Machine Learning

The Learning Problem

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fides et ratio

Purpose of this course

How can machines learn?

Parts:

- Machine Learning *foundations* and *Supervised Learning*
- Brief theory on *Deep Learning*
- Glance at *Unsupervised Learning*
- An even briefer glance at *Reinforcement Learning*

Purpose of the "foundations" part

Based on Dr. Hsuan-Tien Lin's course at NTU

Main focus on *Supervised Learning*
(which we'll define in a couple of slides, hang on)

How can machines generalize to unseen data?

Today: introductory story
(Get comfortable, there is only *one* slide with maths.)

What is Machine Learning?

learning: acquiring *skill* from *observations*

$$\text{observations} \longrightarrow \boxed{\text{learning}} \longrightarrow \text{skill}$$

Compare this to procedural algorithms

What is Machine Learning?

machine learning: acquiring skill from observations

improving some performance measure

$$\text{observations / data} \longrightarrow \boxed{\text{ML}} \longrightarrow \text{skill}$$

Compare this to procedural algorithms

An example of learning

Tree recognition from images

- how do you define what is a tree?
- easier to show examples
- large number of images to learn from: large dataset

Tree

Not a tree

Source: pexels.com

Fun Time

Which of the following is best suited for ML?

1. predicting whether the next cry of the baby girl happens at an even-numbered minute or not
2. determining whether a given graph contains a cycle
3. deciding whether to approve credit card to some customer
4. guessing whether the earth will be destroyed by the misuse of nuclear power in the next ten years

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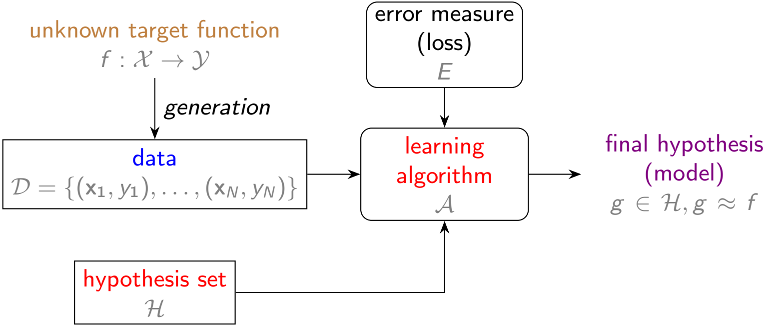
Reference answer: 3

1. no pattern to learn
2. programmable definition, easier to do procedurally
3. there is a pattern, there is data, alternatives are complex rules
4. arguable no (not enough) data

Formalization of learning problem



- input: $\mathbf{x} \in \mathcal{X}$
- output: $y \in \mathcal{Y}$
- target function: $f : \mathcal{X} \rightarrow \mathcal{Y}$
- data: $\mathcal{D} = \{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$
- hypothesis / model with good performance: $g = \arg\max_f E(f)$

Related fields

Machine Learning $\approx$ Data Mining

- ML: use data to compute hypothesis g that approximates f
- DM: use (huge) data to find interesting properties
- DM: more data cleaning, processing, storing, organising, and also feature engineering

Machine Learning $\subset$ Artificial Intelligence

- AI: compute something that shows intelligent behaviour
- ML is one possible way to AI

Machine Learning vs Statistics

- Stat: use data to make inference about an unknown process
- useful tools for ML (with nice mathematical proofs)

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Machine Learning vs Statistics

All the impressive achievements of deep learning amount to just curve fitting.

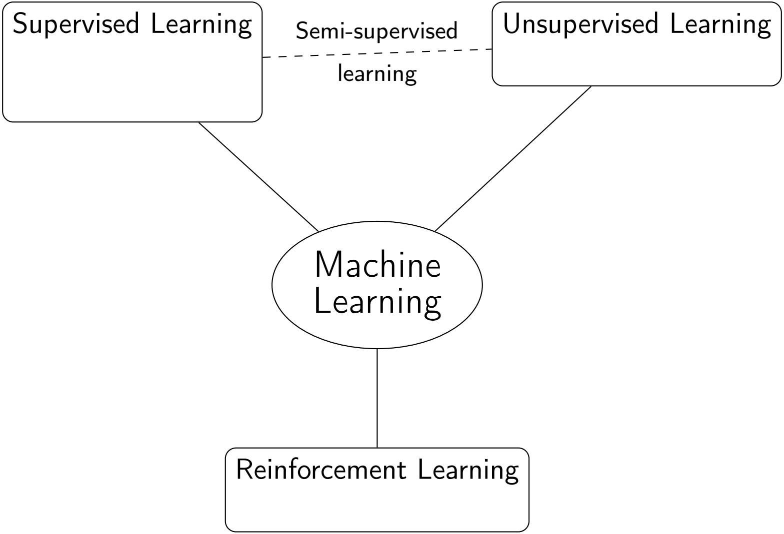
Judea Pearl

Categorization by spaces

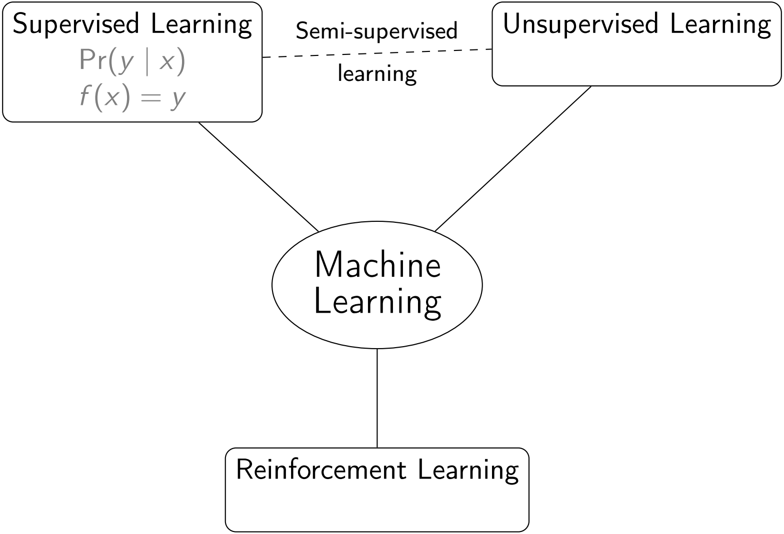
Input/output can be

- discrete (e.g. $\{\text{blue}, \text{black}, \text{brown}\}$)
- ordered (e.g. $\{\text{healthy} < \text{ill} < \text{extremely ill} < \text{horrendously(?) ill} < \text{dead}\}$)
- real (e.g. $\mathbb{R}^d$)
- sequence (e.g. "I love ML", or (healthy, ill, healthy, extremely ill, dead))

Categorization by problem type



Categorization by problem type



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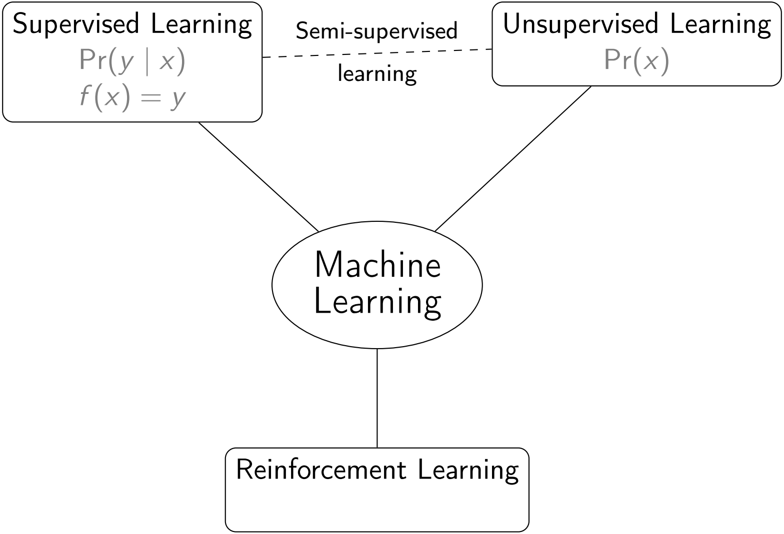

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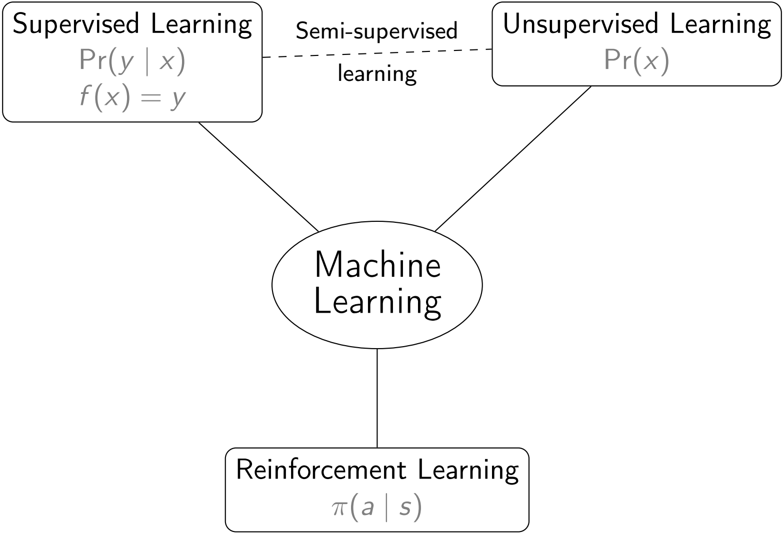

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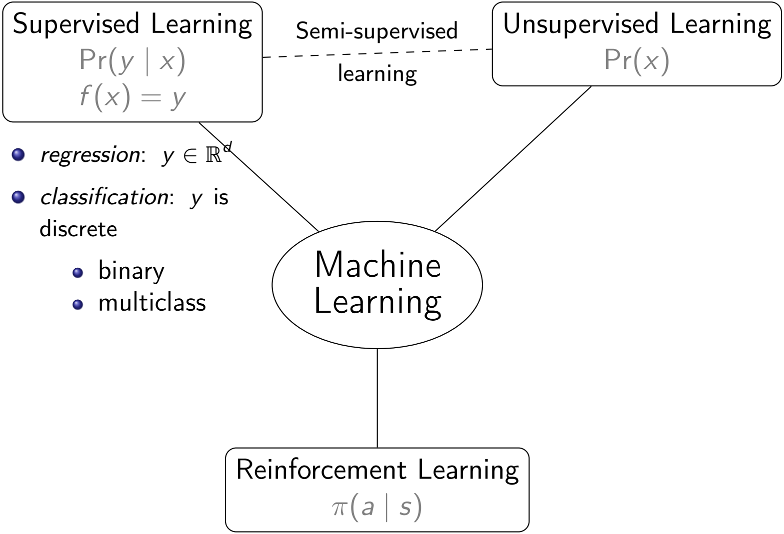
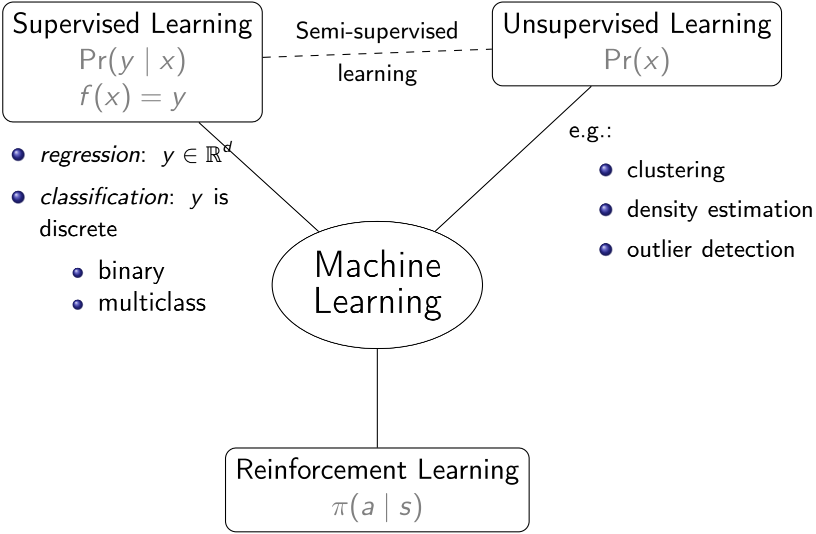


- *regression*: $y \in \mathbb{R}^d$
- *classification*: y is discrete
    - binary
    - multiclass

Categorization by problem type



Categorization by context

- Batch / offline learning
  - learn from all known data
  - dataset does not change during learning
- Online learning
  - new data is received during learning (and potentially at inference time)
  - continuously improve hypothesis
  - e.g. spam filtering
- Active learning
  - the model (agent) asks for new data to learn from
  - strategically observed data