Machine Learning Laboratory
POSTECH

[CSED/AIGS 515] - 2023 Spring

Machine Learning

Dongwoo Kim
POSTECH CSED/GSAI
dongwoo.kim@postech.ac.kr

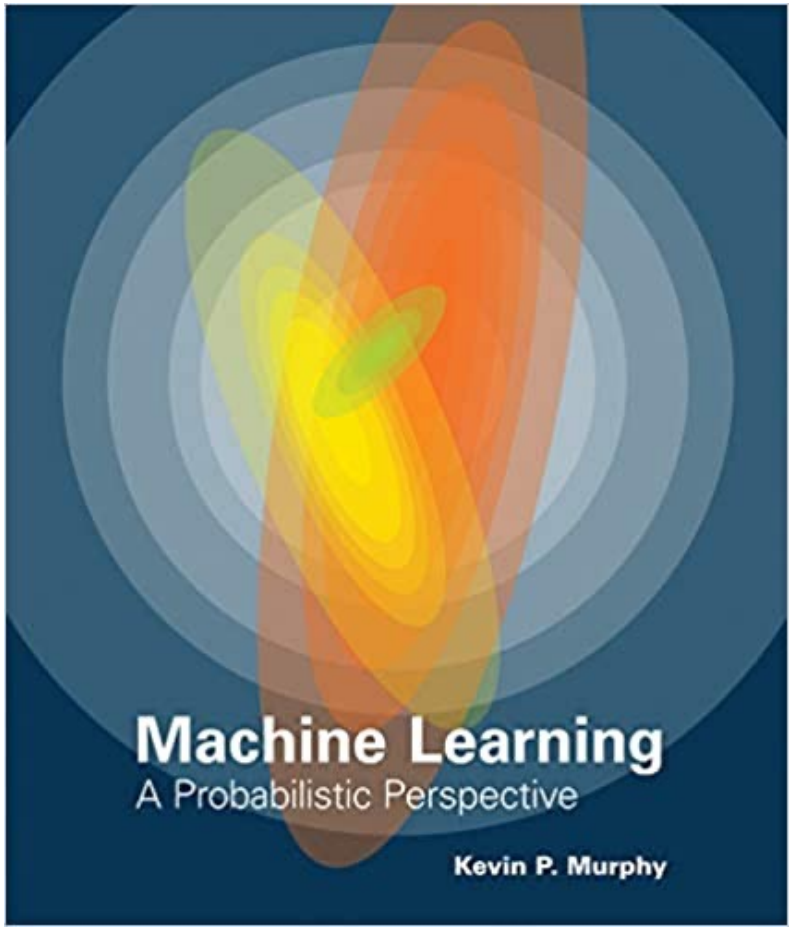
Basic Lecture Information

- Time: 11:00-12:15 (Tue/Thu)
- Classroom
  - 청암학술정보관 502호
- Office hour: contact by email
  - dongwoo.kim@postech.ac.kr

Main Textbook

- Machine Learning: A Probabilistic Perspective, by Kevin Murphy, MIT Press, 2012

- Draft of the book is available at the book webpage: https://probml.github.io/pml-book/book1.html



Attendance Check

- We will not check attendance for the first two weeks.
- We will check the attendance via mobile app.
  - The detailed instruction will be available soon.
  - But you need to satisfy minimum attendance requirement (3/4)

Exams & Assignments

- Midterm exam
- Final exam
- 5~6 assignments
  - Problem solve (handwriting)
  - Programming (numpy + pytorch)

- Midterm 30% / Final 30% / Assignment 40%
  - + need to satisfy minimum attendance requirement (3/4)

Important: **zero tolerance** for plagiarism/cheating

Questions

- Questions during lecture
  - Feel free to interupt
  - **Don’t be shy**

- Offline questions
  - Use Q&A board (Recommanded)
  - Contact by email for personal meeting (dongwoo.kim@postech.ac.kr)

- TA (assignment, grading, attendance,…)
  - Moonjeong Park + …
  - Use email address: csed515-ta@postech.ac.kr

Pre-requisite

- Mandatory
  - Basic programming (Python; numpy + pytorch)
  - Basic (vector) calculus

$$\frac{d \ln x}{dx} = \qquad\qquad \int \exp(-x) dx =$$

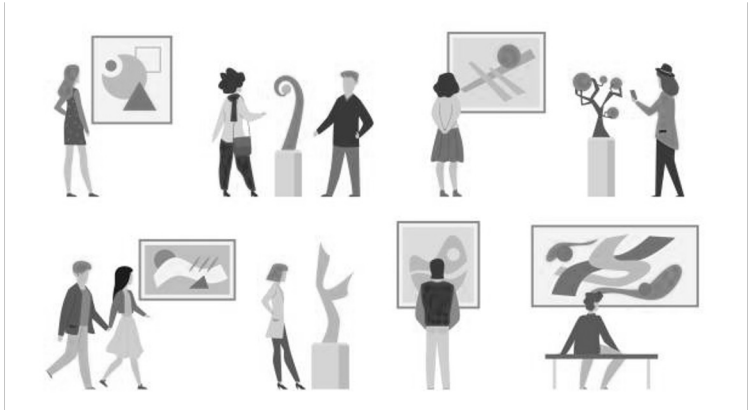
  - Probability (will review)
  - Linear algebra
- The first assignment will be about basic probability and algebra. If you feel not ready for these materials, you may consider taking this course later.
  - CSED490Y: Optimization for Machine Learning
  - CSED500: Advanced Linear Algebra for CSE
  - CSED530 Advanced Probability Theory for CSE

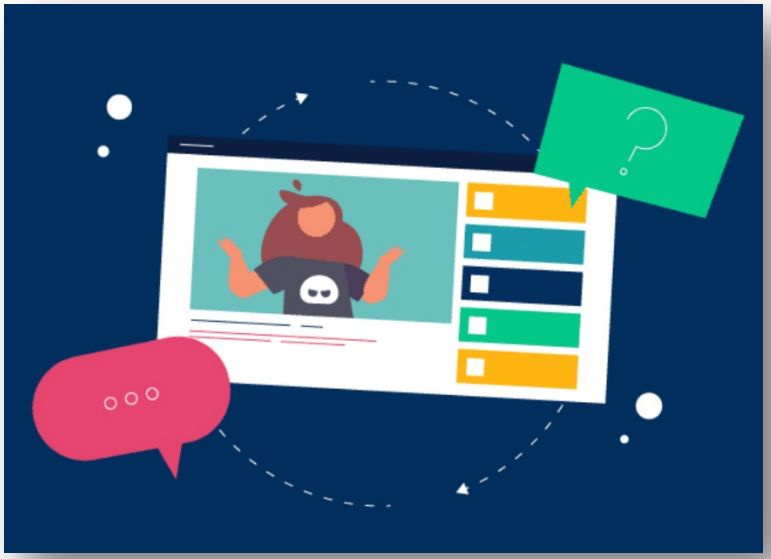
An Introduction to Machine Learning

- What is Machine Learning?
- Three Types of Machine Learning
- Course Overview

Era of Artificial Intelligence

- Recommandation



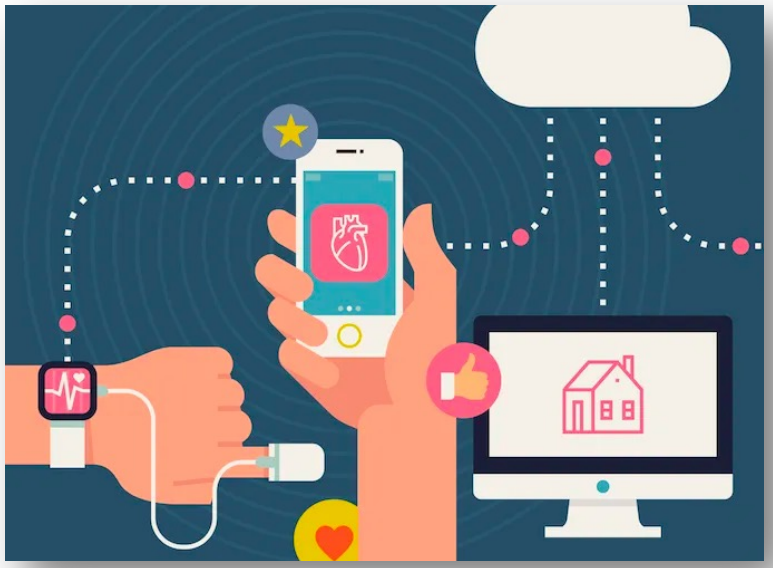


Era of Artificial Intelligence

- Self-Driving Car

Era of Artificial Intelligence

- Heath Care



Era of Artificial Intelligence

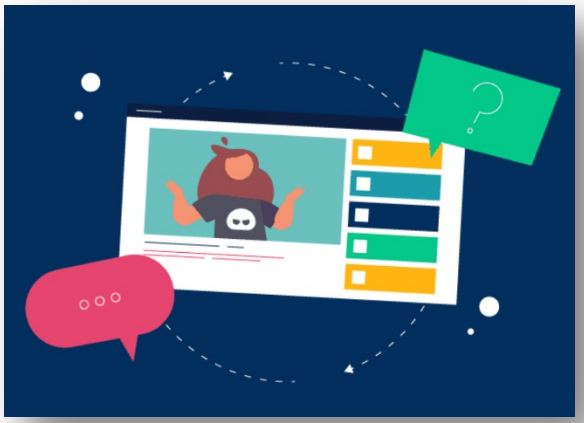
- Intelligent Chatbot

Do you know POSTECH?

Yes, I am familiar with POSTECH, which stands for Pohang University of Science and Technology. It is a private research university located in Pohang, South Korea, and it is considered one of the top universities in the country. POSTECH was founded in 1986 and has a strong focus on science and engineering research, with particular strengths in materials science, nanotechnology, energy, and biotechnology. The university has a highly competitive admissions process and is known for its rigorous academic programs and innovative research.

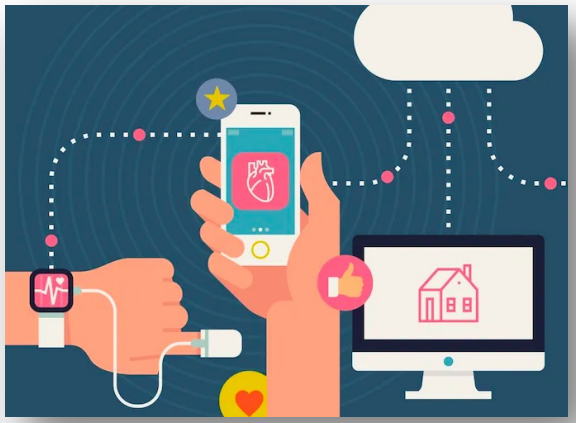
Era of Artificial Intelligence

Recommander System



Self-Drving Car

Healthcare



Household Robot

K. Wyrobek, E. Berger, H.F.M. Van der Loos, and K. Salisbury. ICRA, 2008.

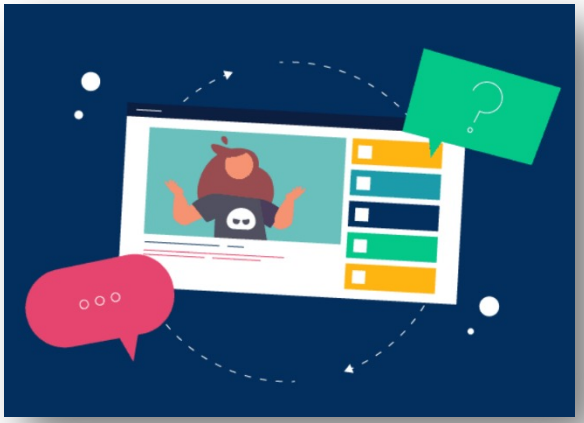
Key Challenge: Software!

- Tele-operated robots, i.e., hardware has been ready since 2008!

Images from CSAIL@MIT, 2017

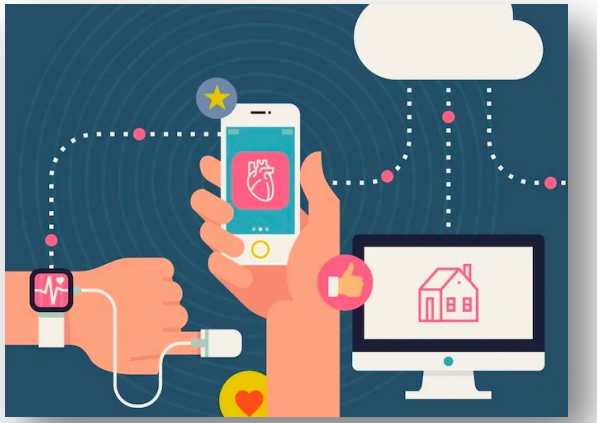
A Paradaim of Building Software

Recommander System



Self-Drving Car

Healthcare



Machine Learning

An Introduction to Machine Learning

- What is Machine Learning?
- Three Types of Machine Learning
- Course Overview

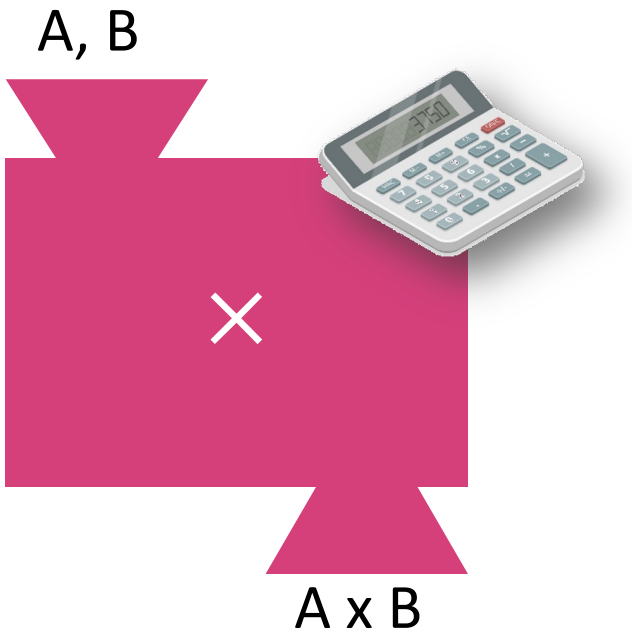
Machine

= Hardware/software to perform an intended function

Input

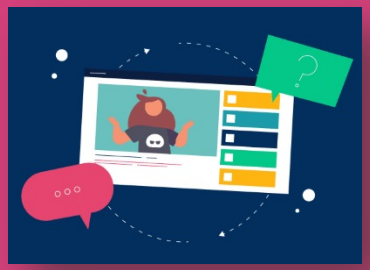
$$f(x) = y$$

Output



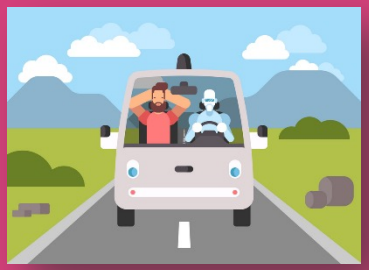
Examples

User history



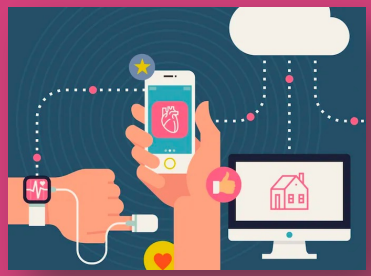
Item list
(preferred)

Destination



Car control
(safe, fast)

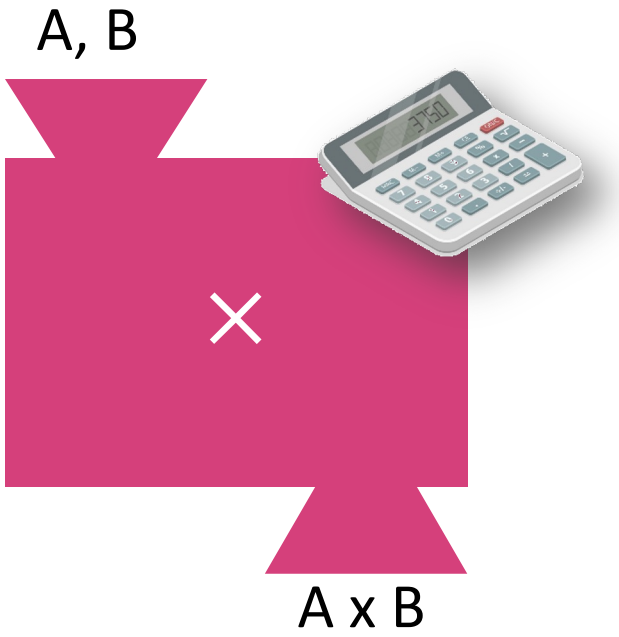
Health data



Diagnosis
(accurate)

Traditional Computer Science

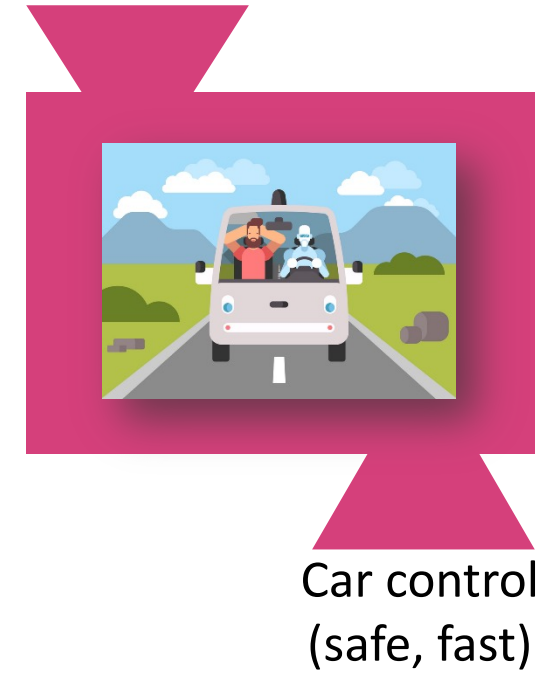
= writing a program code

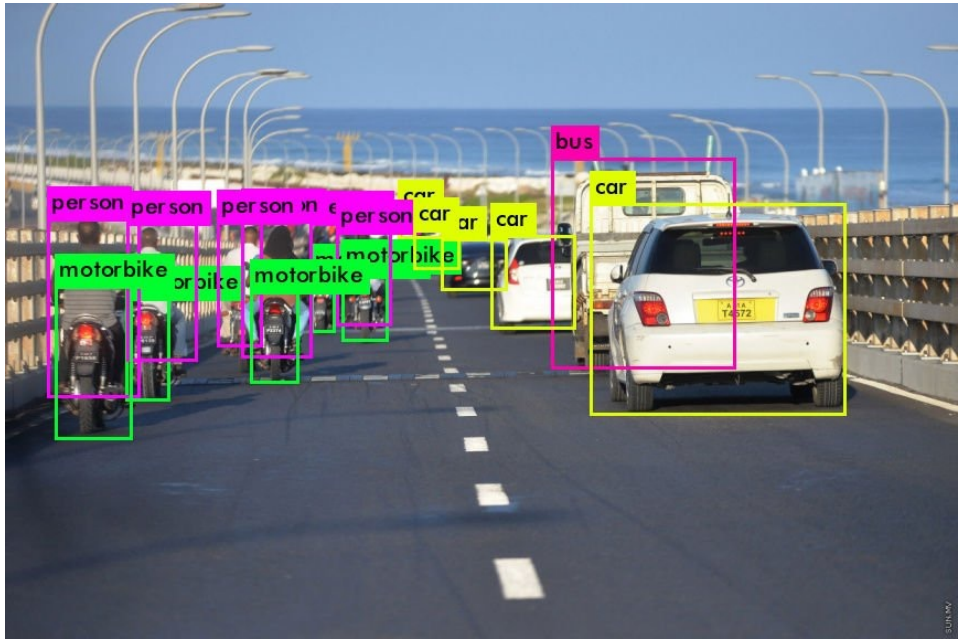


$$\underbrace{(A+A+\ldots+A)}_{\text{B times}}$$

Limitation of Traditional Paradigm (1)

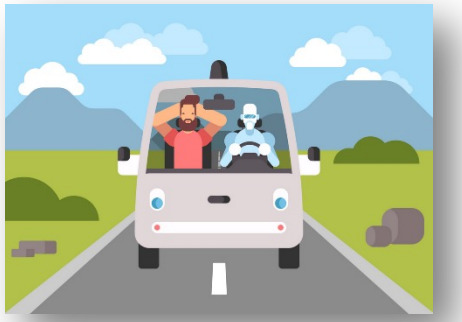
- Sometimes, we do not have a clear description about the function that we want

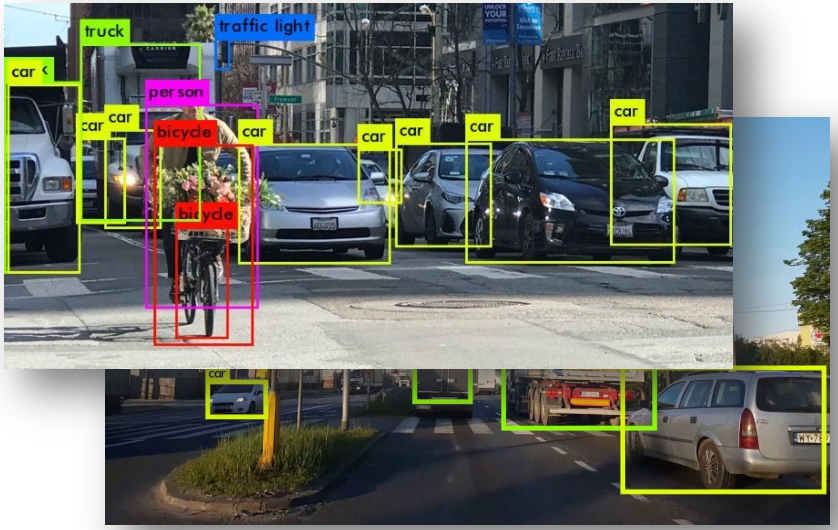


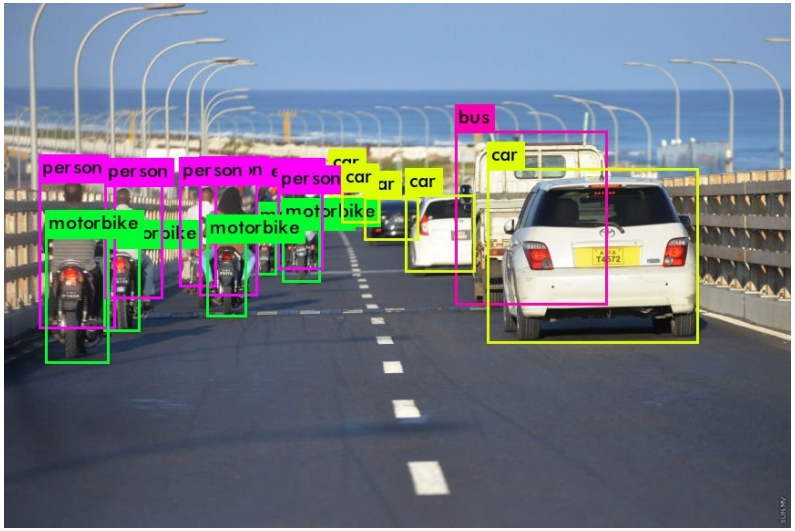


Limitation of Traditional Paradigm (2)

- Traditional paradigm
  - Program all the instructions
- New paradigm
  - Provide examples, and let machine learn

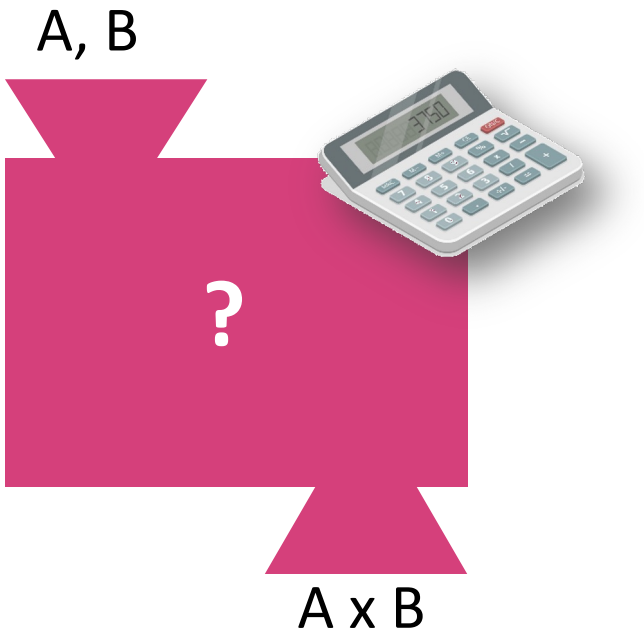






New Paradigm: Machine Learning

= Letting the machine learn the function from dataset



f(5, 2) = 10

f(3, 7) = 21

f(4, 4) = 16

f(2, 3) = 6

f(8, 7) = 56

f(9, 3) = 27

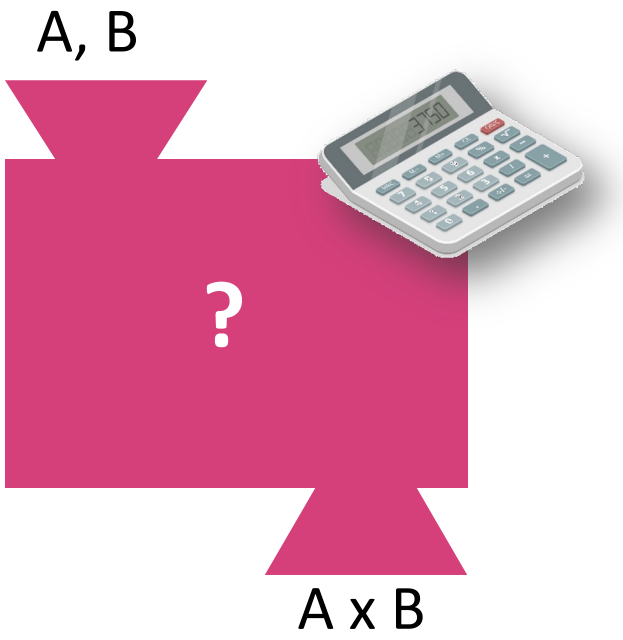
…

Dataset

: a set of samples of mapping between input and output

New Paradigm: Machine Learning

= Letting the machine learn ~~the function~~ from dataset pattern

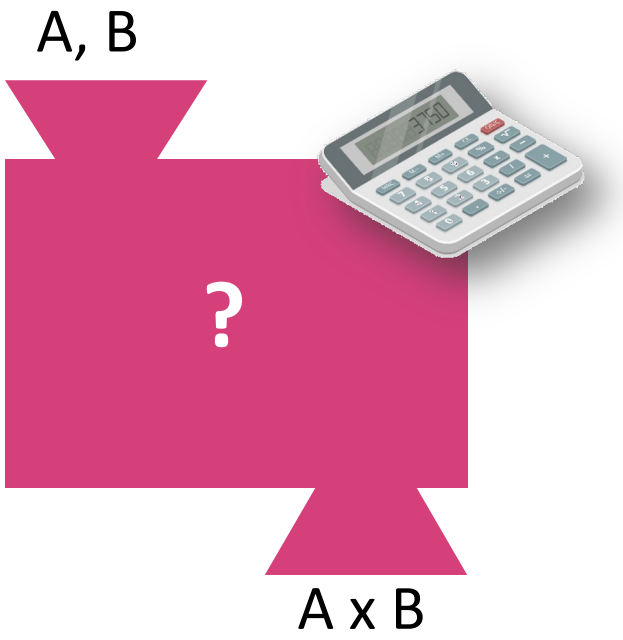


B \ A	1	2	3	4	5	6	7	8	9
1			3	4		6			9
2	2		6		10		14		18
3	3			12		18		24	27
4	4	8	12	16		24	28		
5					25		35	40	
6	6	12	18		30	36		48	54
7	7		21	28	35		49	56	
8		16		32	40		56		72
9	9	18		36		54	64		81

Pattern = Multiplication
(a simple explanation)

New Paradigm: Machine Learning

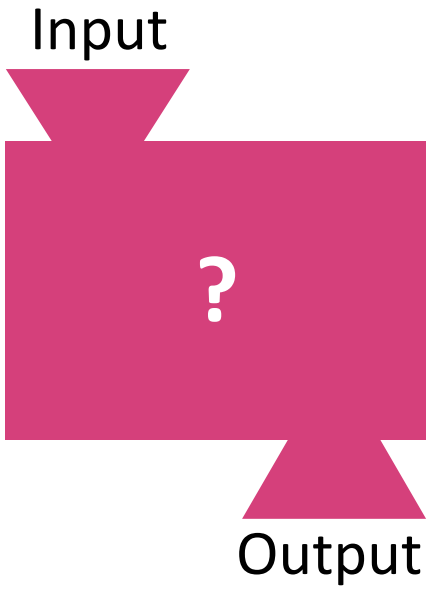
= Letting the machine learn ~~the function~~ from dataset pattern



B \ A	1	2	3	4	5	6	7	8	9
1	1	2	3	4	5	6	7	8	9
2	2	4	6	8	10	12	14	16	18
3	3	6	9	12	15	18	21	24	27
4	4	8	12	16	20	24	28	32	36
5	5	10	15	20	25	30	35	40	45
6	6	12	18	24	30	36	42	48	54
7	7	14	21	28	35	42	49	56	64
8	8	16	24	32	40	48	56	64	72
9	9	18	27	36	45	54	64	72	81

Computer Science vs. Machine Learning

Traditional Computer Science
: **We find** pattern; and translate it to machine



Machine Learning
: **A Machine finds** pattern from dataset

Framework of Machine Learning

- Dataset and … ?

Age, Weight

Heart disease?

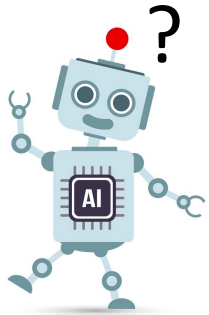
f(42-year, 60 kg) = No

f(8-year, 44 kg) = No

f(75-year, 62 kg) = Yes

f(24-year, 104 kg) = Yes

…



Framework of Machine Learning

- Dataset and model about function

Age, Weight

Heart disease?

f(42-year, 60 kg) = No

f(8-year, 44 kg) = No

f(75-year, 62 kg) = Yes

f(24-year, 104 kg) = Yes

…

Obs1. overweight → heart disease

Obs2. old → heart disease

(Pattern)

Framework of Machine Learning

- Dataset and model about function

e.g., **linear model**

$$A \times \text{Age} + B \times \text{Weight} > C?$$

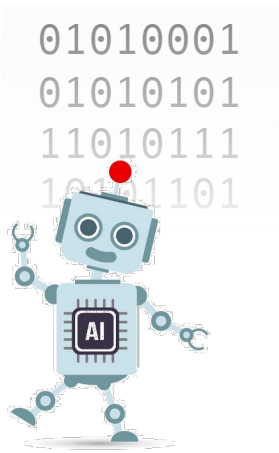
f(42-year, 60 kg) = No

f(8-year, 44 kg) = No

f(75-year, 62 kg) = Yes

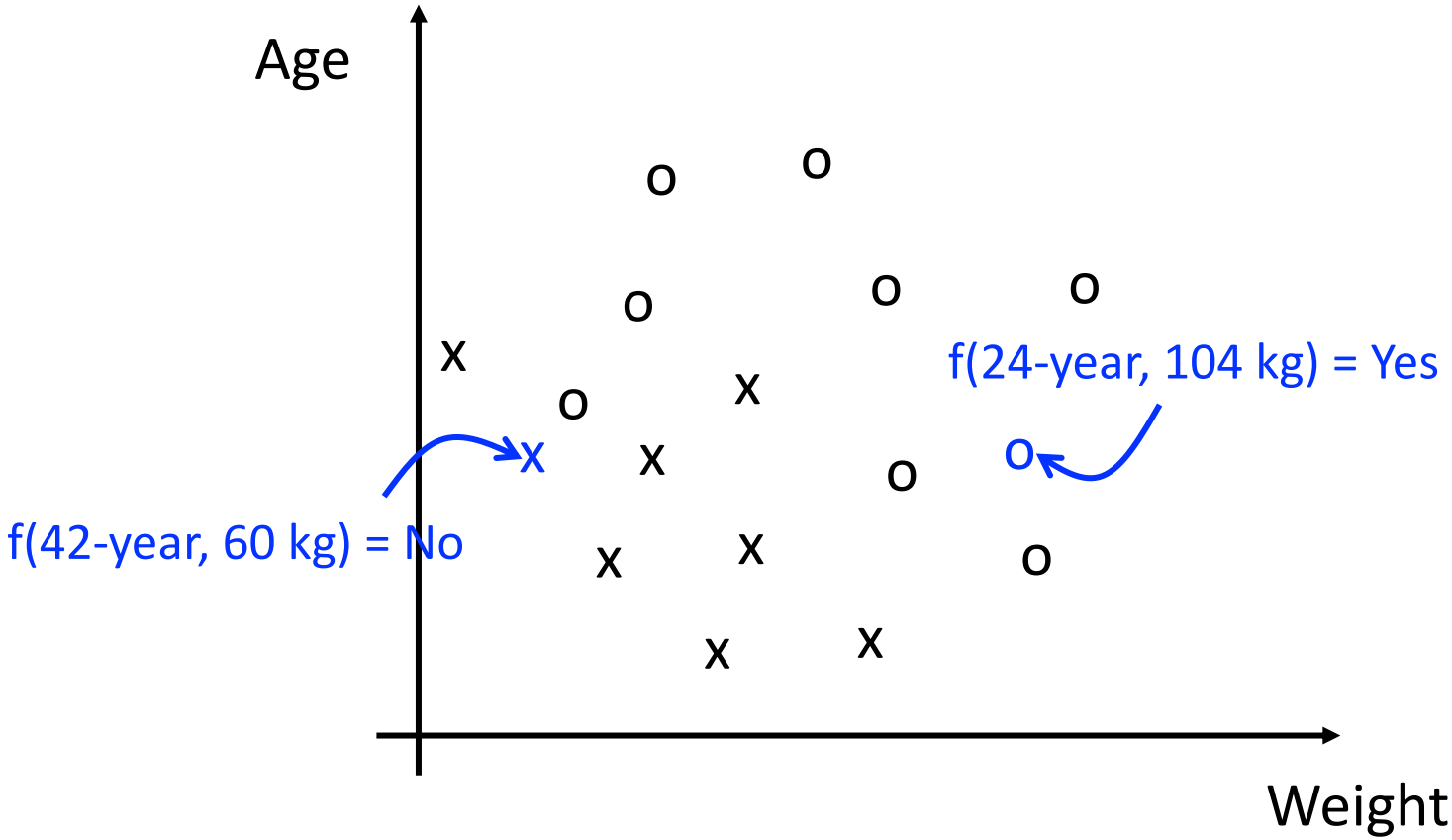
f(24-year, 104 kg) = Yes

…



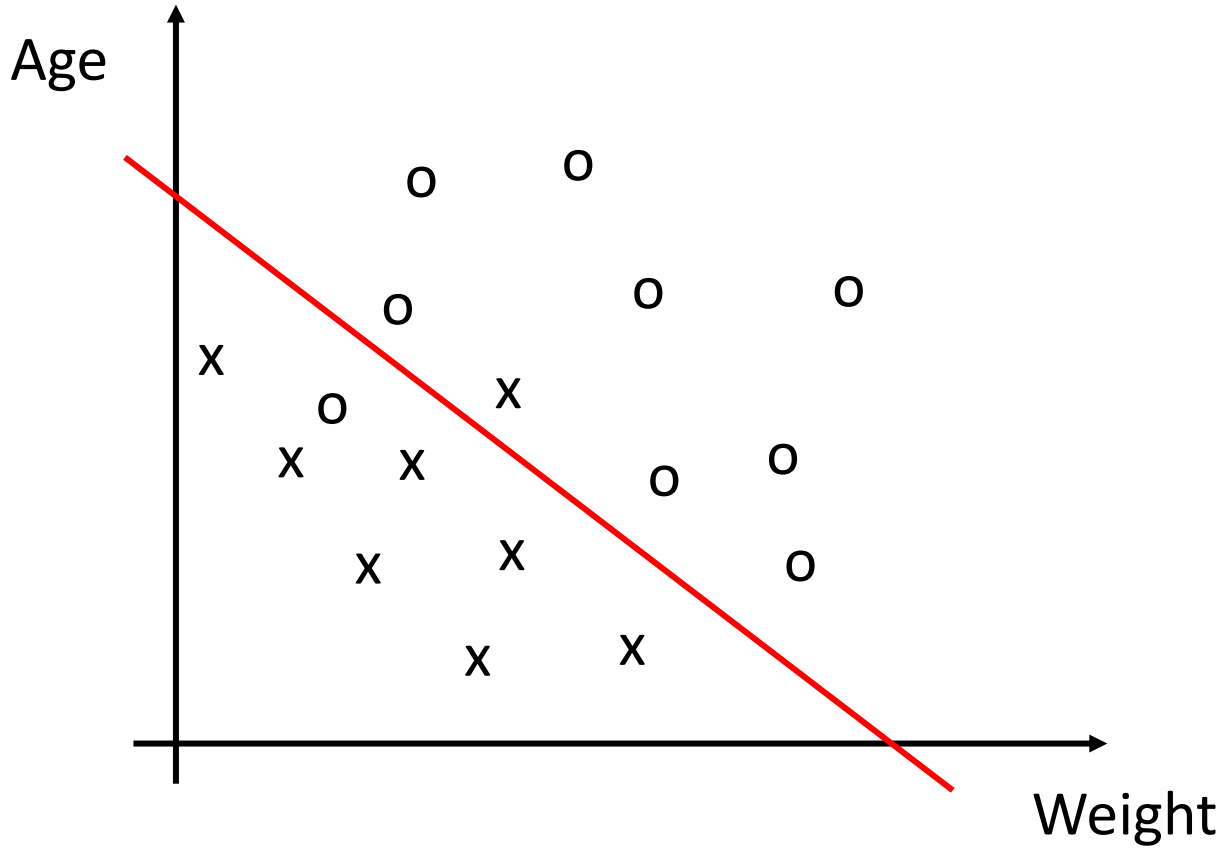
Graphical Interpretation of Linear Model

A x Age + B x Weight > C?



Graphical Interpretation of Linear Model

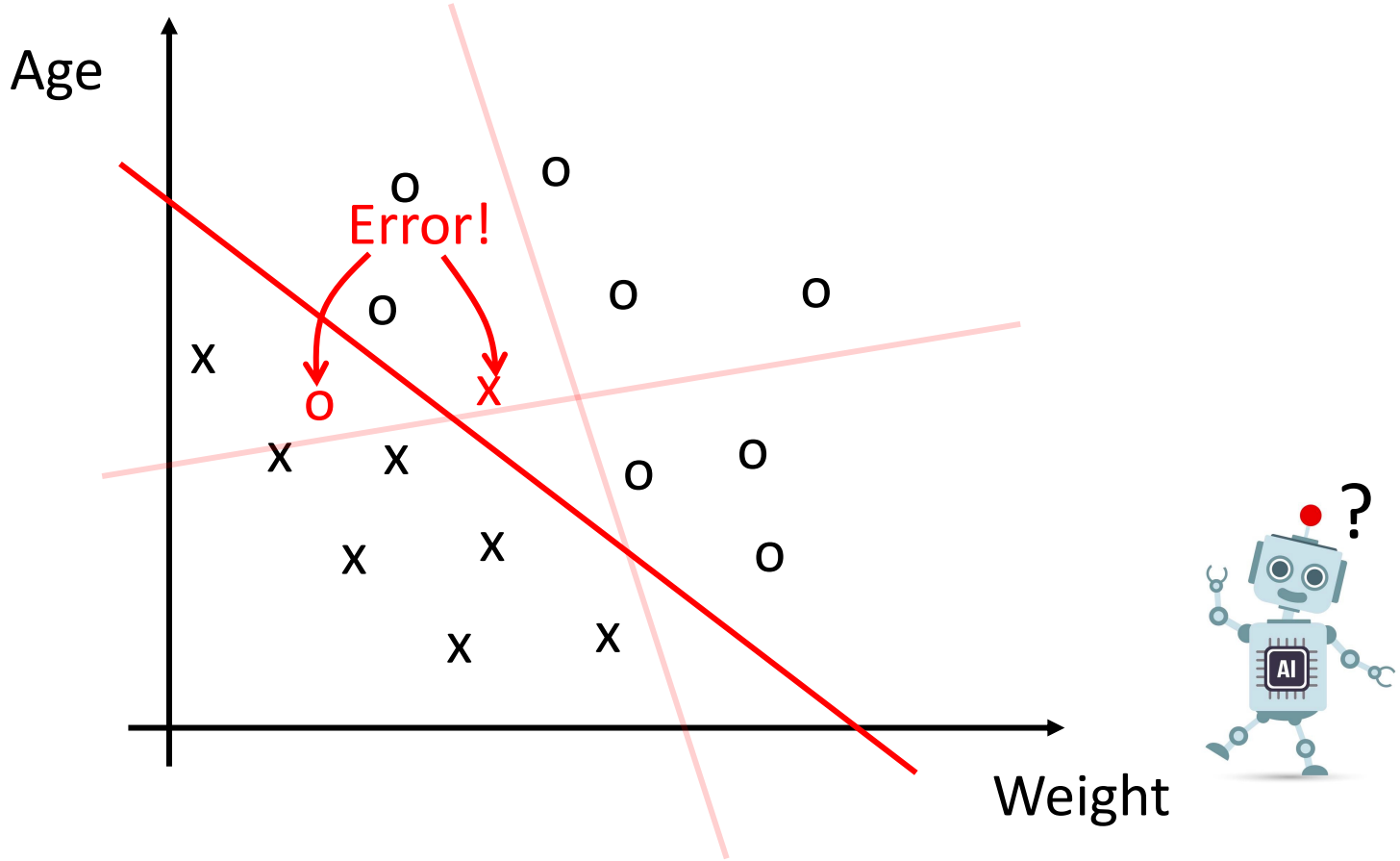
A x Age + B x Weight > C?



Graphical Interpretation of Linear Model

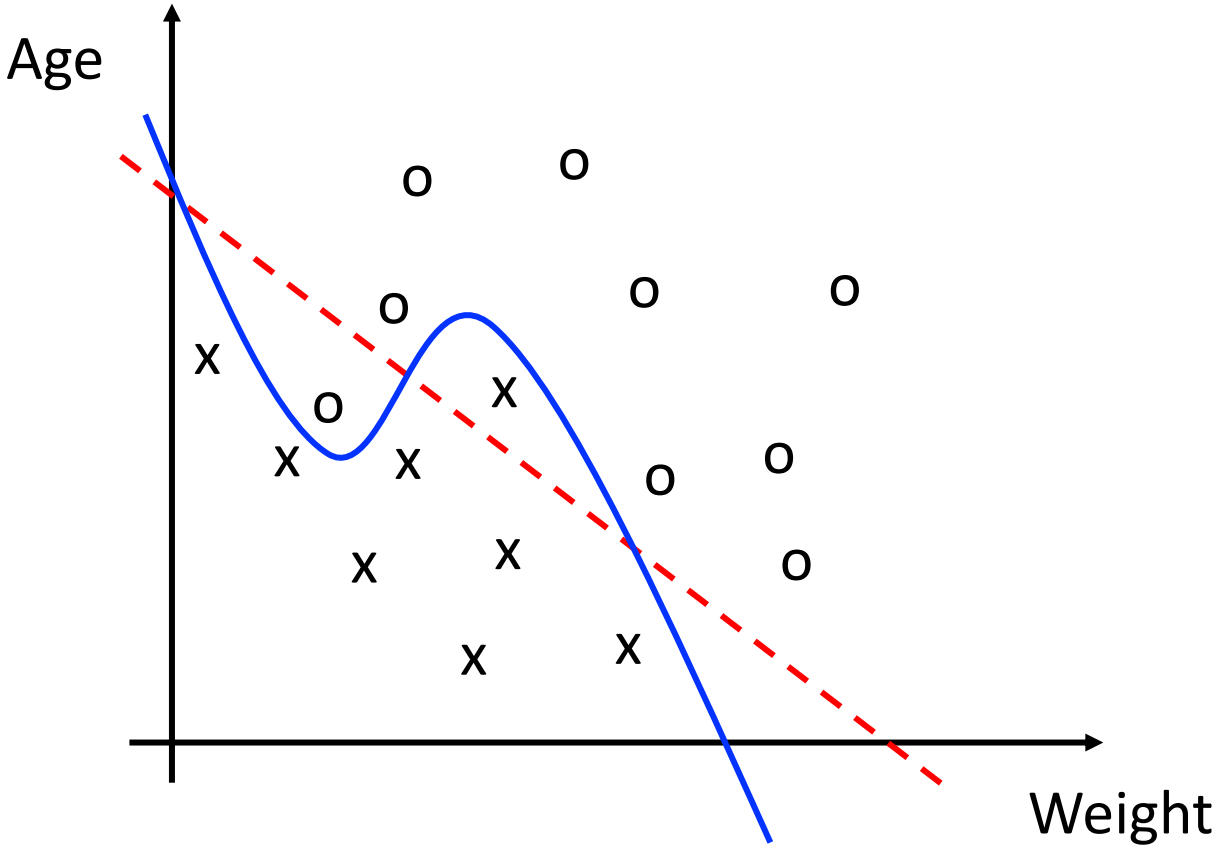
- Learning seeks best function minimizing error

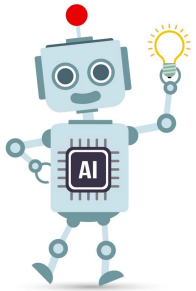
0.47 x Age + 0.92 x Weight > 90?



Better Model?

$A \times Age + B_3 \times Weight^3 + B_2 \times Weight^2 + B_1 \times Weight > C$?





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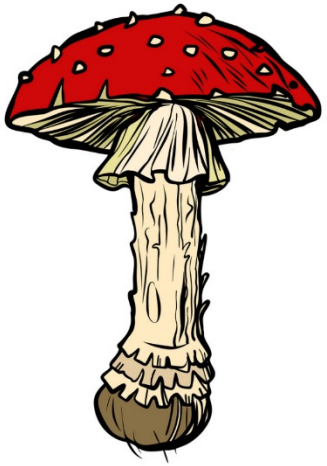
Supervised Learning

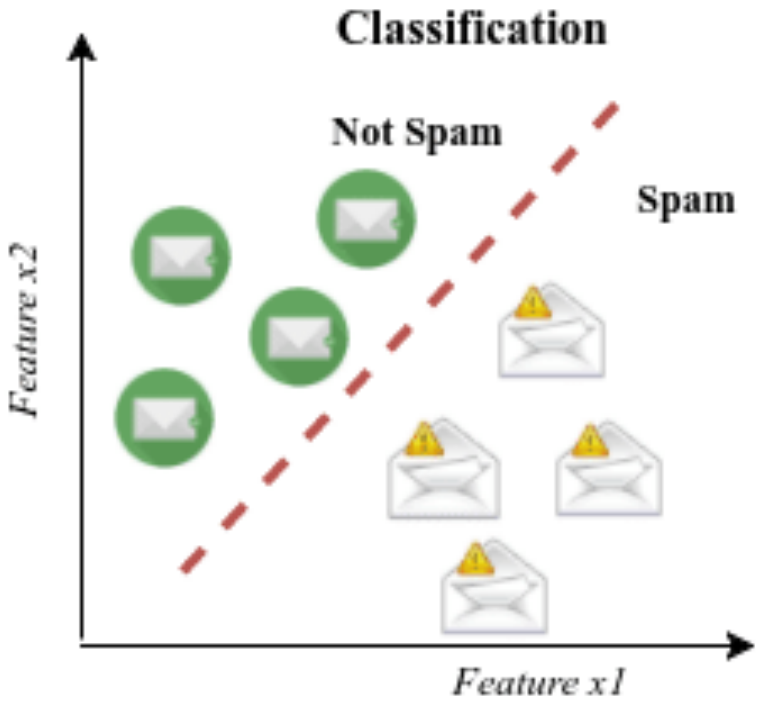
: Dataset is labeled in advance



Edible?
Poisonous?

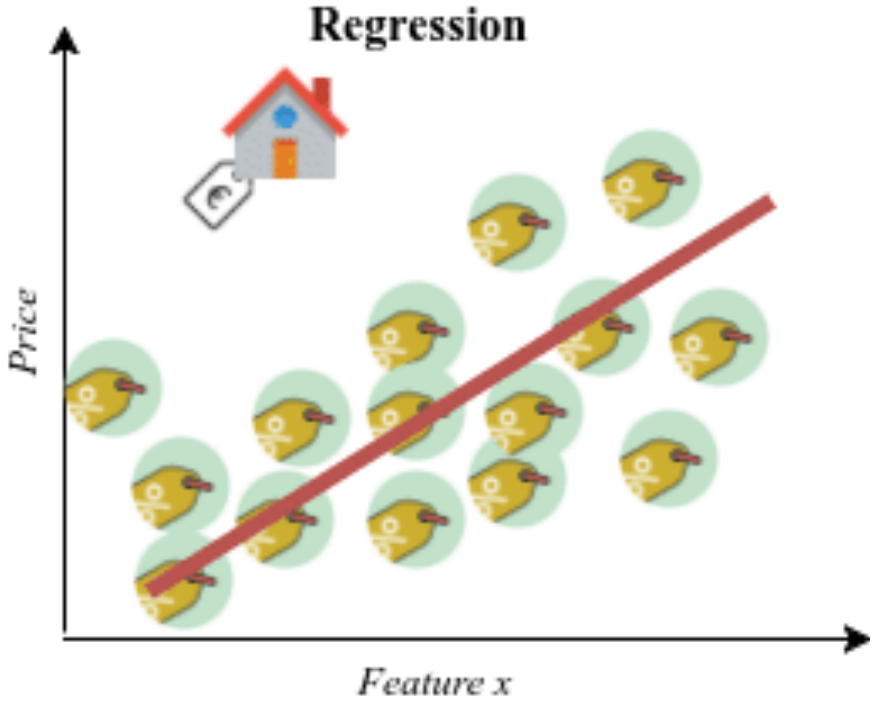
Classification, e.g., Spam Filtering

: to predict categorical labels



Regression, e.g., House Price Prediction

: to predict numerical values

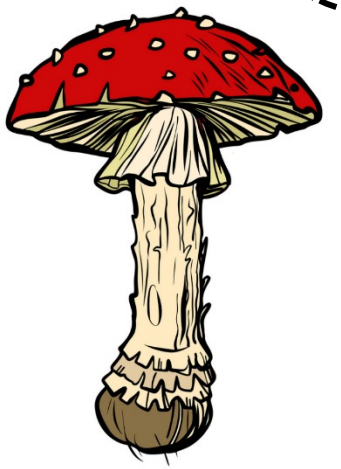


Unsupervised Learning

: Dataset has no labels

Cluster 1

Cluster 2



Which cluster?

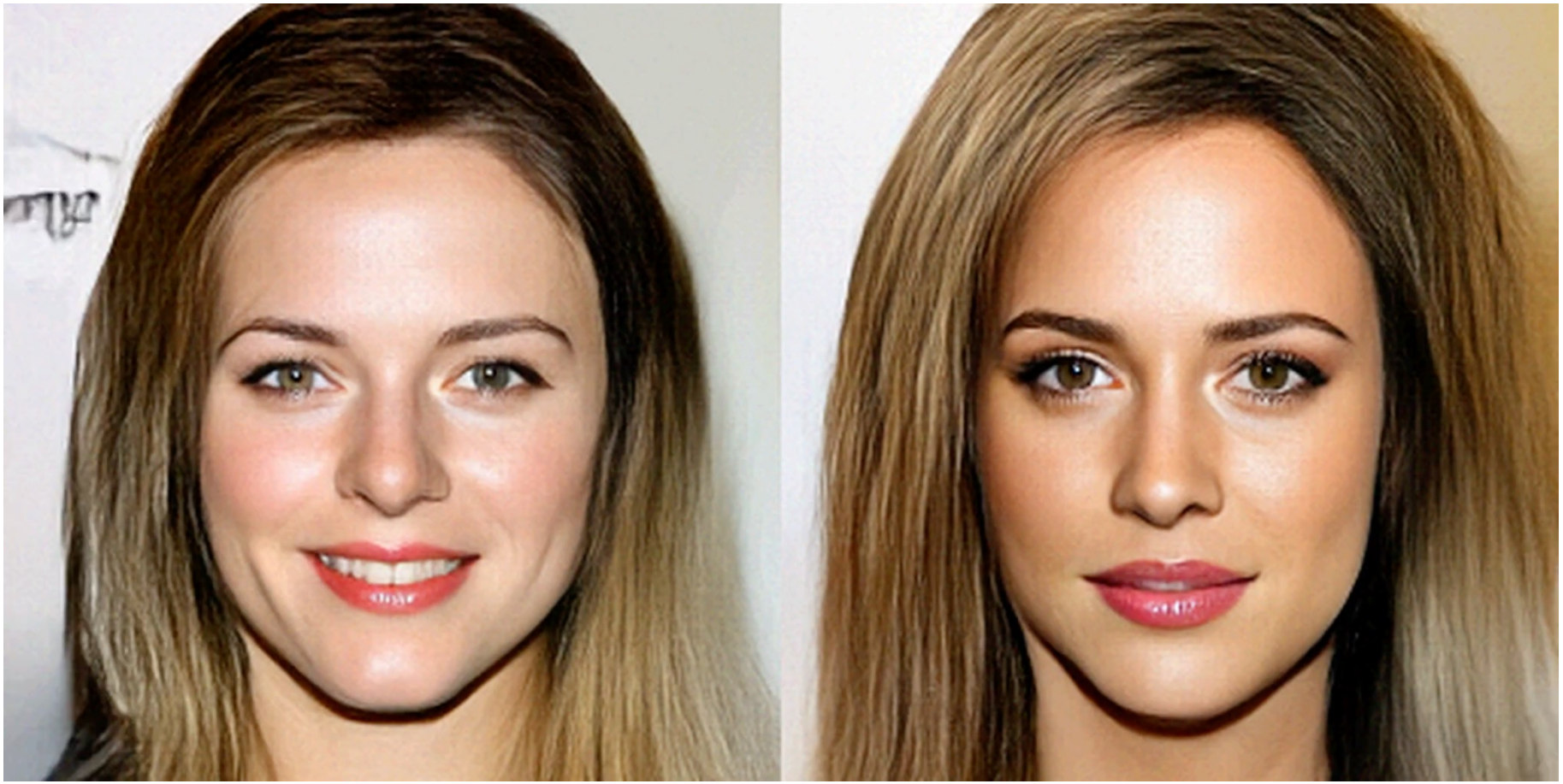
Generative Model

Training data ~ $p_{data}(x)$

Generated samples ~ $p_{model}(x)$

CycleGAN. Zhu et al. 2017.

Generative Model



Reinforcement Learning

: Label is a real-valued reward signal (possibly delayed)

Amanita (toxic): (+2; -5)

t	0	1	2	3
Action				
Reward	2	-4	2.5	-3

Shiitake (edible): (+1; +0.5)

(instant. reward; reward after 1 day)

Reinforcement in Animal Psychology

- Training animals:
  - Positive reinforcements: pleasure and food
  - Negative reinforcements: pain and hunger

Reinforcement learning (RL) performs the same with computers!

AI Playing Atari Games (2013)

AlphaGo vs. Sedol Lee (2016)

AlphaGo defeated the legendary Go player, Sedol Lee

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Tentative Schedule

Categories
Supervised Learning
Unsupervised Learning
Reinforcement Learning
Learning Theory and Other Topics
Graphical Model
Deep Learning
No class

Index	Week	Topic
1	1-1	Introduction to Machine Learning
2	1-2	Review on Probability Theory
3	2-1	Generative Model and Parameter Estimation (1)
4	2-2	Generative Model and Parameter Estimation (2)
5	3-1	Linear Regression (1)
6	3-2	Linear Regression (2) / Logistic Classification (1)
7	4-1	Logistic Classification (2)
8	4-2	Support Vector Machine and Optimization (1)
9	5-1	Support Vector Machine and Optimization (2)
10	5-2	Multi-class SVM and Kernel Method
11	6-1	Neural Network Model and Neural Network Training (1)
12	6-2	Neural Network Model and Neural Network Training (2)
13	7-1	Neural Network Model and Neural Network Training (3)
14	7-2	Network Model and Neural Network Training (4) / Midterm
15	8-1	**Midterm Exam Week**
16	8-2	**Midterm Exam Week**
17	9-1	Some Insights on Model Selection
18	9-2	Mideterm Exam Review & Graphical Model
19	10-1	Graphical Model
20	10-2	Belief Propagation (BP)
21	11-1	Graph Construction
22	11-2	Clustering
23	12-1	EM algorithm
24	12-2	Principal Components Analysis
25	13-1	Non-linear PCA and Autoencoder
26	13-2	VAE and GAN
27	14-1	VAE and GAN
28	14-2	MDP and Dynamic Programming
29	15-1	RL (2)
30	15-2	RL (2)
31	16-1	**Final Exam Week**
32	16-2	**Final Exam Week**

Questions?