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 introduction***
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Course Information

- Schedule
  - Every Friday, class 10-12
  - 7 pm - 21:25 pm
  - Week 1 to 17
- Location
  - Rm 426, Jishi Building
- Office hours
  - 16:30-17:30, Thursday

Course Information

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

Who we are

- Instructors

Shuang LIANG
梁爽

Weixiong RAO
饶卫雄

- 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 Univerisity, 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%
Quiz	10%
Course Project	20%
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

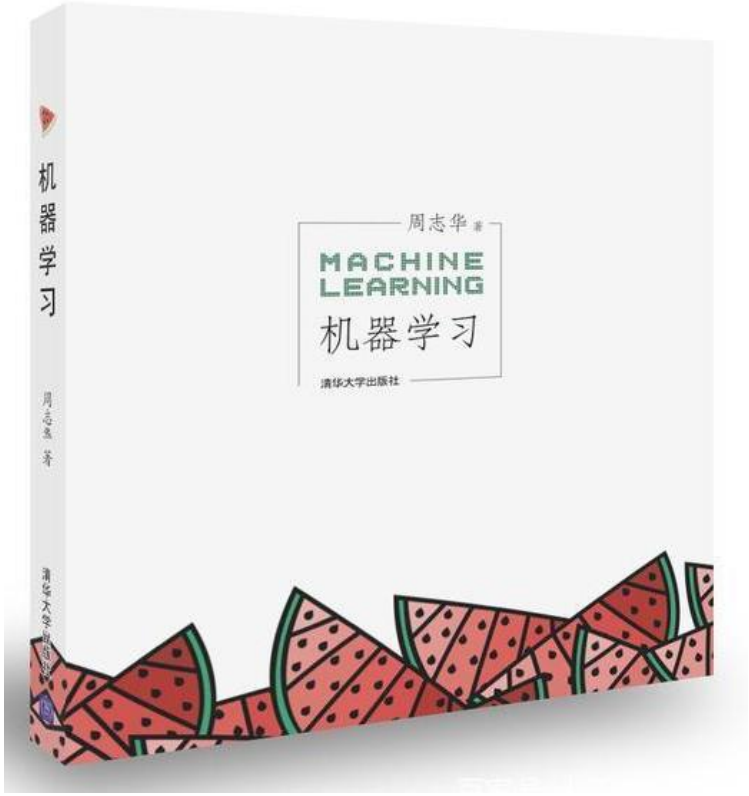
Course Schedule

Week	Date	Topics	Tasks
1	2月25日	Introduction, Basic Concepts	Homework1
2	3月4日	Probability Review, Linear Regression, Gradient Descent	
3	3月11日	Logistic Regression	Homework1 ddl
4	3月18日	KNN	
5	3月25日	Lab1: Classifier	
6	4月1日	Decision Tree	
7	4月8日	Bayes Classifier	Homework2
8	4月15日	Quiz	
9	4月22日	SVM	Homework2 ddl
10	4月29日	项目开题	
11	5月6日	Unsupervised Learning	
12	5月13日	Neural Network	
13	5月20日	CNN&RNN	Homework3
14	5月27日	Lab2: Neural Network	
15	6月3日	端午节	Homework3 ddl
16	6月10日	Deep Learning Application	
17	6月17日	项目答辩	

Materials

- The course slides
- Reference materials

- Textbook
  - 《机器学习》，周志华
    清华大学出版社



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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

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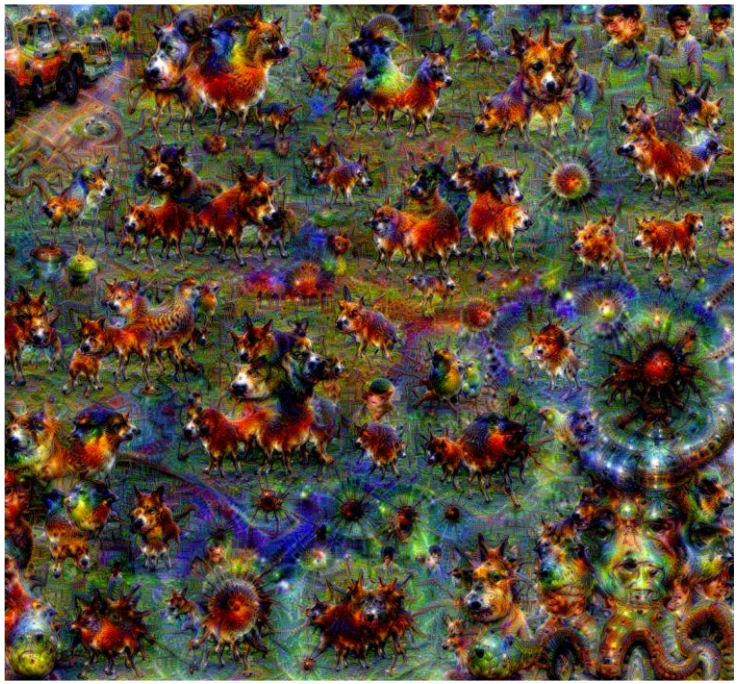
What is the point of studying this course?

- Fun
  - Some fun topics and effects



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What Capabilities can be Improved in this Course?

- Theoretical analysis
- Reasoning ability
- Summarizing ability

- Communication
- Presentation
- Expression

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Class Group chat

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

Today's Topics

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

What is machine learning?

How do human make a decision?

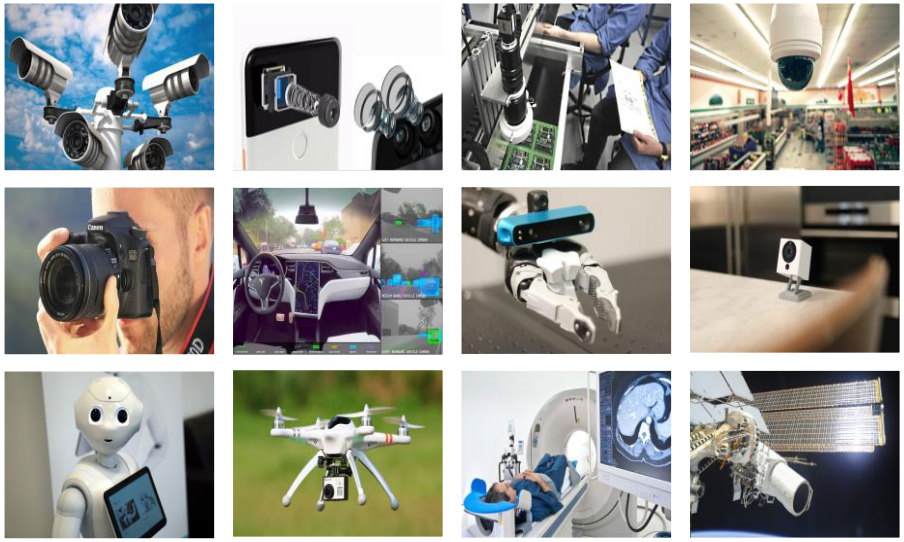
- How to pick a “good” watermelon?
- How do you know you have a cold?
- Can you pick out the apple from bananas?

- *You are trained from the experience*
- *You learn knowledge to make good decisions*

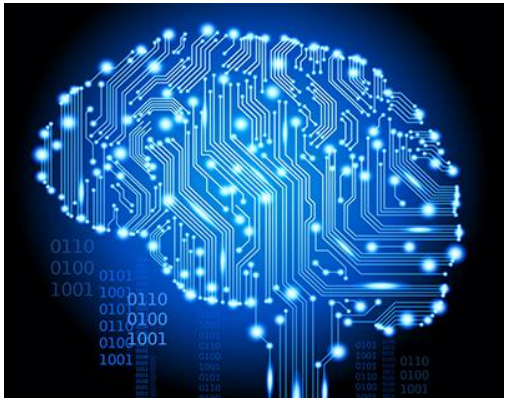
- We could like to give *similar capabilities to machines*

Sensing like human

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



"Eyes"



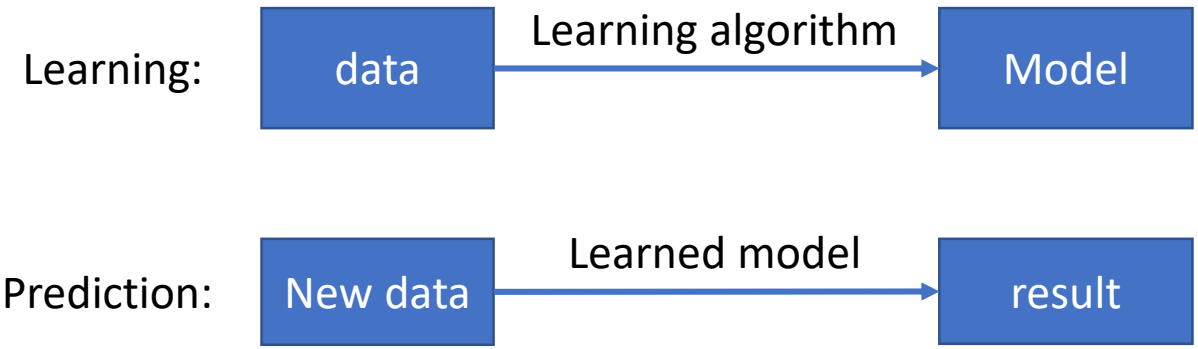
"Brain"

Objects
Activities
Scenes
Locations
Text
Faces
Gestures
Motions
Emotions…

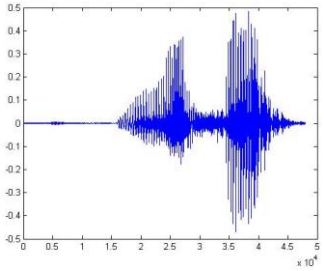
What is machine learning?

- 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."

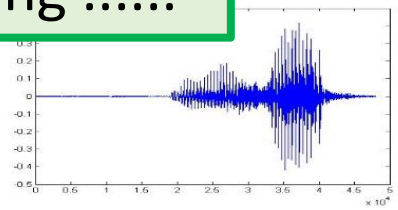


Speech recognition case

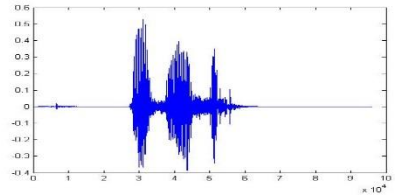


You said “Hello”

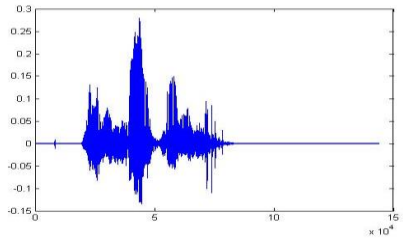
Learning .....



“Hi”



“How are you”



“Good bye”

A large amount of audio data

You write the program for learning.

Image recognition case

Learning .....

This is “cat”

You write the program for learning.

“monkey”

“cat”

“dog”

A large amount of images

Machine learning process

f

Learned model

cat

data → Learning/ modeling → prediction

Collected from past observations

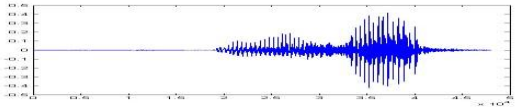
Learn to capture patterns in the data

Training

Apply the model to forecast what is going to happen for new data

Machine learning
≈ Looking for Function (model)

- Speech Recognition

$f($  $)=$ “How are you”

- Image Recognition

$f($  $)=$ “Cat”

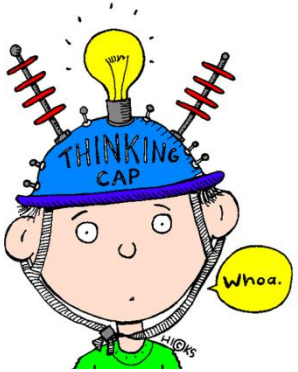
- Playing Go

$f($  $)=$ “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
- ……

How is machine learning related to your area?



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

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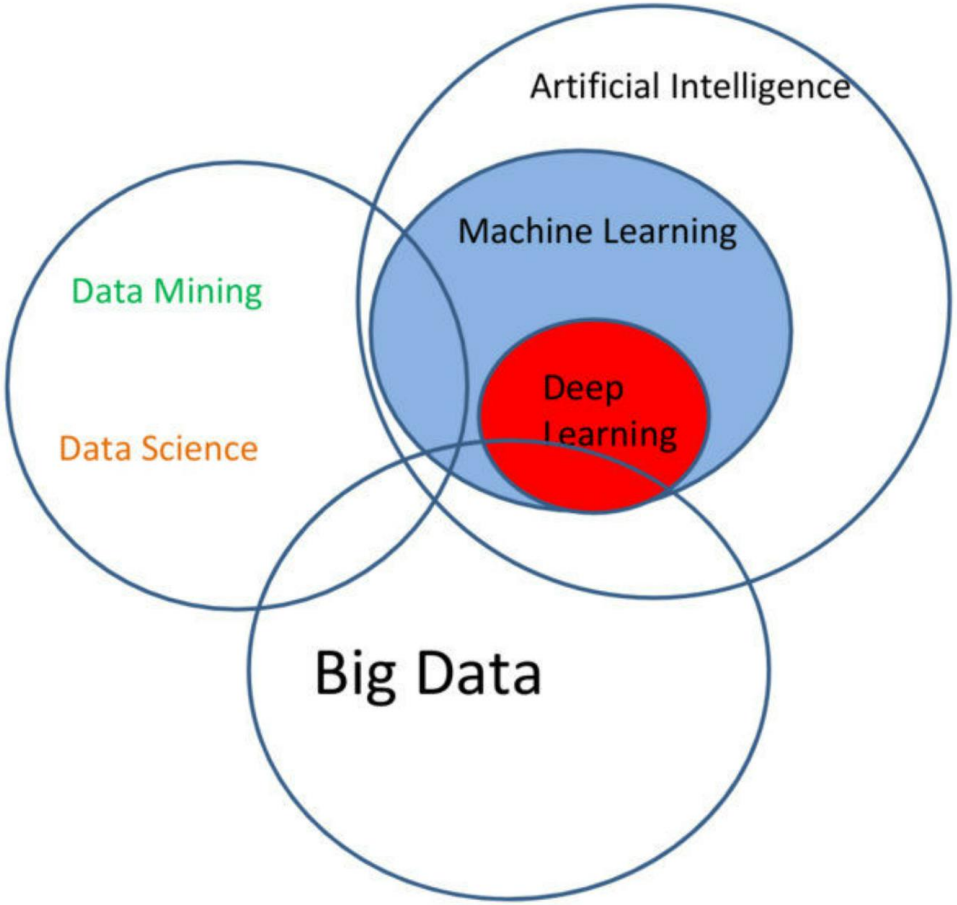
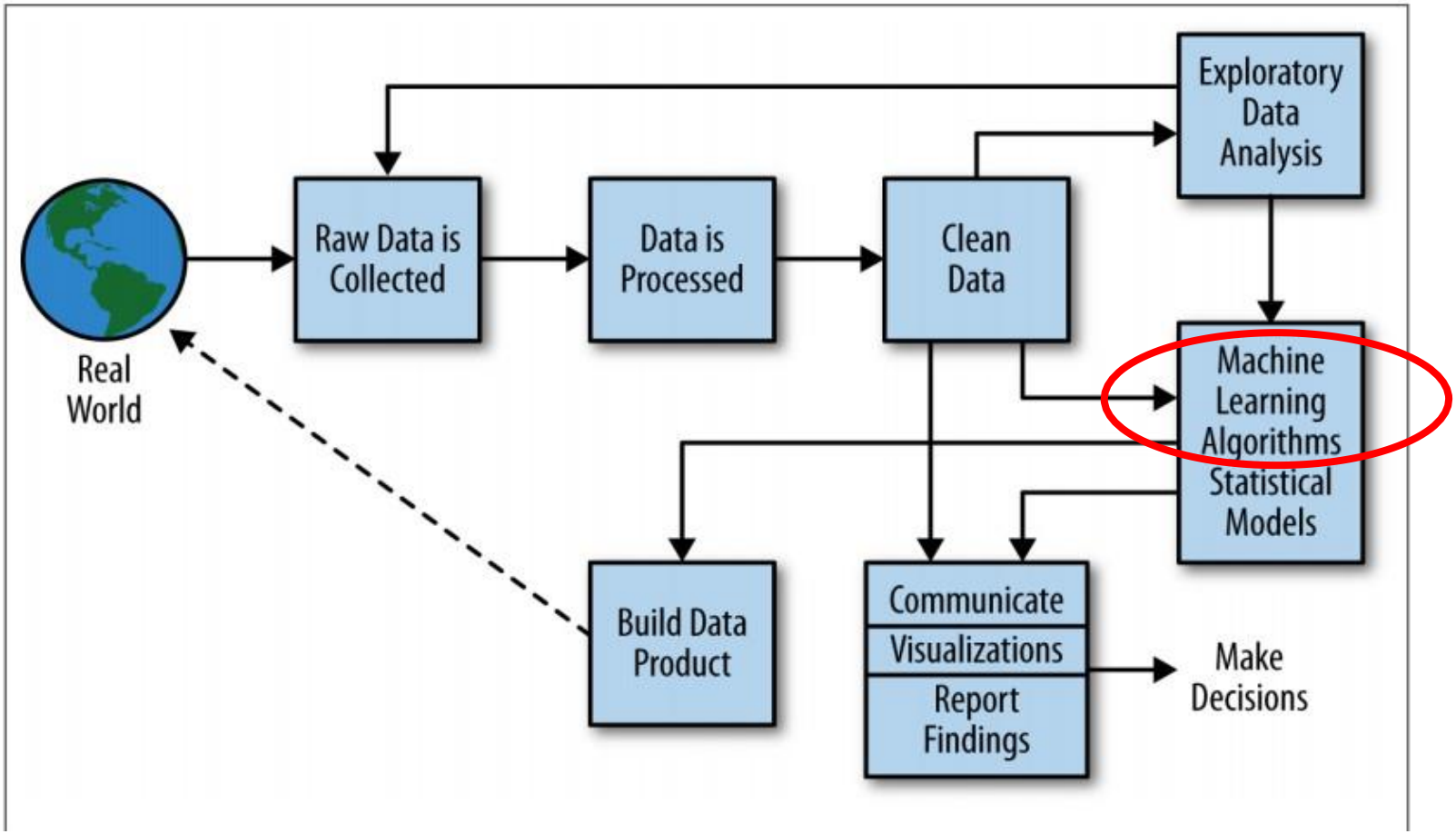
Related concepts

- Relationship between concepts



ML is only a small part!



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- ***Applications***
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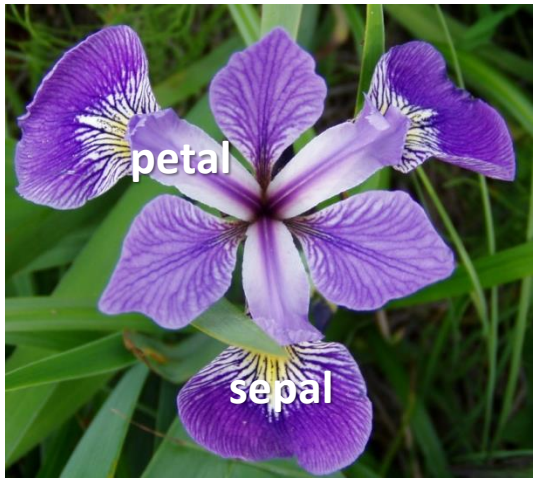
Early statistical learning methods

- Recognizing flowers (by R. Fisher, 1936)

Iris Setosa

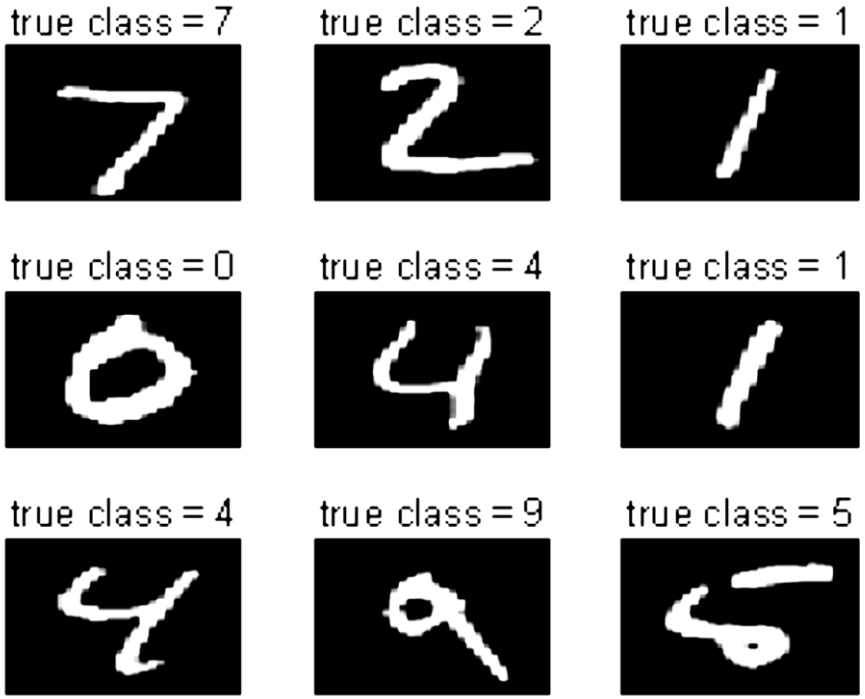


Iris Versicolor

Iris Virginica

Huge success 30 years ago

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



Nowadays: Learn our preferences

- Recommending what you might like

Analyze text data

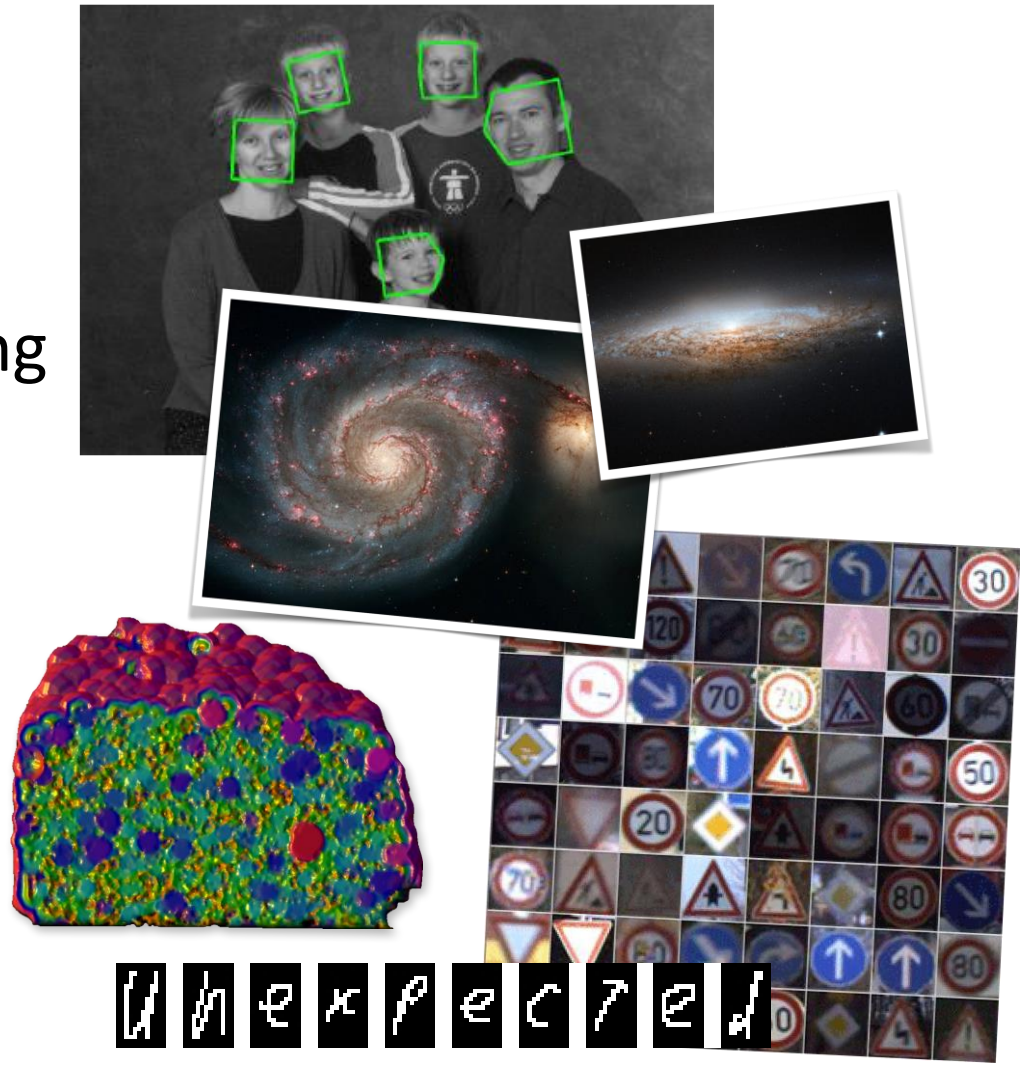
- Machine translation
- Sentiment Analysis

negative	neutral	But i wanna wear my Concords tomorrow though but i don't feel like it
positive	neutral	Gonna watch Grey's Anatomy all day today and tomorrow(:
negative	neutral	@CoachVac heey do you know anything about UVA's fallll fest loll they invited me
neutral	neutral	@DustyEf when that sun is high in that Texas sky, I'll be buckin it to county fair. A
neutral	positive	Up 20 points in my money league with Vernon Davis and L. Fitz still to go tomorro
neutral	positive	DEEJAYING this FRIDAY in THE FIRST CHOP it's CHRIS actual SMITH with a smash
negative	negative	The Rick Santorum signing that was scheduled for tomorrow at the Books A Million
positive	neutral	@dreami9 lol yep looks like it! Was after El Clasico on Sunday. I didn't like her lol
neutral	neutral	Back in Stoke on Trent for the 2nd time today!
neutral	neutral	First Girls Varsity Basketball Game tomorrow at 6:00 pm Then Football Senior nig
neutral	neutral	#UFC lightweights @Young__Assassin VS @jamievarner set for TUF 16 Finale on t
neutral	neutral	@OOOOO_WEEEE slide thru sometime this weekend ill have somethin yu can sip o
negative	negative	@DannyB618 Sure absolutely-- I meant out of the Bachmann, Perry, Santorum, H
negative	negative	@RichardGordon48 re Levein discussion on Wed. Can't keep changing boss, but he
neutral	neutral	Today In History November 02, 1958 Elvis gave a party at his hotel before going o
		n party everyday like its Fri
		ncouver tomorrow! I'm like a kid at Christm

DeepL

Analyze image data

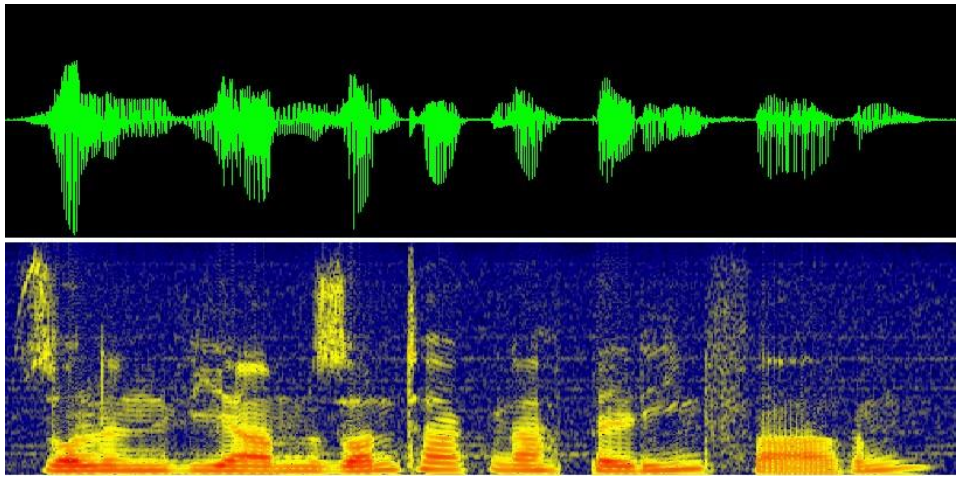
- Astronomy
- Face recognition
- 2D + 3D medical imaging
- OCR
- Self-driving cars



Analyze audio&multimodal data

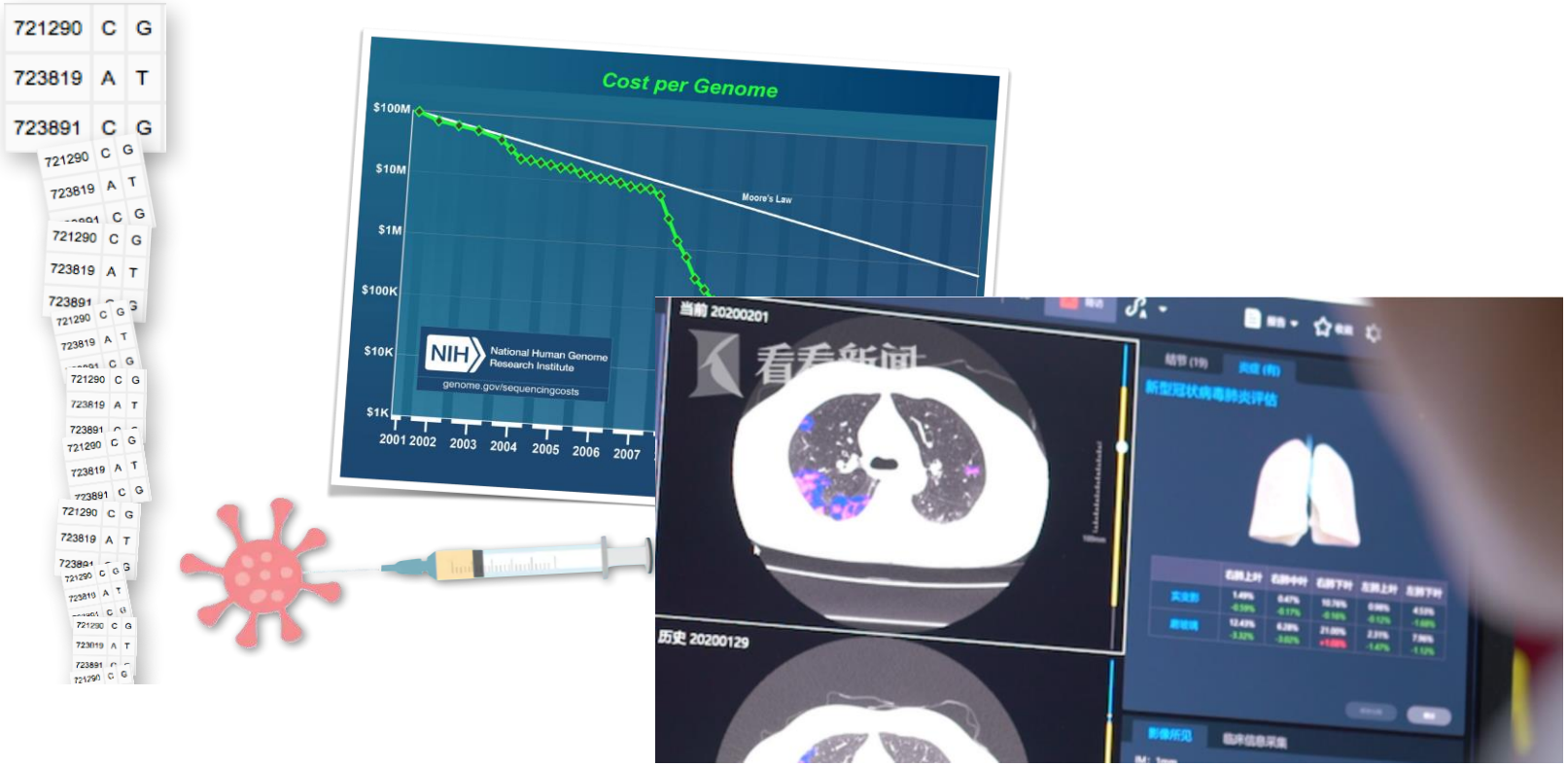
- Hearing aids
- Voice recognition
- Automic Translation
- Lip Reading
- Video Analysis

LYREBIRD



Analyze medical data

- Lesion identification
- Using genes for disease prediction



Analyze numerical/sensor data

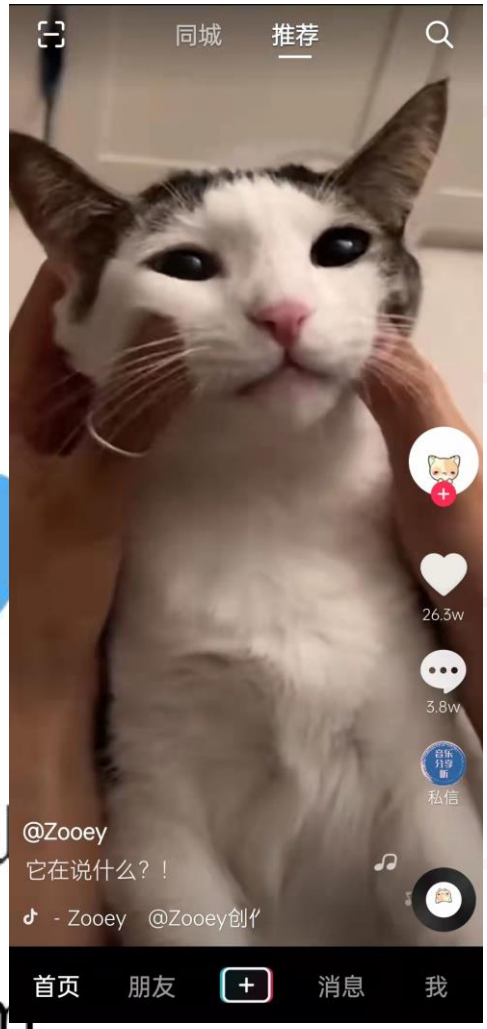
- Cern
- Astronomy/ Telescopes
- Fitness Trackers
- Weather Forecast
- Robotics
- Kinect

Games / Simulations

- Immediate Feedback
- Chess, Go
- Physical World

Analyze internet data

- Recommender systems
- Virtual assistants
- Ads



TikTok

Zhihu

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- ***A bit of history***
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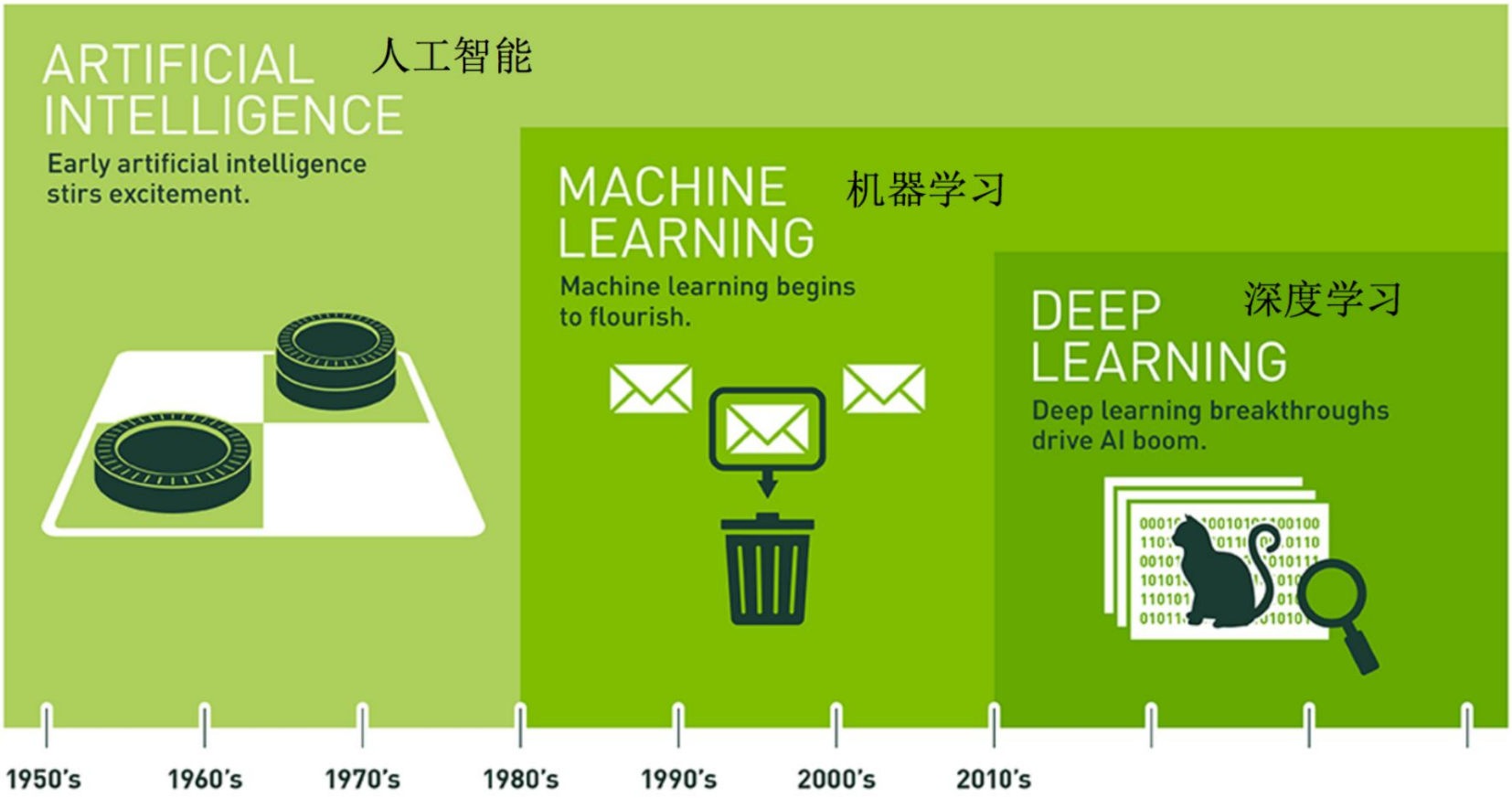
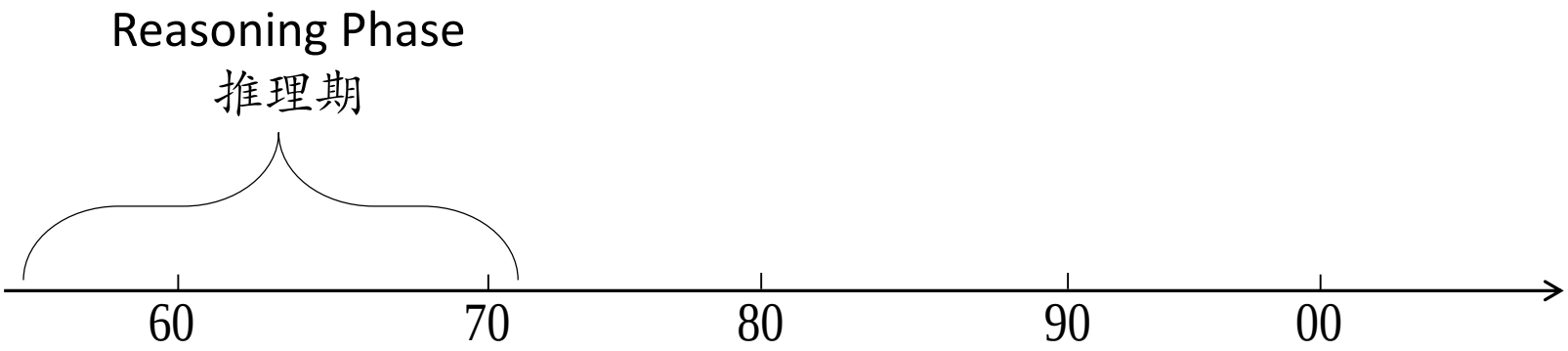
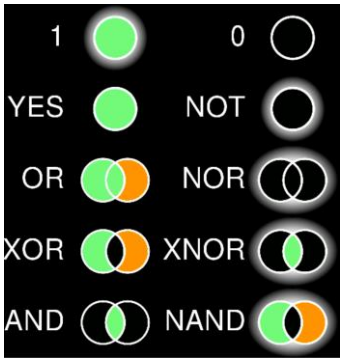
Development of AI



Timeline


Reasoning Phase
推理期
60
70
80
90
00


1
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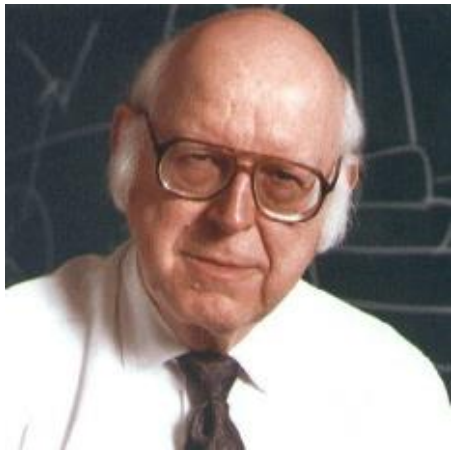
YES
NOT
OR
NOR
XOR
XNOR
AND
NAND

Reasoning Phase

1950s to early 1970s

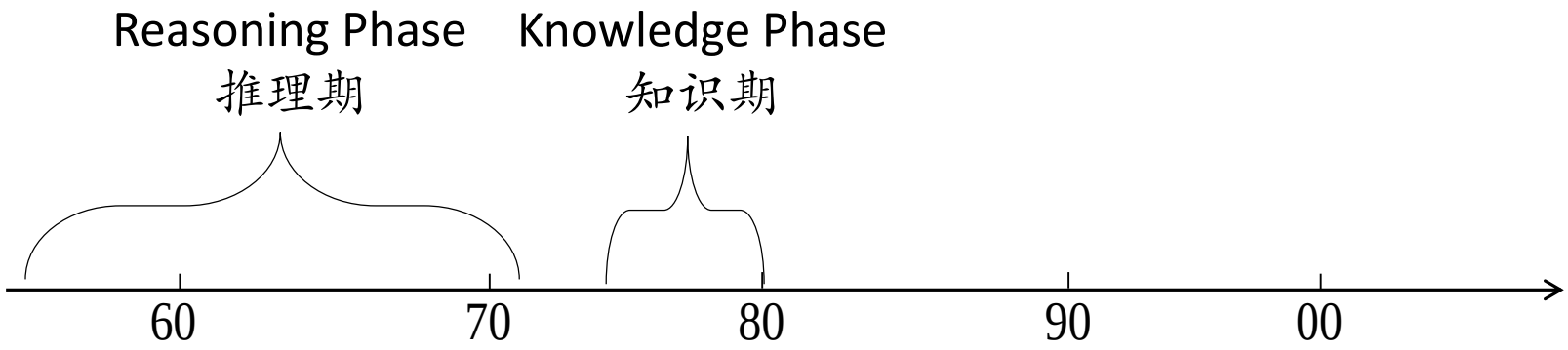
- Goal: Endow the machine with logical reasoning ability
- "Logic Theorist" by A. Newell and H. Simon（逻辑理论家）
  - Prove all 52 theorems in *Principia Mathematica* (by Bertrand Russell & Alfred North Whitehead) in 1963
  - 1963年，“逻辑理论家”程序证明了名著《数学原理》的全部52条定理
  - 1975 Turing Award
- A long way from achieving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

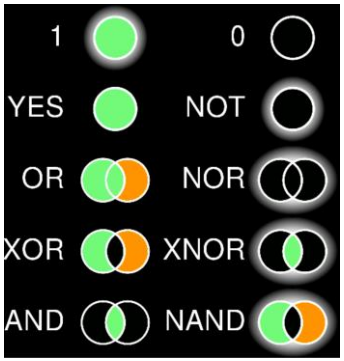


A. Newell

H. Simon

Timeline


Reasoning Phase
推理期
Knowledge Phase
知识期
60
70
80
90
00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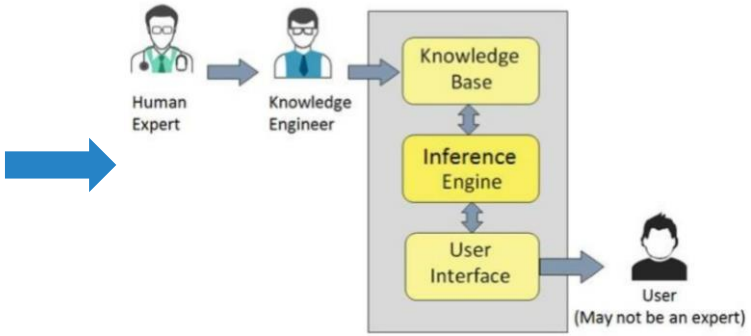
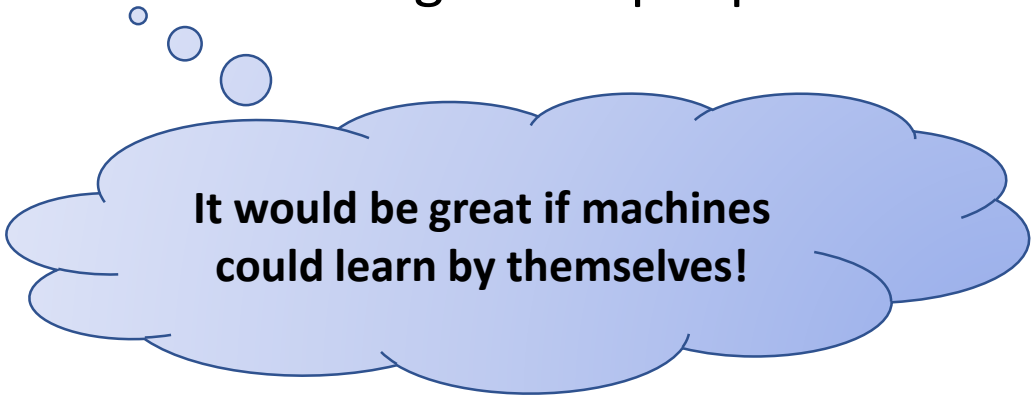

Human Expert
Knowledge Engineer
Knowledge Base
Inference Engine
User Interface
User
(May not be an expert)

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

Reasoning Phase
推理期

Knowledge Phase
知识期

Learning Phase
学习期

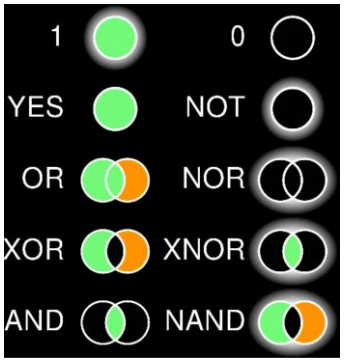
60 70 80 90 00

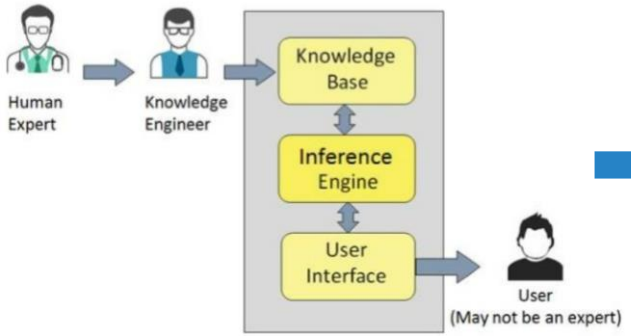
Symbolism
符号主义学习

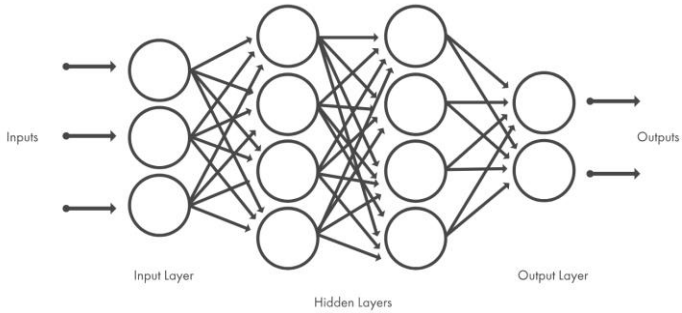
Connectionism
连接主义学习
（Based on Neural Network）

Statistical
统计学习

Connectionism
连接主义学习
(Based on deep learning)







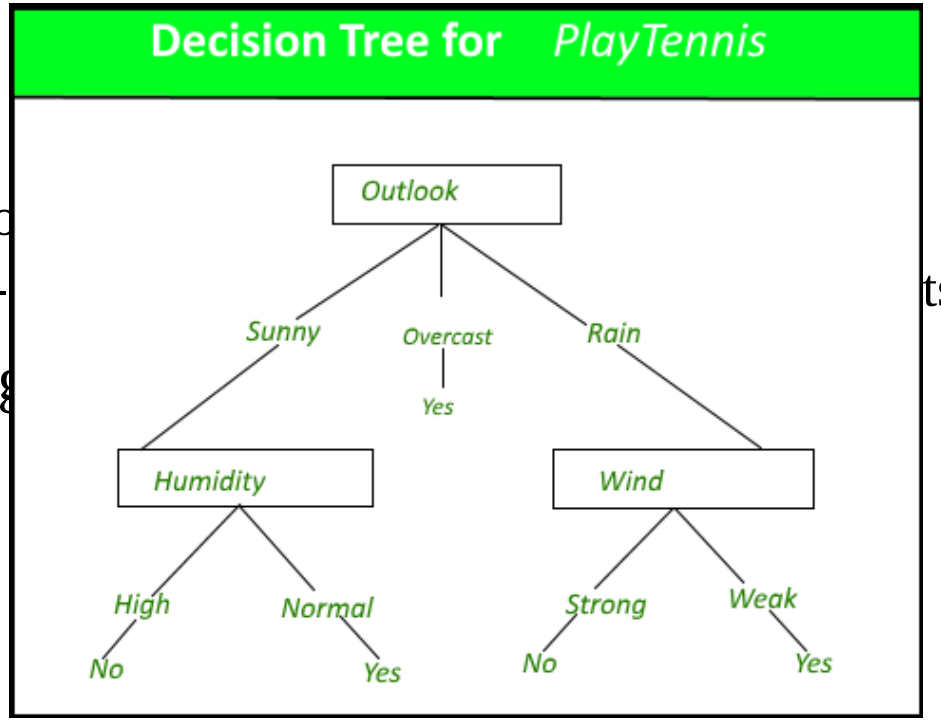
Learning Phase

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
- …

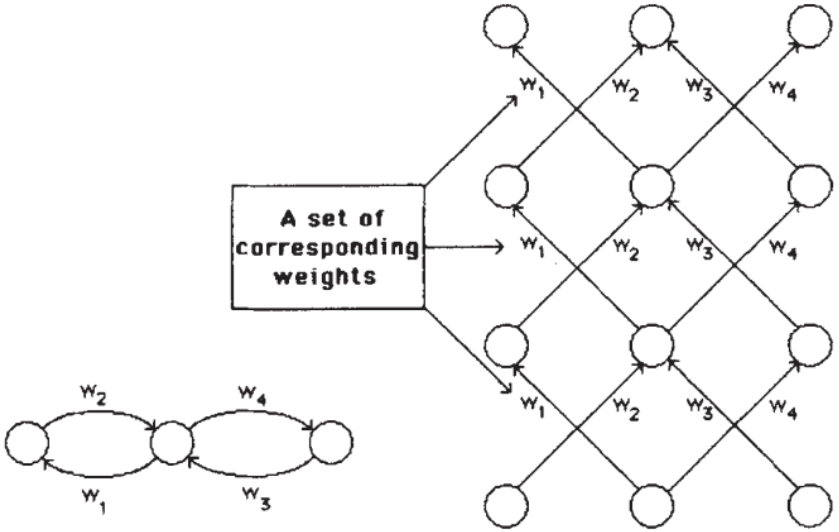
Learning from examples

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



Learning from examples

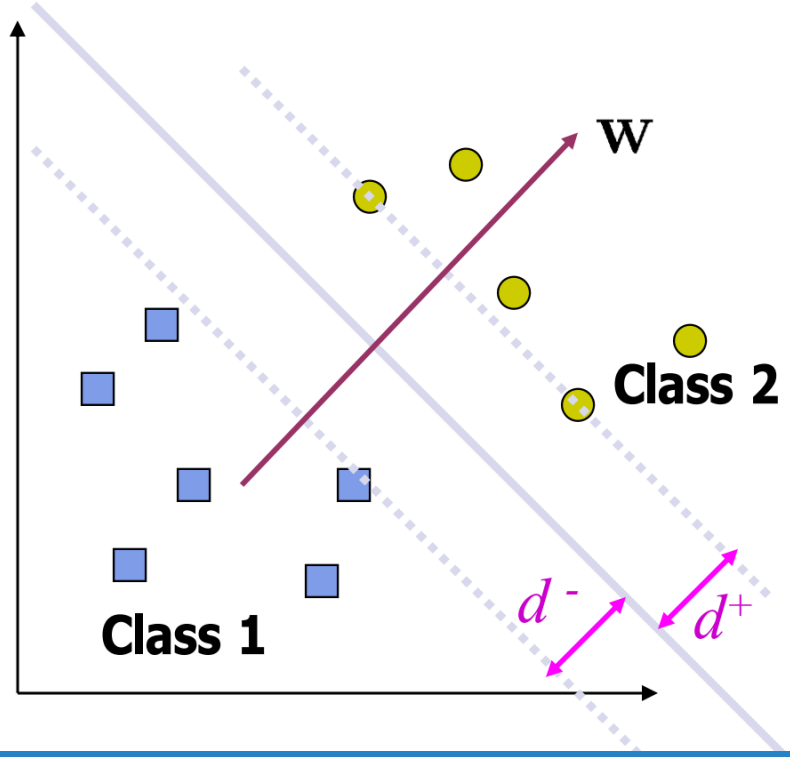
- **Connectionism – Phase 1 连接主义学习**
- Popular before 1990s
- Based on neural networks
- The backpropagation algorithm made a profound impact



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

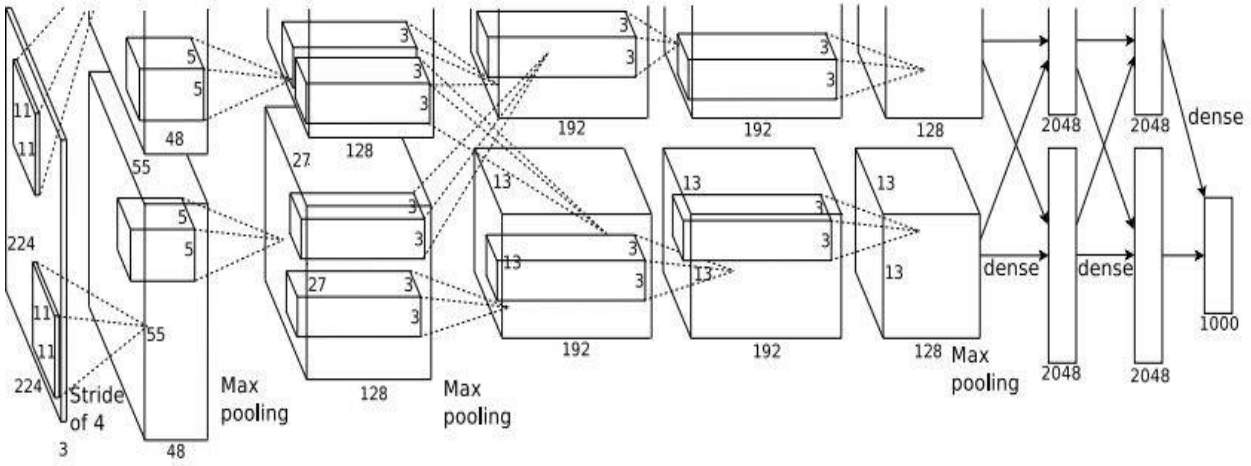
Learning from examples

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

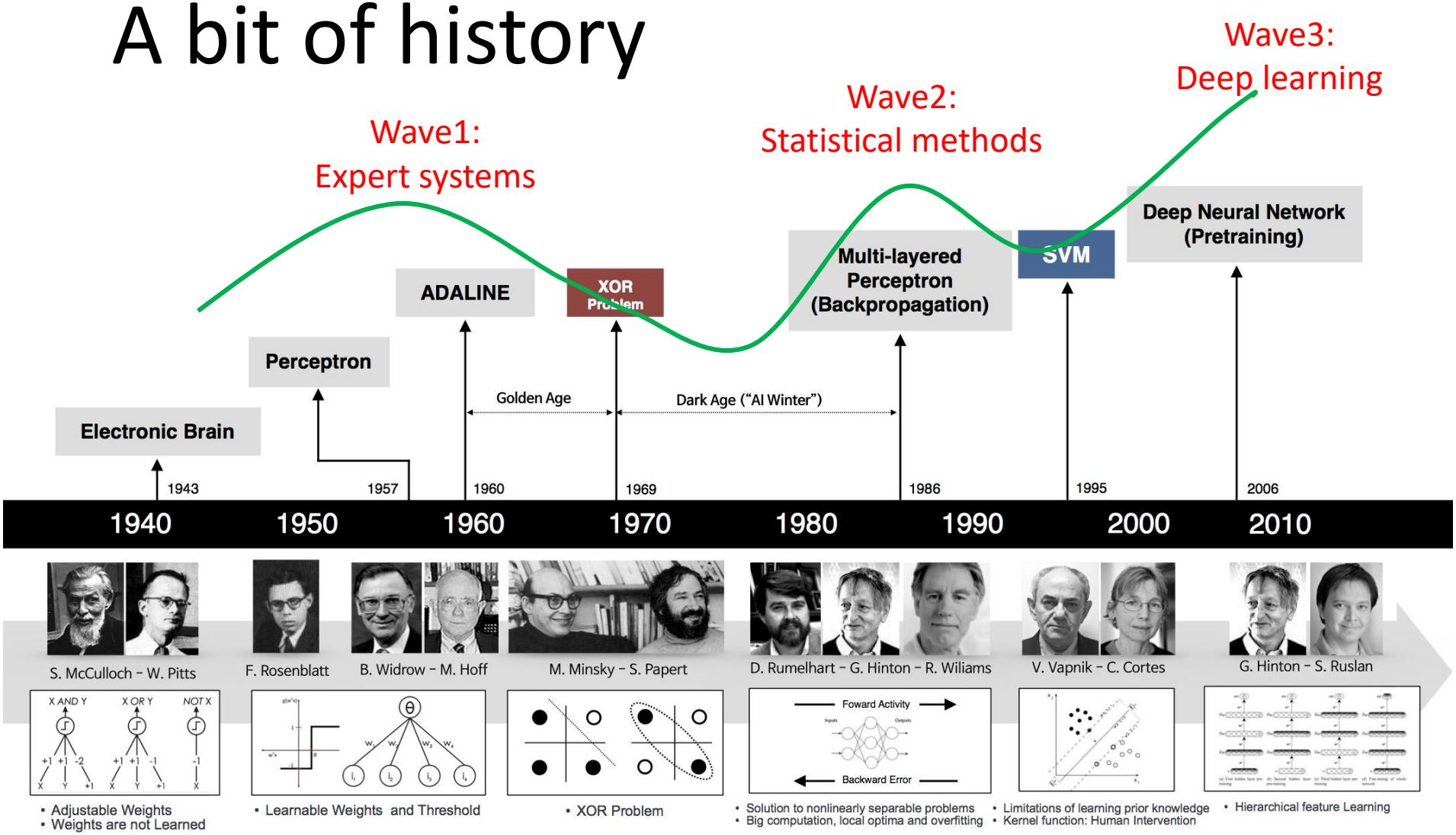


Learning from examples

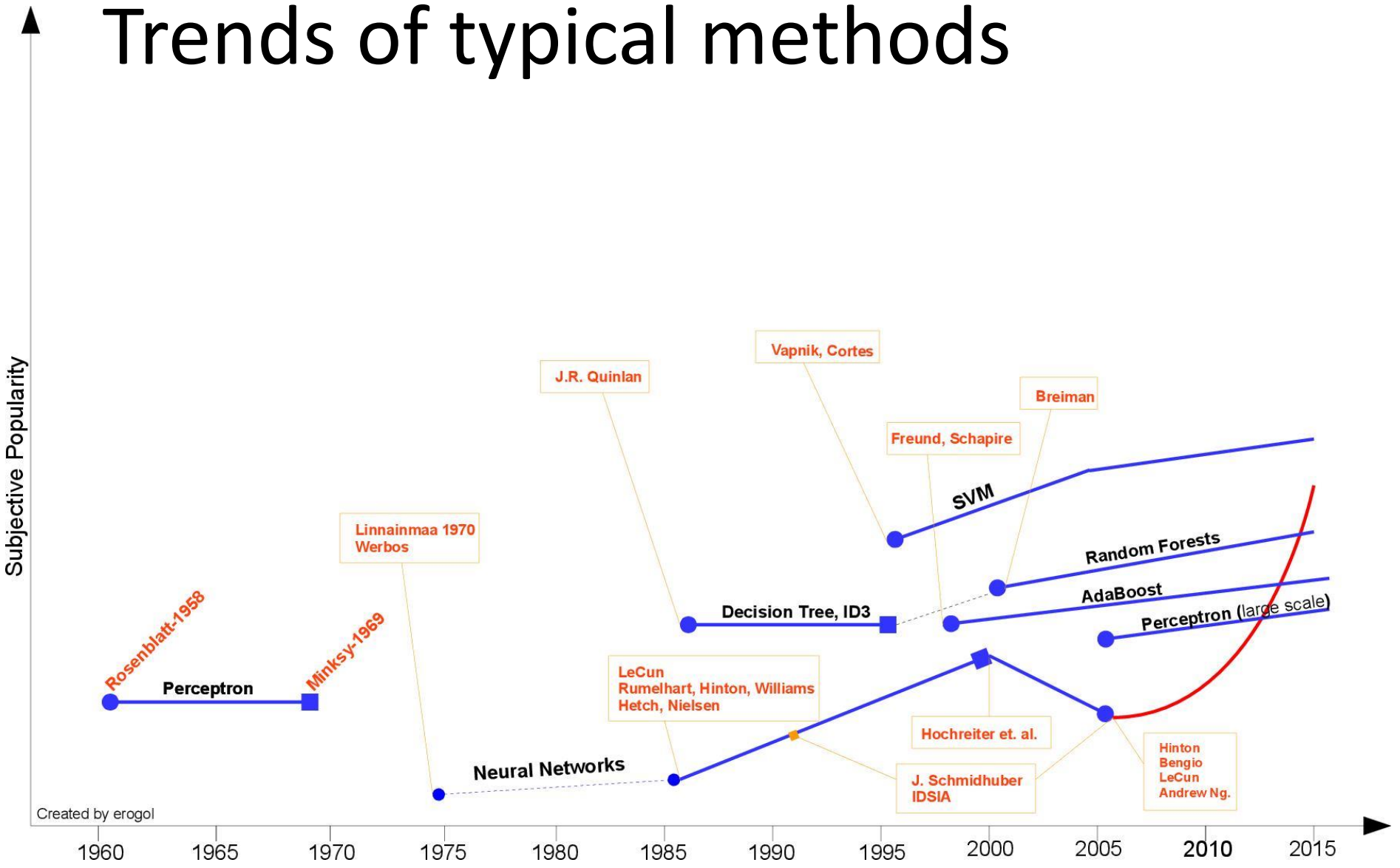
- **Connectionism – Phase 2 连接主义学习**
- Rise in early 21 century, hot now
- Based on deep learning
- A large amount of data and strong computing power provide support for deep learning



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

Today's Topics

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

Framework

Image Recognition:

$f($  $)=$ "cat"

A set of function

Model

$f_1, f_2 \cdots$

$f_1($  $)=$ "cat"

$f_2($  $)=$ "money"

$f_1($  $)=$ "dog"

$f_2($  $)=$ "snake"

Framework

Image Recognition:

$f($  $)=$ "cat"

A set of function

Model

$f_1, f_2 \cdots$

Goodness of function f

Training Data

$f_1($  $)=$ "cat"

$f_2($  $)=$ "money"

Better!

$f_1($  $)=$ "dog"

$f_2($  $)=$ "snake"

function input:   

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

Framework

Image Recognition:

$f($  $)=$ "cat"

Training

Testing

Step 1

A set of function

Model

$f_1, f_2 \cdots$

Step 2

Goodness of function f

Step 3

Pick the "Best" Function

f^*

Using f^*

"cat"

Training Data

"monkey"

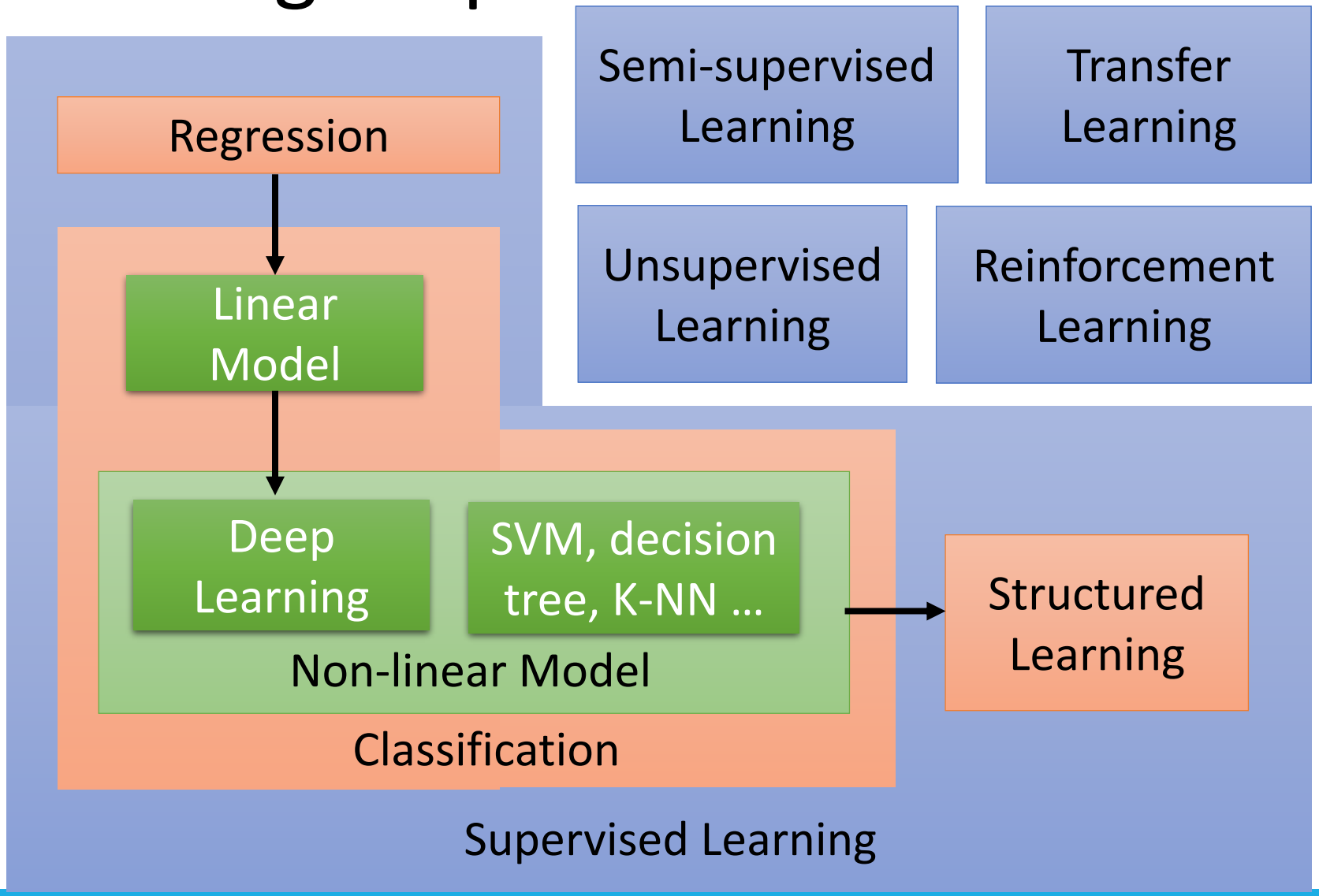
"cat"

"dog"

Today's Topics

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

Learning Map

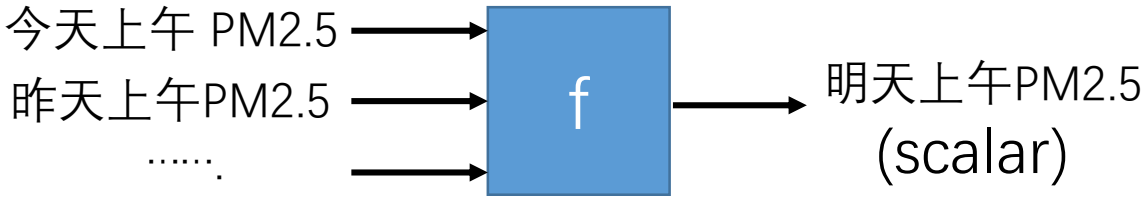


Learning Map

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

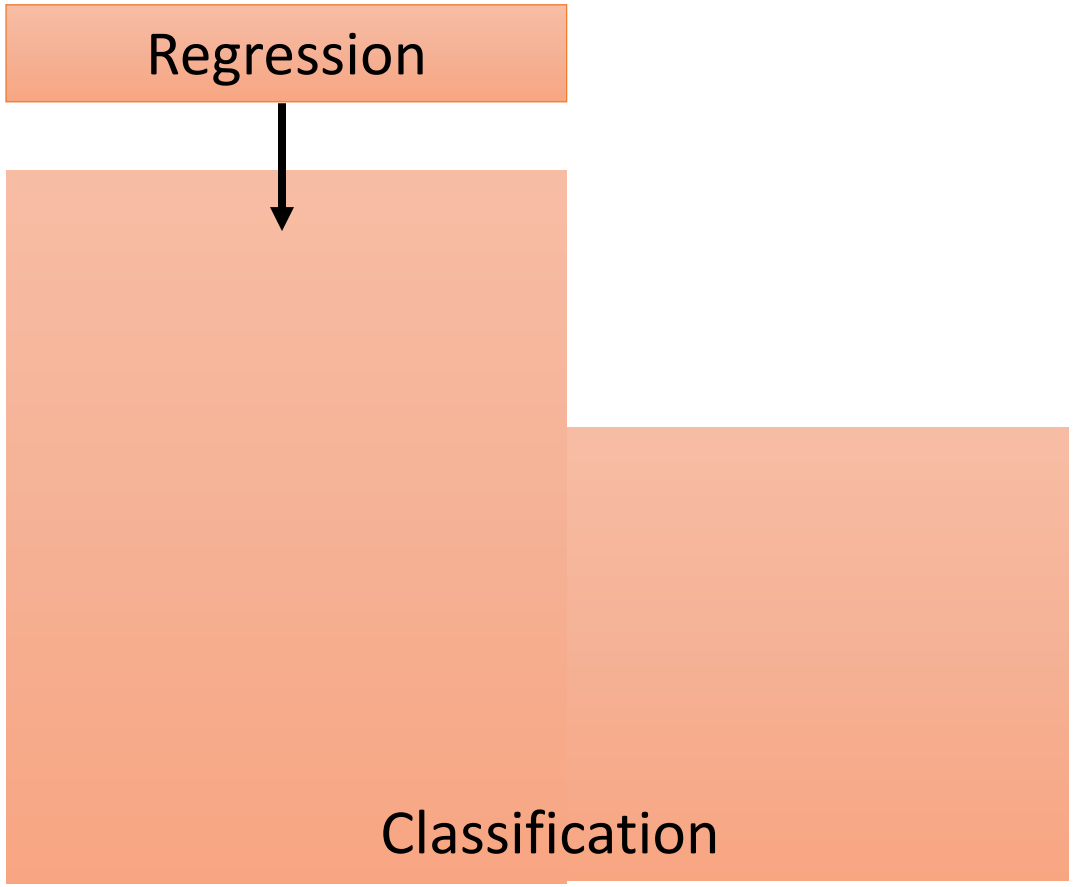
Input:

9/12 上午 PM2.5 = 30 9/13 上午 PM2.5 = 25

Output:

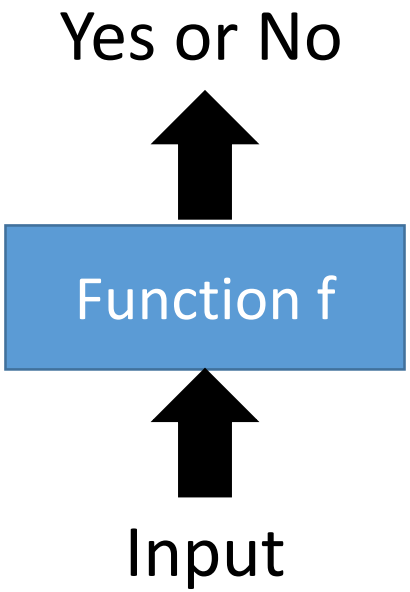
9/14 上午 PM2.5 = 20

Learning Map

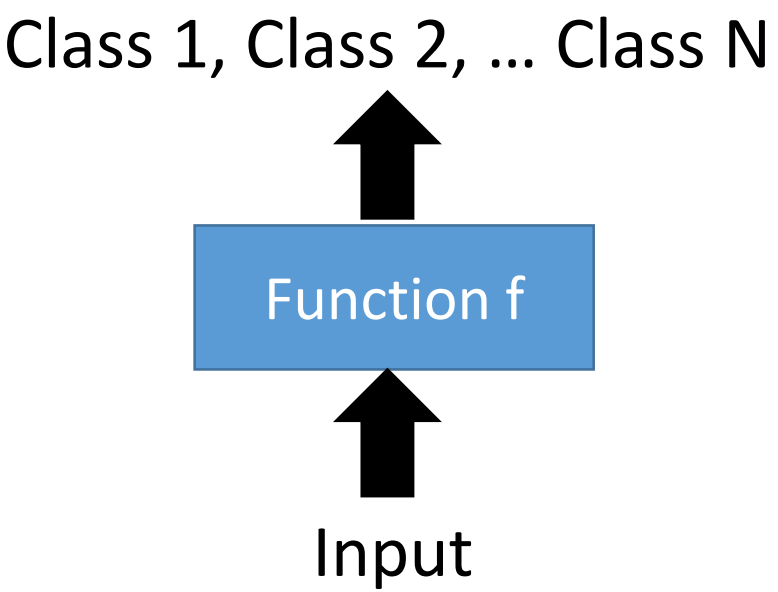


Classification

- Binary Classification



- Multi-class Classification



Binary Classification

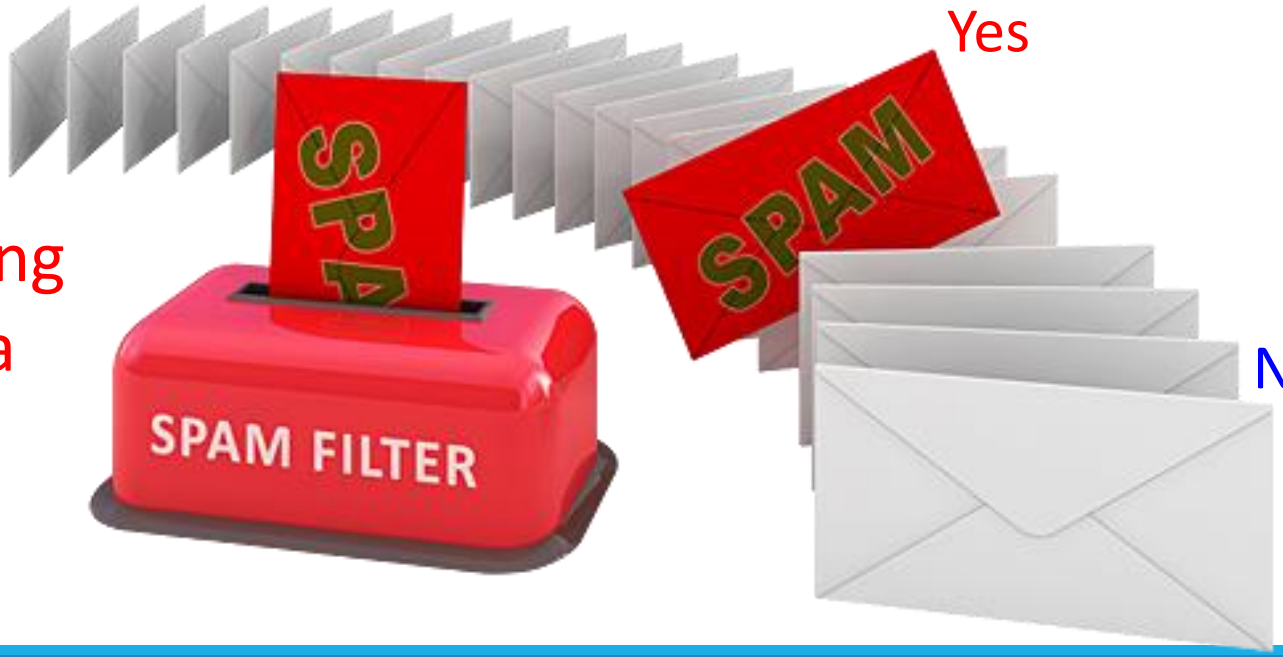
Spam filtering

Function

Yes/No

Yes

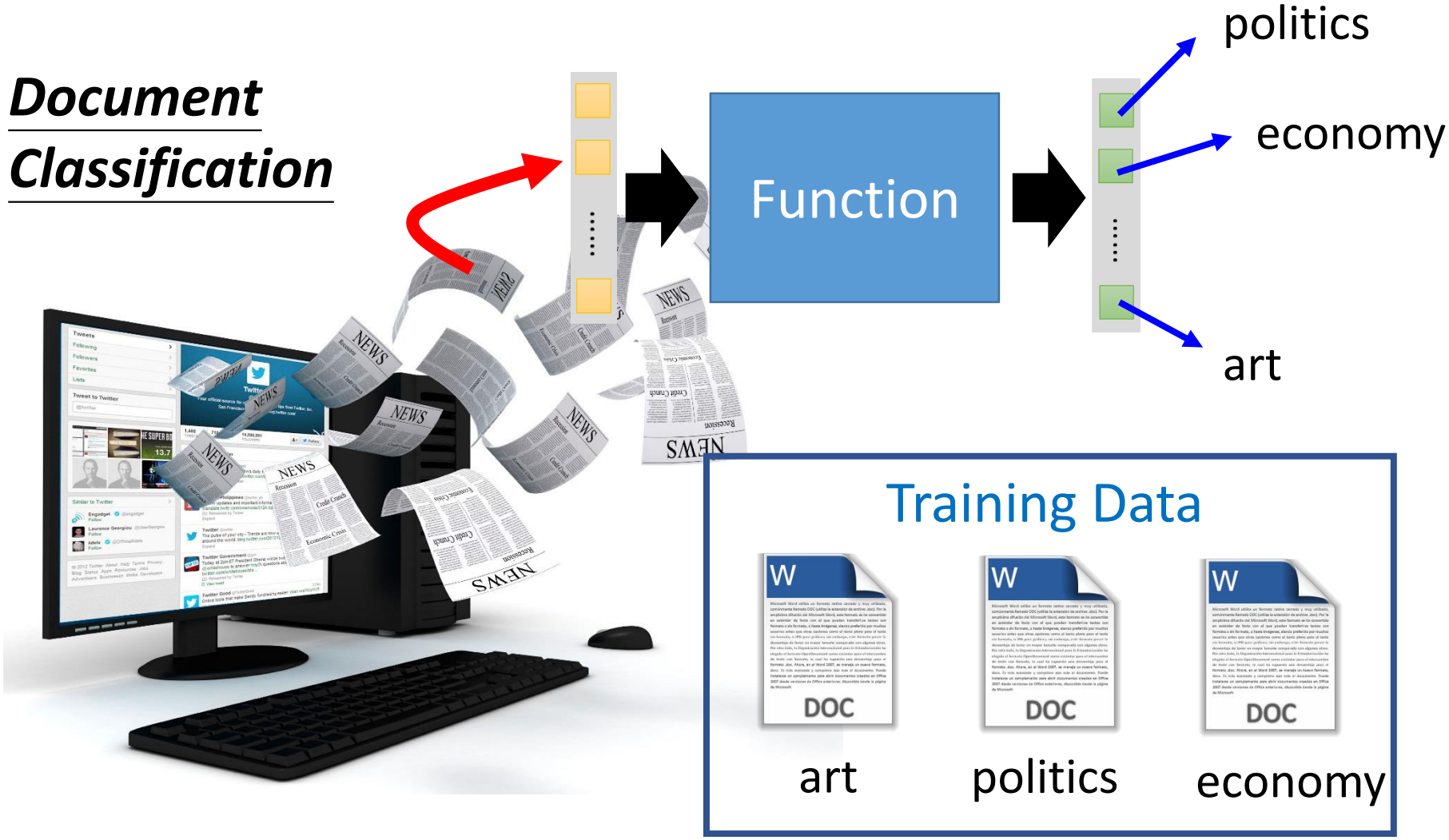
Training Data



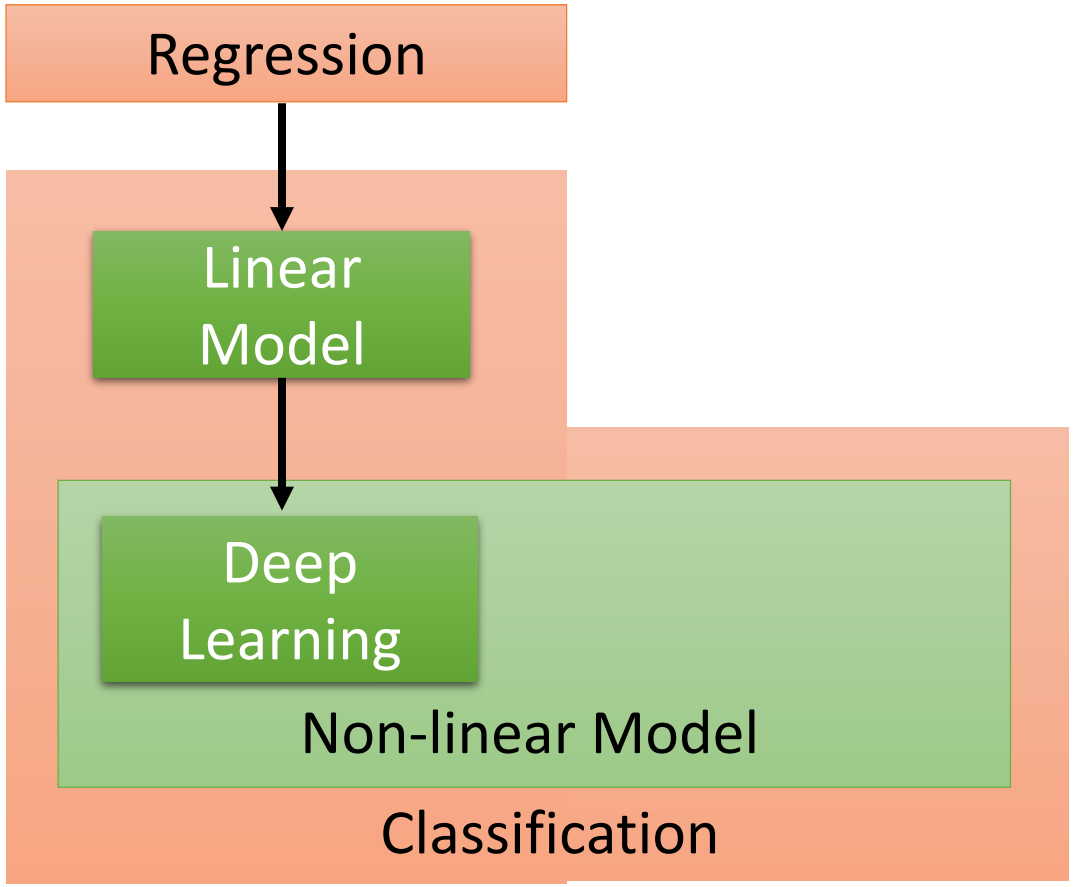
No

Multi-class Classification

Document Classification

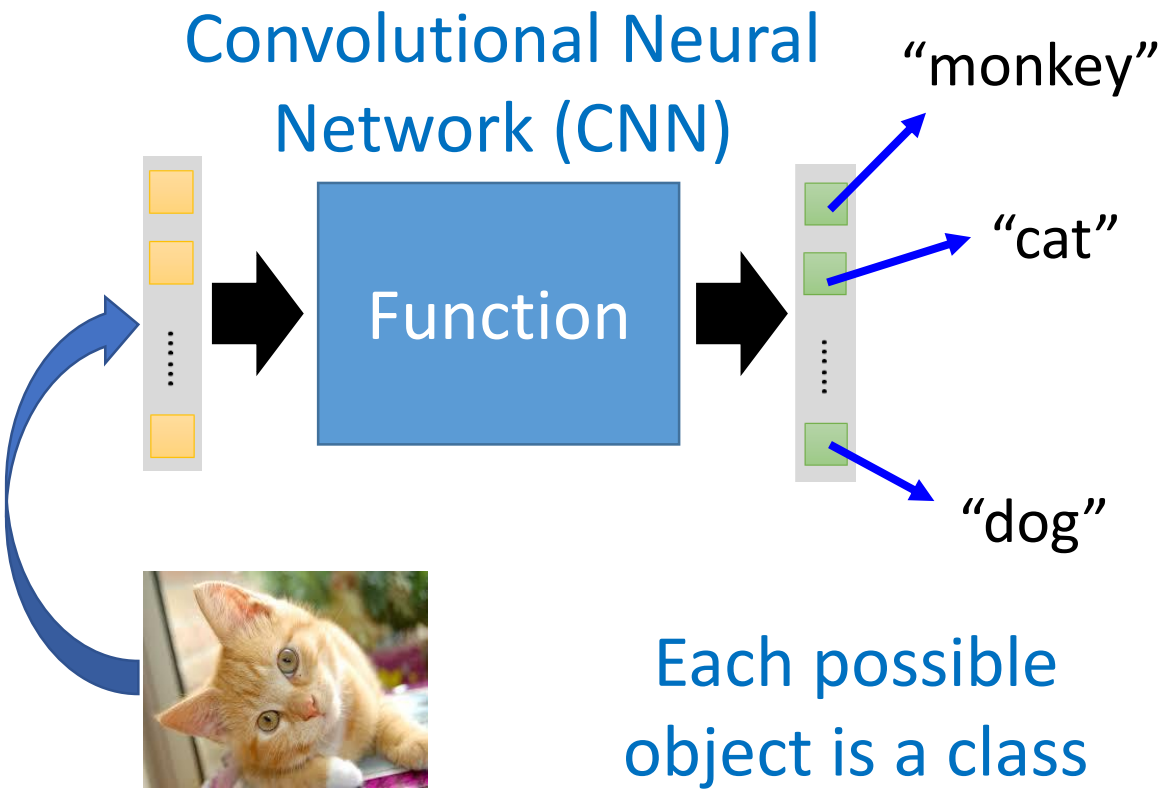


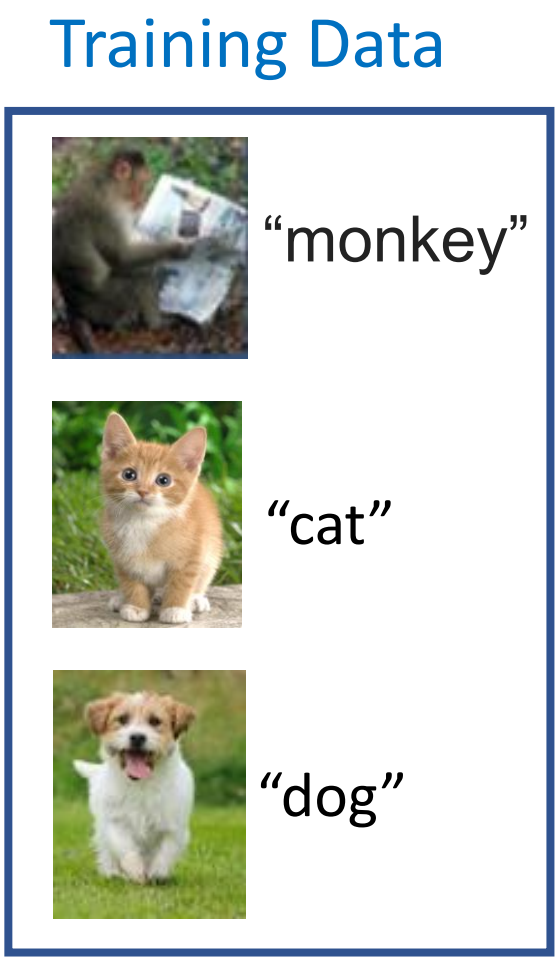
Learning Map



Classification - Deep Learning

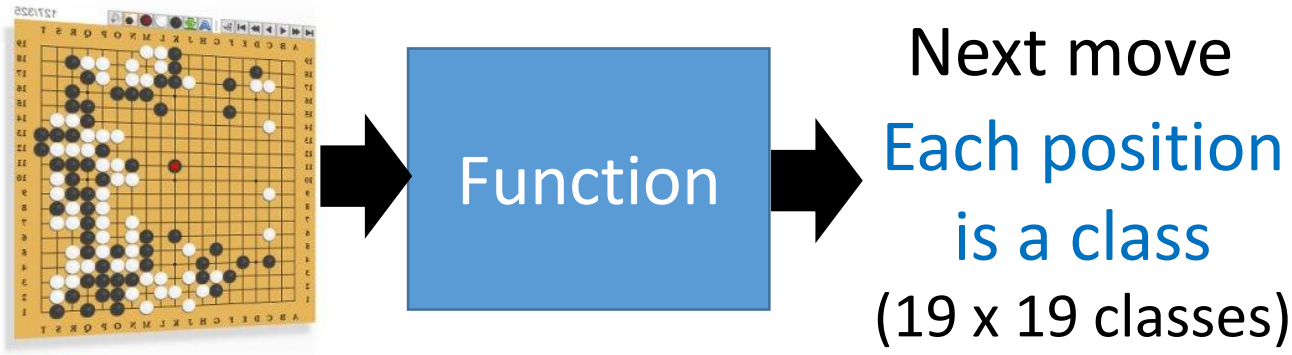
- Image Recognition



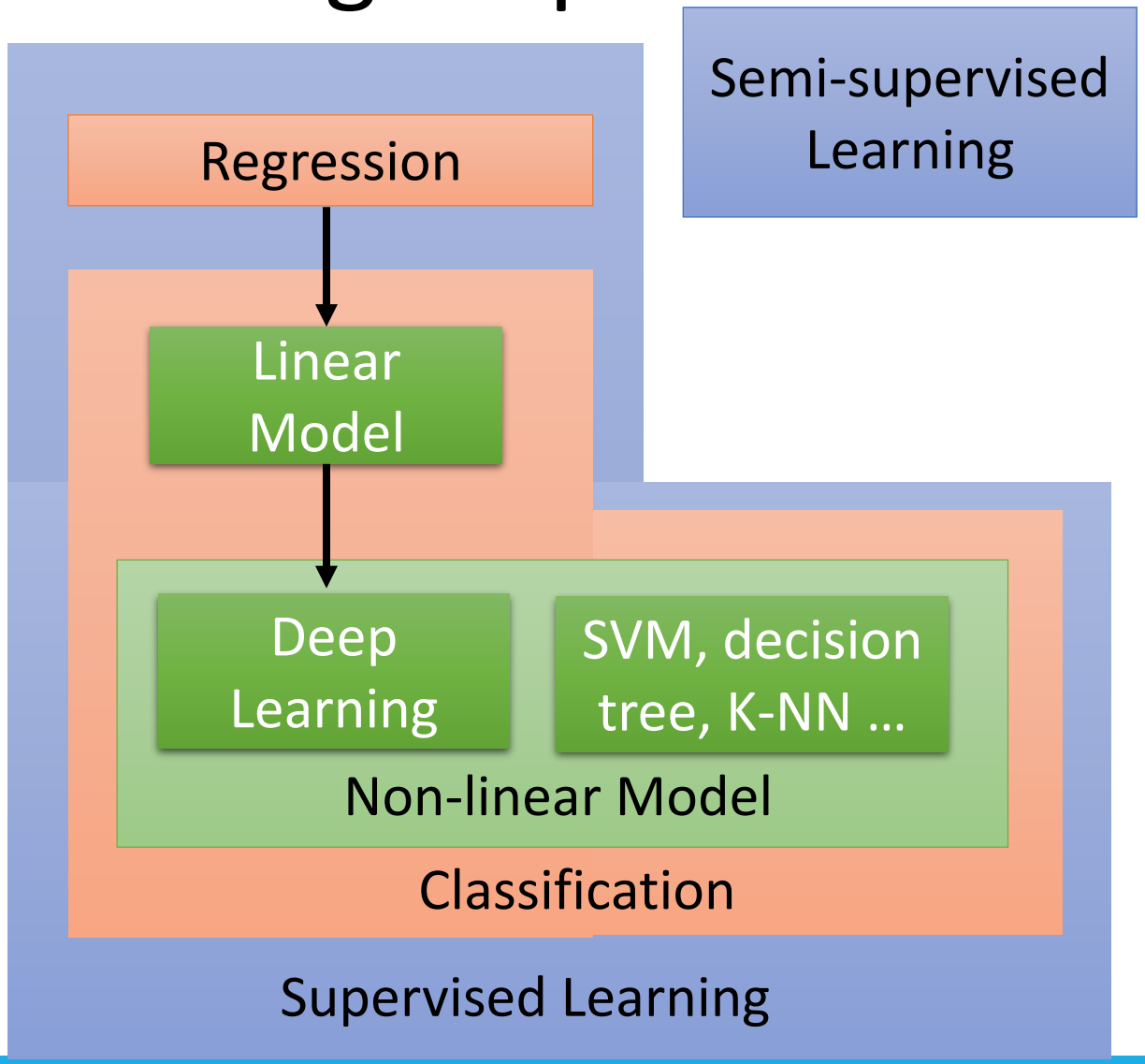


Classification - Deep Learning

- Playing GO



Learning Map



Training Data:

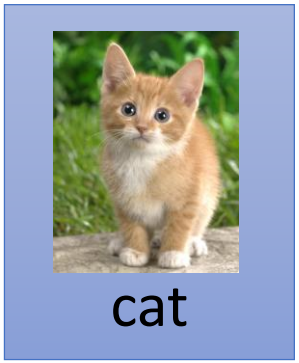
Input/output pair of target function

Function output = label

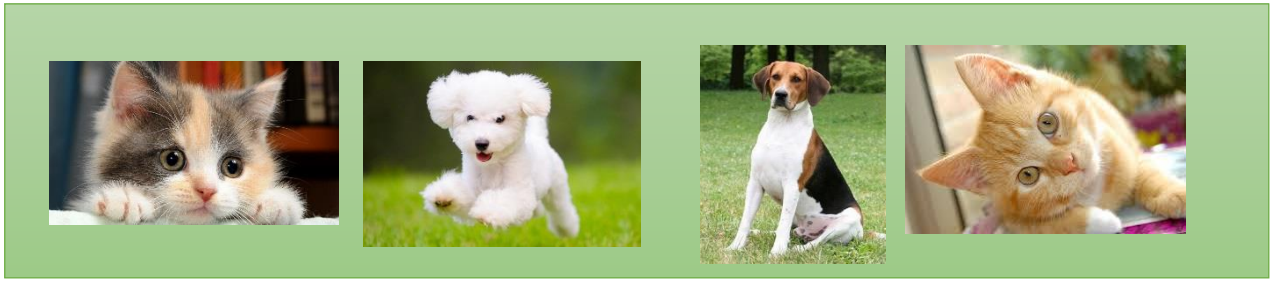
Semi-supervised Learning

For example, recognizing cats and dogs

Labelled data

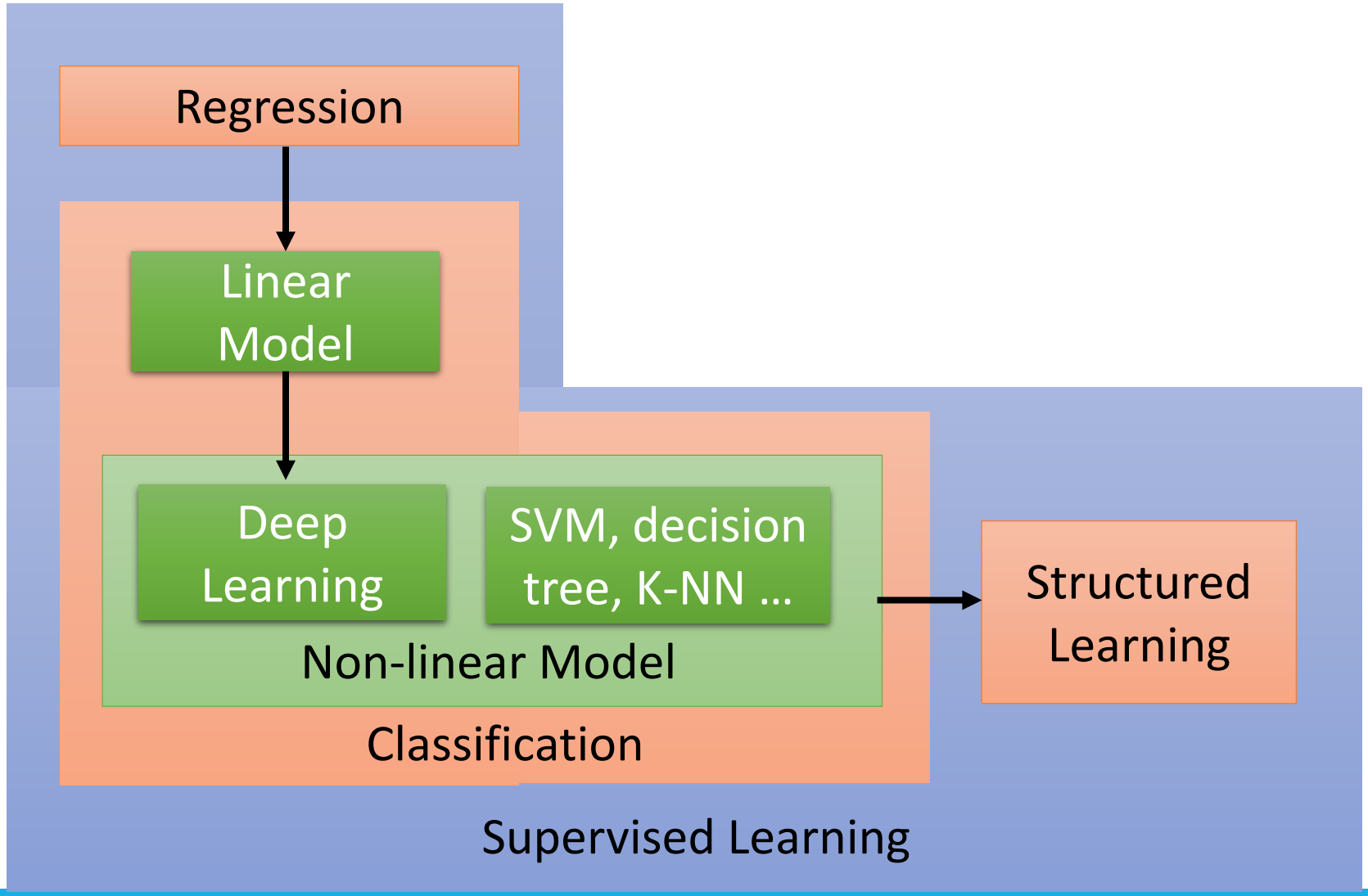


Unlabeled data



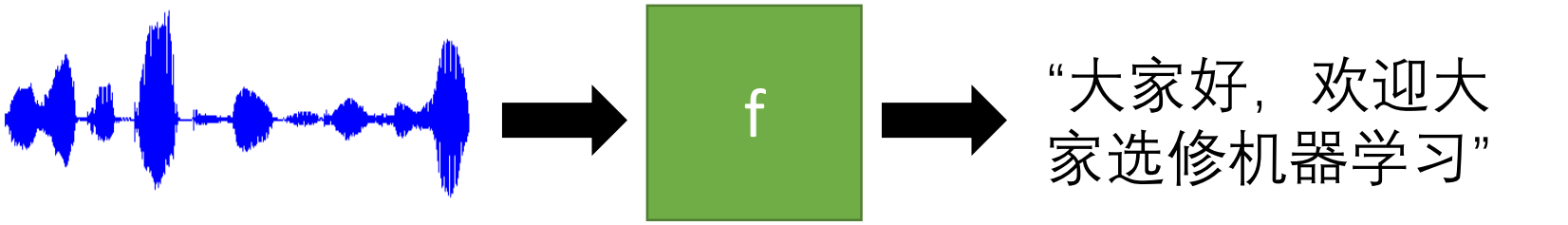
(Images of cats and dogs)

Learning Map



Structured Learning

- Beyond Classification



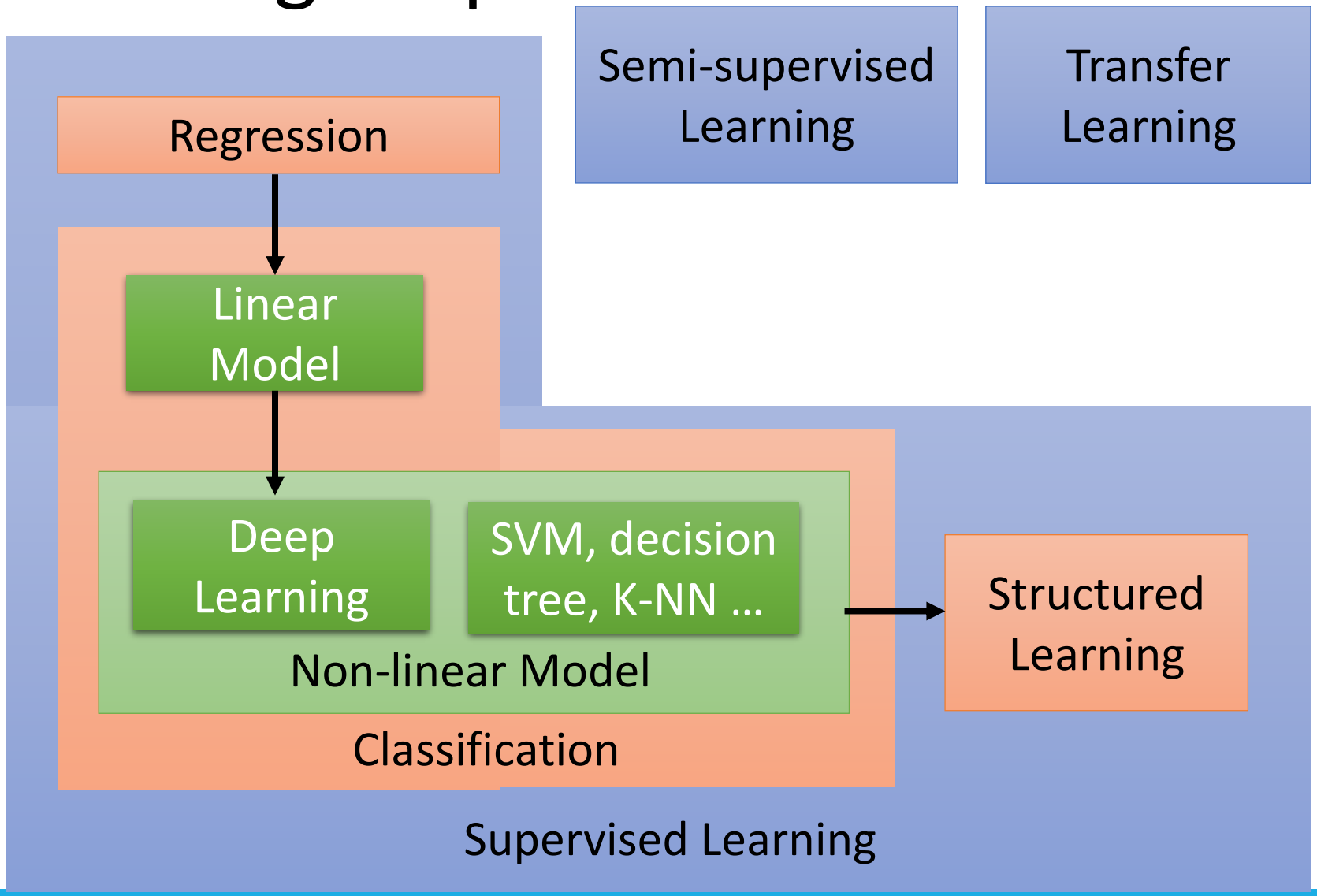
Speech Recognition

“机器学习”

“Machine Learning”

Machine Translation

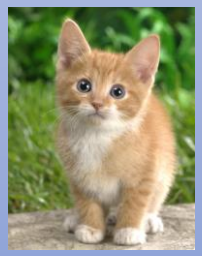
Learning Map



Transfer Learning

For example, recognizing cats and dogs

Labelled data



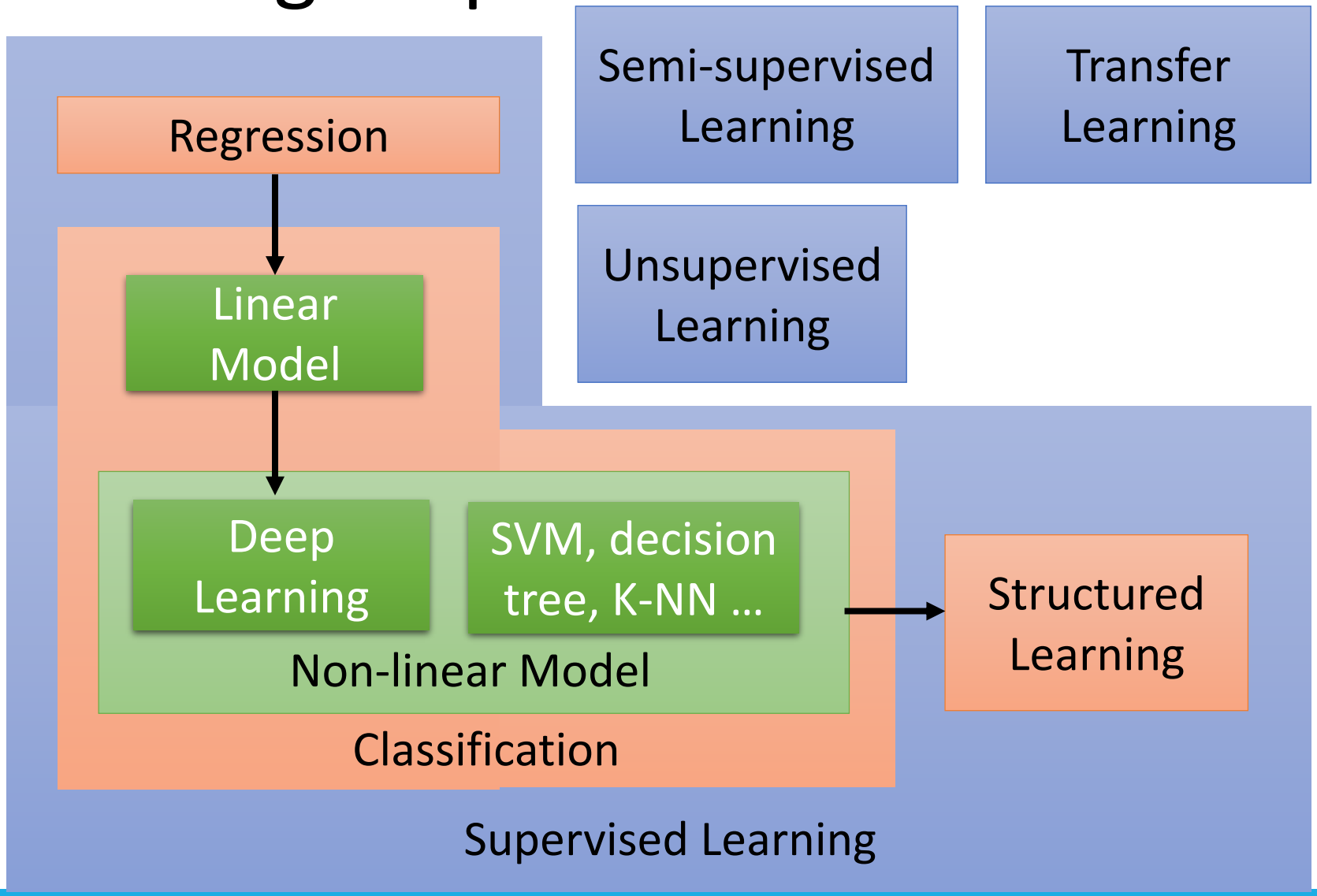
cat

dog

elephant

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

Learning Map



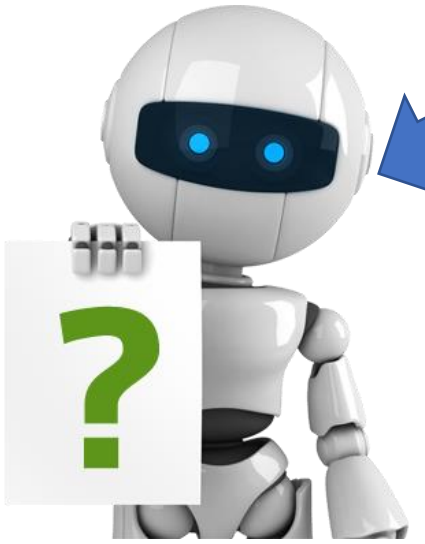
Unsupervised Learning

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

http://top-breaking-news.com/

Unsupervised Learning

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



Draw something!

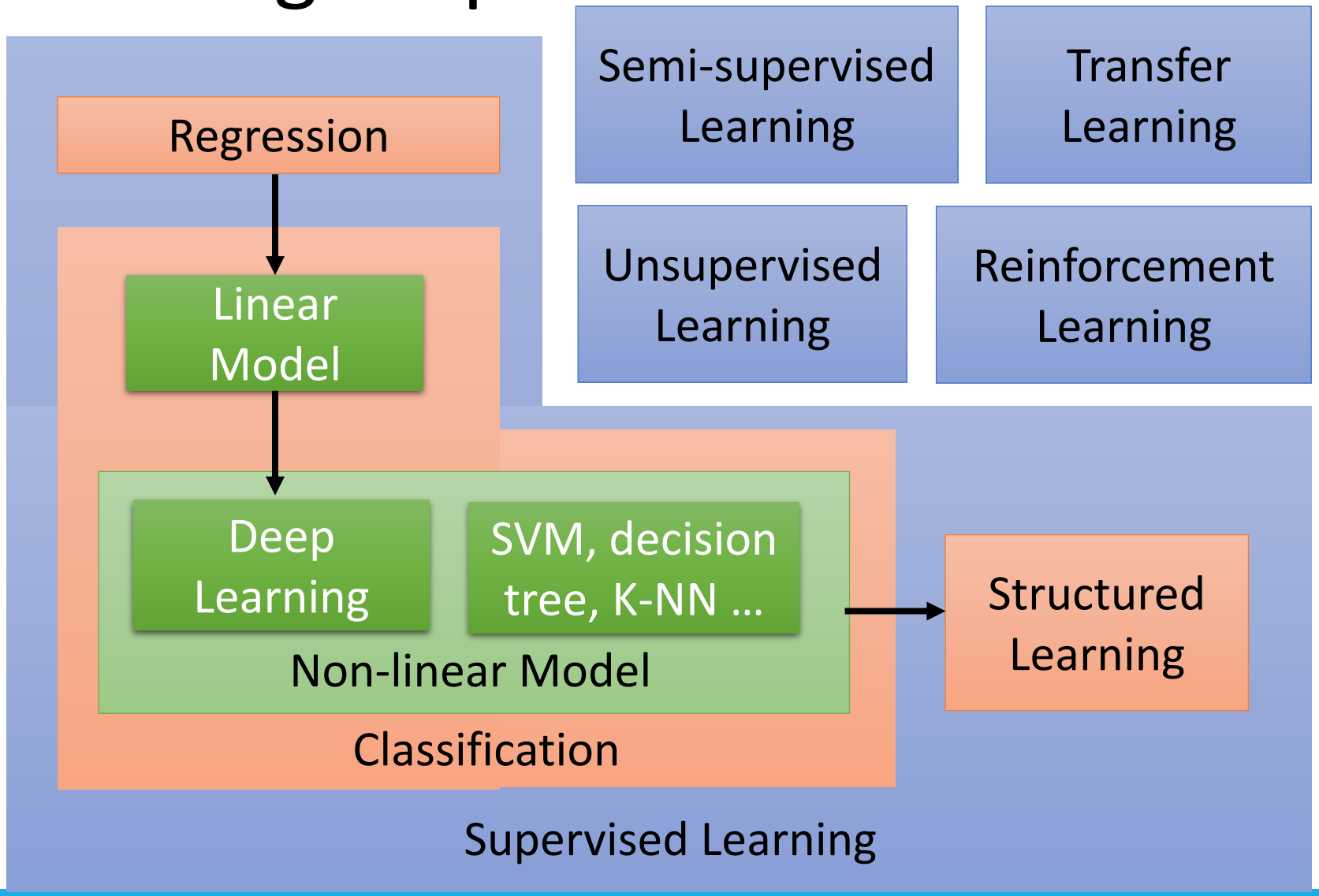
Unsupervised Learning

Machine listens to lots of audio book

[Chung & Lee, INTERSPEECH 2016]

How about machine watch TV?

Learning Map

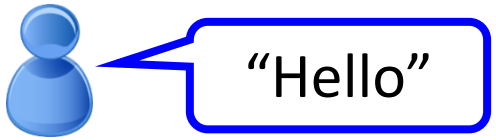


Reinforcement Learning

Supervised v.s. Reinforcement

- Supervised

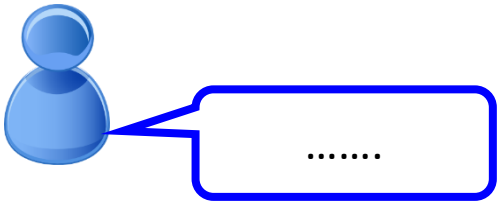
Learning from teacher

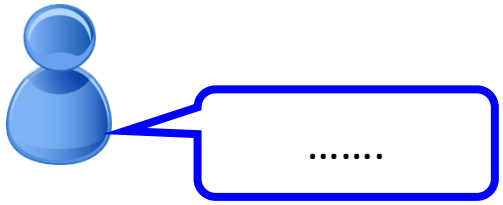


Say "Hi"

Say "Good bye"

- Reinforcement

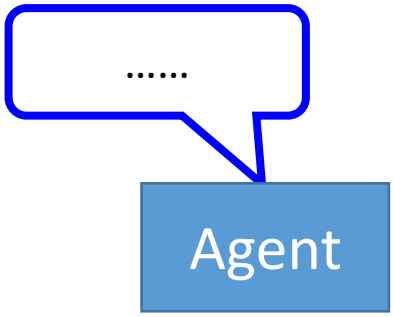




.....

Bad

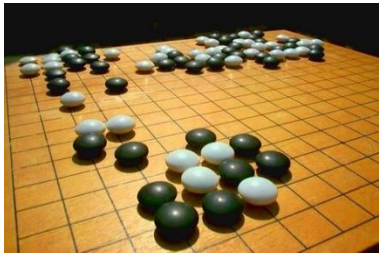
Learning from critics



Supervised v.s. Reinforcement

- Supervised:

Next move:
"5-5"



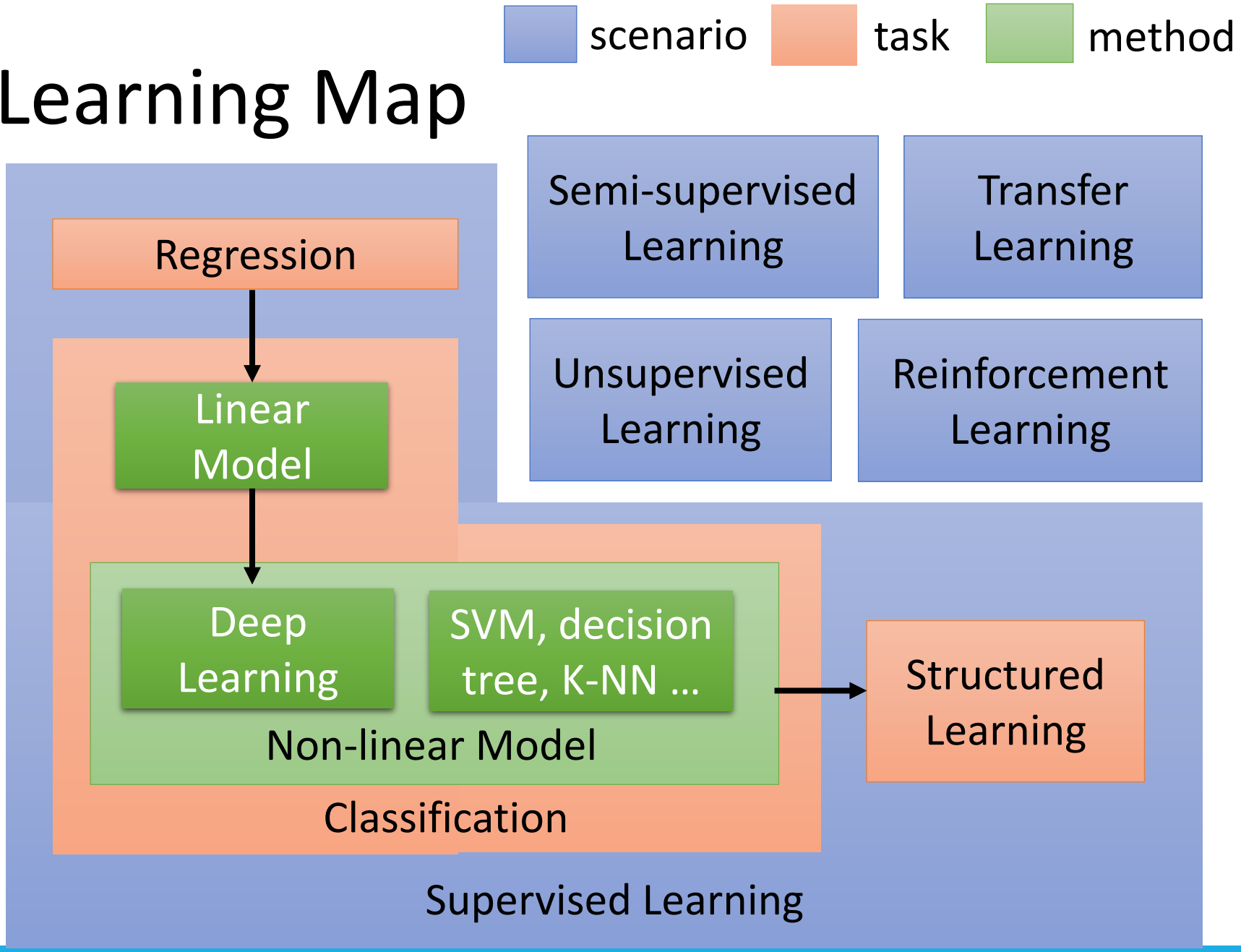
Next move:
"3-3"

- Reinforcement Learning

First move → …… many moves …… → Win!

Alpha Go is supervised learning + reinforcement learning.

Learning Map



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?