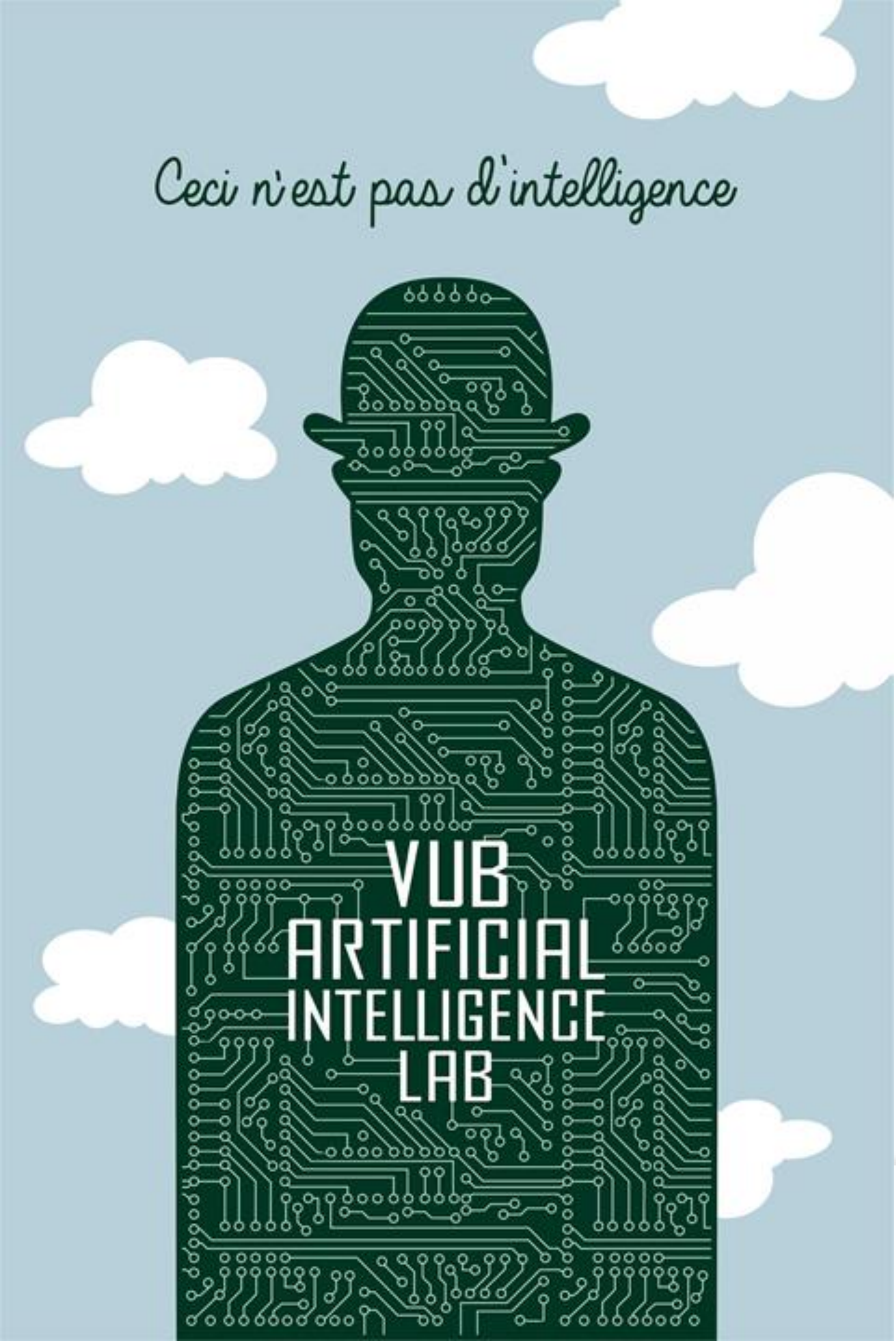


Introduction to AI

Faias LTTA

Marjon Blondeel & Johan Loeckx

June, 1st 2022

FAIaS
Fostering Artificial Intelligence at Schools

With the support of the Erasmus+ Programme of the European Union

VUB
ARTIFICIAL INTELLIGENCE RESEARCH GROUP

My AI & education journey

Educational background

- Appreciated different approaches to education
  - At school: Freinet & regular
  - Music shool: Orff & regular
  - Started own Freinet school, quite complicated ending

- Many things I learnt
  - Philosophy of work: situated, active learning
  - Noncognitive "soft" skills (which are much harder, in my opinion)
  - Meta-cognitive skills

Among other things..

- Not getting what you want = essential for personal growth
- Coping with emotions, how to take decisions in group
- Asking for help
- Never punished --> creates a sense of responsibility
  - You cannot outsource it; you are responsible for learning
  - I flooded the school because I promised a swimming pool
- Scientific method: you can learn from everyone, everywhere
  - Example: fastest way to get pupils in the classroom

Brief timeline

- 1992
  - Fiddled with AI: Q&A, SHRDLU, Expert system, Eliza
- 1996
  - Sold first software, end-to-end: listening to requirements, migration of data, build own DBMS, network, code, documentation, maintenance, upgrades,… Used till 2010.

2000s

- University
  - Took all the AI courses I could take in my Engineering degree
  - Extra 1-year master in AI
  - PhD in "Electronic Design Automation"

- "Academia never again!"
  - 3.5 years in IT for social security; cloud computing, encryption scheme for health data exchange in Flanders (Vitalink)

2012

- Back to academia
  - FP7 project on my three passions
  - Projects with industry
- Starting a conversation on AI ...
  - "boring!!!!"
- 2015: opinion piece on LLL

2016: Creation of a hype

- Suddenly, life at the lab changed completely: visitors!
  - We want to "buy AI" -> not that simple
  - We want your students -> not that many
  - Shit, we need to train our staff!

- 2018: started with lifelong learning programme
  - Universities are not ready
  - Flanders is not ready
  - Industry is not ready

Our lifelong learning programme

Lifelong learners in AI

- Three main segments
  - People who care about the **impact**
  - People who care about the **value**
  - People who care about **implementation**, development

- Gross underestimation of complexity & time it needs
  - Give me three hours to get upto speed
  - Who learns statistics in 3 hours?

Teaching AI = hard

- People come with fragmentary knowledge
  - Especially technical profiles: they don't know they don't know
- Resistance to demystification
  - Don't want to destroy the dream
  - And to mathematics...
  - Especially from technical profiles!!!

Teaching AI = hard

- AI requires **skills that we do not teach at school**
  - Thinking at different abstraction levels at the same time
  - Inter-disciplinary
  - Critical and creative mindset at the same time

- Different backgrounds (lawyers, engineers, CEOs, philosophers,…) & learning goals

- Teaching AI was so far confined to specialist **tracks:** university teachers not prepared for the task / gap in the offer!

LAIKA

- Lifelong learning programme
  - Dialectics
  - Gamification
  - Demos

- CONFRONTATION: learn-from-building
  - Situated learning;
    but far from real world context (because of strong attitudes)

Example: wedding seating arrangement

- Given a number of people N,
  a list of who **must** sit next to each other
  a list of who **must not** sit next to each other

- Write a program that outputs
  who should sit where

What is AI?

Chapter 1: What is a chair?

Write a **precise** definition of a chair.

A kind of procedure that would allow you to answer the question
"is this a chair or not?"

Write a **precise** definition of a chair.







Translating a real-world task into a mathematical problem is called **formalization**.

So they can be manipulated (by an algorithm)

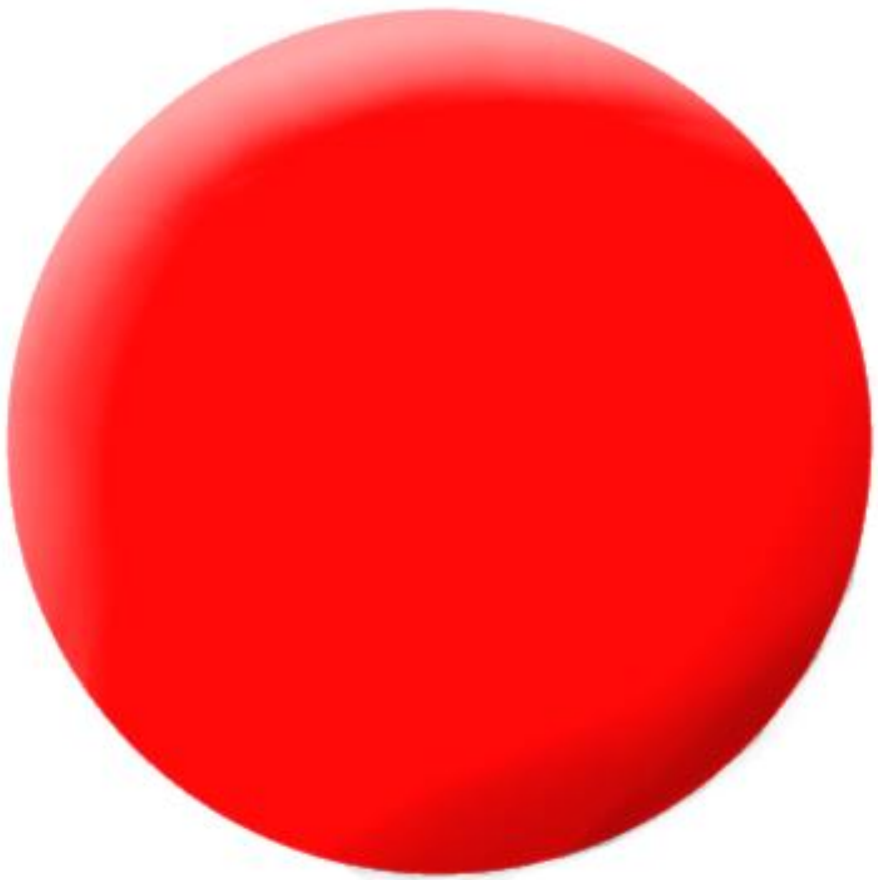
Must be unambiguous, numerical...

Just like the real-world?

Chapter 2: What do you see?

What do you see?

What do you see?



What do you see?

000000000000000000001100000000000111100
000000111111110000000011110000000000011
00000000000000000000

What do you see?

0000000000000000
0000000110000000
0000001111000000
0001111111111000
0000001111000000
0000000110000000
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What do you see?

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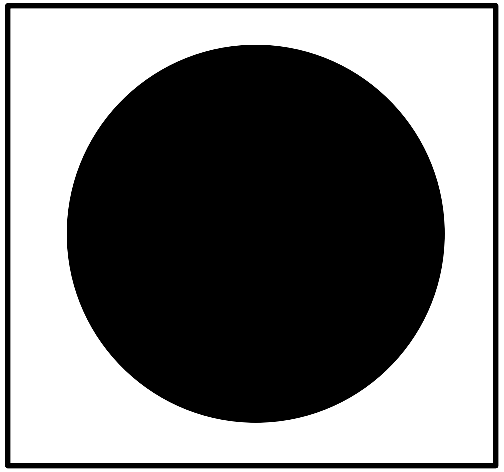
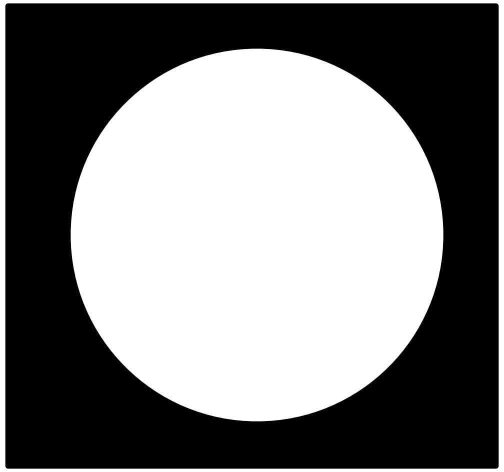


Numbers have **no meaning** in computers.

What do you see?

00000000000000
00000011000000
00000111100000
00011111111000
00000111100000
00000011000000
00000000000000



There is a large **semantic gap** between how we perceive the world and the inputs to a machine.

Chapter 3: Numbers computers can use

The challenge

- Given
  - A world with objects

- Build a system that can
  - answer questions about objects in this world
  - with "true or false"

Example interaction with the system

"The cup is on the table"

> TRUE

"A cup is in front of the man"

> TRUE

"There are three cups"

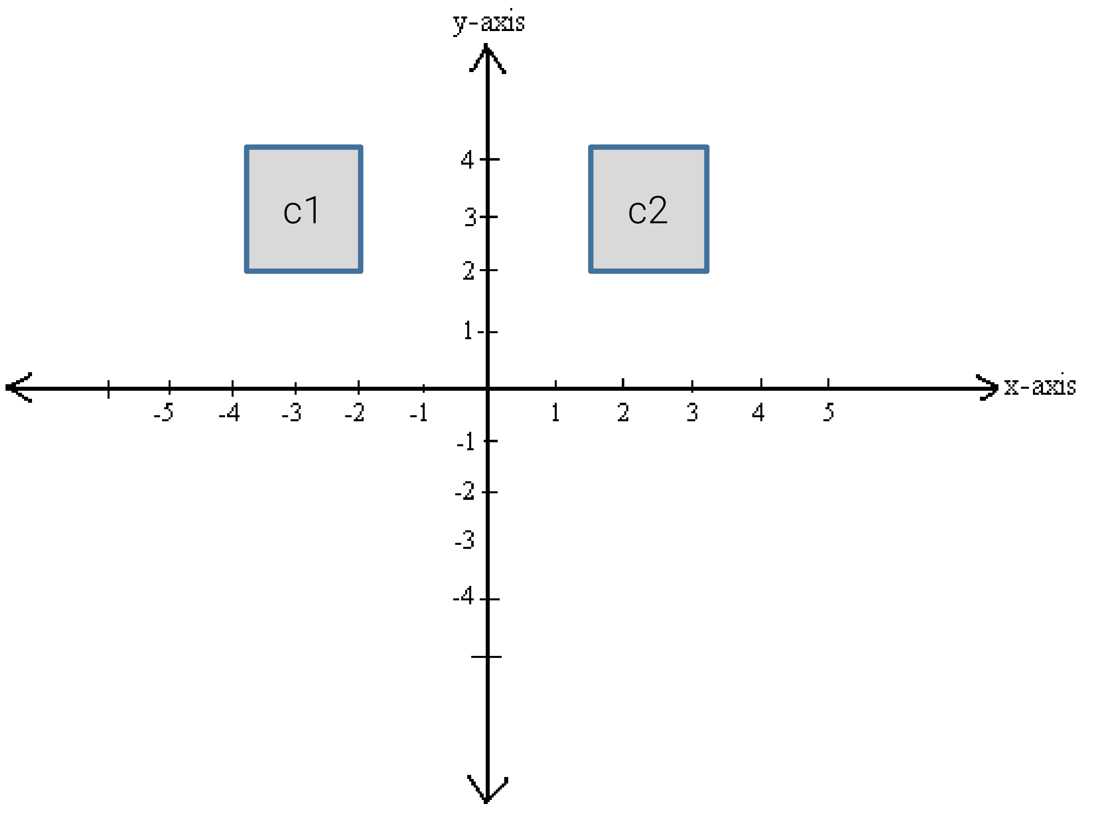
> FALSE

Representation exercise

- Come up with a good representation of a position in space.

A simple and unambigious solution

- Each cube has an **absolute coordinate**



The state of the complete world can be represented by 2 coordinates or 4 numbers:

- (x1,y1)
- (x2,y2)

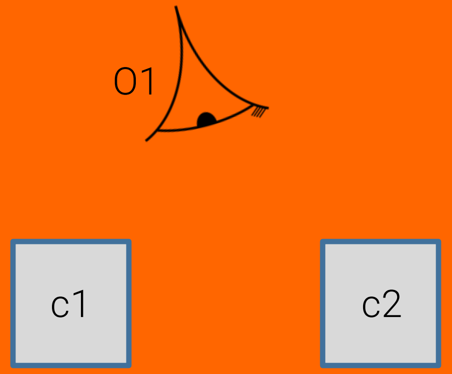
Representation exercise

- How would you assess the **validity** of the statement of *O1: "c1 is left of c2"*

- Given **only your representation**?

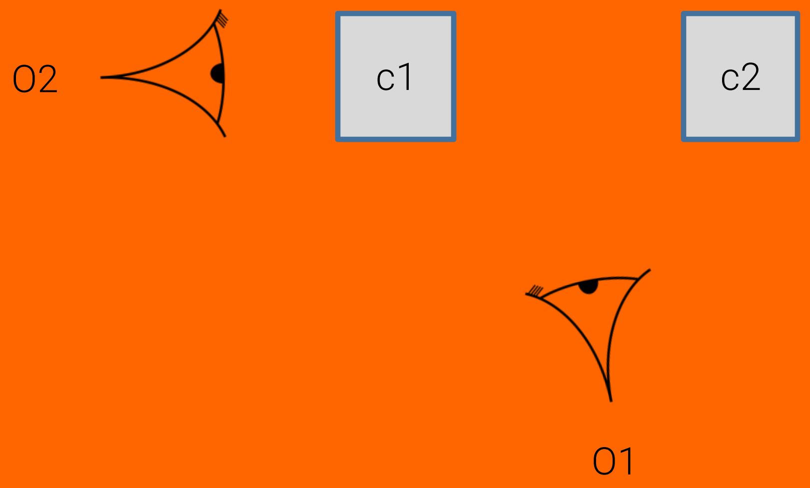
Representation exercise

- What happens if I add an observer O1 on a **random location**?
- How would you assess the **validity** of the statement of *O1: "c1 is left of c2"*
- Given **only your representation**?



Representation exercise

- O2 is blind and O1 needs to help O2 grasp the cube.

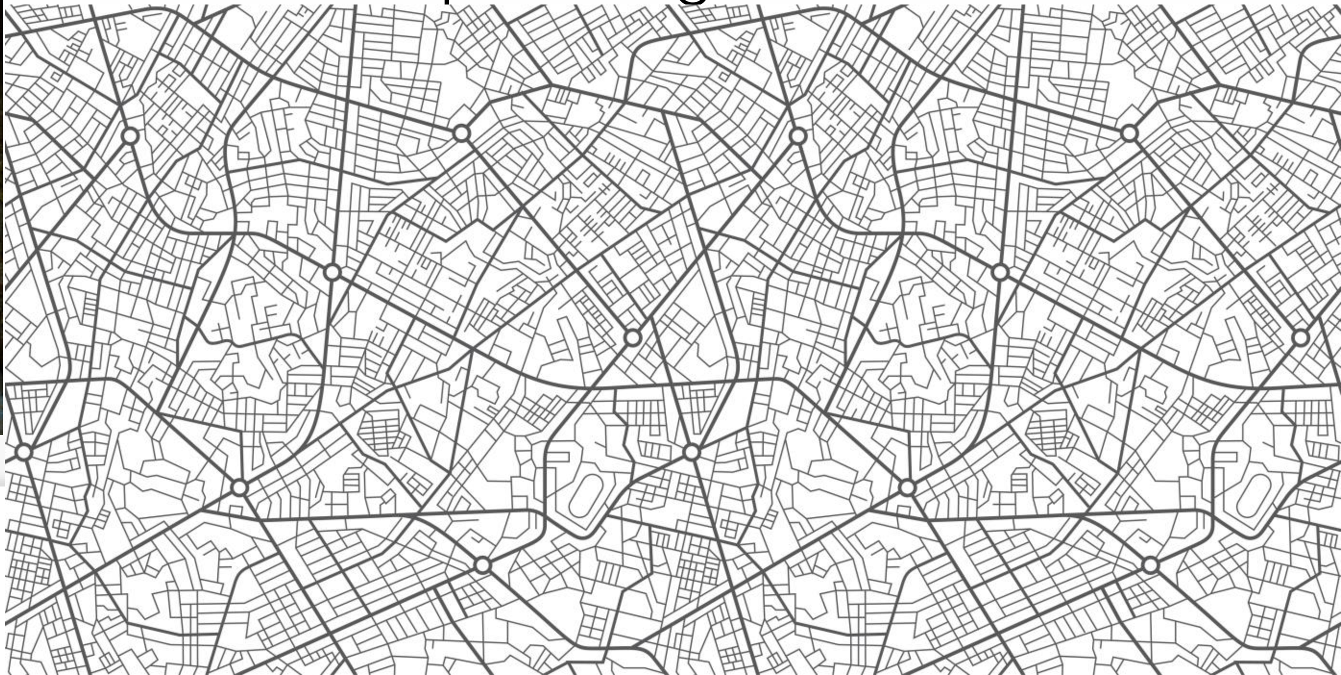


We **reason** over language

A representation should **capture** the **meaning** w.r.t. the **task** you wish to perform.

There is no such thing as a "universal" representation.

- Which do you prefer for...
  - A self-driving car
  - Route planning software



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Chapter 4: Artificial Intelligence

What does this have to do with AI?

- **AI attempts to do "intelligent" things using computers**
- But computers act on numbers...
- So we need to represent the world in numbers
- And "doing something with numbers"... is mathematics!

Artificial Intelligence

- is the scientific field that
- investigates and implements intelligence
- using formalisms & algorithms (mathematics).

Three layers of AI

1. Conceptual / philosophical
   - The nature and mechanisms of **intelligence**
     (big ideas, multi-disciplinary)

2. Mathematical
   1. Formalization

in principle

3. Implementation: attempting to **reconstruct** it.
   (computer science, electronics & robotics)

A machine that can fly

- Do not copy the flapping wings
- But learn how a bird uses physics to fly

The question of whether a computer can think is no more interesting than the question of whether a submarine can swim --
Edsger W. Dijkstra

To understand and reconstruct

Two main goals of AI

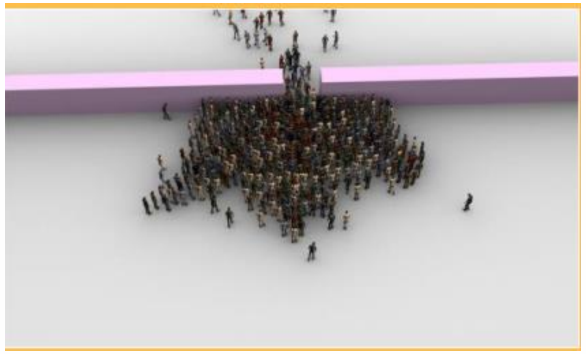
1. Can we **use computers** for a better **understanding** of the world?

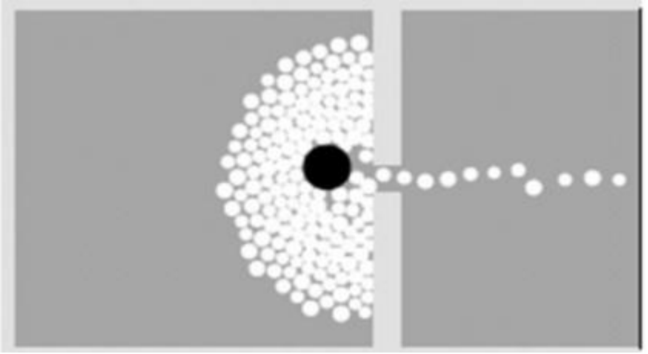
2. How can we **represent** and **reconstruct** intelligence?

Learn from building

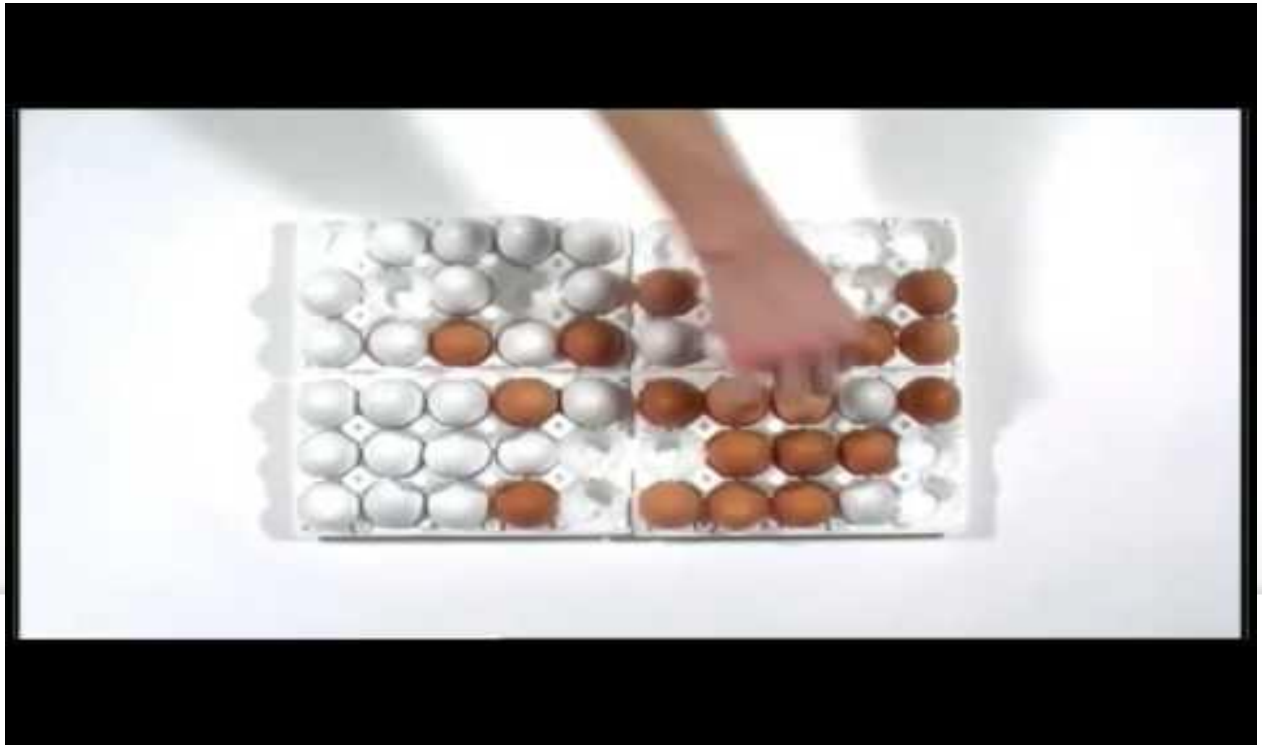
AI leads to a better understanding

- Fire exit design





- Segregation



Do the following tasks require intelligence?

- Grasping a tomato
- Moving to a person to talk to him/her
- Finding a tennis ball on a playground

We **underestimate** our intelligence!

- Tactile feedback
- Substance identification
- Memory of weight
- Geometric reasoning

- Environment
- Relationship
- Personality?

Chapter 5: A narrow view on intelligence

What do we mean with “intelligence”?

- No one agrees on a definition – we are chasing our own tail!
- AI can help understanding what intelligence is
- The “I” mainly reflects the passion for human sophistication & the world’s complexity.
- Pragmatic approach to “I”: tackling problems that traditional approaches cannot solve, or not very well. **AI is always on-the-edge** and thus the goal is a moving **target.**

The “I” in AI mainly reflects **the passion for human sophistication.**

$\boxed{\text{Solving tasks}}$ that are not yet solved.

Let's play a game.

Play Savanna level 1-3

- Hard?
- How do determine which card to play? (first route, then card?)
- What if
  - You do not own all cards
  - Sometimes you slip (random effects)
  - Not all routes are equally fast?

- The cards on top can be considered "an **algorithm**"

Savannah – play level 4b

- Local view:
  - At each point, you know the actions you can take, but **you cannot look ahead** where you will end up when playing several cards
- How do you solve this problem?
  - Monte-Carlo Tree Search / Depth First search / Breadth First search

Savannah - play levels 5, 6 and 10

- Play level 5
  - Some solutions are counter-intuitive...
- Play level 6
- Play level 10 (with AI support)

Concepts

- Theory of mind : what is someone else
- Signalling: when do I lock?
- Meta-level communication on strategy
- Antropomorphising
- Exploit properties of environment
  (e.g. forward too many times against dead end does not hurt
- Cognitive bias: which way will the other choose?
- Heuristics
- Solving smaller subproblems (dynamic programming)

How do humans make this task easier?

- Level 4b

Embodiment

We use our environment to augment our intelligence

Who is more intelligent - judged by the agent's behaviour, its **performance** on path finding only:

- Someone that uses traffic signs, or
- Someone that does not?

Passive walking robot

Robot without active components like a motor

When our **intelligence is extended...** we often do not become smarter but become depend on it and **stop thinking!**

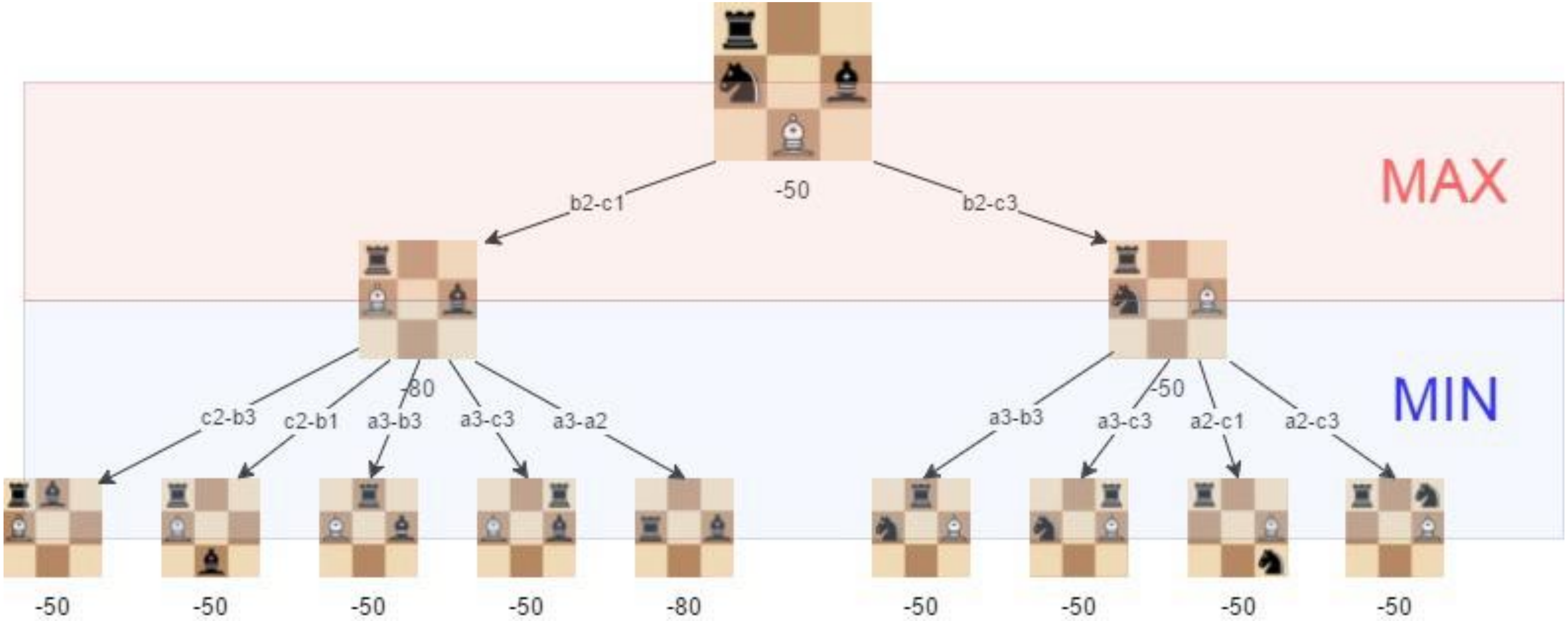
(Google Maps, calculator, ...)

Task 1: Problem solving

Search - level 1: idea

- A problem is "solved" when in the right "state" of the world
  - Called the *goal state* (e.g. arrived at your destination)
- Actions change the state of the world
- This state can be described computationally (a structure of numbers)
- The potential futures can be represented as a tree.

Search - level 1: idea of a **search tree**

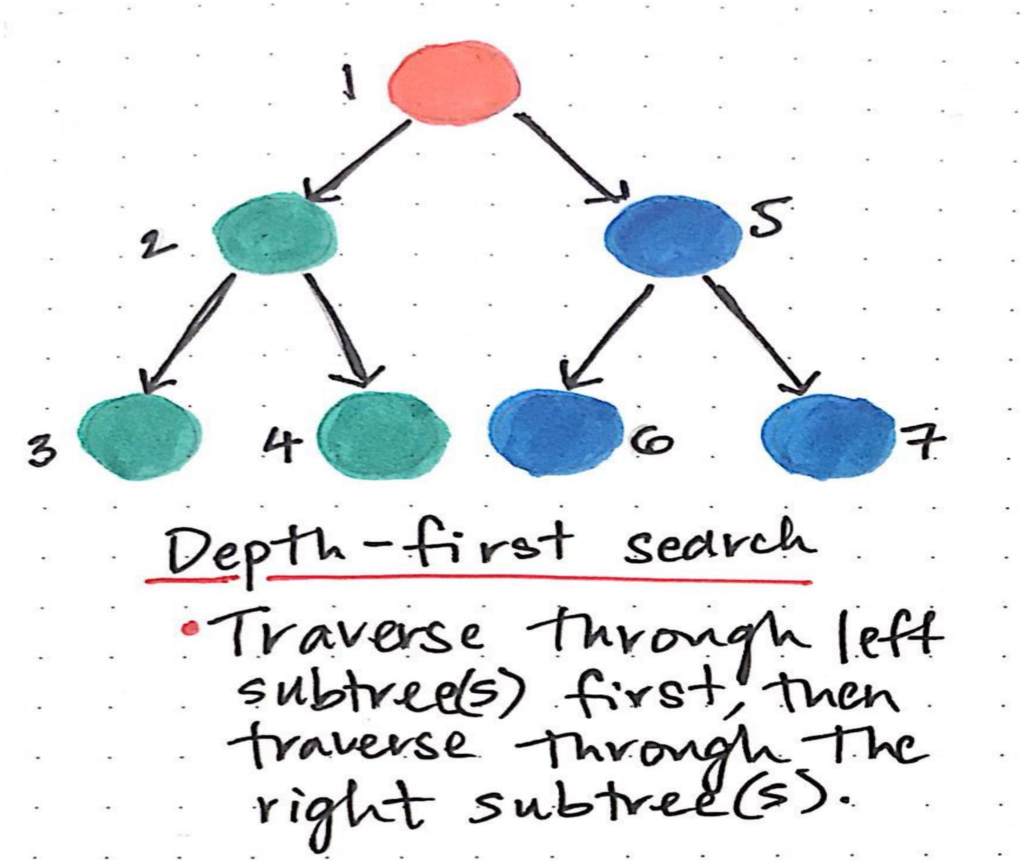


SEARCH

How to find the **solution?**

(i.e. the *goal state*)

Depth-first search - level 2: **formalism**



Algorithm 1: Recursive DFS

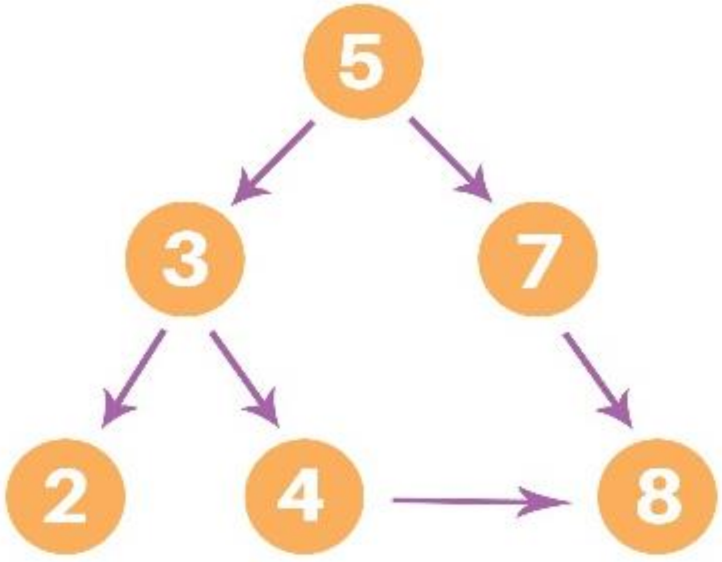
Data: G: The graph stored in an adjacency list
root: The starting node
Result: Prints all nodes inside the graph in the DFS order
$visited \leftarrow \{false\}$;
$DFS(root)$;

Function $DFS(u)$**:**
  if $visited[u] = true$ **then**
    return;
  end
  $print(u)$;
  $visited[u] \leftarrow true$;
  for $v \in G[u].neighbors()$ **do**
    $DFS(v)$;
  end
end

https://www.baeldung.com/cs/depth-first-search-intro

https://medium.com/basecs/breaking-down-breadth-first-search-cebe696709d9

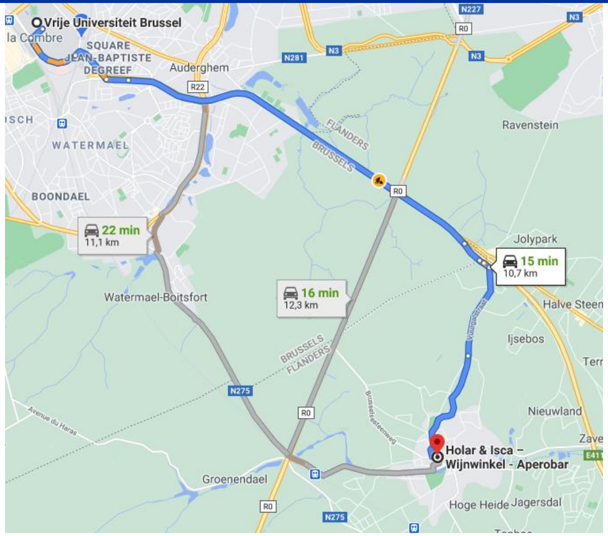
Depth-first search - level 3: code

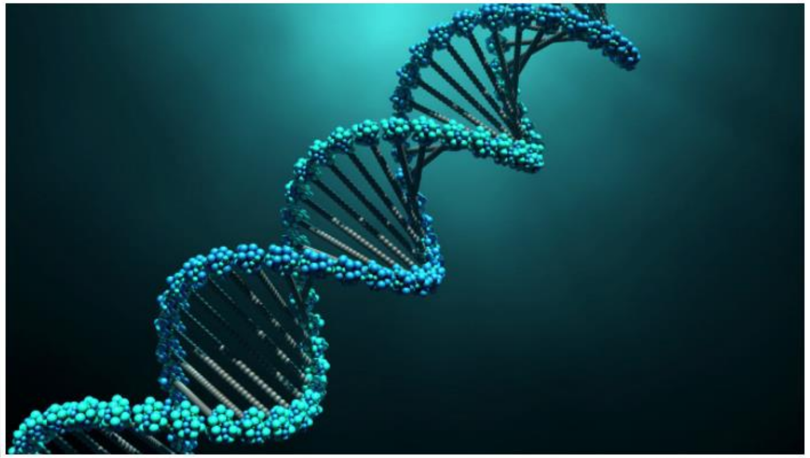



```python
# Using a Python dictionary to act as an adjacency list
graph = {
  '5' : ['3','7'],
  '3' : ['2', '4'],
  '7' : ['8'],
  '2' : [],
  '4' : ['8'],
  '8' : []
}

visited = set() # Set to keep track of visited nodes of graph.

def dfs(visited, graph, node):  #function for dfs
    if node not in visited:
        print (node)
        visited.add(node)
        for neighbour in graph[node]:
            dfs(visited, graph, neighbour)

# Driver Code
print("Following is the Depth-First Search")
dfs(visited, graph, '5')
```

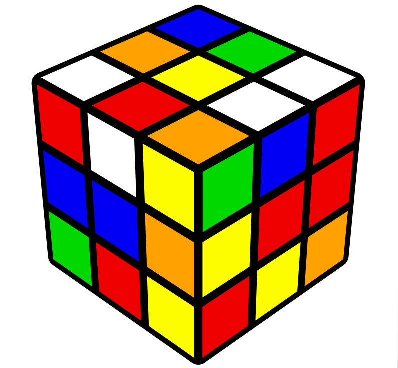
https://favtutor.com/blogs/depth-first-search-python

Real-world applications





DESIGN CELLS/ISTOCK.COM



Algorithms perform generic tasks on well-specified inputs.

They are the motors behind machine intelligence.

Like a mechanical motor, that is at the heart of many appliances: car / hair dryer / mixer / toys / beard trimmer / drill / refrigerator / elevator / …

What is an algorithm?

- Wikipedia: An algorithm is a finite sequence of well-defined instructions, typically used to solve a class of specific problems or to perform a computation.

- "Quasi" algorithms in our everyday lives
  - Cake recipe from your favorite cookbook
  - How do I get to the park? -> different algorithms
  - Building Ikea furniture

Observations / thoughts?

- Not a lot of code, looks very similar to math & pseudocode
- Brute-force (more "intelligent" algorithms exist)
- Not that easy to interpret how it works.

- Agnostic: **does not use any knowledge about the problem!!**

AI is **stupid but powerful.**

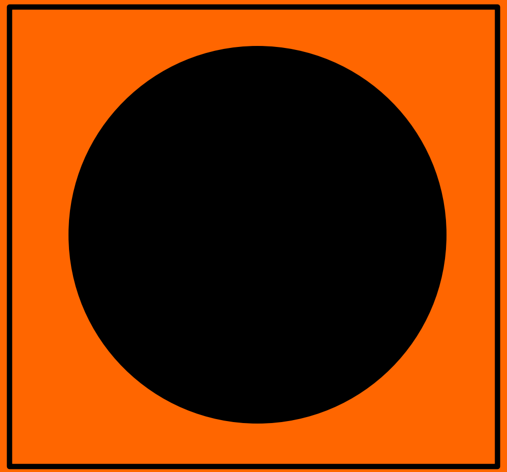
It is a general-purpose technology

Task 2: recognize a ball in a picture

Write an algorithm to recognize a ball

00000000000000
00000011000000
00000111100000
00011111111000
00000111100000
00000011000000
00000000000000

Matrix x_ij



Example of an "algorithm"

0000000000000
0000001100000
0000011100000
0001111111000
0000011100000
0000001100000
0000000000000

1. Compute average of all entries
2. If average > 0.2 it is a ball. Otherwise it is not a ball.

Example of an algorithm

0000000000000
0000001100000
0000011100000
0001111111000
0000011100000
0000001100000
0000000000000

1. Compute average of all entries
2. If average > 0.2 it is a ball. Otherwise it is not a ball.

→ Average = 0.204 → It is a ball!

Example of an algorithm

10000000000001
01000000000010
00100000000100
00011111111000
00100000000100
01000000000010
10000000000001

1. Compute average of all entries
2. If average > 0.2 it is a ball. Otherwise it is not a ball.

→ Average = 0.204 → It is a ball!

Write an algorithm that recognizes a ball

0000000000000000

0000000110000000

0000001111000000

0001111111111000

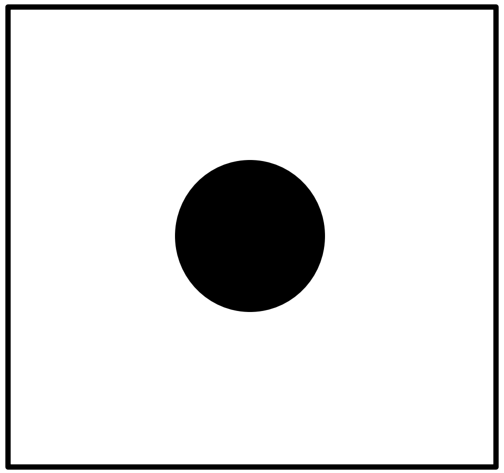
0000001111000000

0000000110000000

0000000000000000

Is this a ball?

00000000000000
00000000000000
00000011000000
00000111100000
00000011000000
00000000000000
00000000000000



Is this a ball?

00000000000000

00000011000000

01100000000110

00011111111000

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00000011000000

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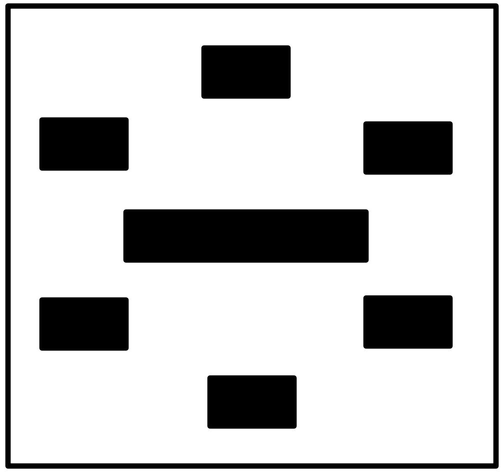


Is this a ball?

00000000000000

00000000000000

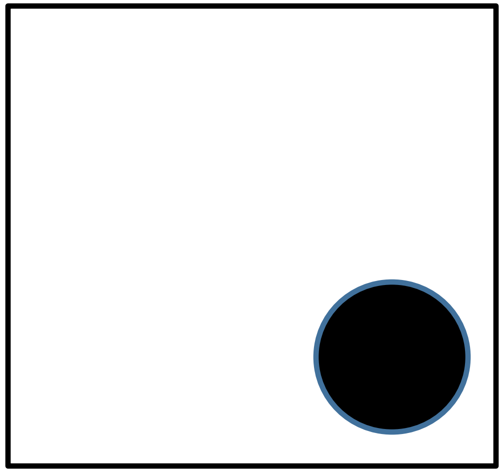
00000000000000

00000000000110

00000000001111

00000000000110

00000000000000



Is this a ball?

00000000000000
00011111111000
00011111111000
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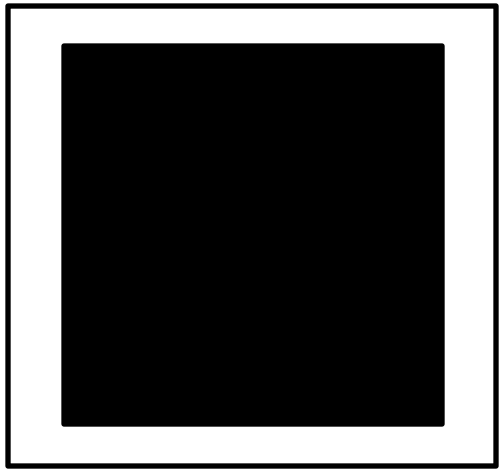
00011111111000
00011111111000
00000000000000



Is this a ball?

0110000000000

0110000000000

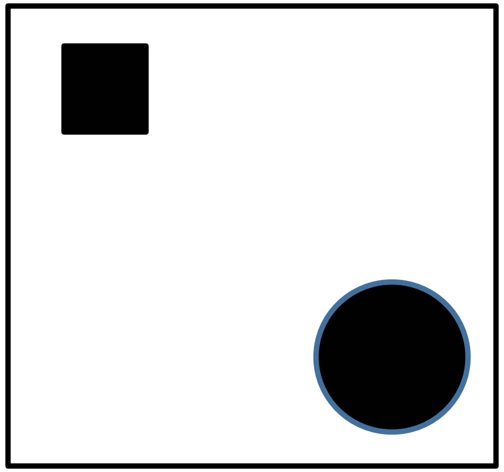
0000000000000

0000000000000

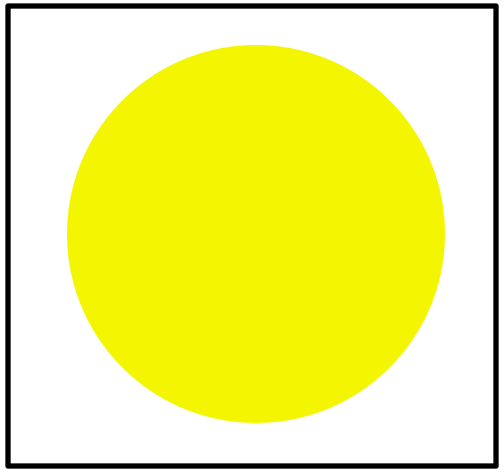
0000000000110

0000000001111

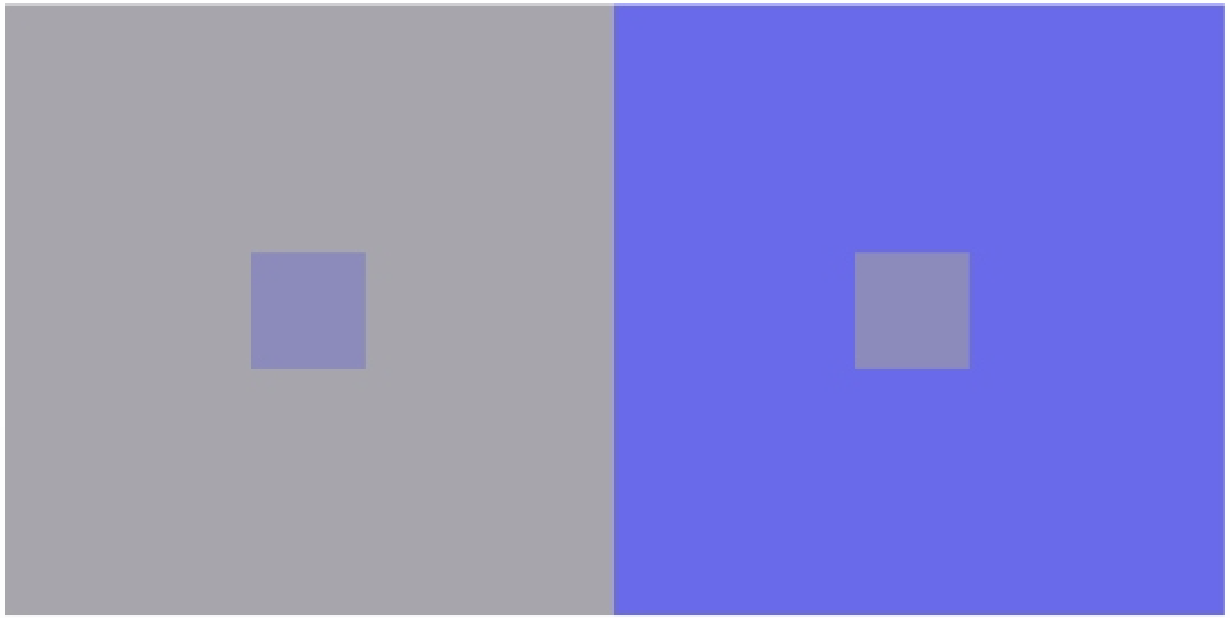
0000000000110



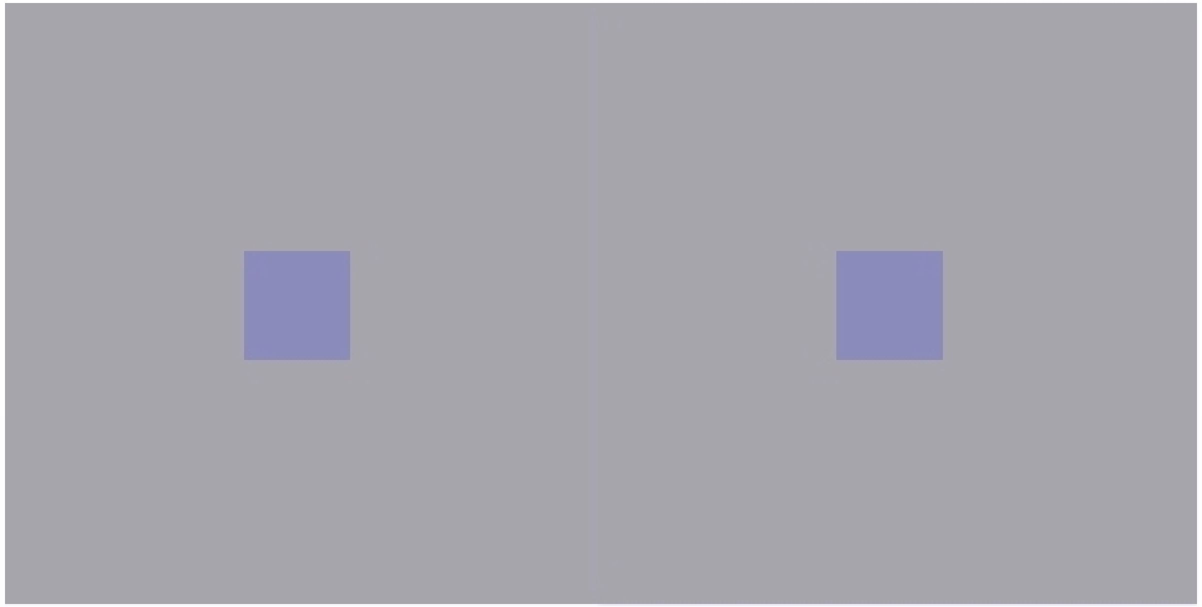
Write an algorithm that recognizes a tennis ball: Add color



Human perception



Human perception



Write an algorithm that recognizes a tennis ball

Write an algorithm that recognizes a tennis ball

Credit picture: The Countryman magazine

Not as easy as it seems

So far: **symbolic**/good old-fashioned AI

- Concepts/symbols understandable by humans
- Manipulation and querying of these concepts/symbols
- High-level human-readable representations of problems

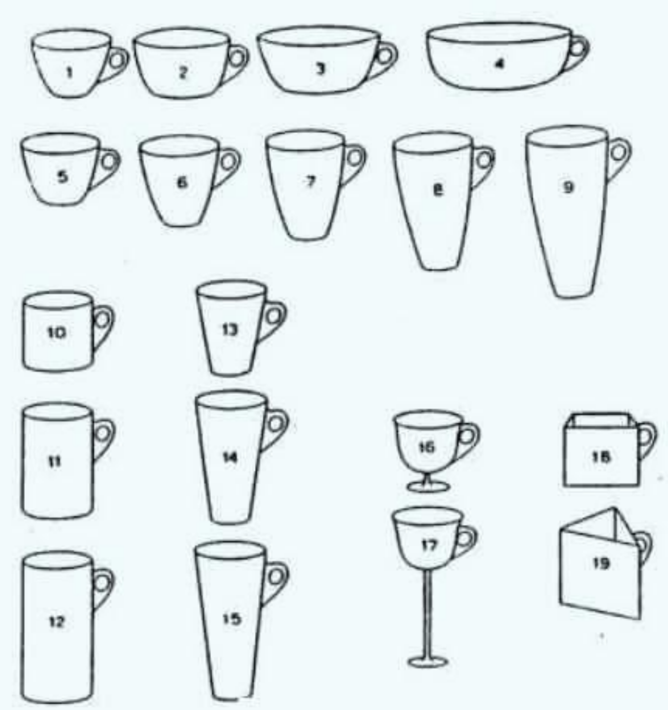
- During many decades, the field of AI was dominated by symbolic AI.
- Starts to break when dealing with the messiness of the world

Learning from examples

The top-down symbolic approaches had limits that sub-symbolic techniques, mainly based on machine learning, tried to tackle.

Cup or bowl?

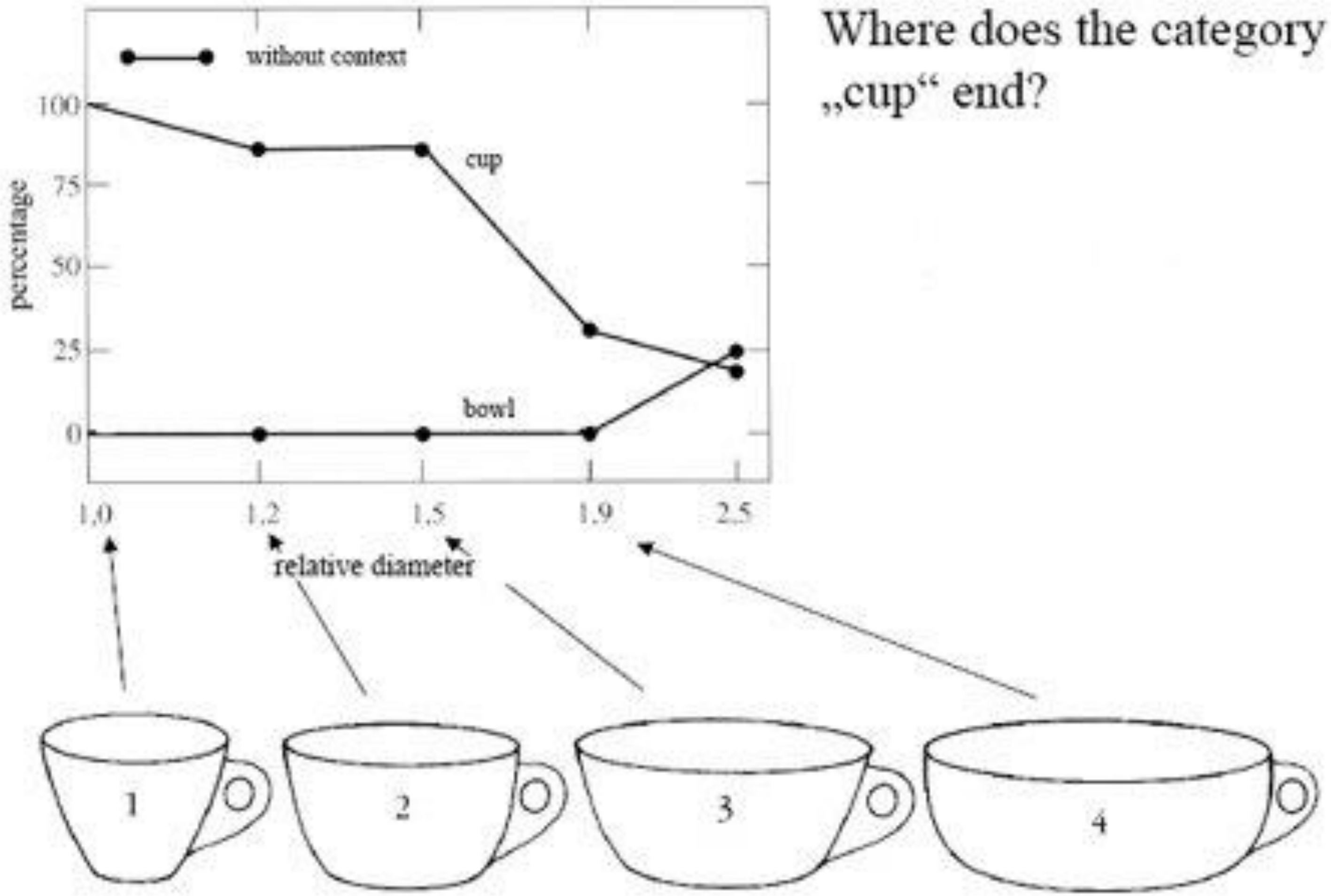
- We are considering the very important problem...



(Labov, 2004)

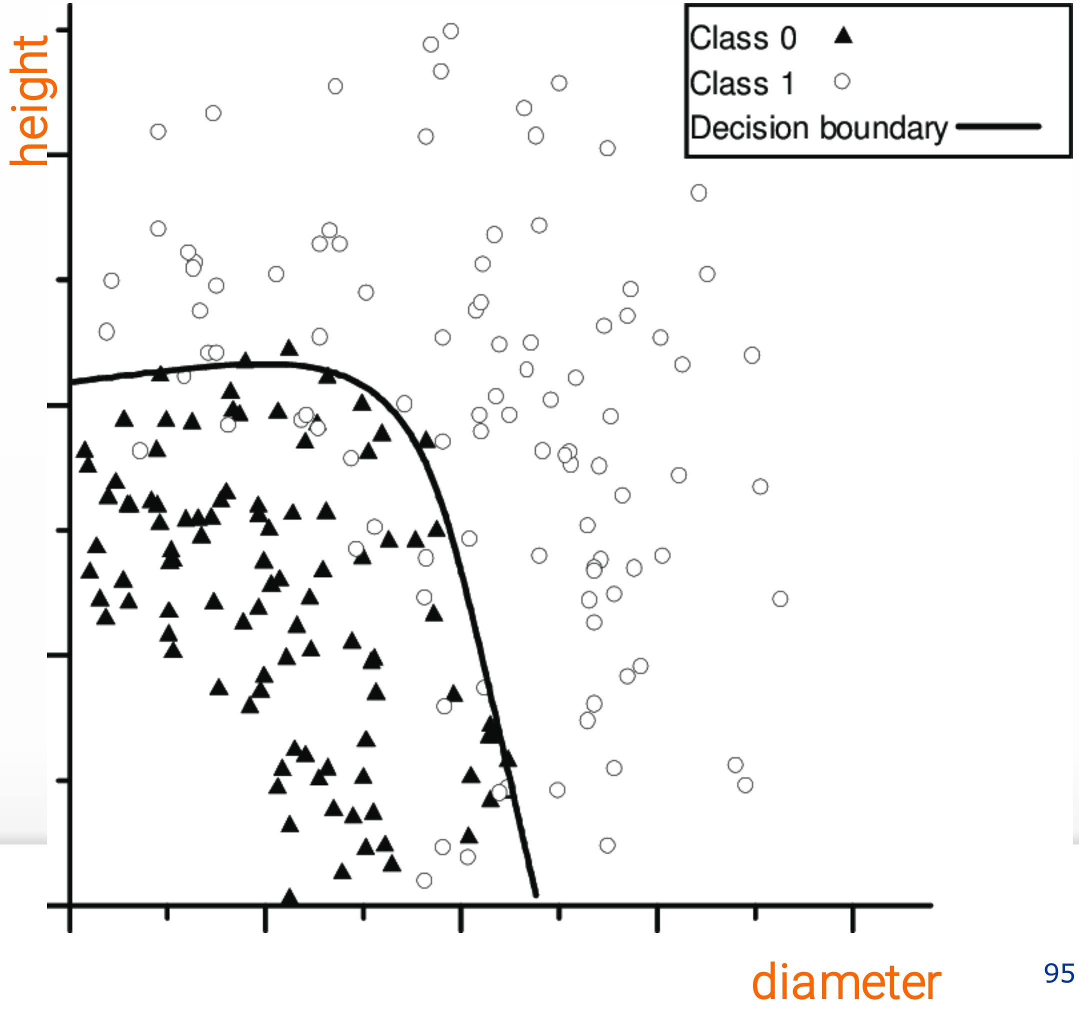
How to detect which one it is?

- Collect data, e.g. the relative diameter wrt height.



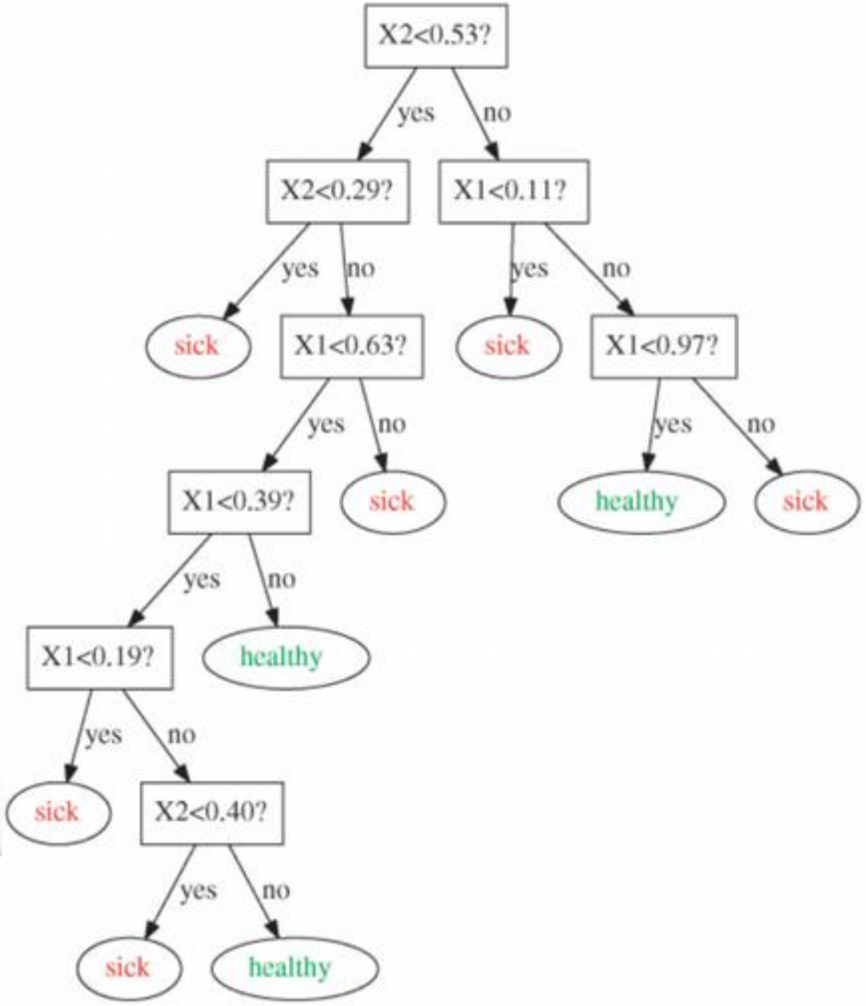
Where does the category „cup“ end?

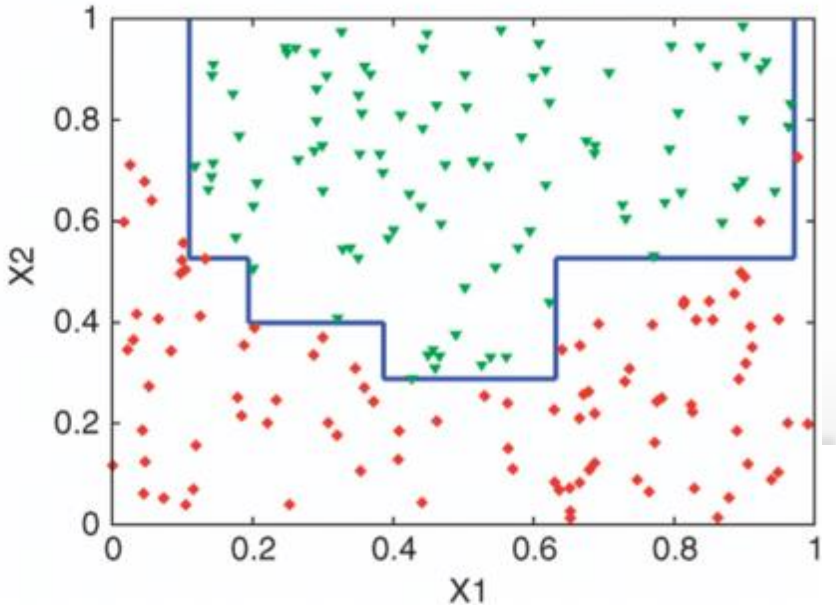
Find a decision boundary



A decision tree

- One of the possible machine learning models





Visual tutorial

- http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

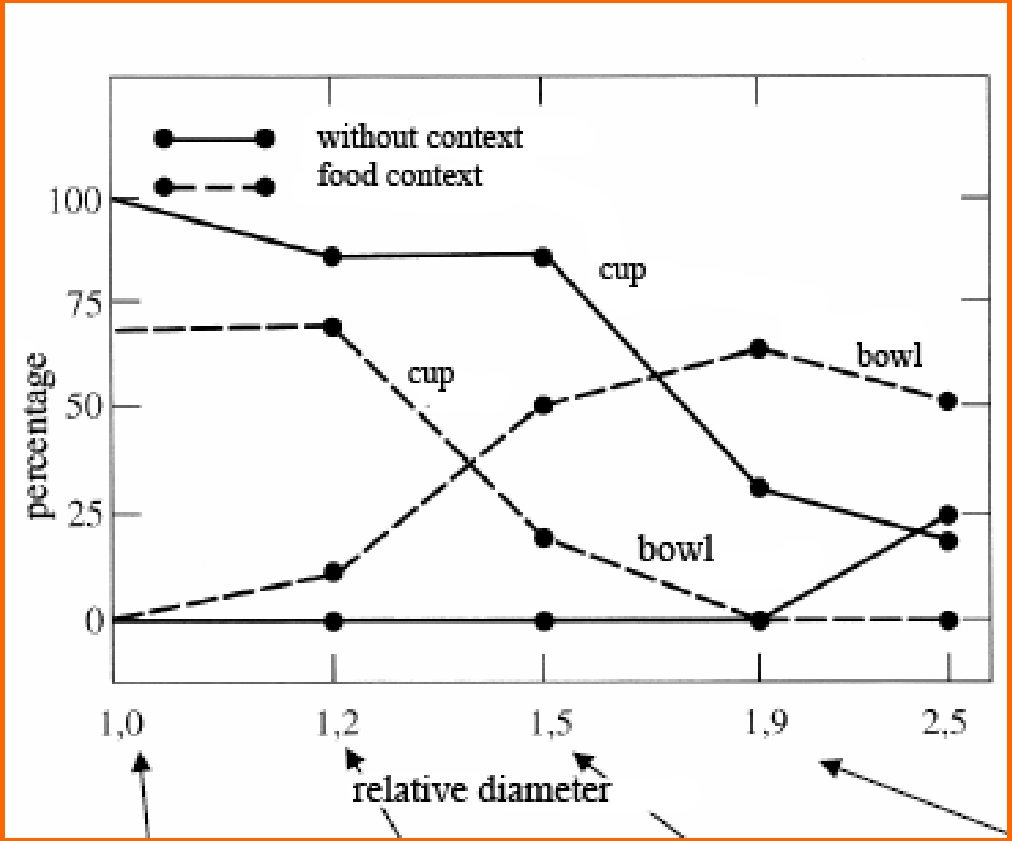
Sub-symbolic AI

- The world is intriguingly complex.
- Start bottom-up from raw measurable data
- Learn simple, mathematically well-defined tasks.
- Not a magic solution.

Machine learning learns a **mapping** between input & output **from examples.**

What are the limitations of this model?

- What if you forget to measure the context (food/not?)
- Not everyone agrees… Which one do you choose: cup or bowl?



We need a mathematical definition...

Figure 1: Labov's (2004) definition of 'cup'

The term *cup* is used to denote round containers with a ratio of depth to width of $1 \pm r$ where $\boxed{r \leq r_b, \text{ and } r_b = \alpha_1 + \alpha_2 + \ldots \alpha_\upsilon \text{ and } \alpha_1}$ is a positive quality when the feature i is present and 0 otherwise.

feature
1 = with one handle
2 = made of opaque vitreous material
3 = used for consumption of food
4 = used for the consumption of liquid food
5 = used for consumption of hot liquid food
6 = with a saucer
7 = tapering
8 = circular in cross-section

Cup is used variably to denote such containers with ratios width to depth $1 \pm r$ where $r_b \leq r \leq r_1$ with a probability of $r_1 - r/r_t - r_b$. The quantity $1 \pm r_b$ expresses the distance from the modal value of width to height.

(Labov, 2004, p. 86)

We can either

- handcraft, or
- learn

This expression!

Learning from **interaction**

What if you cannot explain or engineer HOW a task is to be solved?

Learning by doing

Learn by doing, exploring and exploiting

- Like learning to ride a bike: there is no book that explains how it works!

- Can you give feedback on individual actions? (like, the change in steering wheel position?)

UBER

Example: inverted pendulum

Actions

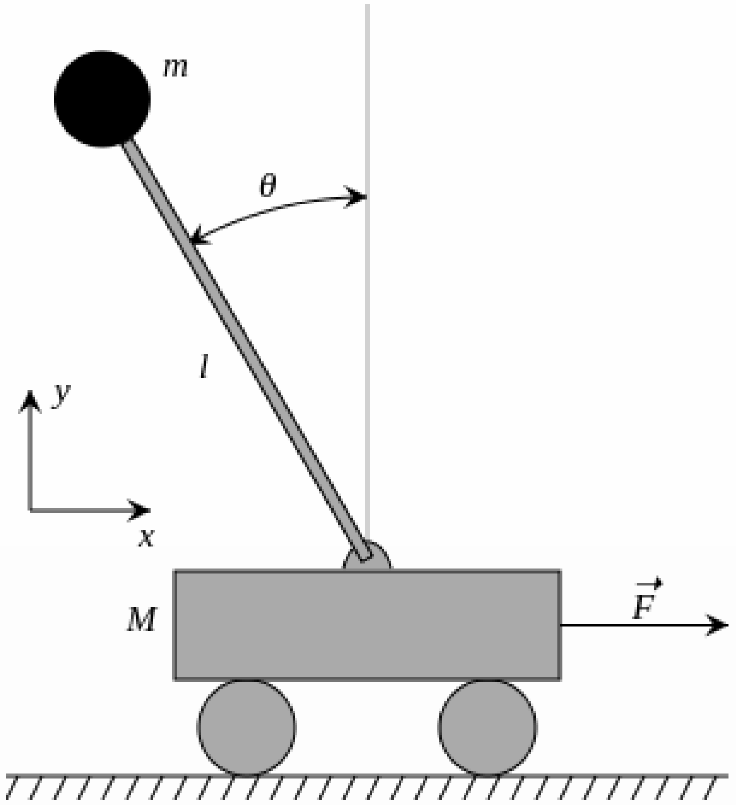
move motor left/right by controlling voltage

Reward

how close is angle to 0°?

Environment

motor, servo, pole, nature




testing controller after trial 180

Reinforcement learning learns how to ACT in an environment by interacting with it.

It learns a decision process / policy.

Reinforcement learning

$$Q^{new}(s_t, a_t) \leftarrow \underbrace{Q(s_t, a_t)}_{\text{old value}} + \underbrace{\alpha}_{\text{learning rate}} \cdot \overbrace{\Bigg(\underbrace{\underbrace{r_t}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(s_{t+1}, a)}_{\text{estimate of optimal future value}}}_{\text{new value (temporal difference target)}} - \underbrace{Q(s_t, a_t)}_{\text{old value}} \Bigg)}^{\text{temporal difference}}$$

Roots in psychology; rewards & punishments, “behaviourism”

Encourage actions, for each state of the environment that lead to success

E.g. Q-learning algorithm to learn an optimal policy

A problem is defined by

- Human designs
  - Reward
  - state
  - Actions

- Cobra effect


KBA
Google DeepMind
Challenge Match
8 - 15 March 2016
AlphaGo
Google DeepMind
Challenge Match


Google


Ads.
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Machines can learn in 3 ways

from
knowledge

Symbolic AI

Human creates
rules

from
examples

Machine Learning

Humans annotate
data

from
interaction

Reinforcement Learning

Human designs
rewards/success

Hybrid architectures

- All of the above approaches are equally relevant
- Typical systems combine all 3 approaches into a hybrid architecture
- Creating systems involves a lot of human design, and adapting to the concrete task & context

Wrap-up

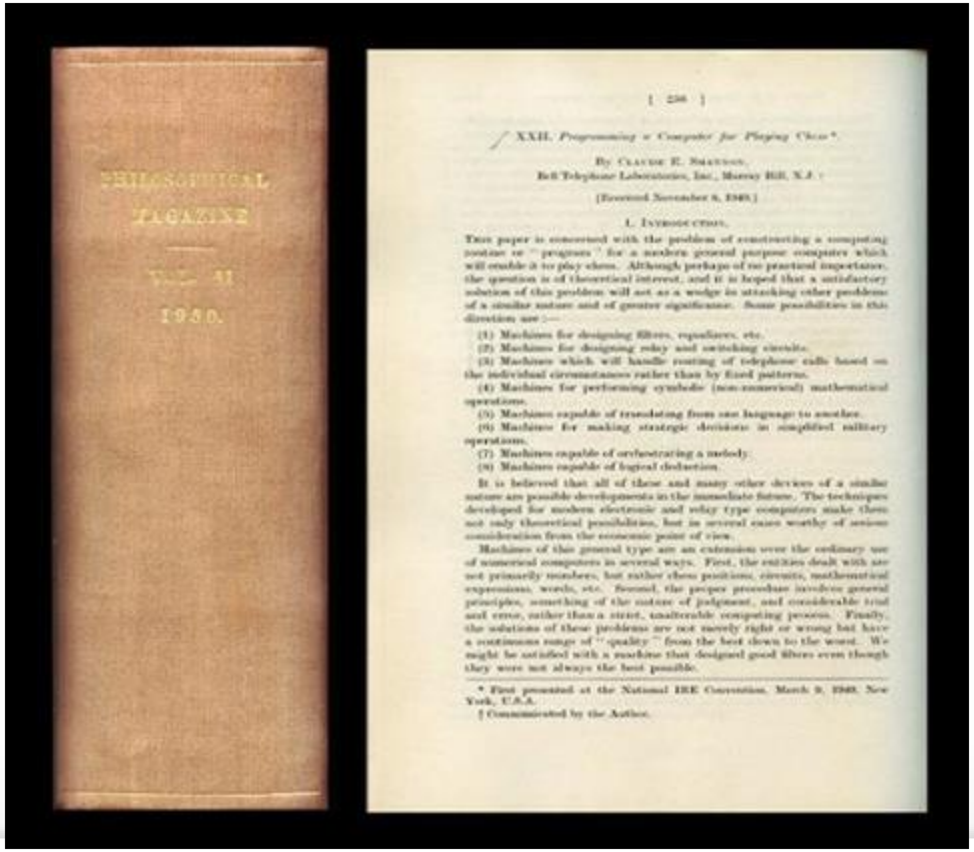
Wrap up

- AI is a research field, delivering **conceptual technology**
  - To **understand** intelligence & **build** intelligent systems
- Covers philosophy over mathematics to implementation
- Systems can **learn** from knowledge, examples & interaction.
- Algorithms perform generic tasks on data. These data have no meaning to the machine. Representations are key.

Reading list

The classics

- De artikels van de jaren ‘50-’60 zijn razend interessant



THE ARCHITECTURE OF COMPLEXITY

HERBERT A. SIMON*

Professor of Administration, Carnegie Institute of Technology

(*Read April 26, 1962*)

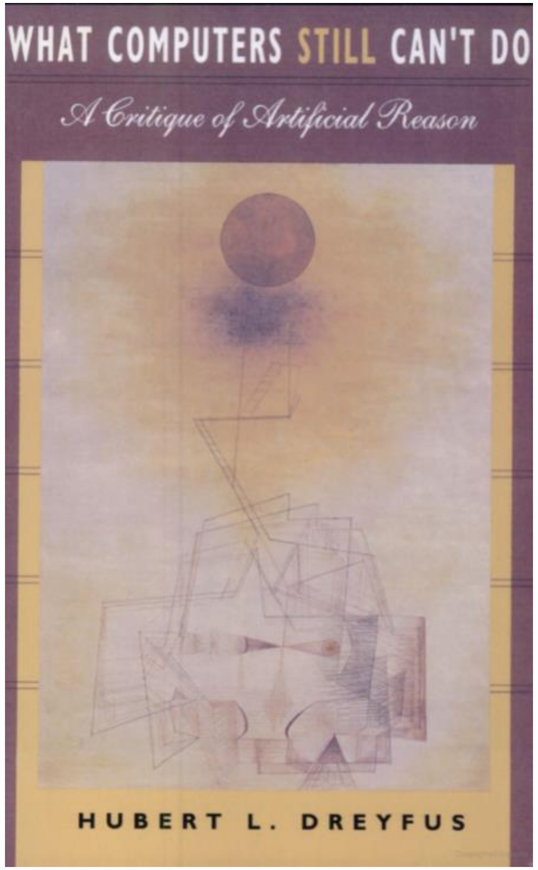
A NUMBER of proposals have been advanced in recent years for the development of “general systems theory” which, abstracting from properties peculiar to physical, biological, or social systems, would be applicable to all of them. [1] We might well feel that, while the goal is laudable, systems of such diverse kinds could hardly be expected to have any nontrivial properties in common. Metaphor and analogy can be helpful, or they can be misleading. All depends on whether the similarities the metaphor captures are significant or superficial.

sis, and to analyze adaptiveness in terms of the theory of selective information.[3] The ideas of feedback and information provide a frame of reference for viewing a wide range of situations, just as do the ideas of evolution, or relativism, of axiomatic method, and of operationalism.

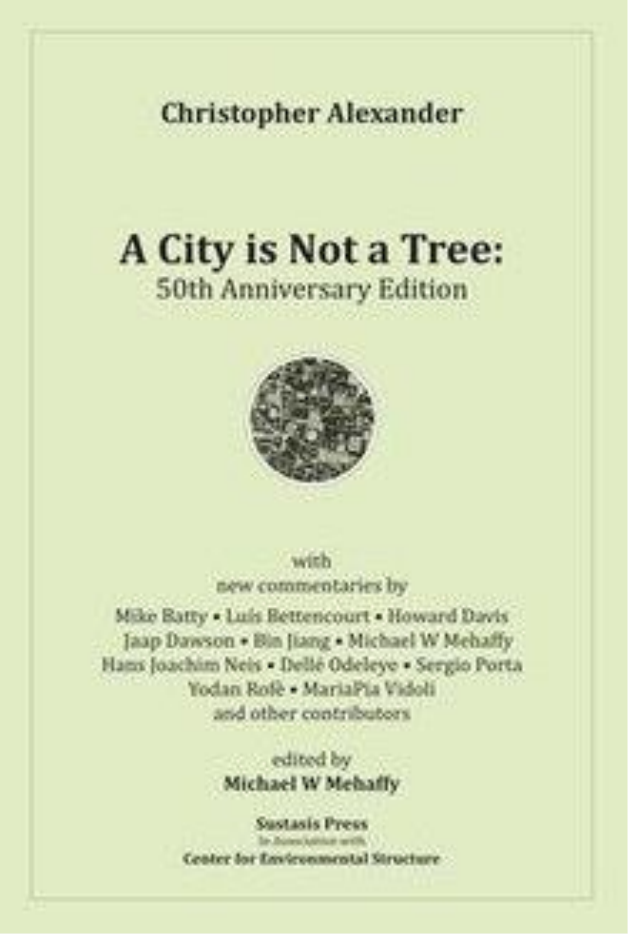
In this essay I should like to report on some things we have been learning about particular kinds of complex systems encountered in the behavioral sciences. The developments I shall discuss arose in the context of specific phenomena, but the theoretical formulations themselves make

Philosophy

- "What Computers Still Can't Do: A Critique of Artificial Reason", Hubert L. Dreyfus

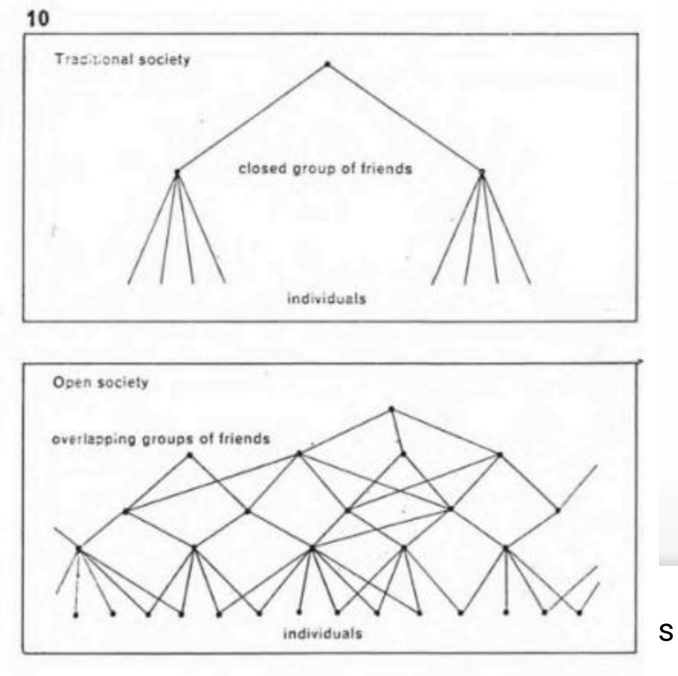


AI & architecture

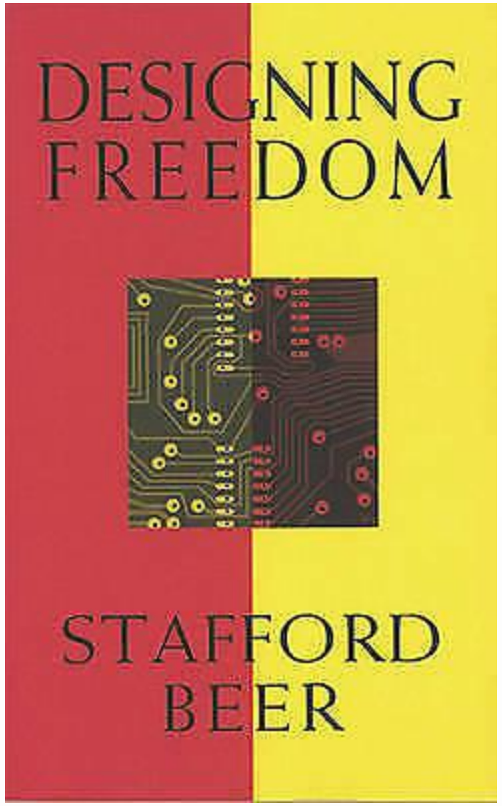


- “A city is not a tree”, Christopher Alexander

- Mental models have a big impact on how we think, and the decisions we make

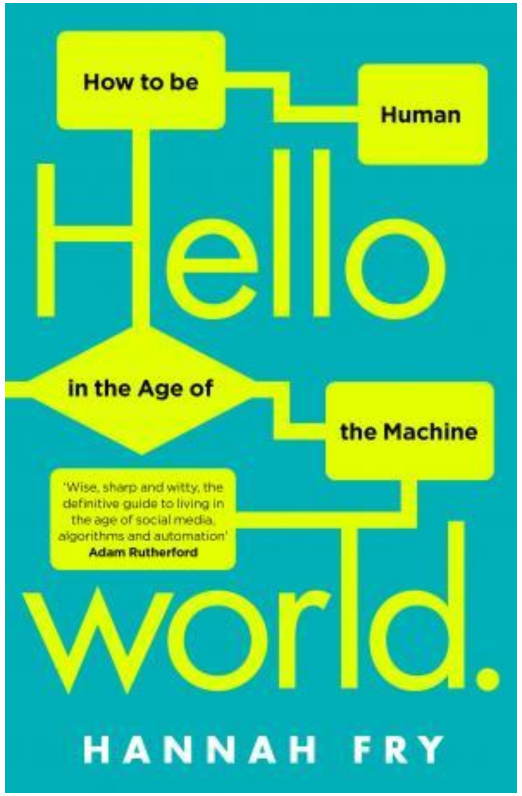


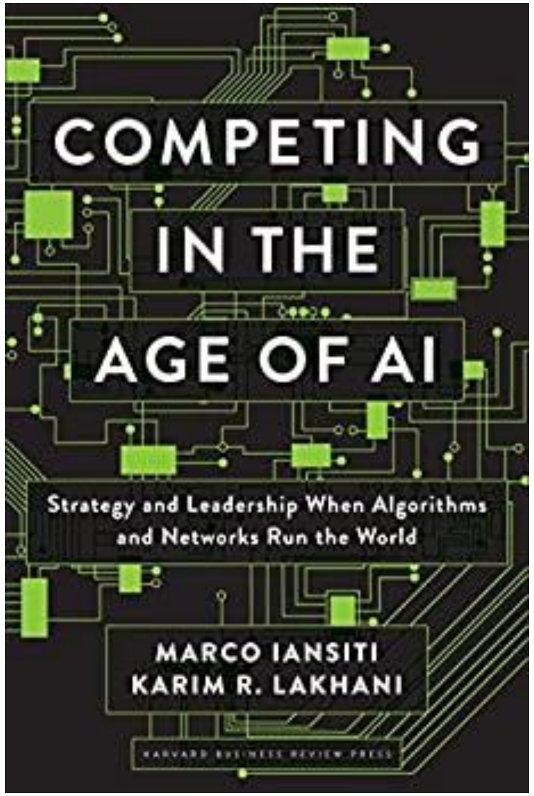
AI & government / democracy

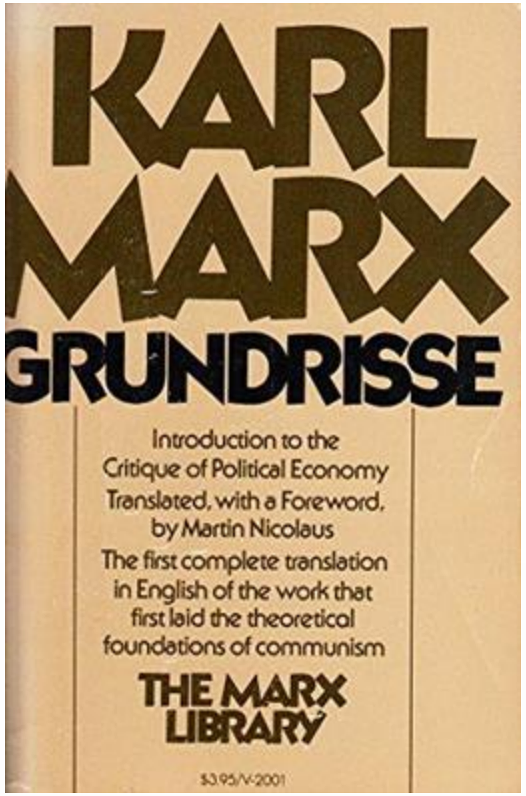


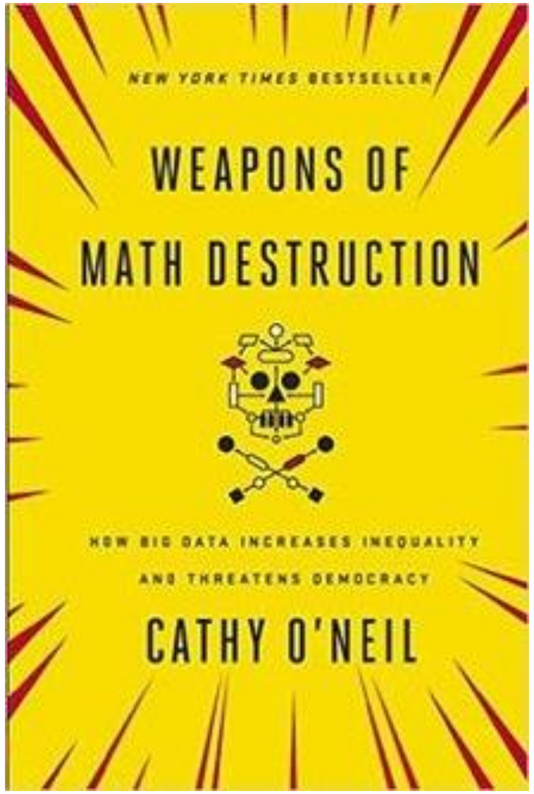
- "Designing freedom", Stafford Beer
- CyberSyn experiment in Chile, 1970-1973 to use AI to organise the economy

Impact on society

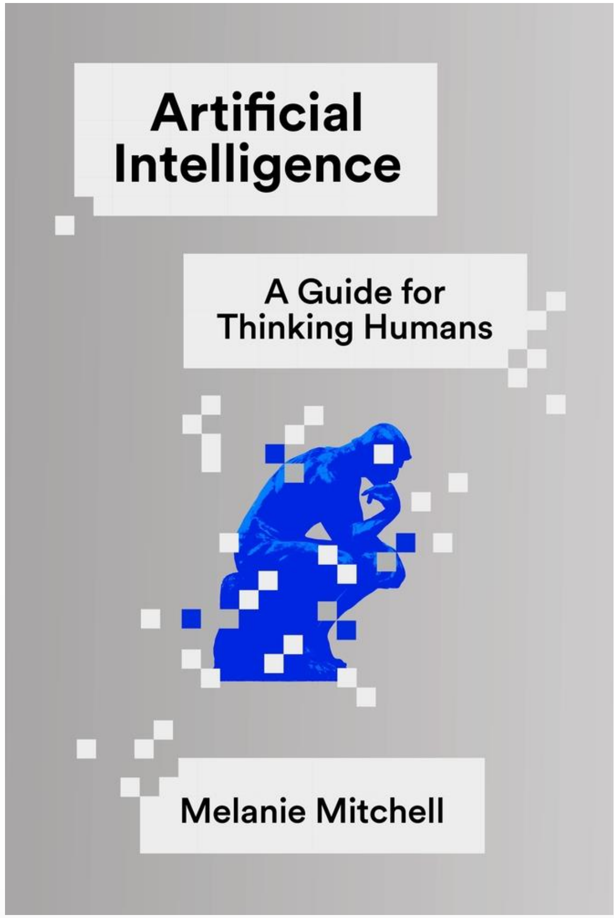


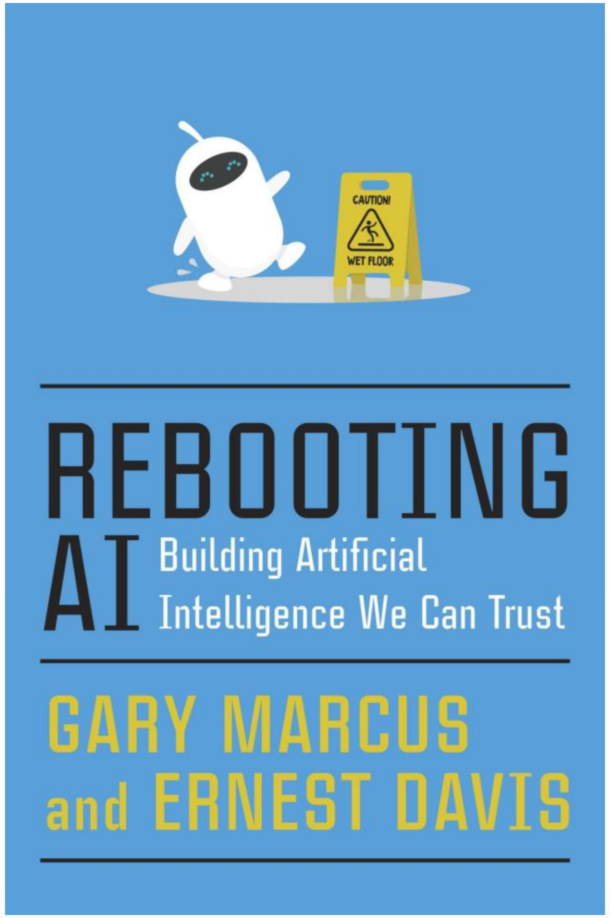


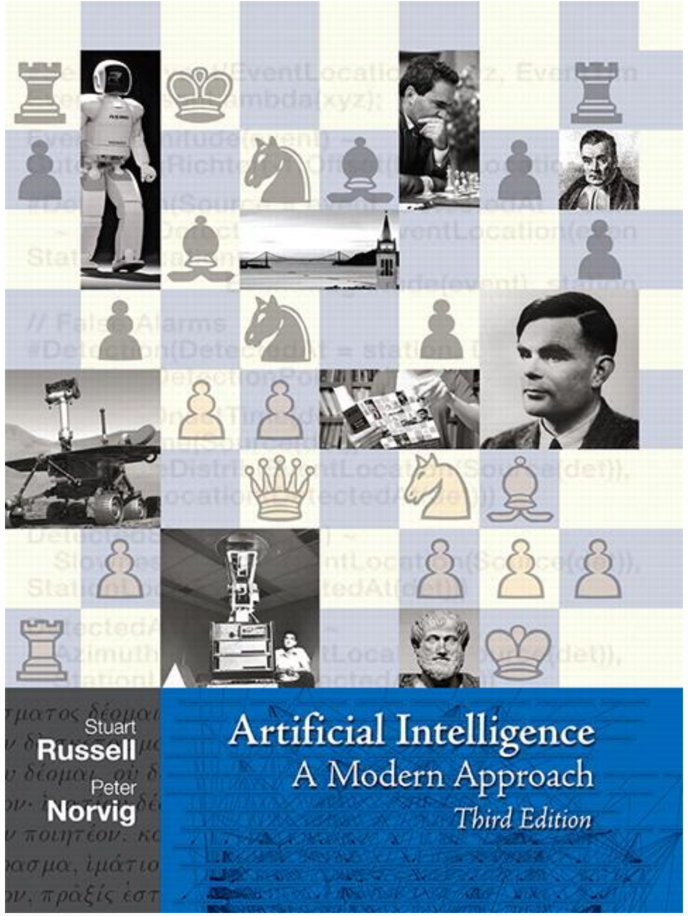




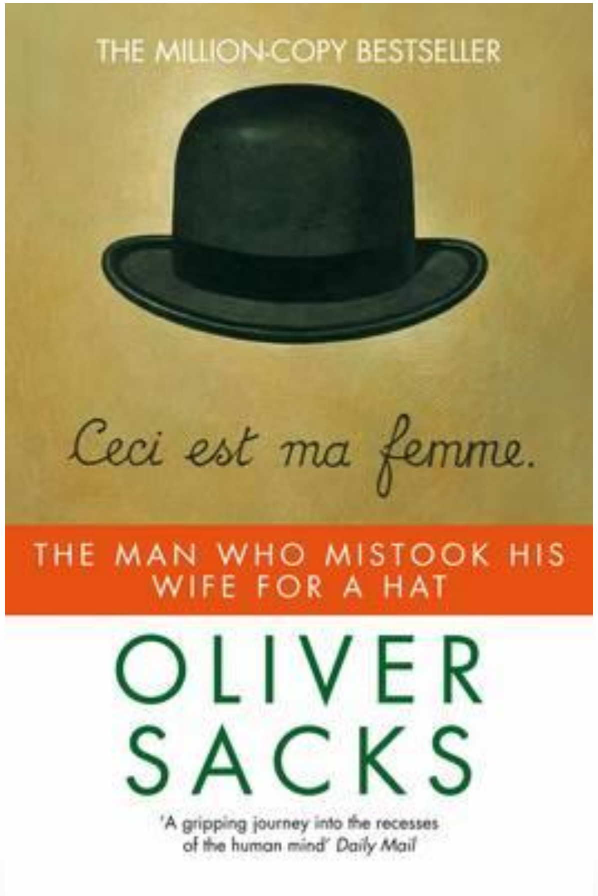
How AI works


Artificial Intelligence
A Guide for Thinking Humans
Melanie Mitchell


CAUTION!
WET FLOOR
REBOOTING AI
Building Artificial Intelligence We Can Trust
GARY MARCUS and ERNEST DAVIS


Stuart Russell
Peter Norvig
Artificial Intelligence
A Modern Approach
Third Edition

How little we know...



- "The man who mistook his wife for a hat" - Oliver Sacks
- Let's stay humble, openminded and creative

My cat is a biology.

AI is a scientific field; it makes no sense to say “an AI”!

Questions?

Subfields of AI

AI is a young and vast field

A scientific domain in concrete terms

AI is a **toolbox** of

- concepts (domain model, meta-level thinking)
- formalisms (logic, search, reinforcement learning, …)
- tasks (modelling, clustering, prediction, classification)
- algorithms (decision trees, neural networks,…)
- methodologies

Most importantly, intuition on how to translate problems into **mathematical problem-solving blueprints** that can be solved by algorithms.

Embodiment

Possibilities are limited to the closed world.

- AI is typically implemented in software (cheap)
- "Embodied" through interfaces
  - Sensors & actuators (robots)
  - Microphones, speakers
  - Displays, keyboards, …
  - "Data"
- To build **a model of "reality"**

Embodiment

Our intelligence is related to our body

- Our body determines our computing architecture
- And they interact: our body determines our capacity as well!
- Who will move most smoothly, for the same computing power?
  - A robot with wheels
  - A robot with legs

Passive walking robot

Robot without active components like a motor

- An AI <> A biology?

Real-world applications

- Self-organisation in ant colonies
- Grasping
- Social robotics: afstand
- Or…

Embodiment

We use our environment to augment our intelligence

Who is more intelligent - judged by the agent's behaviour, its **performance** on path finding only:

- Someone that uses traffic signs, or
- Someone that does not?