

Machine Learning

42041501

Dr. Shuang LIANG

Today's Topics

- Course introduction
- What is machine learning?
- Applications
- A bit of history
- Machine learning framework
- The learning map

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Course Information

- Schedule
 - Every Wednesday, class 10-12
 - 7 pm - 21:25 pm
 - Week 1 to 17
- Location
 - Rm 434, Jishi Building
- Office hours
 - 16:30-17:30, Tuesday

Course Information

- Theory
- Hands-on tutorials
- Lab & Discussion
- Presentations



Who we are

- Instructors



Shuang LIANG
梁爽



Weixiong RAO
饶卫雄 (替补)

- Teaching Assistants

- TBA...
- Please resort to TA for all programming issues

Who we are

- Dr. Shuang LIANG
 - Associate professor, SSE, Tongji
 - Education
 - B.Sc in Computer Science, Zhejiang University, 1999-2003
 - PhD in Computer Science, Nanjing University, 2003-2008
 - Visit in Utrecht University, The Netherlands, 2007, 2008
 - Research Fellowship
 - The Chinese University of Hong Kong, 2009
 - The Hong Kong Polytechnic University, 2010-2011
 - The City University of Hong Kong, 2012
 - Contact
 - Office: Room 314, Jishi Building, Jiading Campus
 - Email: shuangliang@tongji.edu.cn
 - Tel: 69585491

Pre-requisite

- Proficiency in Python
- Some high-level familiarity with C/C++
- College Calculus
- Linear Algebra

Grading Policy

Please do NOT be absent
for more than **5** times,
otherwise you will fail.

Item	Percentage
Class participation	10%
Assignment ×3	30%
Course Project & Quiz	20% + 10%
Exam	30%

- *Late policy*
 - *7 free late days*
 - *Use up to 4 late days per assignment*
 - *Afterwards, 25% off per day late*
 - *No late days for course project*

Collaboration Policy 禁止抄袭剽窃

- **Rule 1:** Don't look at solutions or code that are not your own; everything you submit should be your own work
- **Rule 2:** Don't share your solution code with others; however discussing ideas or general strategies is fine and encouraged
- **Rule 3:** Indicate in your submissions anyone you worked with
- Turning in something late / incomplete is better than violating the collaboration policy

Collaboration Policy 禁止抄袭剽窃

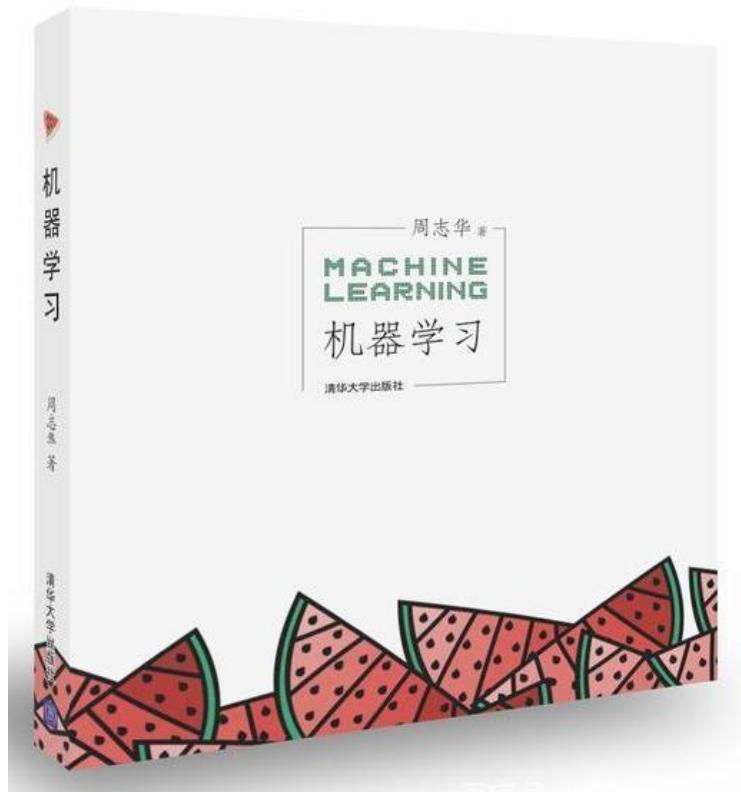
- You may discuss general techniques with other students
- You may give or receive help understanding assignments and debugging work
- You may copy examples from the lecture notes and then change them to meet the assignment requirements
- You may *NOT* copy code or allow anyone to copy your code

Collaboration Policy 禁止抄袭剽窃

- Cheating:
 - Copying code from other students or internet sources
 - Copying text from other students for homework or other questions
 - Copying text from the internet or a book for homework or other reports

Materials

- The course slides
- Reference materials
- Textbook
 - 《机器学习》, 周志华
清华大学出版社

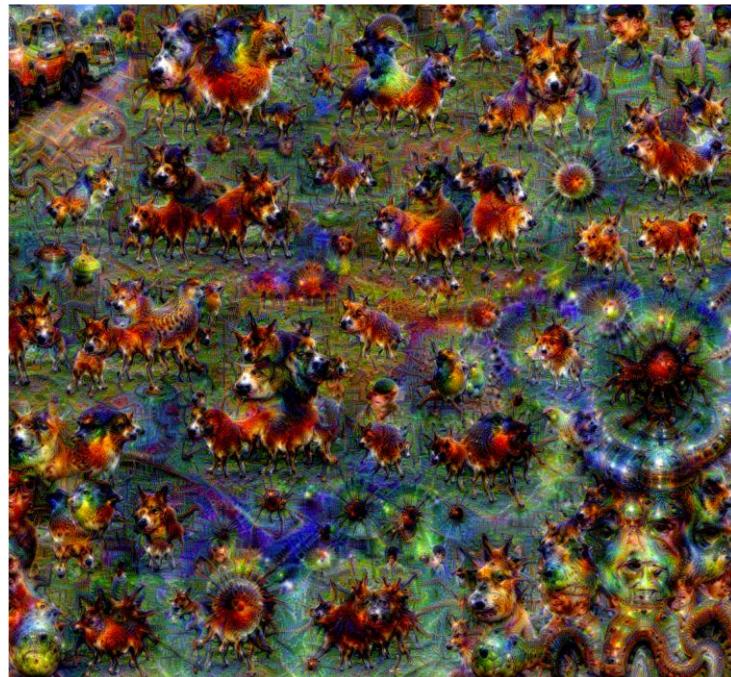


What is the point of studying this course?

- What should you be able to do after this course?
 - Understand why and how it is possible to do machine learning
 - Understand how to write from scratch, debug and train machine learning models
 - Focus on practical techniques for training these models at scale, (e.g. will touch on GPUs, distributed optimization, differences between CPU vs. GPU, etc.)
 - Also look at state of the art software tools such as TensorFlow, and PyTorch

What is the point of studying this course?

- Fun
 - Some fun topics and effects



What Capabilities can be Improved in this Course?

- Theoretical analysis
 - Reasoning ability
 - Summarizing ability
-
- Communication
 - Presentation
 - Expression



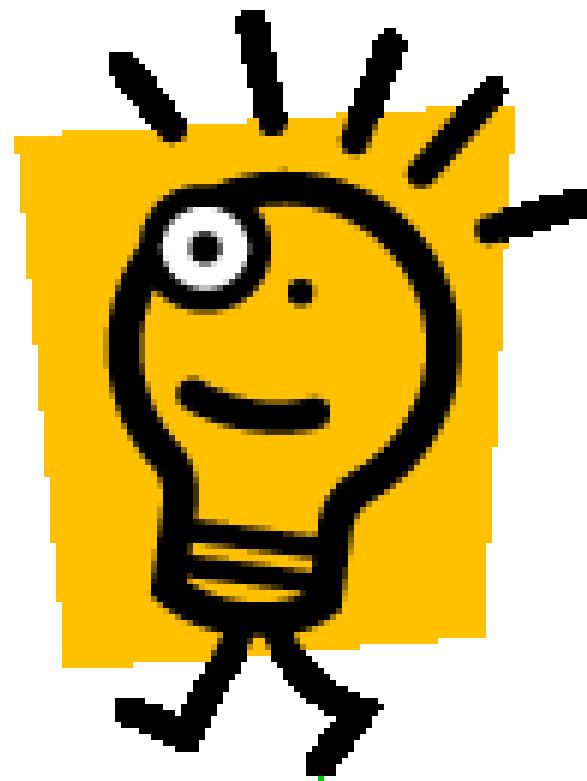
Class Group chat

- Course Group
 - WeChat
- Rename as
 - “studentID-name”

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What is machine learning?



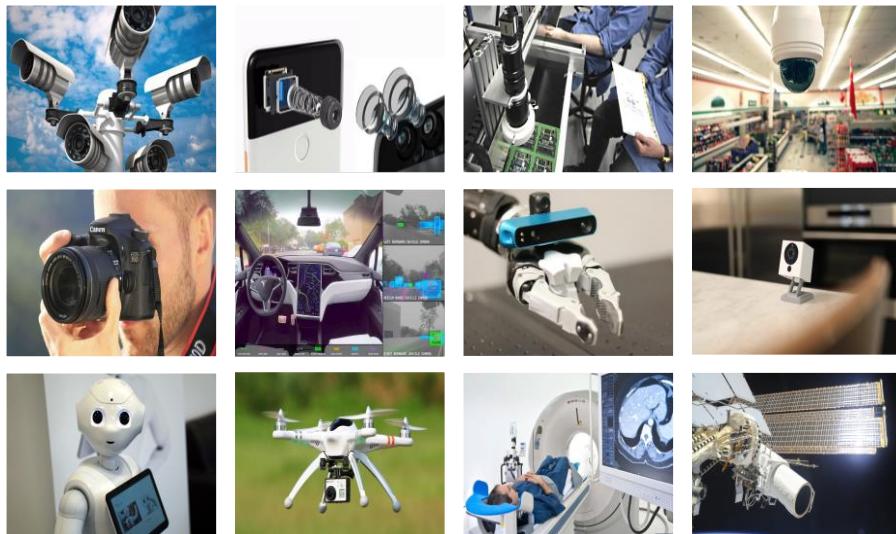
How do human make a decision?

- How to pick a “good” watermelon?
- How do you know you have a cold?
- Can you pick out the apple from bananas?
- You are *trained* from the experience
- You *learn knowledge* to make good *decisions*
- We could like to give *similar capabilities* to machines

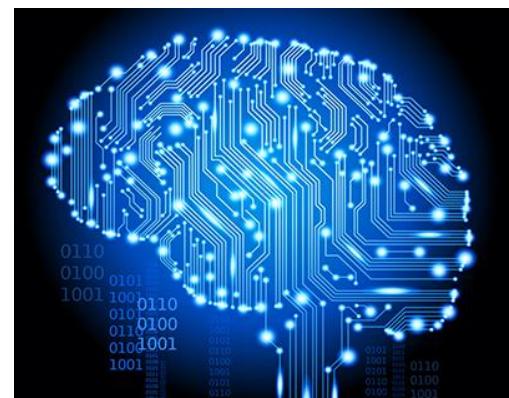


Sensing like human

- Human uses **eyes** and their **brains**
- Computer uses **cameras** and **computation**



“Eyes”



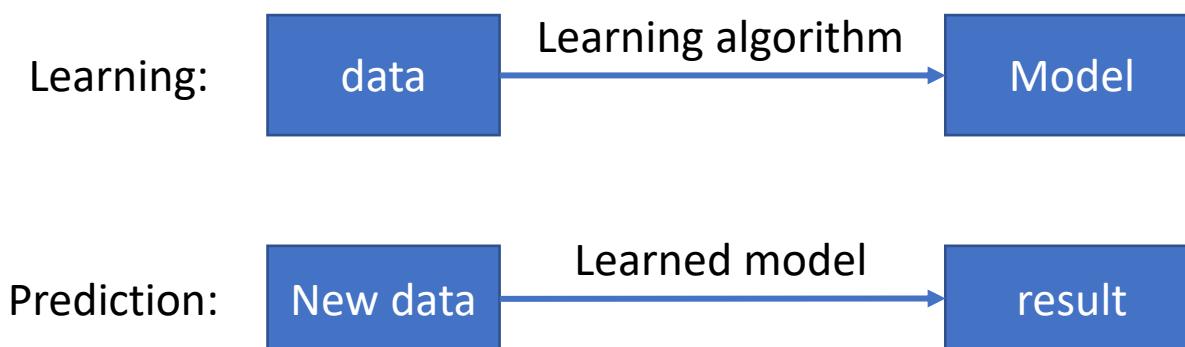
“Brain”

Objects
Activities
Scenes
Locations
Text
Faces
Gestures
Motions
Emotions...

What is machine learning?

- One possible definition

“a set of methods that can automatically detect patterns in data, and then use the uncovered patterns to predict future data, or to perform other kinds of decision making under uncertainty.”



Speech recognition case

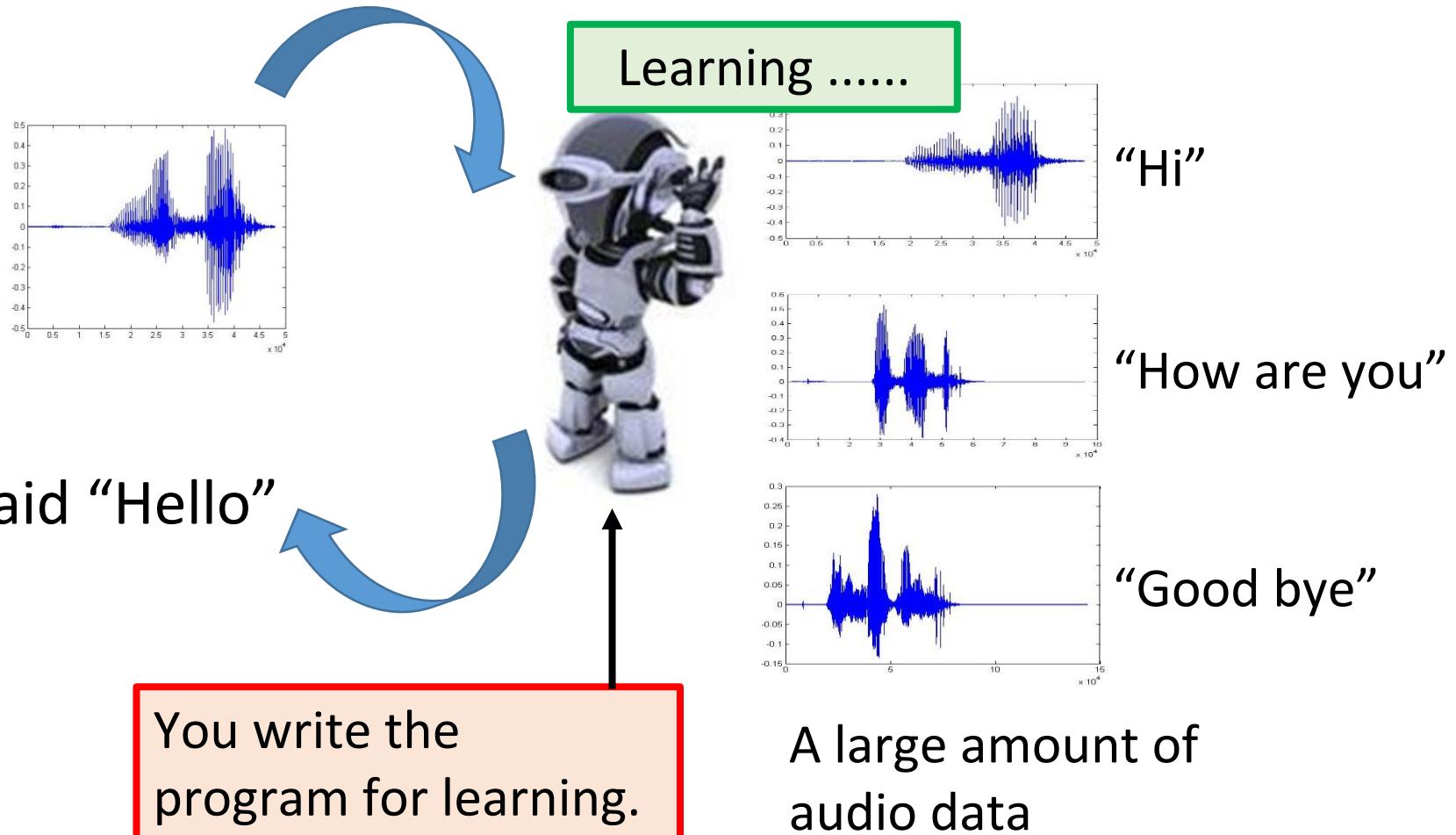
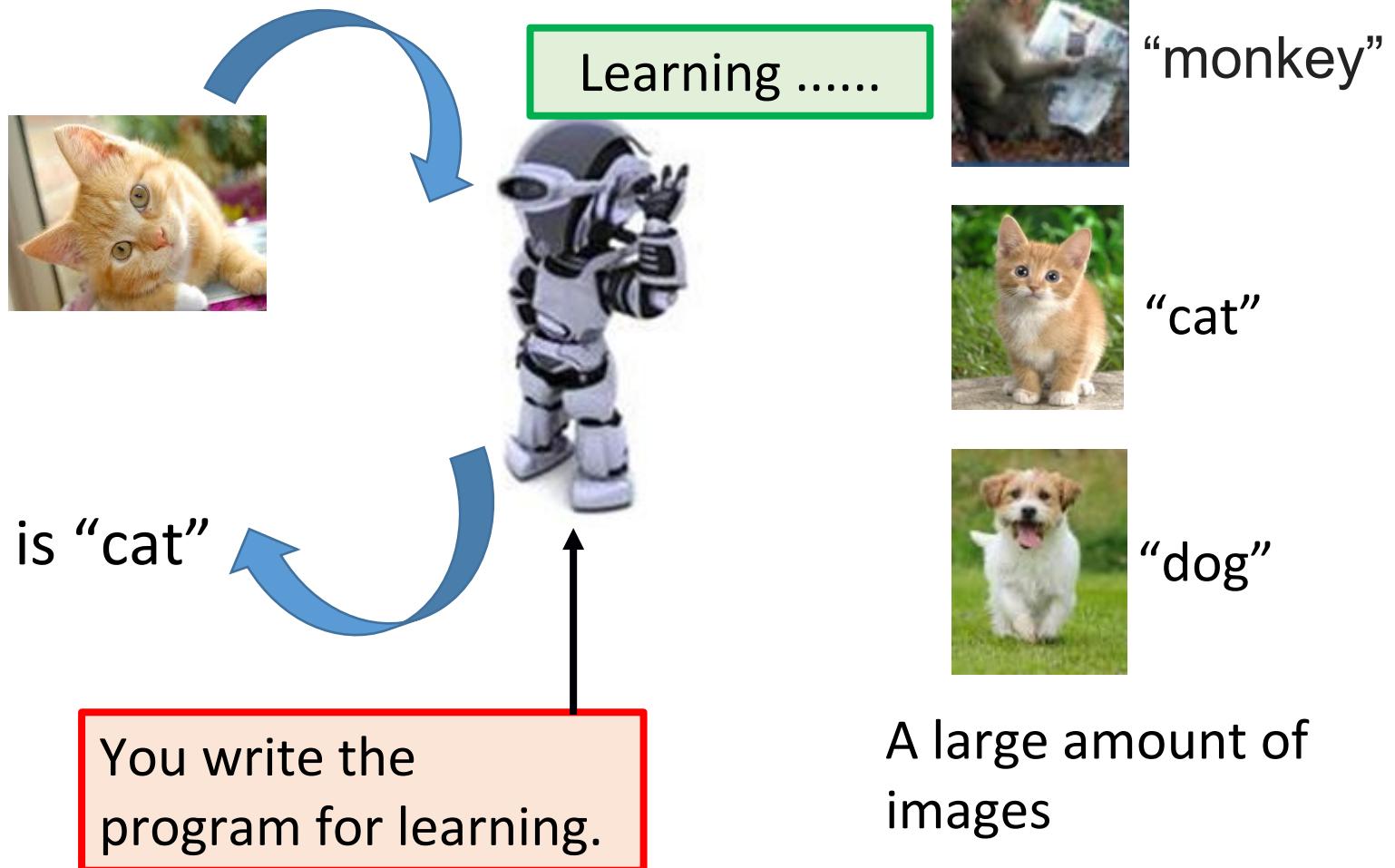
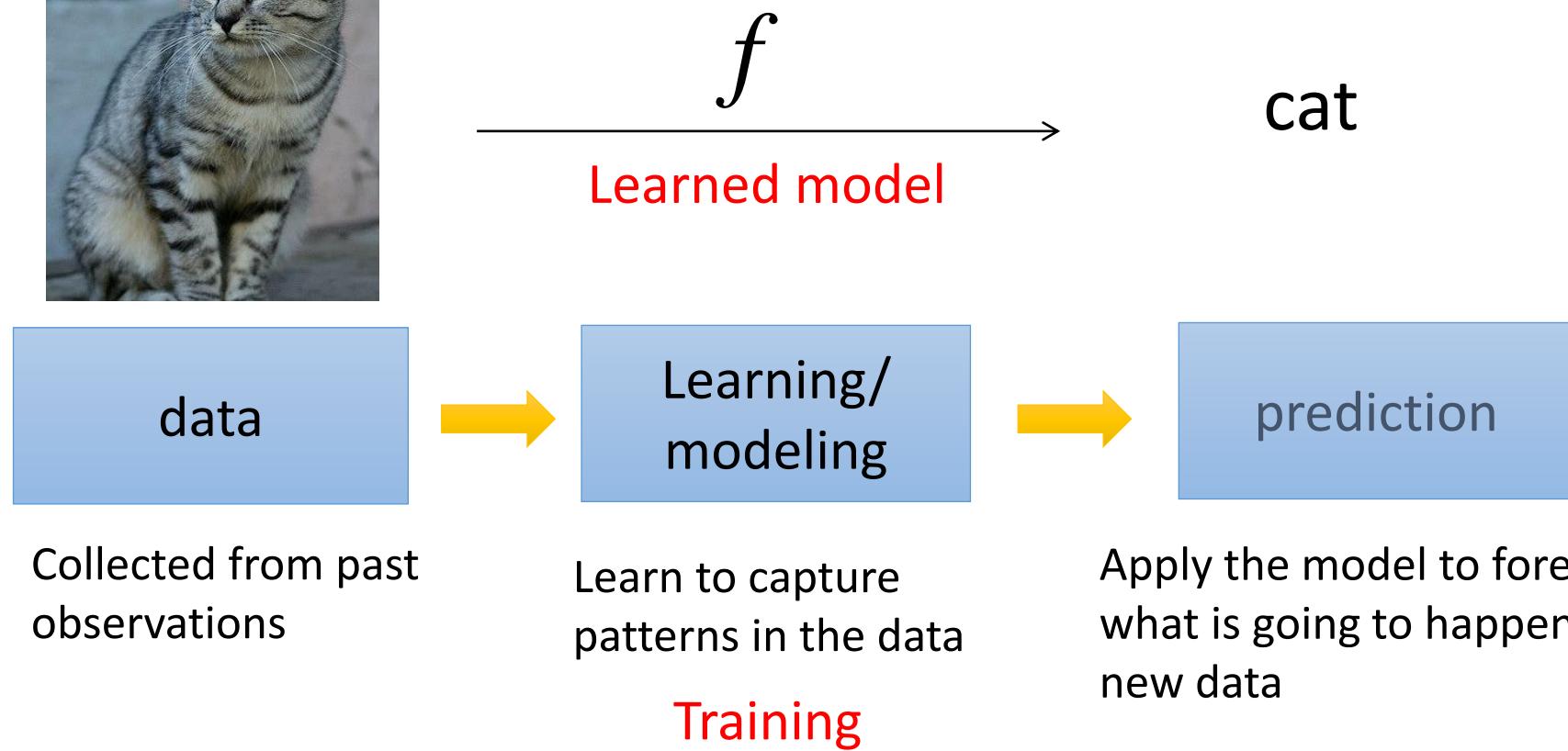


Image recognition case

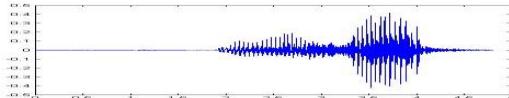


Machine learning process



Machine learning ≈ Looking for Function (model)

- Speech Recognition

$f($ ) = “How are you”

- Image Recognition

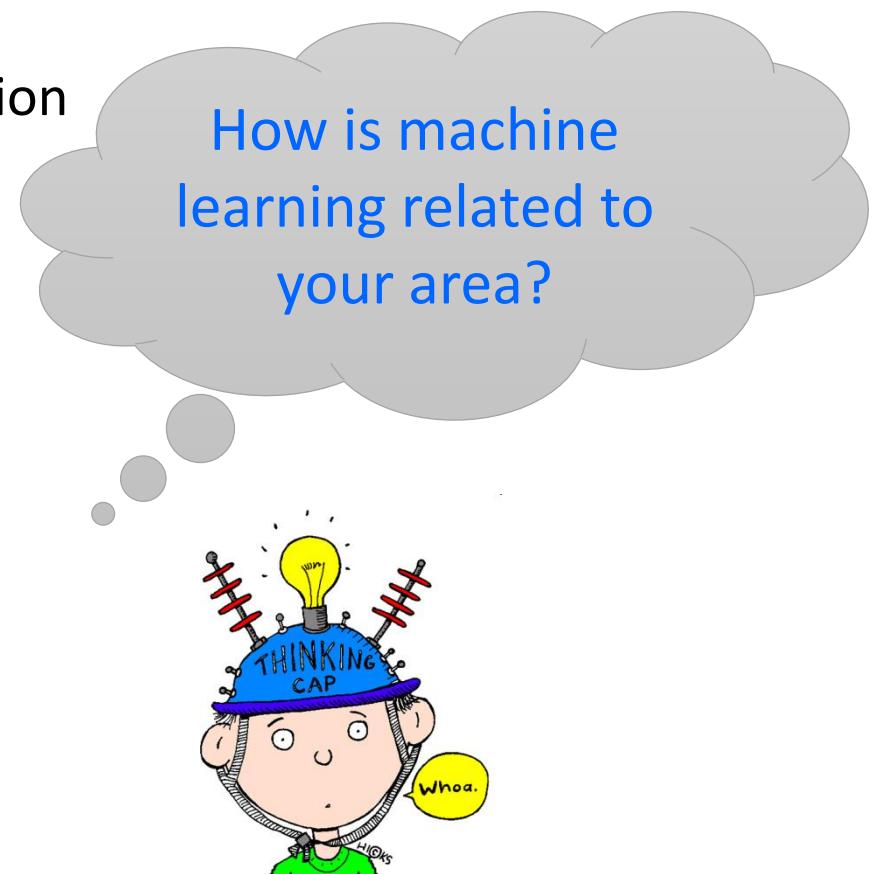
$f($ ) = “Cat”

- Playing Go

$f($ ) = “5-5”
(next move)

Related Areas

- Brain science
- Image analysis and computer vision
- Language modeling
- Speech modeling
- Handwriting recognition
- Risk management
- Medical imaging
- Web analytics
- Recommender engines
- Financial modeling
- Intelligent management
-



Related concepts

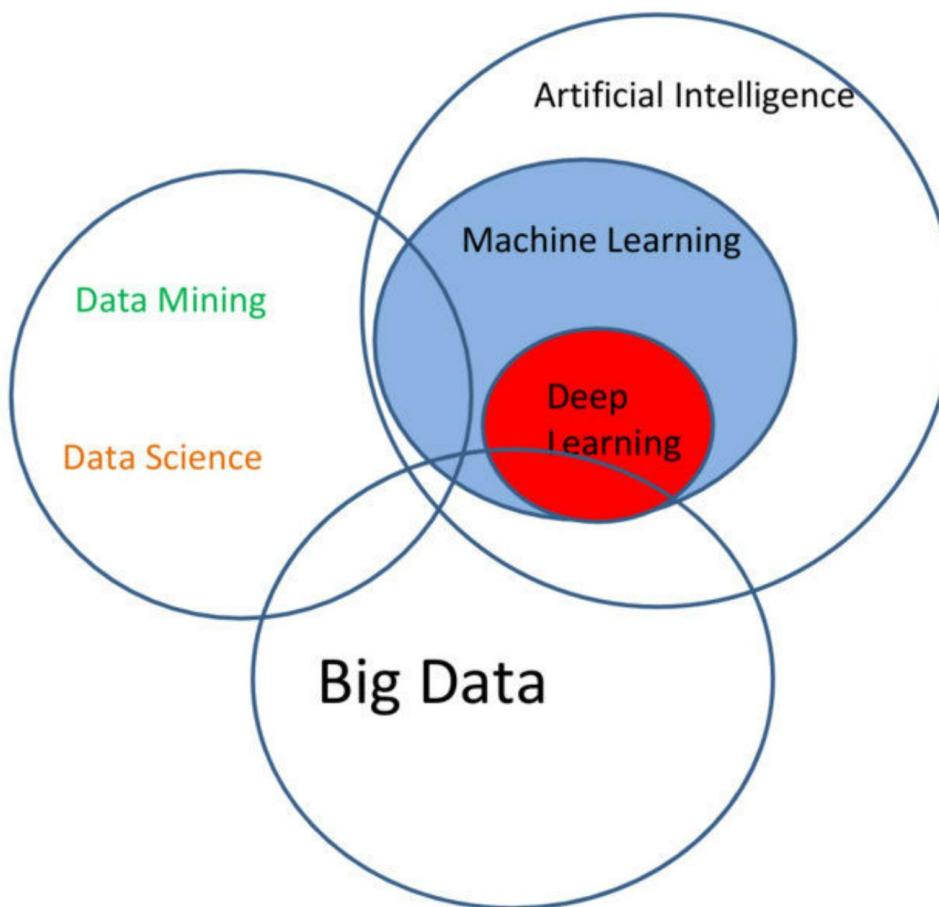
- Artificial intelligence
 - Final GOAL of machine intelligence
- Pattern recognition
 - Early term from 70s/80s, heuristic methods involved
- Machine learning
 - New term from 90s, data-driven, learn a model to predict
- Data mining
 - Find out knowledge from big data, may resort to machine learning methods, but not limited to.
- Deep learning
 - The new wave of machine learning techniques based on convolutional neural networks



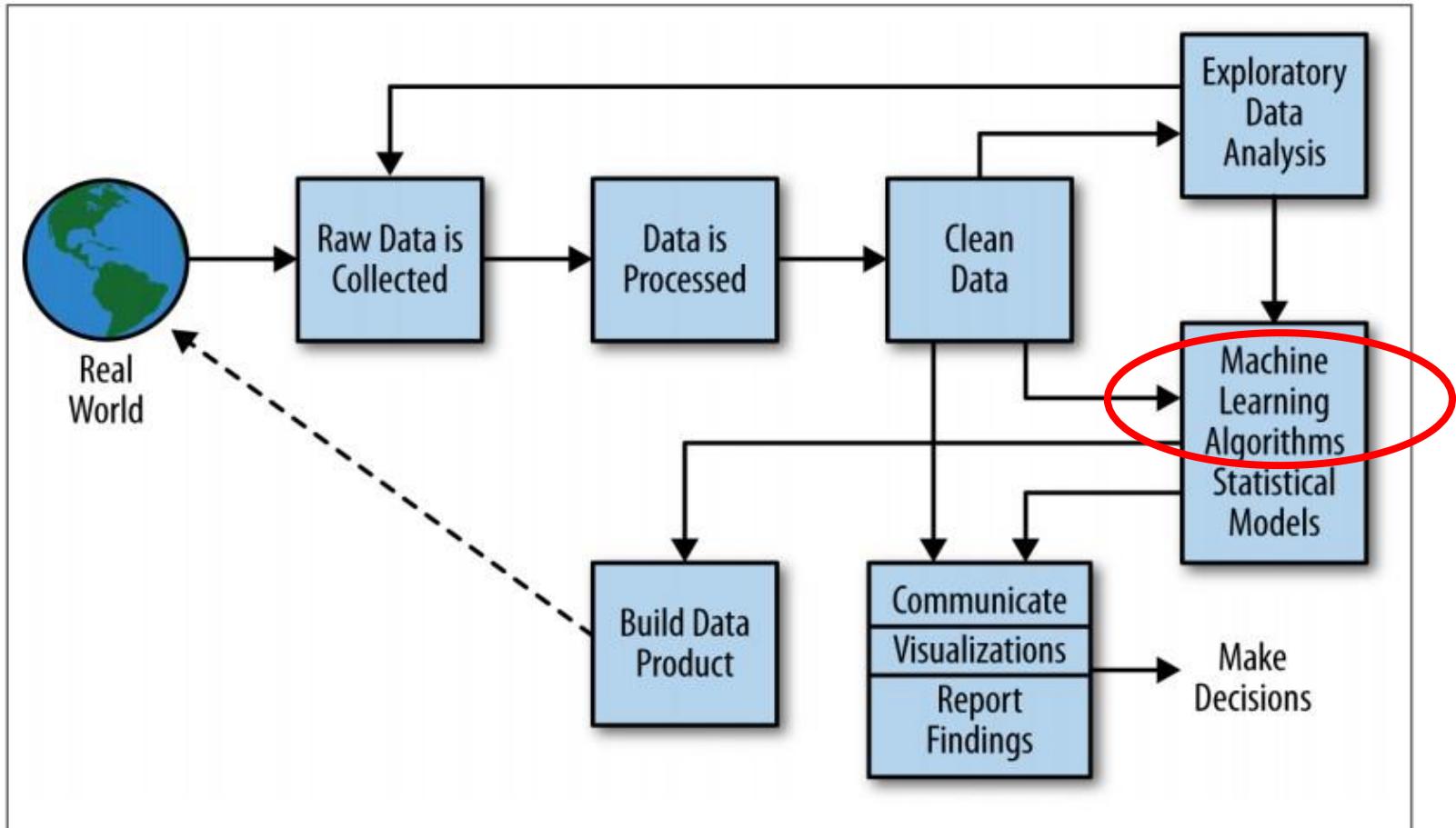
Can you tell the differences among them?

Related concepts

- Relationship between concepts



ML is only a small part!



Today's Topics

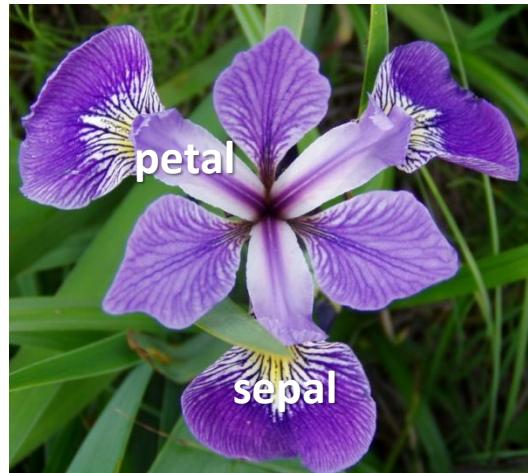
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Early statistical learning methods

- Recognizing flowers (by R. Fisher, 1936)



Iris Setosa



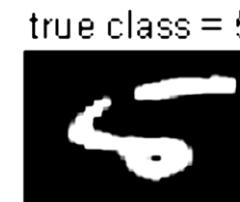
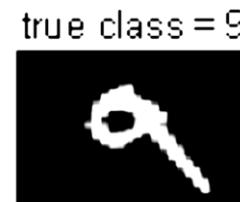
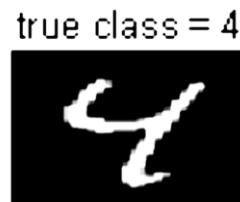
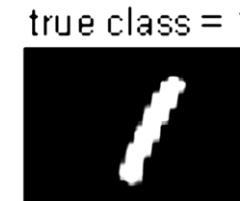
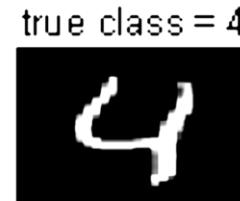
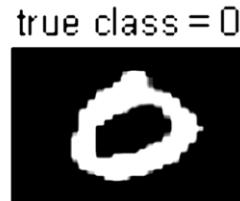
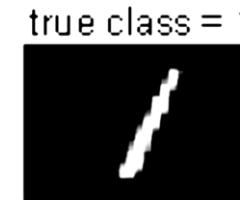
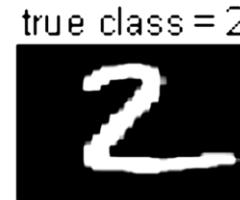
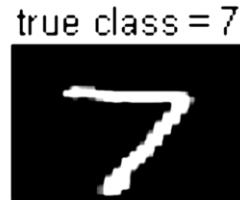
Iris Versicolor



Iris Virginica

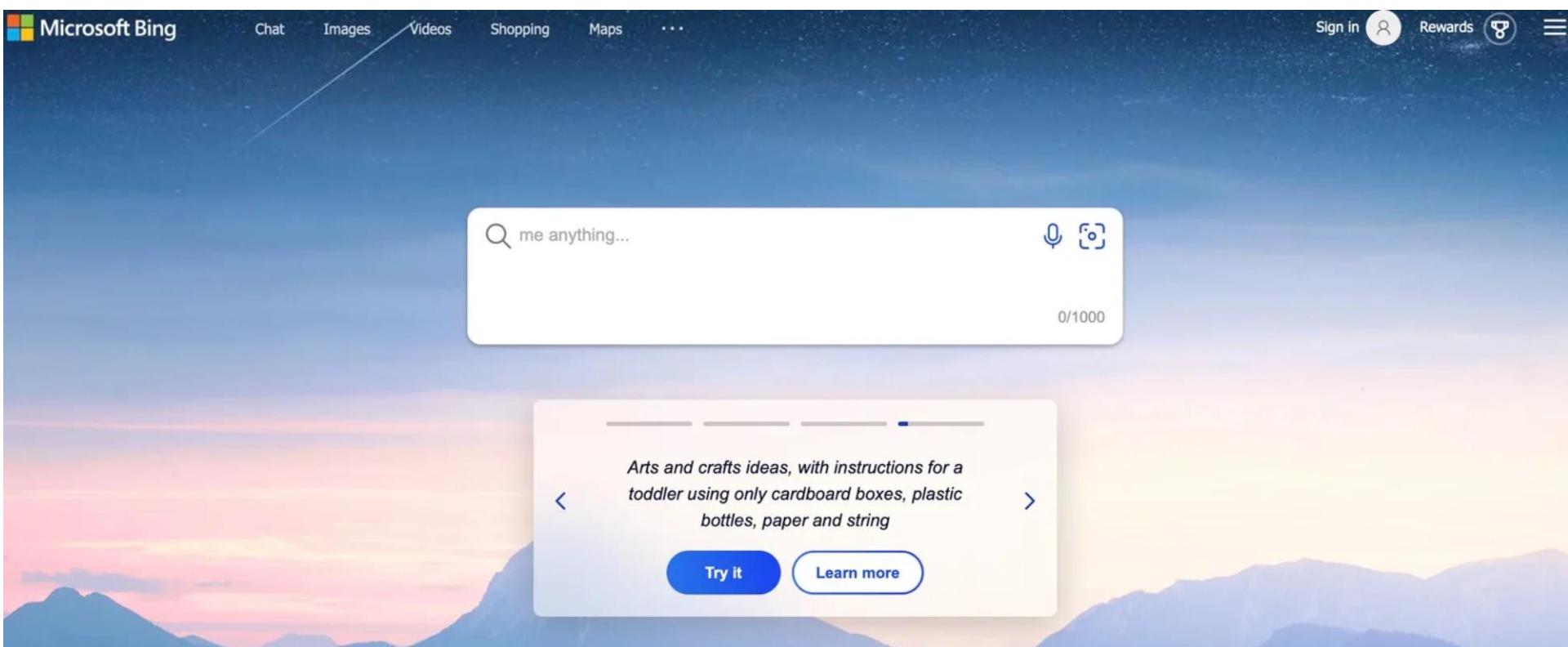
Huge success 30 years ago

- Recognizing handwritten zipcode and checks (AT&T Labs, circa late 1990s)



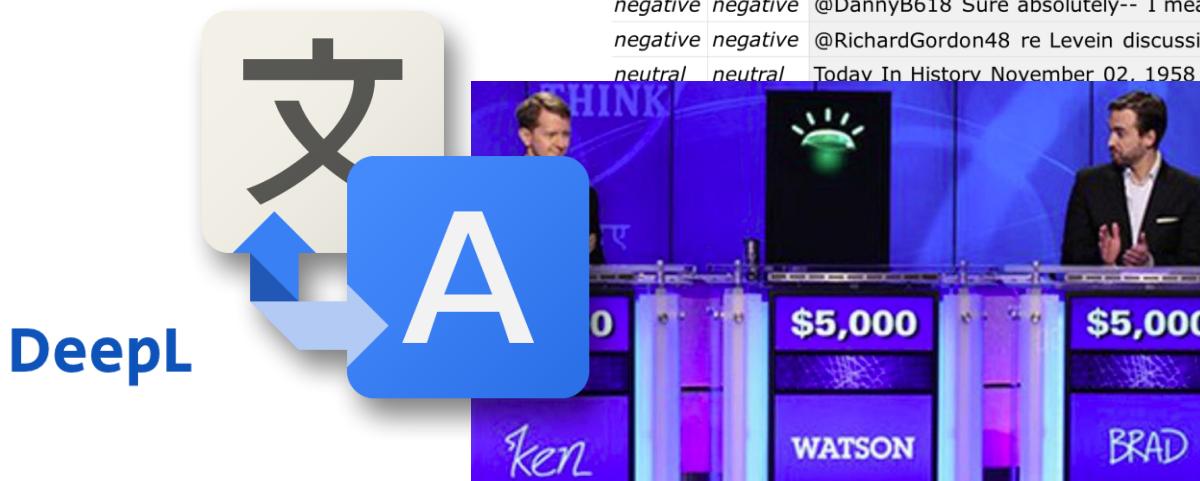
Nowadays: Learn our preferences

- Recommending what you might like



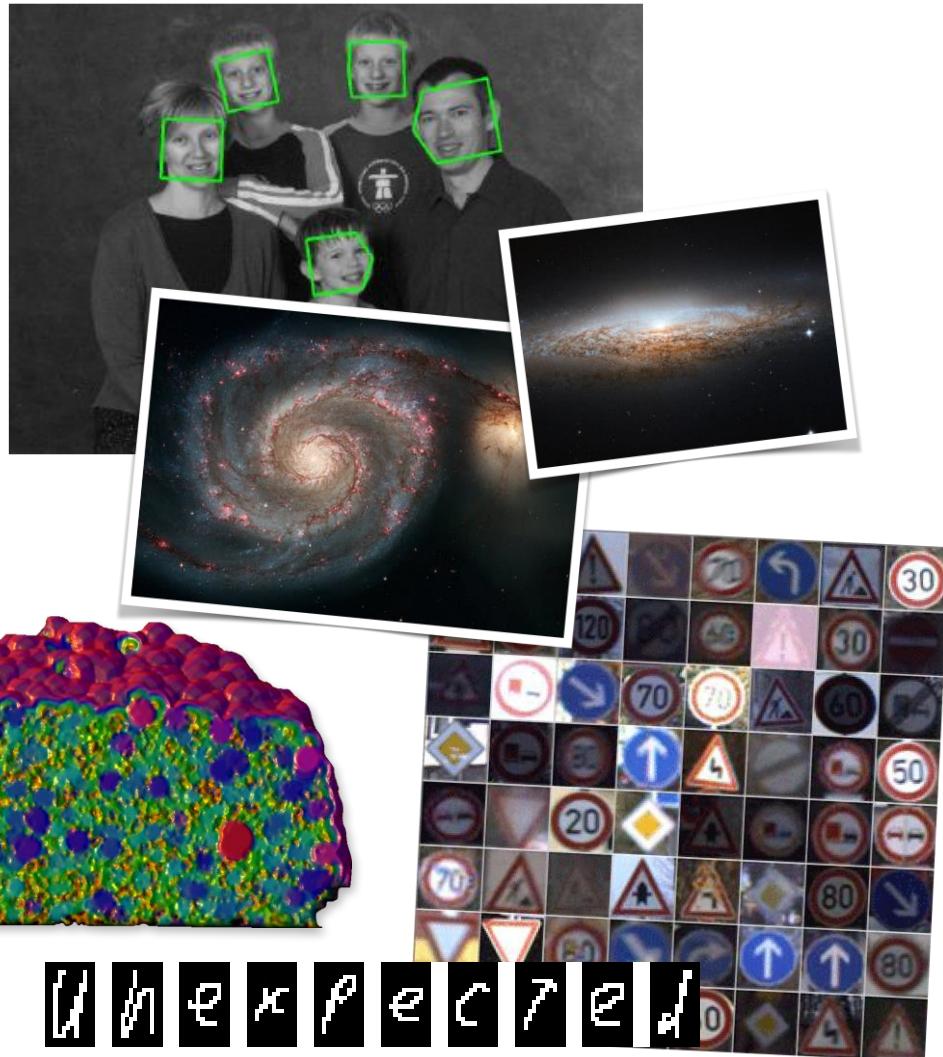
Analyze text data

- Machine translation
- Sentiment Analysis



Analyze image data

- Astronomy
- Face recognition
- 2D + 3D medical imaging
- OCR
- Self-driving cars

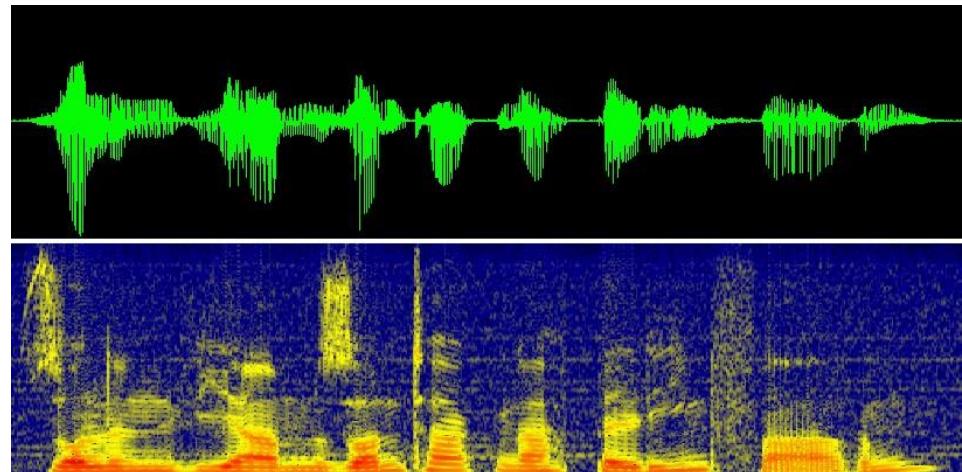


Analyze audio&multimodal data

- Hearing aids
- Voice recognition
- Automatic Translation
- Lip Reading
- Video Analysis

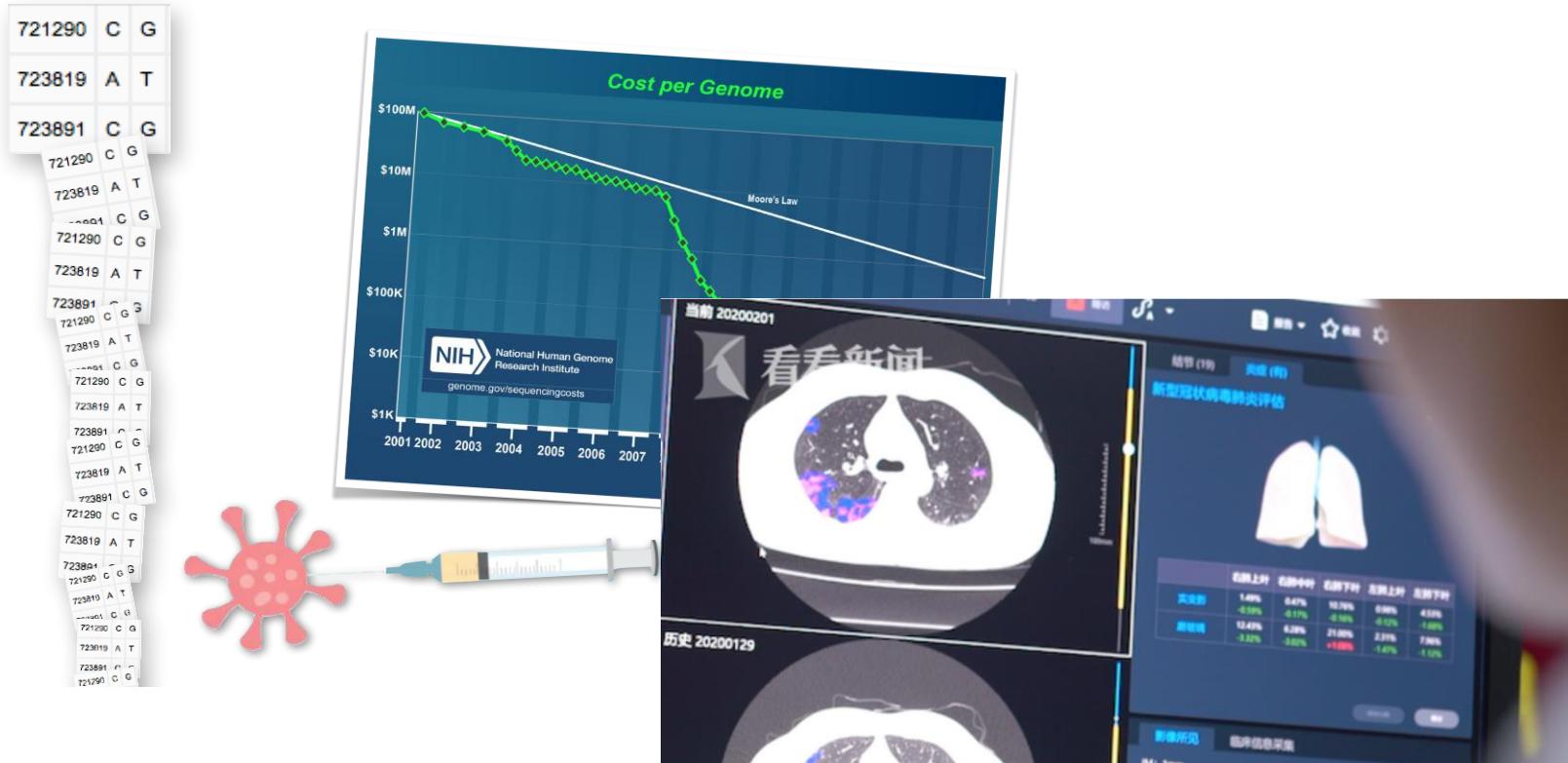


LYREBIRD



Analyze medical data

- Lesion identification
- Using genes for disease prediction

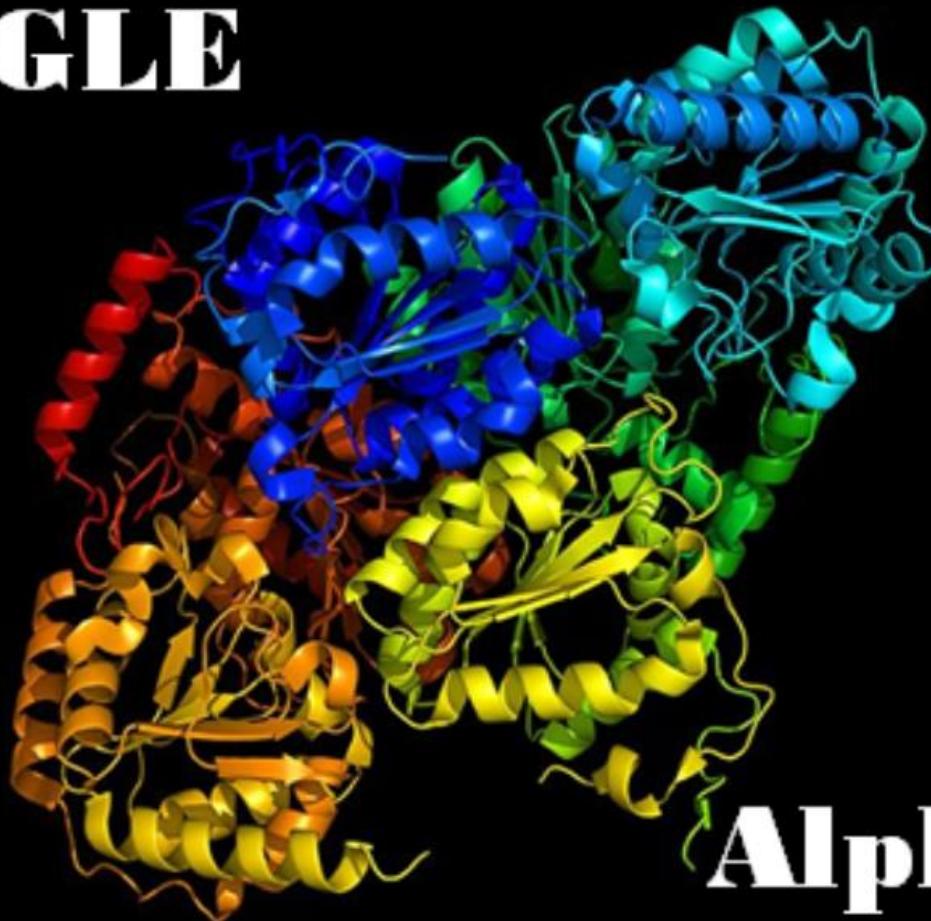


AlphaFold

GOOGLE

Proteínas

CASP



AlphaFold

Analyze numerical/sensor data

- Cern
- Astronomy/ Telescopes
- Fitness Trackers
- Weather Forecast
- Robotics
- Kinect



Games / Simulations

- Immediate Feedback
- Physical World
- Chess, Go
- StarCraft II



Analyze internet data

- Recommender systems
- Virtual assistants
- Ads



WIKIPEDIA

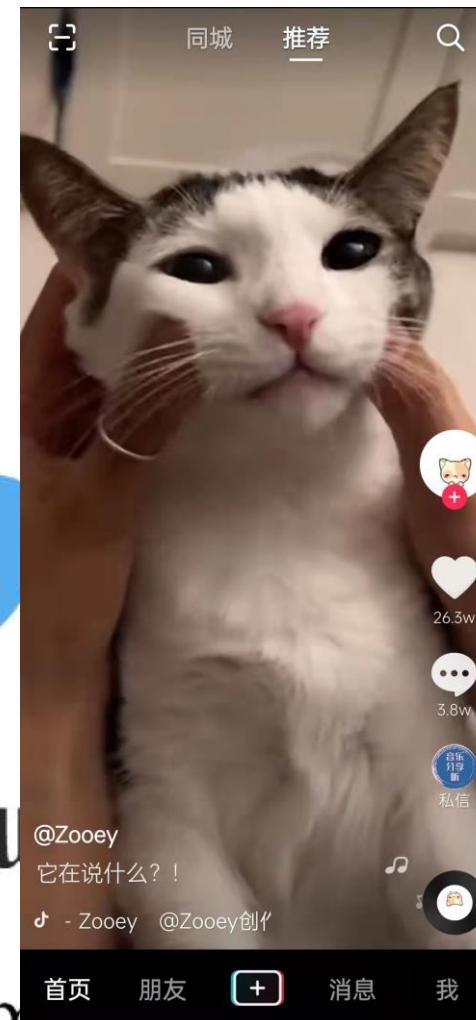


Google



YouTu

amazon.com



TikTok



Zhihu

OpenAI Sora: text to video AI

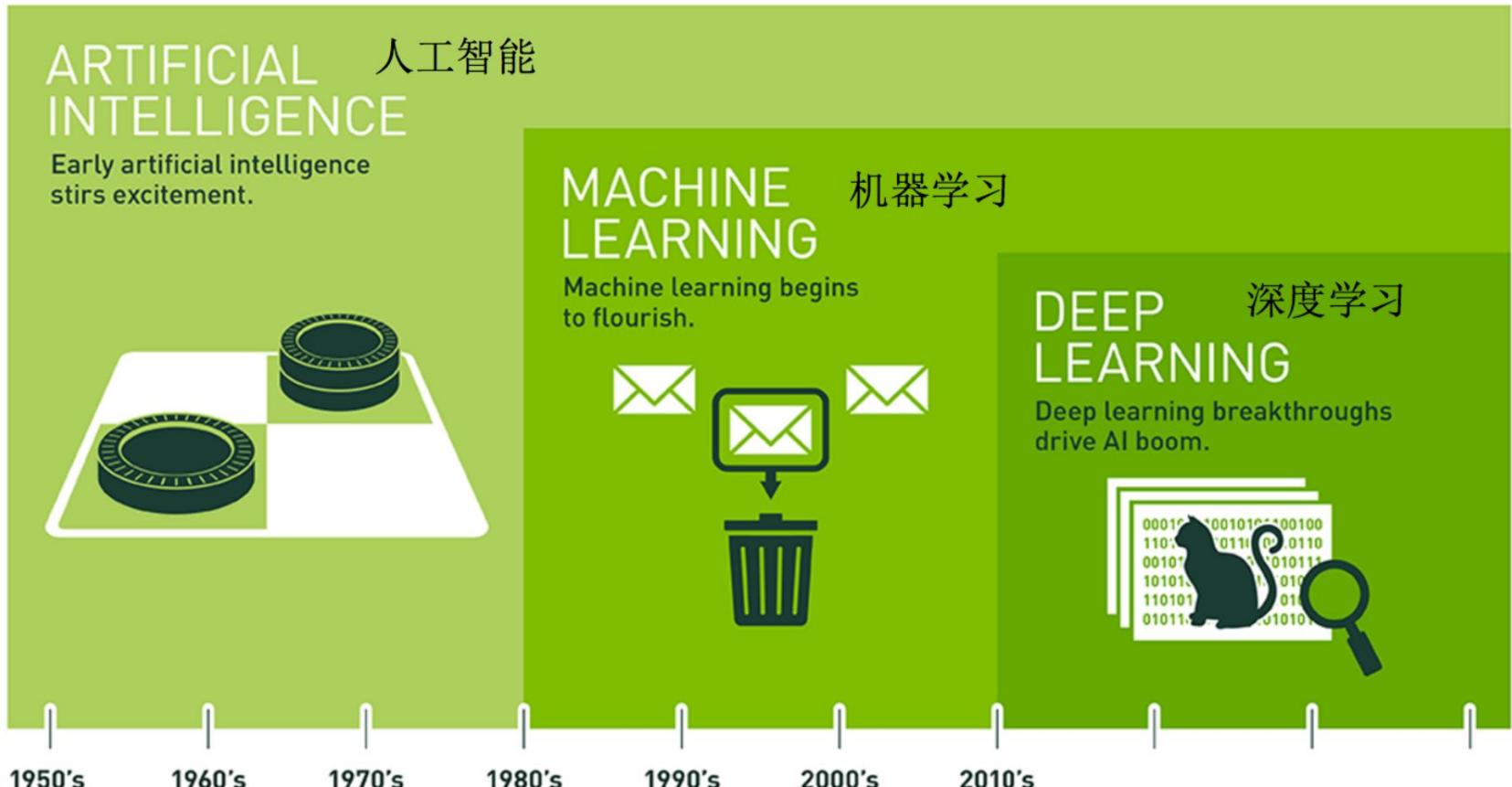


文字提示：一只巨型鸭子在波士顿街头漫步

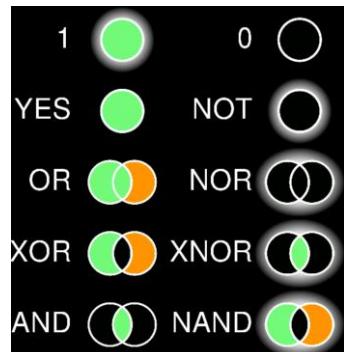
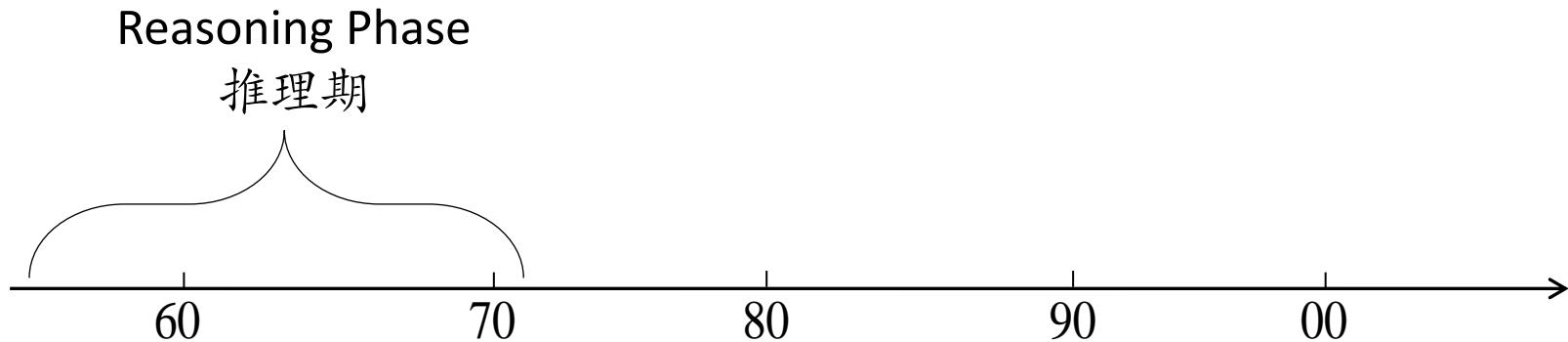
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Development of AI



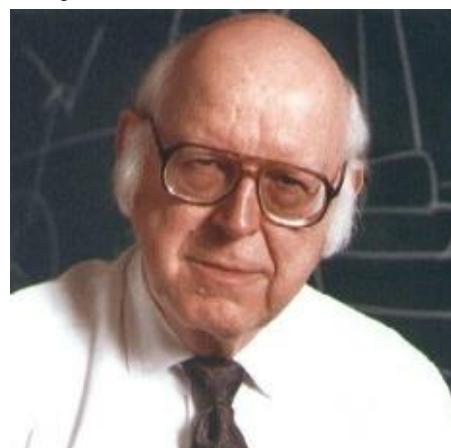
Timeline



Reasoning Phase

1950s to early 1970s

- Goal: Endow the machine with logical reasoning ability
- “Logic Theorist” by A. Newell and H. Simon (逻辑理论家)
 - Prove all 52 theorems in *Principia Mathematica* (by Bertrand Russell & Alfred North Whitehead) in 1963
 - 1963年，“逻辑理论家”程序证明了名著《数学原理》的全部52条定理
 - 1975 Turing Award
- A long way from achieving artificial intelligence

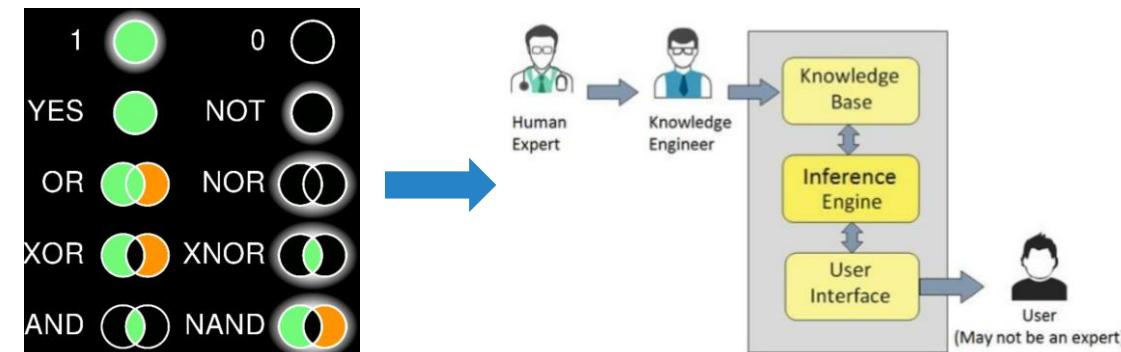
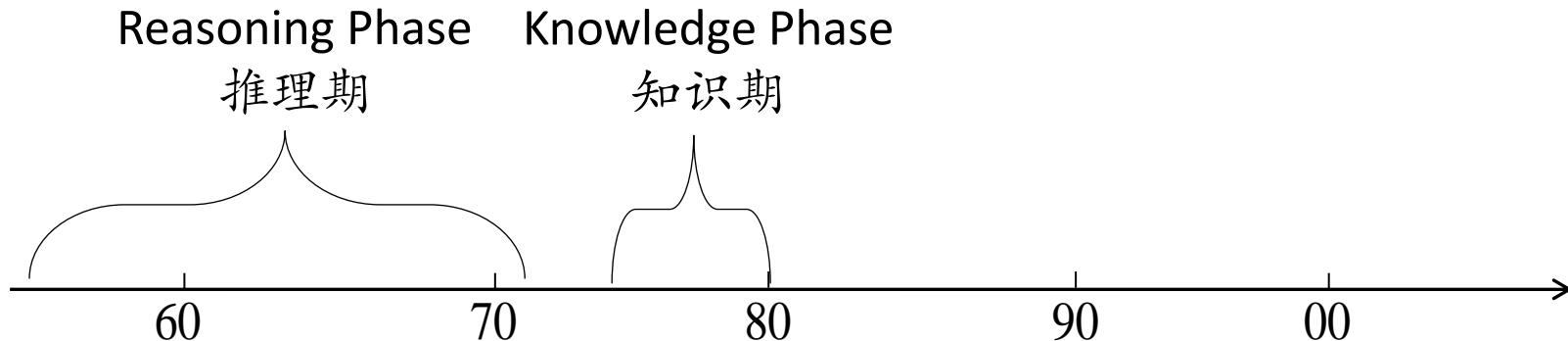


A. Newell



H. Simon

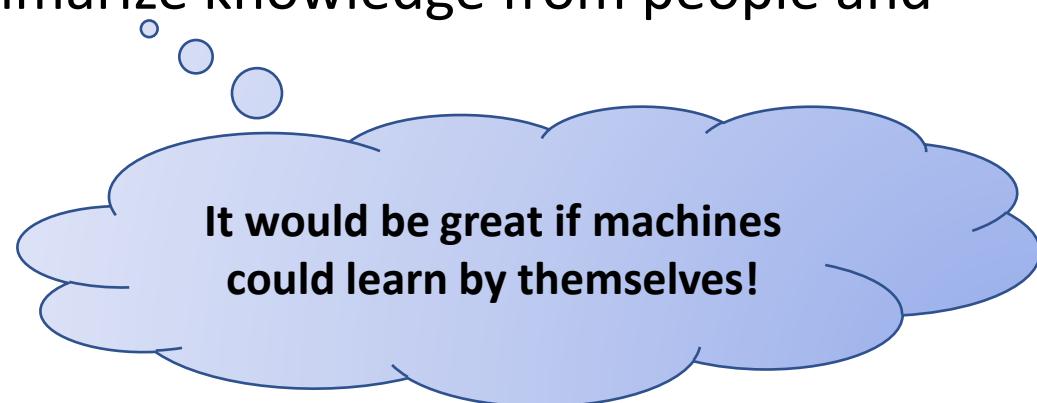
Timeline



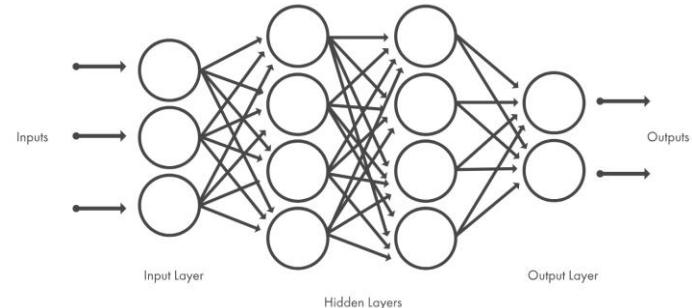
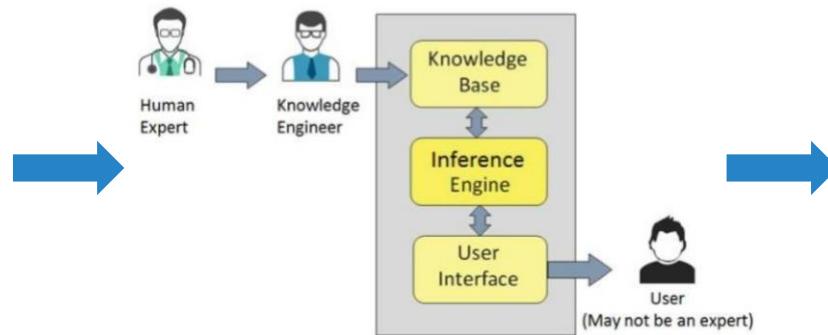
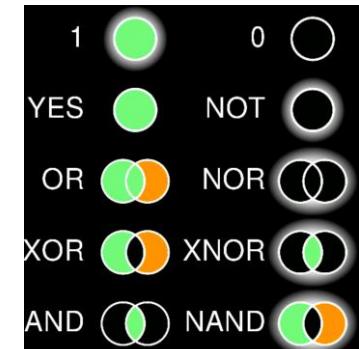
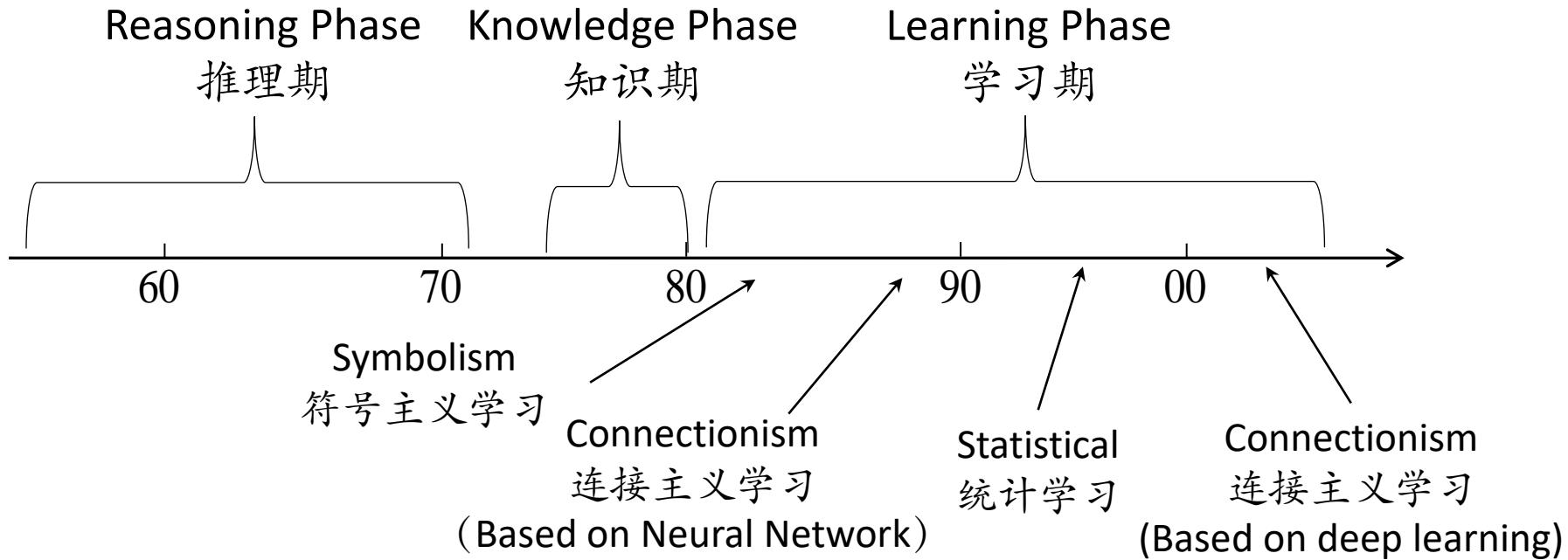
Knowledge Phase

Mid 1970s to early 1980s

- Goal: Give machines knowledge
- A large number of expert systems have come out
- “DENDRAL”(1965) by E. A. Feigenbaum and Joshua Lederberg
 - The first successful expert system in the world
 - A chemical-analysis expert system
 - Edward Feigenbaum: the father of expert systems technology, 1994 Turing Award
- It is very difficult to summarize knowledge from people and teach it to computers



Timeline



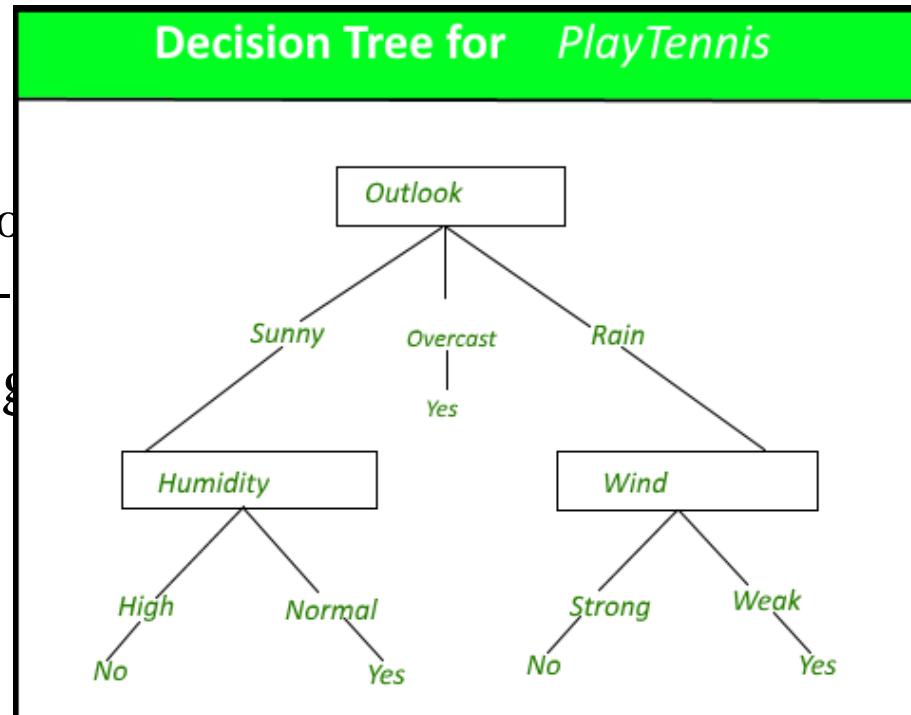
Learning Phase

1980s to present

- Goal: Enable machines to learn by themselves
- Learning from examples **Most researched, most widely used**
- Learning by observation and discovery
- Learning by analogy
- ...

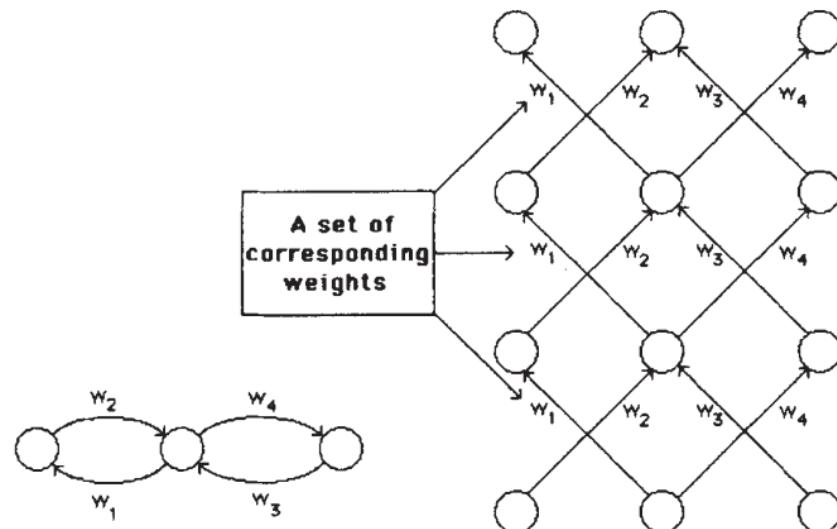
Learning from examples

- **Symbolism** 符号主义学习
- Popular in the 1980s
- Decision Tree 决策树
 - Based on information theory
 - Directly simulate the tree
- ILP (Inductive Logic Programming)



Learning from examples

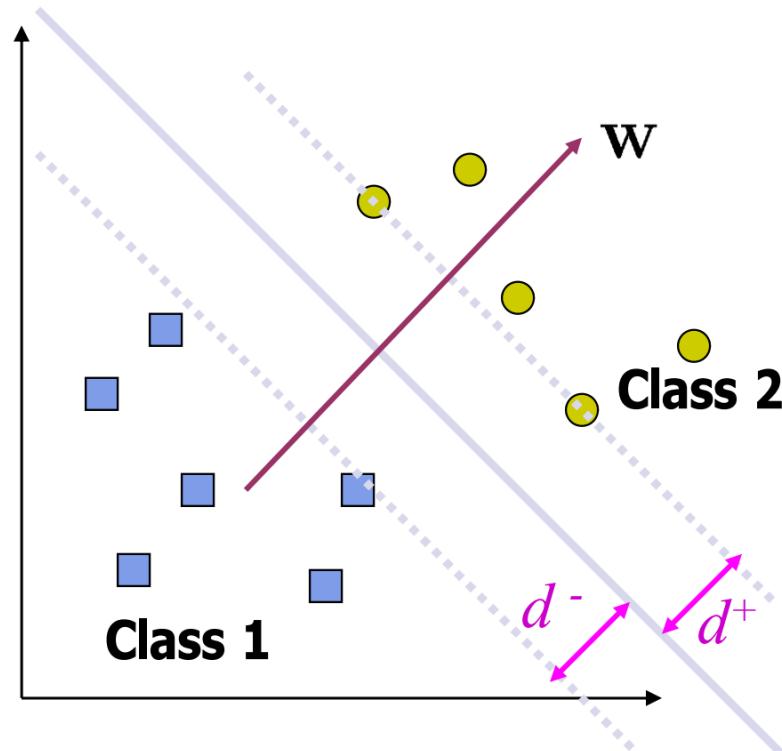
- Connectionism – Phase 1 连接主义学习
- Popular before 1990s
- Based on neural networks
- The backpropagation algorithm made a profound impact



Rumelhart D E, Hinton G E, Williams R J. Learning representations by back-propagating errors[J]. nature, 1986, 323(6088): 533-536.

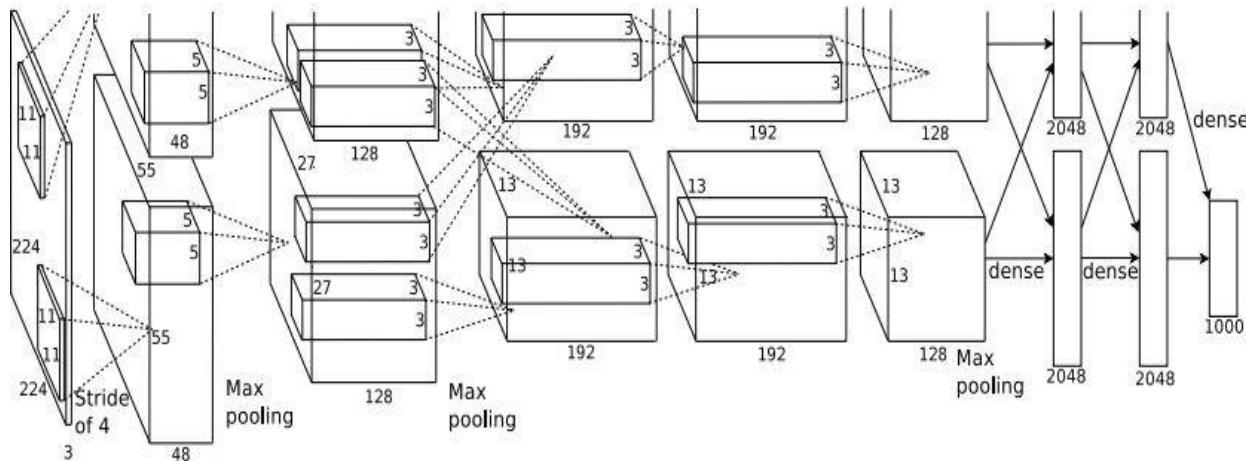
Learning from examples

- Statistical 统计学习
- Became popular in the mid-1990s
- SVM and other kernel methods

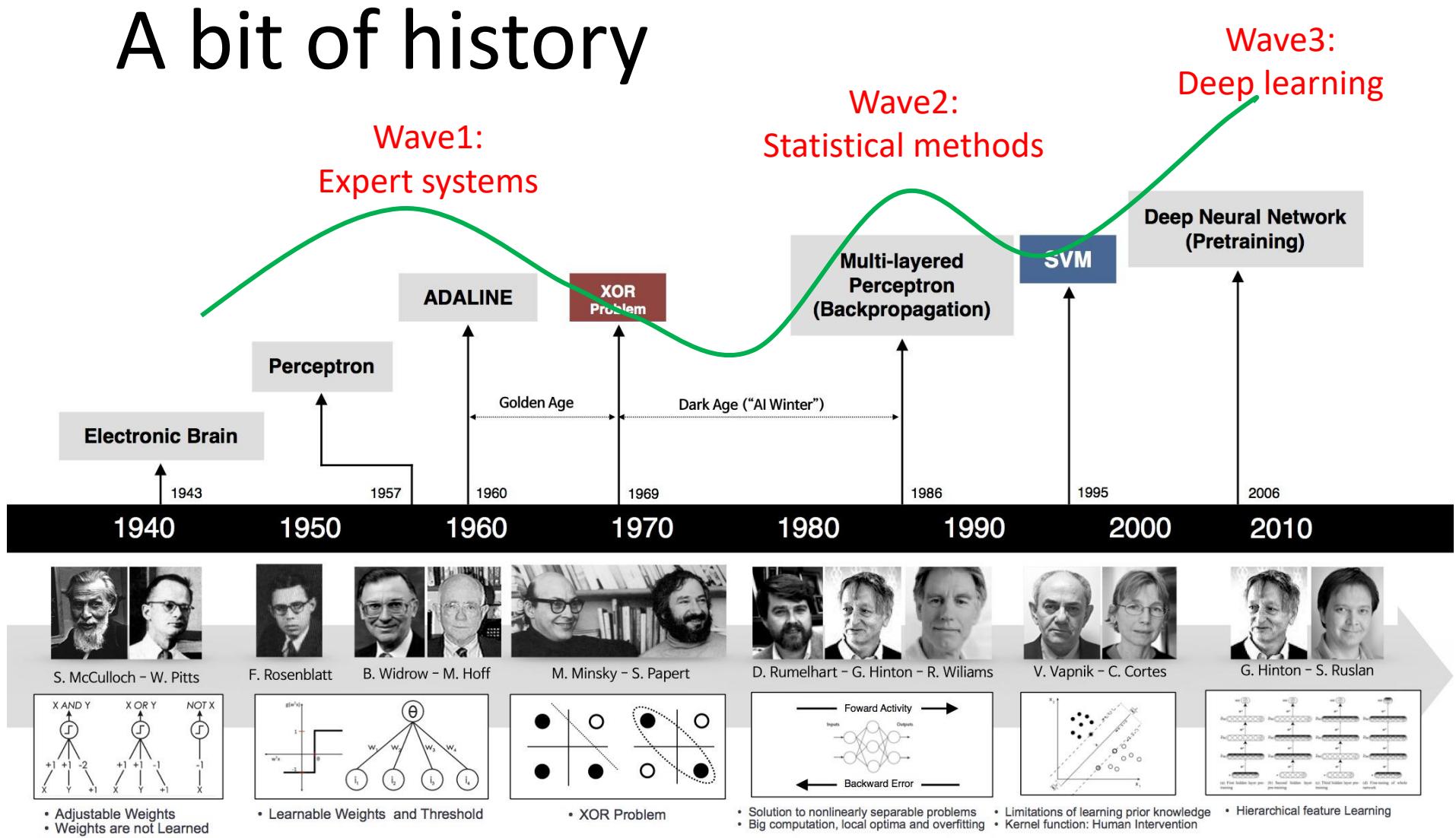


Learning from examples

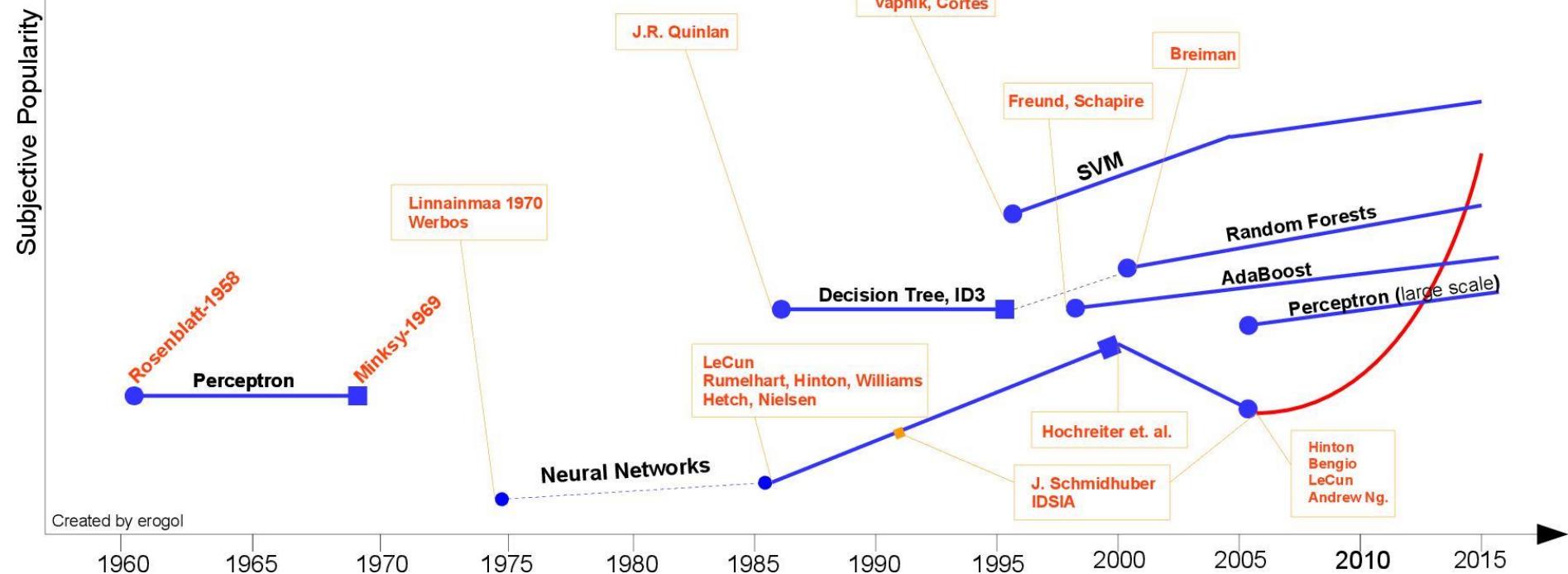
- Connectionism – Phase 2 连接主义学习
- Rise in early 21 century, hot now
- Based on deep learning
- A large amount of data and strong computing power provide support for deep learning



A bit of history



Trends of typical methods



Challenges

- Hype
 - Cycles of AI popularity
- Data Ethics, Privacy, Fairness
- Lack of Interpretability
 - Example: medical applications of deep learning
- Social Implications of AI
 - Threats from Super-human AI?

Need: Scientific Method, Reproducible Research, Open Source and Open Data

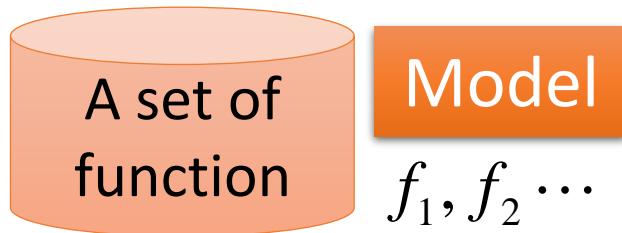
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Framework

Image Recognition:

$$f(\text{ }) = \text{ "cat"}$$

$$f_1(\text{ }) = \text{ "cat"}$$


$$f_2(\text{ }) = \text{ "money"}$$


$$f_1(\text{ }) = \text{ "dog"}$$


$$f_2(\text{ }) = \text{ "snake"}$$


Framework

A set of function

Model
 $f_1, f_2 \dots$

Goodness of function f

Training Data

Image Recognition:

$$f\left(\begin{array}{c} \text{Image of a cat} \end{array} \right) = \text{"cat"}$$

$$\begin{array}{ll} f_1\left(\begin{array}{c} \text{Image of a cat} \end{array} \right) = \text{"cat"} & f_2\left(\begin{array}{c} \text{Image of a cat} \end{array} \right) = \text{"money"} \\ f_1\left(\begin{array}{c} \text{Image of a dog} \end{array} \right) = \text{"dog"} & f_2\left(\begin{array}{c} \text{Image of a dog} \end{array} \right) = \text{"snake"} \end{array}$$

Better!

function input:

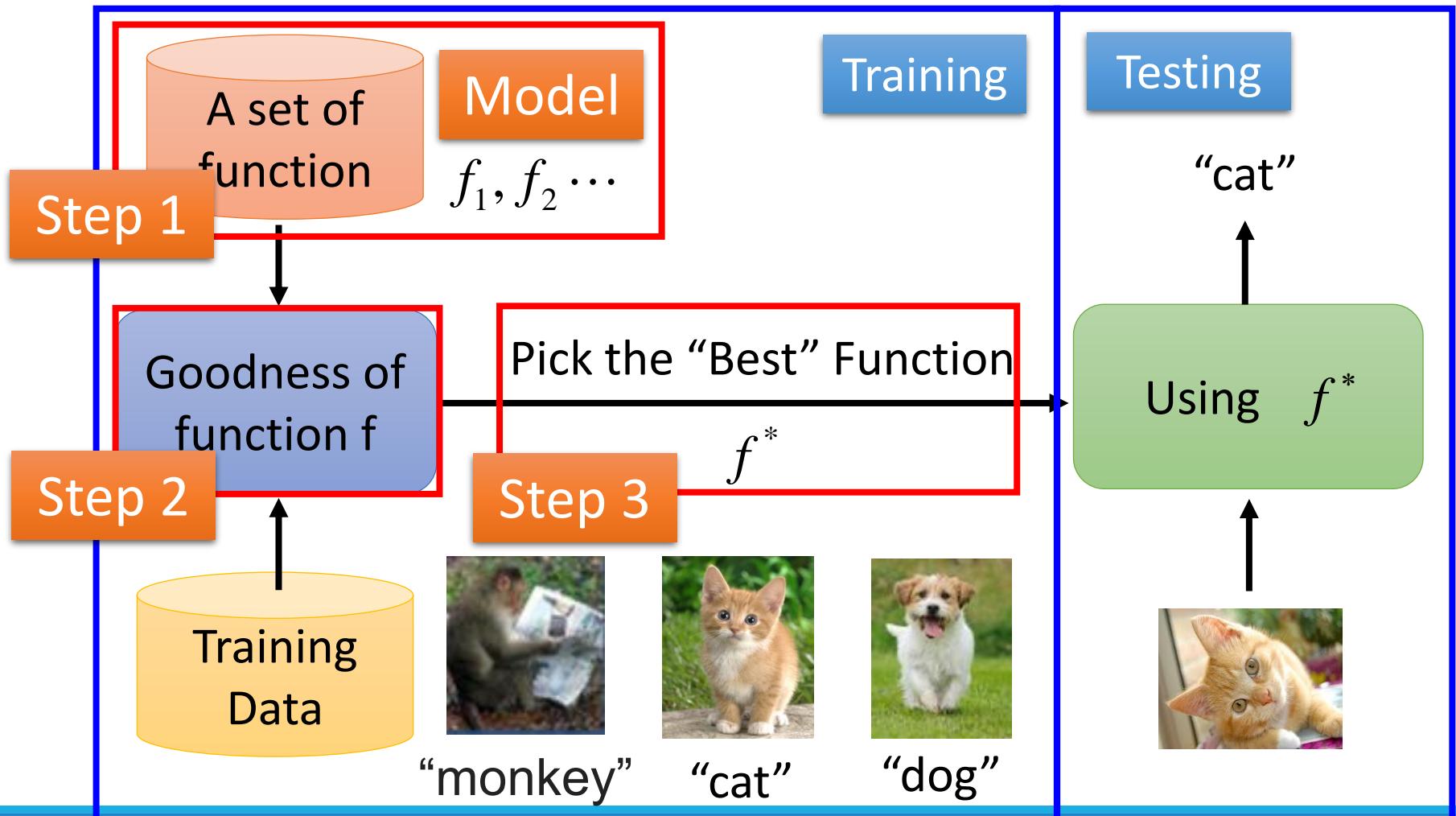


function output: "monkey" "cat" "dog"

Framework

Image Recognition:

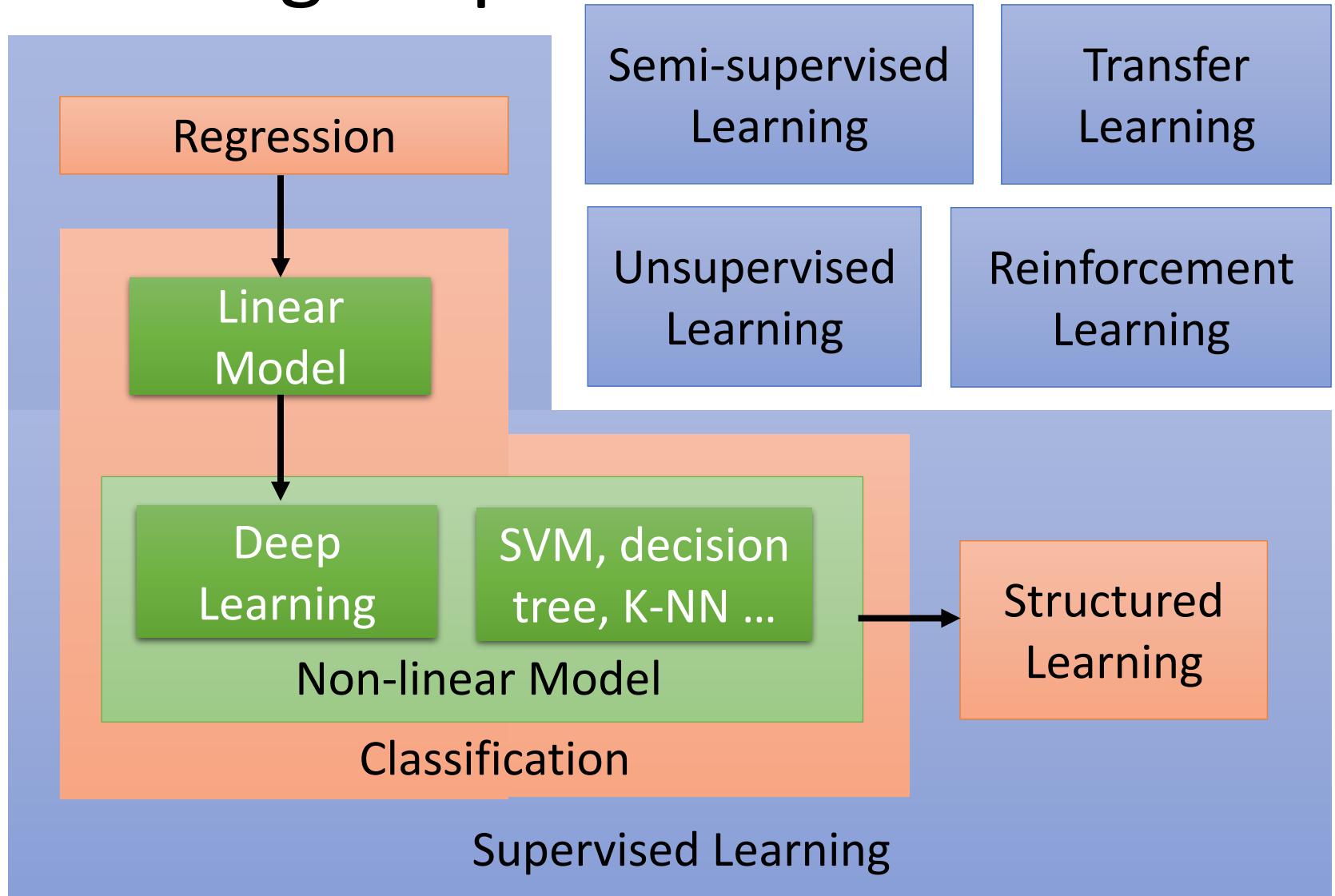
$$f(\text{cat}) = \text{"cat"}$$



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Learning Map

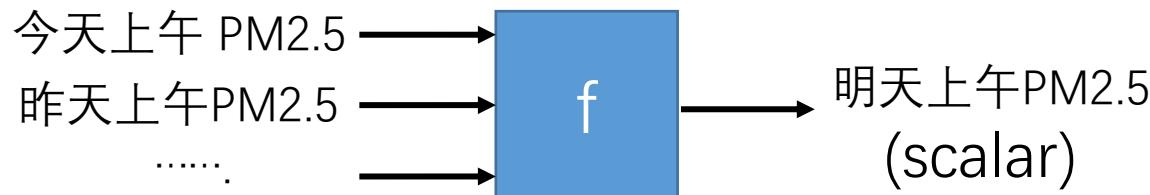


Learning Map

Regression

The output of the target function f is “scalar”.

预测
PM2.5



Training Data:

Input:

9/01 上午 PM2.5 = 63 9/02 上午 PM2.5 = 65

Output:

9/03 上午 PM2.5 = 100

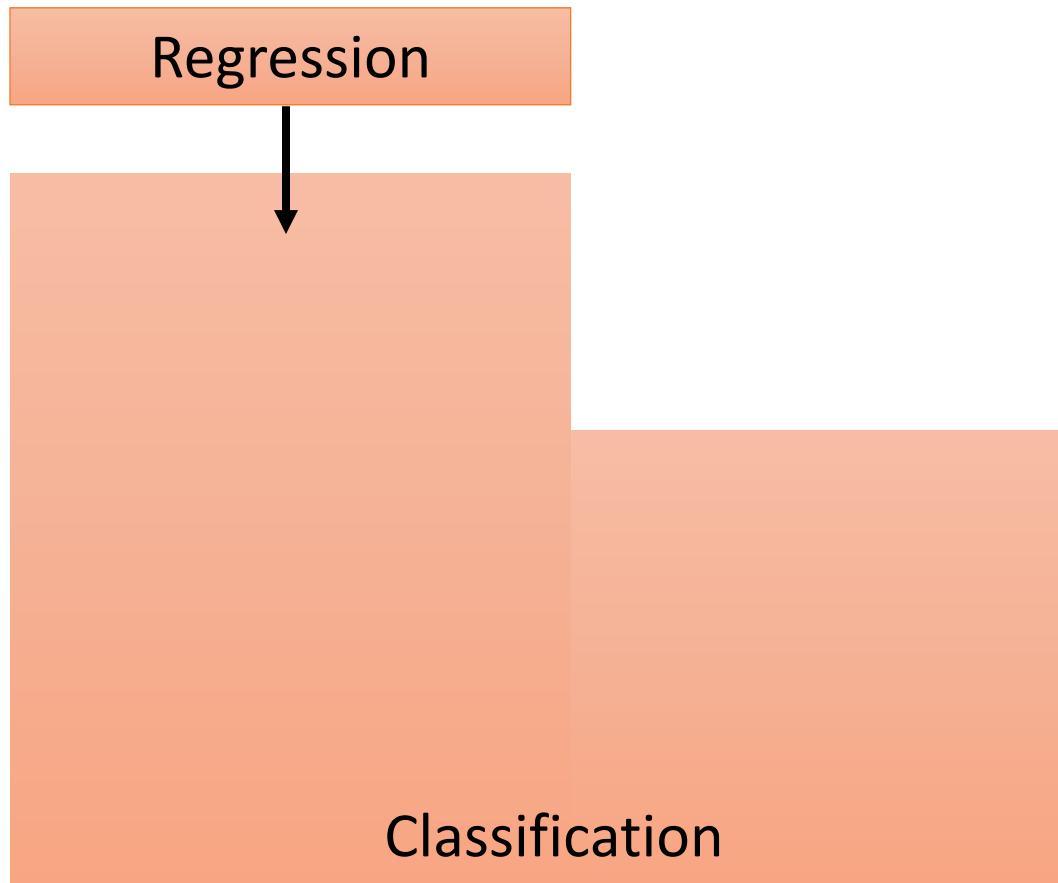
Input:

9/12 上午 PM2.5 = 30 9/13 上午 PM2.5 = 25

Output:

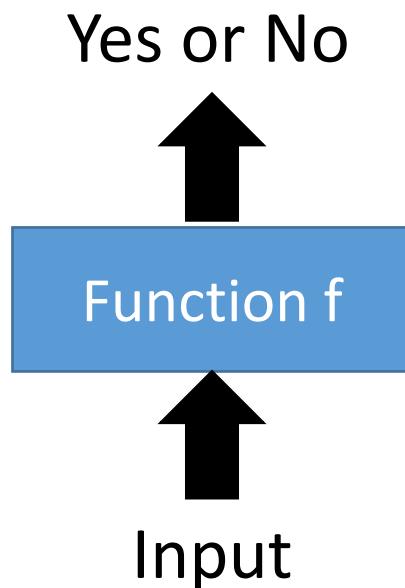
9/14 上午 PM2.5 = 20

Learning Map

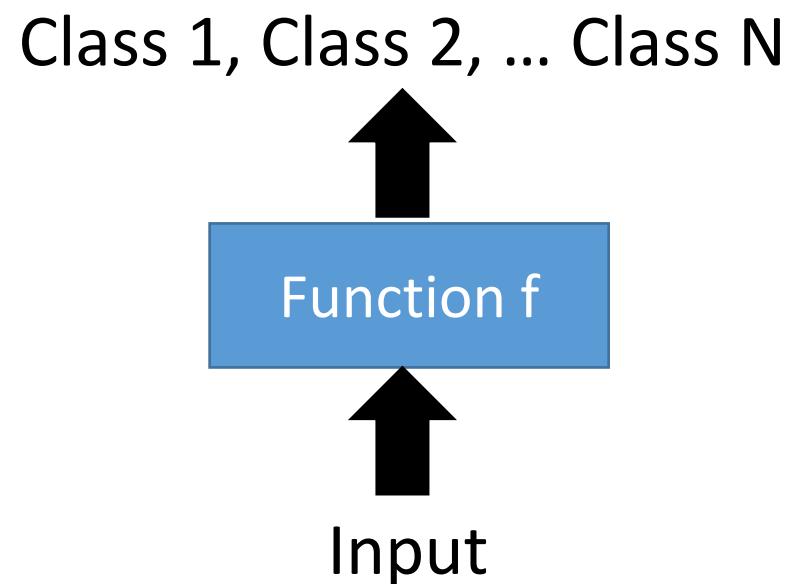


Classification

- Binary Classification

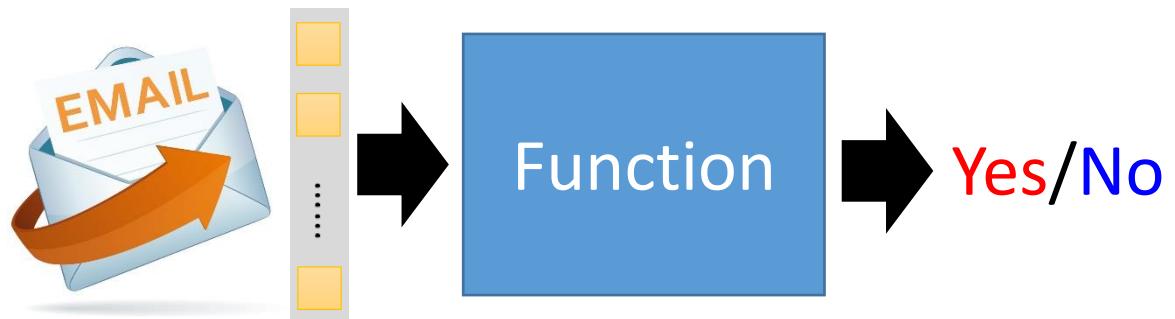


- Multi-class Classification



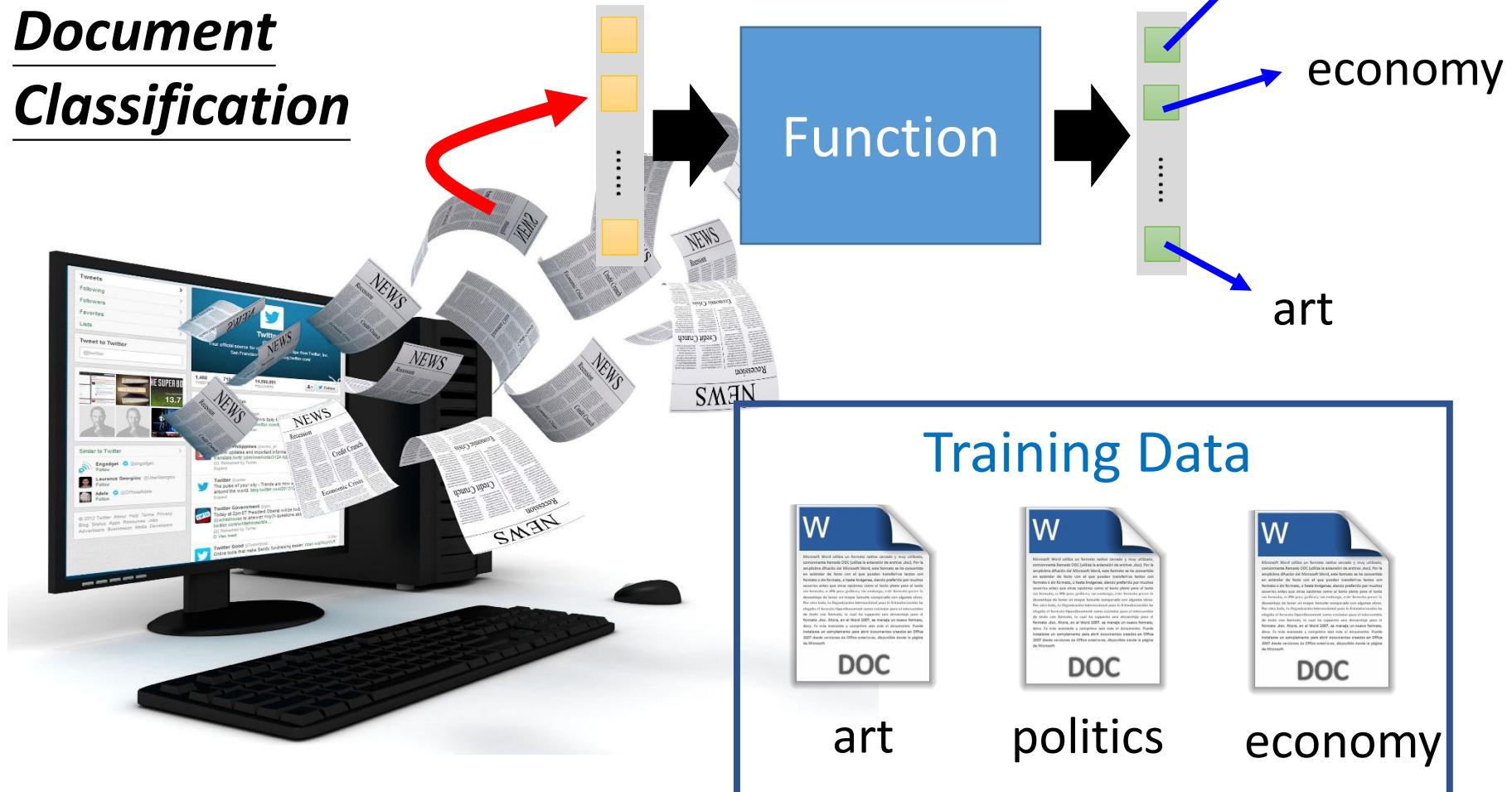
Binary Classification

Spam
filtering

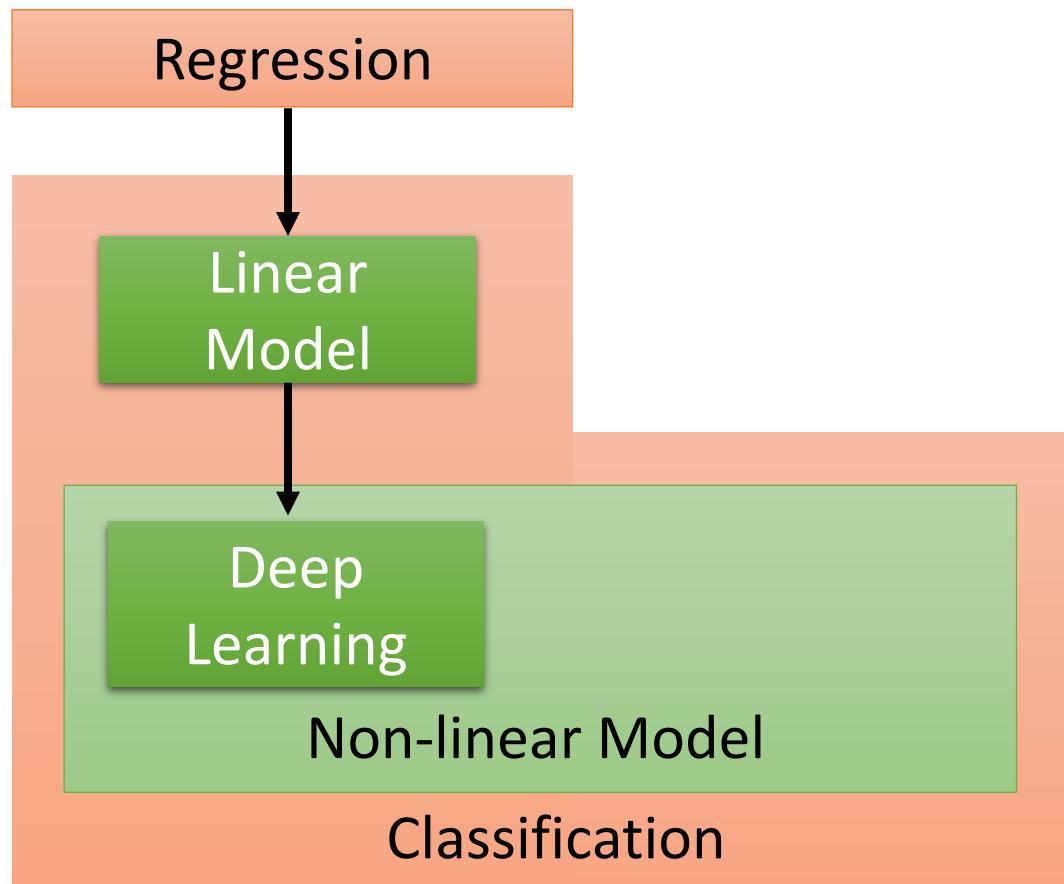


Multi-class Classification

Document Classification

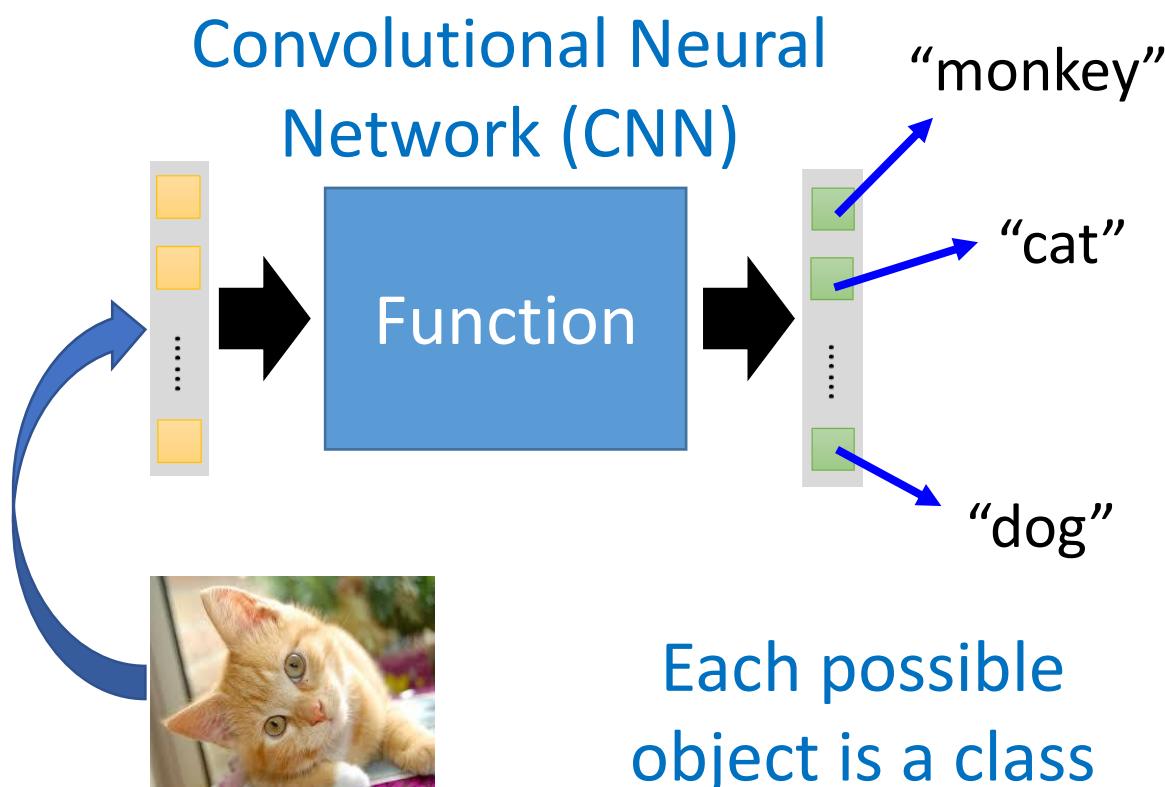


Learning Map



Classification - Deep Learning

- Image Recognition

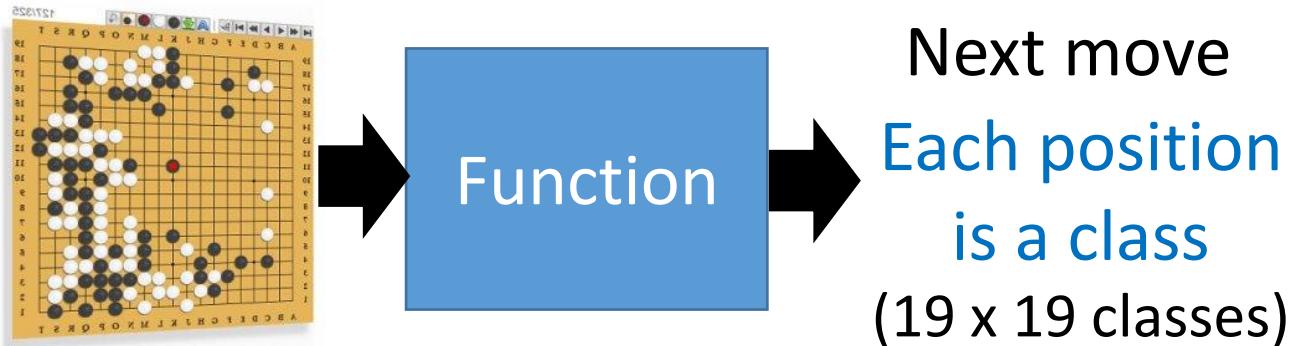


Training Data

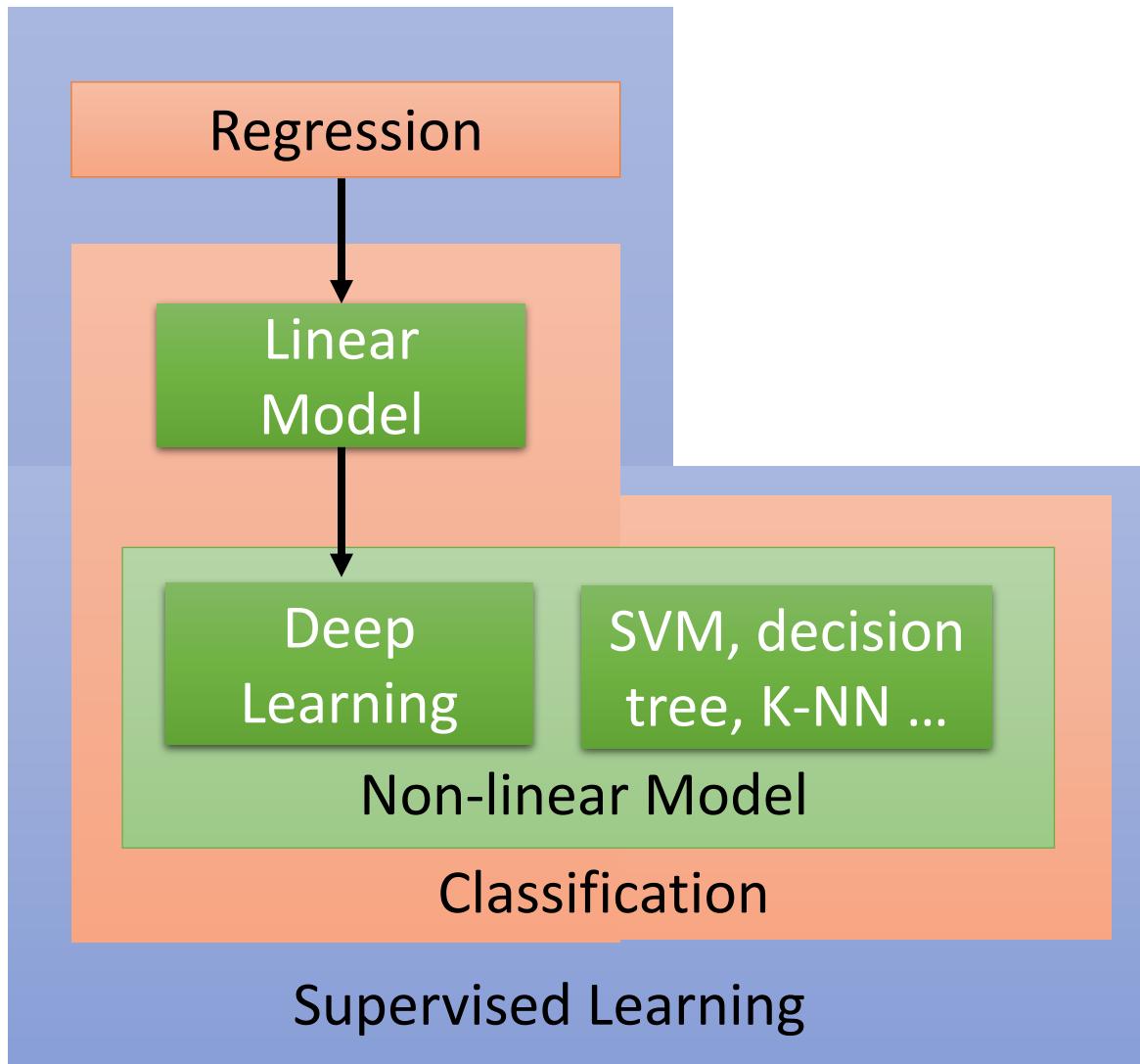


Classification - Deep Learning

- Playing GO



Learning Map

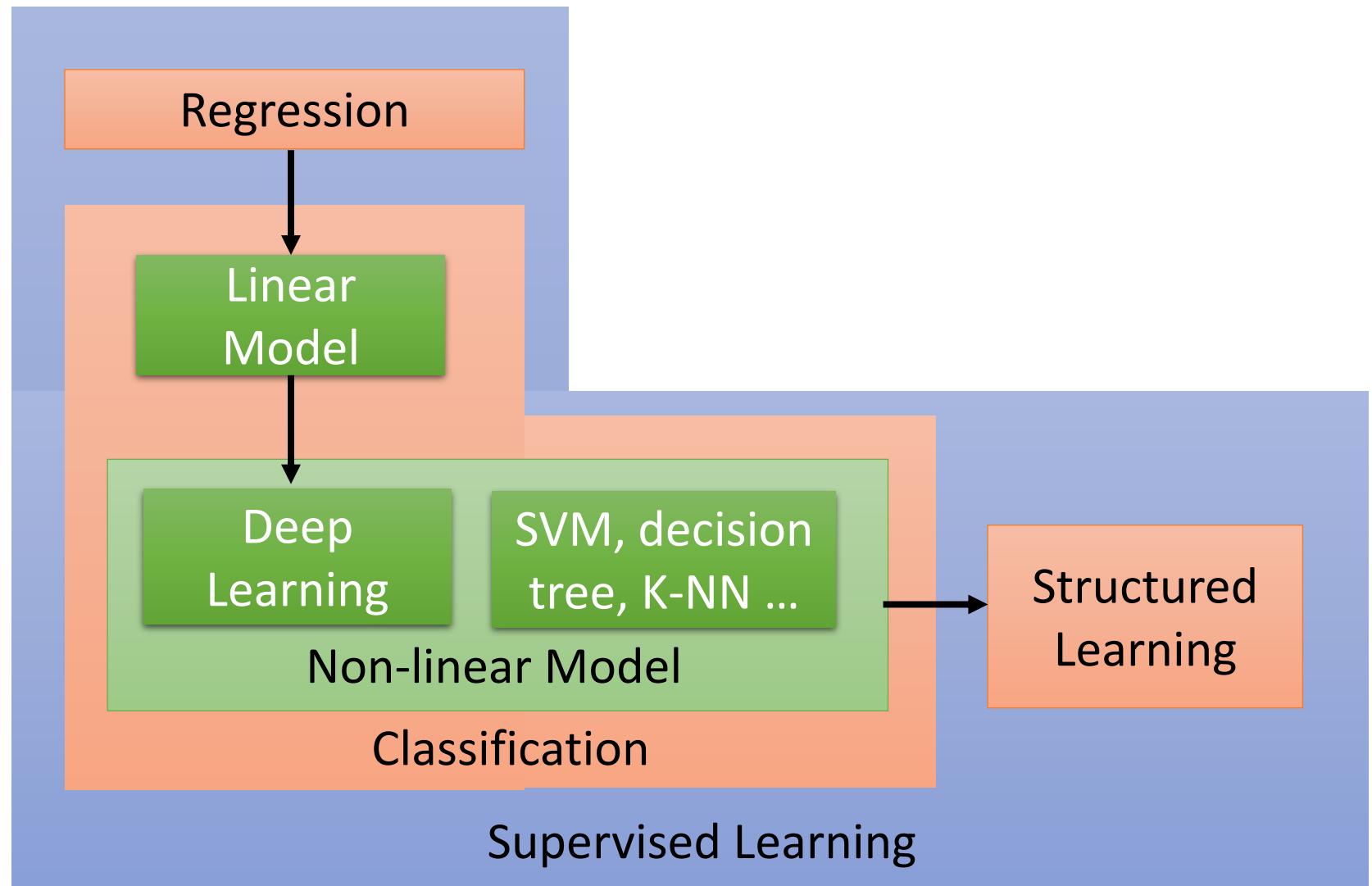


Training Data:

Input/output
pair of target
function

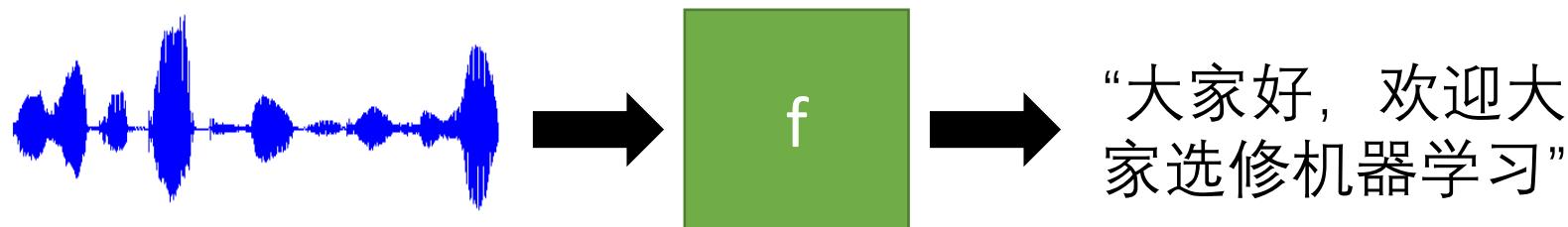
Function
output = label

Learning Map



Structured Learning

- Beyond Classification

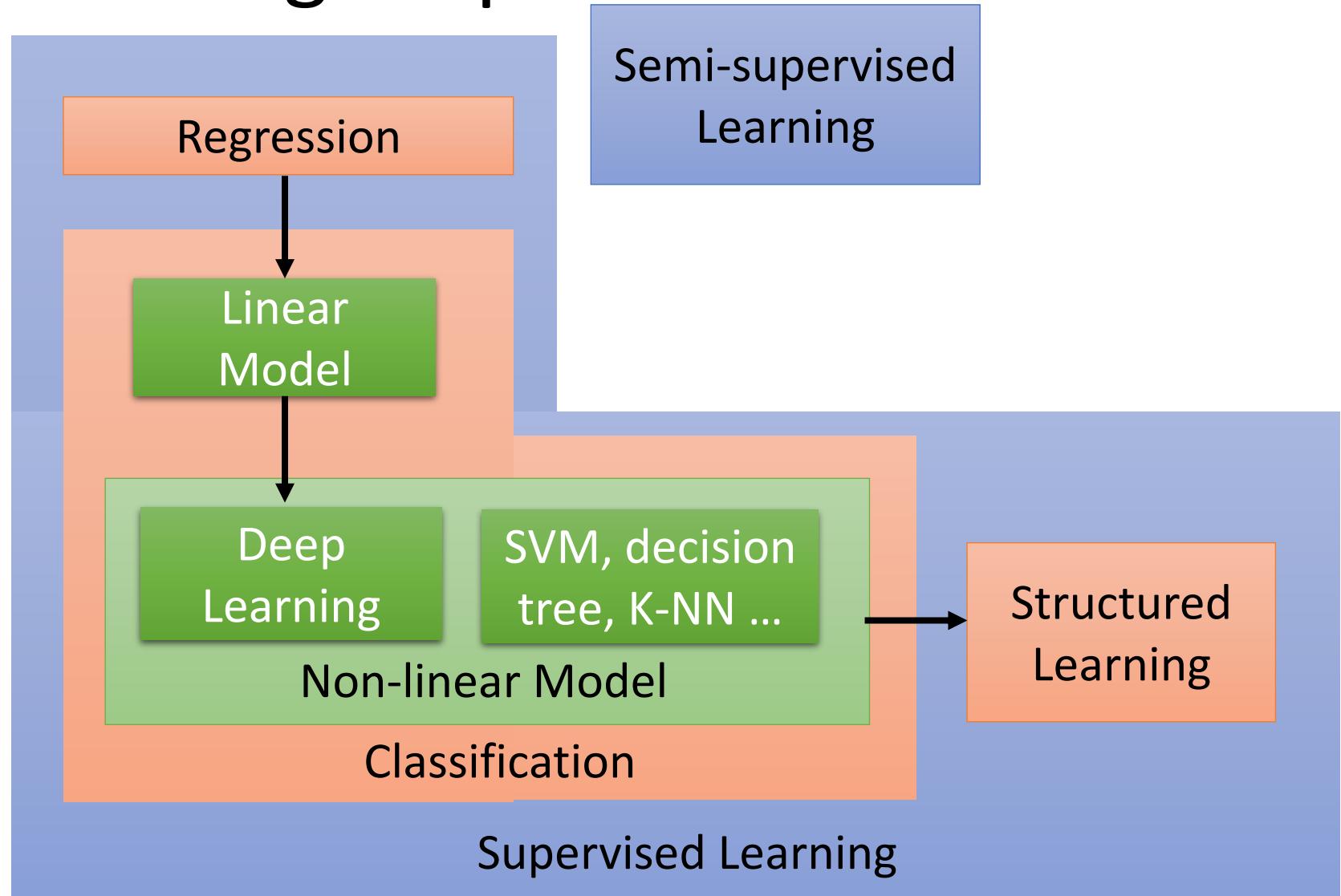


Speech Recognition

“机器学习” → f → “Machine Learning”

Machine Translation

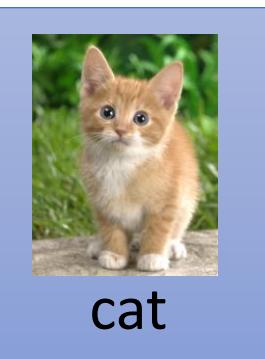
Learning Map



Semi-supervised Learning

For example, recognizing cats and dogs

Labelled
data

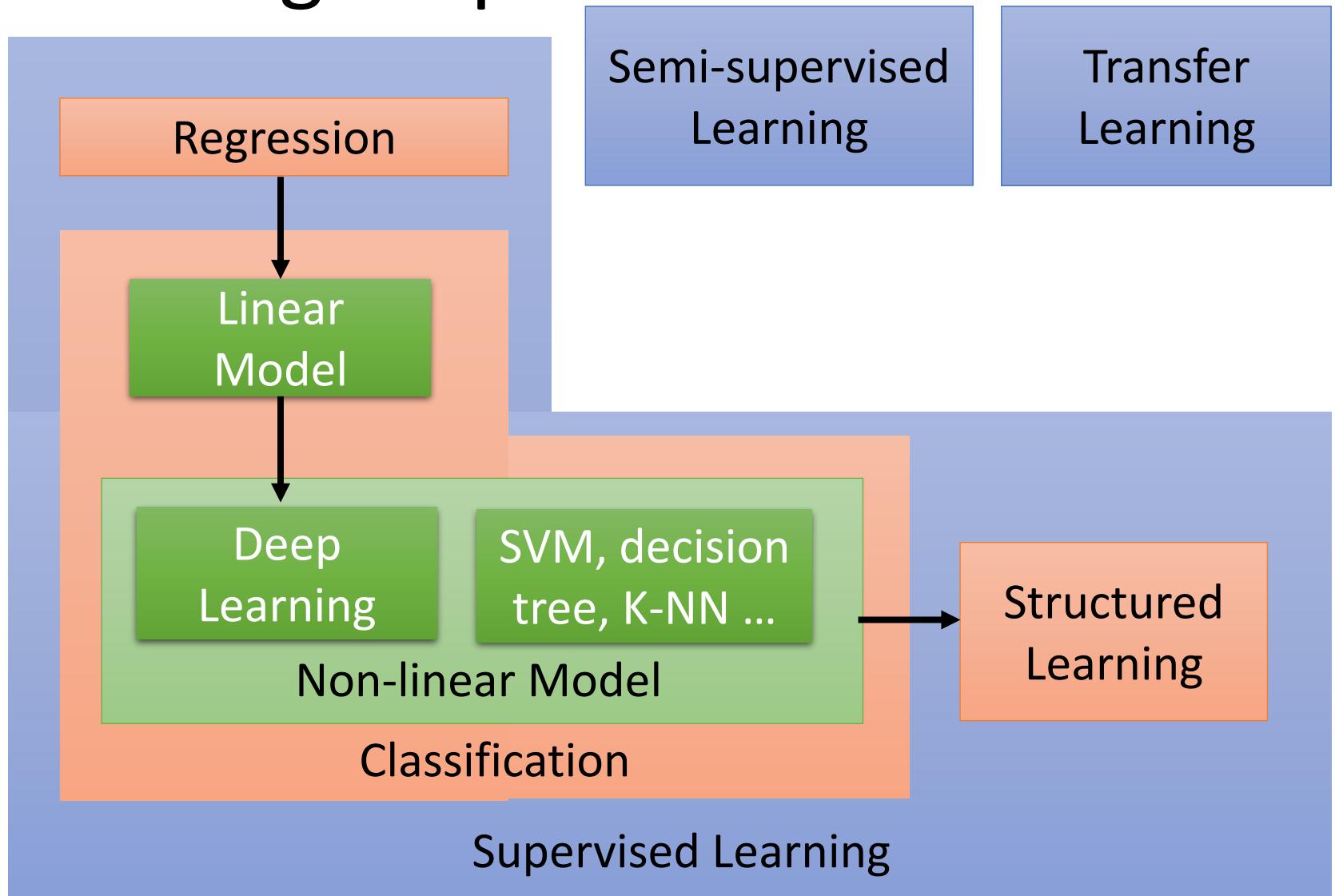


Unlabeled
data



(Images of cats and dogs)

Learning Map



Transfer Learning

For example, recognizing cats and dogs

Labelled
data



cat



dog

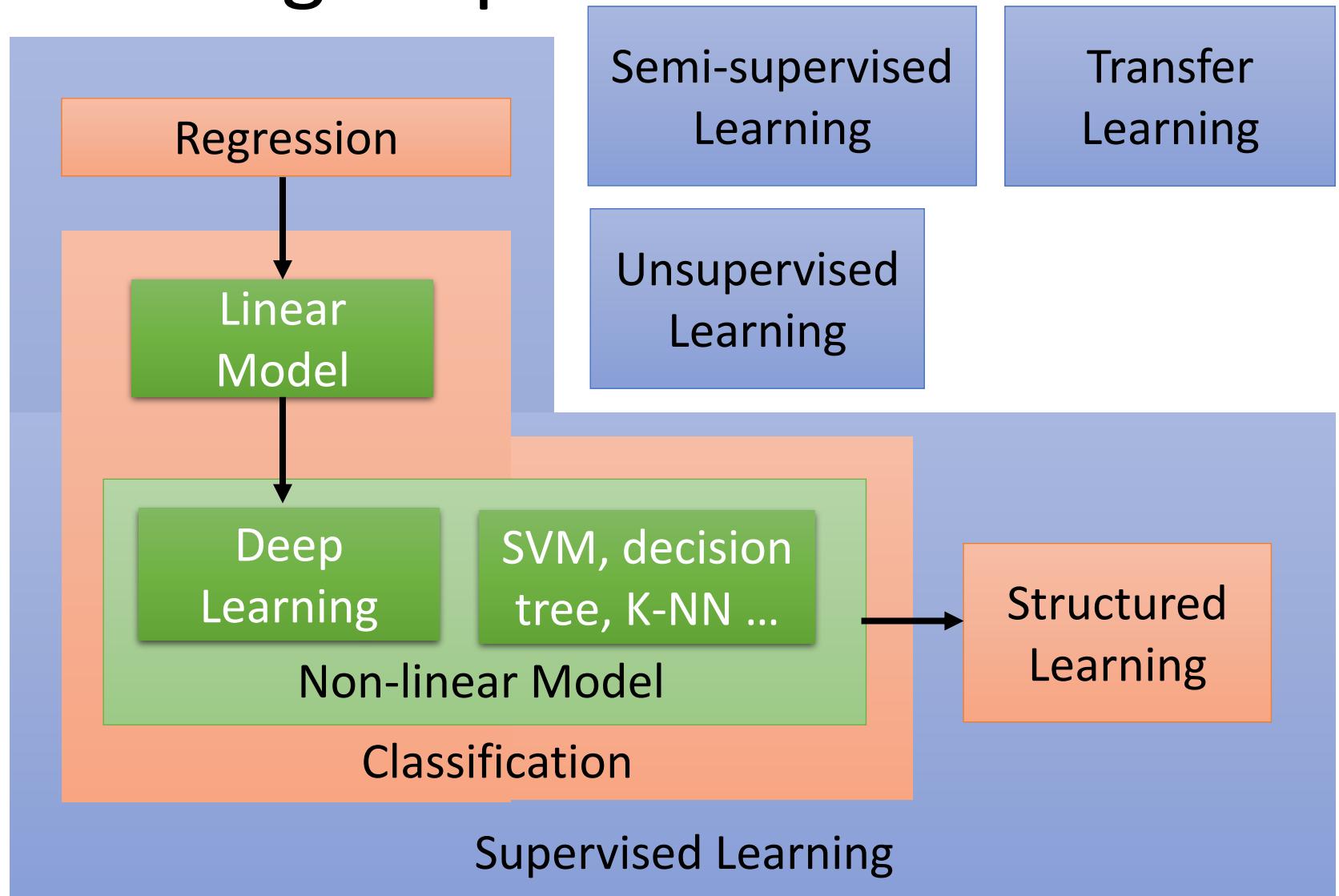


elephant



Data not related to the task considered
(can be either labeled or unlabeled)

Learning Map



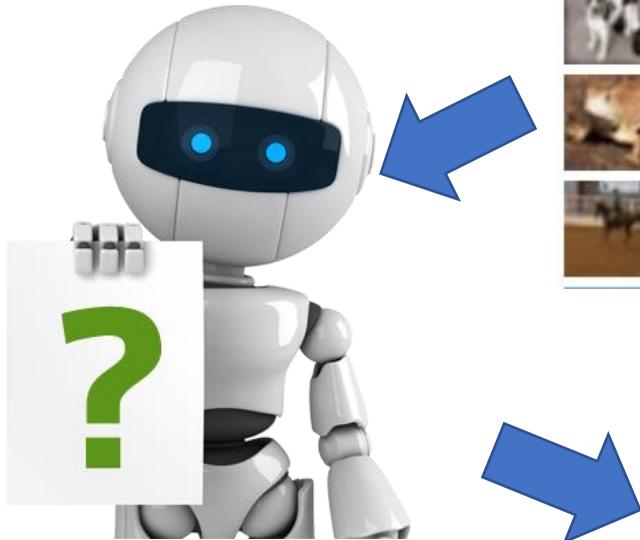
Unsupervised Learning

- Machine Reading: Machine learns the meaning of words from reading a lot of documents without supervision

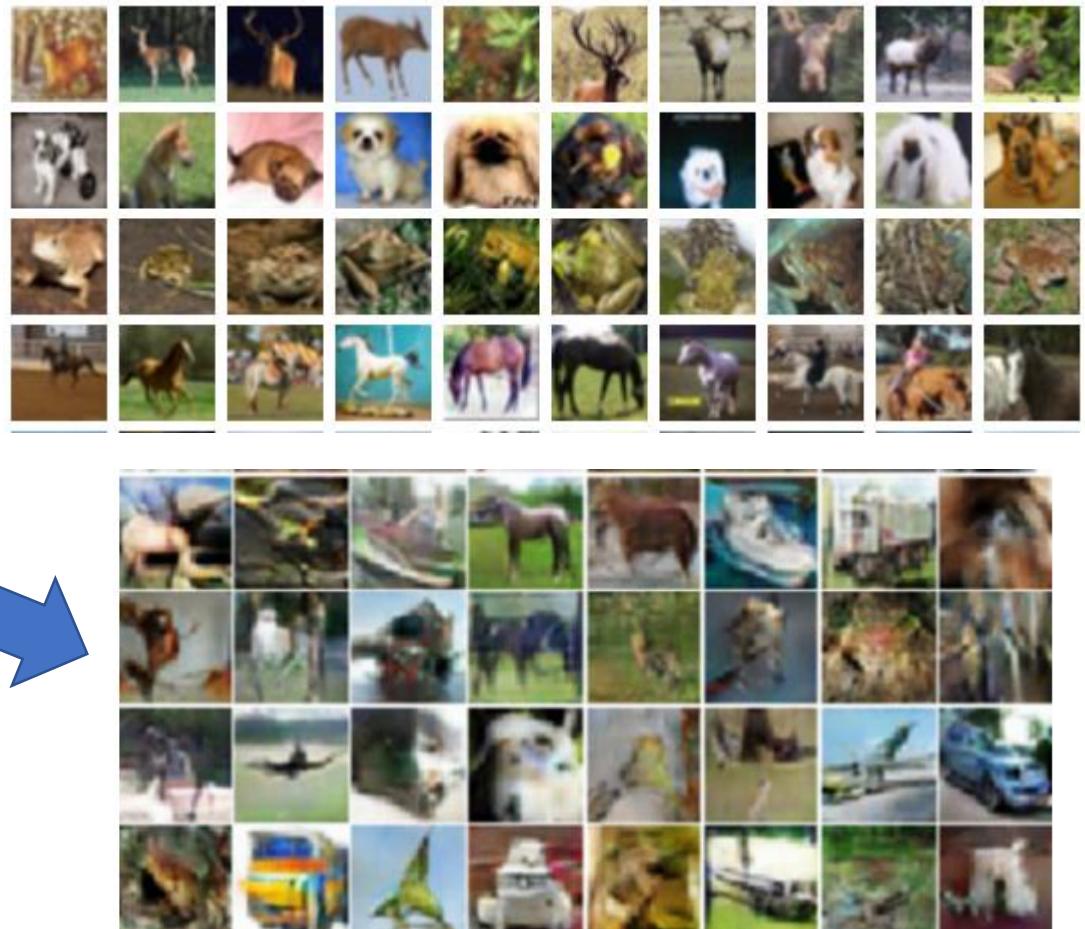


Unsupervised Learning

Ref: <https://openai.com/blog/generative-models/>



Draw something!



Unsupervised Learning

Machine listens to lots of
audio book



How about machine watch TV?



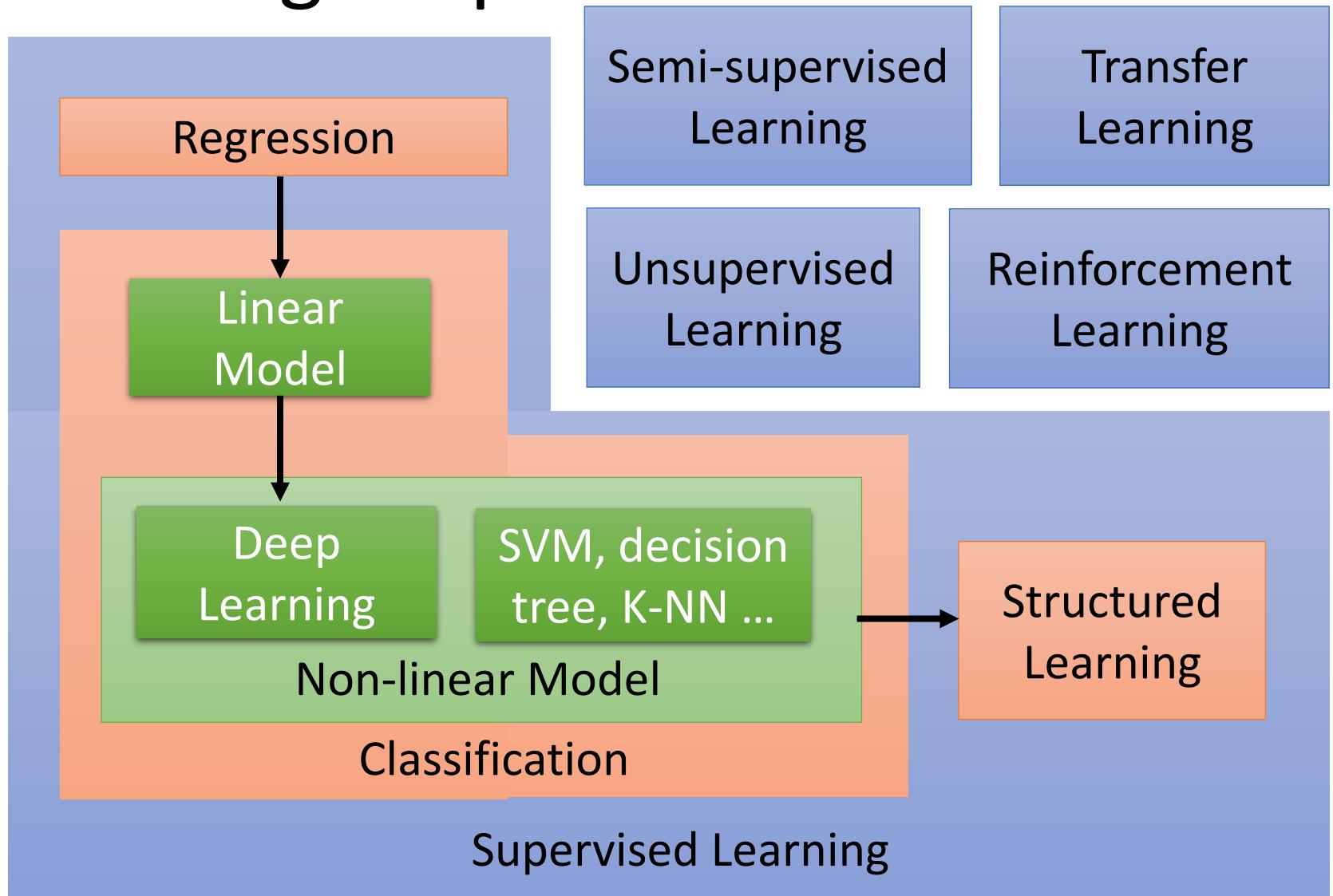
[Chung & Lee, INTERSPEECH 2016]

Questions: How many group members are favorable when forming a group?
团体成员数量喜欢用几个?

“七”个单位的团体有哪些？

- 竹林七贤
- 江南七怪
- 武当七侠
- 七剑下天山
- 七个葫芦娃
- 七条神龙（七龙珠）

Learning Map



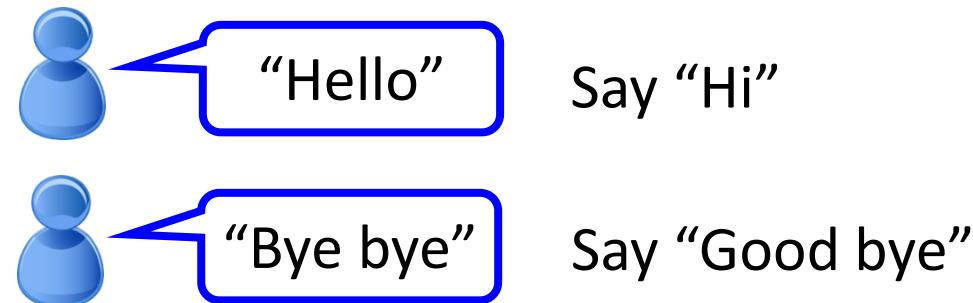
Reinforcement Learning



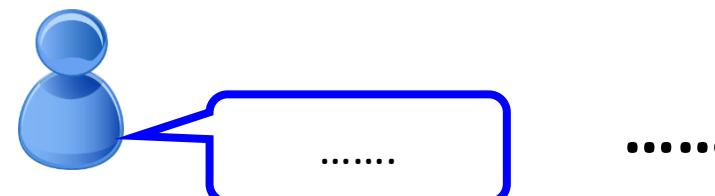
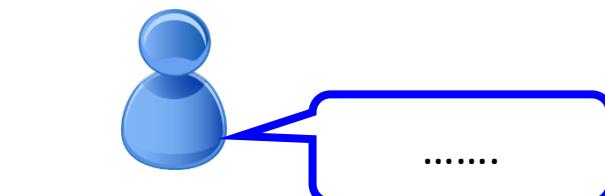
Supervised v.s. Reinforcement

- Supervised

Learning from
teacher



- Reinforcement



.....



Bad

Learning from
critics

Agent

Agent

Supervised v.s. Reinforcement

- Supervised:



Next move:
“5-5”



Next move:
“3-3”

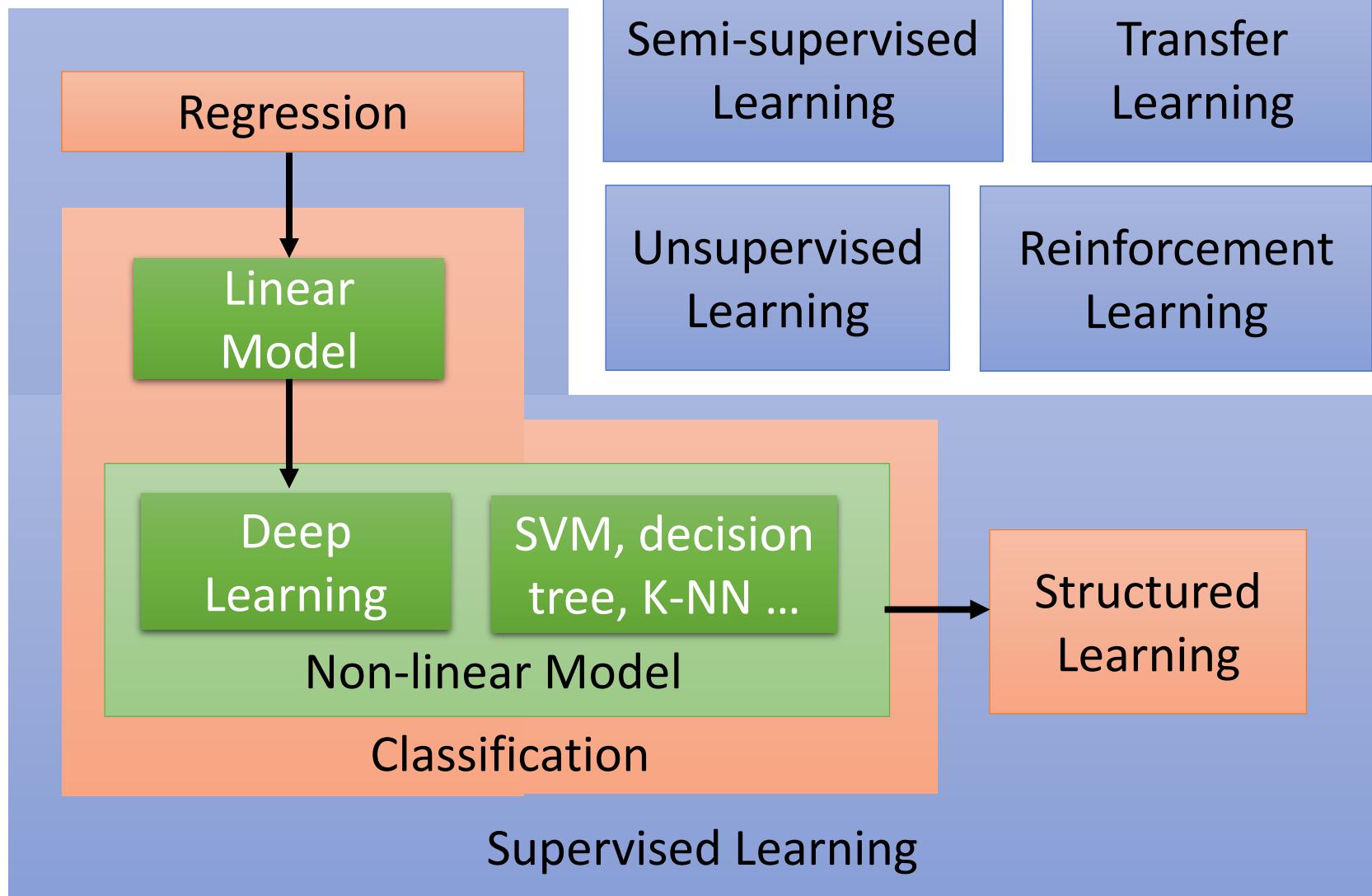
- Reinforcement Learning

First move → many moves → Win!

Alpha Go is supervised learning + reinforcement learning.

Learning Map

scenario task method



Summary

- **What is machine learning ?**
 - What is machine learning?
 - Can you distinguish: ML/DL/AI?
- **Application**
- **History**
- **Framework**
 - Learning/training, prediction/testing
- **Learning Map**
 - Classification/Regression
 - Supervised Learning/Unsupervised Learning...

Open thinking...

- Do you think AI will replace humans one day?

