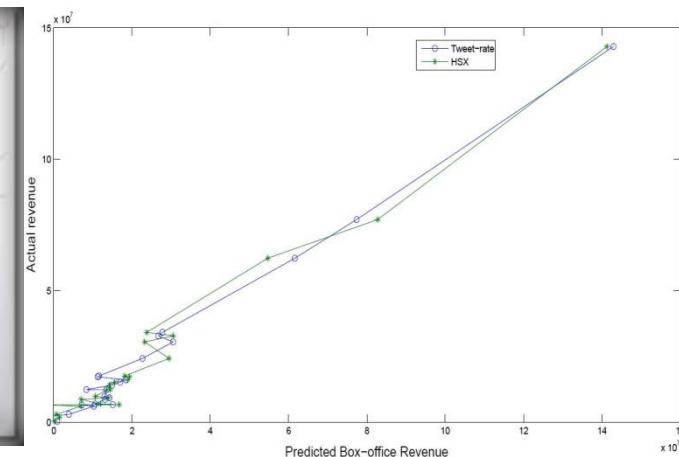
Data Science Applications

2

Predict, Diagnosis, and Detection



자료 : Opinet 유가정보서비스



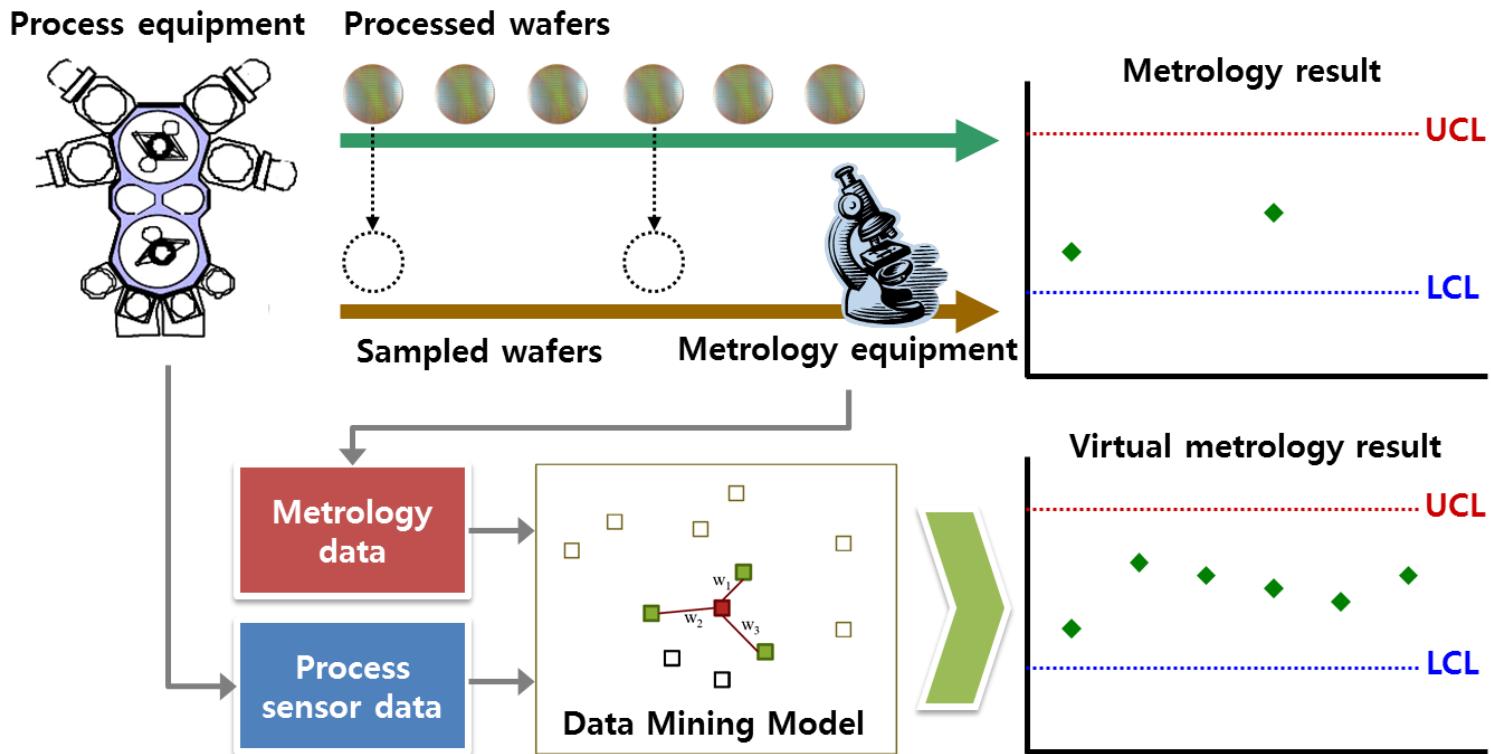
Asur and Huberman (2010) Predicting the Future with Social Media, WI-IAT10: 492-499

Data Science Applications

Predict, Diagnosis, and Detection

2

Virtual Metrology in Semiconductor Manufacturing



Data Science Applications

Support decision making in everyday life (recommendation system)

3



Roll over image to zoom in

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

by Apple

★★★★★ 5 129 customer reviews | 141 answered questions

List Price: \$799.00

Price: **\$699.99**

You Save: \$99.01 (12%)

In Stock.

This item does not ship to Seoul, Korea; Republic of (South Korea). Please check other sellers who may ship internationally. [Learn more](#)

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 Promotional, 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

Support decision making in everyday life (recommendation system)

3

Your recently viewed items and featured recommendations

Customers who searched for "ipad" ultimately bought



Apple iPad (Wi-Fi, 32GB) -
Space Gray (Latest Model)
★★★★★ 1,594
\$249.99



Apple iPad 2 MC769LL/A
9.7-Inch 16GB (Black)
1395 - (Refurbished)
★★★★☆ 3,075
\$94.88



Apple iPad with Retina
Display MD510LL/A (16GB,
Wi-Fi, Black) 4th
Generation (Refurbished)
★★★★☆ 599
\$124.99



Apple iPad Pro (11-inch,
Wi-Fi, 256GB) - Space Gray
(Latest Model)
★★★★★ 129
\$849.99



Apple iPad Air A1474
16GB, Wi-Fi - space gray
(Refurbished)
★★★★☆ 1,481
\$156.98

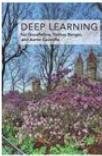


Apple iPad Mini
FD528LL/A - MD528LL/A
(16GB, Wi-Fi, Black)
(Refurbished)
★★★★☆ 1,242
\$114.00

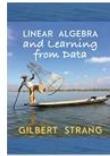


Apple iPad Pro (10.5-inch,
Wi-Fi, 256GB) - Space Gray
★★★★★ 581
\$719.00

Recommendations & Popular Items



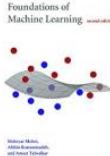
Deep Learning (Adaptive
Computation and...
› Ian Goodfellow
★★★★☆ 190
Hardcover
\$27.96



Linear Algebra and
Learning from Data
› Gilbert Strang
Hardcover
\$77.24



Deep Reinforcement
Learning Hands-On...
› Maxim Lapan
Paperback
\$35.99



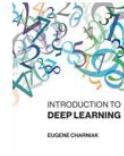
Foundations of Machine
Learning (Adaptive...
Mehryar Mohri
★★★★☆ 3
Hardcover
\$51.16



Grokking Deep Learning
Andrew Trask
★★★★☆ 6
Paperback
\$45.45



The Hundred-Page
Machine Learning Book
Andriy Burkov
★★★★★ 19
Paperback
\$33.57

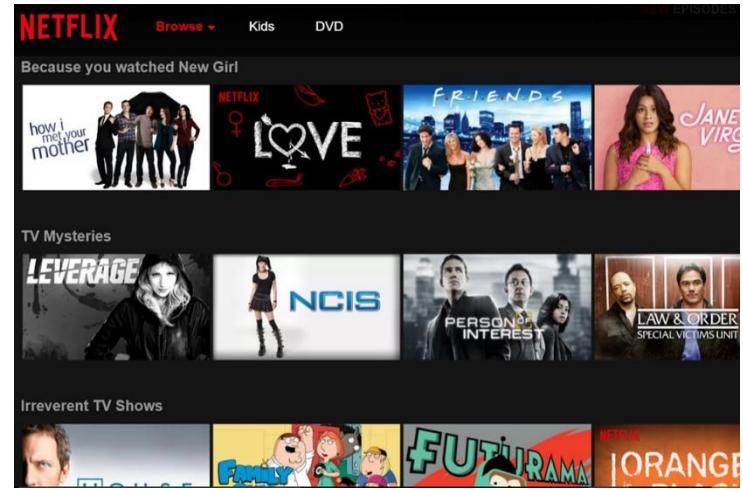
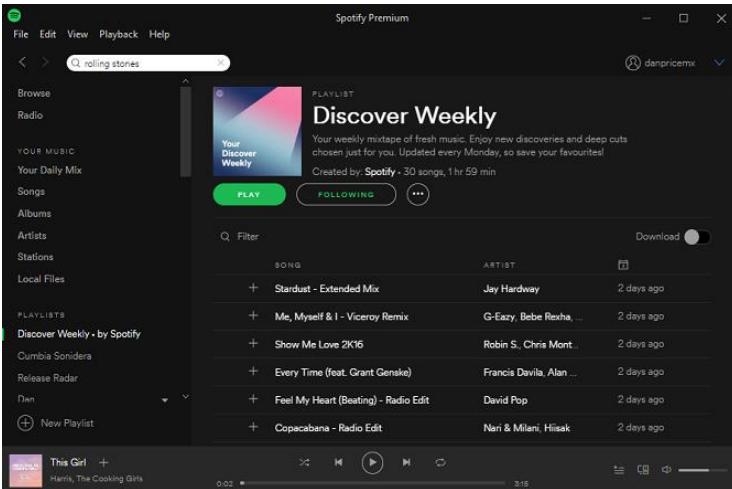


Introduction to Deep
Learning (The MIT Press)
› Eugene Charniak
Hardcover
\$31.50

Data Science Applications

Support decision making in everyday life (recommendation system)

3



AGENDA

01 Introduction to Data Science

02 Data Science Applications

03 Multivariate Data Analysis in Data Science

04 Data Science Procedure

Multivariate Data Analysis for Data Science

Data Reduction/
Structural
Simplification

Sorting and
Grouping

Investigation of the
dependence among
variables

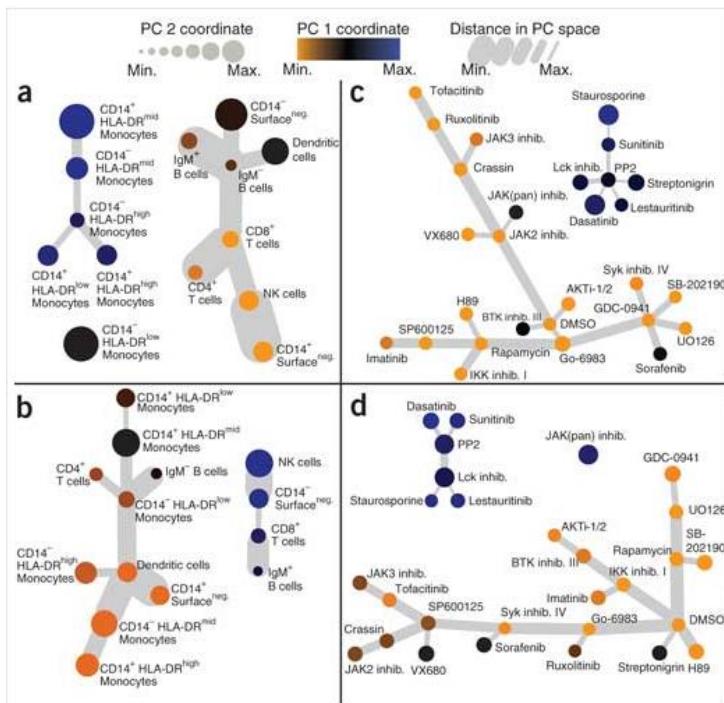
Prediction

Hypothesis
construction and
testing

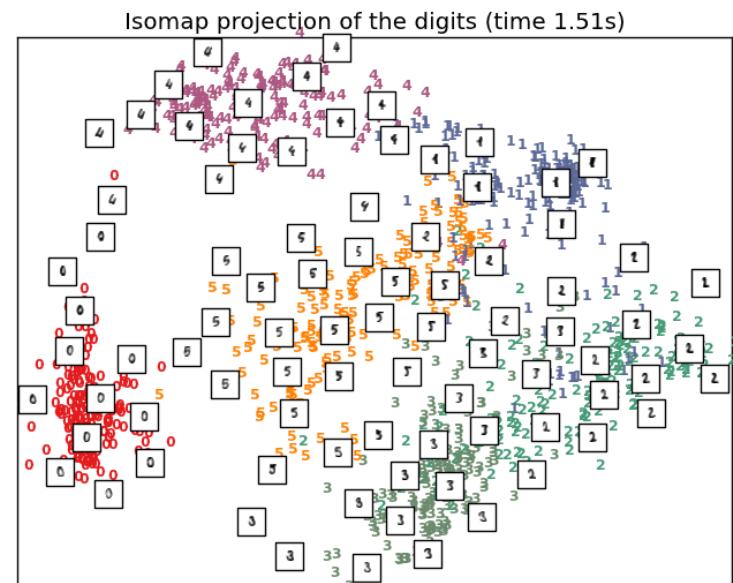
The phenomenon being studied is represented as simply as possible without sacrificing valuable information.

It is hoped that this will make interpretation easier.

Principal Component Analysis



Variable Reduction



Multivariate Data Analysis for Data Science

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Structural
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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

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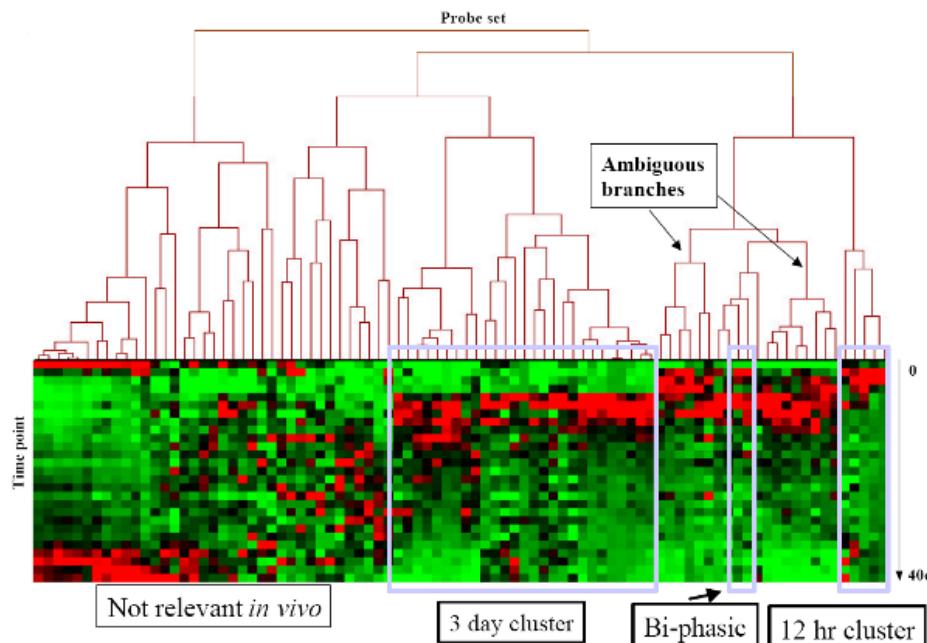
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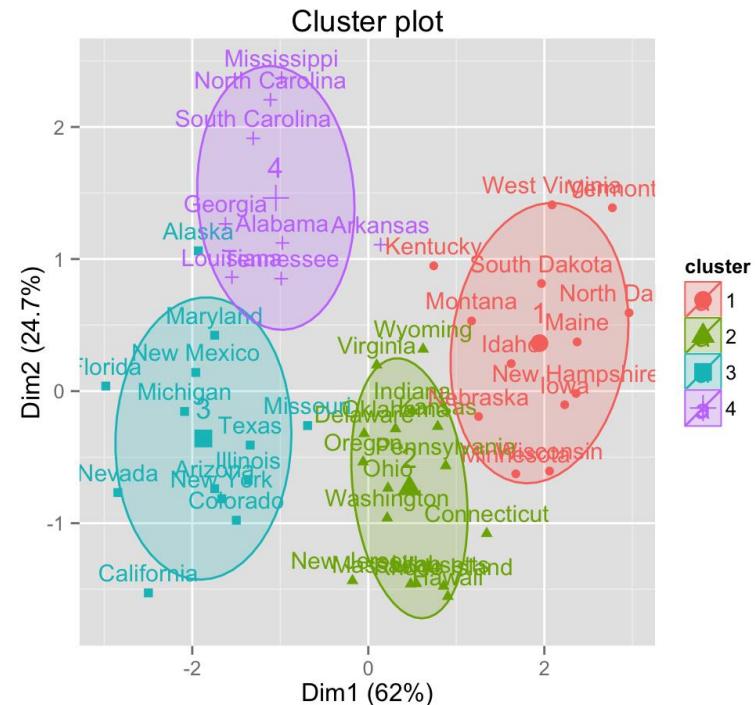
Groups of “similar” objects or variables are created, based upon measured characteristics.

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

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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

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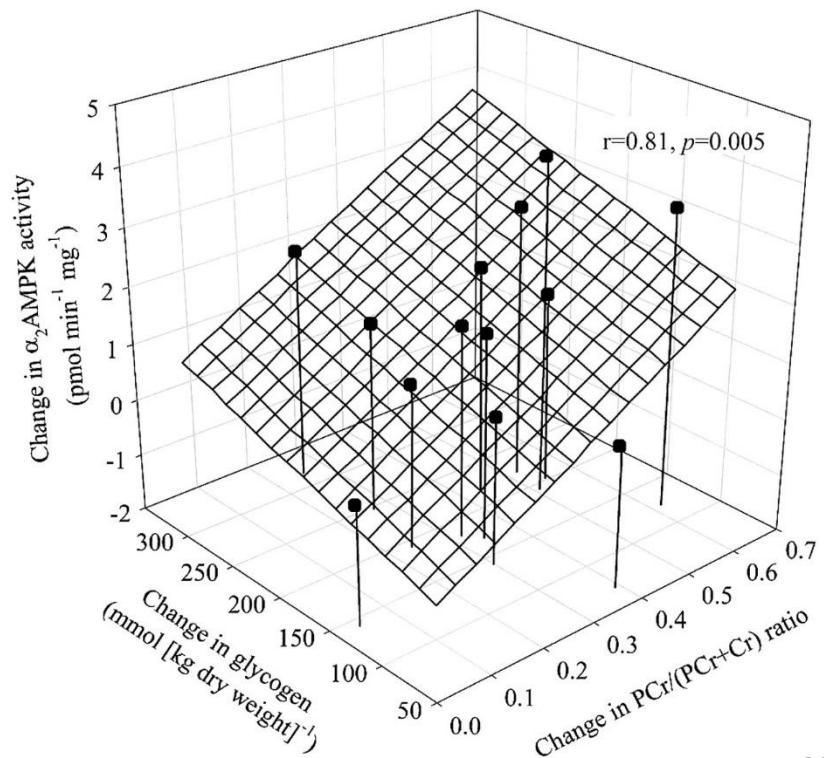
The nature of the relationships among variables is of interest

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

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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 one 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 assess the relation between risk-taking behavior and performance

Multivariate Data Analysis for Data Science

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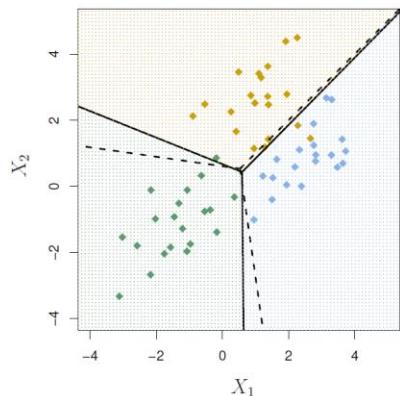
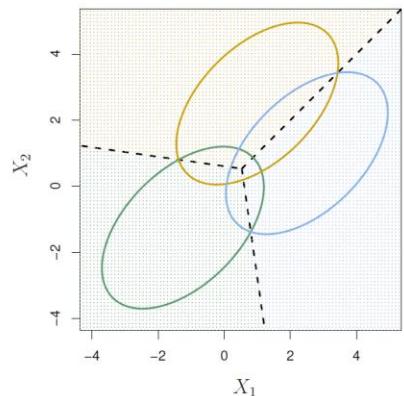
Investigation of the
dependence among
variables

Prediction

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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.

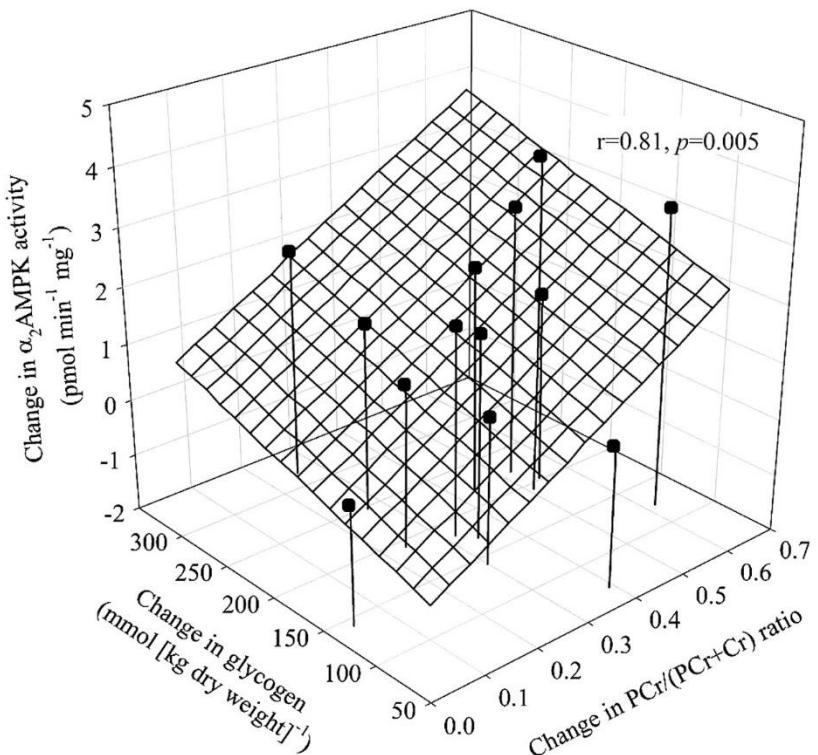
Discrimination and Classification



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

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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

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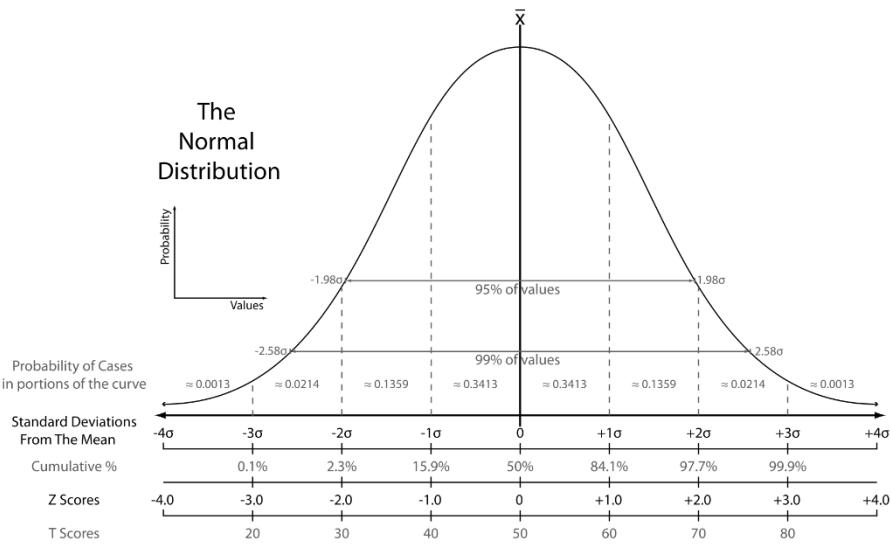
Prediction

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testing

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

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

Inferences about a Mean Vector



Comparisons of Several Multivariate Means

		Treatment			
		1	2	...	
Subject	1	$\mathbf{Y}_{11} = \begin{pmatrix} Y_{111} \\ Y_{112} \\ \vdots \\ Y_{11p} \end{pmatrix}$	$\mathbf{Y}_{21} = \begin{pmatrix} Y_{211} \\ Y_{212} \\ \vdots \\ Y_{21p} \end{pmatrix}$	\dots	
		$\mathbf{Y}_{12} = \begin{pmatrix} Y_{121} \\ Y_{122} \\ \vdots \\ Y_{12p} \end{pmatrix}$	$\mathbf{Y}_{22} = \begin{pmatrix} Y_{221} \\ Y_{222} \\ \vdots \\ Y_{22p} \end{pmatrix}$	\dots	
		\vdots	\vdots	\vdots	
		$\mathbf{Y}_{1n_1} = \begin{pmatrix} Y_{1n_11} \\ Y_{1n_12} \\ \vdots \\ Y_{1n_1p} \end{pmatrix}$	$\mathbf{Y}_{2n_2} = \begin{pmatrix} Y_{2n_21} \\ Y_{2n_22} \\ \vdots \\ Y_{2n_2p} \end{pmatrix}$	\dots	
		$\mathbf{Y}_{gn_g} = \begin{pmatrix} Y_{gn_g1} \\ Y_{gn_g2} \\ \vdots \\ Y_{gn_gp} \end{pmatrix}$			

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 done 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

01 Introduction to Data Science

02 Data Science Applications

03 Multivariate Data Analysis in Data Science

04 Data Science Procedure

Data Science Procedure

Ask an interesting question

- ▶ 풀고자 하는 문제가 무엇인가?
- ▶ 만약 관련해 모든 데이터를 보유하고 있다면 무엇을 할 것인가?
- ▶ 무엇을 예측하고 추정하기를 원하는가?

Get the data

- ▶ 데이터는 어떻게 샘플링할 것인가?
- ▶ 어떤 데이터와 정보가 우리 목표와 관련이 있는가?
- ▶ 프라이버시나 개인정보 이슈는 없는가?

Explore the data

- ▶ 데이터를 그려보며 데이터의 속성과 구조를 알아보기
- ▶ 데이터에서 이상한 점은 없는가?
- ▶ 데이터에 어떠한 패턴이 존재하는가?

Model the data

- ▶ 모델 수립
- ▶ 모델 적합화
- ▶ 모델 검증

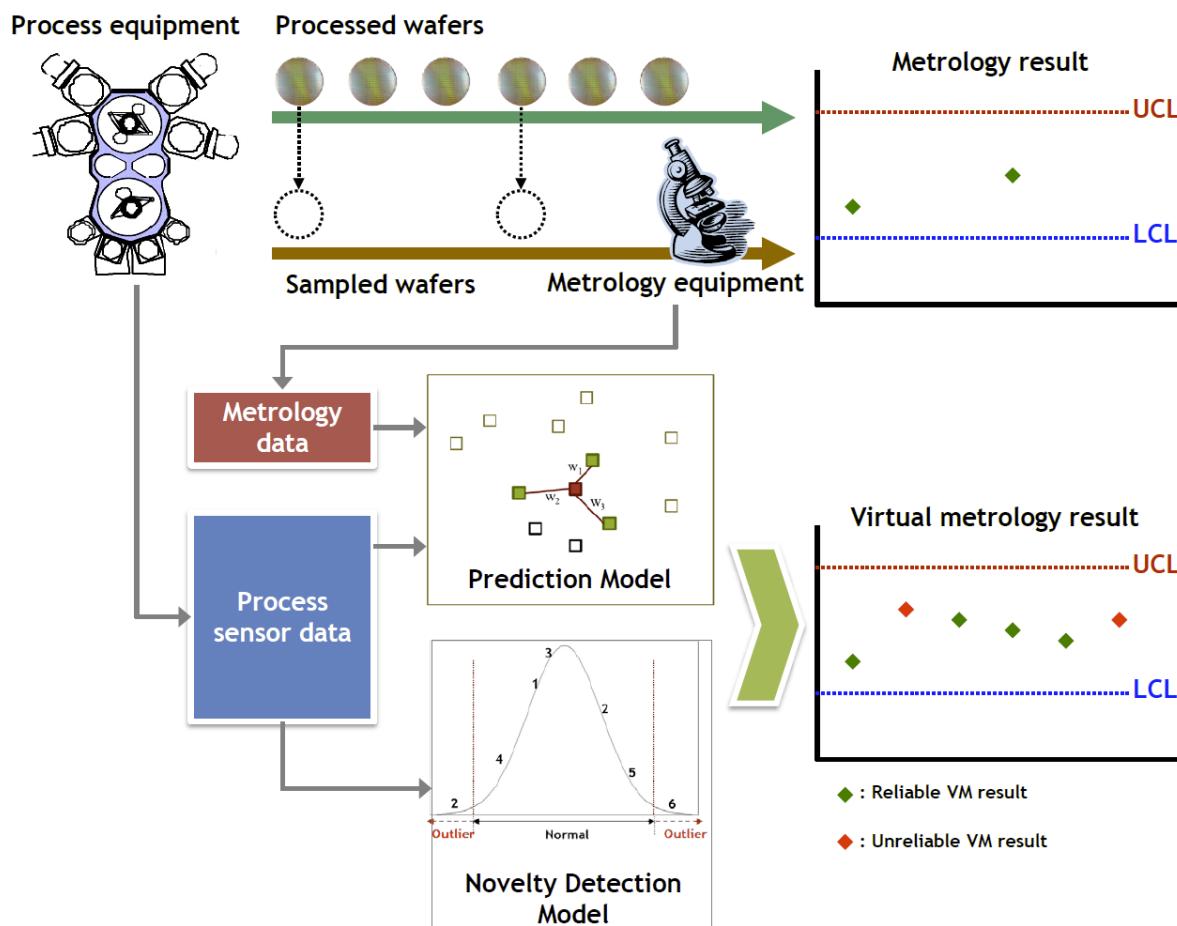
Communicate and visualize the results

- ▶ 결과 요약 및 시사점 분석
- ▶ 결과가 타당한가?
- ▶ 스토리를 말할 수 있는가? (전략 수립)

Ask an Interesting Question

- Step 1: Ask an interesting question

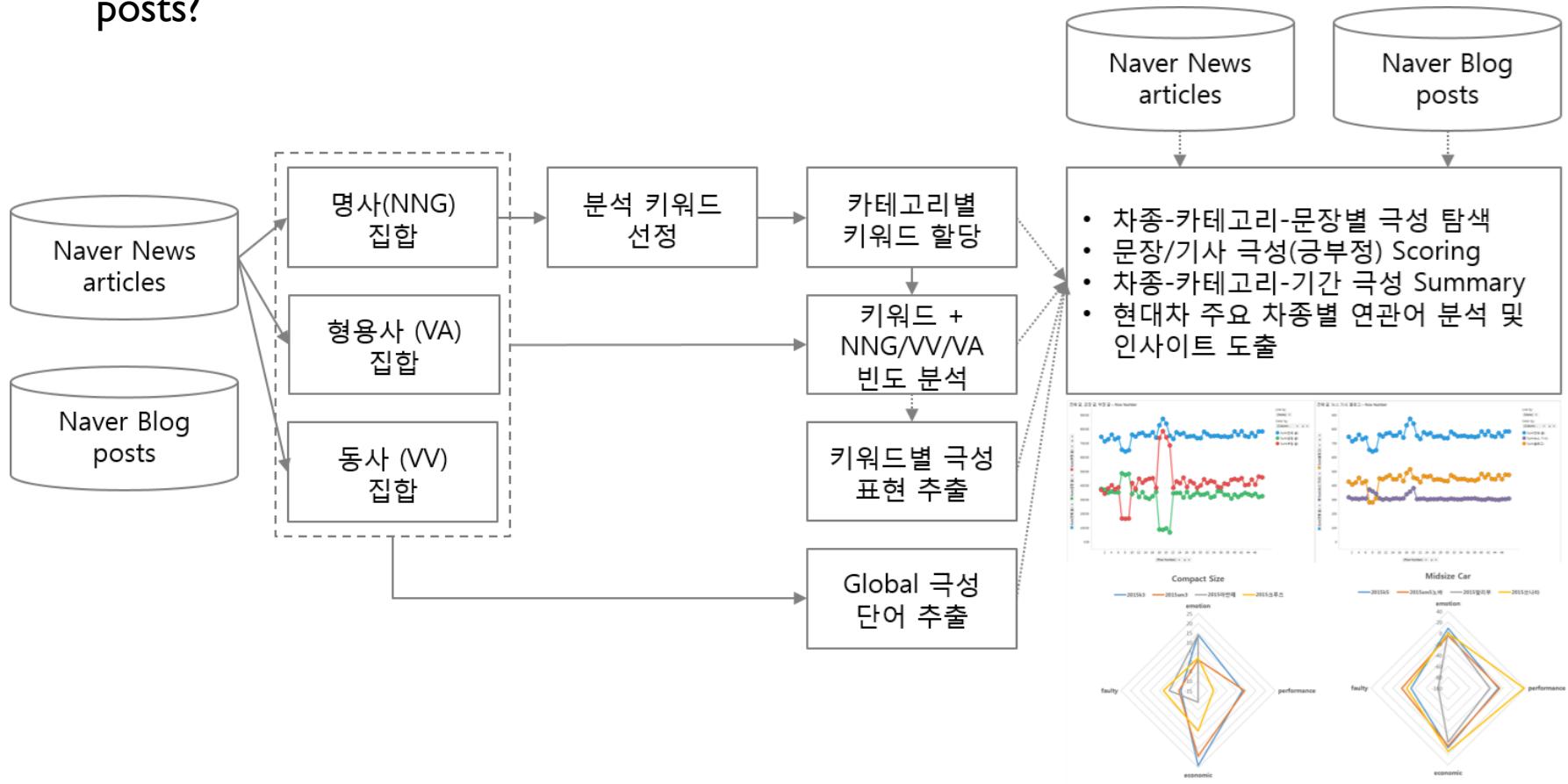
- ✓ Can we predict the product quality based on the sensor data collected from equipment?



Ask an Interesting Question

- Step 1: Ask an interesting question

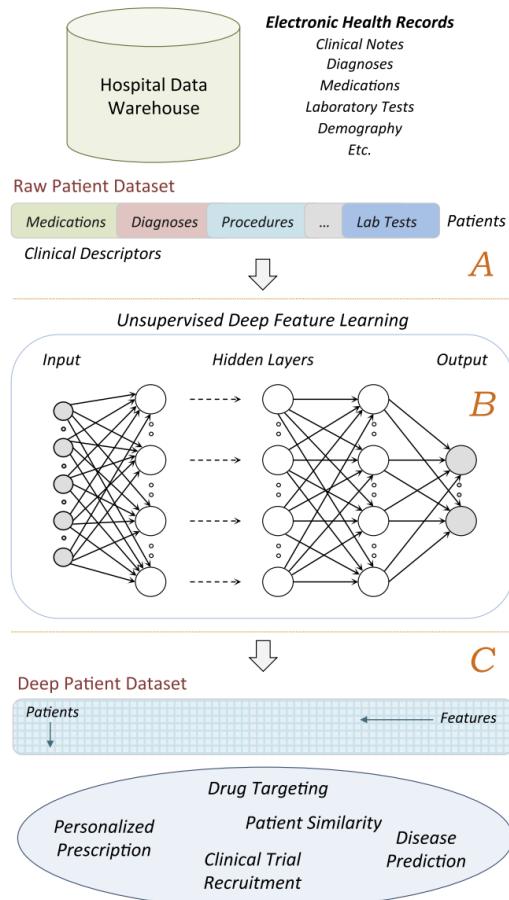
- ✓ Is it possible to understand customers' preference based on news articles and blog posts?



Ask an Interesting Question

- Step 1: Ask an interesting question

✓ Can we predict various diseases based on the electric health records (EHR)?

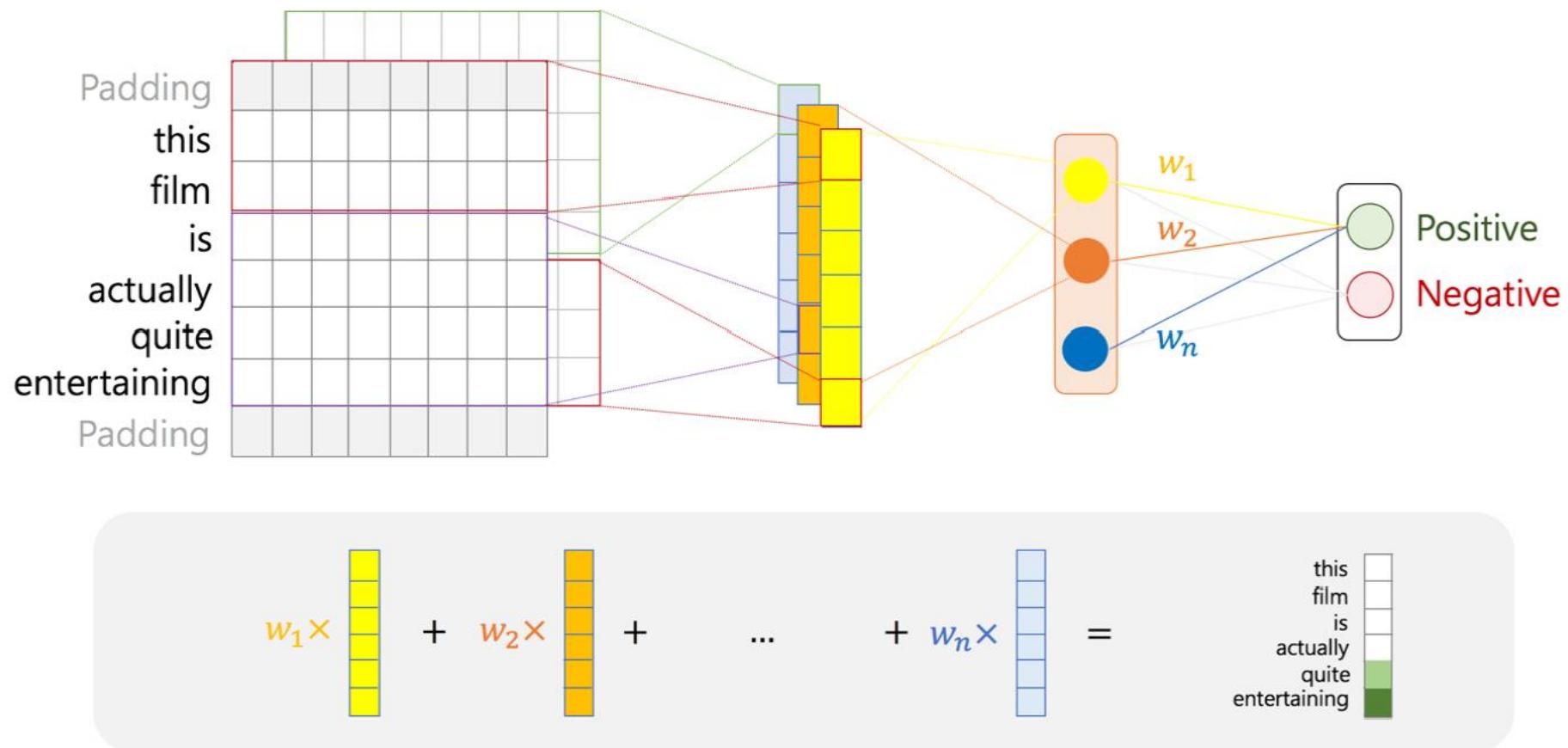


Disease	Area under the ROC curve		
	RawFeat	PCA	DeepPatient
Diabetes mellitus with complications	0.794	0.861	0.907
Cancer of rectum and anus	0.863	0.821	0.887
Cancer of liver and intrahepatic bile duct	0.830	0.867	0.886
Regional enteritis and ulcerative colitis	0.814	0.843	0.870
Congestive heart failure (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

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

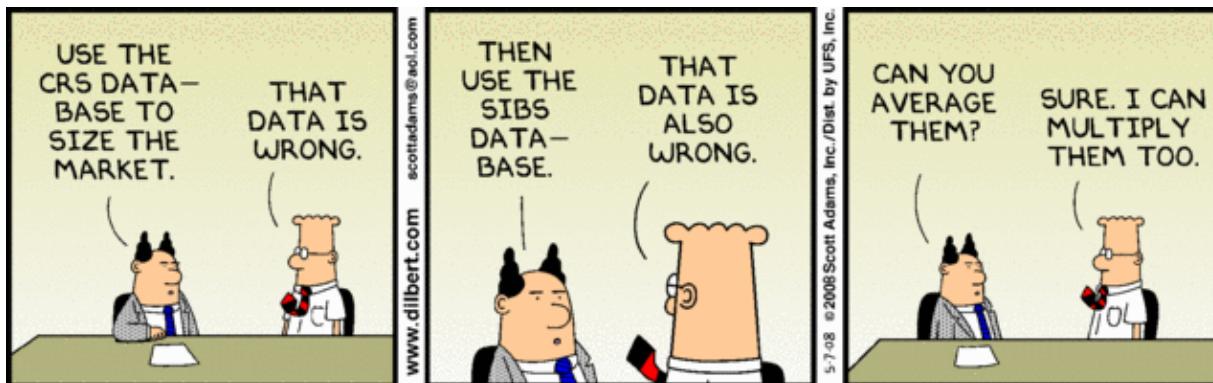
✓ Can we find the emotional expressions automatically from review texts?

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 well. Giovanni Ribisi's character was quite annoying. For some reason he seems to like repeating what he says. If Rain Man it would have 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 well. Giovanni Ribisi's character was quite annoying For some reason he seems to like repeating what he says. If Rain Man it would have 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 well. Giovanni Ribisi's character was quite annoying For some reason he seems to like repeating what he says. If Rain Man it would have been 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 well. Giovanni Ribisi's character was quite annoying For some reason he seems to like repeating what he says. If Rain Man it would have been fine 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 well. Giovanni Ribisi's character was quite annoying For some reason he seems to like repeating what he says. If Rain Man it would have 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)

The screenshot shows a medical research article from JAMA. At the top, there is a red header bar with the word "Research". Below it, the journal title "JAMA" and the article type "Original Investigation | INNOVATIONS IN HEALTH CARE DELIVERY" are displayed. The main title of the article is "Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs". Below the title, a list of authors is provided. A summary section follows, containing three main points: "IMPORTANCE", "OBJECTIVE", and "DESIGN AND SETTING". To the right of the summary, there are two links: "Editorial" and "Supplemental content".

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).

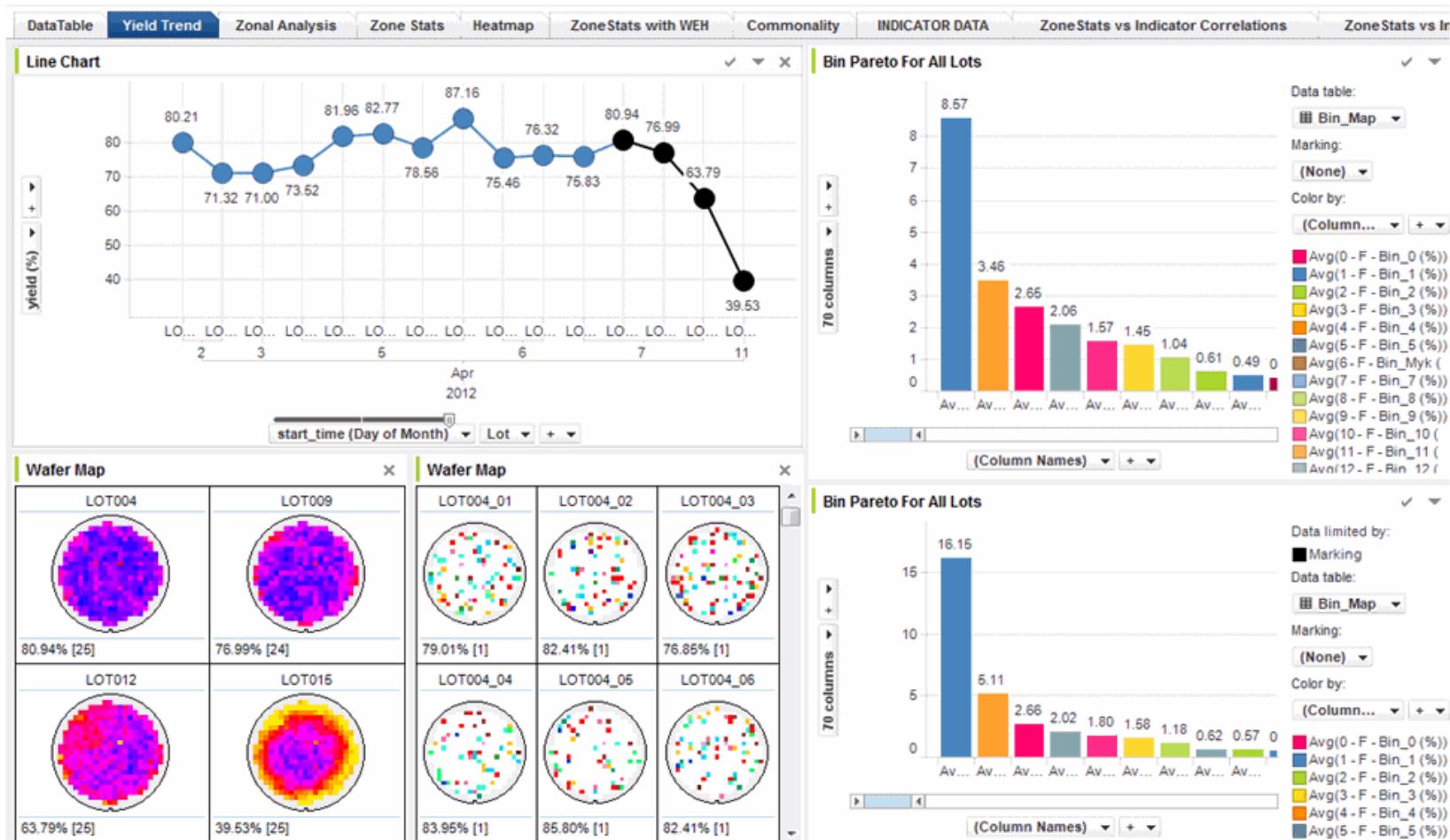
^c Individual-level data including age and sex were available for 66.1% of the development set ($n = 84\,734$ images).

^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

The collage illustrates various data visualization platforms:

- TIBCO Spotfire:** Shows a dashboard titled "Laws of Attrition" with a background of colored circles.
- Qlik:** Shows a "Qlik Demos" page with sections for "Salesforce" and "Industry Focus".
- Tableau:** Shows a map titled "Boris Bikes by Station During the July 2015 Tube Strike in London" with many colored dots representing bike stations.
- Qlik Demos:** Shows a "Demos Gallery" with various dashboard thumbnails, including "FDIC - Summary of Deposits" and "QlikView Governance Dashboard".

Self Service Analytics at Scale

Multiply your data's potential

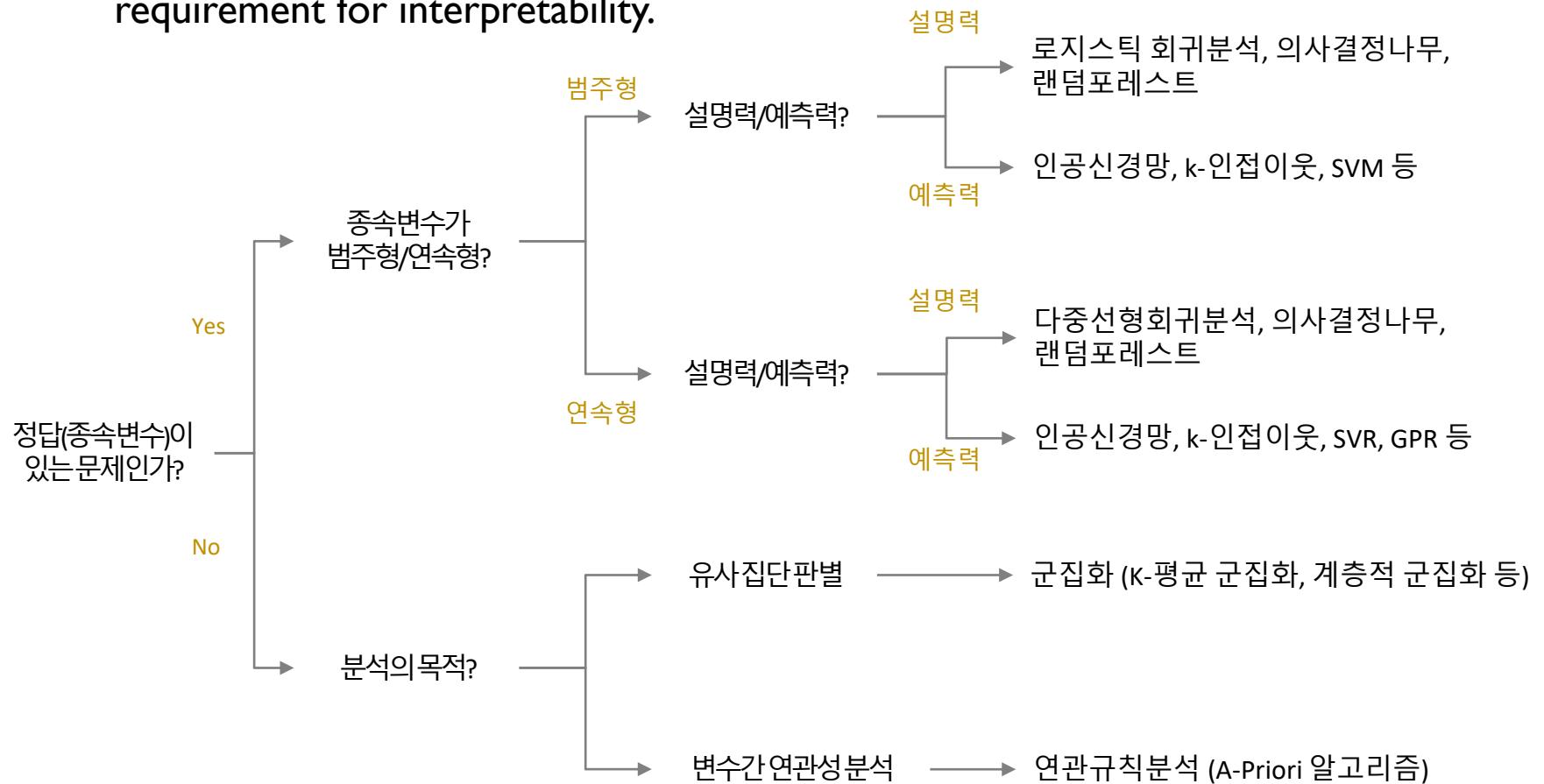
Extend the value of your data across your organization with Tableau Server. Empower your business with the freedom to explore data in a trusted environment—without limiting them to pre-defined questions, wizards, or chart types. And have the peace of mind that your data is governed and secure.

START A FREE TRIAL →

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.

