PMILab
Pattern Recognition & Machine Intelligence

Hankuk University of Foreign Studies

A Tour of Machine Learning
A Comprehensive Overview

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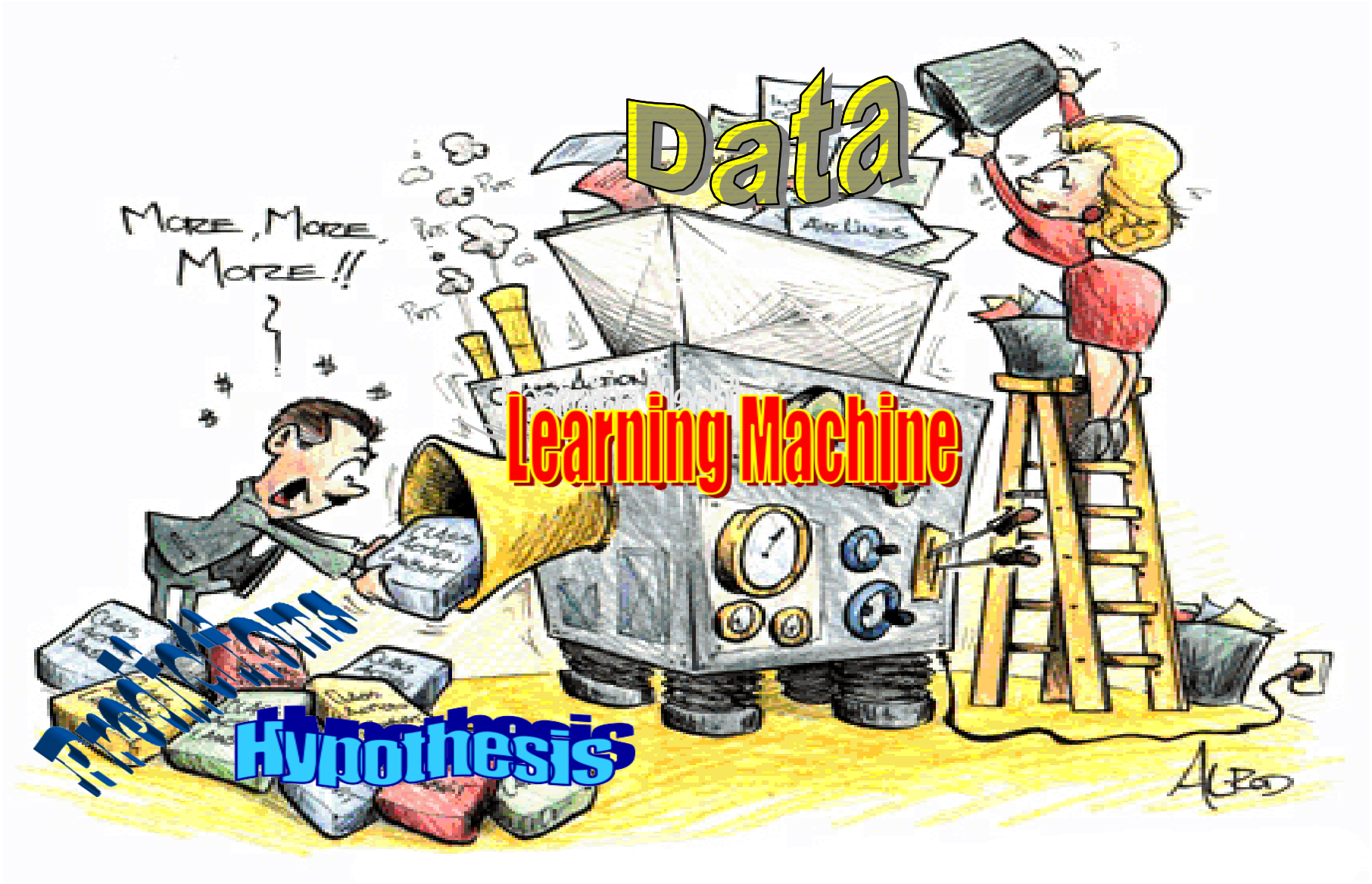
WHAT IS MACHINE LEARNING?

Greek alphabet list

Upper Case Letter	Lower Case Letter	Greek Letter Name	English Equivalent
Α	α	Alpha	a
Β	β	Beta	b
Γ	γ	Gamma	g
Δ	δ	Delta	d
Ε	ε	Epsilon	e
Ζ	ζ	Zeta	z
Η	η	Eta	h
Θ	θ	Theta	th
Ι	ι	Iota	i
Κ	κ	Kappa	k
Λ	λ	Lambda	l
Μ	μ	Mu	m
Ν	ν	Nu	n
Ξ	ξ	Xi	x
Ο	ο	Omicron	o
Π	π	Pi	p
Ρ	ρ	Rho	r
Σ	σ,ς*	Sigma	s
Τ	τ	Tau	t
Υ	υ	Upsilon	u
Φ	φ	Phi	ph
Χ	χ	Chi	ch
Ψ	ψ	Psi	ps
Ω	ω	Omega	o

WHAT IS MACHINE LEARNING?



WHAT IS MACHINE LEARNING?

- **A computer program is said to learn from experience *E* with respect to tas k *T* and performance measure *P*, if its performance at tasks *T*, improves wi th experience *E***

  [Mitchell, 1997]

- **Machine learning is the systematic study of algorithms and systems that i mprove their knowledge or performance with experience**

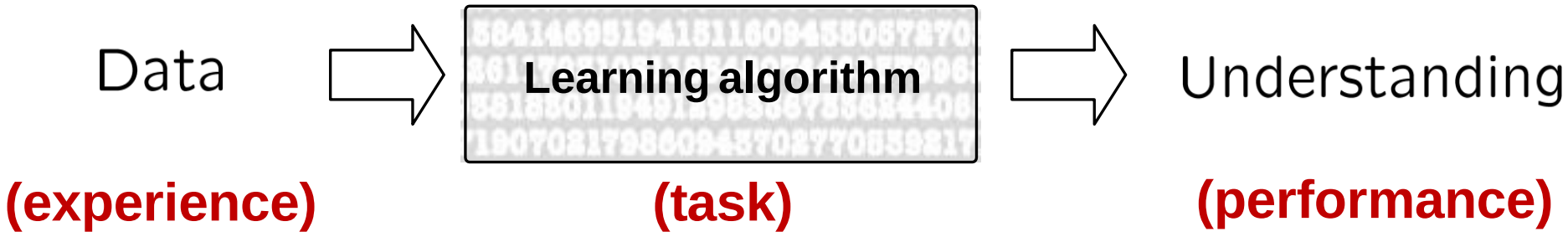
  [Peter A. Flach, 2015]

- 특정 작업 ***T*** 에서 획득한 경험적인 데이터 ***D***를 바탕으로 모델 ***M***을 자동으로 구성하여 스스로 성능 ***P***를 향상하는 컴퓨터 프로그램

WHAT IS MACHINE LEARNING?

- Study of algorithms that
  - improve their performance
  - at some task
  - with experience

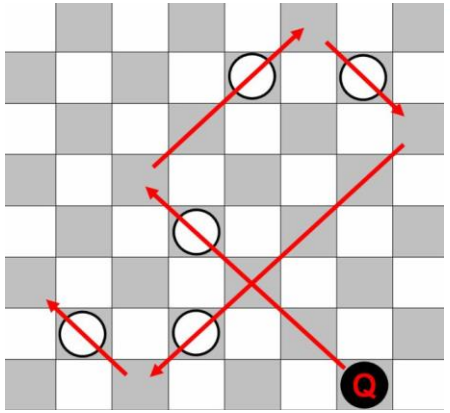
well-defined learning task: <P,T,E>



WHAT IS MACHINE LEARNING?

A checkers Learning Problem:

- Task ***T*** : playing checkers
- Performance measure ***P*** : percent of games won against opponents
- Training experience ***E***: playing practice games against itself



A Handwriting Recognition Learning Problem:

- Task ***T*** : recognizing and classifying handwritten words within images
- Performance measure ***P*** : percent of words correctly classified
- Training experience ***E*** : a database of handwritten words with given classifications

MACHINE LEARNING COMPONENT

- Tens of thousands of machine learning algorithms

- But, there are common things! Every machine learning algorithm has three components:
  - **Model**
  - **Evaluation**
  - **Optimization**

hypothesis 와 처리공간

머신 러닝 특성

- 특성 1: Self-improving Systems (인공지능)
- 특성 2: Knowledge Discovery (데이터마이닝)

- 특성 3: Data-Driven SW Design (SW공학)
- 특성 4: Automatic Programming (컴퓨터공학)

WHY MACHINE LEARNING?

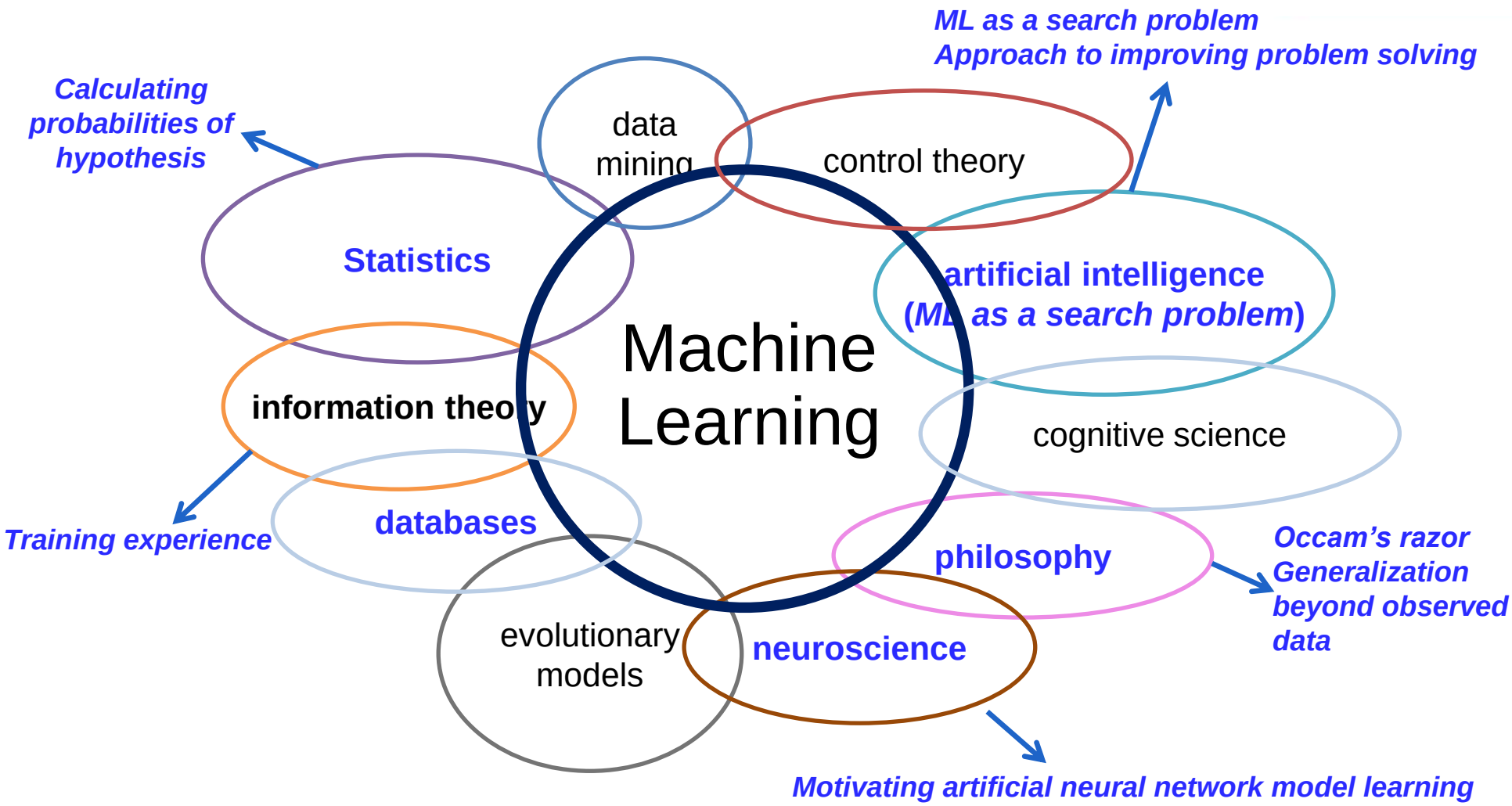
- 전문가 부족
  - industrial/manufacturing control
  - mass spectrometer analysis, drug design, astronomic discovery

- 단순 프로그래밍이 어려운 문제들
  - face/handwriting/speech recognition
  - driving a car, flying a plane

- 급격한 기술 변화
  - credit scoring, financial modeling
  - diagnosis, fraud detection

- 개인화 필요성
  - personalized news reader
  - movie/book recommendation

RELATED FIELDS



HISTORY OF MACHINE LEARNING

- **1948: Checkers Player (Samuel)**
- **1958**: **Perceptron** (Rosenblatt)
- 1975: Near miss concept learning (Winston)
- **1980: First ICML Conference (Machine Learning Workshop)**
- 1982: Self-organizing maps (Kohonen)
- 1983: Boltzmann machine (Hinton & Sejnowski)
- **1984**: **PAC computational learning theory** (Valiant)
- **1986: Backpropagation algorithm (Rumelhart, Hinton, & Williams)**
- **1986**: **Decision trees** (Quinlan)
- **1986: Machine Learning Journal**
- **1987: First NIPS Conference (Neural Information Processing Systems)**
- 1992: TD-Gammon (Tesauro)
- **1992: Support vector machines (Boser, Guyon, & Vapnik)**
- 1994: Learning Bayesian networks (Hackerman)
- 1995: Statistical learning theory (Vapnik)
- 1995: Neural Networks for Pattern Recognition (Bishop)

Checkers Player (Samuel)

ICML

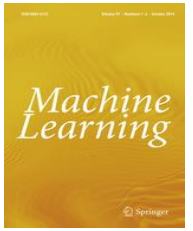
ICML Conference

Perceptron (Rosenblatt)

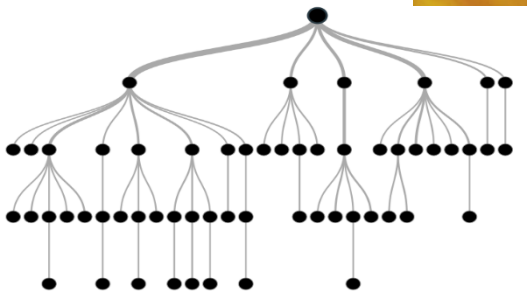
PAC Computational Learning theory (Valiant)

N I P S

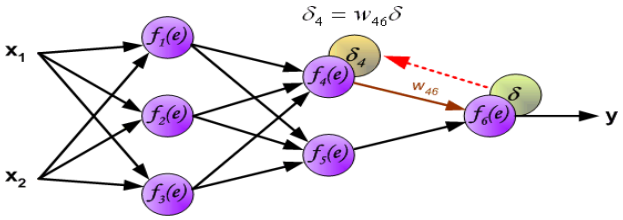
NIPS Conference



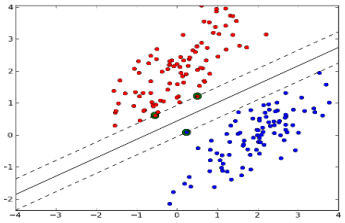
Machine Learning Journal



Decision trees



Backpropagation algorithm

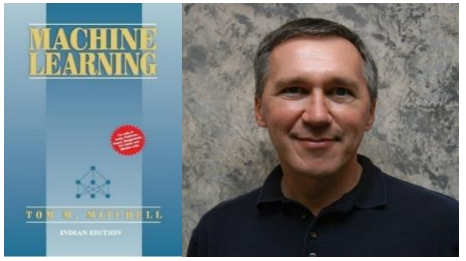


Support Vector Machine

11

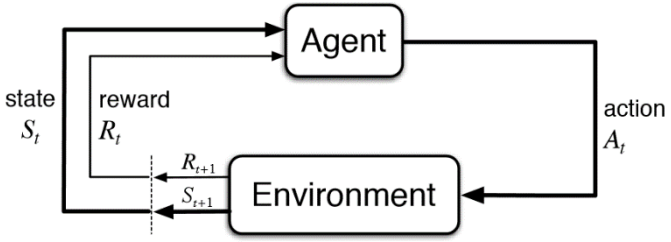
HISTORY OF MACHINE LEARNING

- **1997: Machine Learning Textbook (Mitchell)**
- 1998: Neural networks (Haykin)
- **1998**: **Reinforcement learning** (Sutton & Barto)
- 1999: Learning in graphical models (Jordan)
- 1999: Kernel machines (Schoelkopf & Smolar)
- **2001: Journal of Machine Learning Research (JMLR)**
- **2003**: **Boosting algorithms** (Freund)
- 2003: Information theory, inference, and learning algorithms (MacKay)
- 2005: Probabilistic Robotics (Thrun, Burgard, & Fox)

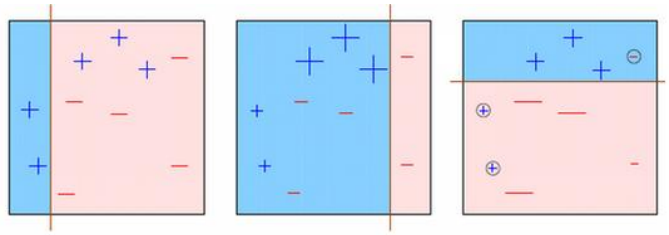


Machine Learning Textbook(Mitchell)

Journal of Machine Learning Research (JMLR)



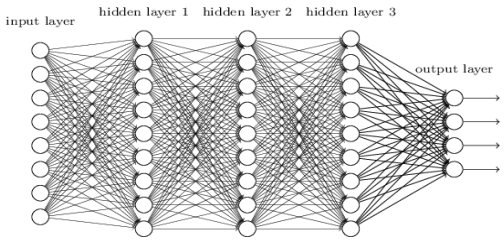
Reinforcement learning



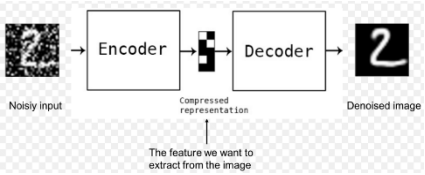
Boosting Algorithms

HISTORY OF MACHINE LEARNING

- **2006: Deep Neural Networks (DBNs) with Autoencoder (Hinton)**
- 2006: Pattern Recognition and Machine Learning (Bishop)
- 2008: Neural Networks and Learning Machines (Haykin)
- 2009: Probabilistic Graphical Models (Koller)
- 2009: Siri personal assistant (Apple)
- 2009: Google Car (Thrun)
- **2011**: **Watson AI supercomputer (IBM)**
- **2012: AlexNet (DCNN) wins ImageNet** (Alex Krizhevsky)
- 2012: DNNresearch deep learning (Hinton & Google)
- 2012: Large-scale image retrieval (Google)
- 2013: Human Brain Project HBP (EU)
- **2013: Quantum AI Lab for machine learning (Google)**
- **2014: Generative Adversarial Networks (Goodfellow)**
- 2015: Institute of Deep Learning (Baidu)

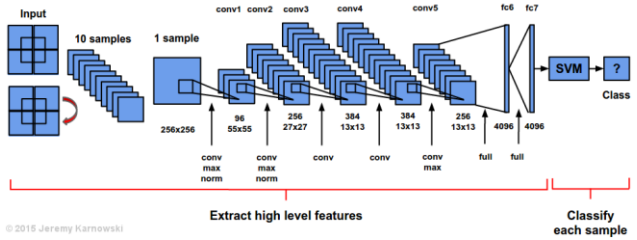


Deep Neural Netw

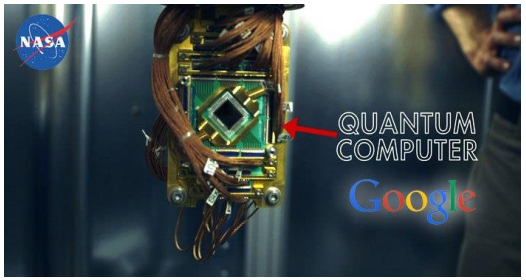


Autoencoder

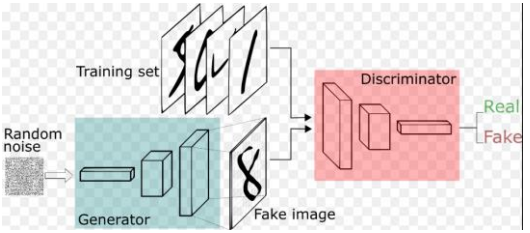
Watson AI supercomputer



AlexNet



Quantum AI Lab



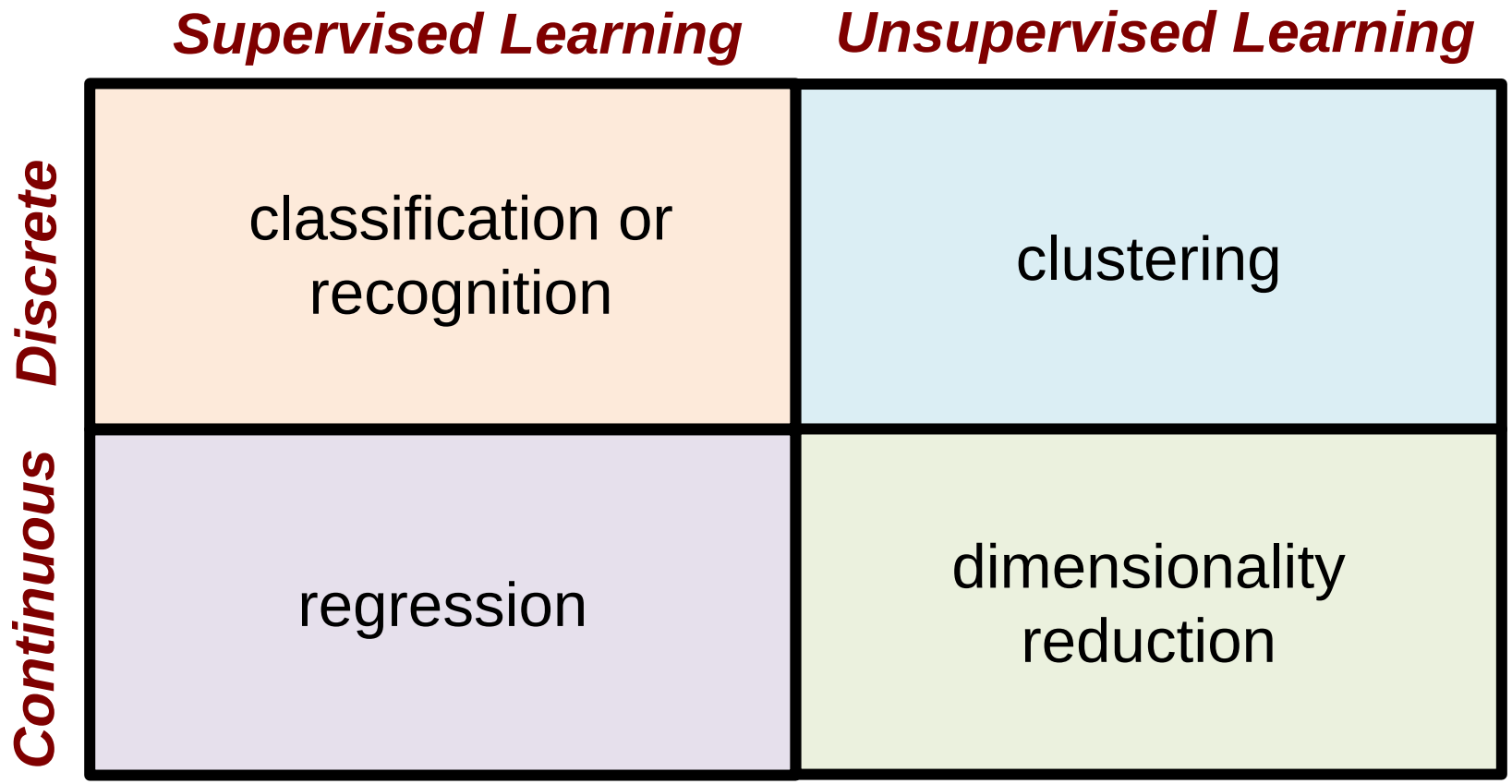
GANs

TYPES OF MACHINE LEARNING APPROACH

THREE DIFFERENT TYPES

- **Supervised (inductive) Learning**
  - Training data includes desired outputs
- **Unsupervised Learning**
  - Training data does not include desired outputs
- **Reinforcement Learning**
  - Rewards from sequence of actions

TYPES OF MACHINE LEARNING



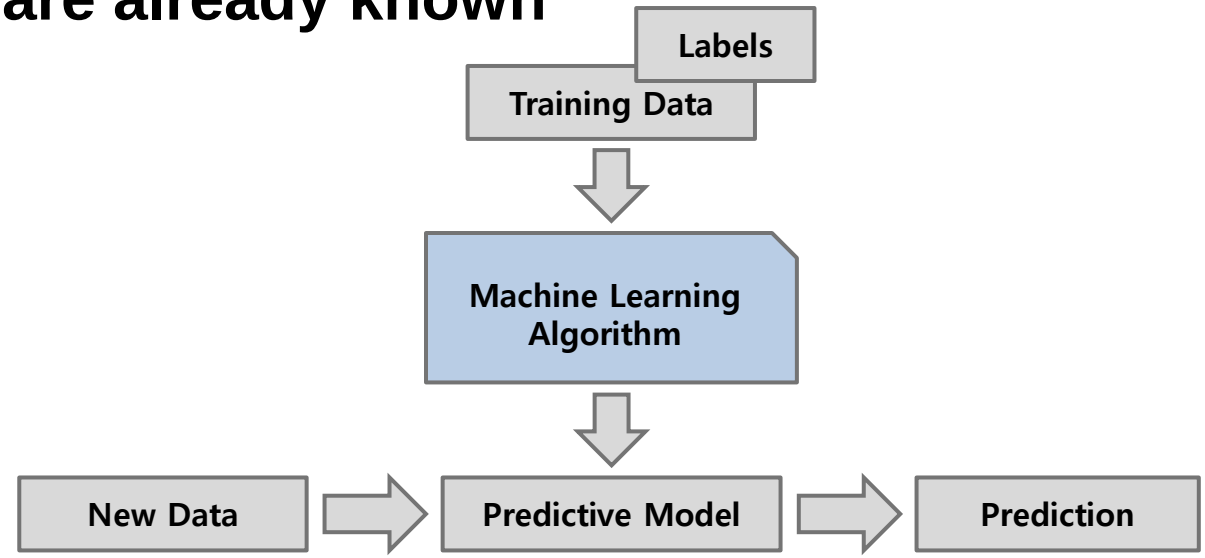
머신러닝 학습 방법 및 모델 구조

학습 방법	학습 문제의 예
감독 학습	**인식, 분류, 진단, 예측, 회귀분석**
무감독 학습	**군집화, 밀도추정, 차원 축소, 특징추출**
강화 학습	**시행착오, 보상 함수, 동적 프로그래밍**

모델 구조	표현	기계학습 모델 예
논리식	명제 논리, 술어논리, Prolog 프로그램	Version Space, 귀납적 논리 프로그래밍(ILP)
규칙	If-Then 규칙, 결정규칙	AQ
함수	Sigmoid, 다항식, 커널	신경망, RBF망, SVM, 커널머신
트리	유전자 프로그램, Lisp 프로그램	결정 트리, 유전자 프로그래밍, 뉴럴트리
그래프	방향성/무방향성 그래프, 네트워크	확률그래프 모델, 베이지안망, HMM

SUPERVISED LEARNING

- **Learn a model from labeled training data**
- **Make classification/predictions about new (unseen) data**
- **“Supervised” refers to a set of samples where the desired output signals (labels) are already known**
- **Two categories**
  - Classification task
  - Regression task



SUPERVISED LEARNING (FORMAL DEFINITION)

- **Given examples of a function *(X, F(X))***

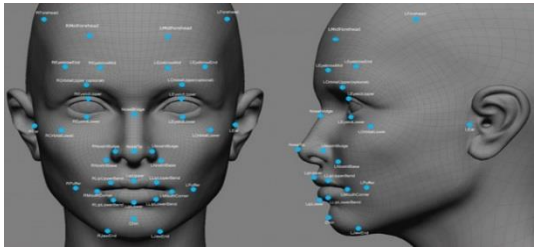
- **Predict function *F(X)* for new examples *X***
  - Discrete *F(X)*: Classification
  - Continuous *F(X)*: Regression
  - *F(X)* = Probability(*X*): Probability estimation

Example Applications

- **Credit risk assessment**
  x: Properties of customer and proposed purchase.
  f(x): Approve purchase or not.

- **Disease diagnosis**
  x: Properties of patient (symptoms, lab tests)
  f(x): Disease (or maybe, recommended therapy)

- **Face recognition**
  x: Bitmap picture of person's face
  f(x): Name of the person.



- **Automatic Steering**
  x: Bitmap Picture of road surface in front of car.
  f(x): Degrees to turn the steering wheel.

SUPERVISED LEARNING-CLASSIFICATION

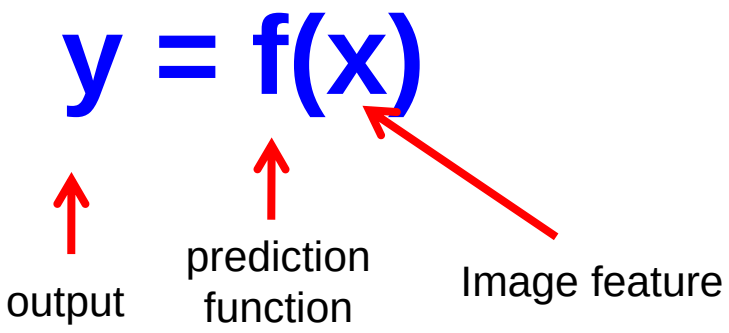
- **Apply a prediction function to a feature representation of the image to get the desired output:**

f() = “apple”

f() = “tomato”

f() = “cow”

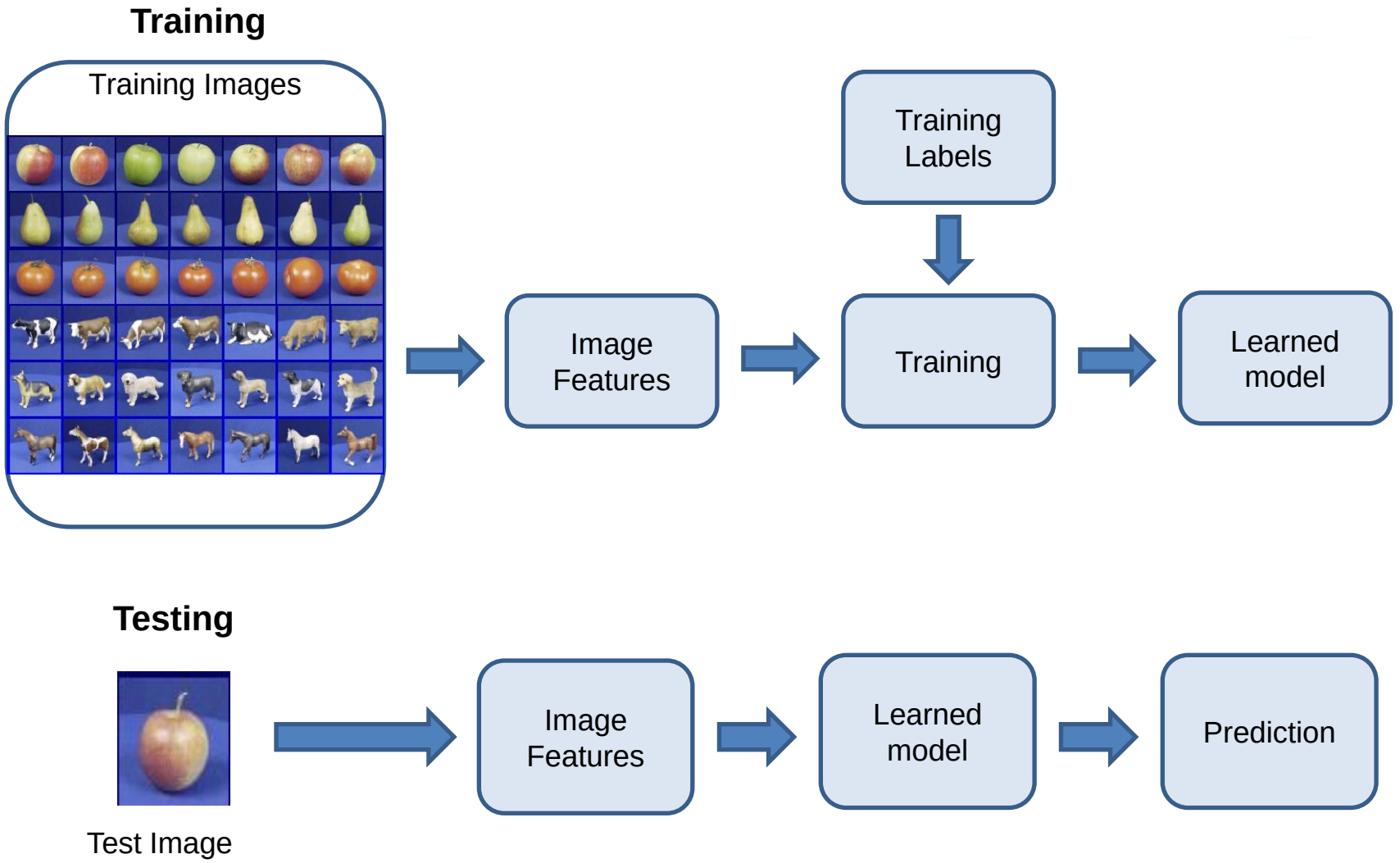
SUPERVISED LEARNING-CLASSIFICATION



- **Training:** given a *training set* of labeled examples $\{(x_1,y_1), \ldots, (x_N,y_N)\}$, estimate the prediction function $f(\cdot)$ by minimizing the prediction error on the training set

- **Testing:** apply $f(\cdot)$ to a never before seen *test example* x and output the predicted value $y = f(x)$

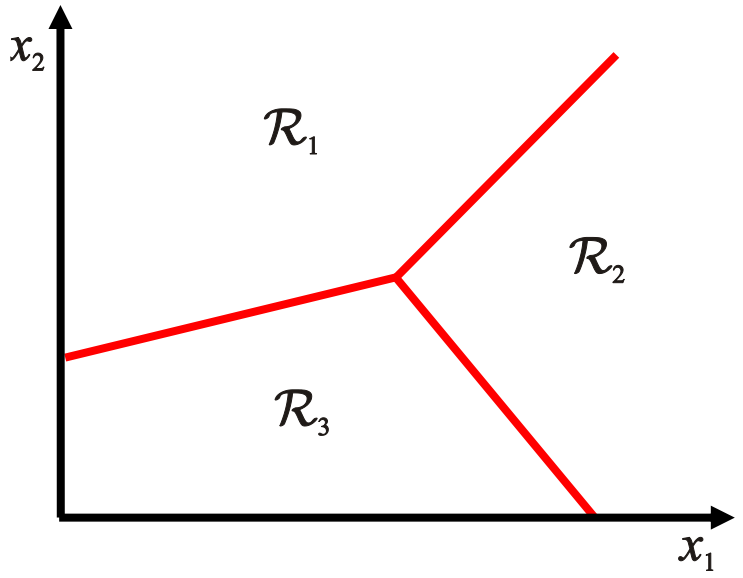
SUPERVISED LEARNING-CLASSIFICATION



SUPERVISED LEARNING-CLASSIFICATION FROM GEOMETRIC PERSPECTIVE

- **Assign input vector to one of two or more classes**

- **Any decision rule divides input space into *decision regions* separated by *decision boundaries***

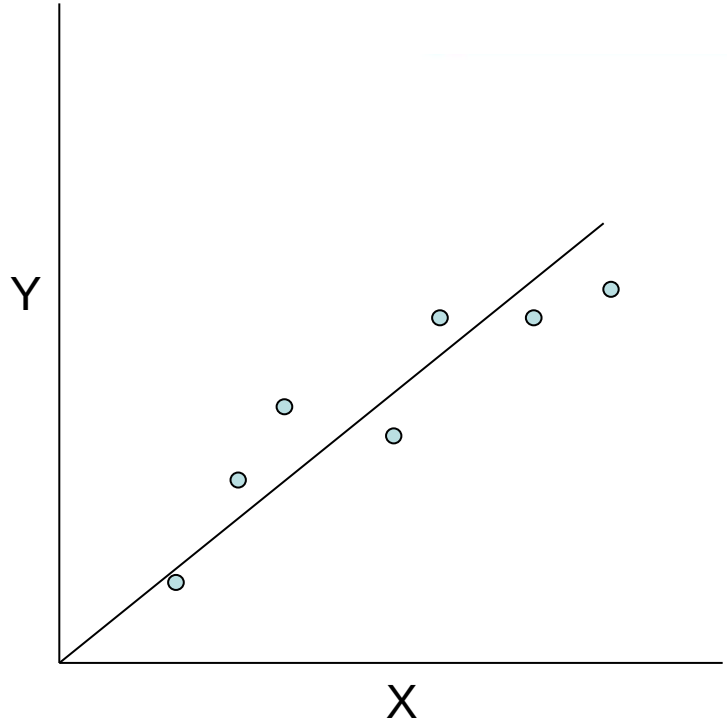


SUPERVISED LEARNING-CLASSIFICATION (TYPES OF SOME CLASSIFIERS)

- **K-Nearest Neighbor (K-NN)**
- **Support Vector Machines (SVMs)**
- **Boosted Decision Trees**
- **Neural networks (NNs)**
- **Naïve Bayes**
- **Logistic regression**
- **Randomized Forests**
- **Etc.**

SUPERVISED LEARNING - REGRESSION

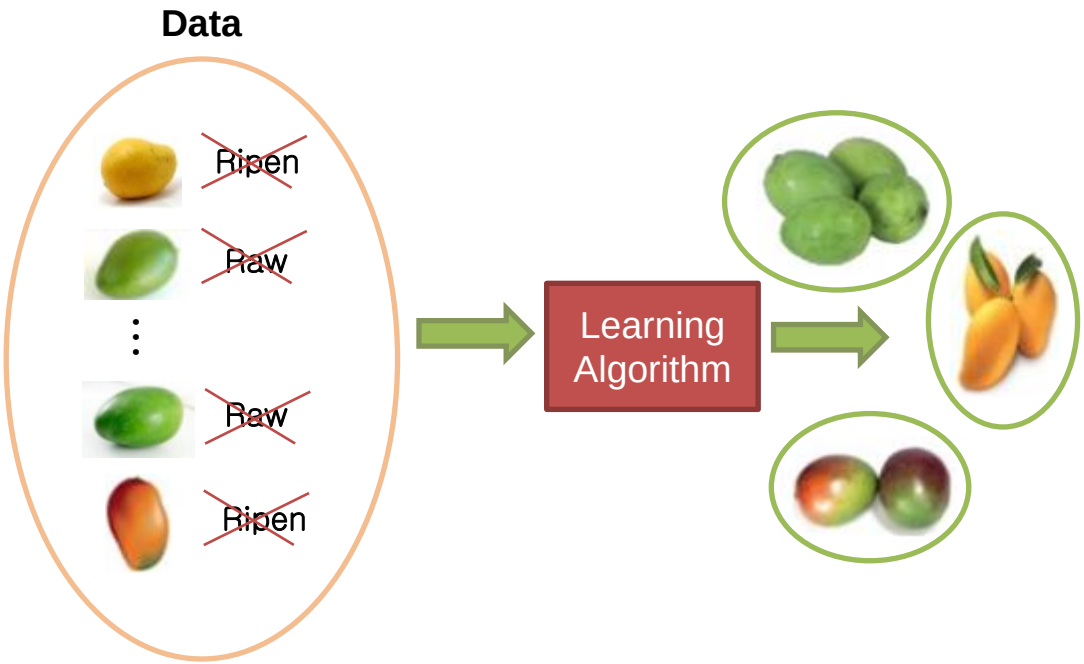
- **Given an input x we would like to compute an output y**
  - Given a number of predictor (explanatory) variables
  - Outcome (response variable)
- **For example:**
  - Predict height from age
  - Predict Google's price from Yahoo's price
  - Predict distance from wall using sensor readings



Note that now Y can be **continuous**

UNSUPERVISED LEARNING

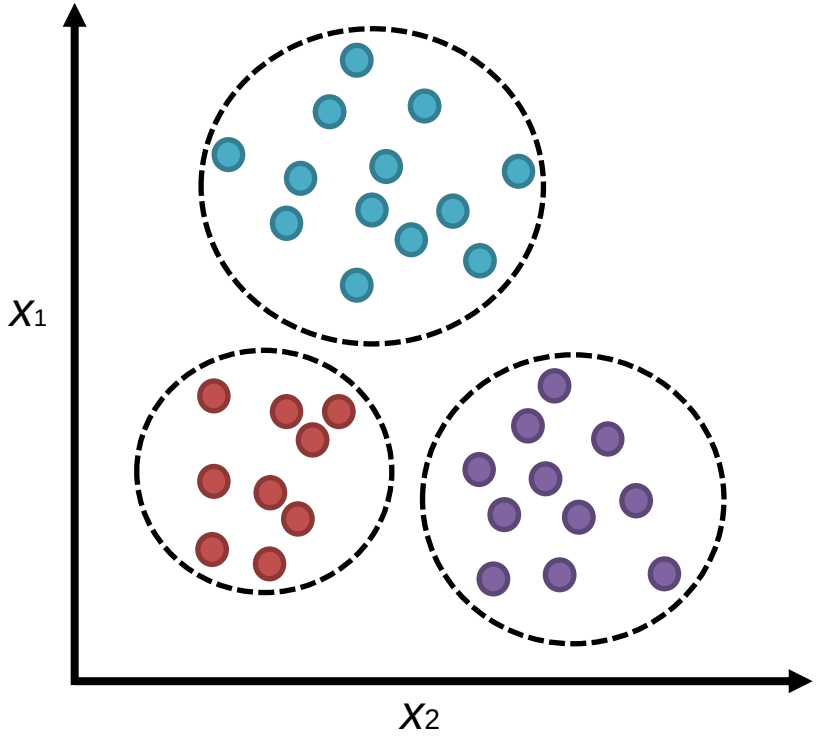
- **We don’t know the *right answer* before we train our model**
- **Dealing with *unlabeled* data or data of *unknown structure***
- **Using supervised learning, we can explore the *structure of our data* to extract meaningful information without guidance…**
  - Known outcome variable
  - Reward function



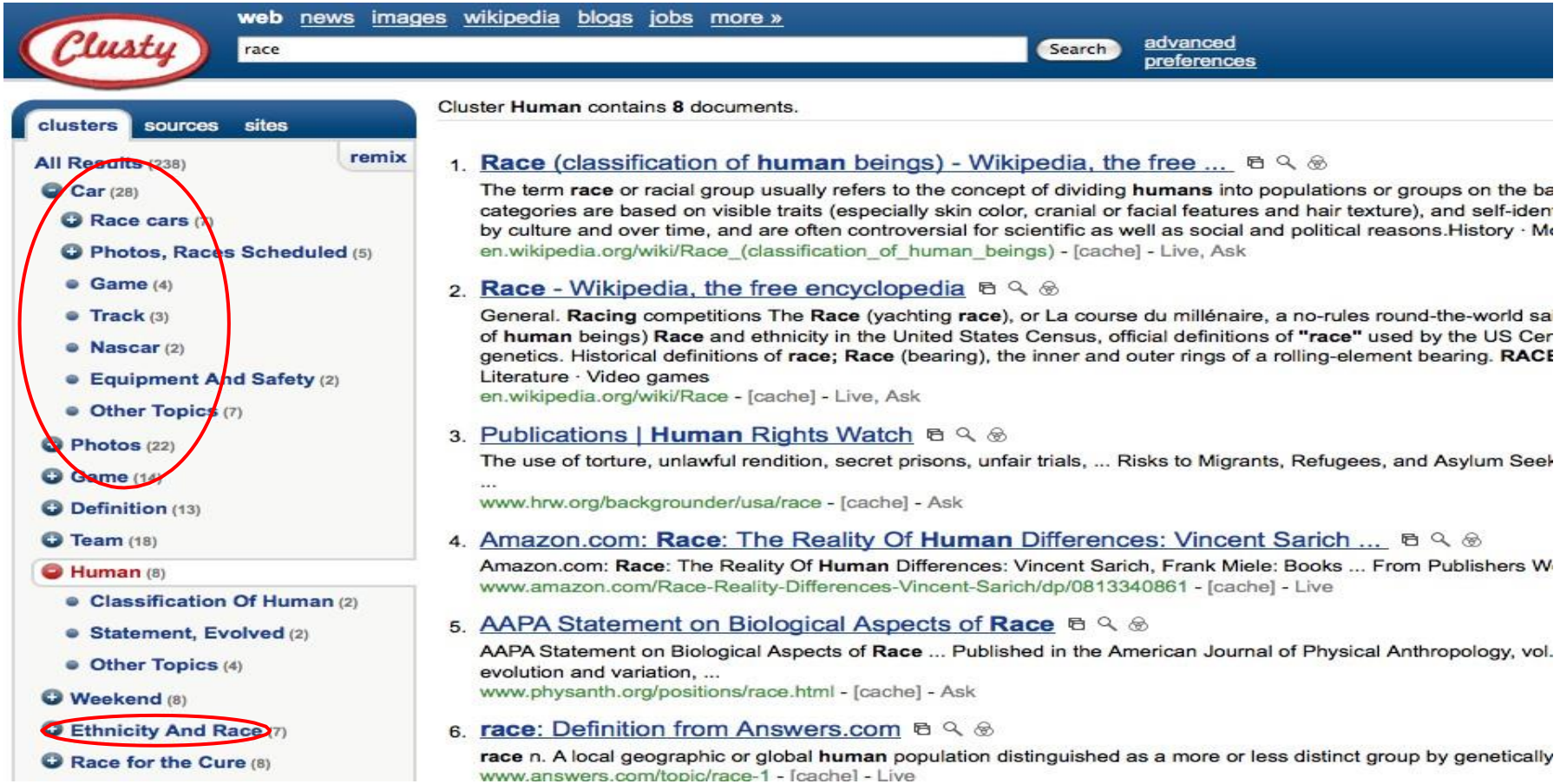
UNSUPERVISED LEARNING - CLUSTERING

- ***Clustering*** is an exploratory data analysis that organizes a pile of information into ***meaningful subgroups* (*clusters*)** without having any prior knowledge of their group memberships

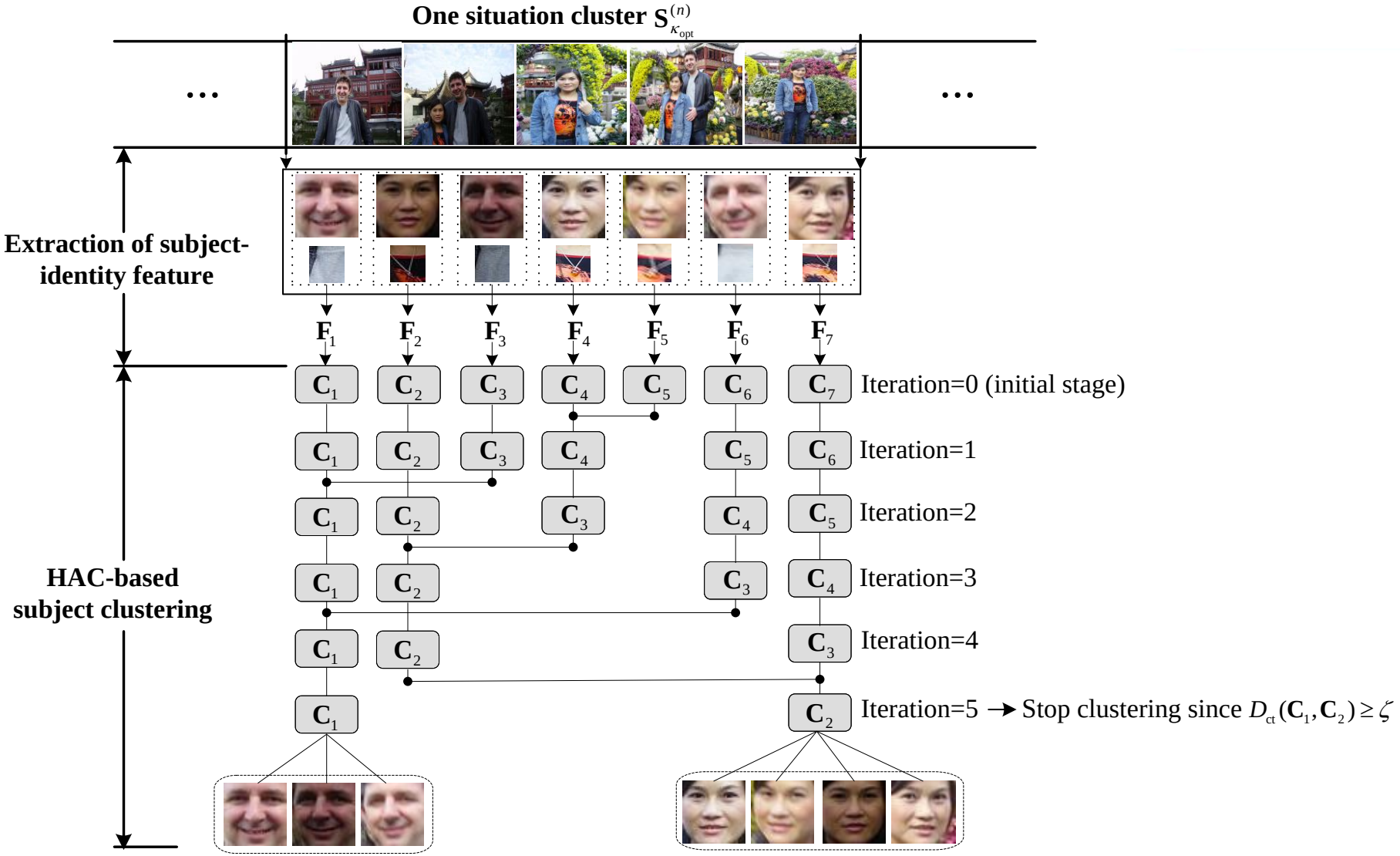
- The figure (on right-hand side) illustrates how clustering can be applied to organizing unlabeled data into three distinct groups based on similarity of their features x_1 and x_2



UNSUPERVISED LEARNING – CLUSTERING WEB SEARCH RESULTS



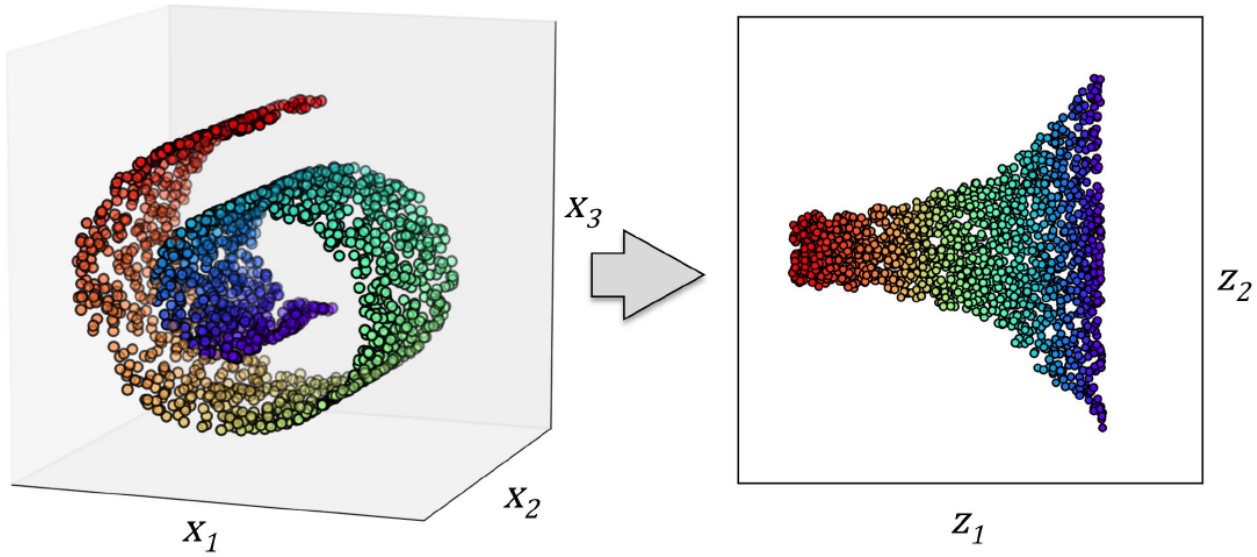
UNSUPERVISED LEARNING – CLUSTERING PHOTO CATEGORIZATION BASED ON PERSON



UNSUPERVISED LEARNING-DIMENSIONALITY REDUCTION

- **For feature processing to remove data from noise**

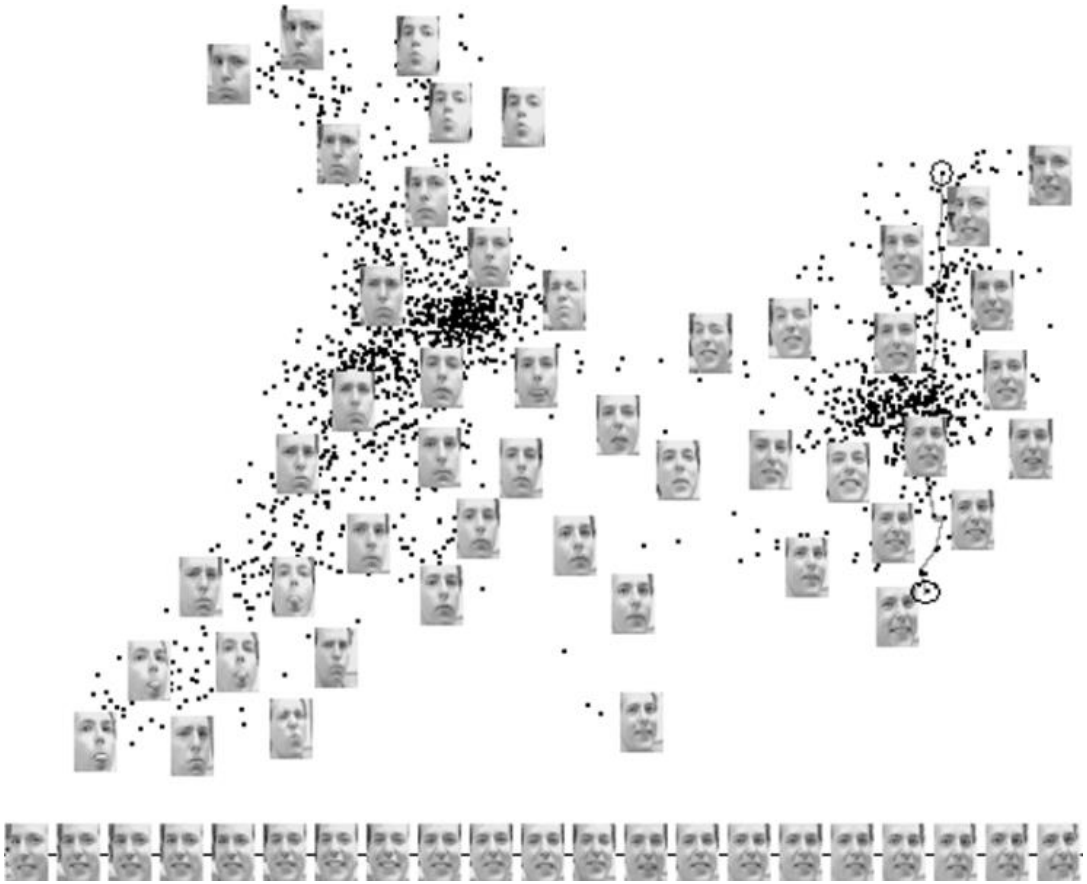
- **Compress the data onto a smaller dimensional subspace while retaining most of the relevant information**



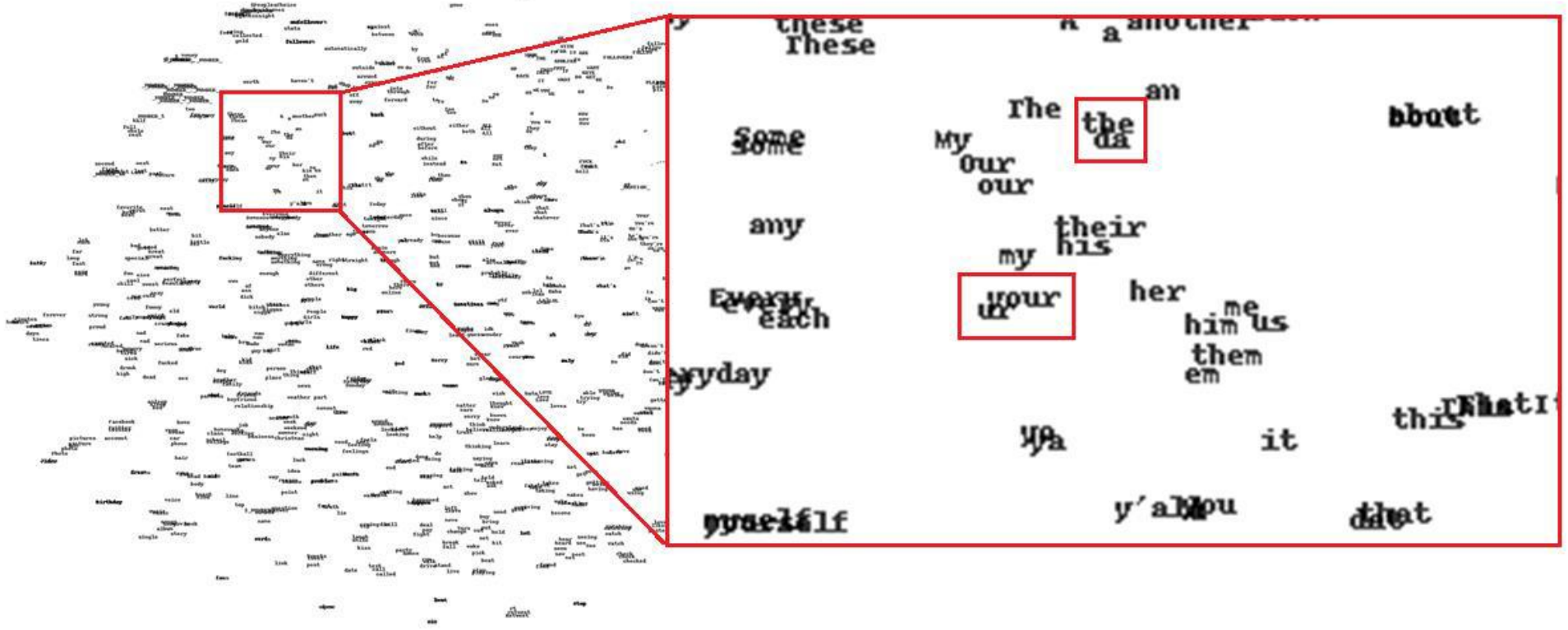
UNSUPERVISED LEARNING-DIMENSIONALITY REDUCTION MAINFOLD LEARNING

Images have thousands or millions of pixels

Can we map each image into subspace (manifold) such that similar images are near each other?



UNSUPERVISED LEARNING-DIMENSIONALITY REDUCTION WORD EMBEDDING FOR NLP

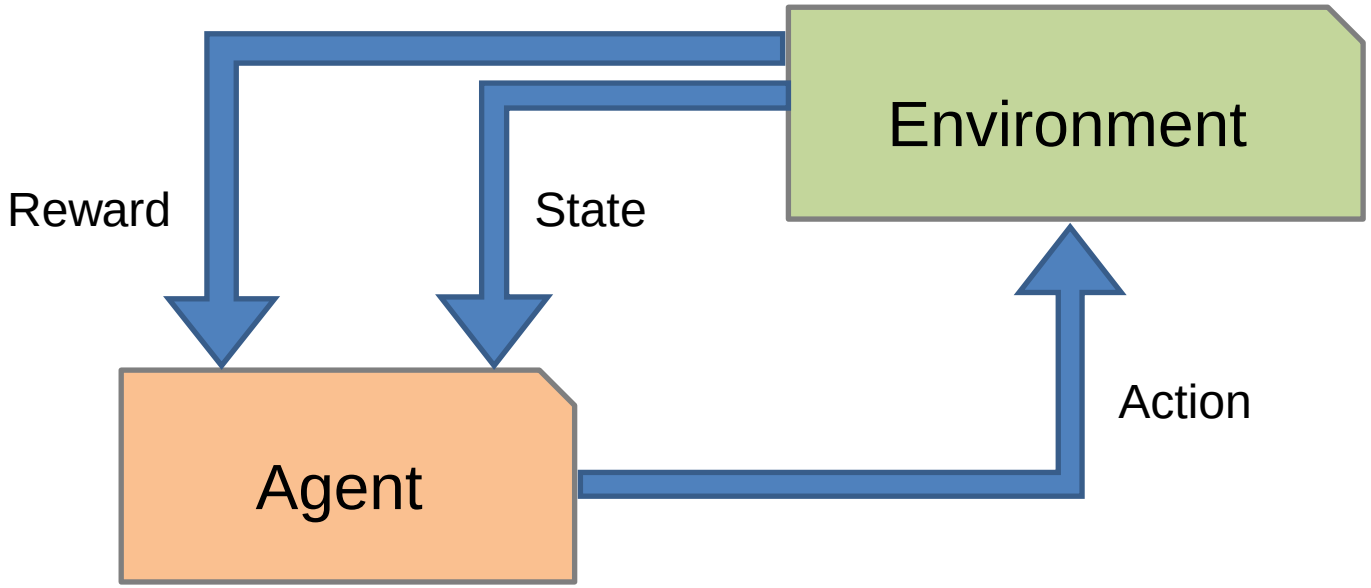


2-D projection of the top 100 words used on Twitter

REINFORCEMENT LEARNING

- Goal is to develop a system (***agent***) that improves its performance based on ***interaction with environment***
- Instead of using ground truth label, a ***reward function*** is used

  → Measuring of how well the action
- Through the interaction with the environment, an agent can learn a series of actions that ***maximizes the reward*** via an exploratory ***trial-and-error*** approach



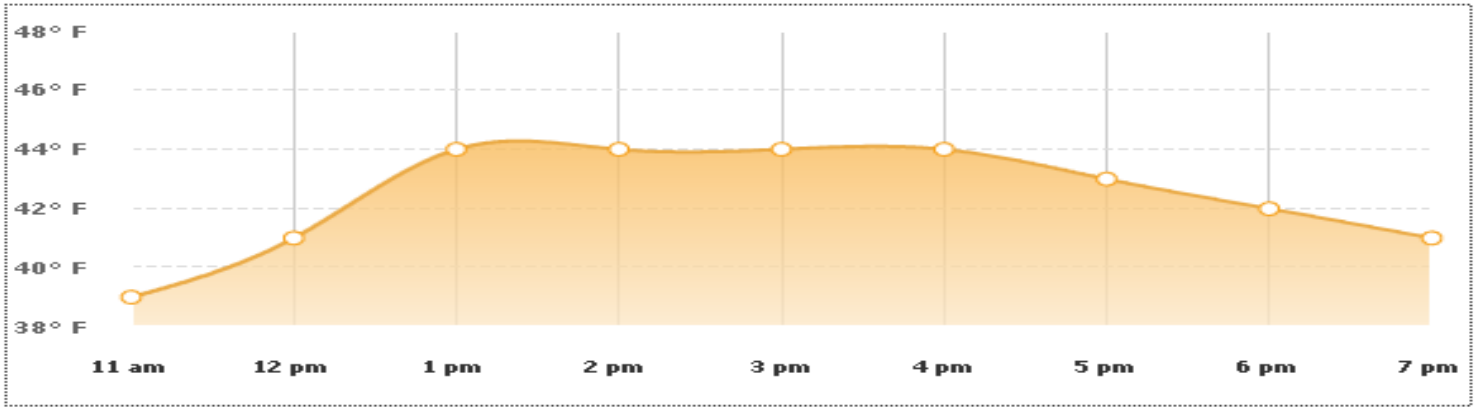
Pop Quiz 1

- **Supervised/Unsupervised?** **Labels?** **Classification/Regression?**

Supervised

Temperature

Regression



Temperature prediction for weather forecasting

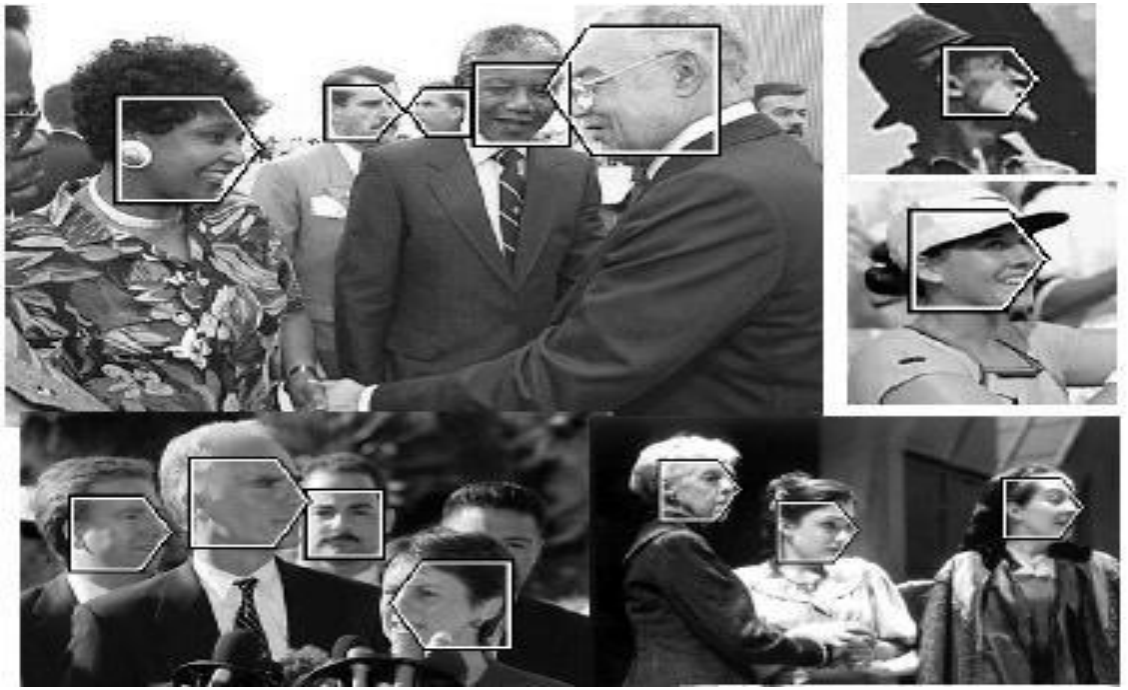
Pop Quiz 2

- **Supervised/Unsupervised?** **Labels?** **Classification/Regression?**

Supervised

Pos: face , Neg: non-face

classification



Face Detection