Machine Learning Principles

Class1 : Sept. 4
Introduction & Course Logistics

Instructor: Diana Kim

Today's Lecture

1. Why Machine Learning?

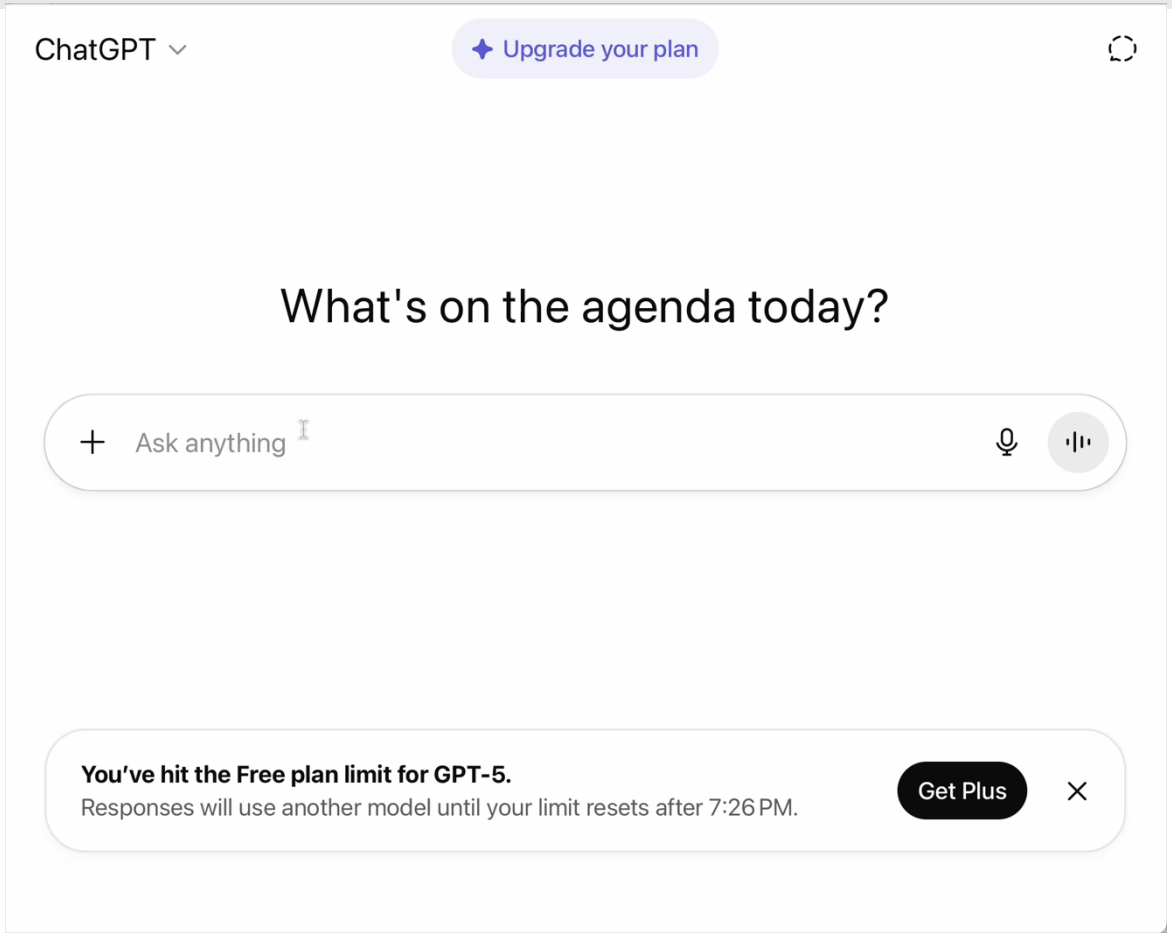
2. What is Machine Learning?

3. ML in AI (symbolistic AI vs. connectionism)

4. Course Logistic

[1] Why Machine Learning?

AI is opening the fair access to advanced knowledge.



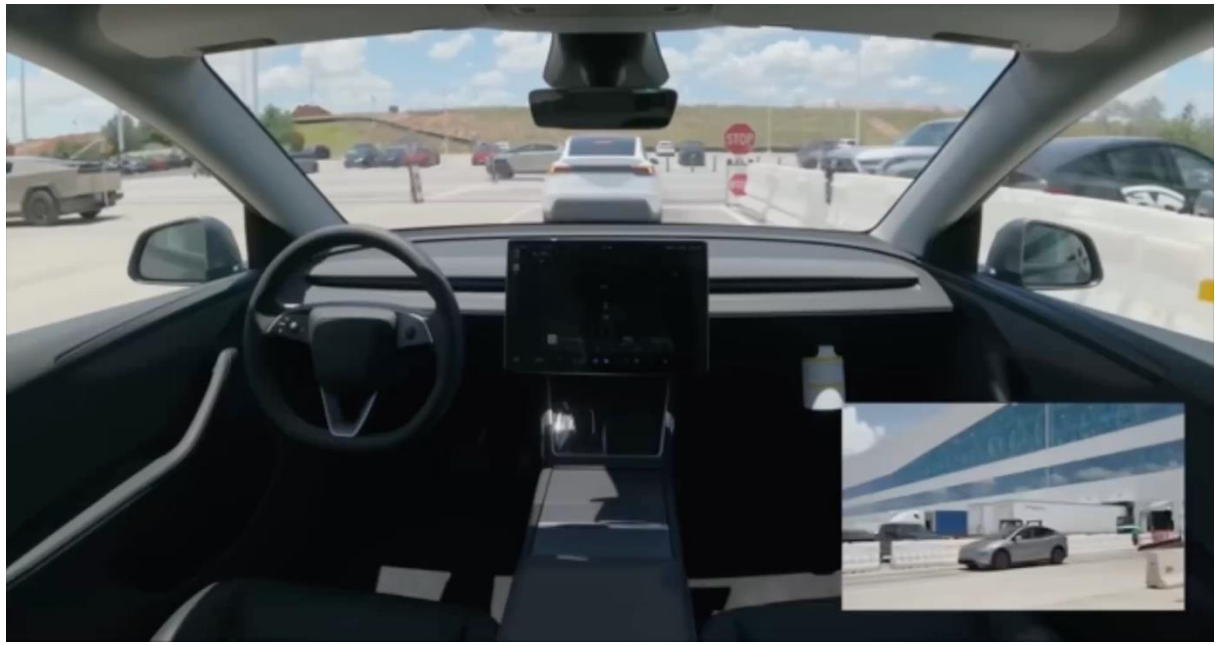
- ChatGPT repones:

Essentially, symbolic AI is a computational realization of Platonic thinking: it assumes the world can be described through abstract, manipulable representations that reflect underlying reality.

[2] Why Machine Learning?

AI is transforming the way of we live and work.

- Driver Assistance System



- Robots in warehouse

[3] ML is the central system of AI.

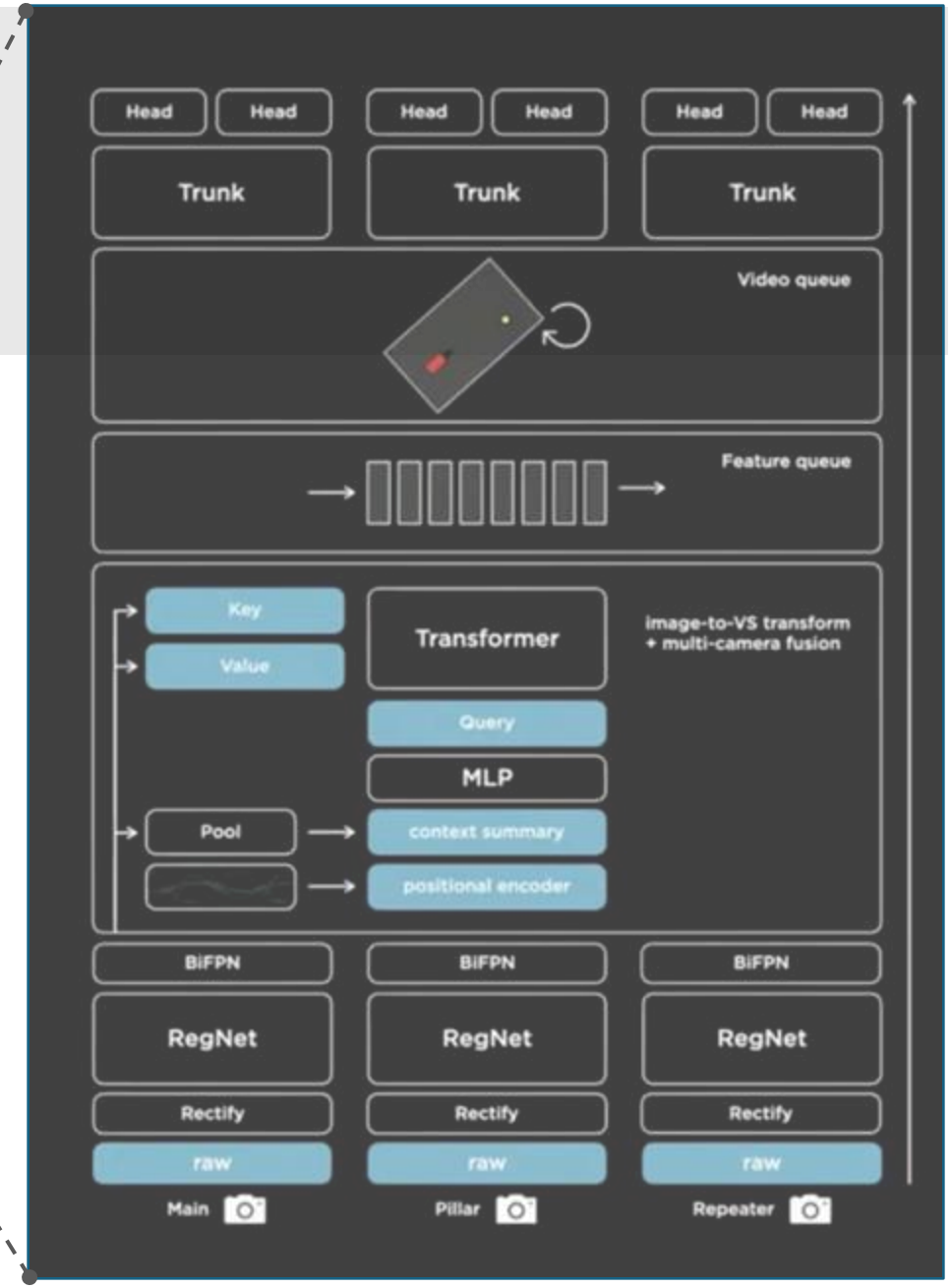
Sensors (camera)

Augo Agent (Ego Vehicle)
ML architecture

Actions (auto steering, braking, etc.)

[Tesla Full Self Driving explained by Andrej Karpathy]

https://www.youtube.com/watch?v=3SypMvnQT_s



- What is Machine Learning?

- What is “Learning”?

[1] What is Learning?

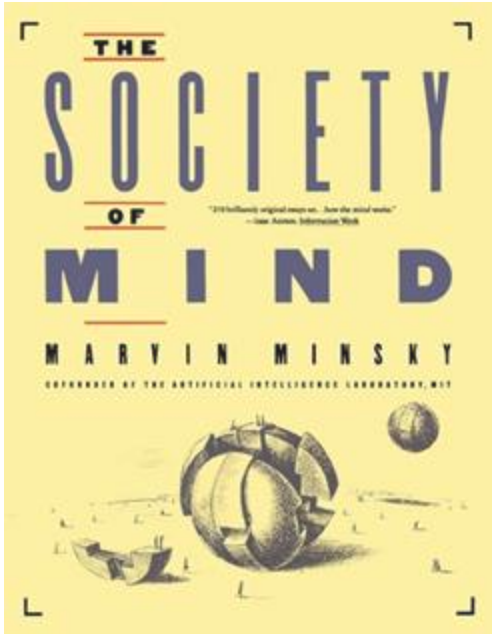
- change in mind and physical state
- positive/ useful change (measured by a proper metric)
- through repetitive trials, following instructions, and practices (interaction with outer world, experience)
- continual/ non-linear/ dynamic process

- memorization
- generalization

[2] Dictionary Definition of Learning

ENCYCLOPÆDIA Britannica

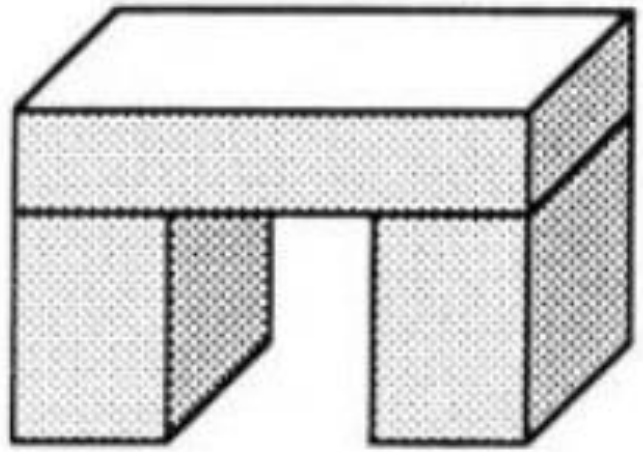
learning, the alteration of behaviour as a result of individual experience. When an organism can perceive and change its behaviour, it is said to learn.



Learning is making useful changes in the workings of our minds.

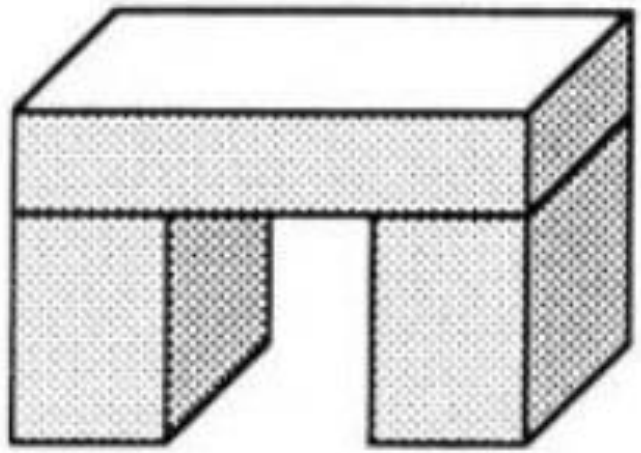
[1] Example of Learning Process: A Block-Arch Scenario

Suppose we don't know what is arch,
but someone told you ``this is an arch".
You are going to form a set of
mental descriptions for the concept of **Arch.**



from the Society of Mind by Marvin Minsky (1988)

[2] A Block-Arch Scenario : Observation of “Hand Change”



Arch seems to cause a strange phenomenon:
when you push the car through it, your arm gets trapped!
You must release the car and reach around to the other side of arch
by changing hands. Let’s call it “*Hand-Change*” phenomenon.

from the Society of Mind by Marvin Minsky (1988)

[3] A Block-Arch Scenario : Building the Concept of Block Arch

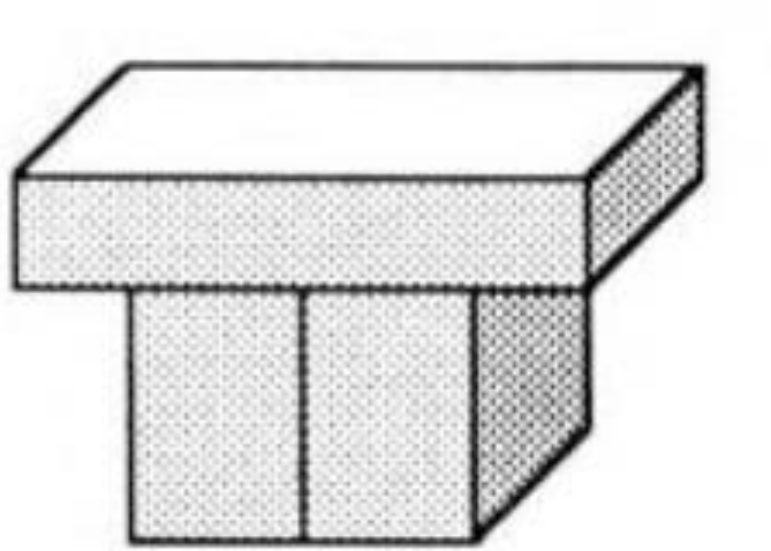
[Mental description 1]

+ Two standing blocks and a lying block.

[4] A Block-Arch Scenario : Building the Concept of Block Arch

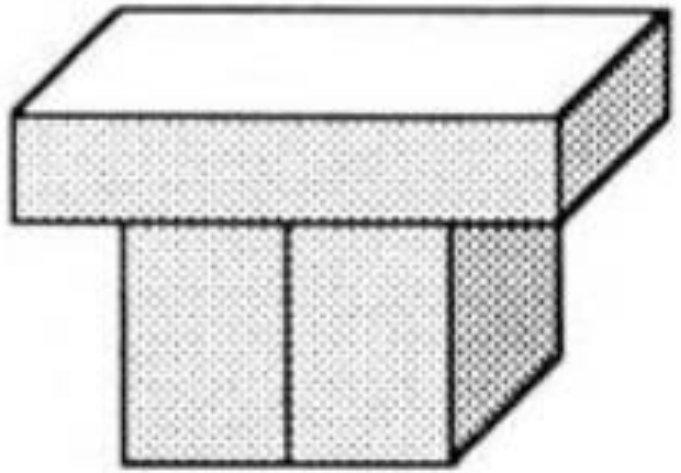
[Mental description 1]

+ Two standing blocks and a lying block.



[5] A Block-Arch Scenario : Building the Concept of Block Arch

[Mental description 1]
+ Two standing blocks and a lying block.



hand-change disappears!
We need to refine the mental description to avoid the example failing in hand-change.

[6] A Block-Arch Scenario : Building the Concept of Block Arch

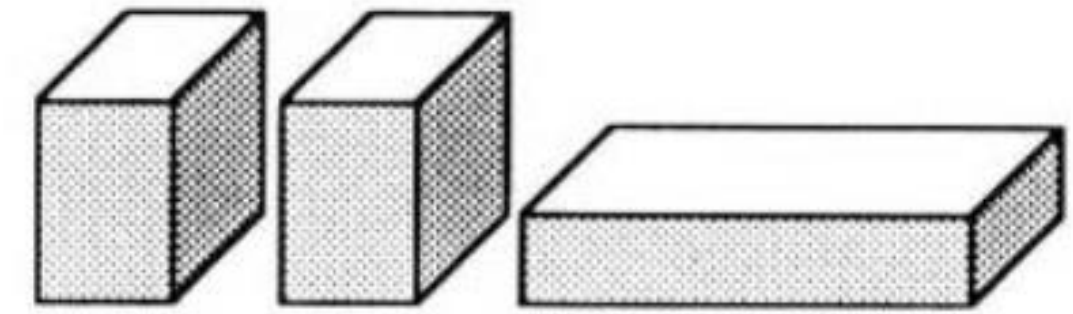
[Mental description 1]
+ Two standing blocks and a lying block.

[Mental description 2]
+ The standing blocks must not touch.

[7] A Block-Arch Scenario : Building the Concept of Block Arch

[Mental description 1]
+ Two standing blocks and a lying block.

[Mental description 2]
+ The standing blocks must not touch.



hand-change disappears!
We need to update the mental description to avoid the example failing in hand-change.

[8] A Block-Arch Scenario : Building the Concept of Block Arch

[Mental description 1]
+ Two standing blocks and a lying block.

[Mental description 2]
+ The standing blocks must not touch.

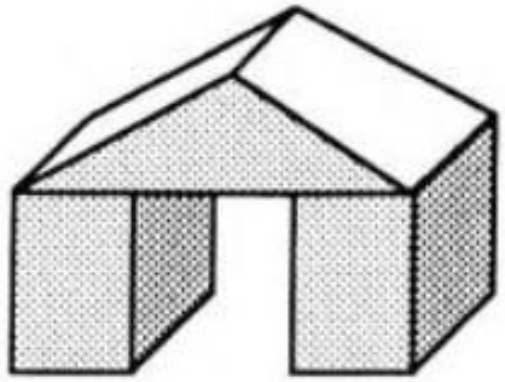
[Mental description 3]
+ They must support the lying block.

[9] A Block-Arch Scenario : Building the Concept of Block Arch

[Mental description 1]
+ Two standing blocks and a lying block.

[Mental description 2]
+ The standing blocks must not touch.

[Mental description 3]
+ They must support the lying block.



Another variation!
It produces hand-change.

[10] A Block-Arch Scenario : Building the Concept of Block Arch

[Finalized Descriptions about Block-Arch]

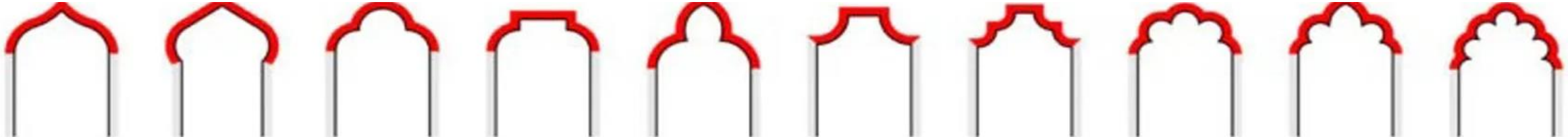
+ Two standing blocks and a lying block.
+ The standing blocks must not touch.
+ They must support the lying block.
+ The other things may be a wedge or a block.

Now it produces hand-change!
Right learning necessitate
a right criterion that describes the original task fundamentally.

[11] A Block-Arch Scenario : Building the Concept of Block Arch

[Finalized Mental Descriptions about Block-Arch]

+ Two standing blocks and a lying block.
+ The standing blocks must not touch.
+ They must support the lying block.
+ The other thing may be a wedge or a block.



Based on the descriptions,
we can recognize the various types of block-arches.
"hand-change" provides a good metric/criterion.

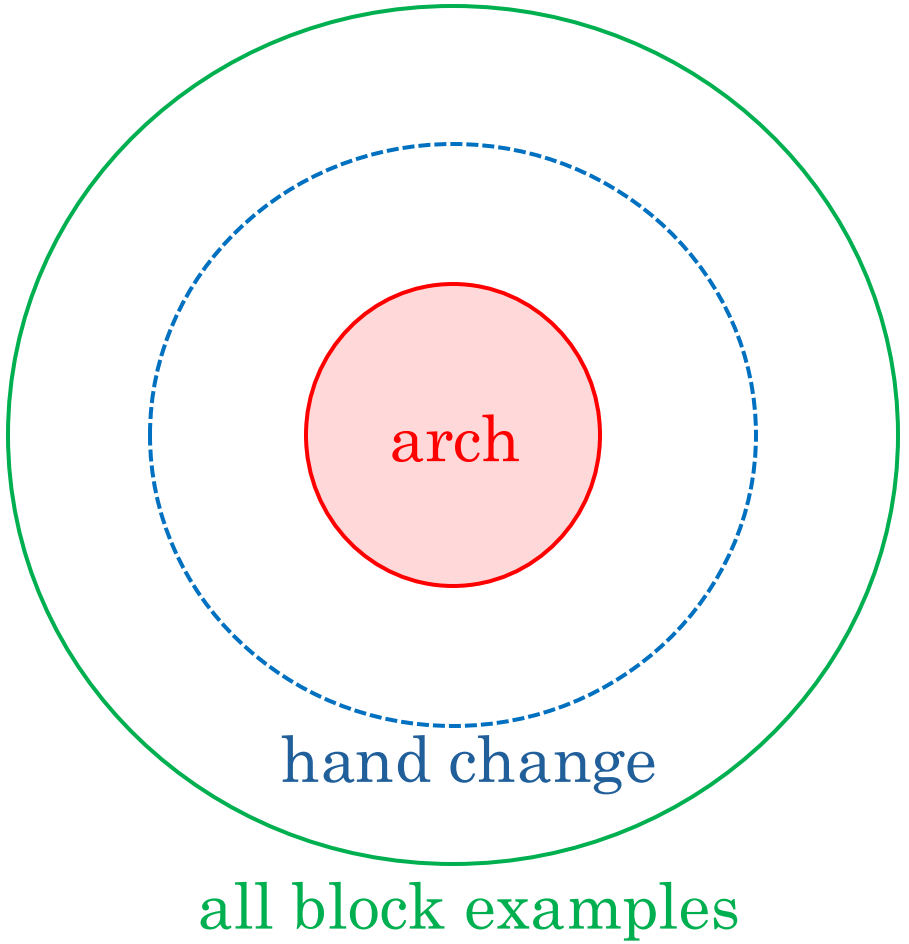
[12] A Block-Arch Scenario : Building the Concept of Block Arch

In this example,
we learned the concept of arch
by reviewing the counter examples
based on hand-change metric.

[13] A Block-Arch Scenario : Building the Concept of Block Arch

+ important to have a right learning metric

+ important to have enough examples



- What is Machine Learning?

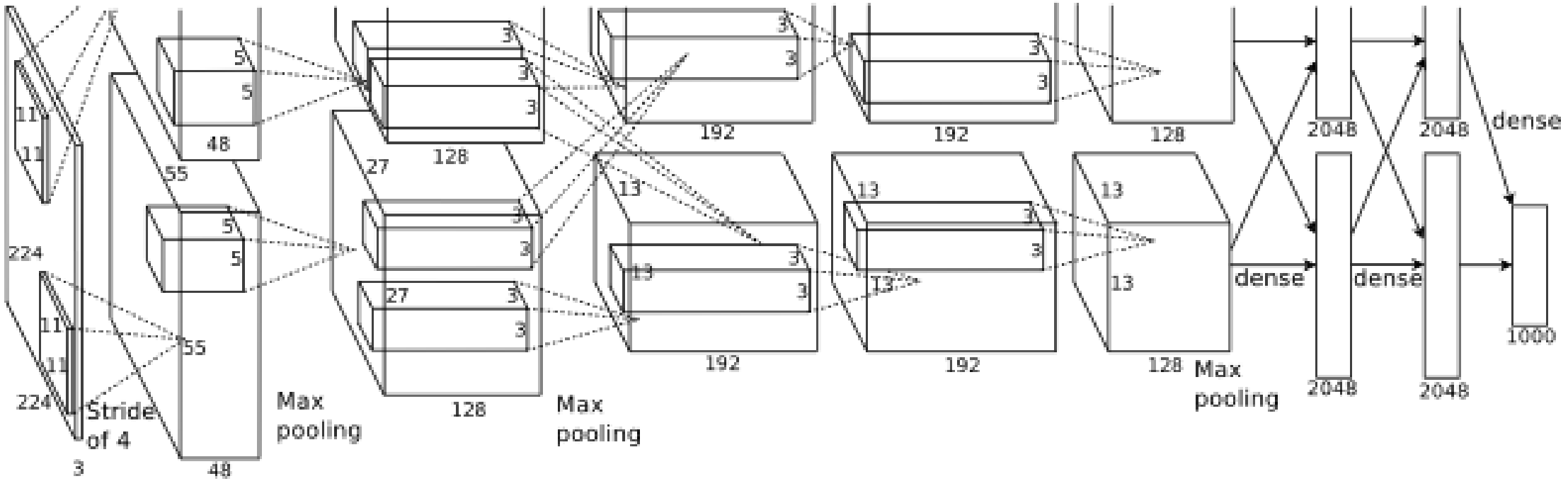
[1] Machine Learning?

A machine learns the way to perform a task.
such as (1) classification, (2) object detection, (3) sentence generation, and (4) simulation of human intelligence.

[2] Learning Machine? (automatic & heuristic)

- heuristic programming: finding a practical solution rather than targeting the exact and theoretical frameworks. (learning a function)
- automatic learning: functional models are be updated based on observations (past data) and performance metric
- It is impossible to program the process of human recognition (no direct instructional programming)

[3] ML as a heuristic solution for classification



[the Architecture of AlexNet: classification for 1,000 objects]

From the original paper:
https://proceedings.neurips.cc/paper_files/paper/2012/file/c399862d3b9d6b76c8436e924a68c45b-Paper.pdf

[4] ML as a heuristic solution for classification

Top Five Inference Results

Luncheon In Fur by Meret Oppenheim (1936)

- AlexNet

```
mortar 0.69256192445755
cup 0.0365808382630348 2
hook 0.0281020123511552 8
mushroom 0.0181499235332012 18
spindle 0.0178330074995756 15
```

- VggNet11

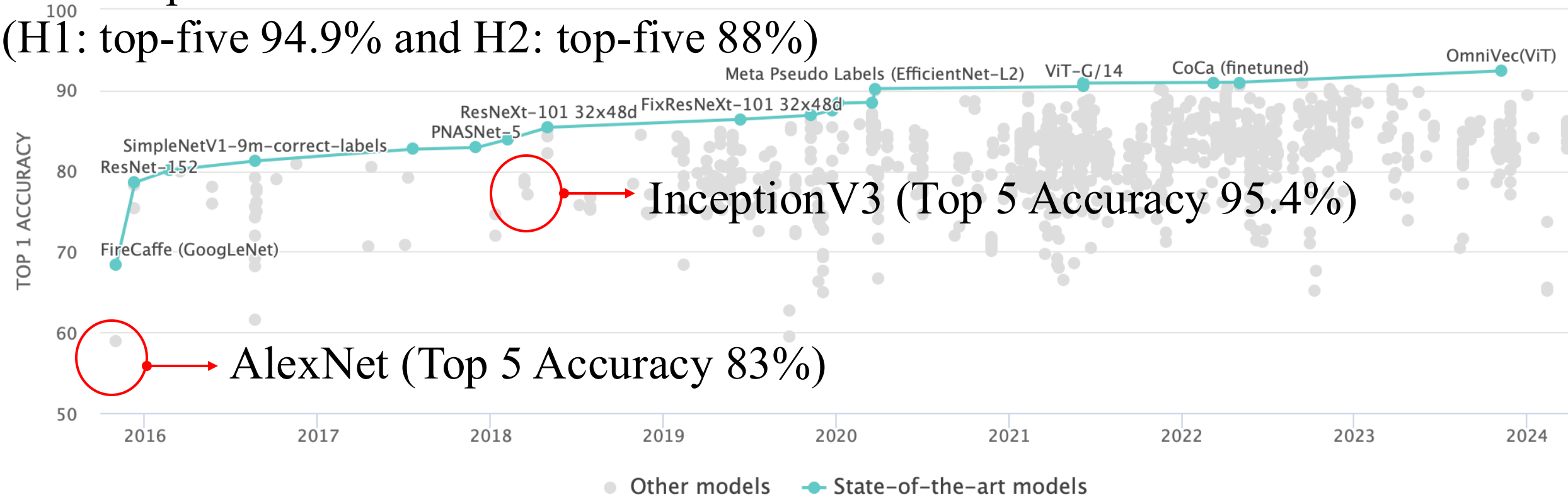
```
bath towel 0.3279417753219604 5
wool 0.0928330346941948
cup 0.0814137831330299 4
pug 0.0336339585483074 2
hair slide 0.0257150121033191 68
```

Different models give different classification results.

Generalization is a primary challenge for ML.

[5] ML as a heuristic solution for classification

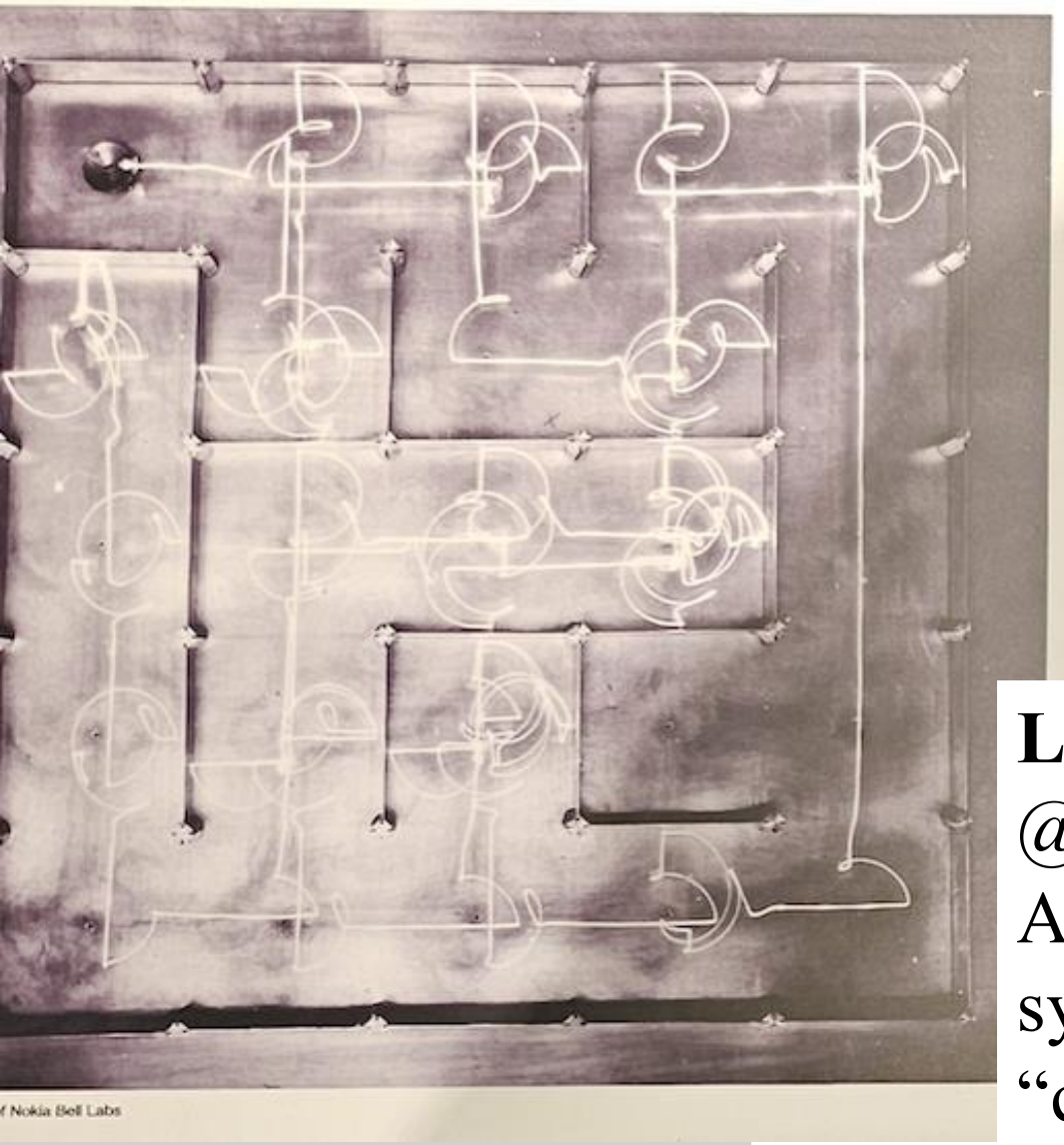
Comparison the performance of large-scale image classification method with the performance of humans on this task
(H1: top-five 94.9% and H2: top-five 88%)



The heuristic/simulating methods can be much beyond human performance.
(more accurate, faster, the higher memory capacity)

- The Early Example of Learning Machine

[1] The Early Example of Learning Machine: Theseus (1950)



LEARNING MACHINE

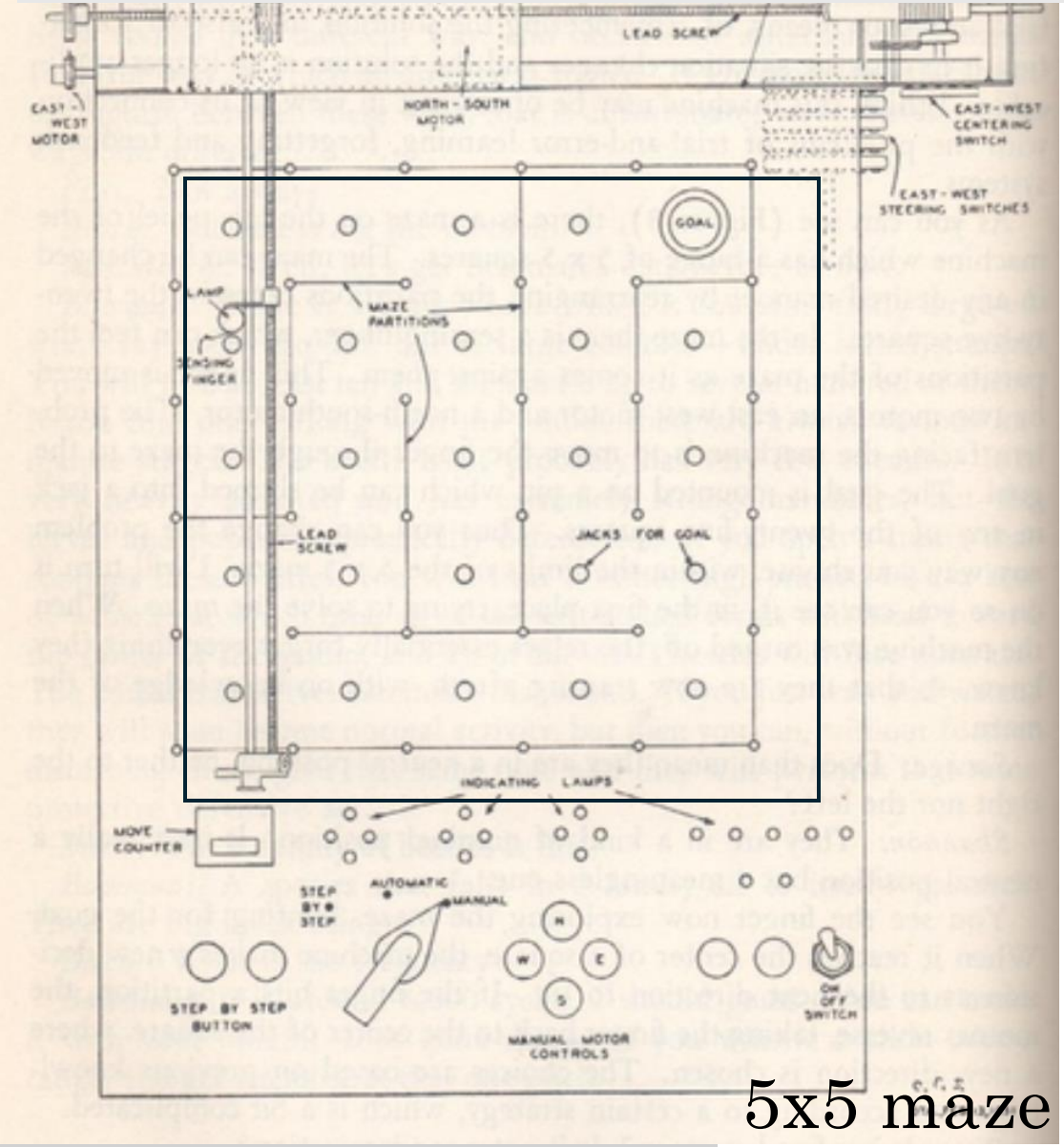
Betty Moore was a mathematician at Bell Labs when she met Claude Shannon in 1948. They married a few months later in March 1949. For their first Christmas, Betty bought Claude the largest Erector set she could find. Within hours, they were immersed in a remarkable maze-building project.

Claude Shannon wanted to build a mechanical device with an electronic "brain" made of relays used for telephone circuits. A magnetized "mouse" named Theseus would systematically explore the maze until it found the "cheese." Placed in the maze a second time, *Theseus* would go straight to the cheese. Change the maze partitions and *Theseus* would "forget" the old solution and start the learning process anew. Demonstrated at state fairs and the National Academy of Science, Shannon's device is considered one of the earliest —and most vivid—examples of machine learning.

Learning Machine

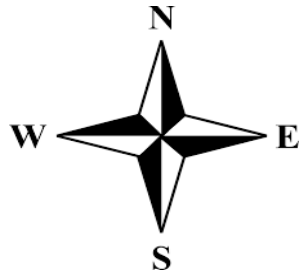
@ the exhibition "MIT Objects" at MIT museum.
A magnetized mouse named "Theseus" would systematically explore the **maze** until it found the "cheese".

[2] Theseus Operation: Maze Solving Machine



5x5 maze

- A <u>finger</u>
  to move Theseus E/W/N/S



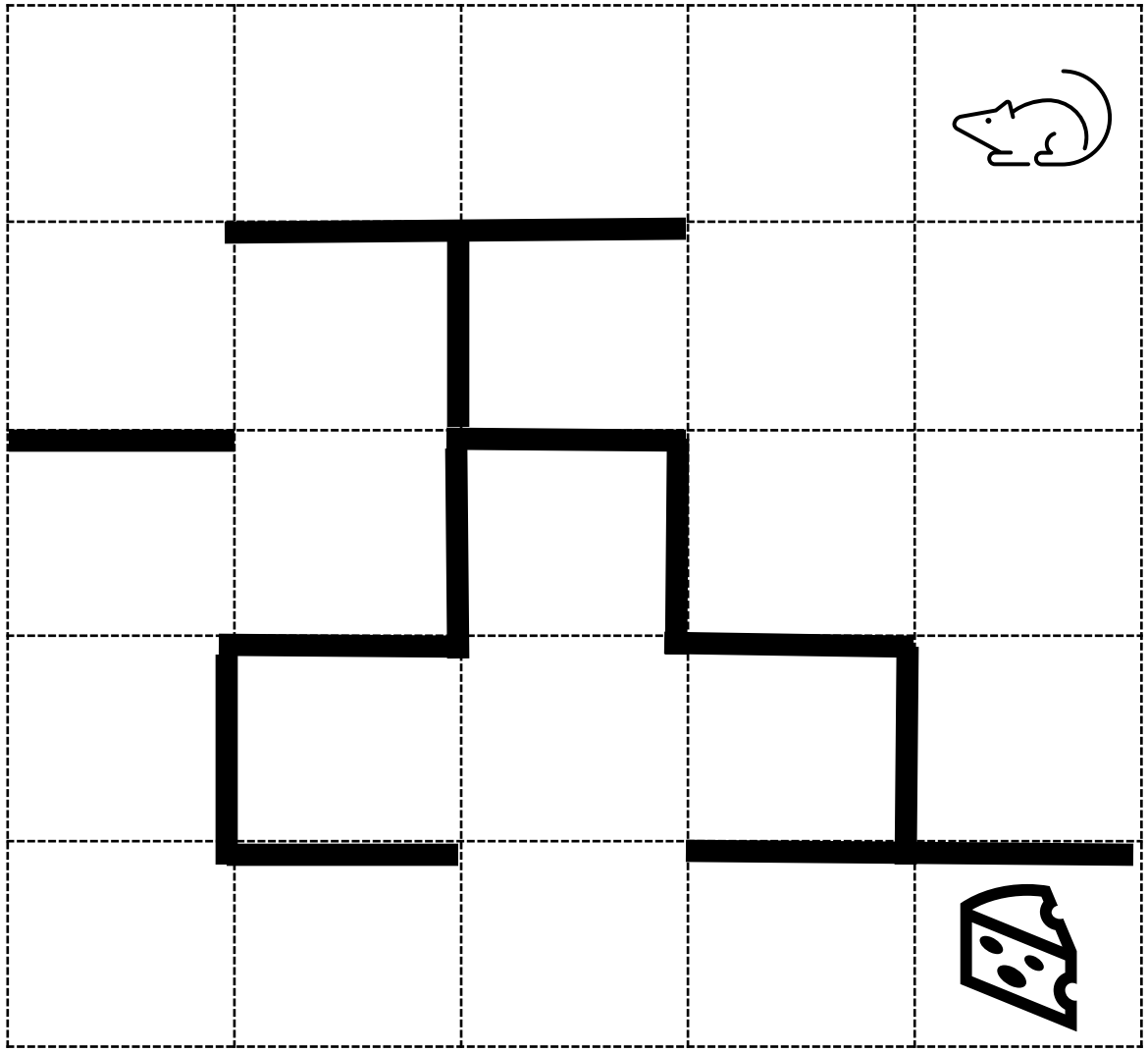
- There is a <u>memory</u> for each square
  to remember the direction by which the the figure left the square on its last visit.

  As Theseus comes to the square again, the memory is <u>updated counterclockwise</u>.
  ex) left easterly and updated to northern

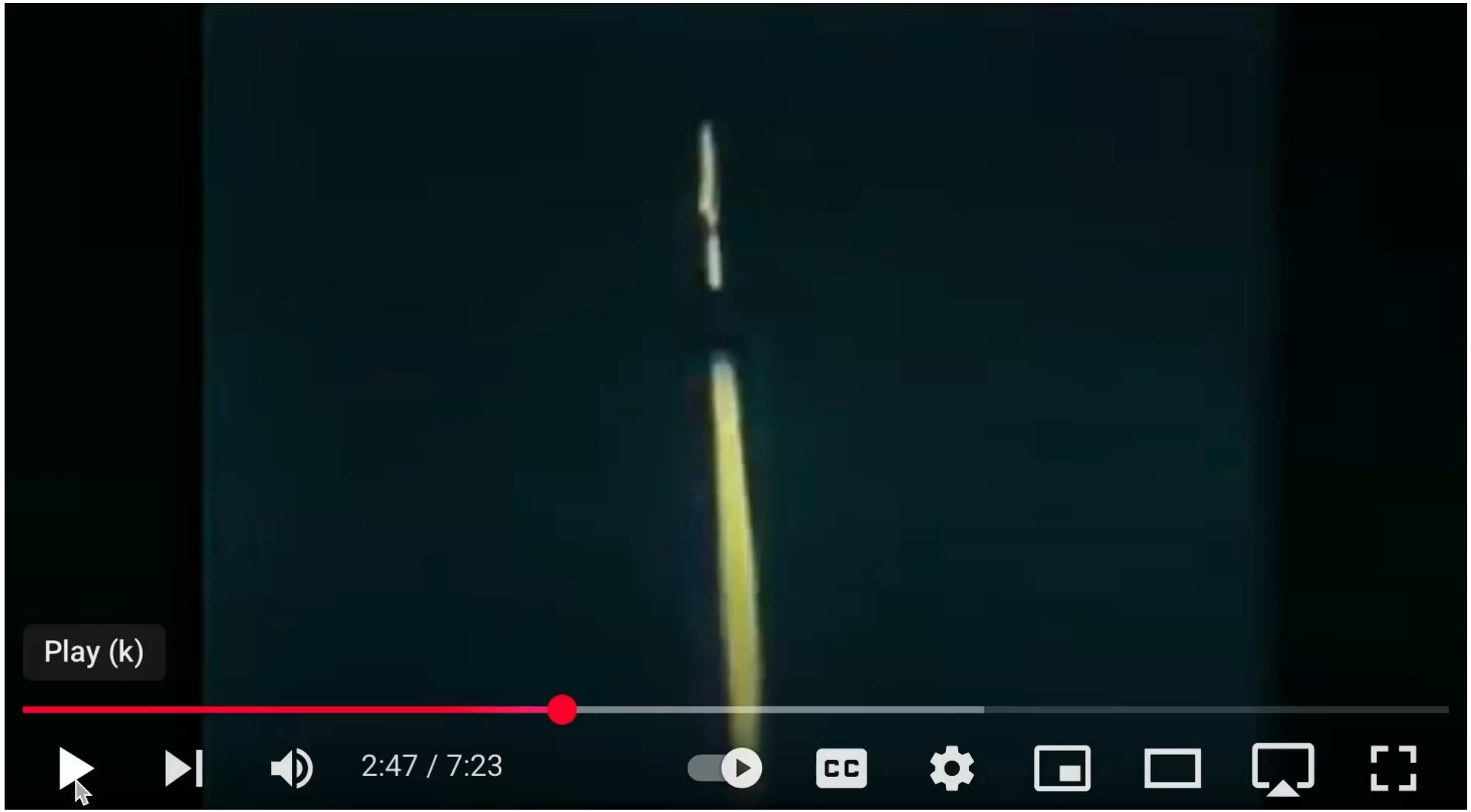
- Two modes of Machine Operations:
  Exploration and **Goal strategy**

From Cybernetics, Transaction of the Eighth Conference, 1951
"Presentation of a Maze-Solving Machine" by Claude Shannon

[3] Theseus Operation: Maze Solving Machine



[4] Theseus Demonstration by Claude Shannon @ Bell LAB (1950s)



https://www.youtube.com/watch?v=_9_AEVQ_p74

[5] Why Theseus is a Learning Machine?

Theseus is a learning machine

- Theseus finds a path in the maze by trial & error method.
- Theseus memorizes the found path.
- It also automatically explore the new path when the maze is changed.

Machine Learning Definition

Machine Learning Definition from Textbook (Murphy2022)

1.1 What is machine learning?

A popular definition of **machine learning** or **ML**, due to Tom Mitchell [Mit97], is as follows:

> A computer program is said to learn from experience E with respect to some class of tasks T, and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.

- Machine Learning Principles.

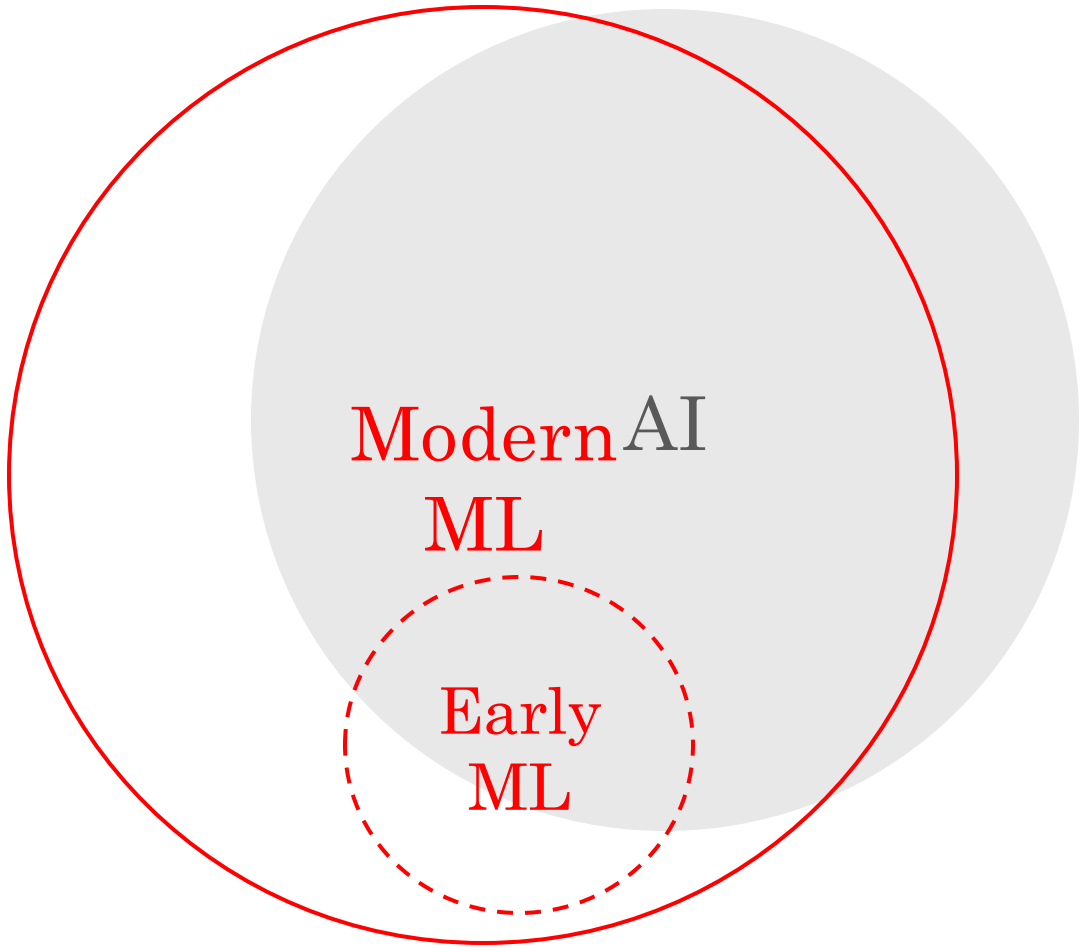
Machine Learning Principles

- Functions: model
- Experience: data
- Metric : loss
- Change: training/ updating parameters.

Q: why it is not a good idea to just pursue a complex modeling?
why do we need to consider the number of data points we have?

- Machine Learning & AI

[1] Machine Learning & AI



[2] Machine Learning & AI

Many of ML schemes already existed before AI appearance, like decision, estimation theory, and optimization theory. But they are reframed as ML in the context of AI to emphasize its ability of automatic learning and their role in achieving the tasks related to human intelligence.

A PROPOSAL FOR THE DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

[Summer, 1956]

[3] The Birth of AI in 1956

The study is to proceed on the basis of conjecture that
every aspect of learning or any other feature of intelligence can in principle be precisely described that
a machine can be made to simulate it.

from "*A Proposal for The Dartmouth Summer Research Project on AI*"

[4] Two Poles in AI : Heuristic vs. Symbolic Approach

"prior knowledge"

- Connectionism
- Heuristic Approach

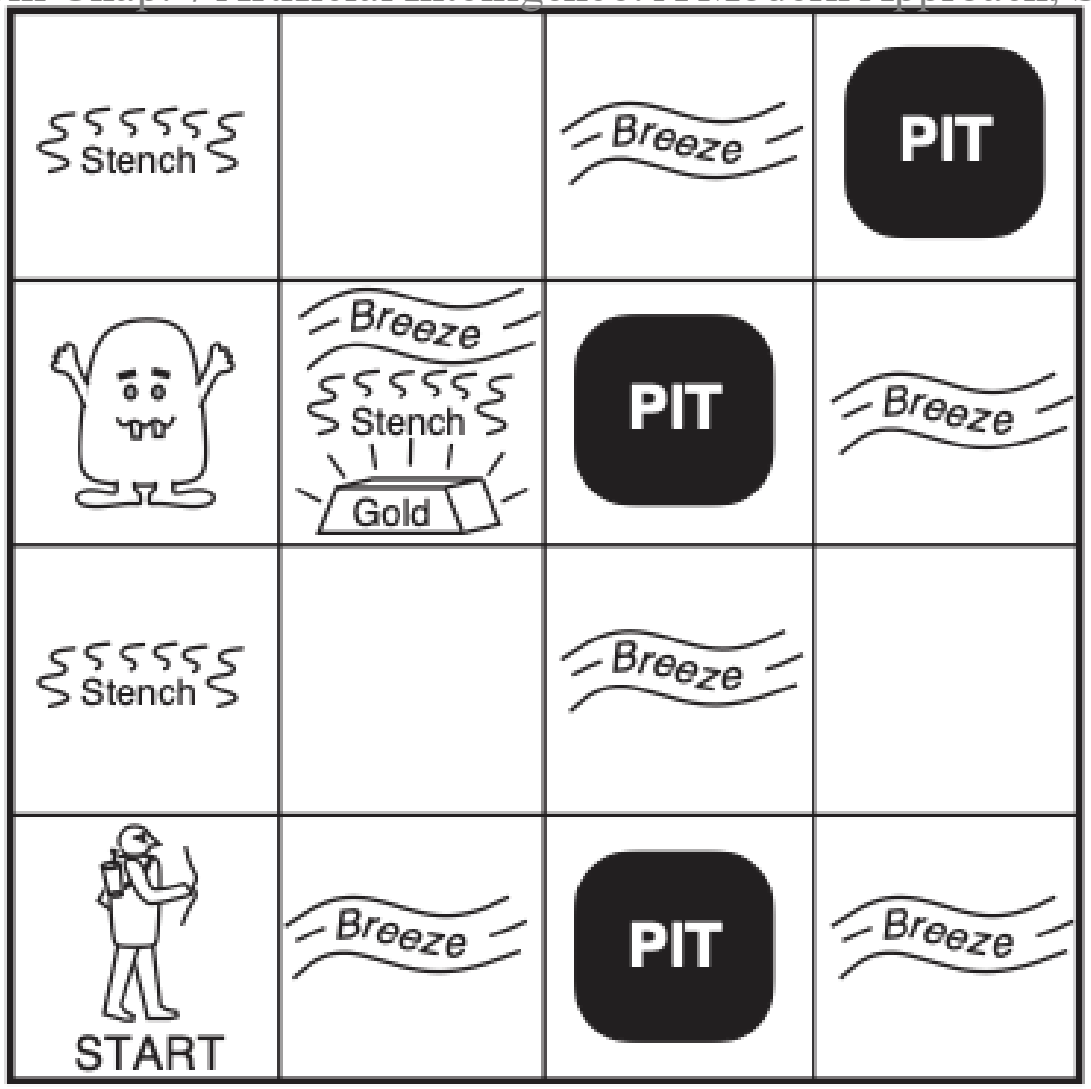
+ learning a function
+ data driven
+ focus on end-effect
+ make it work
+ inductive

- Symbolic AI / Uses General Knowledge
  (rule-based/ classic)

+ focus on
  the representation of true knowledge
+ serial & logical processing of symbolic
  expression to drive new knowledge
+ no data, no function
+ deductive

[5] Example of Symbolic Reasoning

From Chap. 7 Artificial Intelligence: A Modern Approach, Stuart J. Russell



1,3	2,3	3,3	4,3
1,2 OK	2,2	3,2	4,2
1,1 A OK	2,1 OK	3,1	4,1

1

1,3	2,3	3,3	4,3
1,2 OK	2,2 P?	3,2	4,2
1,1 V OK	2,1 A B OK	3,1 P?	4,1

2

1,4	2,4	3,4	4,4
1,3 W!	2,3	3,3	4,3
1,2 A S OK	2,2 OK	3,2	4,2
1,1 V OK	2,1 B V OK	3,1 P!	4,1

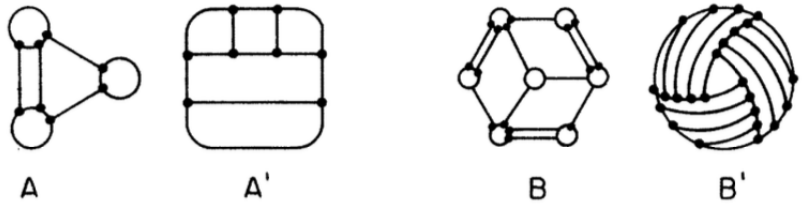
3

[6] Heuristic Programming Approaches to solve AI problems

- Make a machine to Search
  Q: how effectively test all possible solutions and find an optimal?

- Make a machine to do Pattern Recognition:
  Q: what patterns/features would be useful for AI problem?

  A≡A' and B≡B'
  (topological equivalent
  for connectivity relations)



- Make a machine to do Learning from past and predict future:
  Q: how could we find a model
  to generalize the experience from past so enable to predict future?

From "Steps Toward Artificial Intelligence" by Marvin Minsky [1961]

[7] Heuristic Programming Approaches to solve AI problems

- Make the machine to Search
  Q: how effectively search all possible solutions?

- Make the machine to do Pattern Recognition:
  Q: what patterns/features would be useful for AI problem?

- Make the machine to do Learning from past and predict future:
  Q: how could we find a model
  to generalize the experience from past so enable to predict future?

From "Steps Toward Artificial Intelligence" by Marvin Minsky [1961]

[8]Historical Outlines of AI

- Connectionism
- Symbolic AI

CS 461 Course Logistics
(syllabus in Canvas)

In the next class,

- Probability theory axioms
- Conditional probability
- **Bayes rule**
- Discrete and Continuous Random Variables.
- First and second order statistics : Mean, Variance, Covariance
- Estimation:

  Maximum A posteriori (**MAP**) or Maximum Likelihood (**ML**) Rule