

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 Friday, class 2-4
 - 8:50 am - 11:35 am
 - 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	5%
Assignment × 3	30%
Quiz x 2	10% (w11~13) + 20%(w16)
Project	35%

- *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

Reasonable Usage of LLM

- 倡导“**人类主导，AI协作**”模式，确保技术服务创新
 - 辅助工具定位
 - 大模型（如ChatGPT、文心一言、Deepseek等）应作为人类知识生产与创作的辅助工具，而非替代独立思考或原创性工作
 - 禁止直接提交大模型生成的文本、代码、设计等内容作为个人的原创成果
 - 场合合规性
 - 禁止将AI生成内容直接用于论文、报告等学术成果，需经深度修改并符合学术诚信要求
 - 禁止提交AI生成的作业或考试答案
 - 知识产权与版权意识
 - 若需引用生成内容，须明确标注来源（如声明“**由AI生成**”），并遵守引用规范

Materials

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

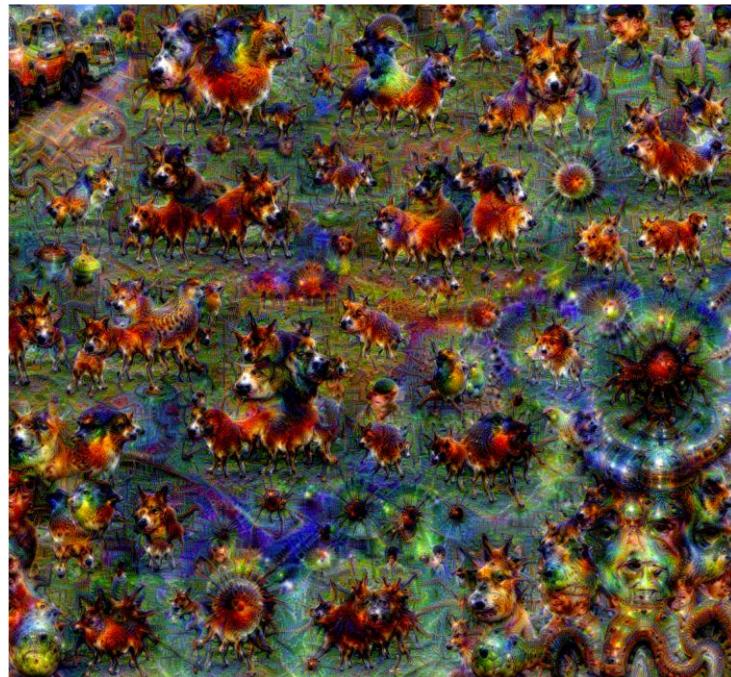


What is the point of studying this course?

- 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



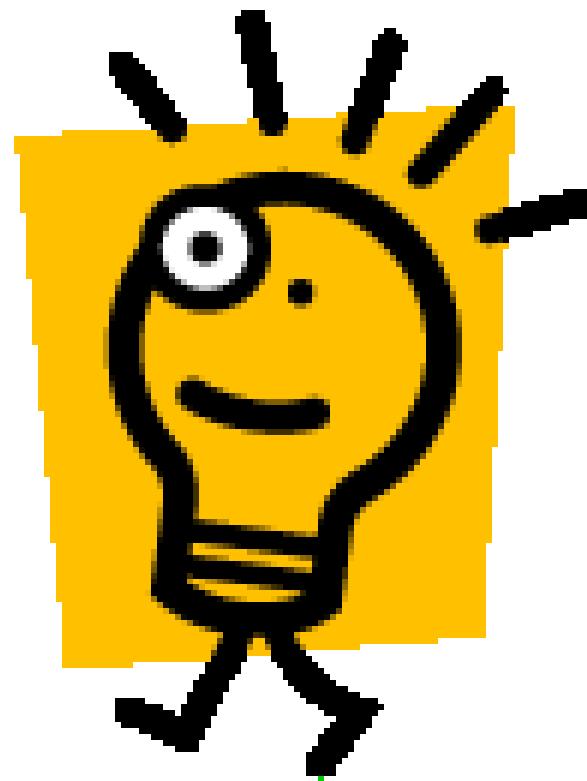
Class Group chat

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

Today's Topics

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- *What is machine learning?*
- Applications
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What is machine learning?



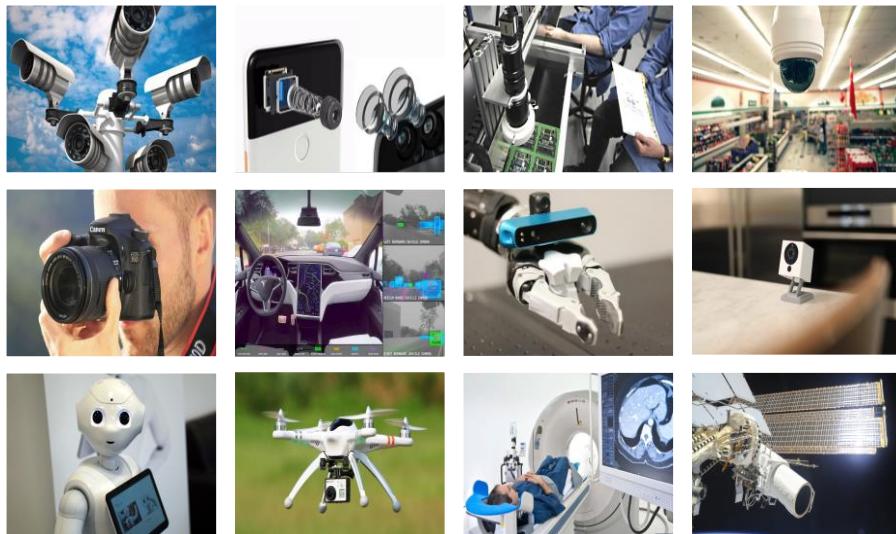
How do human make a decision?

- 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

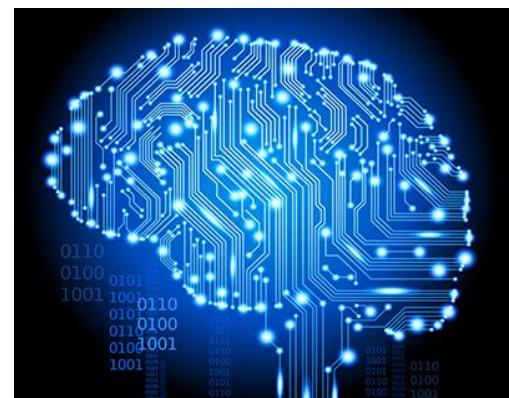


Sensing like human

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



“Eyes”



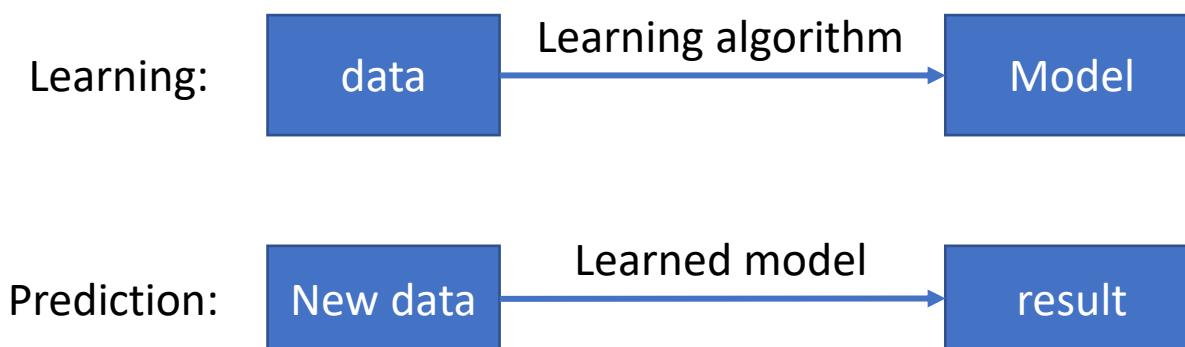
“Brain”

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

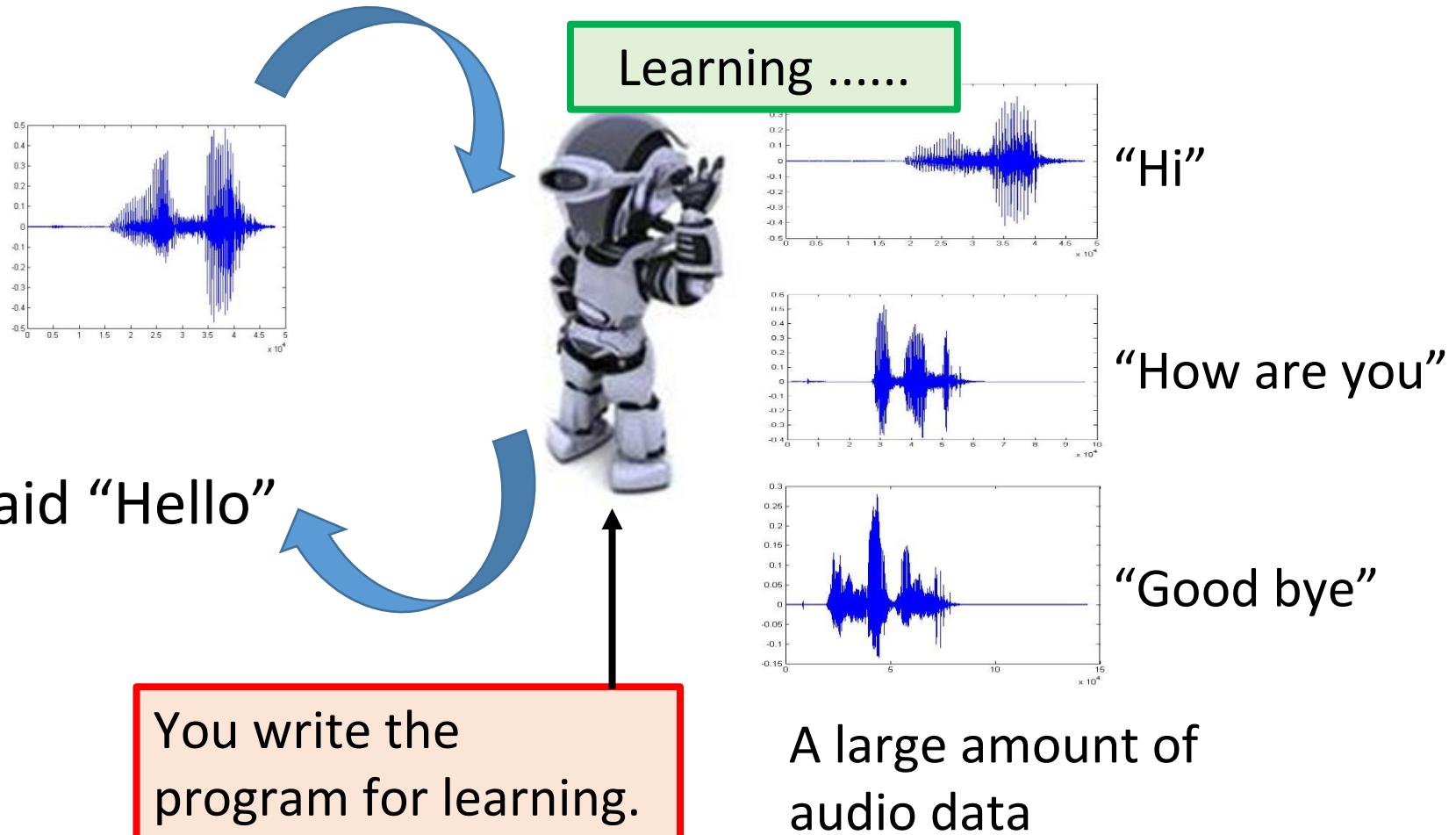
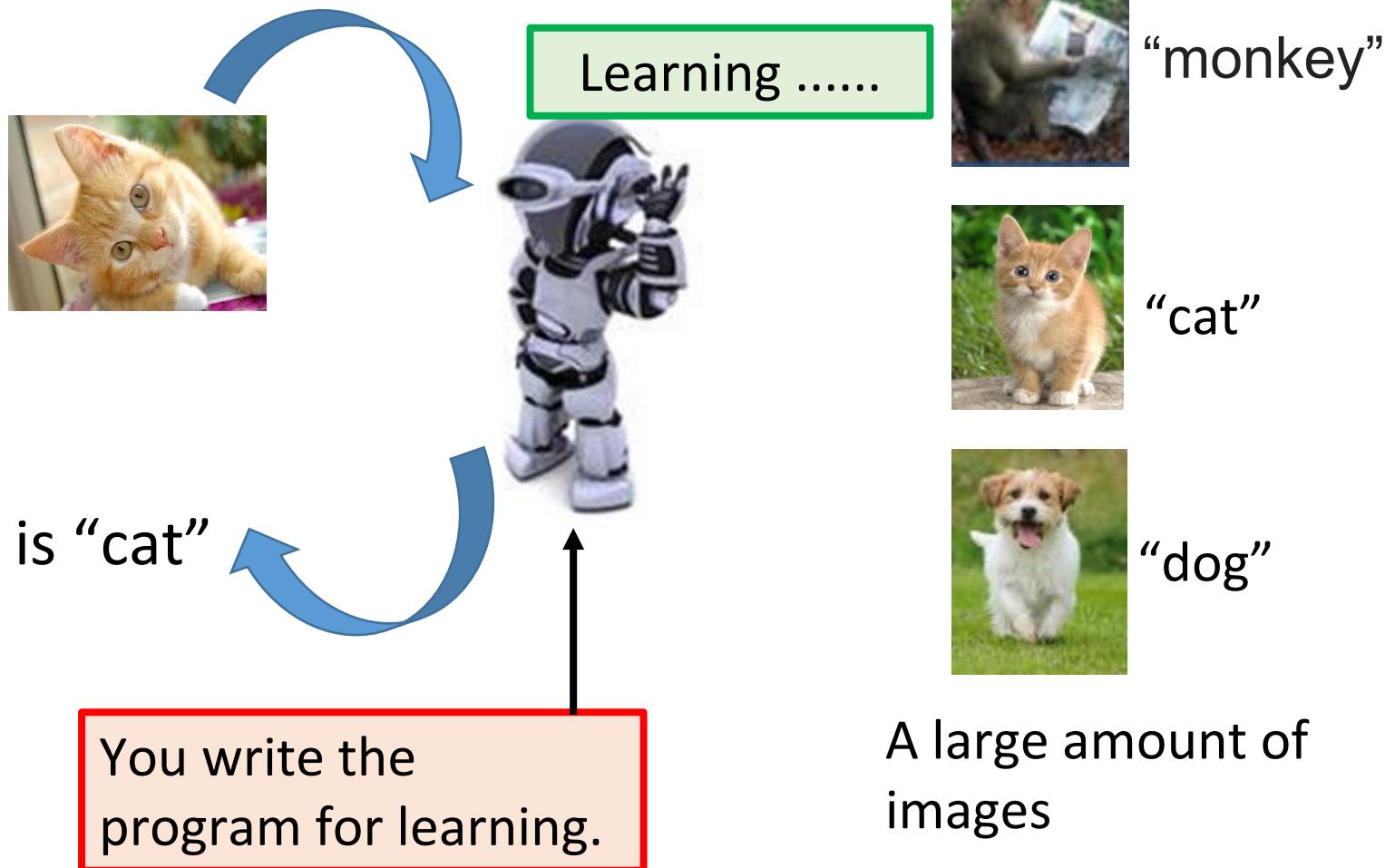
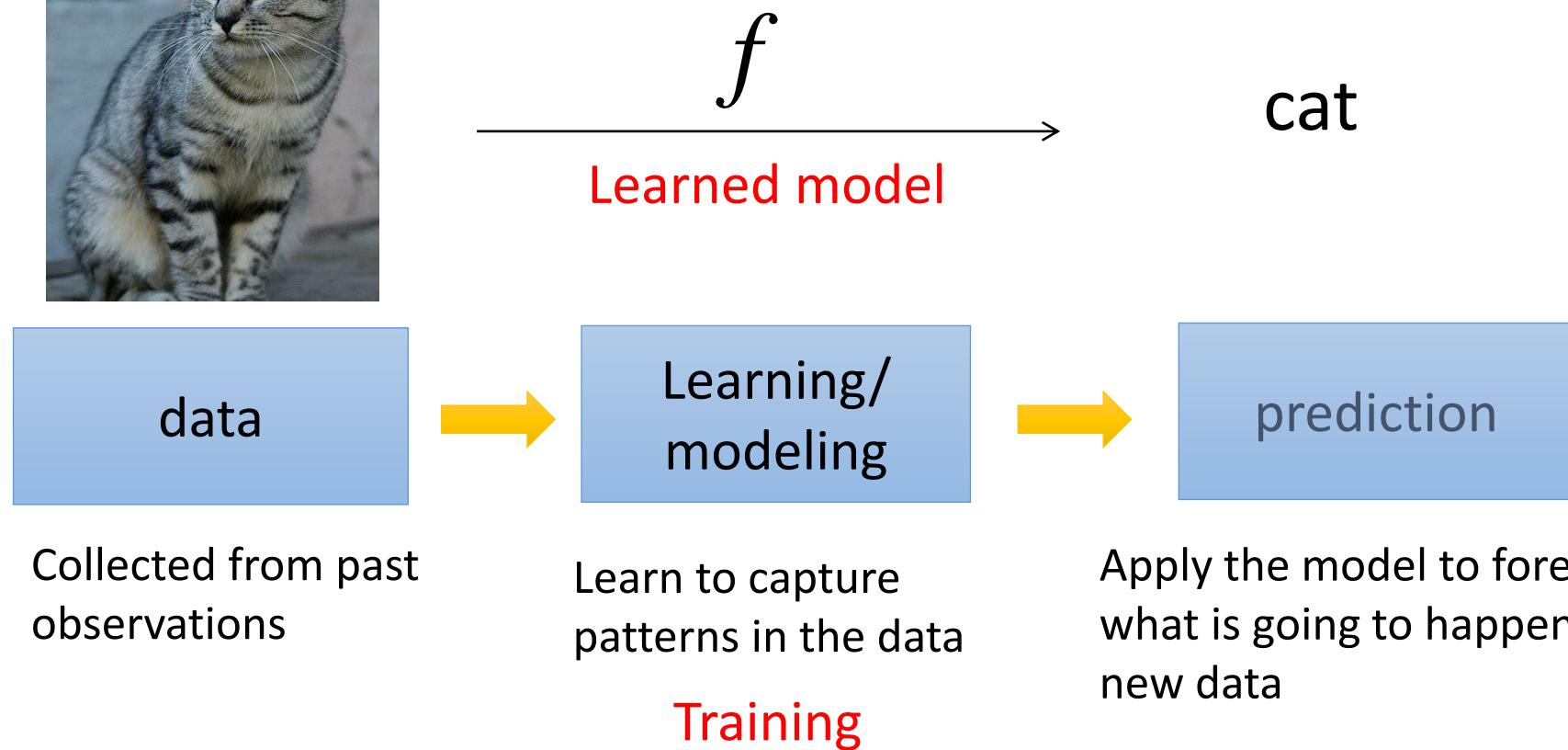


Image recognition case

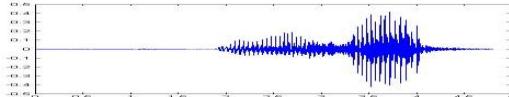


Machine learning process



Machine learning ≈ Looking for Function (model)

- Speech Recognition

$f($ ) = “How are you”

- Image Recognition

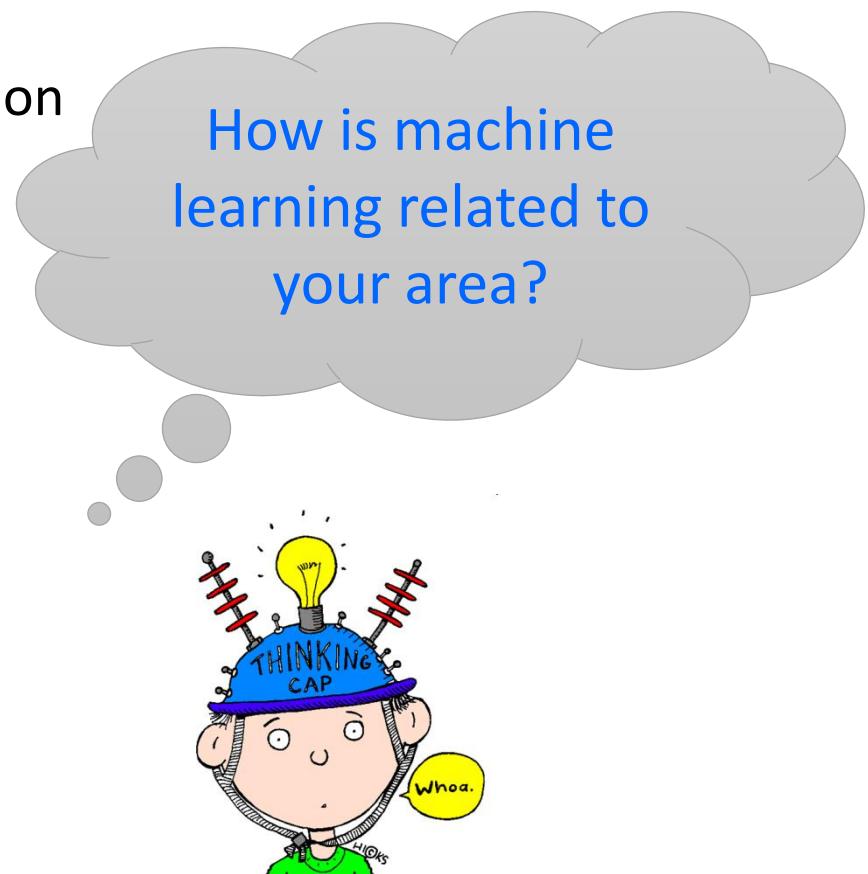
$f($ ) = “Cat”

- 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

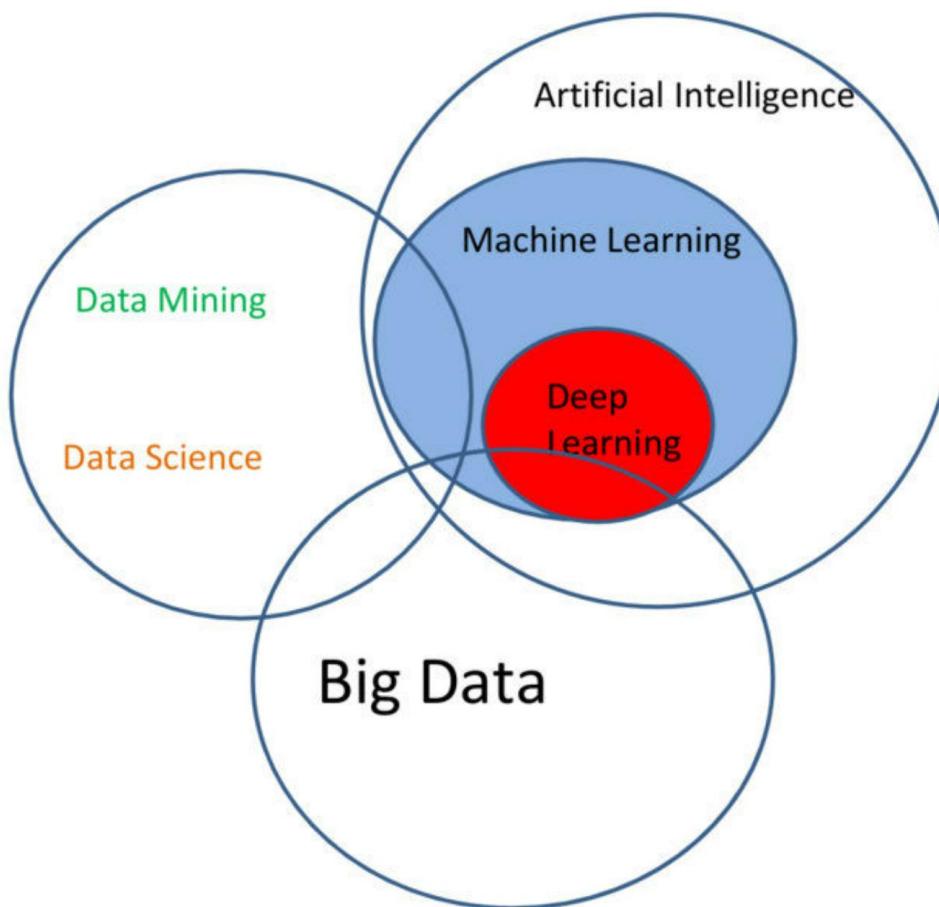
- Artificial intelligence
 - Final GOAL of machine intelligence
- Pattern recognition
 - Early term from 70s/80s, heuristic methods involved
- Machine learning
 - New term from 90s, data-driven, learn a model to predict
- Data mining
 - Find out knowledge from big data, may resort to ML methods, but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



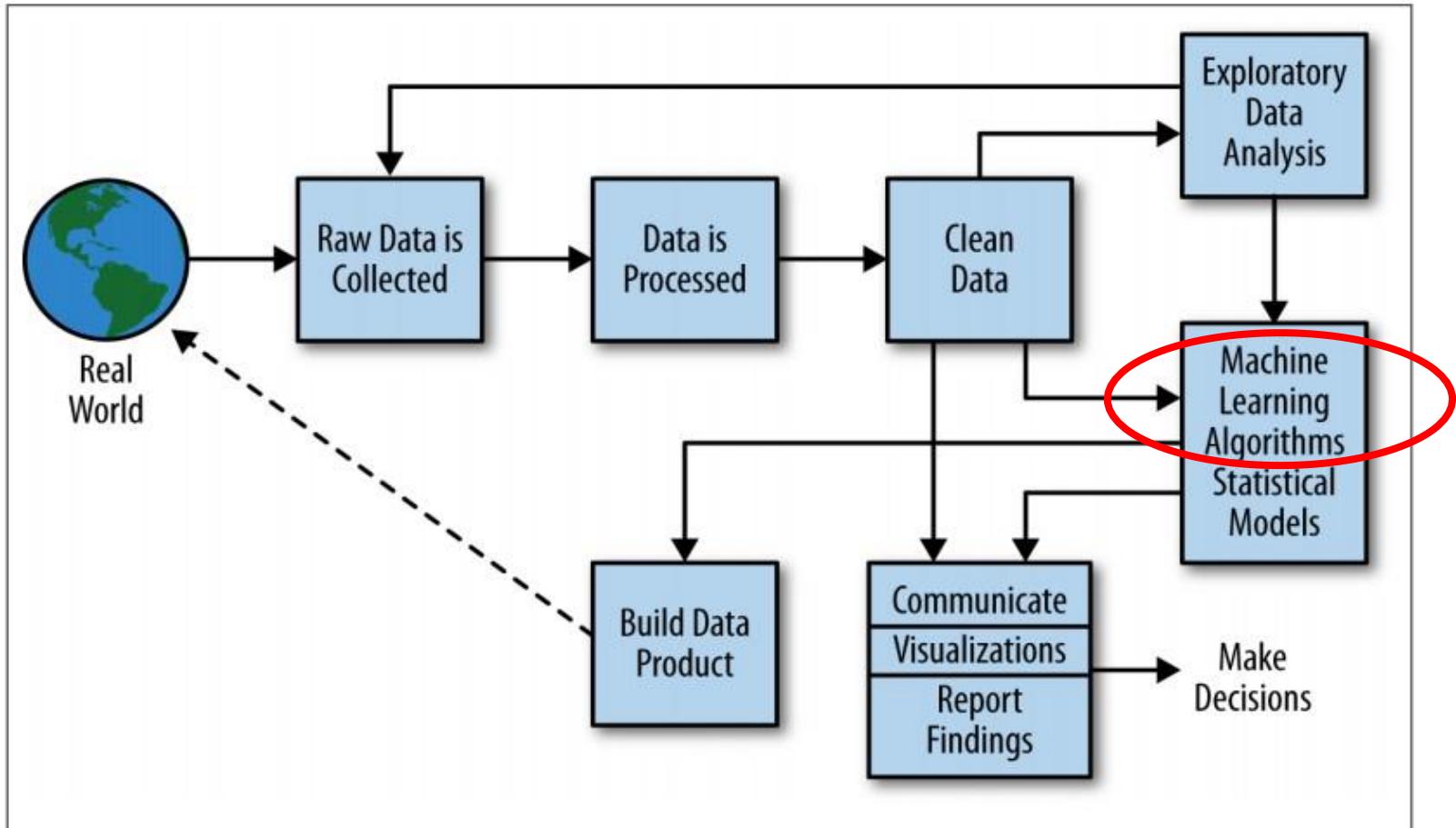
Can you tell the differences among them?

Related concepts

- Relationship between concepts



ML is only a small part!



Today's Topics

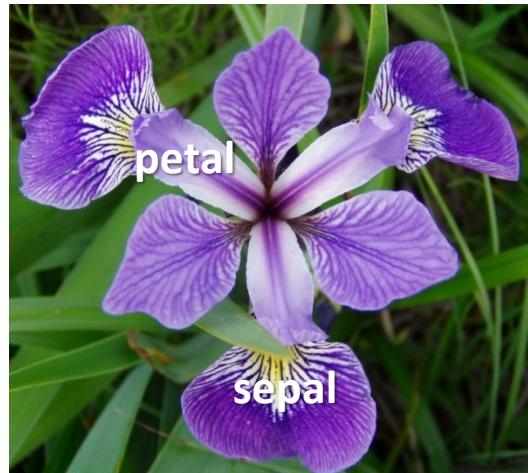
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Early statistical learning methods

- Recognizing flowers (by R. Fisher, 1936)



Iris Setosa



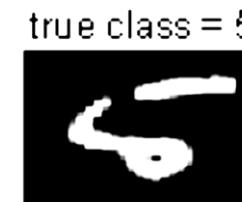
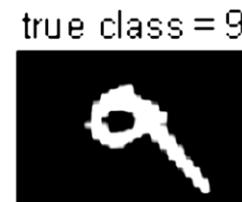
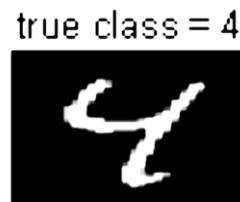
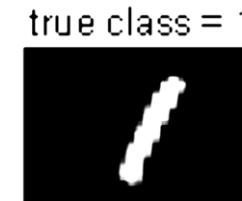
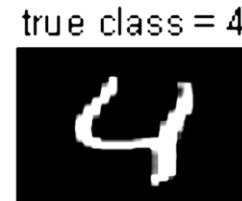
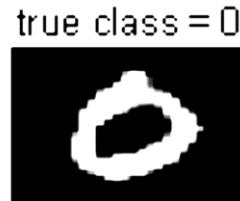
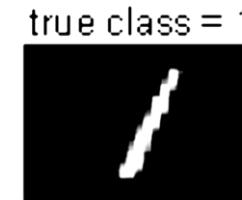
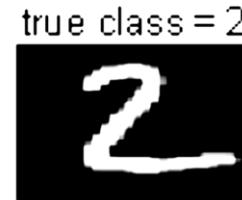
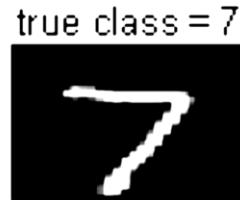
Iris Versicolor



Iris Virginica

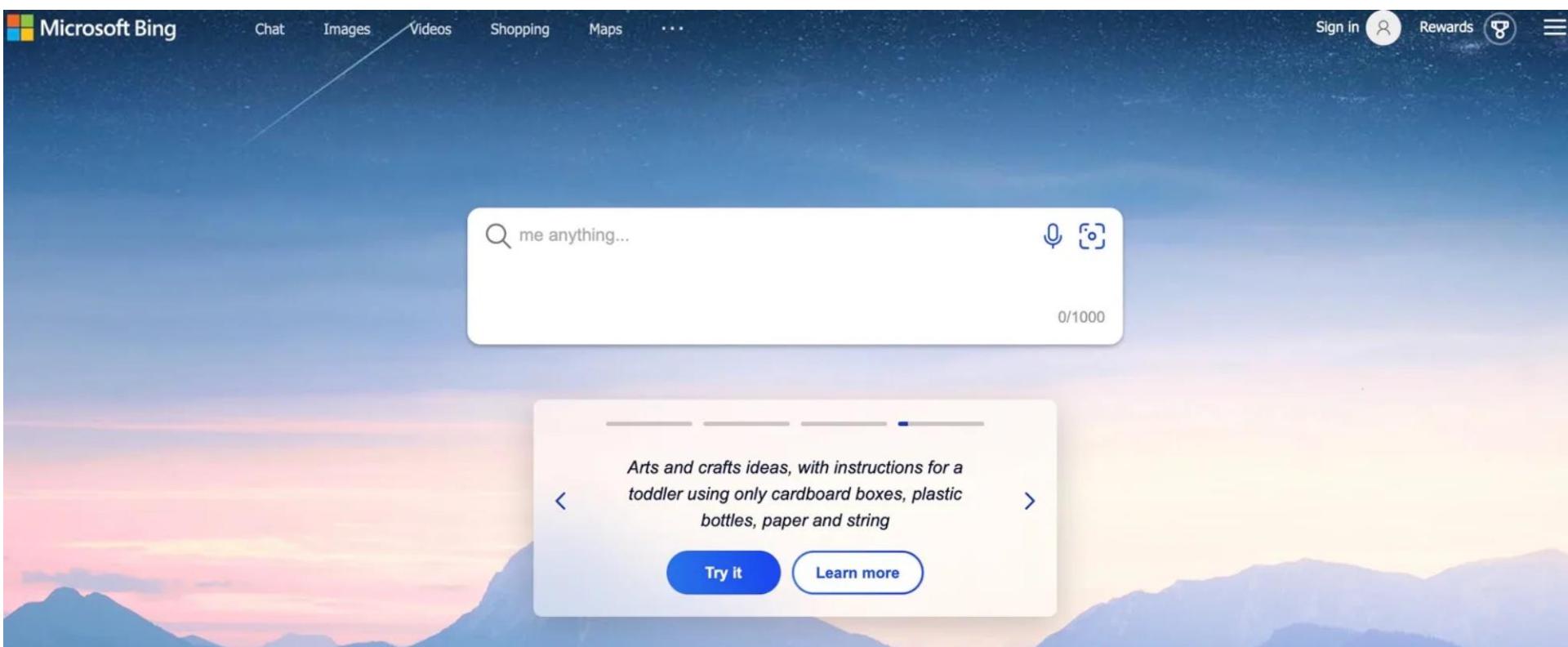
Huge success 30 years ago

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



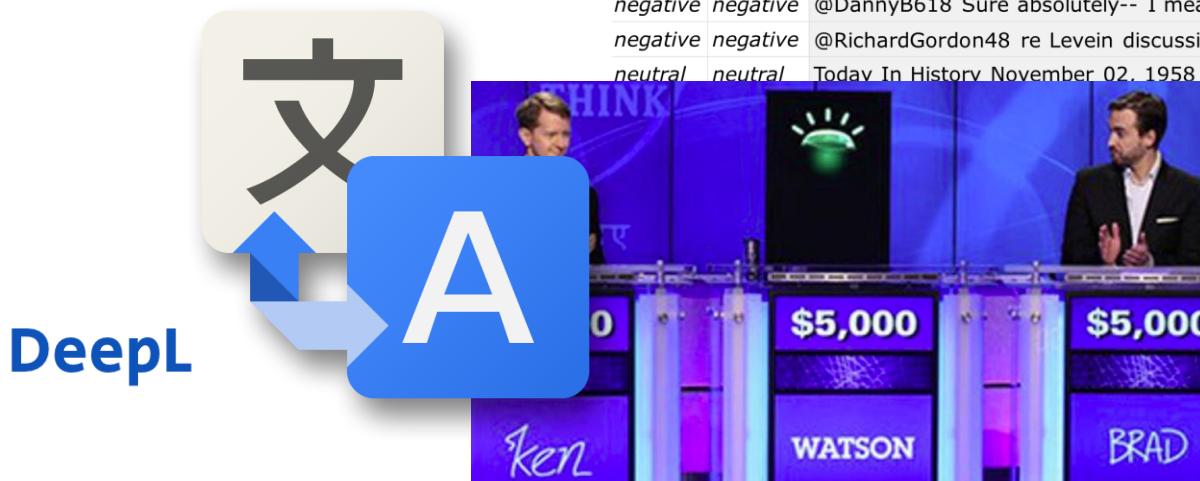
Nowadays: Learn our preferences

- Recommending what you might like



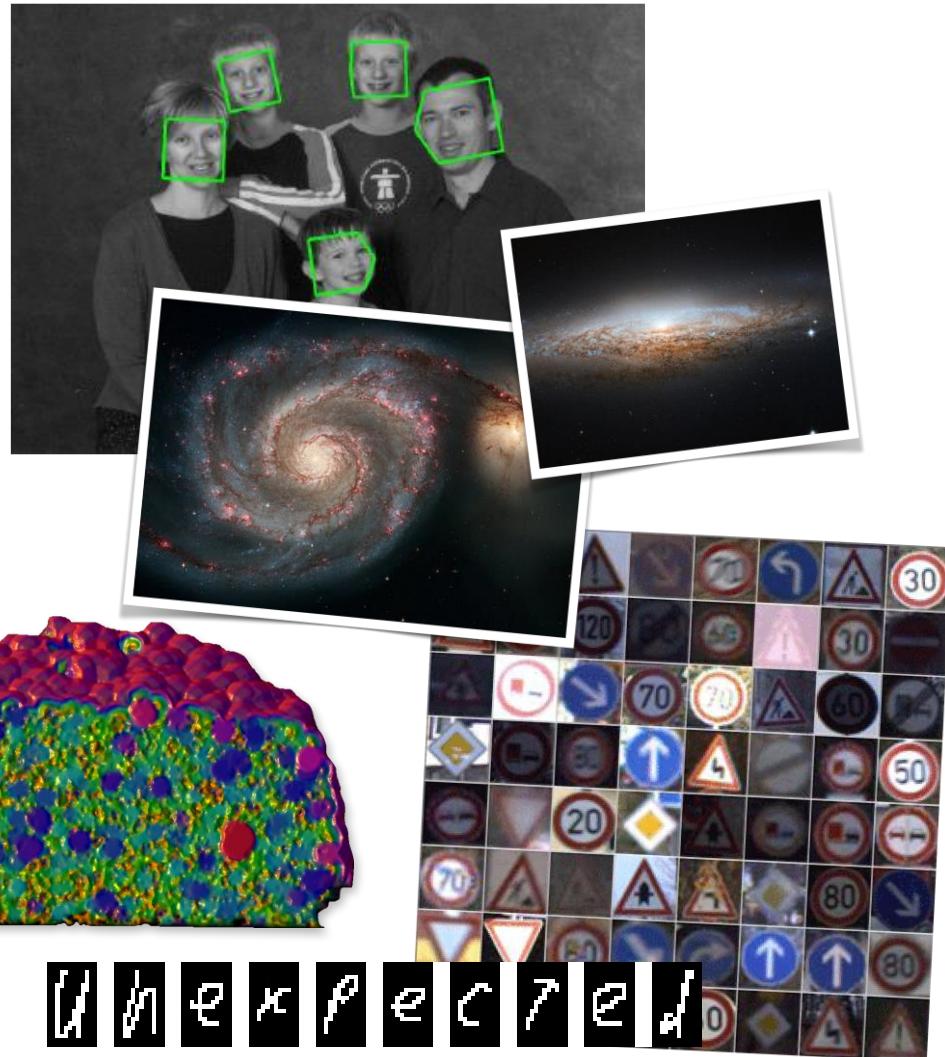
Analyze text data

- Machine translation
- Sentiment Analysis



Analyze image data

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

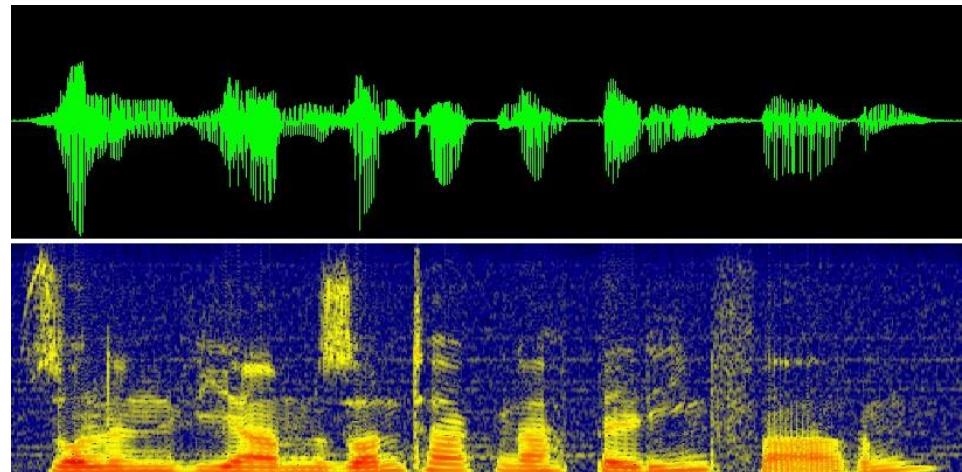


Analyze audio&multimodal data

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

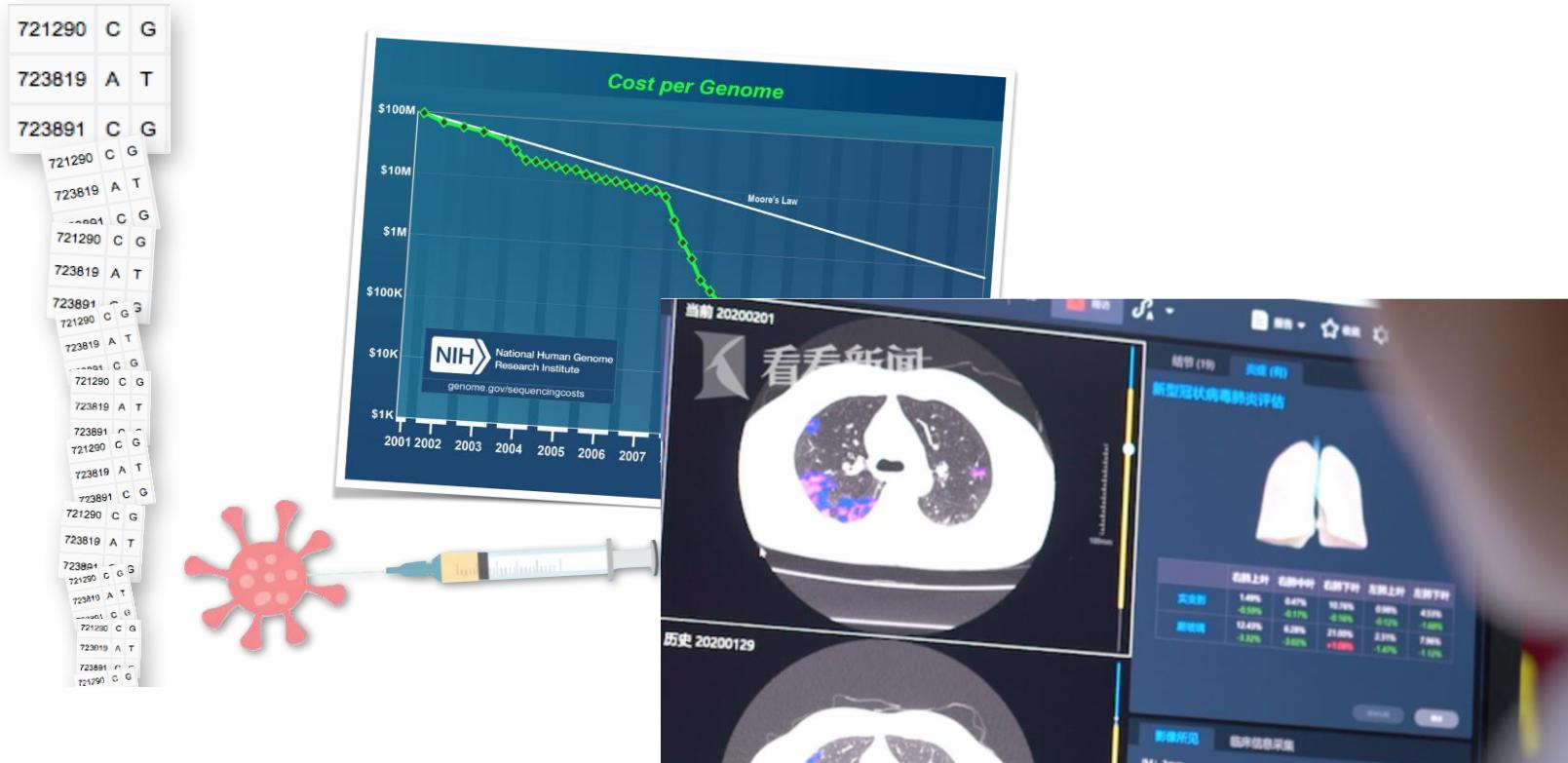


LYREBIRD



Analyze medical data

- Lesion identification
- Using genes for disease prediction

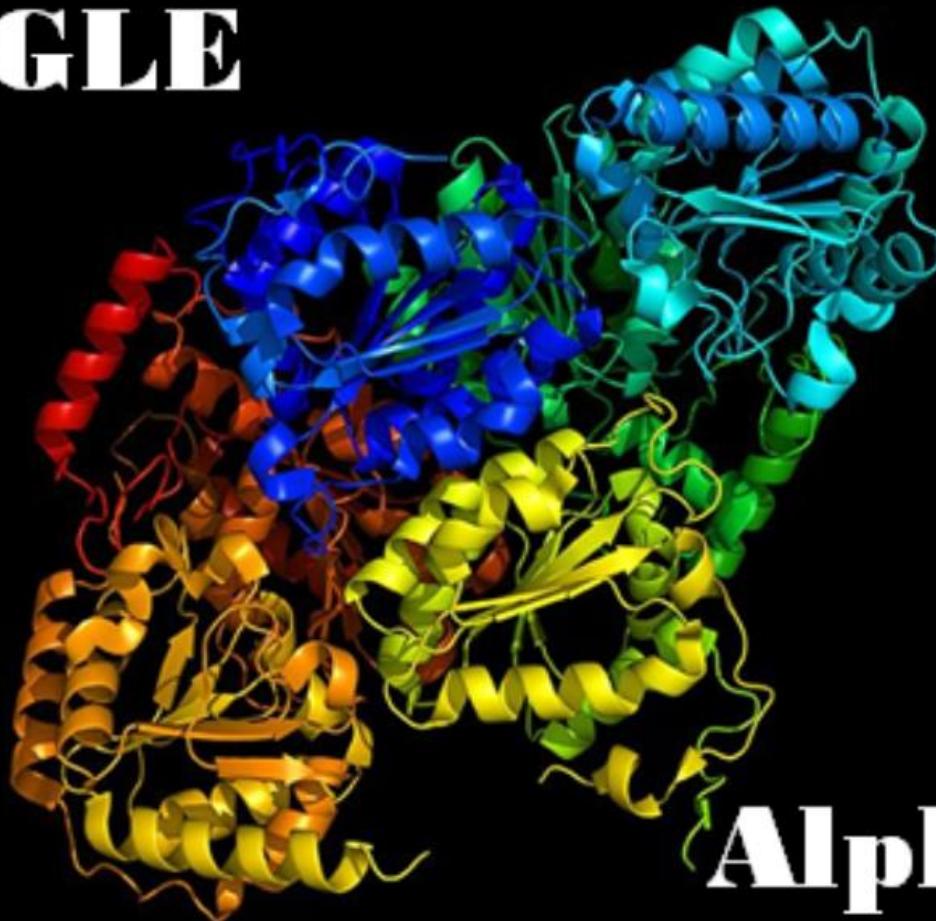


AlphaFold

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

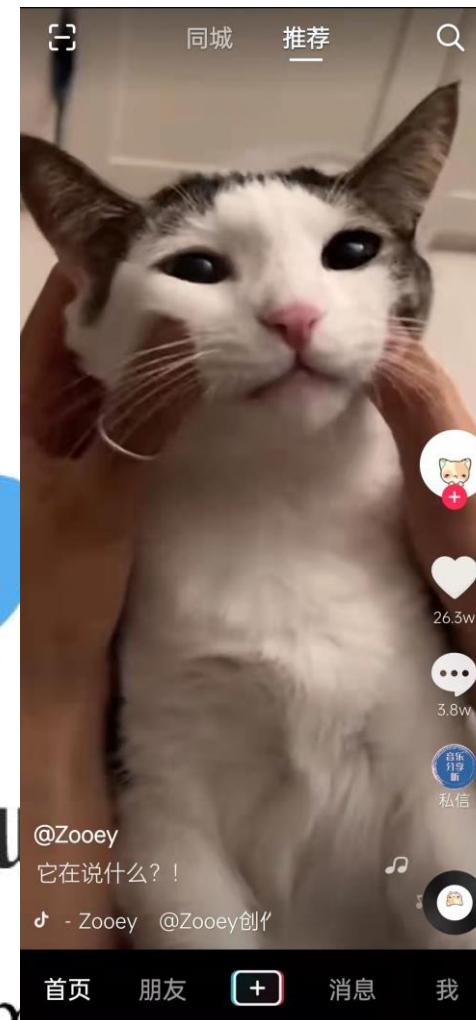


Google



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

GPT

Q: If a b c changes to a b d what does p q r change to?

A: p q r changes to p q s

Q: If a b c changes to a b d what does p q r s change to?

A: p q r s changes to p q r t

Q: If a b c changes to a b d what does p p q q r r change to?

A: p p q q r r changes to p p q q s s

Q: If a b c changes to a b d what does p p p q q q r r change to?

A: p p p q q q r r changes to p p p q q q s s

Q: If a b c changes to a b d what does i j k change to?

A: i j k changes to i j l

Q: If a b c changes to a b d what does i i j j k k change to?

A: i i j j k k changes to i i j j l

```
function setupBoard() {
    for (let i = 0; i < grid; i++) {
        board[i] = [];
        for (let j = 0; j < grid; j++) {
            board[i][j] = null;
        }
    }
}

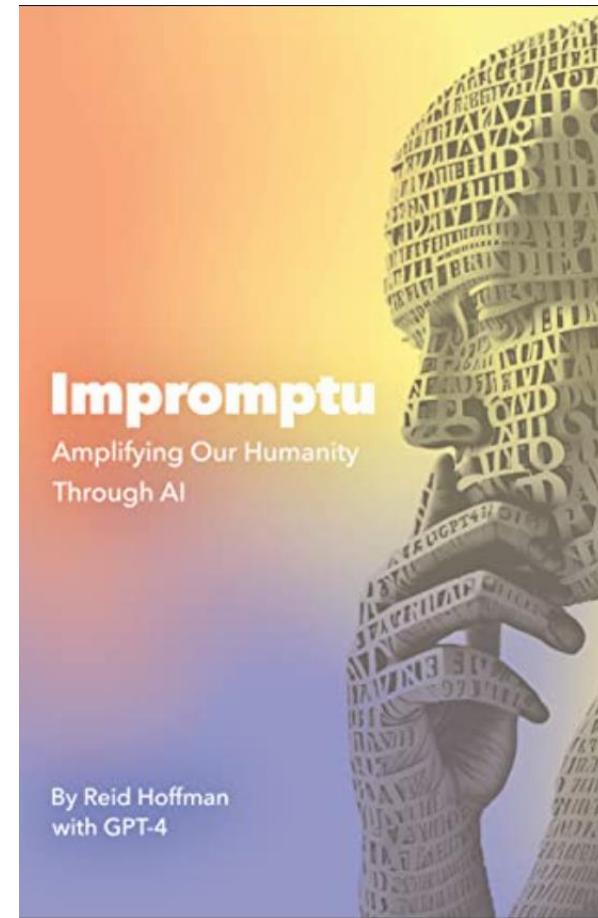
function calculateScore() {
    let score = 0;
    for (let i = 0; i < grid; i++) {
        for (let j = 0; j < grid; j++) {
            if (board[i][j] === 'black') {
                score += 1;
            } else if (board[i][j] === 'white') {
                score -= 1;
            }
        }
    }
    return score;
}

function bestMove() {
    let bestMove = null;
    let bestScore = -Infinity;
    for (let i = 0; i < grid; i++) {
        for (let j = 0; j < grid; j++) {
            if (board[i][j] === null) {
                let score = calculateScore();
                if (score > bestScore) {
                    bestScore = score;
                    bestMove = {i, j};
                }
            }
        }
    }
    return bestMove;
}
```

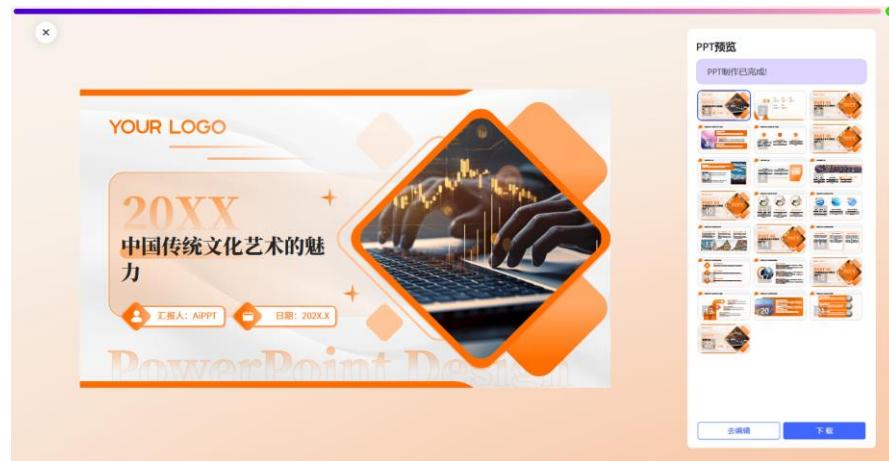
此函数首先获取所有可用的空位，然后随机选择一个位置并在该位置下棋。然后，检查机器人选手是否获胜。

2. 将“canvas”的“click”事件监听器，使用户下棋后机器人进行回应：

```
function() {
    function robotMove() {
        let bestMove = null;
        let bestScore = -Infinity;
        for (let i = 0; i < grid; i++) {
            for (let j = 0; j < grid; j++) {
                if (board[i][j] === null) {
                    let score = calculateScore();
                    if (score > bestScore) {
                        bestScore = score;
                        bestMove = {i, j};
                    }
                }
            }
        }
        if (bestMove) {
            let [i, j] = bestMove;
            board[i][j] = 'black';
            updateBoard();
            setTimeout(() => {
                let [x, y] = [i * gridSize, j * gridSize];
                const dot = document.createElement('div');
                dot.style.position = 'absolute';
                dot.style.left = `${x}px`;
                dot.style.top = `${y}px`;
                dot.style.width = '10px';
                dot.style.height = '10px';
                dot.style.backgroundColor = 'black';
                dot.style.borderRadius = '50%';
                document.body.appendChild(dot);
            }, 500);
        }
    }
}
```



Multi-Modal AI



Multi-Modal AI

Text to Video

Runway Gen-2: 可通过文本、图像或视频片段生成新颖的视频的多模态AI系统

AI+

深圳福田：“AI公务员”效率惊人：70名上线

1天



深圳福田：“AI公务员”效率惊人：70名上线
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【中国新“AI 公务员”引发关注】随着 DeepSeek 人工智能模型推出，中国各地政府加速在日常政务中应用 AI 技术。深圳市福田区近日上线 70 名“AI 数智员工”，覆盖 11 大类政务服务场景。一系列中国城市，如广州、呼和浩特、赣州、无锡等已将 AI 技术整合到政府服务平台或内部运营系统。在福田区，人工智能系统大幅缩短政府通告生成时间，提高公文修正准确率，缩短审核时间，控制错误率。福田区首批“AI 公务员”新闻走红，引发社交媒体广泛讨论。无锡公务员苏珊·周称使用 AI 节省时间但也带来新压力。福田区政务服务和数据管理局副局长高增澄清，AI 是辅助决策工具，不会取代公务员，但仍有人担忧。某高校王晓舟对未来就业前景感到忧虑。

AI+基层服务

“AI医生”上岗了，我们能信任它吗？

科普中国的报道 • 2 天 • 1 分钟读取

深夜，北京儿童医院急诊科的智能终端前，新手妈妈扫描孩子的检查报告，几秒钟后，屏幕上的诊疗建议与半小时前值班医生的诊断完全吻合……

最近，由DeepSeek引发的AI应用热潮席卷医疗领域，智慧医疗话题再度引发热议。日前，北京儿童医院的“AI儿科医生”正式上岗，更是让人们对于智慧医疗的认知变得更加具象。



“AI医生”上岗了，我们能信任它吗？

当AI“穿上”白大褂，看病这件事又会产生怎样的“化学反应”？

此前，山东临沂的徐先生将孩子的血检报告上传到DeepSeek，得到的诊断与医生给出的基本吻合。类似的案例，在网络上已经开始频繁出现。

“AI之所以能够精准诊断病症，得益于其强大的数据处理和分析能力。”南京航空航天大学人工智能学院副教授李博涵表示，通过对患者的病史、症状、影像资料等数据进行深度学习，AI能够识别出疾病与各种特征之间的复杂模式和关联，从而为诊断提供依据。

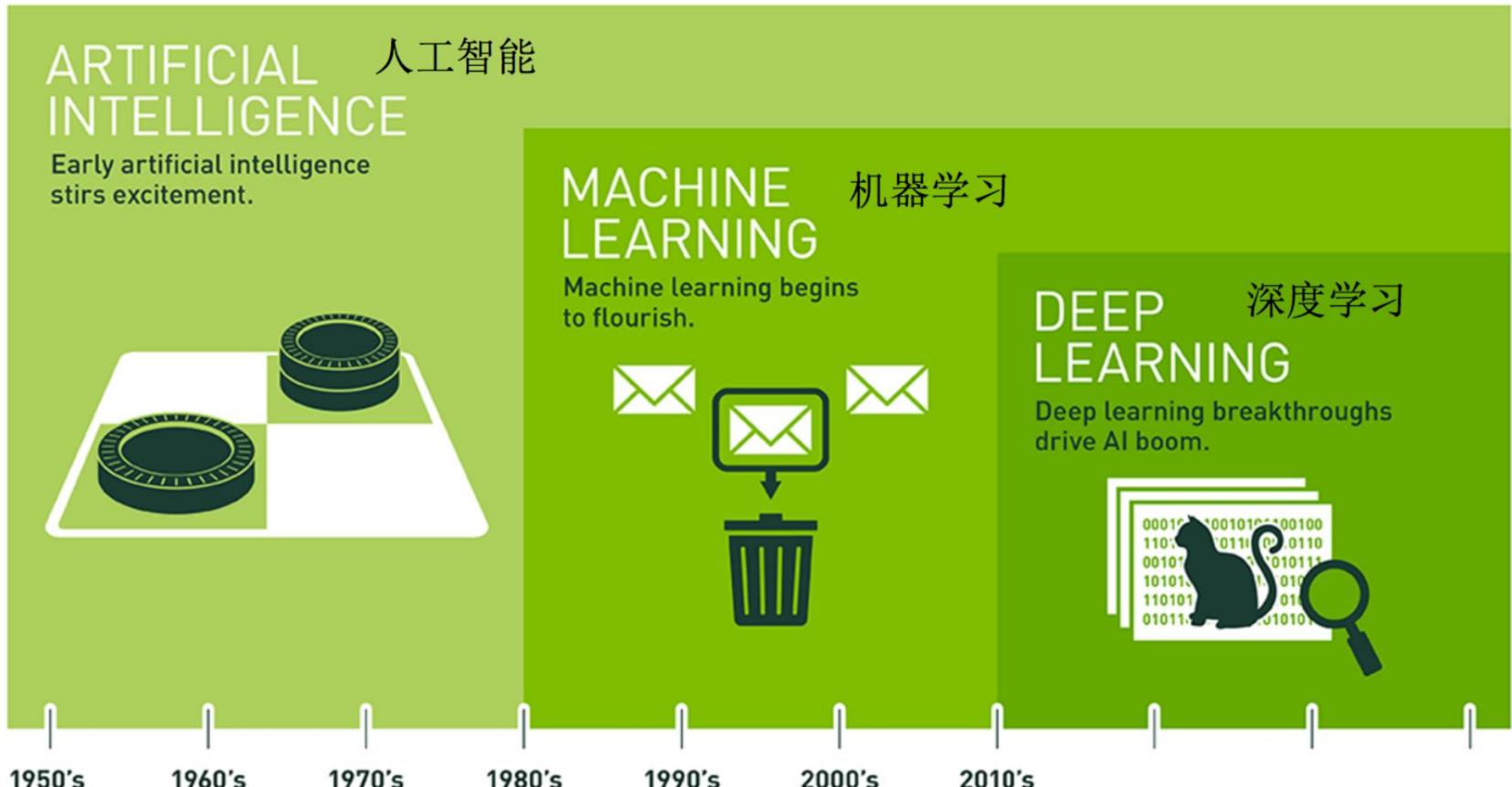
在医学影像分析方面，AI的诊断准确率超乎寻常。前不久，浙江大学推出融合视觉与语言模型的AI病理助手，能在1至3秒内锁定病理图中的癌症病灶，并且在多种癌症的诊断上已取得95%以上的准确性。

AI+医疗

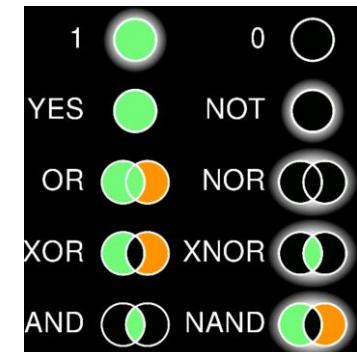
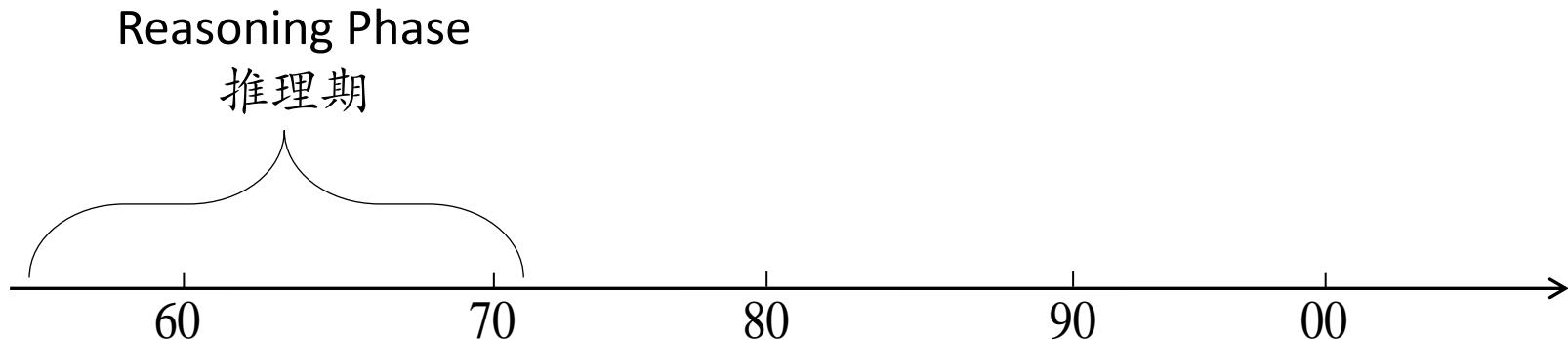
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Development of AI



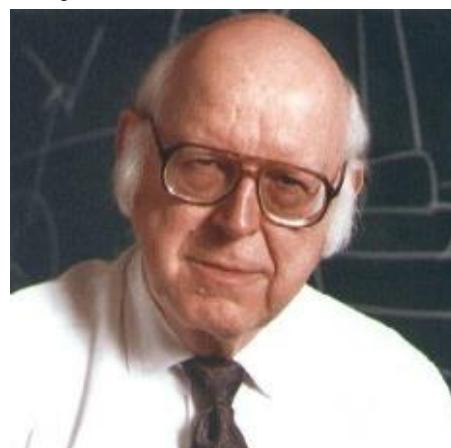
Timeline



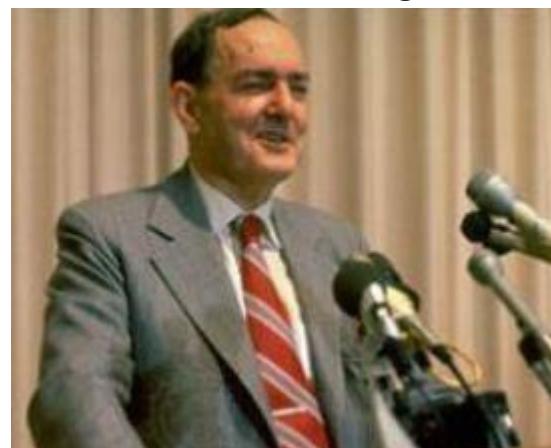
Reasoning Phase

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

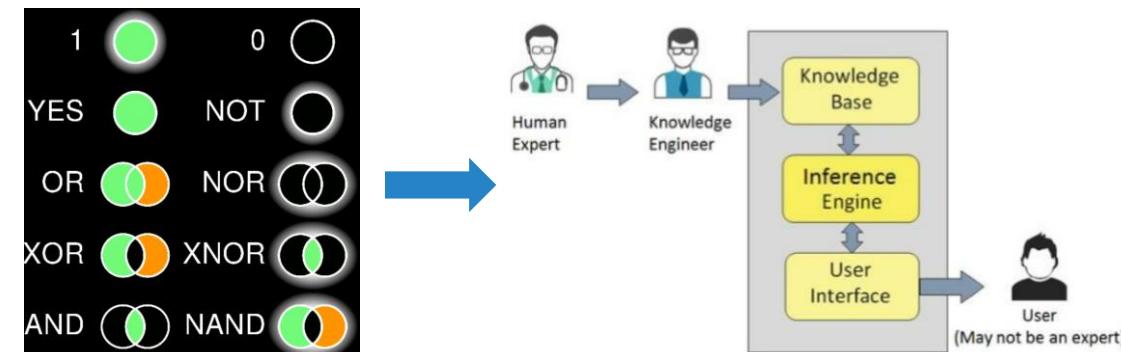
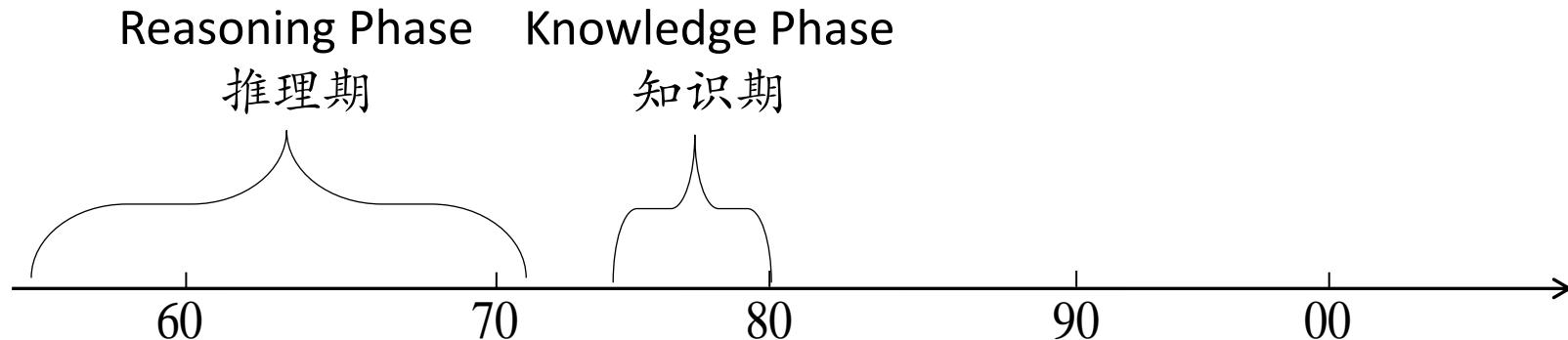


A. Newell



H. Simon

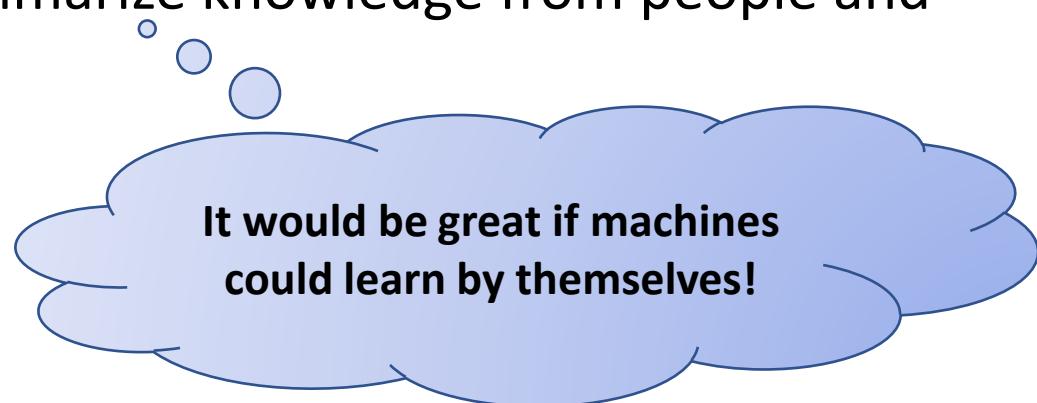
Timeline



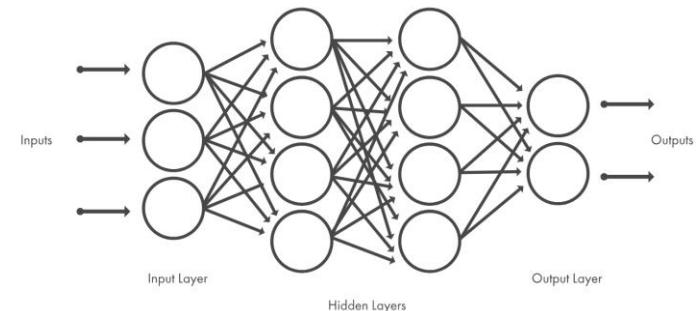
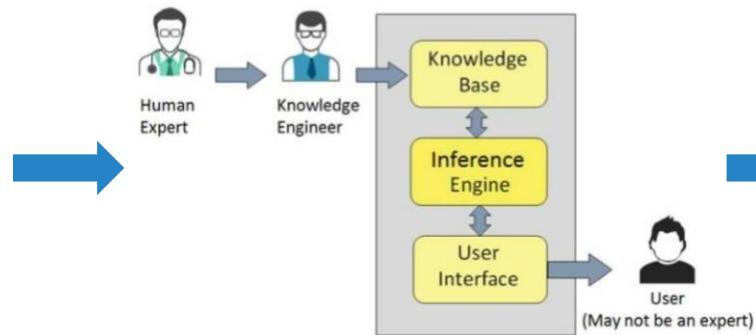
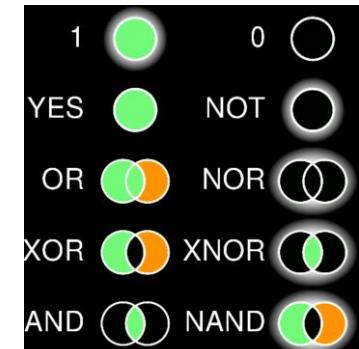
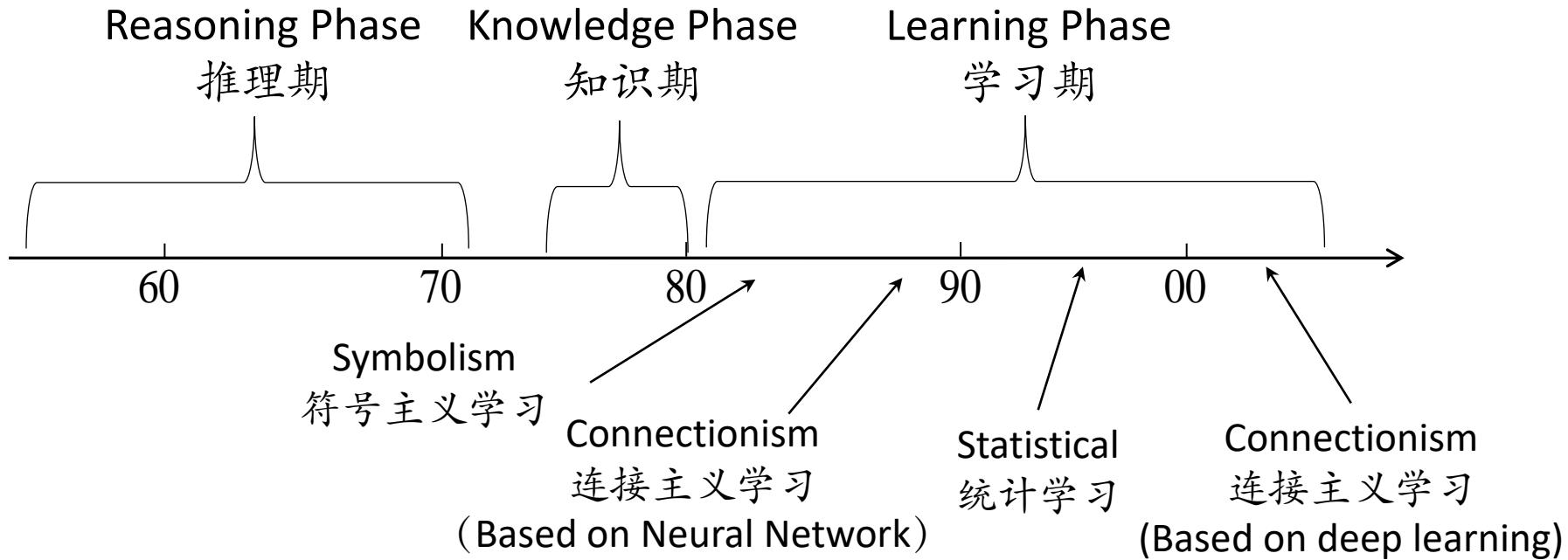
Knowledge Phase

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



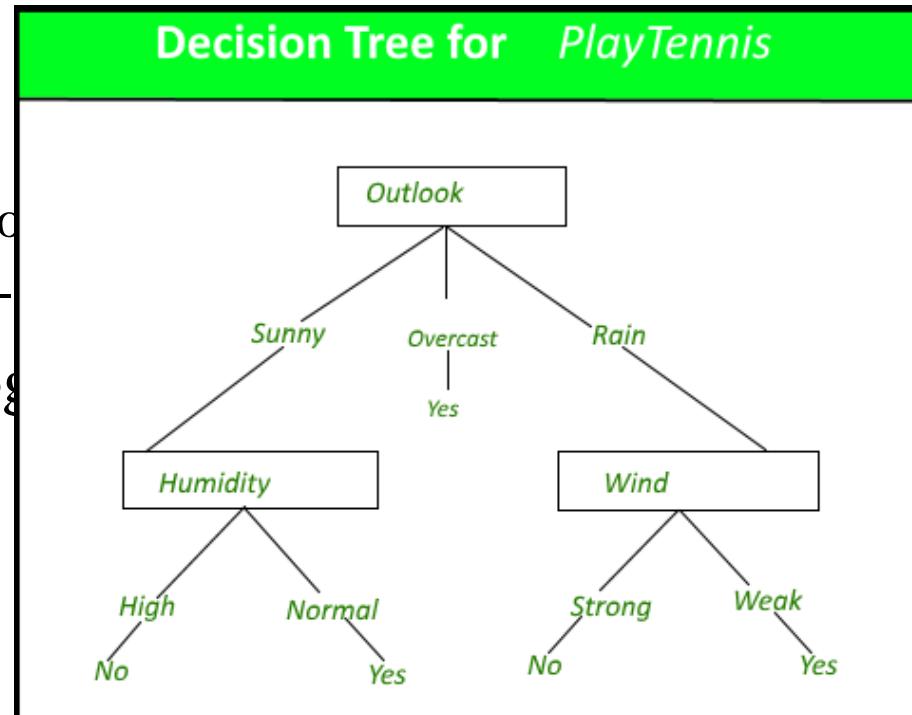
Learning Phase

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
- ...

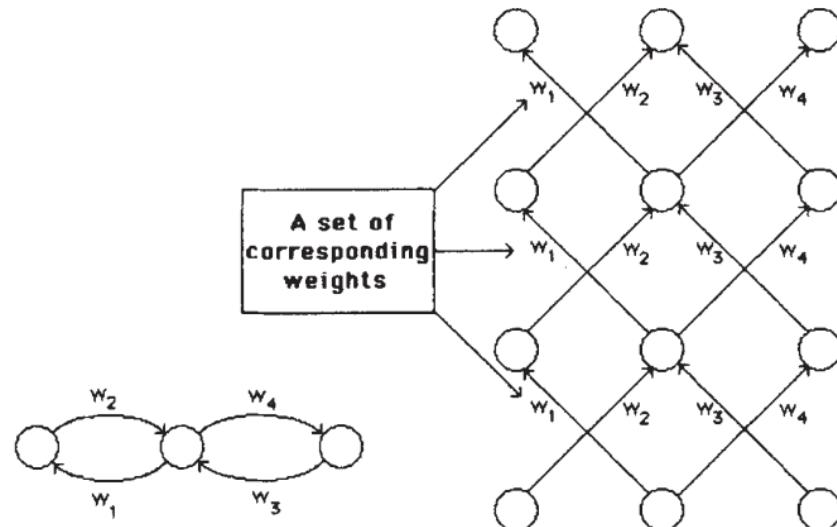
Learning from examples

- **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

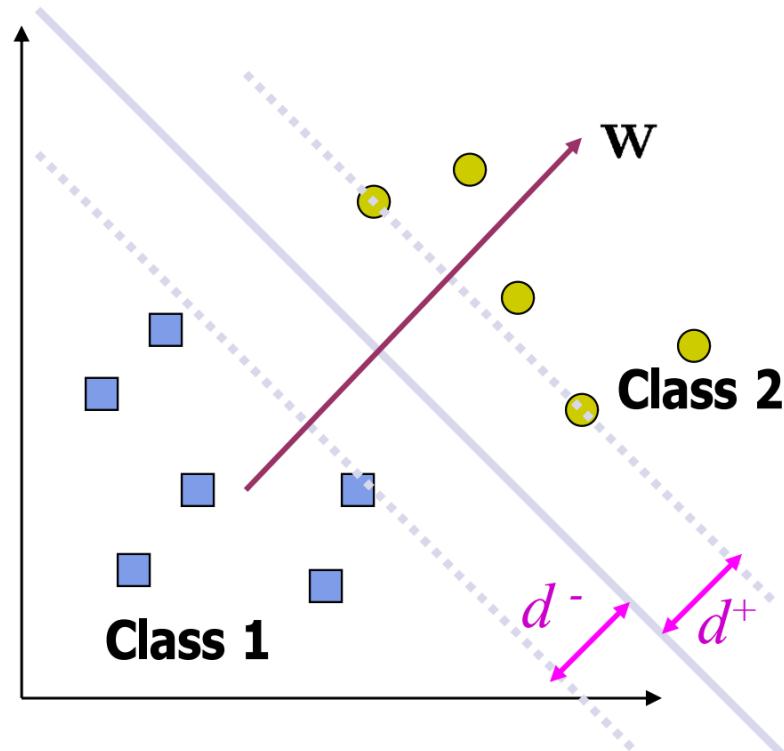
- Connectionism – Phase 1 连接主义学习
- Popular before 1990s
- Based on neural networks
- The backpropagation algorithm made a profound impact



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

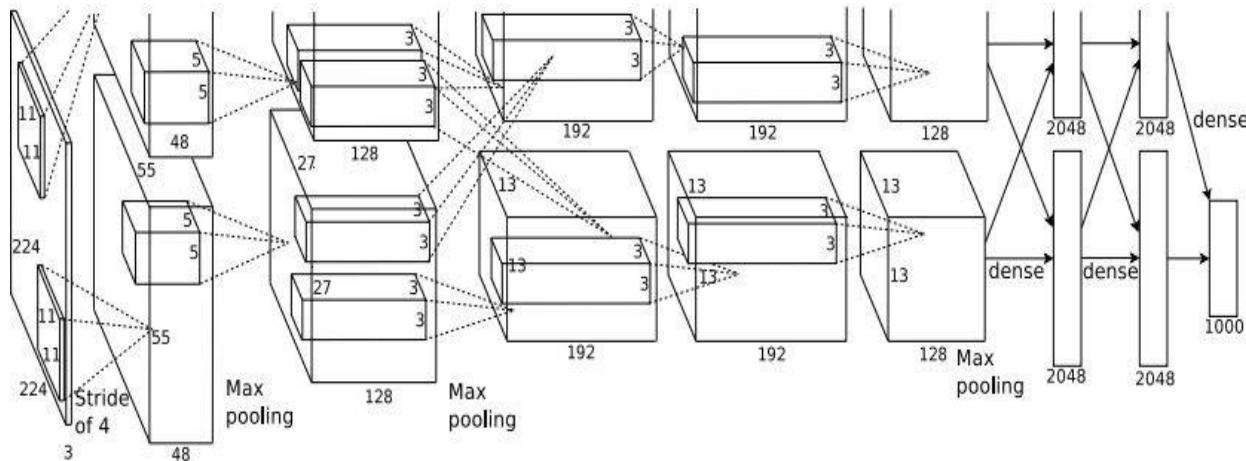
Learning from examples

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

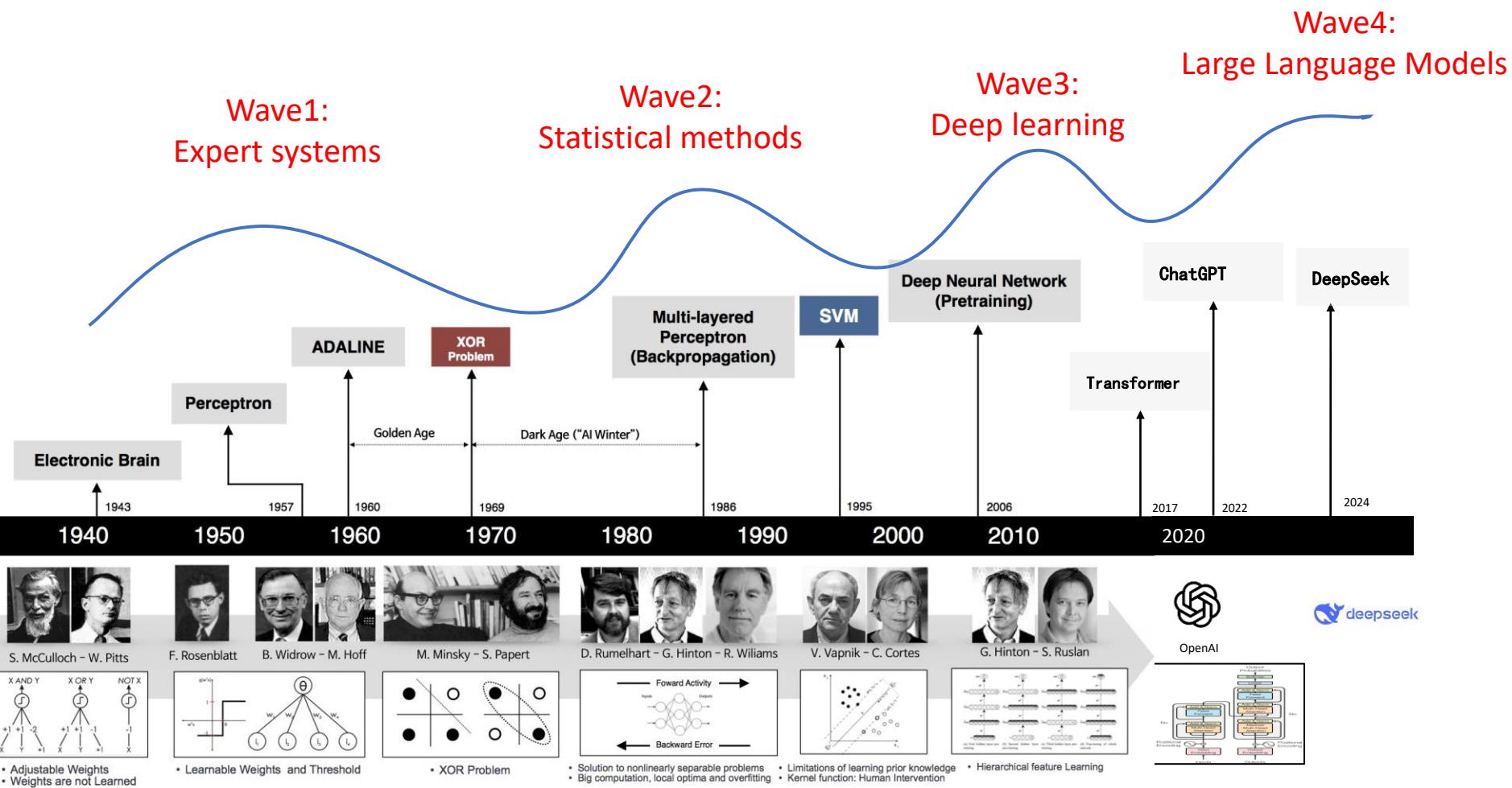


Learning from examples

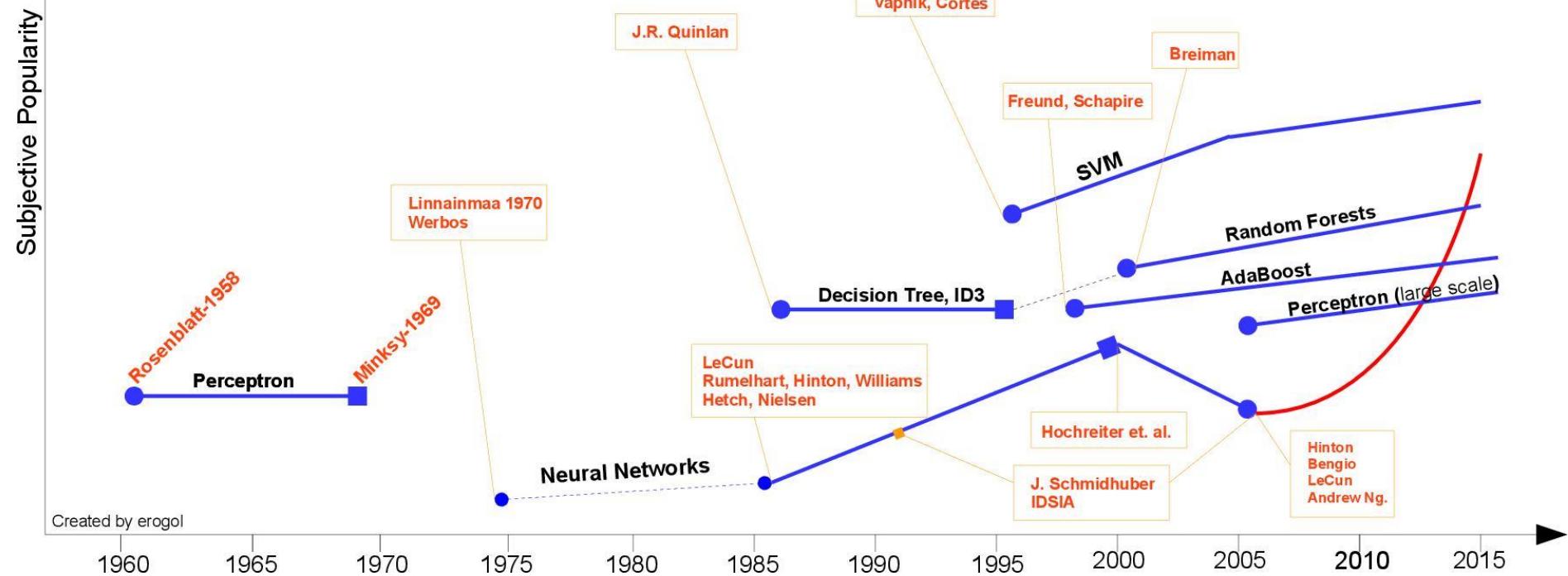
- Connectionism – Phase 2 连接主义学习
- Rise in early 21 century, hot now
- Based on deep learning
- A large amount of data and strong computing power provide support for deep learning



A bit of history

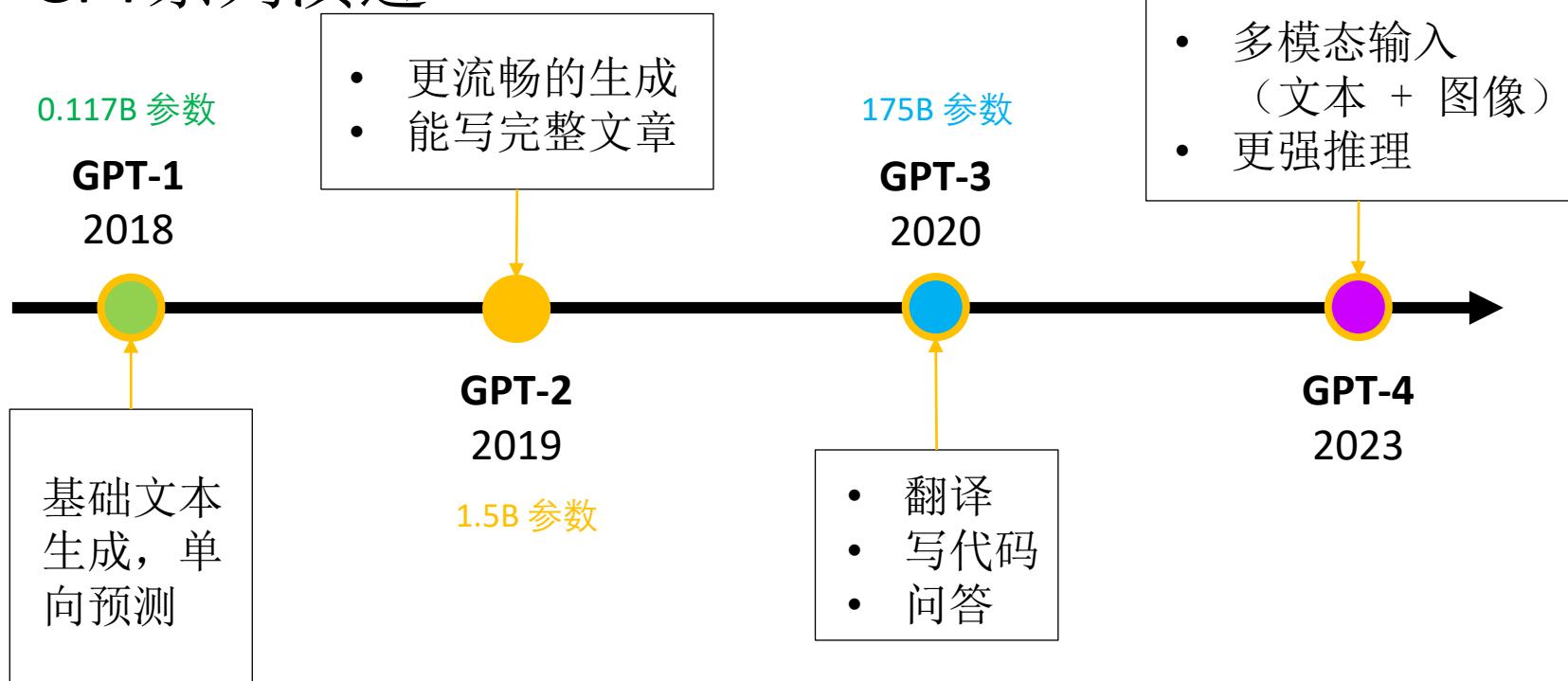


Trends of typical methods



Generative AI and LLMs

- GPT系列演进



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

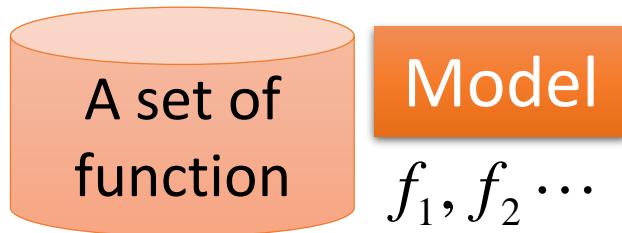
Today's Topics

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

Framework

Image Recognition:

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

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


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


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


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


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:

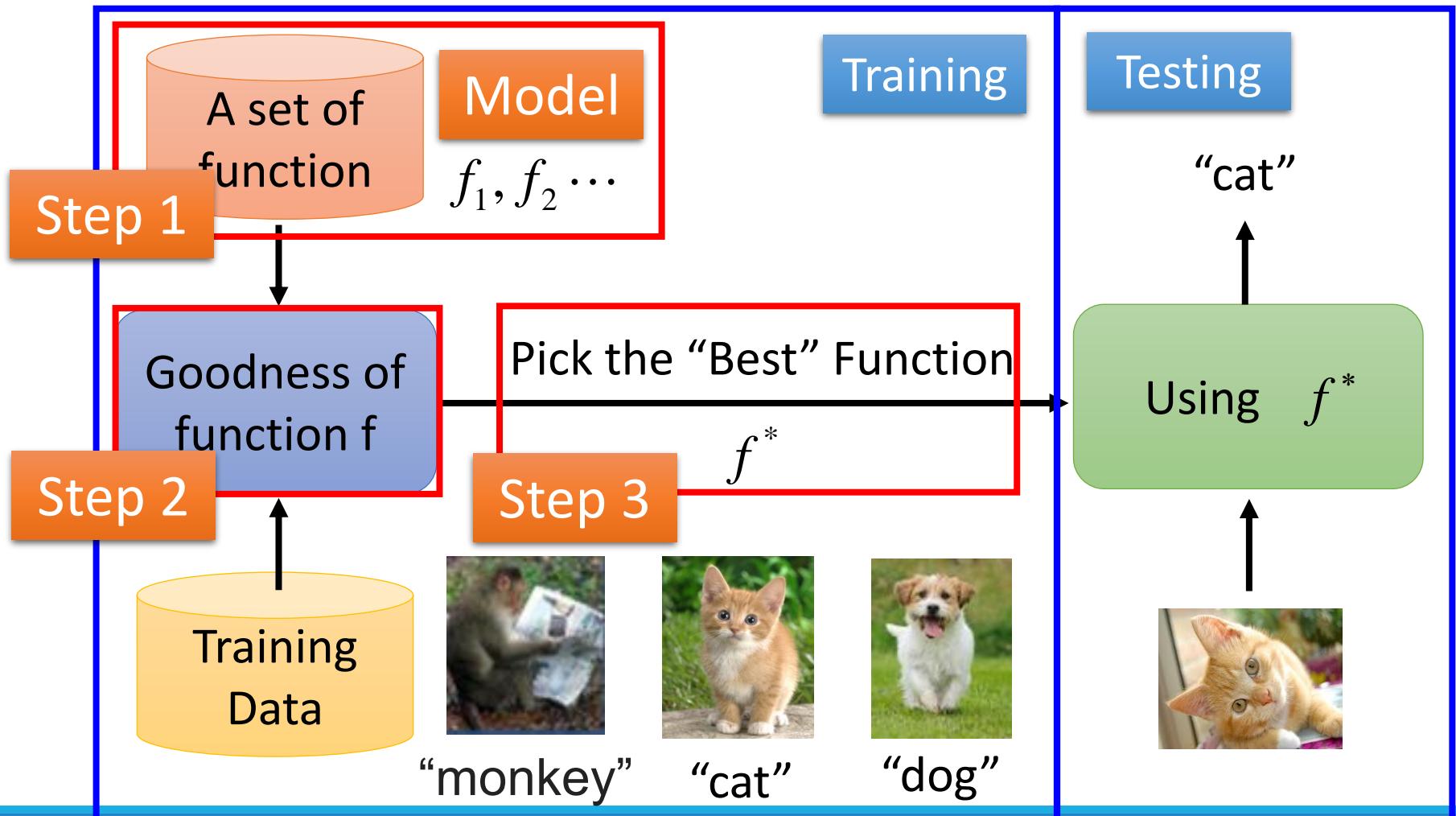


function output: "monkey" "cat" "dog"

Framework

Image Recognition:

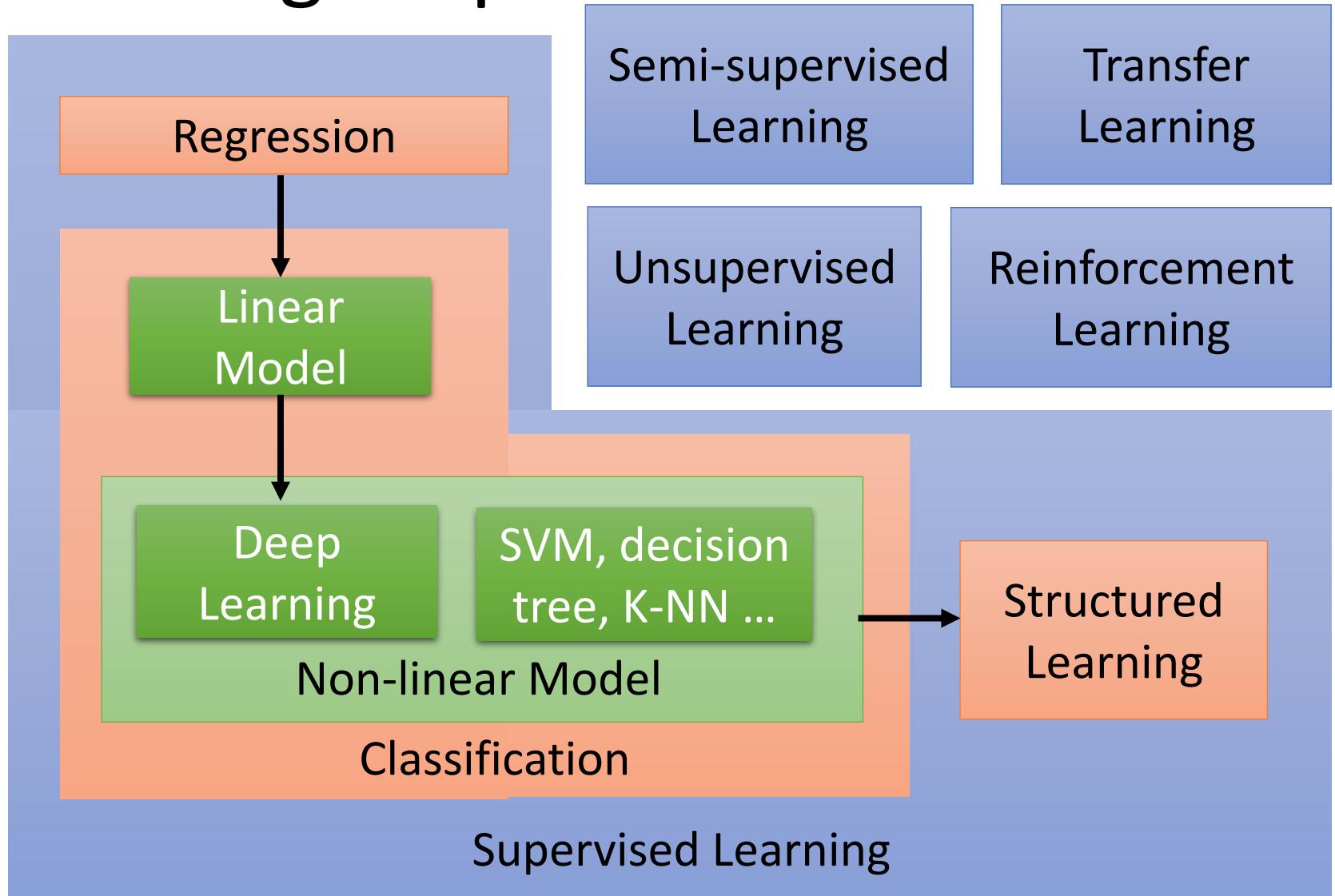
$$f(\text{cat}) = \text{"cat"}$$



Today's Topics

- Course introduction
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Learning Map

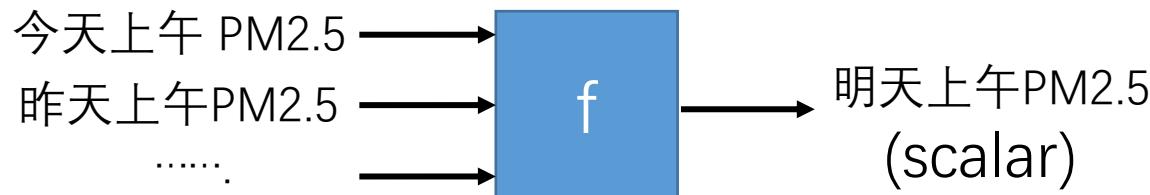


Learning Map

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

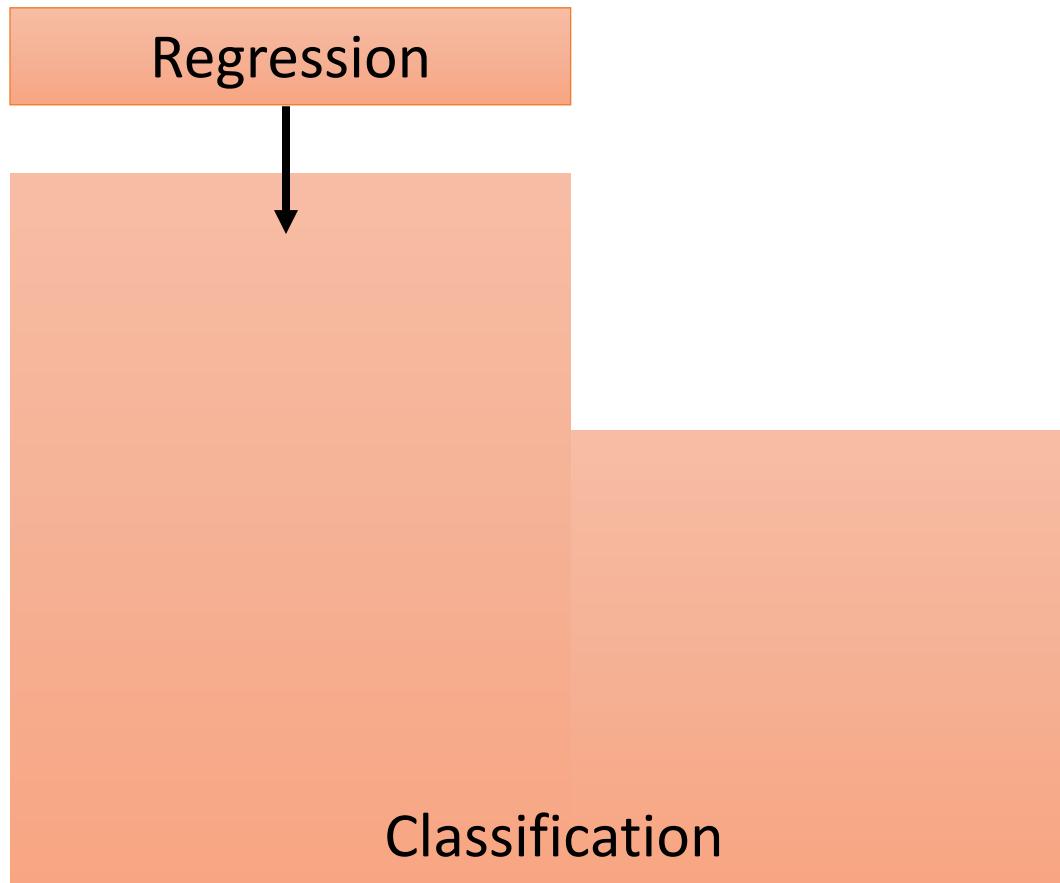
Input:

9/12 上午 PM2.5 = 30 9/13 上午 PM2.5 = 25

Output:

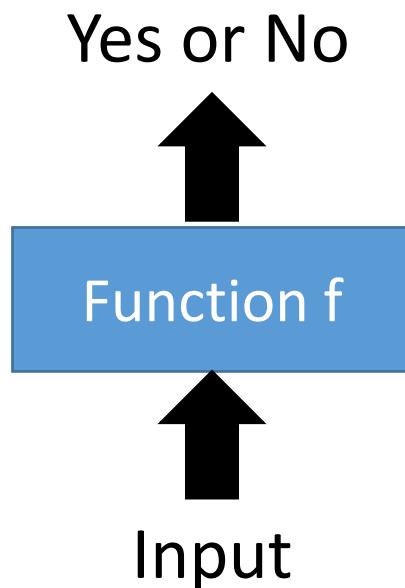
9/14 上午 PM2.5 = 20

Learning Map

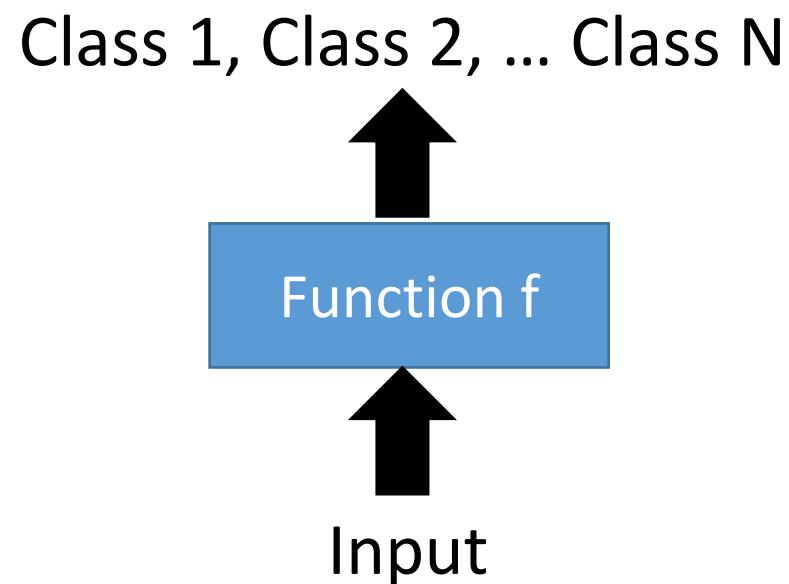


Classification

- Binary Classification

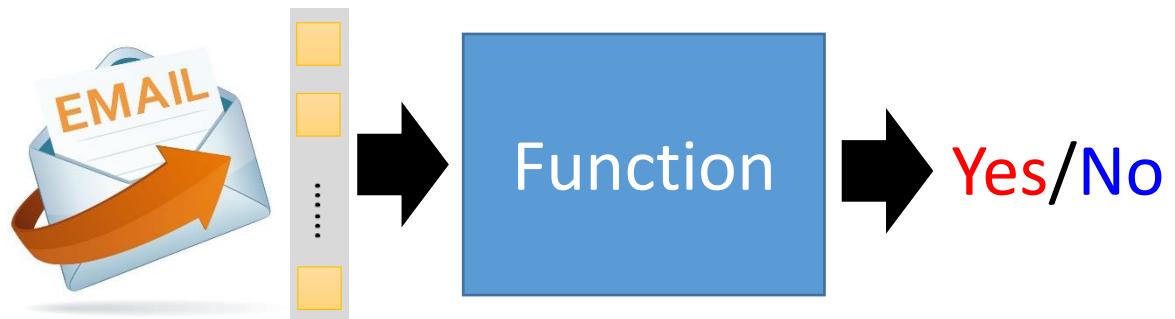


- Multi-class Classification



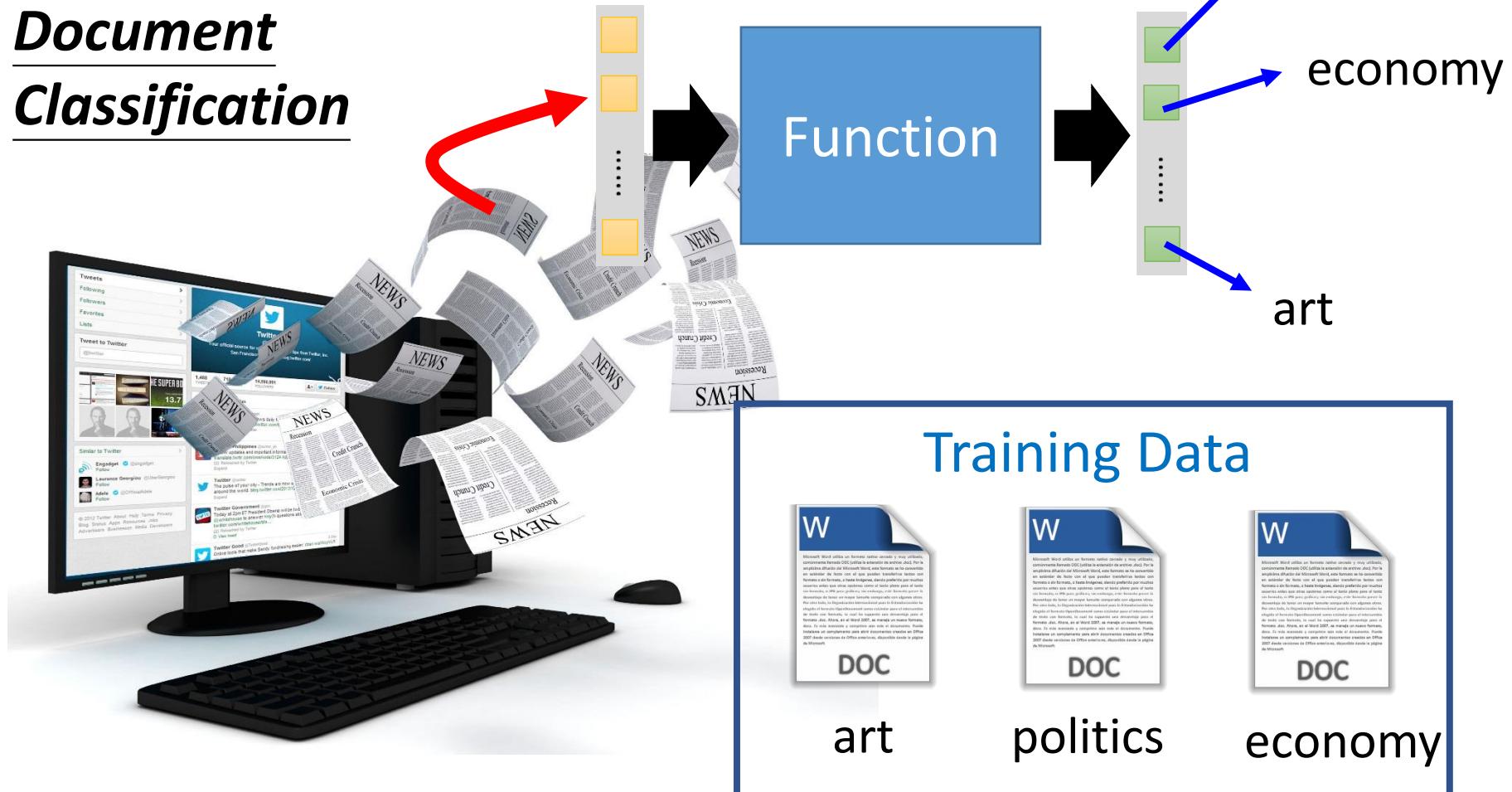
Binary Classification

Spam
filtering

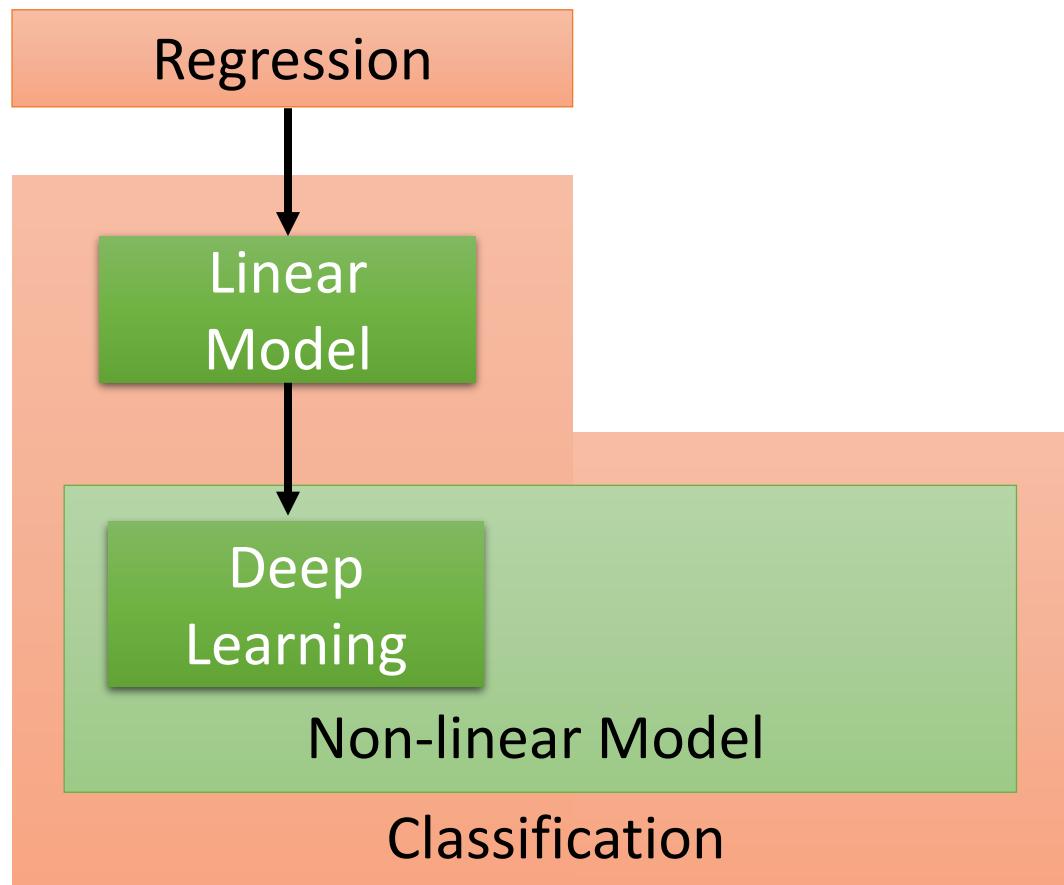


Multi-class Classification

Document Classification

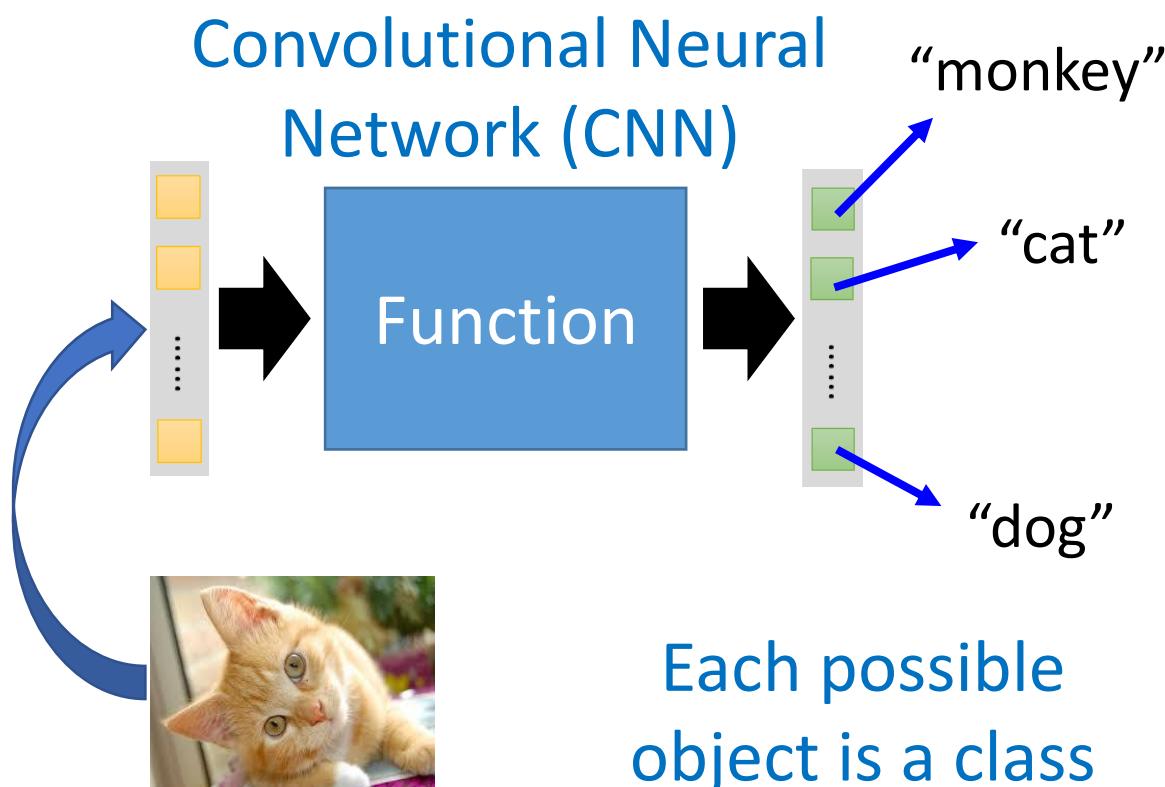


Learning Map



Classification - Deep Learning

- Image Recognition

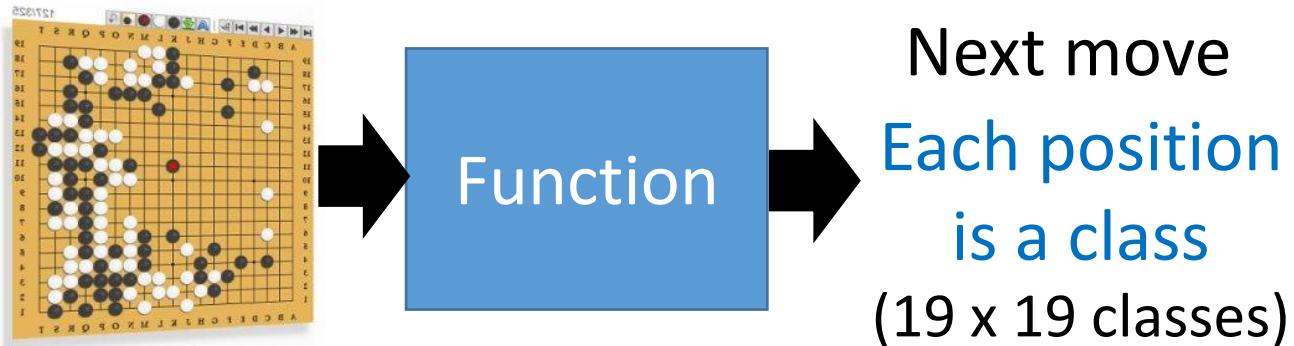


Training Data

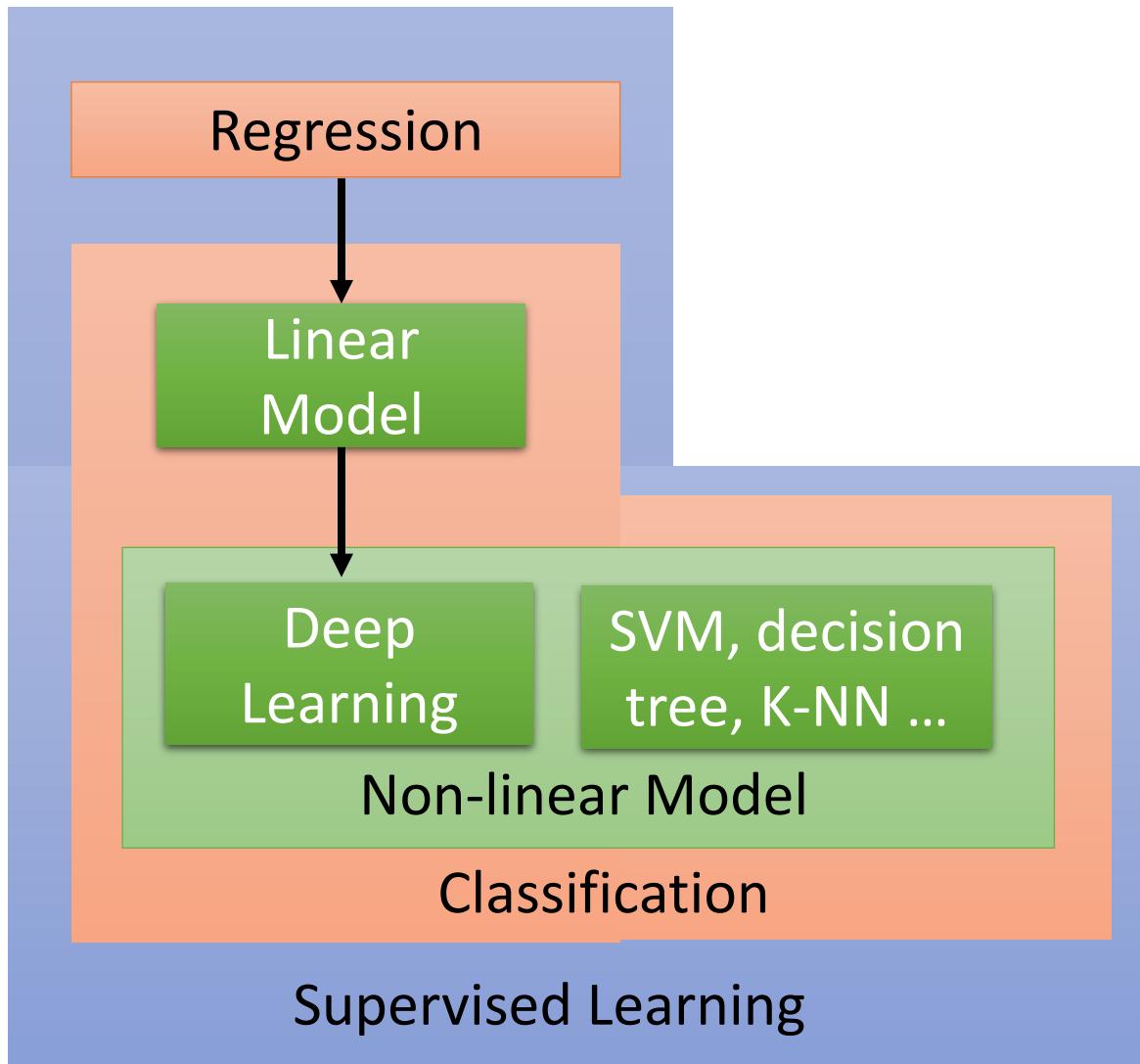


Classification - Deep Learning

- Playing GO



Learning Map

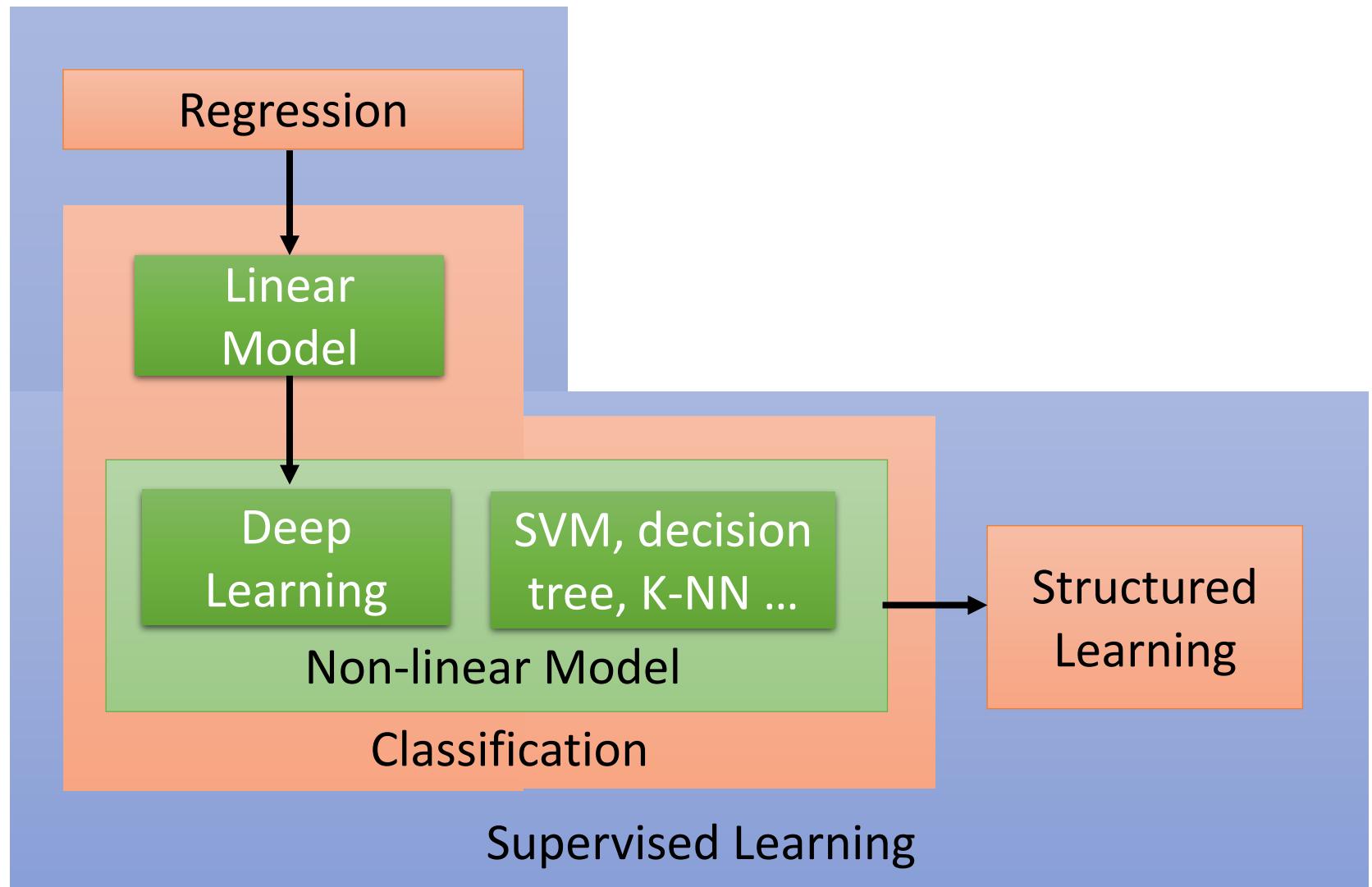


Training Data:

Input/output
pair of target
function

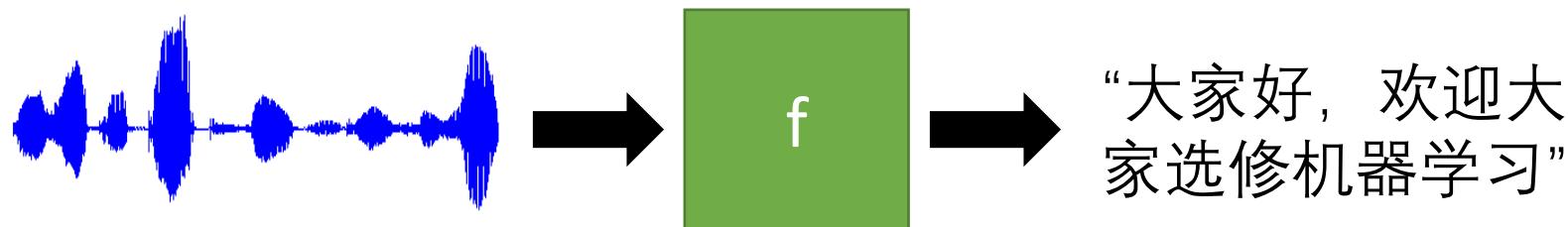
Function
output = label

Learning Map



Structured Learning

- Beyond Classification

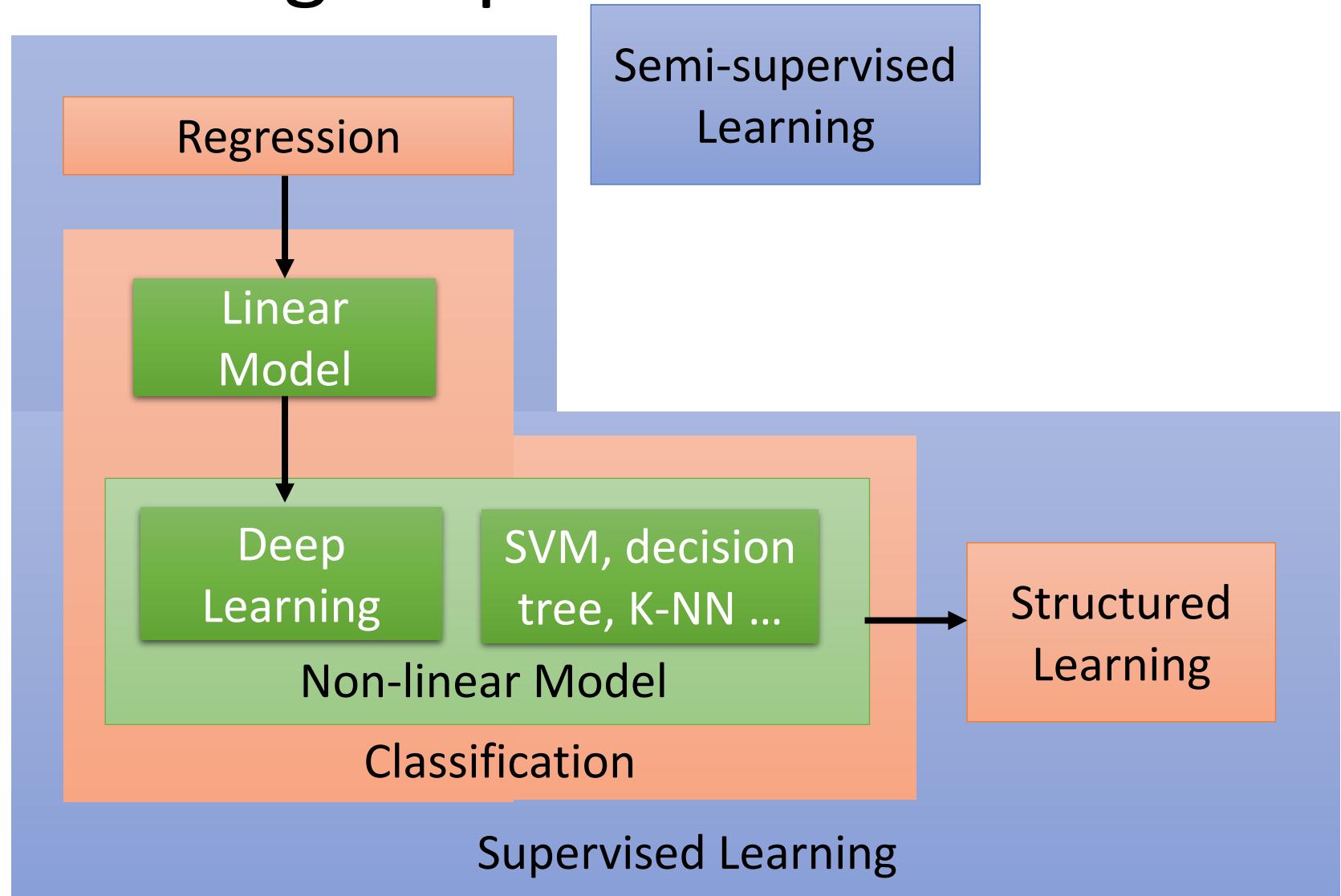


Speech Recognition



Machine Translation

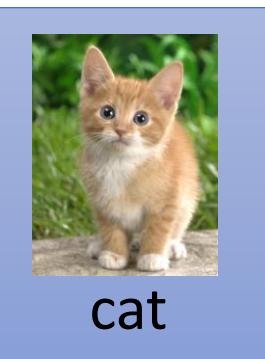
Learning Map



Semi-supervised Learning

For example, recognizing cats and dogs

Labelled
data

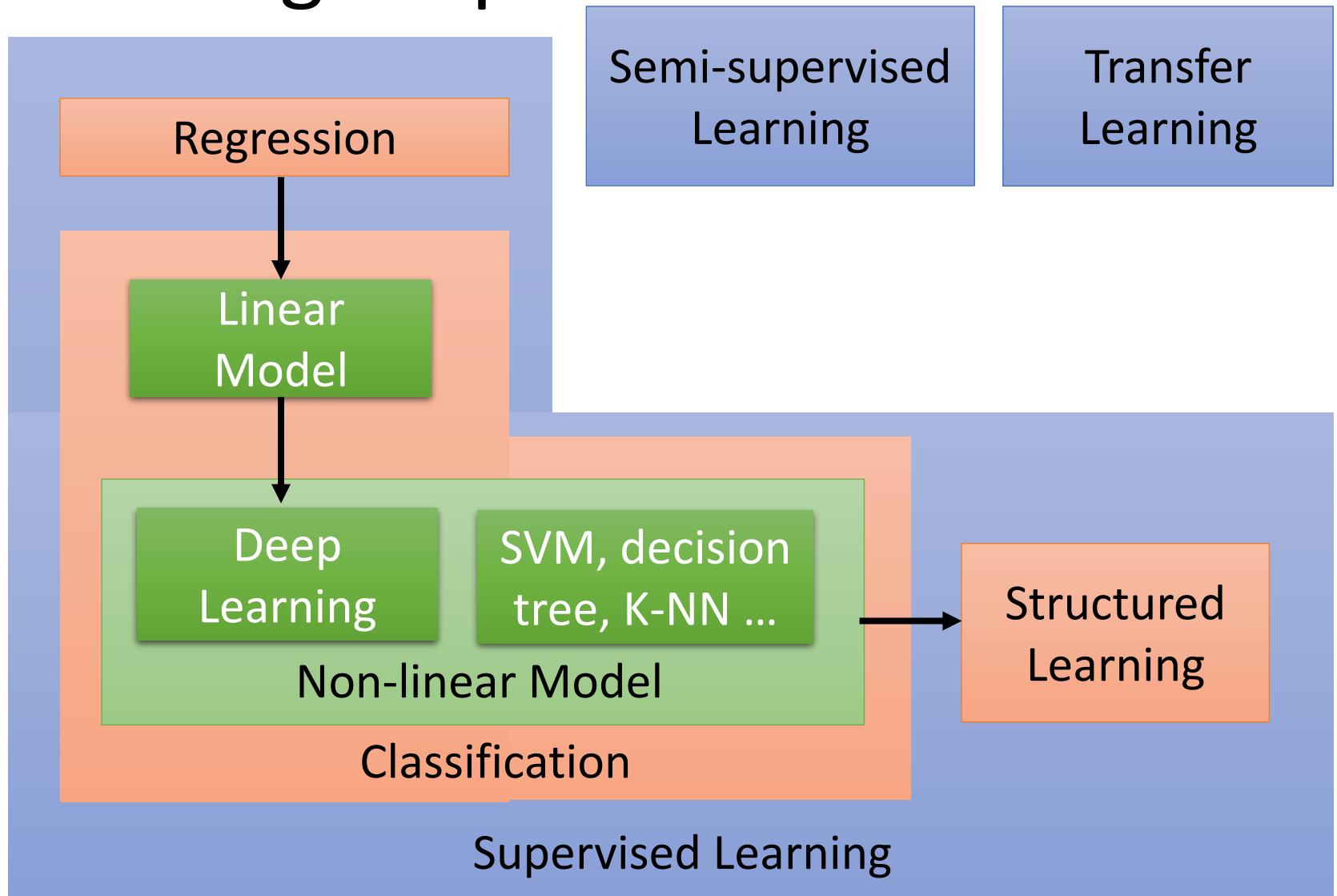


Unlabeled
data



(Images of cats and dogs)

Learning Map



Transfer Learning

For example, recognizing cats and dogs

Labelled
data



cat



dog

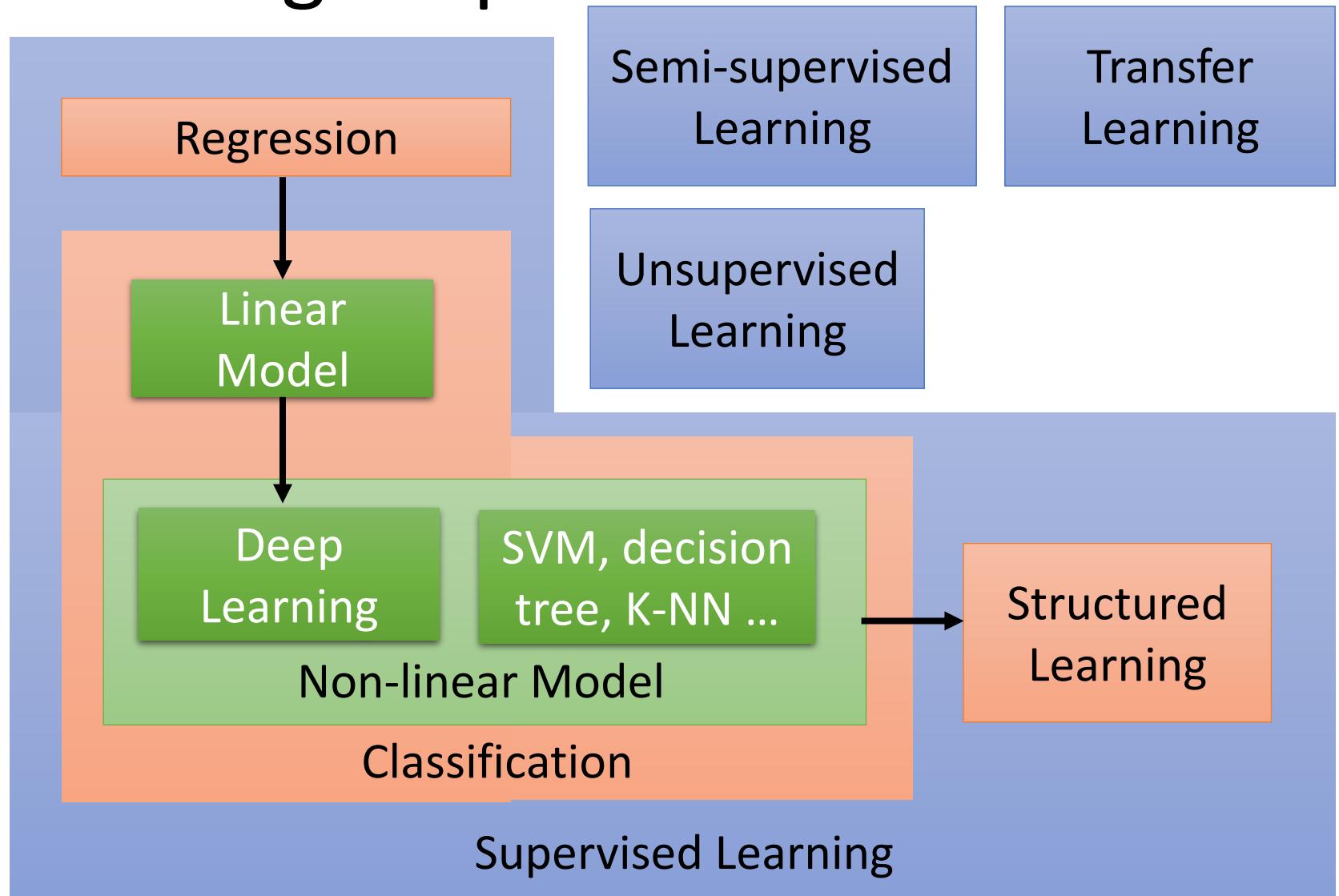


elephant



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

Learning Map



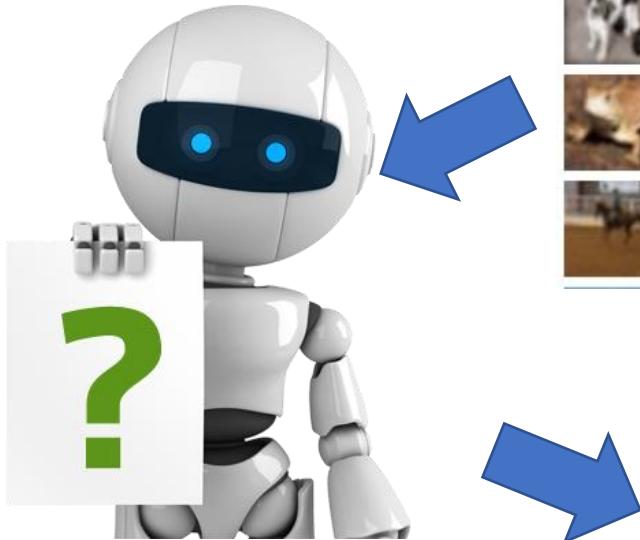
Unsupervised Learning

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

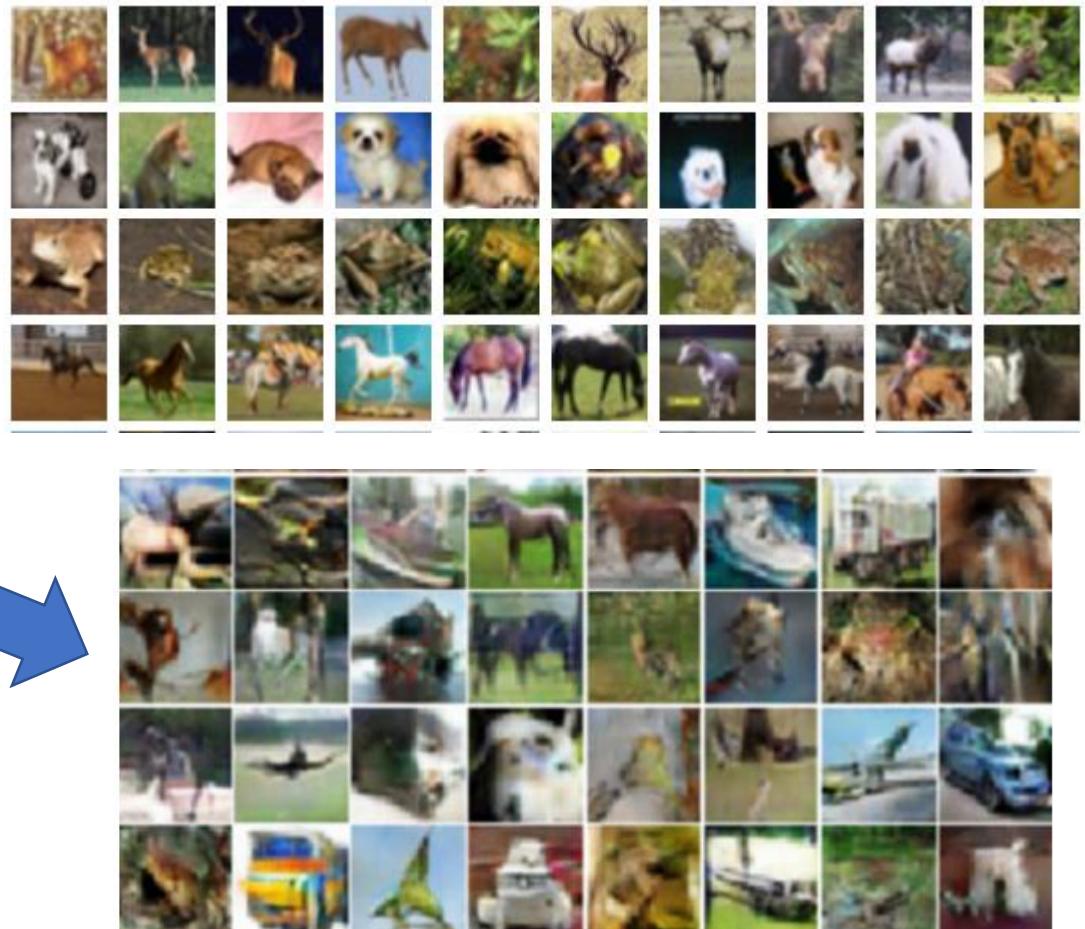


Unsupervised Learning

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



Draw something!



Unsupervised Learning

Machine listens to lots of
audio book



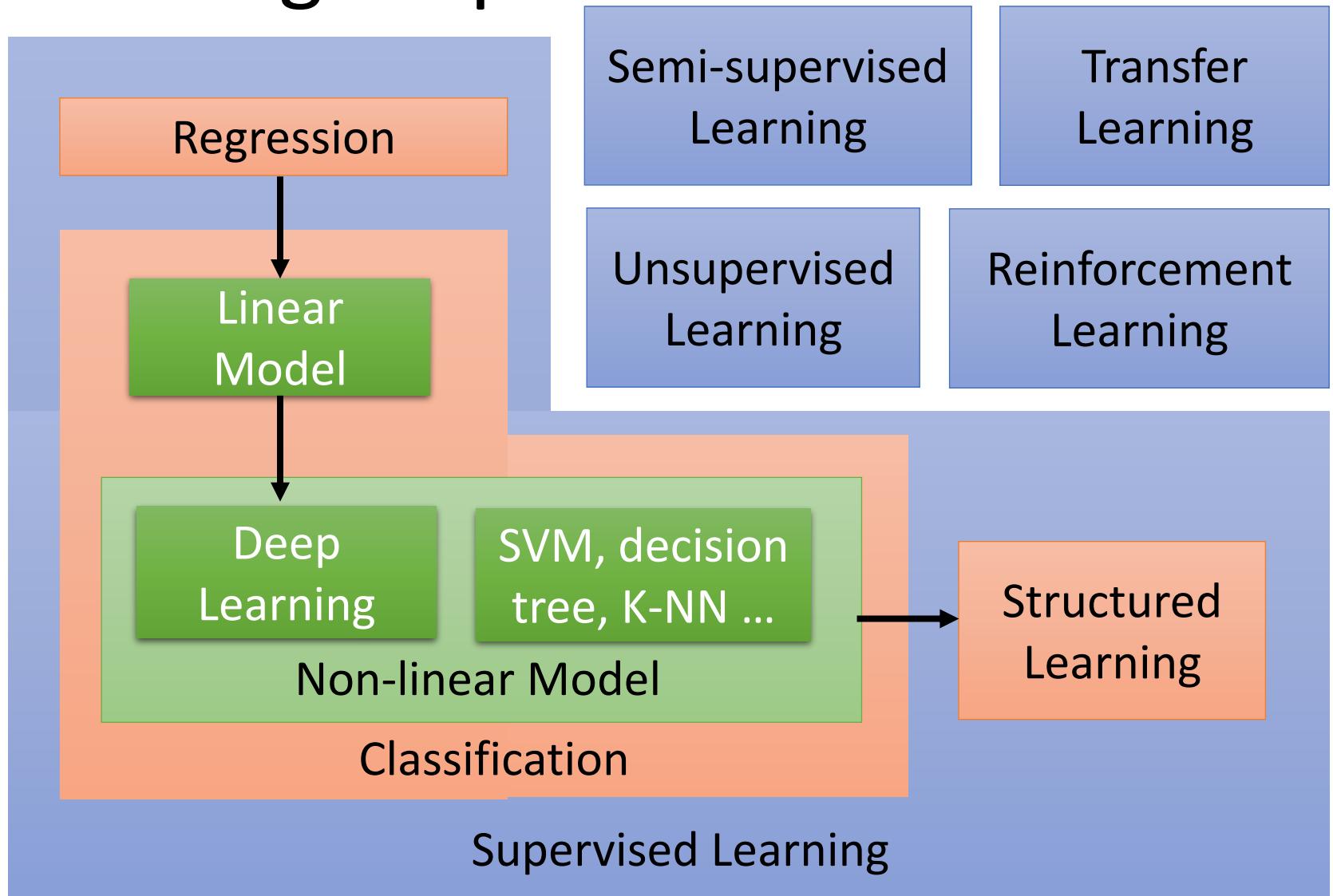
How about machine watch TV?



[Chung & Lee, INTERSPEECH 2016]

Questions: What is the preferred number of team members?
团体成员数量喜欢用几个?

Learning Map



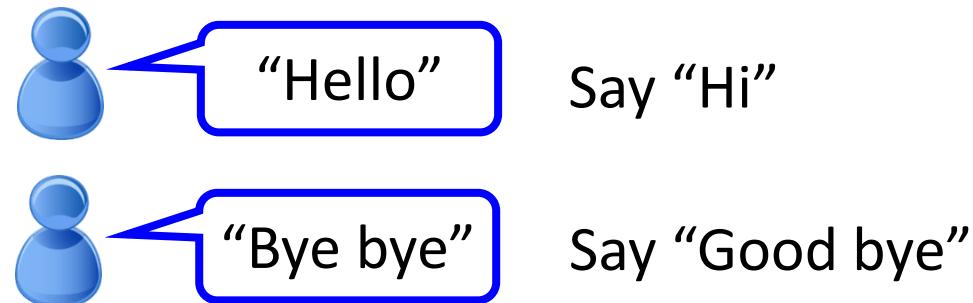
Reinforcement Learning



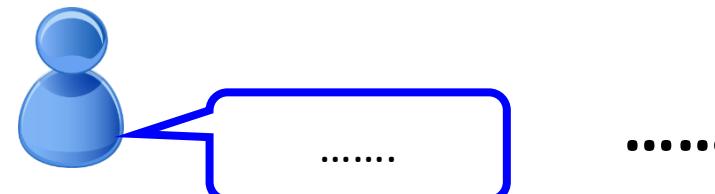
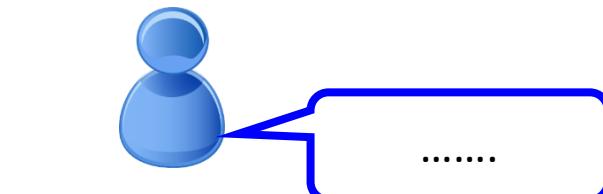
Supervised v.s. Reinforcement

- Supervised

Learning from
teacher



- Reinforcement



Bad

Learning from
critics

Agent

Agent

Supervised v.s. Reinforcement

- Supervised:



Next move:
“5-5”



Next move:
“3-3”

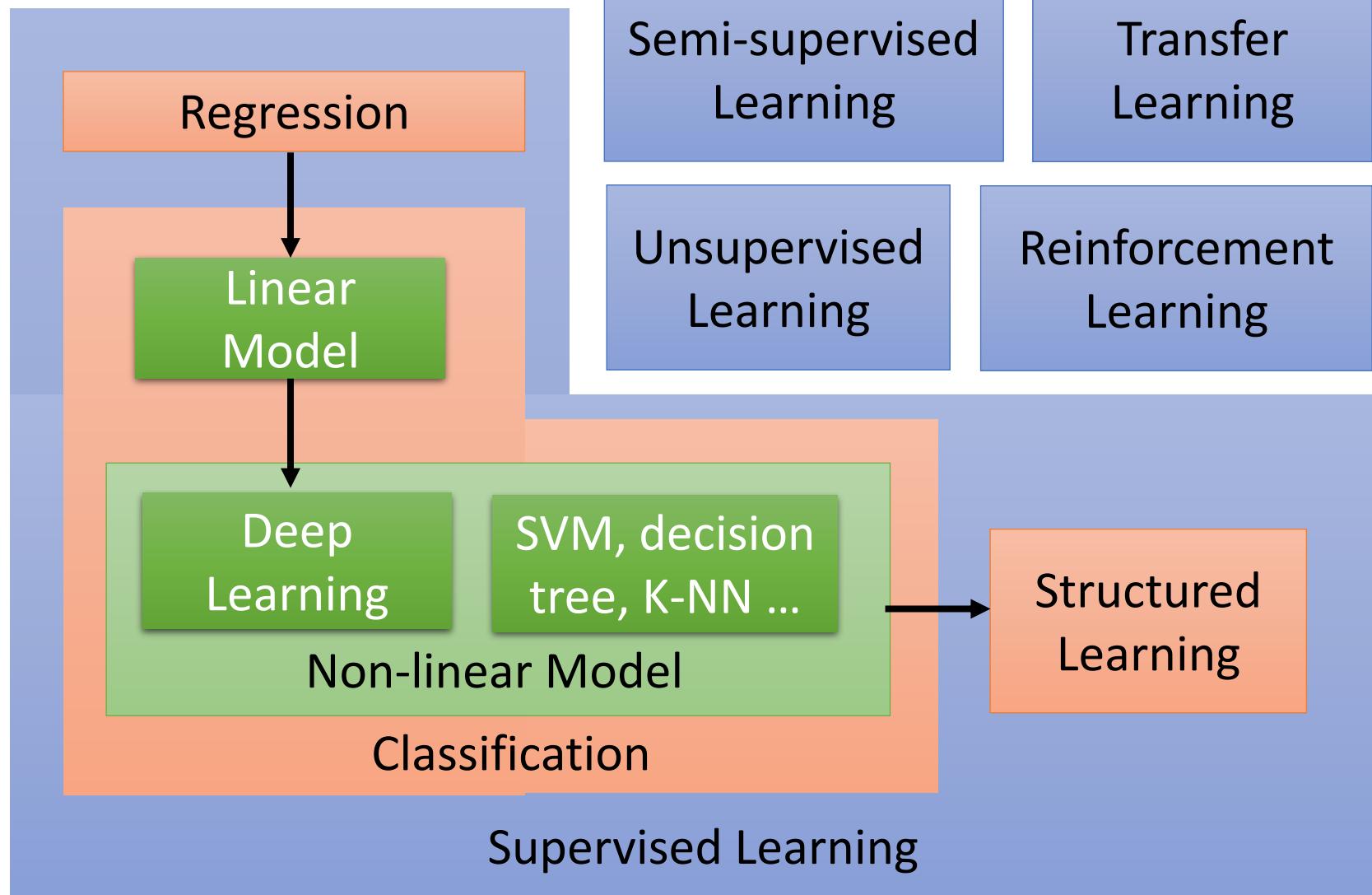
- Reinforcement Learning

First move → many moves → Win!

Alpha Go is supervised learning + reinforcement learning.

Learning Map

scenario task method

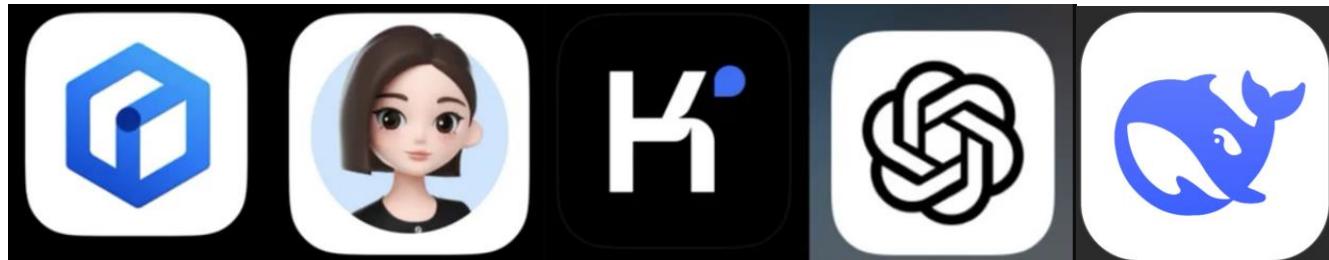


Summary

- **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

- Which AI tools do you like most? And why?



GPT

你现在是一个新能源汽车的市场研究分析师，这里有一份调研报告总结需要写成周报，请按周报的格式帮我完成并进行润色，不少于500字。

清晰地表达

DeepSeek

帮我把这份报告包装一下，我要写成周报给老板看，老板很看重数据。

把AI当人看



2025年1月，美国旧金山科技公司Artisan投放广告牌《停止雇用人类》

Open thinking...

- Do you think AI will replace humans one day?

