Problem Solving with AI Techniques
Introduction

Paul Weng

UM-SJTU Joint Institute

VE593, Fall 2018

Logistics

- Instructor: Paul Weng
  Email paul.weng@sjtu.edu.cn
  Office JI 406
- Class time:
  Wed. 10-11:40am Graduate School 121
  Fri. 10-11:40am Graduate School 207
- Canvas
  - Announcements
  - Slides available before class
  - Project descriptions
- Piazza
  - Questions/discussions

Teaching Staff

- TA to be recruited
- Office hour
  - JI 406 on Friday 1pm-2pm
  - also possibly by appointment
- Avoid questions by email
- Preferably use Piazza, or go to OH

Prerequisites

Two important skills to succeed in this course:

- Computer science
  - programming
  - data structures (list, stack, queue, tree, graph)
  - basics of complexity analysis (big 0, complexity classes: P vs NP)
- Mathematics
  - discrete mathematics (logic, graphs)
  - linear algebra
  - (vector) calculus

Covered roughly in:

- VE281
- VE203
- VV216/256/286

Grading

- Composition
  - About four programming projects (40%)
  - Oral presentation or final project (20%)
  - Mid-term exam (written) (20%)
  - Final exam (written) (20%)

- Any questions about grading?
  - Must be mentioned to TAs and instructor within one week after receiving the item

Textbooks

No required textbooks, but for more details can be found in:

- S. Russell and P. Norvig. **Artificial Intelligence: a Modern Approach**. Pearson.
- T. Hastie, R. Tibshirani, J. Friedman. **The Elements of Statistical Learning**. Springer.
- I. Goodfellow, Yoshua Bengio, Aaron Courville. **Deep Learning**. MIT Press.
- R.S. Sutton and A.G. Barto. **Reinforcement Learning: an Introduction**. MIT Press.

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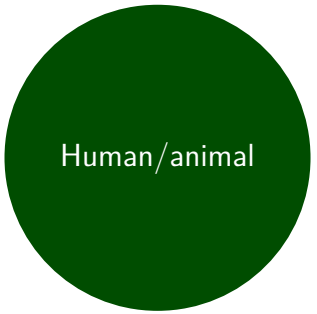

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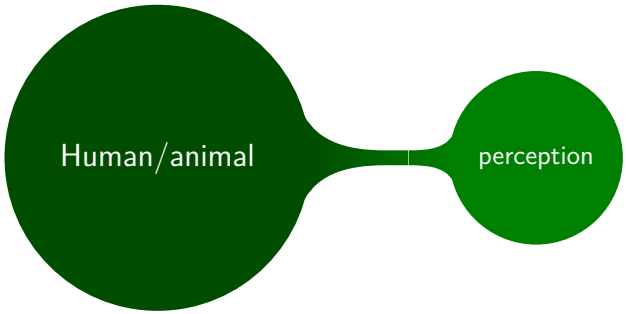

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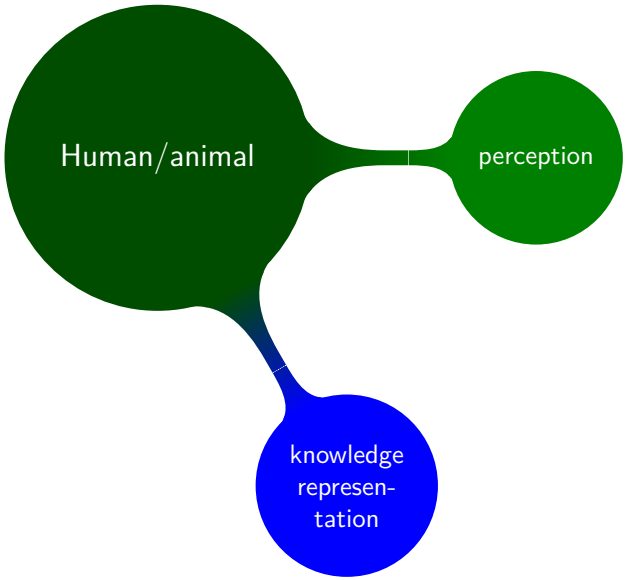

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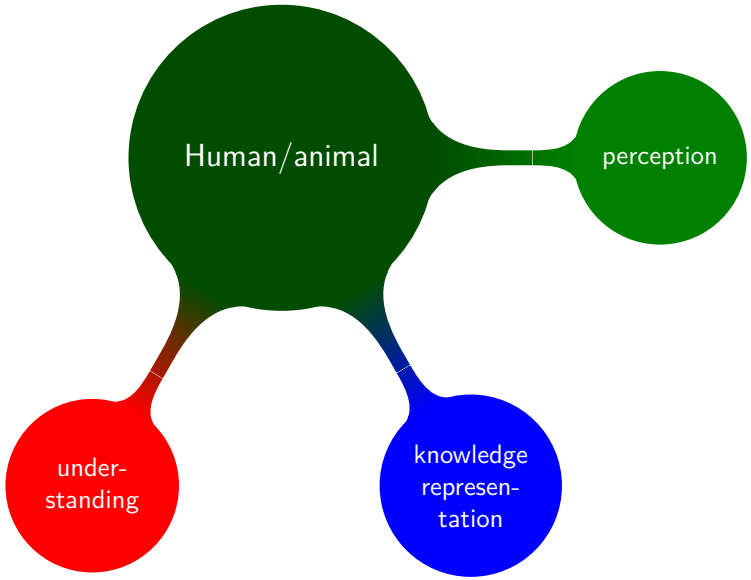

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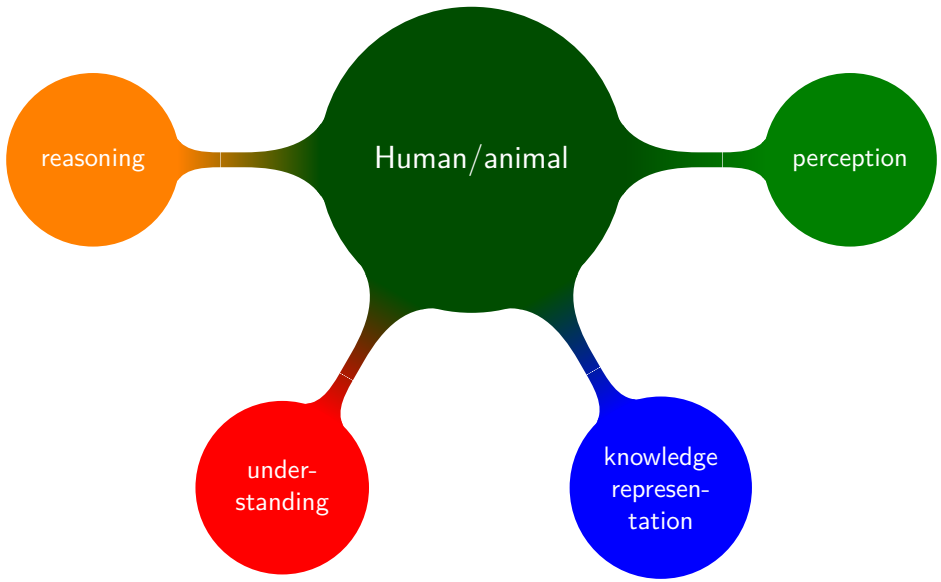

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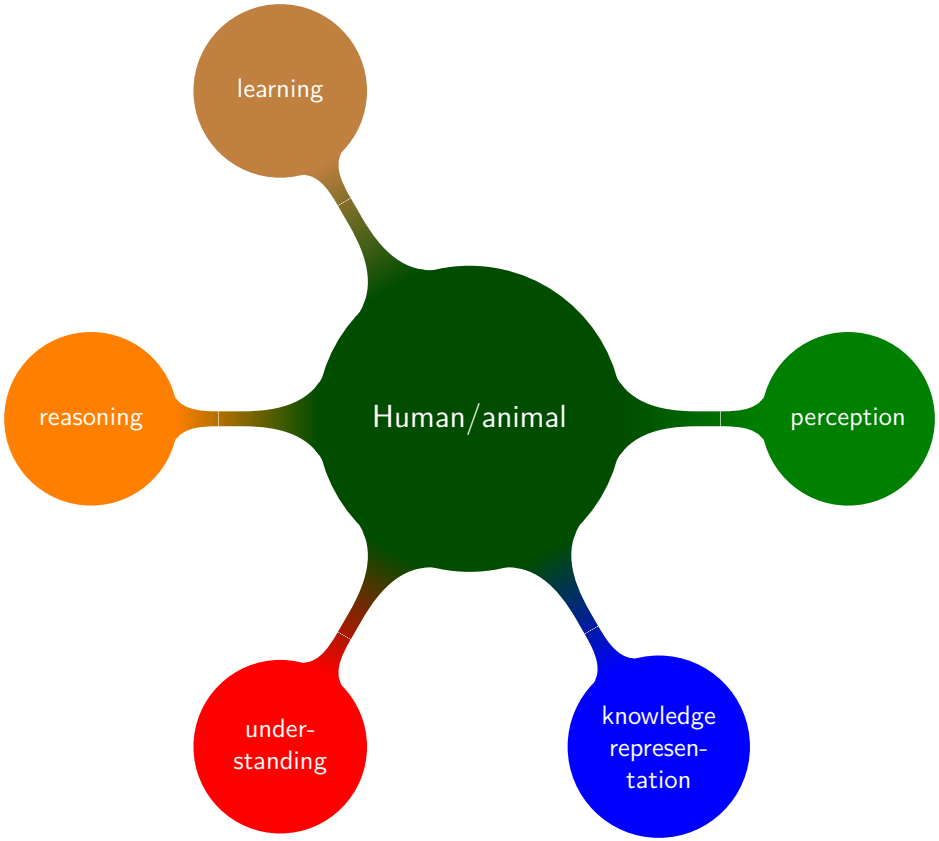

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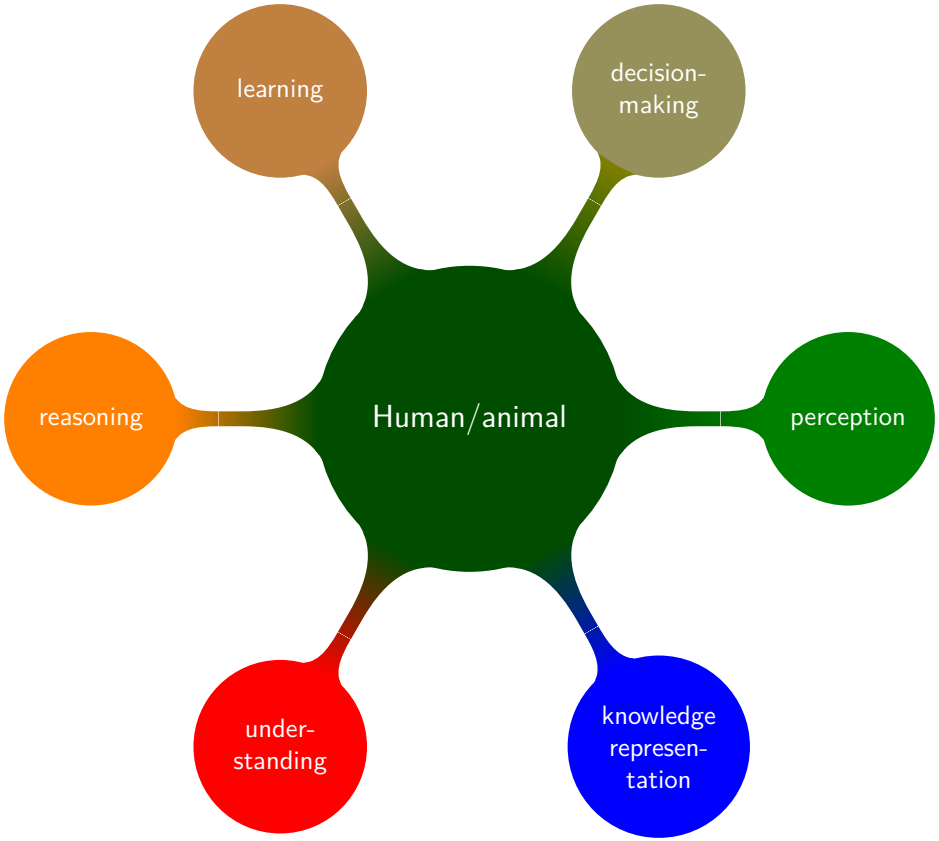

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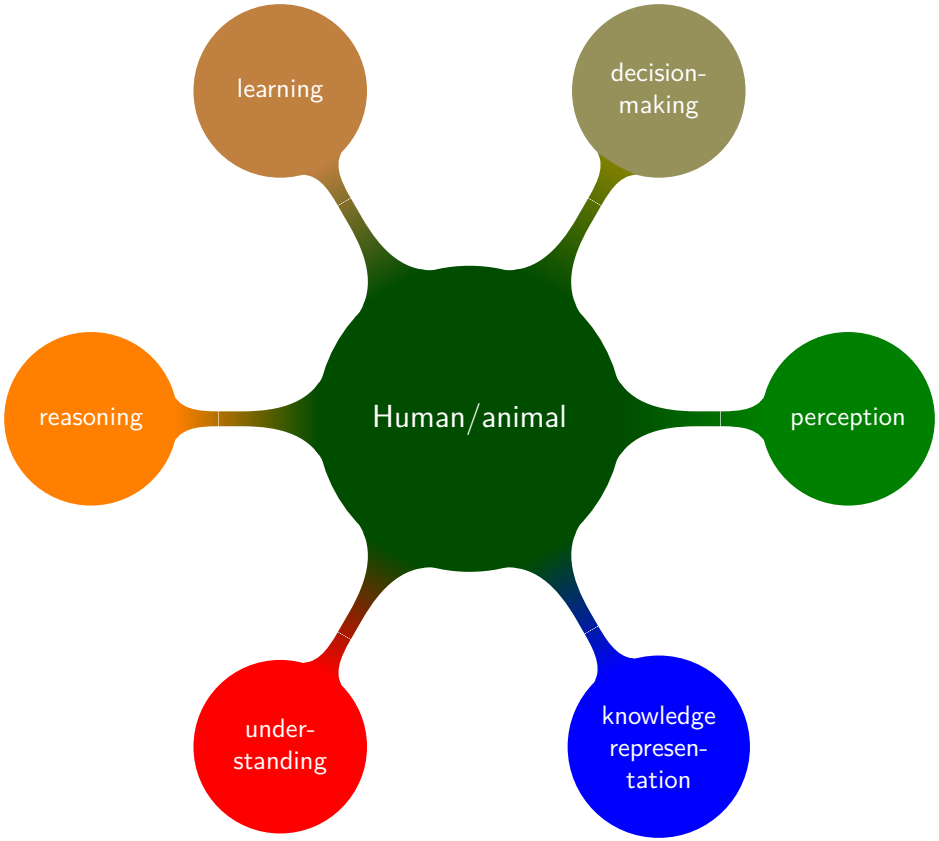

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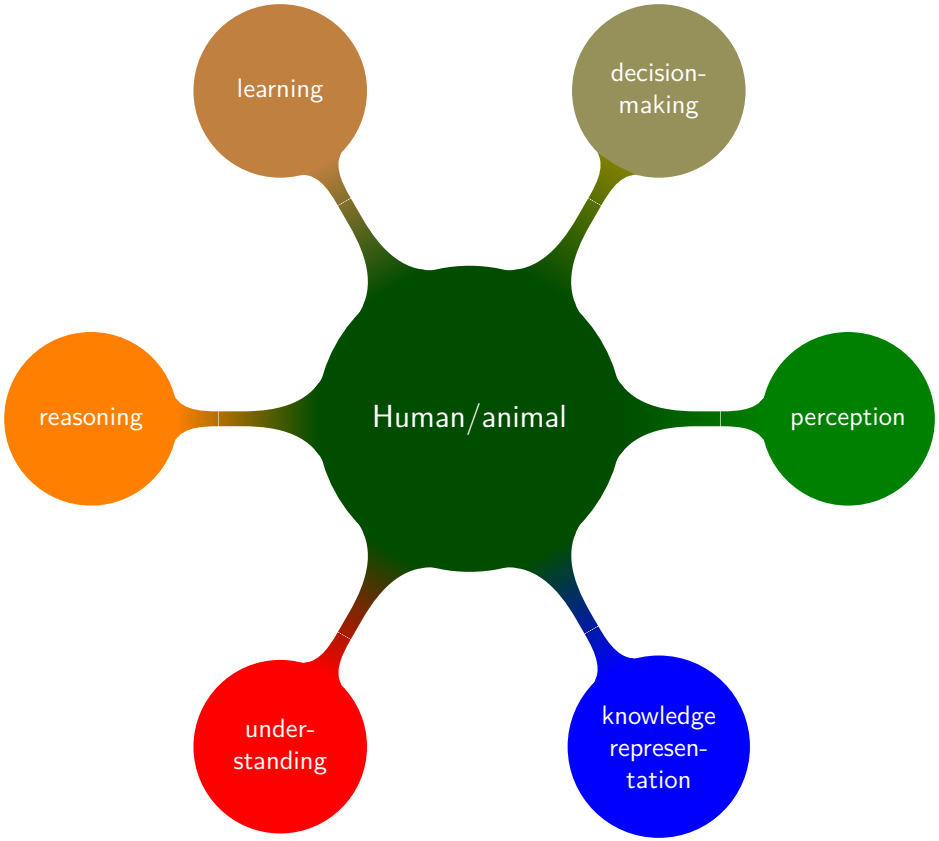

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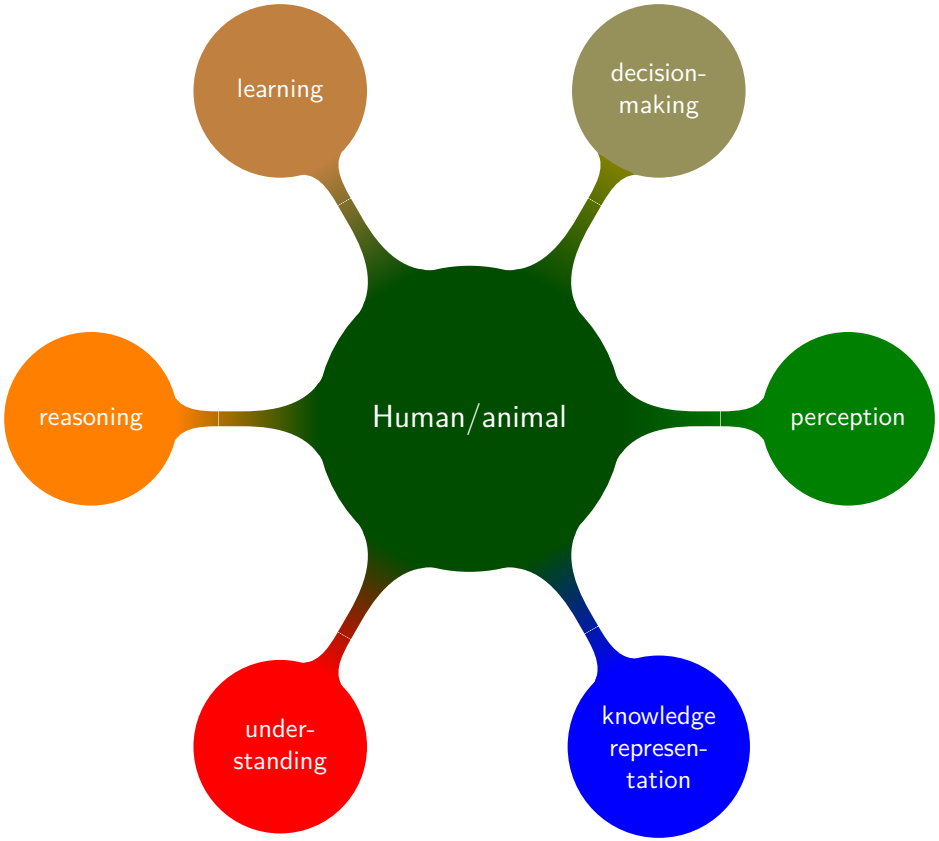

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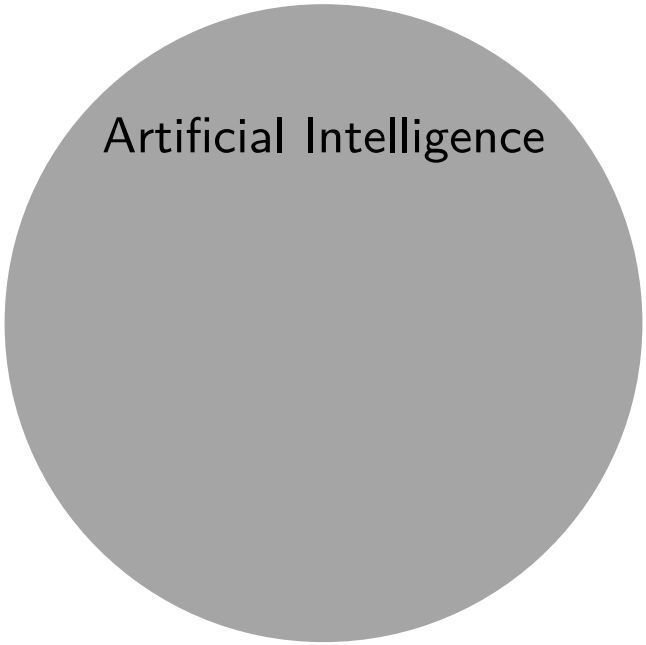

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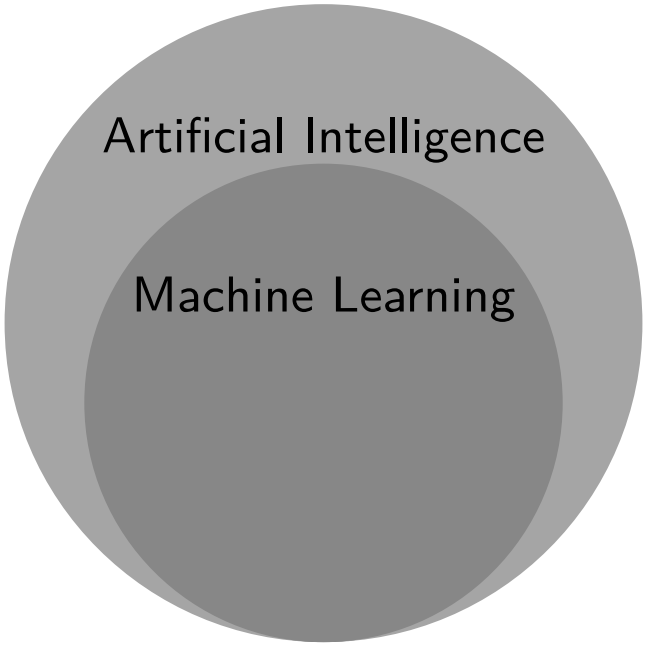

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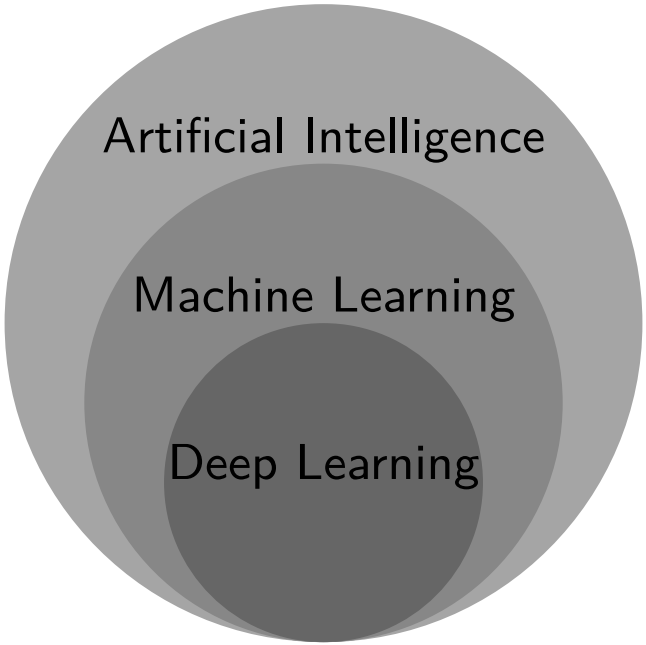

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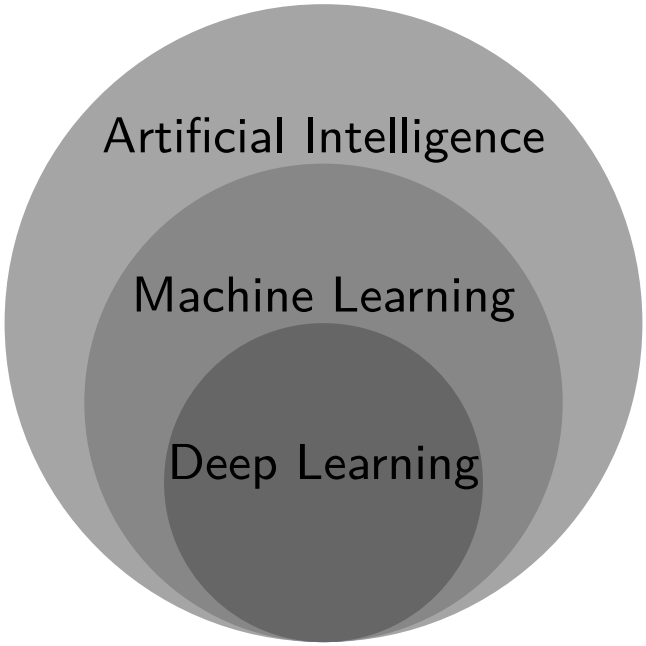

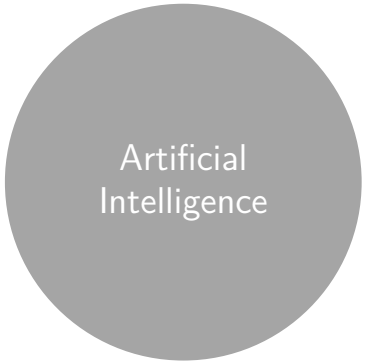

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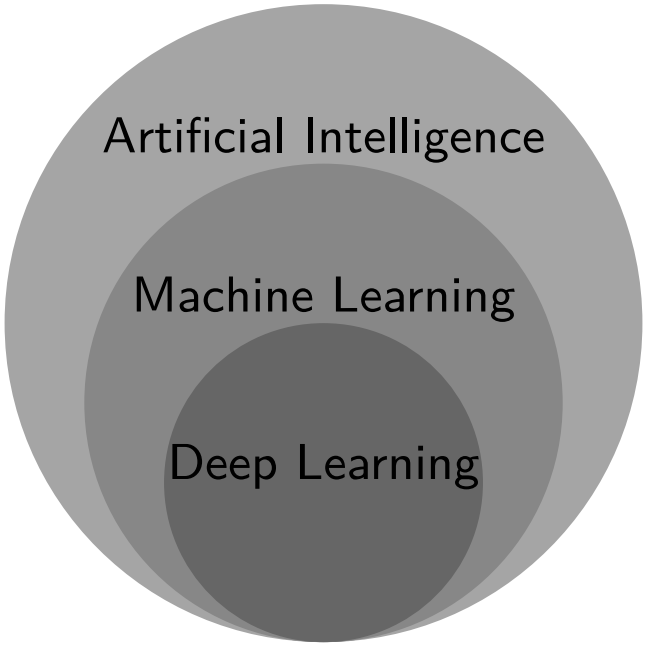

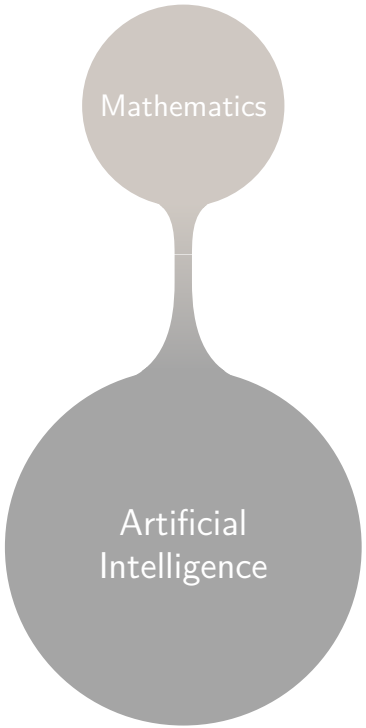

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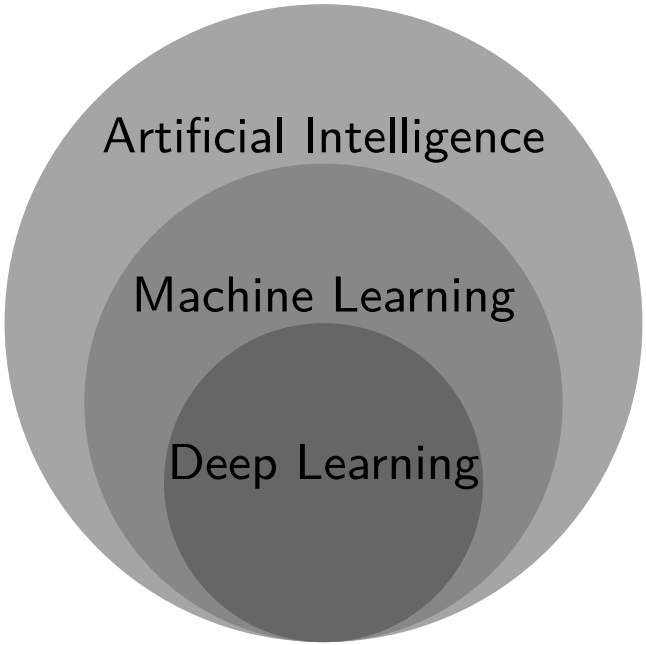

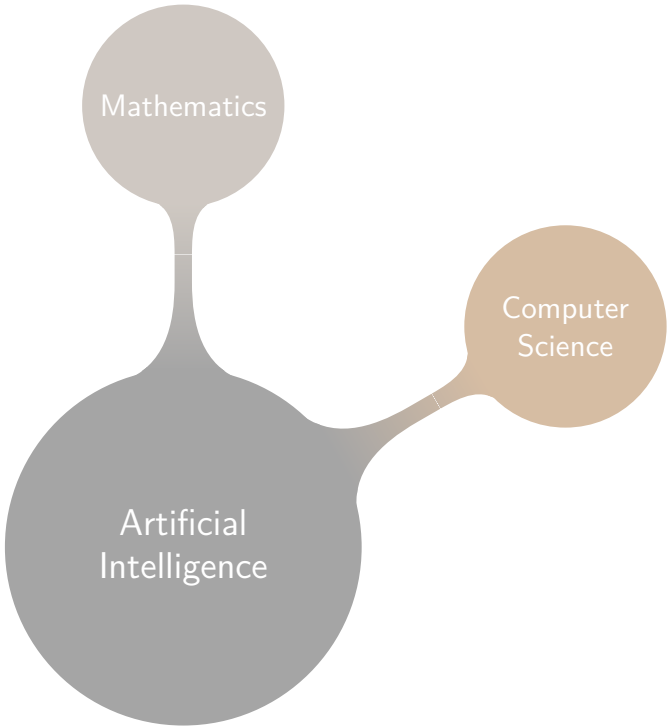

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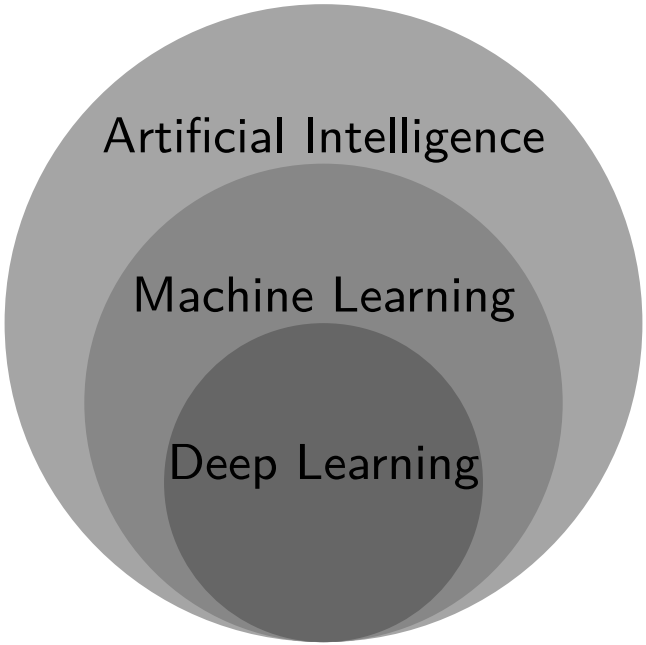

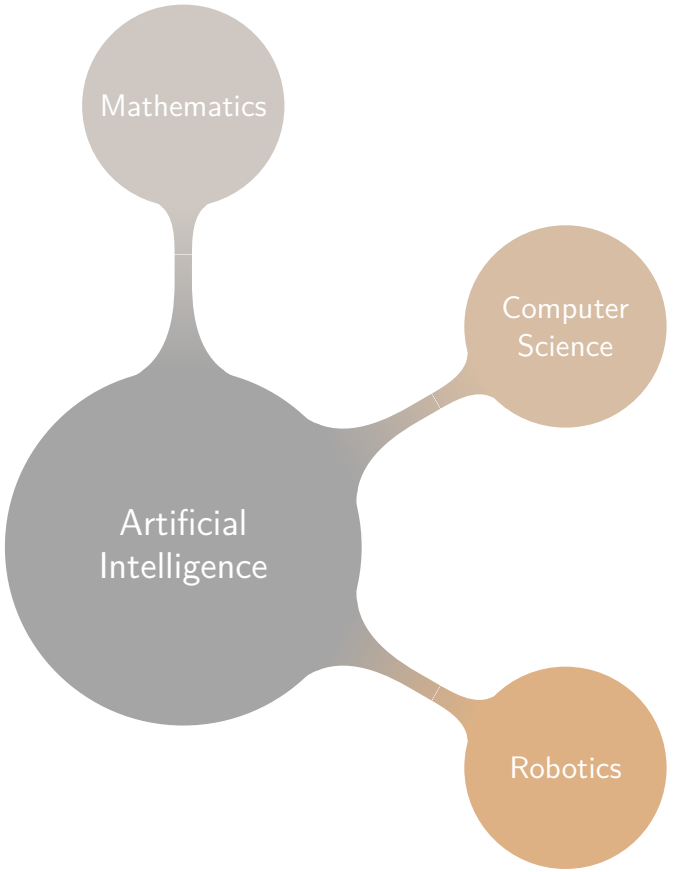

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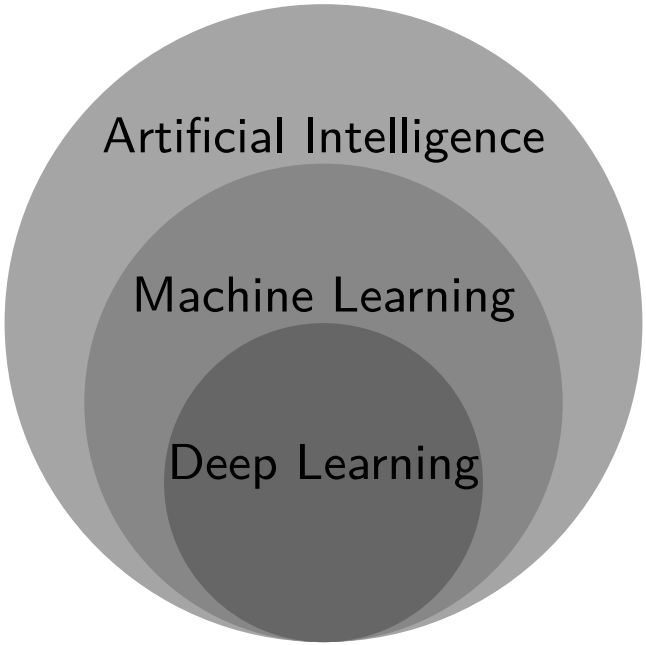

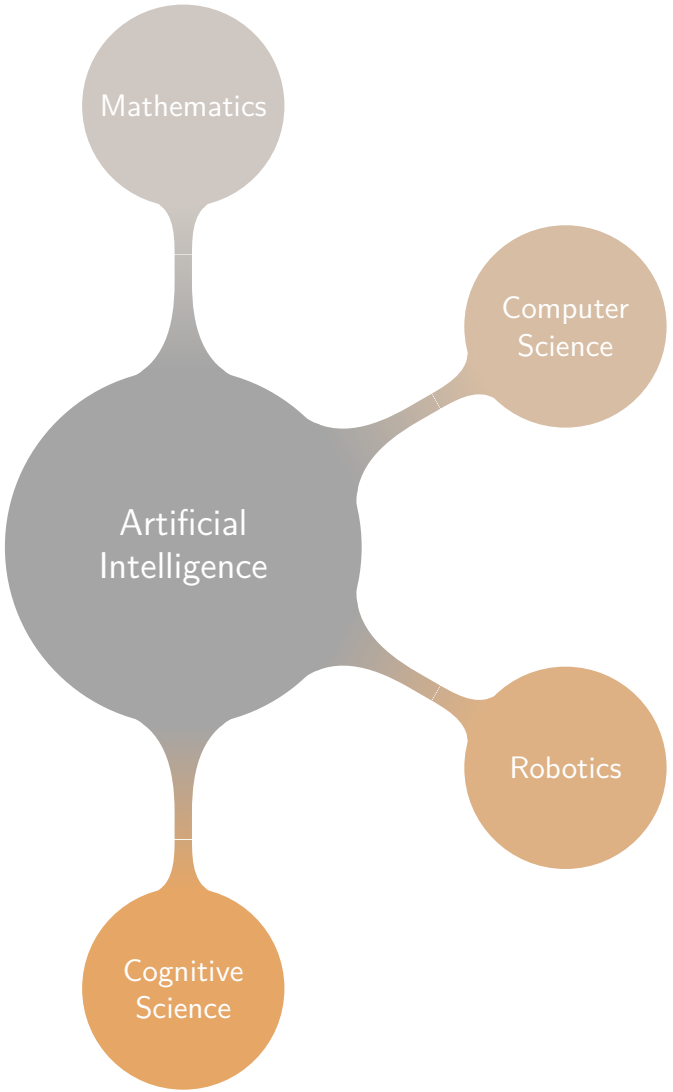

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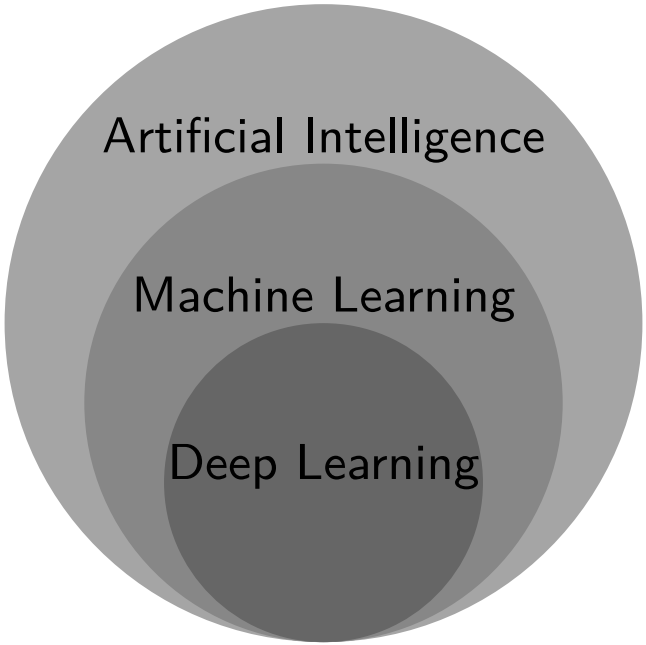

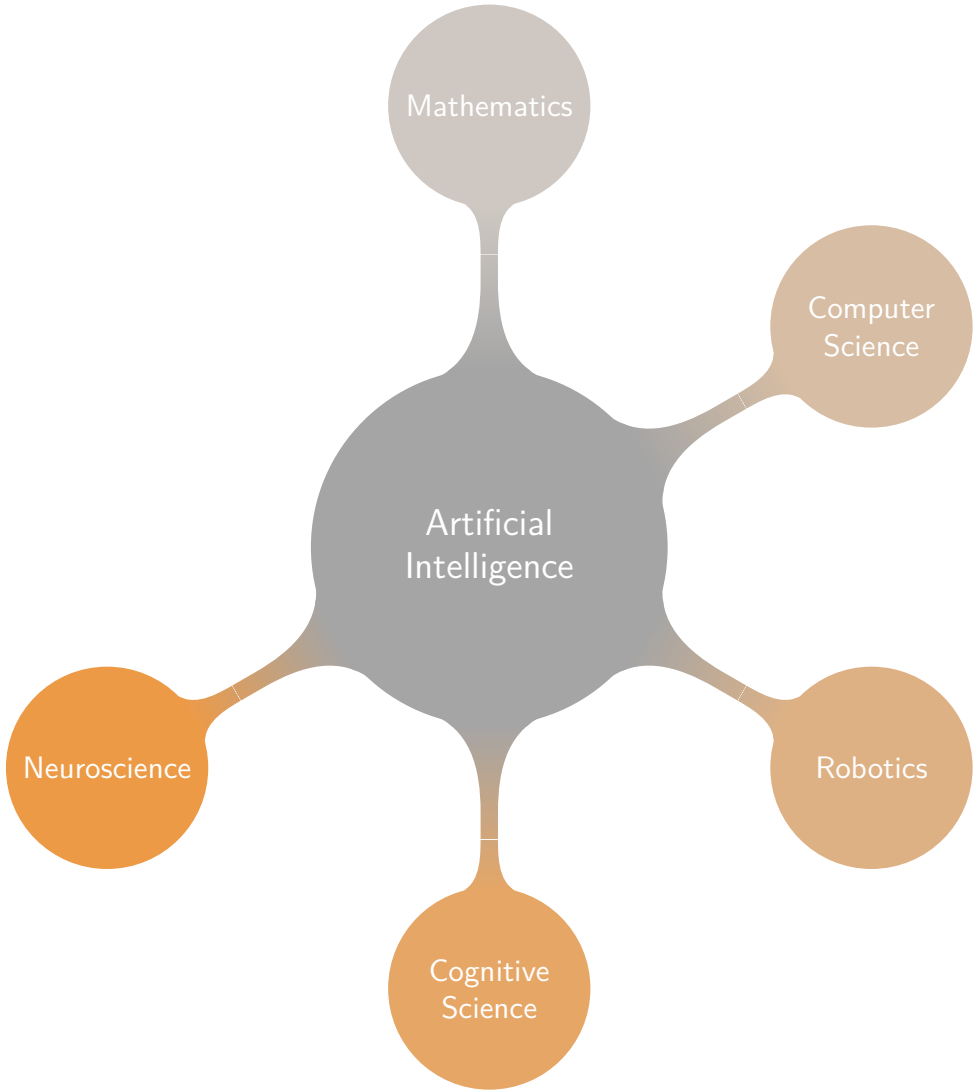

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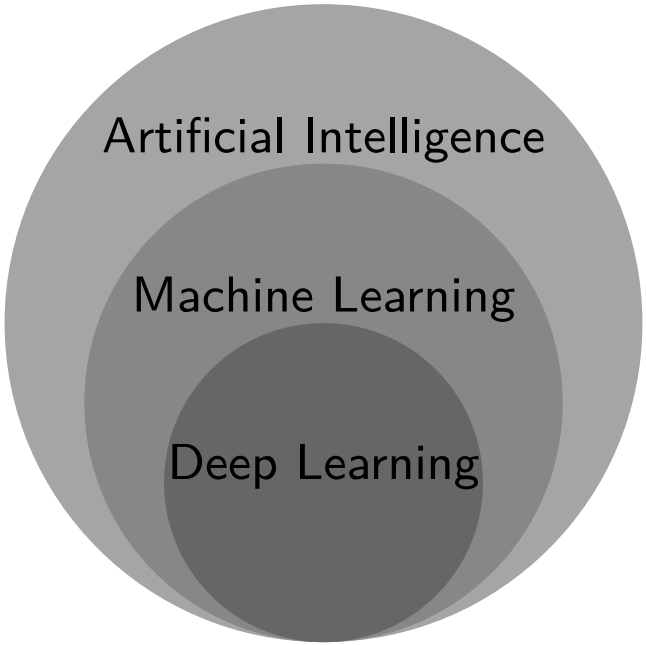

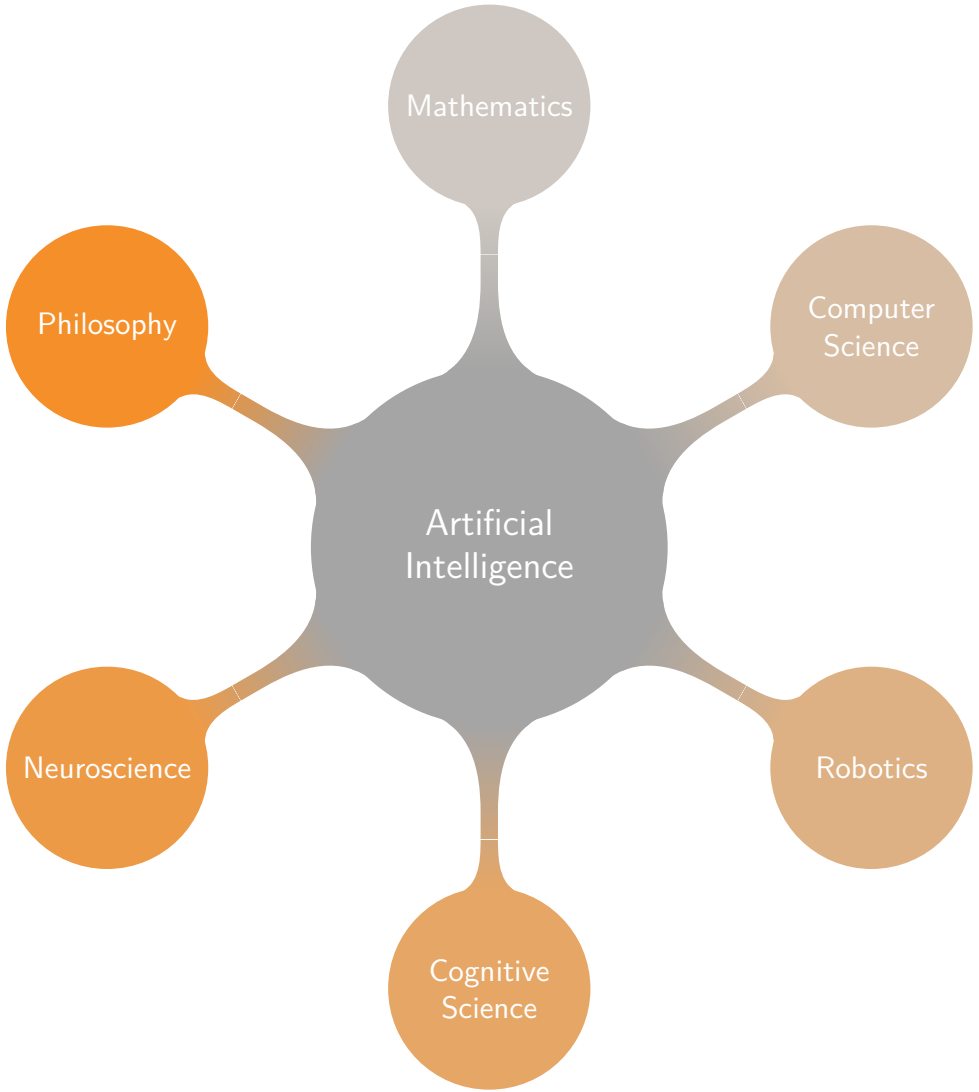

Some Issues Raised by AI

- Ethical questions:
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- Societal impact:
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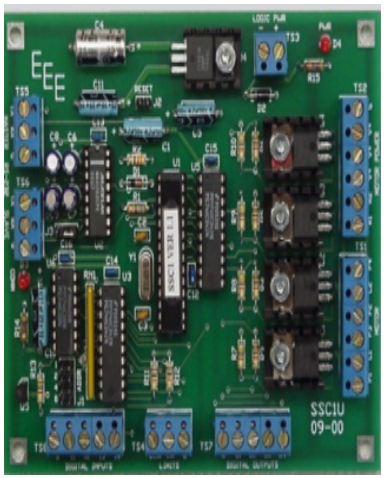
- Philosophical questions
  - What is being a human?
- Existential consequences
  - Is AI a threat to humanity?

What can we do with AI?



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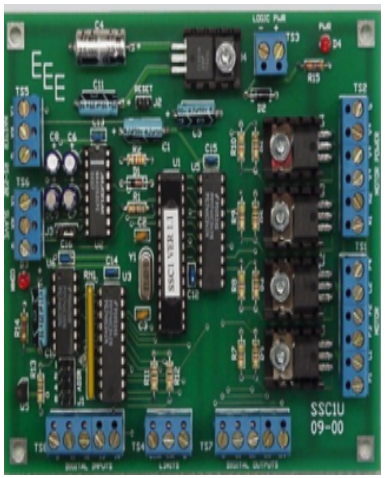

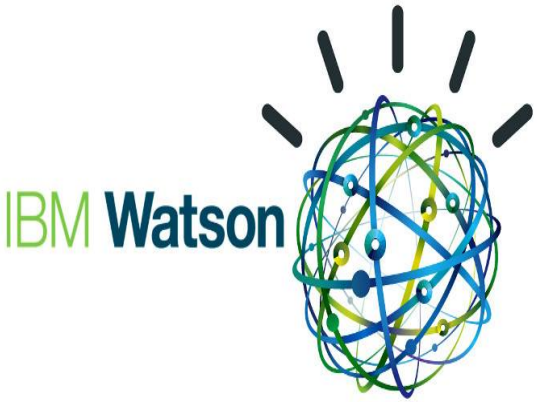

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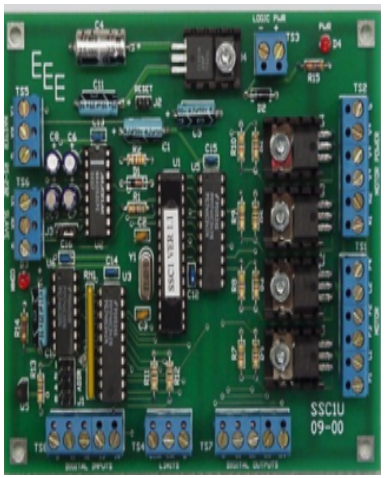

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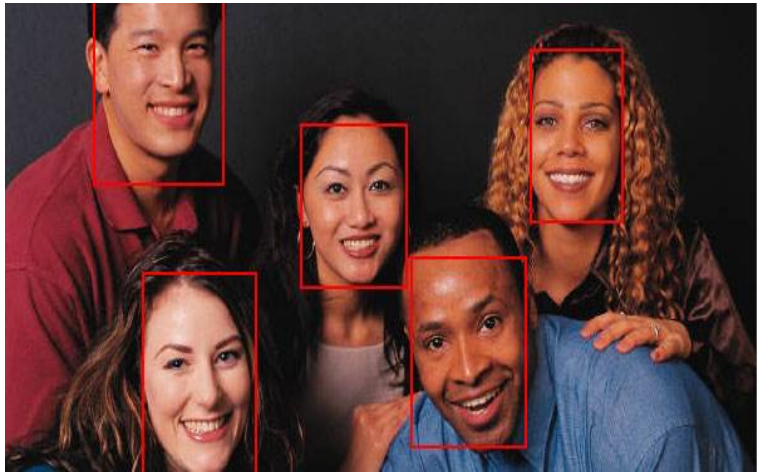

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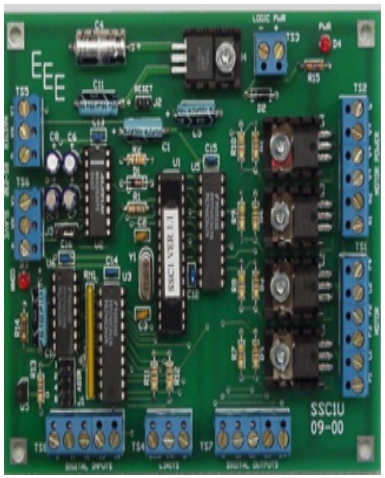

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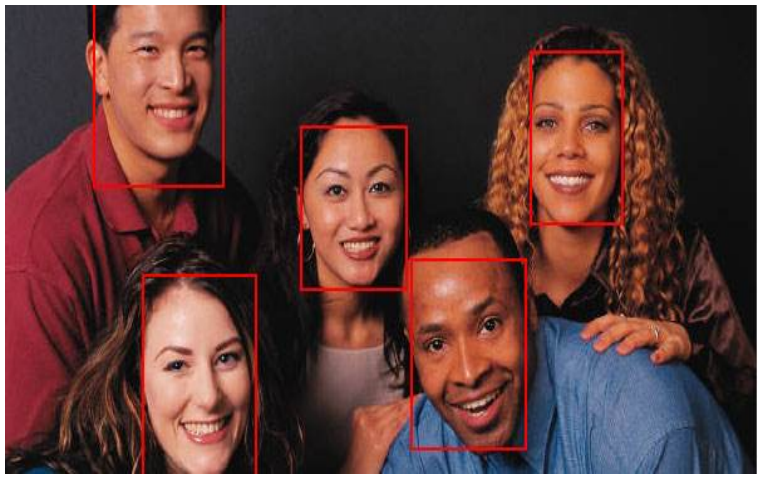

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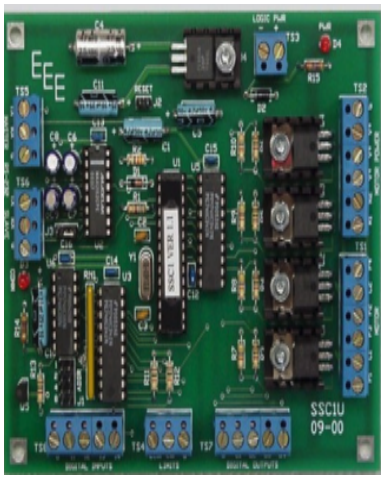

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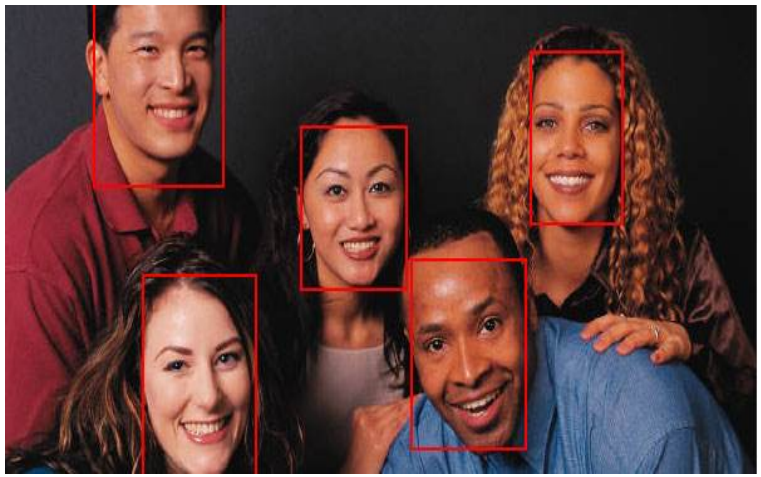

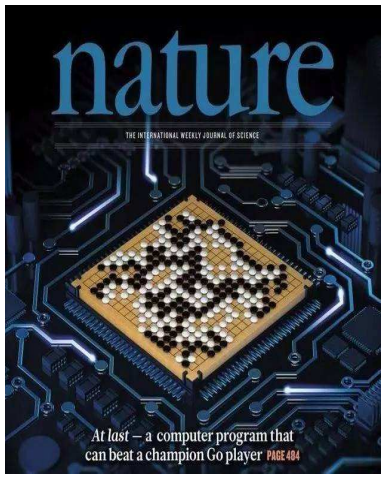

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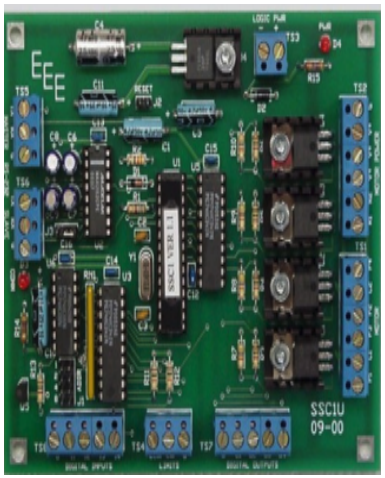

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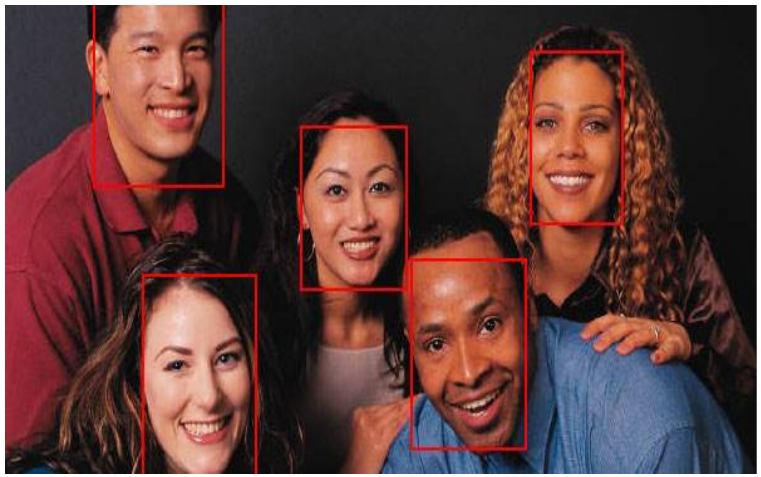
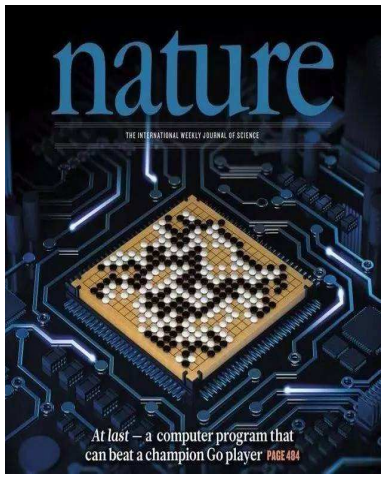


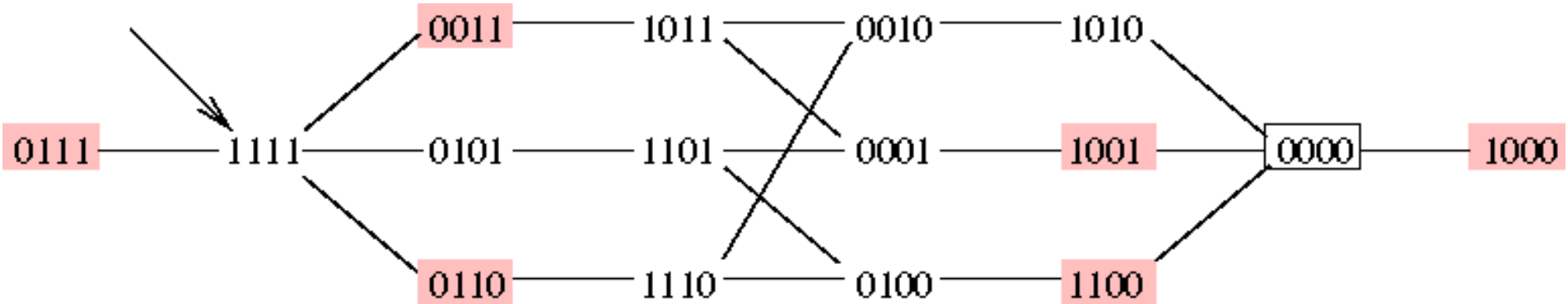


Current state of AI

Boston Dynamics Atlas
Darpa Robotics Challenge 2015

Reasoning: Motivation and Principles

- Reasoning as a search problem
- Example: the wolf, goat, cabbage problem
  You are on the bank of a river with a boat, a cabbage, a goat, and a wolf. Your task is to get everything to the other side. Rules:
  1. only you can handle the boat
  2. when you're in the boat, there is only space for one more item
  3. you can't leave the goat alone with the wolf, nor with the cabbage (or something will be eaten)



Reasoning: Applications

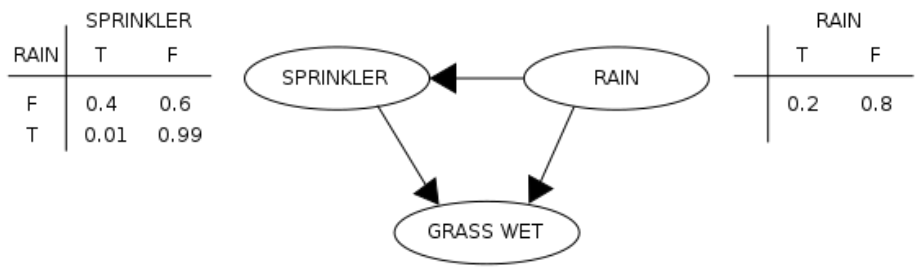
- Constraint Satisfaction Problems (SAT/SMT/CSP solvers)
  - Chip design
  - Software checking
- Minimax Search and Alpha-Beta Pruning
  - Deep blue
- Monte Carlo Tree Search
  - AlphaGo

Reasoning under Uncertainty: Motivation

- World is uncertain
  - Observations come from imperfect sensors
  - Data is often imprecise, missing or contradictory
  - Uncertain knowledge, only beliefs
- Previous reasoning techniques don't work anymore!
- We need a new framework

Reasoning under Uncertainty: Principles and Applications

- Graphical models, e.g., Bayesian network



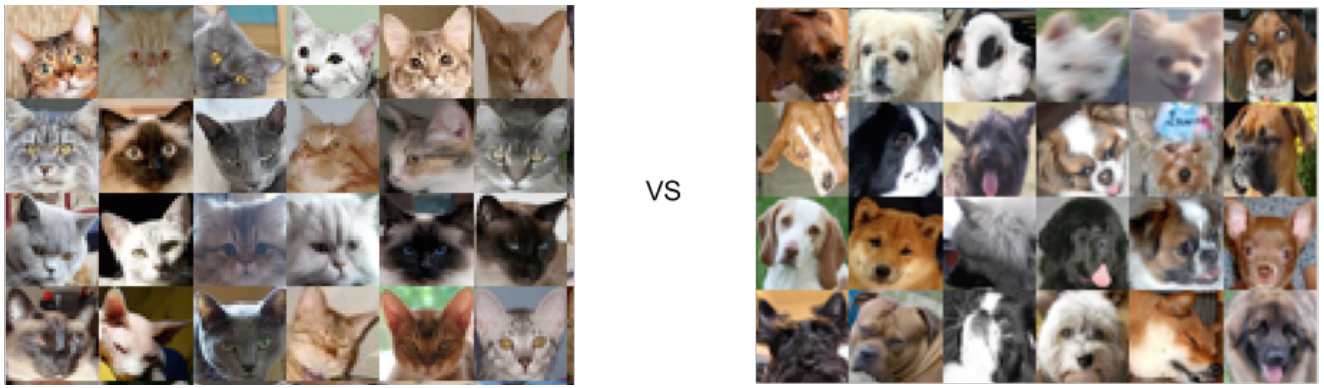
RAIN	SPRINKLER T	SPRINKLER F
F	0.4	0.6
T	0.01	0.99

RAIN T	RAIN F
0.2	0.8

SPRINKLER	RAIN	GRASS WET T	GRASS WET F
F	F	0.0	1.0
F	T	0.8	0.2
T	F	0.9	0.1
T	T	0.99	0.01

- Applications:
  - Diagnostic
  - Prediction

Learning: Principles



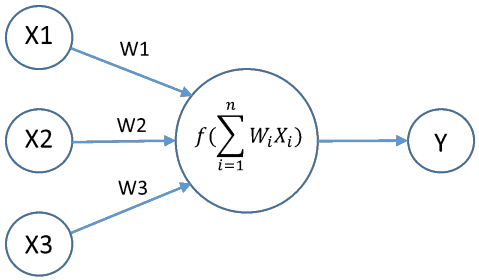
- Statistical learning as an optimization problem

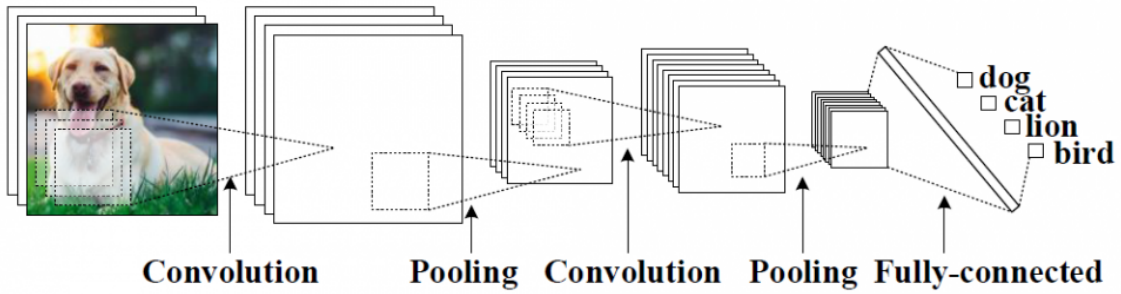
$$R_{\text{emp}}(h) = \frac{1}{m} \sum_{i=1}^{m} L(h(x_i), y_i) + \lambda C(h)$$

- (Stochastic) gradient descent

Learning: Techniques

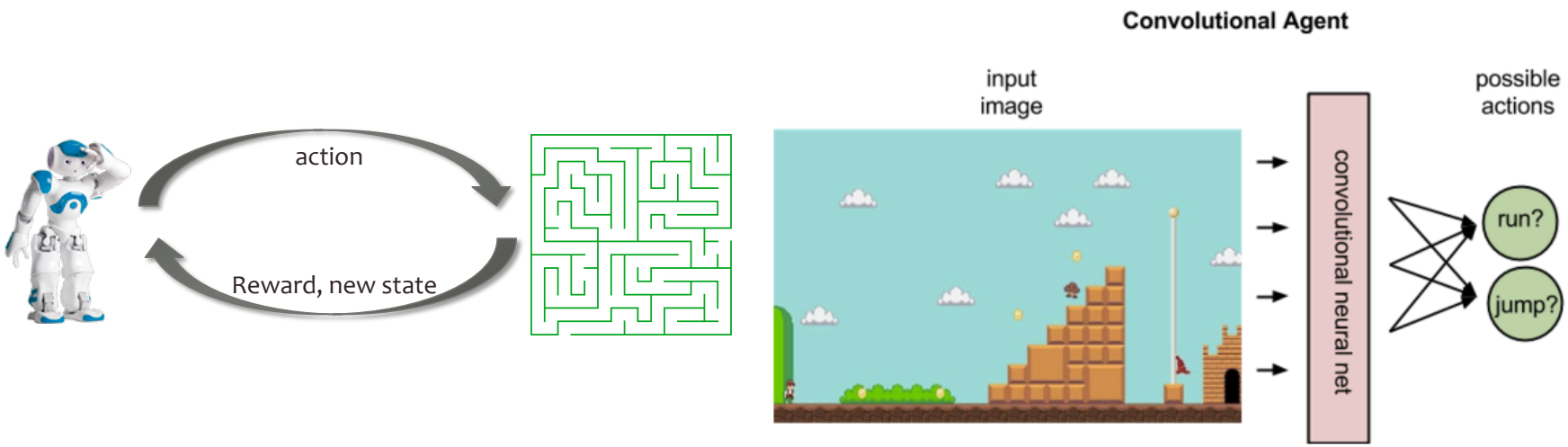
- Deep learning





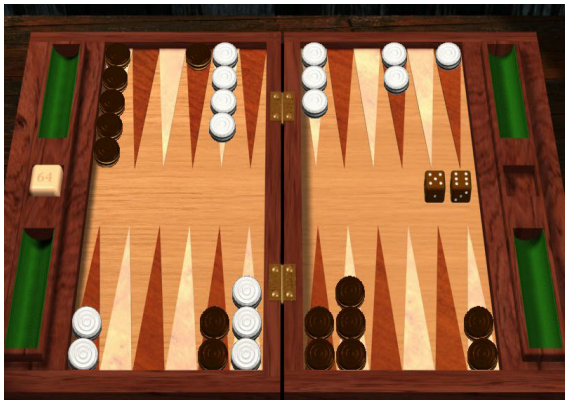
- Gradient boosting (usually with decision trees)
  - Yahoo ranking challenge
  - Higgs machine learning challenge

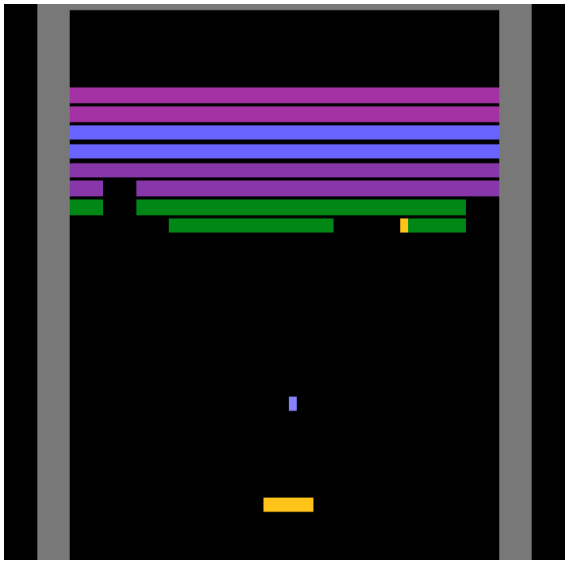
((Sequential) Decision-making (under uncertainty)



- Markov decision process
- (Deep) reinforcement learning

Decision-making: applications



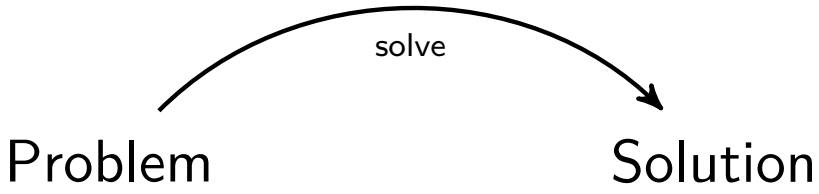


What is not covered in this course?

- Optimization problems (e.g., linear programming, convex optimization)
  VM 555 Engineering Optimization
- Many AI techniques not covered (e.g., logic-based knowledge representation, Markov random field)
- Many machine learning techniques (e.g., SVM, semi-supervised learning, unsupervised learning)
  VE492 Artificial intelligence
  VE572 Methods and tools for big data
  Courses from visiting faculty
- Advanced deep learning (e.g., latest neural architecture, GAN)

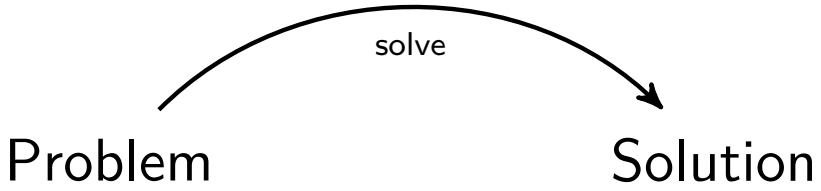
Problem Solving

Ideally

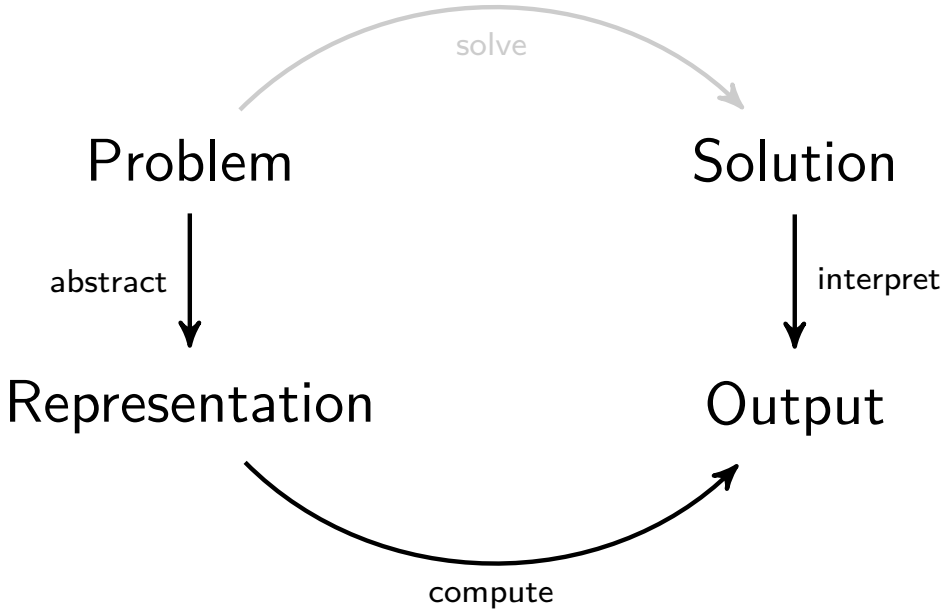


Problem Solving

Ideally



In practice



Problem Solving

Real-World Problem

Formulation of Abstract Problem

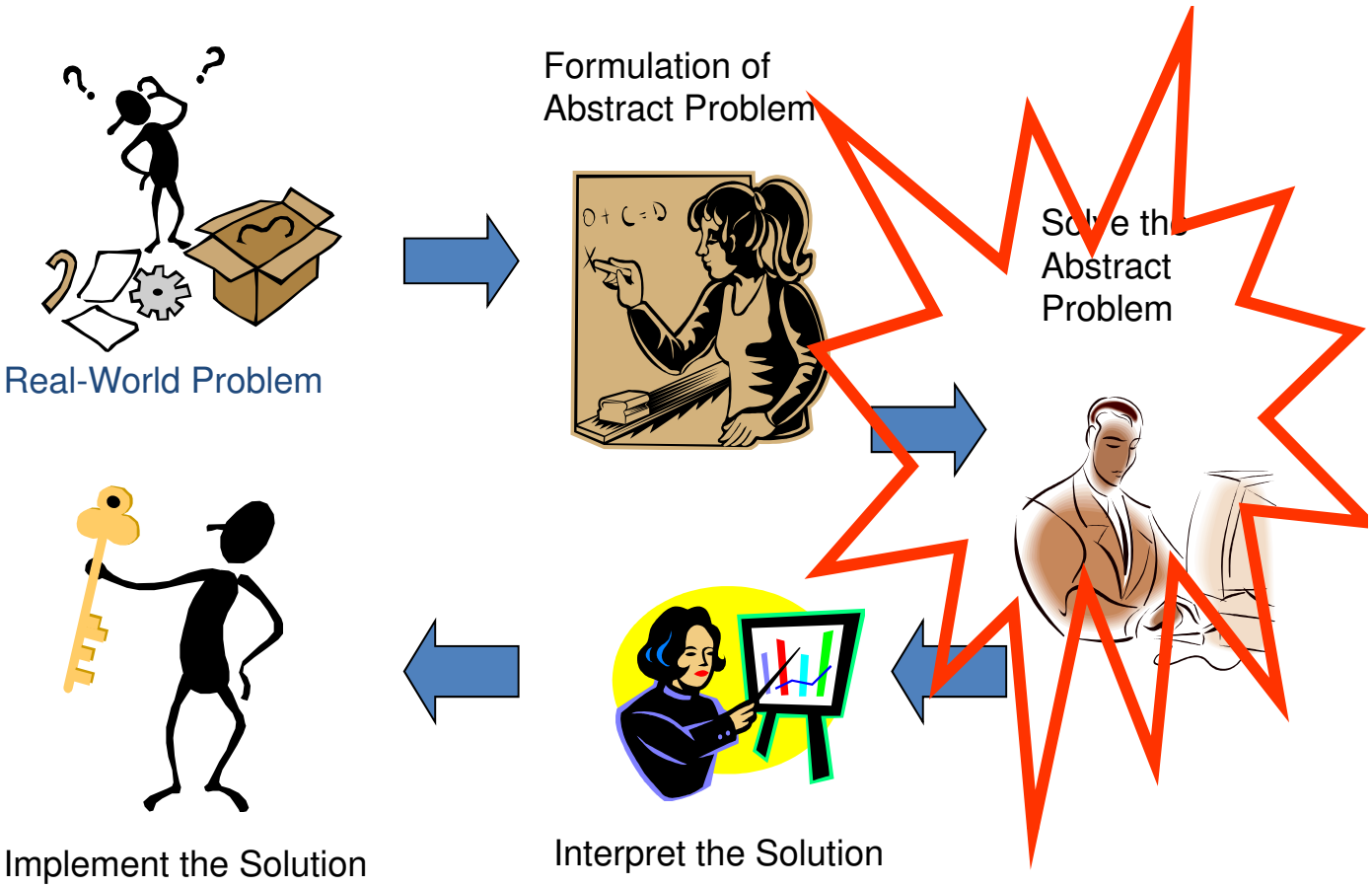
Solve the Abstract Problem

Interpret the Solution

Implement the Solution

[From A. Løkketangen]

Problem Solving



[From A. Løkketangen]