LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Praktikum Autonome Systeme

An Introduction to Autonomous Systems

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WiSe 2019/20

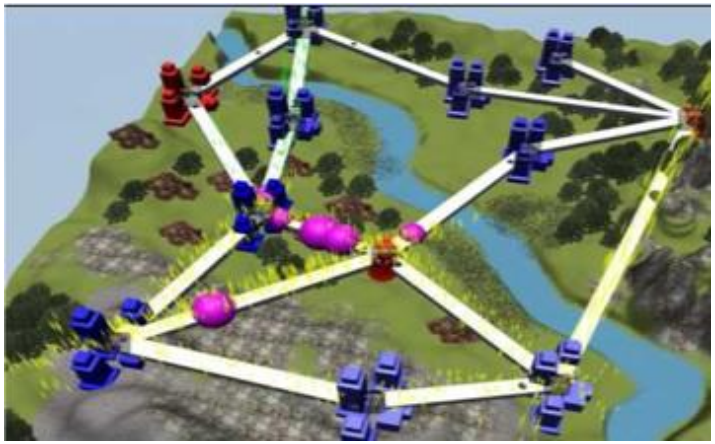
→ **Autonomous Systems**

What is an Autonomous System?

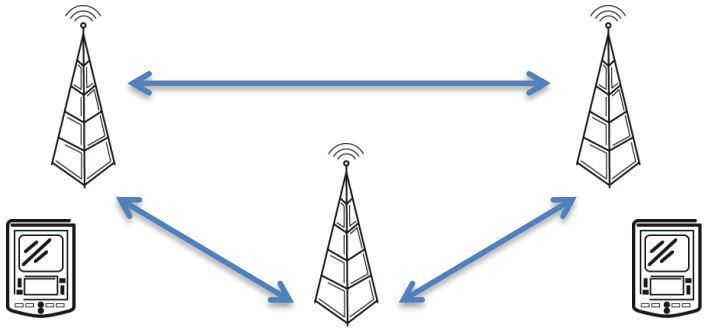
Definition: A system, which can operate without human intervention.

(Possible) Real-World Applications

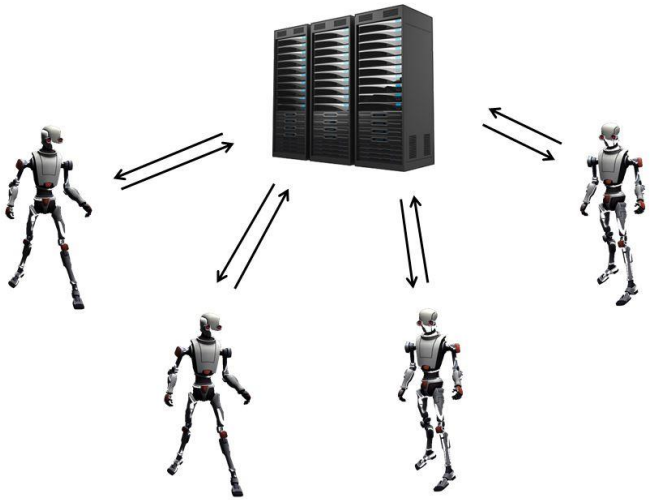
Smart Grids / Cities



Intelligent / Mobile Networks



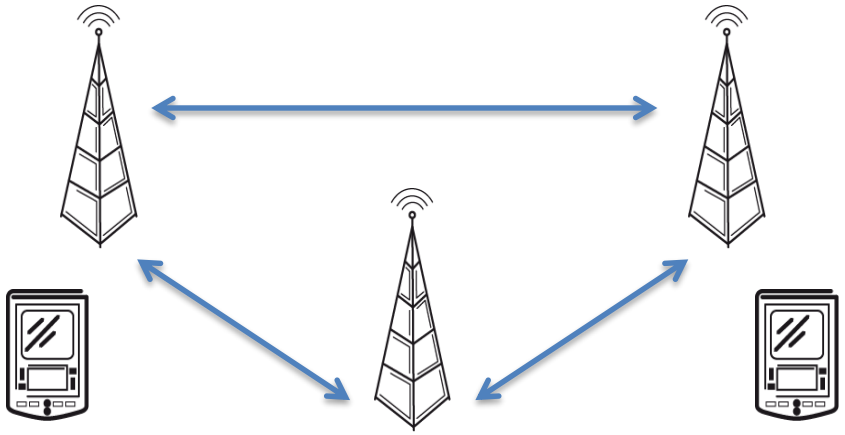
Robotics



Industry 4.0

Properties of Autonomous Systems

- Self-CHOP
  - Self-Configuration
  - Self-Healing
  - Self-Optimization
  - Self-Protection
- More Self-Properties
  - Self-Learning
  - Self-Organization
  - Self-Regulation
  - …



M. Salehie and L. Tahvildari, Autonomic Computing: Emergent Trends and Open Problems, ACM SIGSOFT Software Engineering Notes, 2005

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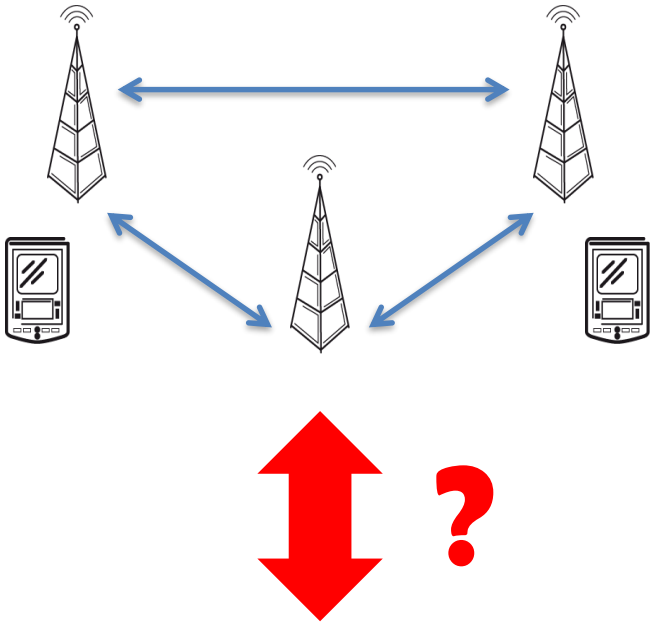
Challenges of Autonomous Systems

- Dynamic Environments
- High Complexity
- Many Constraints:
  - Perception
  - Computational and Memory Resources
  - Energy Consumption
  - Communication
- Safety and Risk
- Security
- Quality Management



→ **Artificial Intelligence**

Why Artificial Intelligence?

AlphaGo (Zero)

https://deepmind.com/research/case-studies/alphago-the-story-so-far

AlphaStar

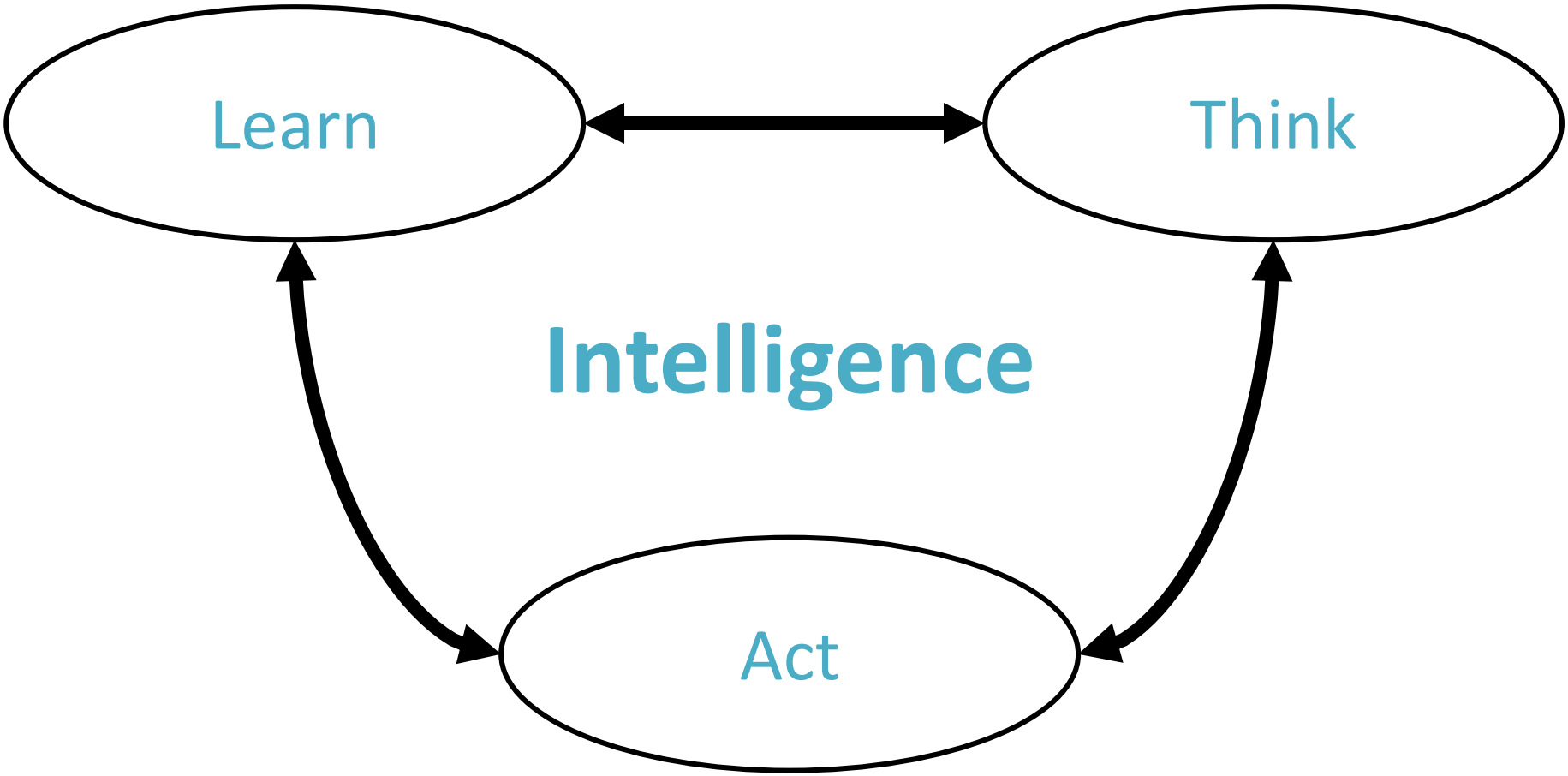
https://deepmind.com/blog/article/alphastar-mastering-real-time-strategy-game-starcraft-ii

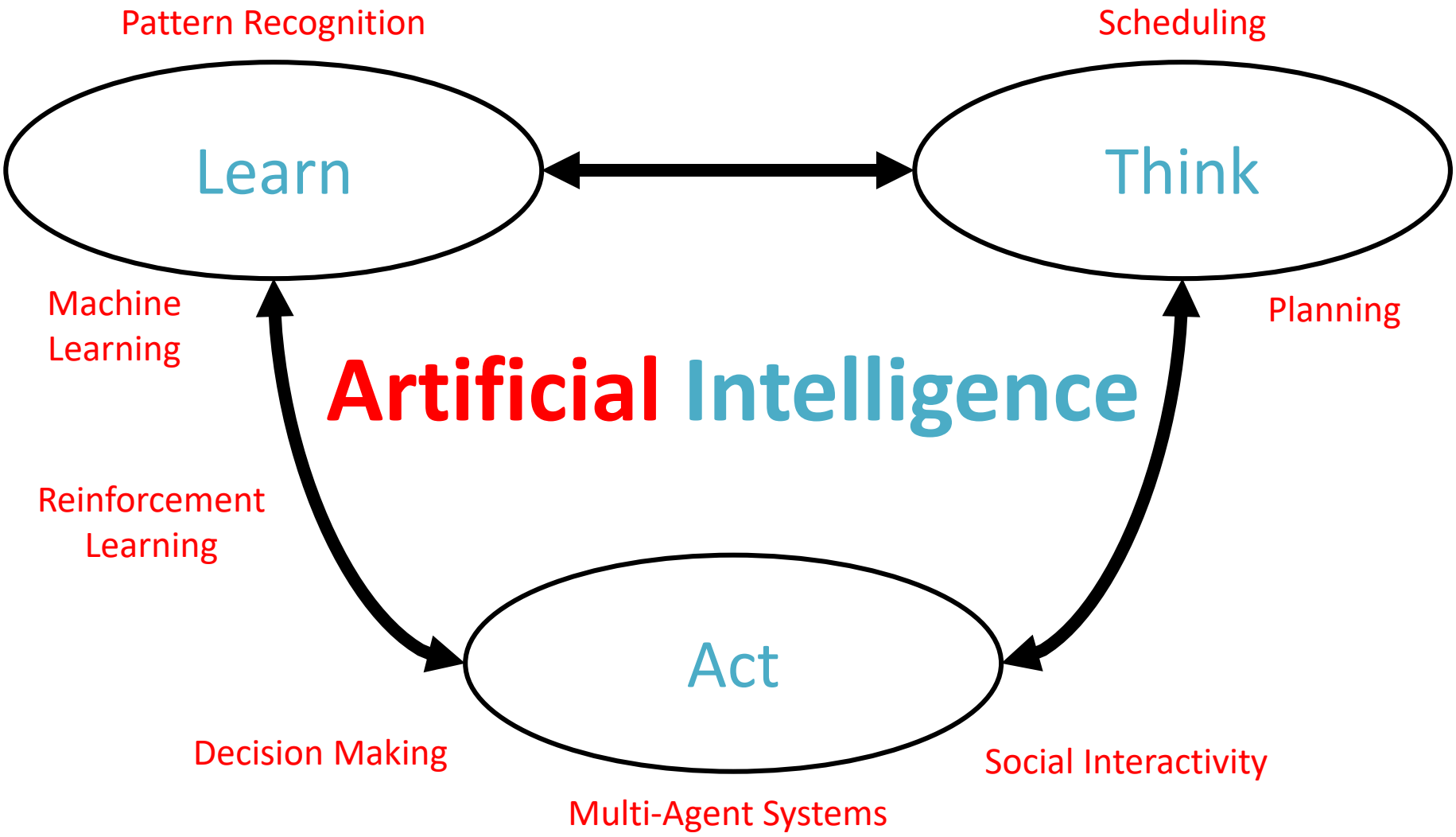
OpenAI Five

https://openai.com/blog/openai-five/

Walking Robot

https://bair.berkeley.edu/blog/2018/12/14/sac/


Learn
Think
Intelligence
Act


Pattern Recognition
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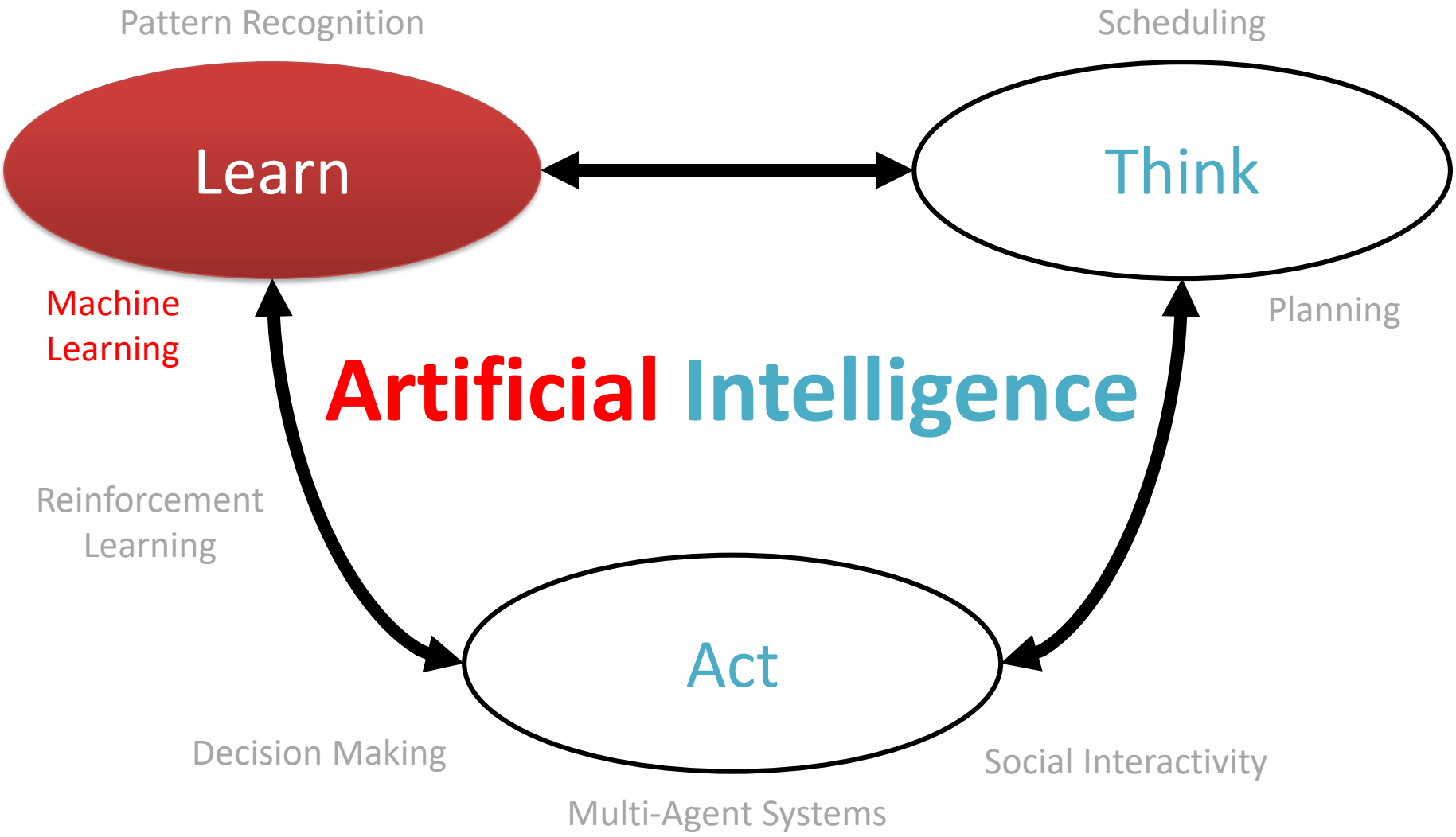
Social Interactivity
Multi-Agent Systems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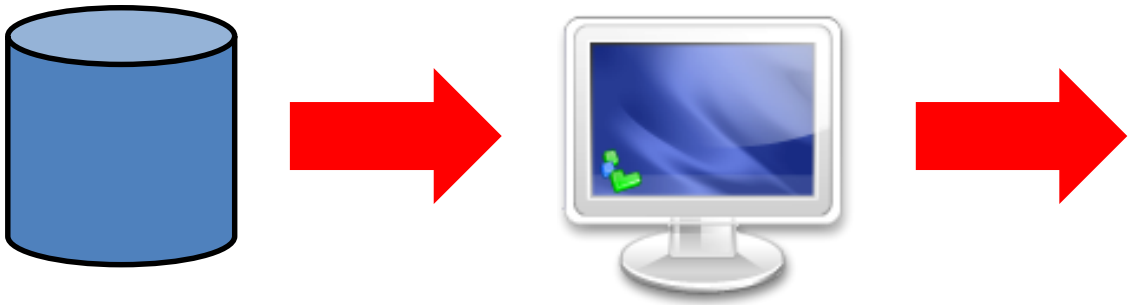
Machine Learning

- **Goal:** Create programs that learn how to solve complex problems
- Learn statistical models from **experience / data**



Object Recognition

Prediction

Control

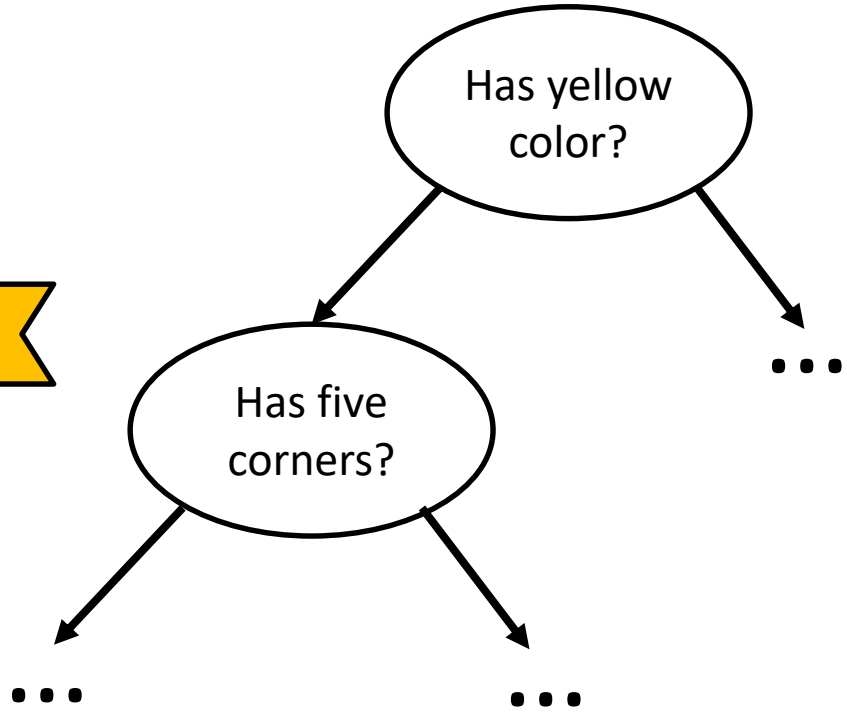
Compression

Data Generation

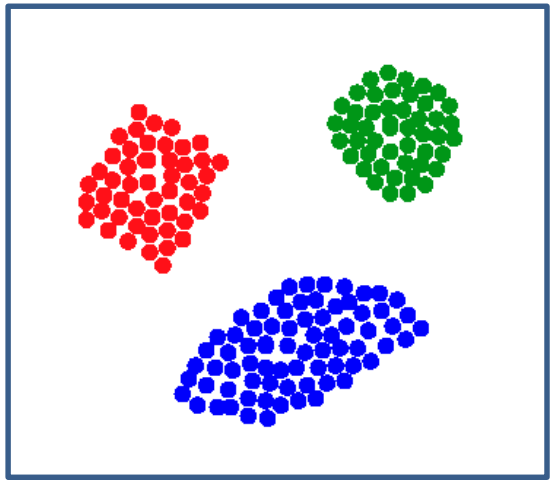
...

Why Machine Learning?

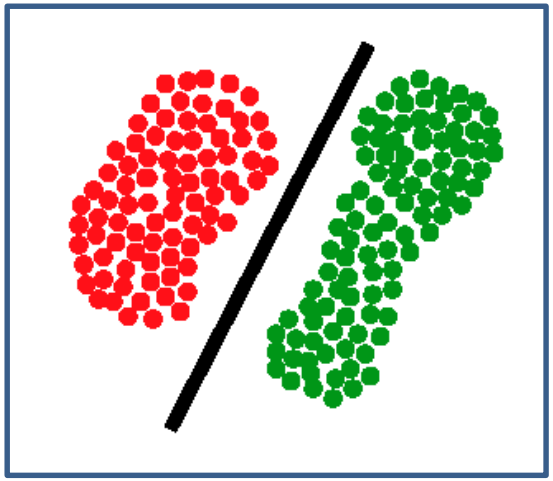
- **Goal:** Create programs that learn how to solve complex problems
- Many problems cannot be solved by engineering handcrafted solutions
  - Too many aspects to consider
  - Too many rules
  - Hard adaption to changes
  - Hard generalization
- **Example:**
  - How to classify a star?



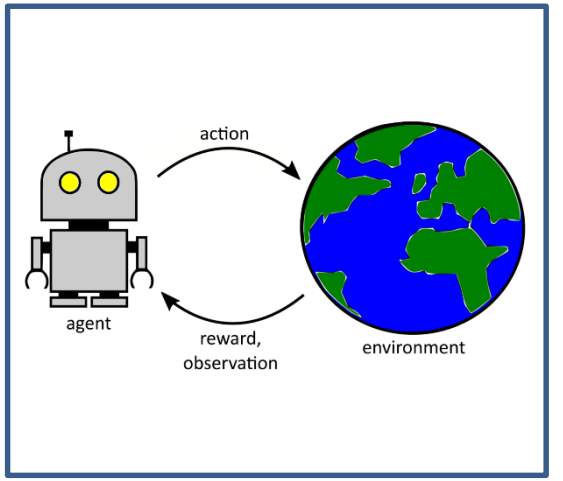
Types of Machine Learning



Unsupervised Learning



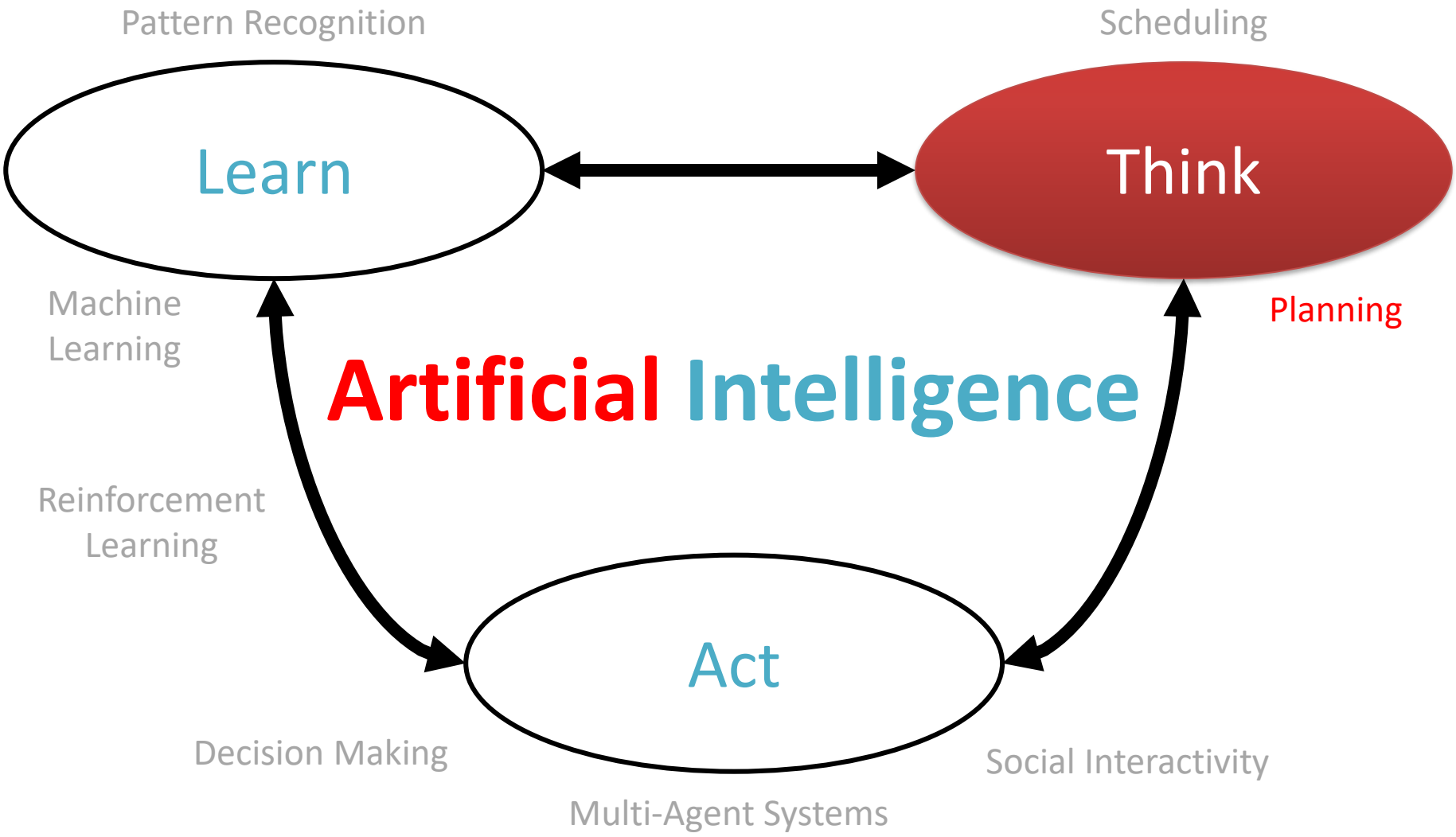
Supervised Learning



Reinforcement Learning

Challenges of Machine Learning

- Data Availability
- Data Complexity
- Efficiency
- Compactness
- Interpretability
- Robustness
- Adaptivity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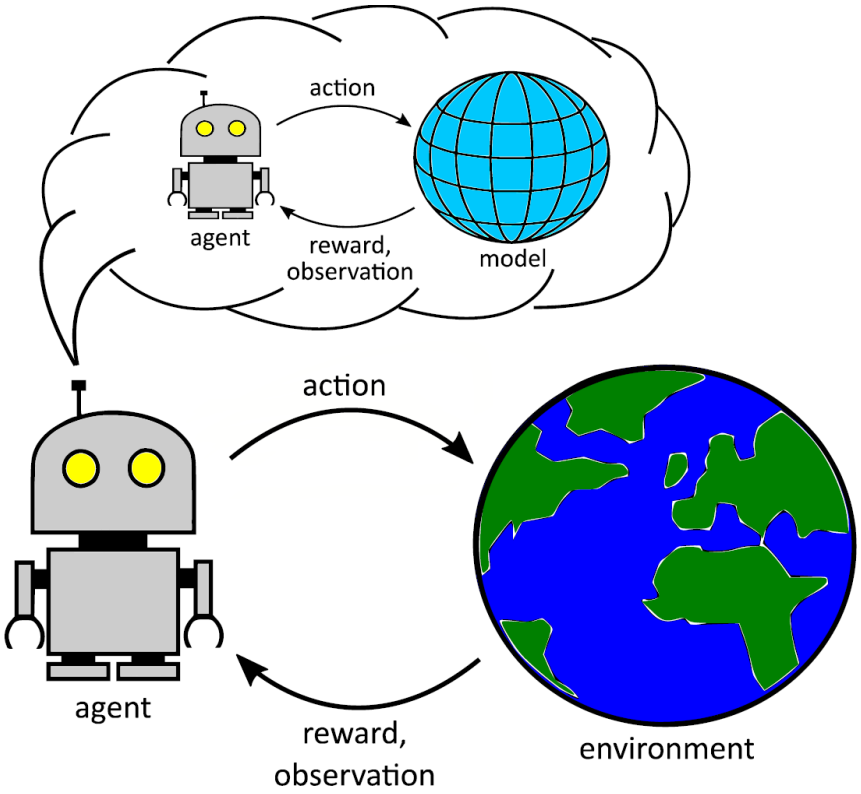
Automated Planning

- **Goal:** Find (near-)optimal strategies to solve complex problems
- Use (heuristic) lookahead search on a **given model** of the problem

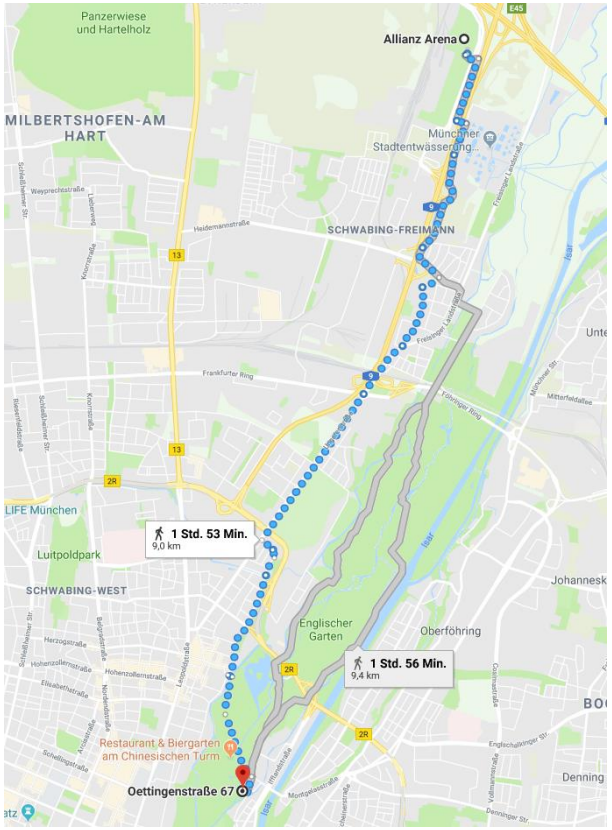


Why Automated Planning?

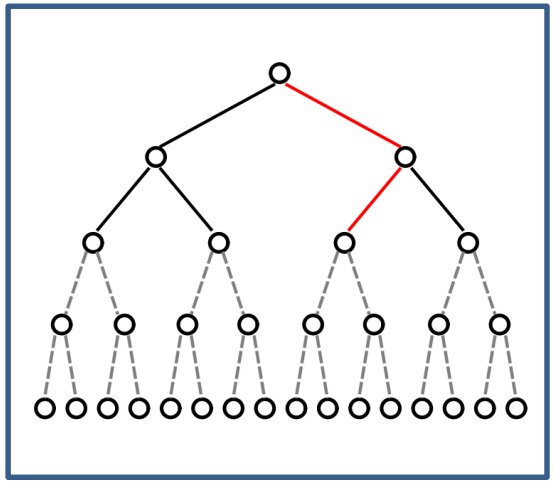
- **Goal:** Find (near-)optimal strategies to solve complex problems

- Planning is necessary, if **explicit reasoning** is required:
  - Consideration of risks and uncertainties
  - Consideration of hard constraints

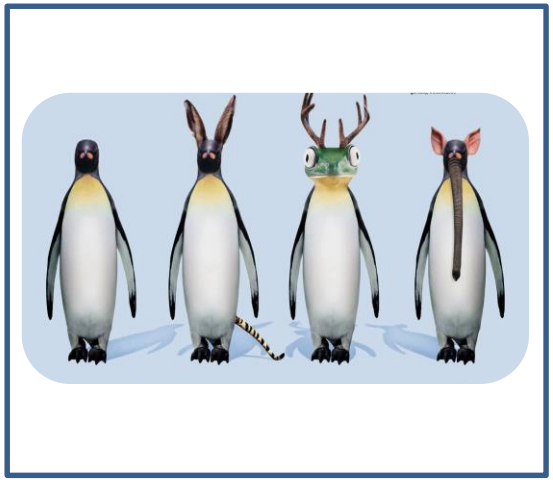
- Planning is **flexible**:
  - Use the same method for different problems by replacing the model
  - Search for multiple alternative strategies



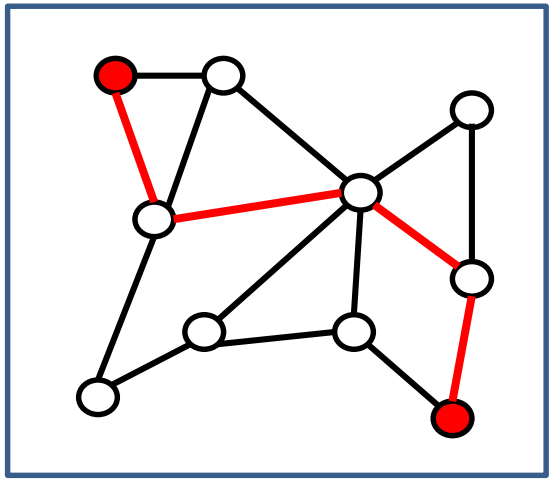
Planning Approaches (Examples)



Tree Search



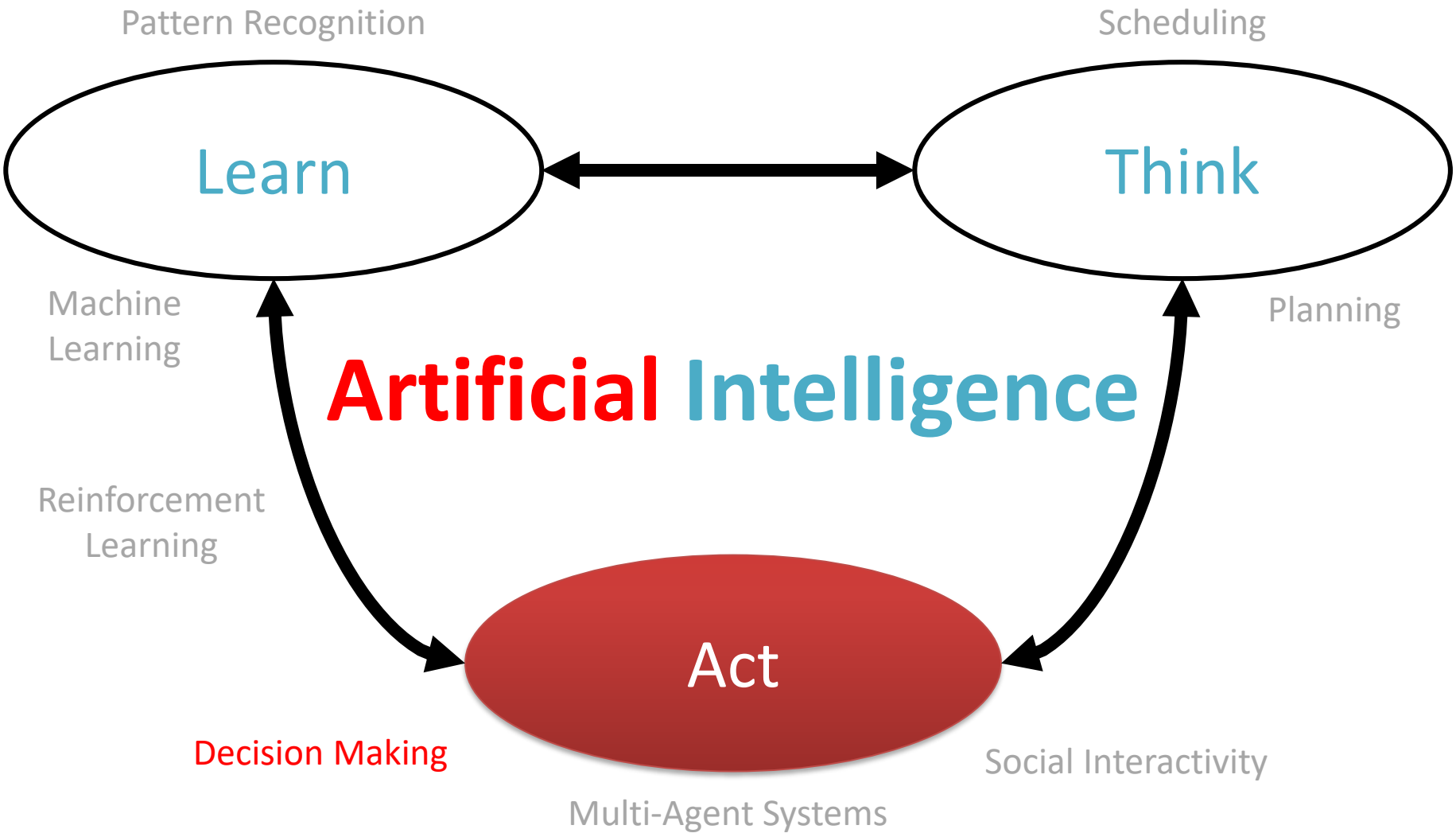
Evolutionary Computation



Dynamic Programming

Challenges of Automated Planning

- Model Availability
- Model Uncertainty
- Computational and Memory Efficiency
- Real-time Planning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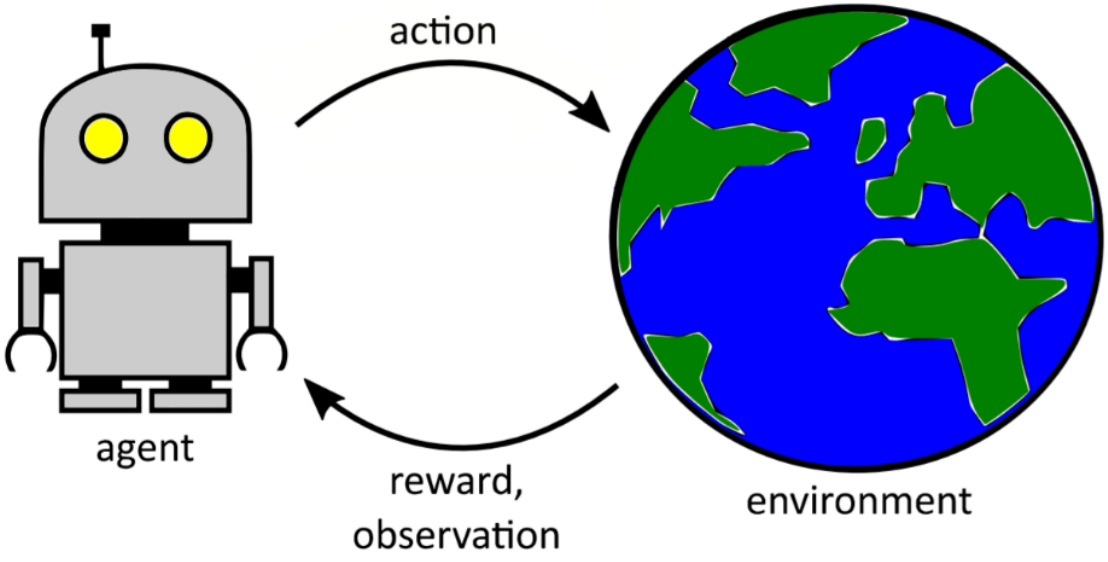
→ Decision Making

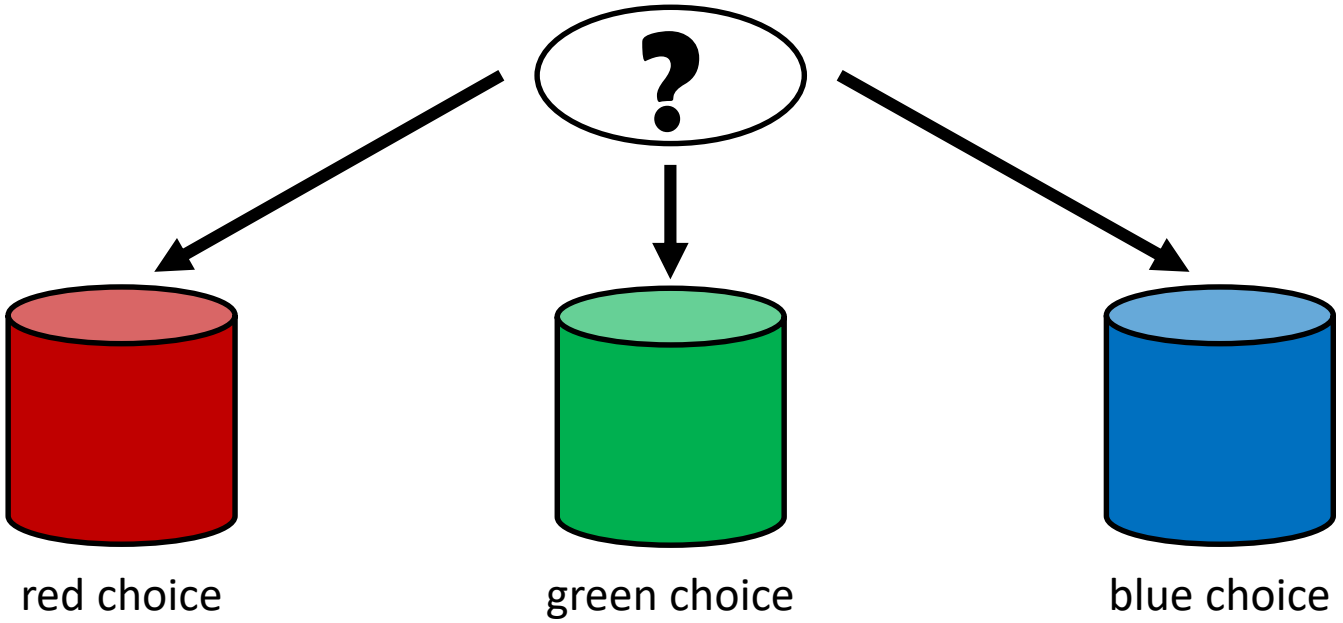
Decision Making

- **Goal:** Autonomously select actions to solve a (complex) task
  - time could be important (but not necessarily)
  - maximize the **expected reward** for each state



Decision Making Example

- Consider a situation, where you have to make a **choice**
- **Example:** What are you going to do after this lecture?



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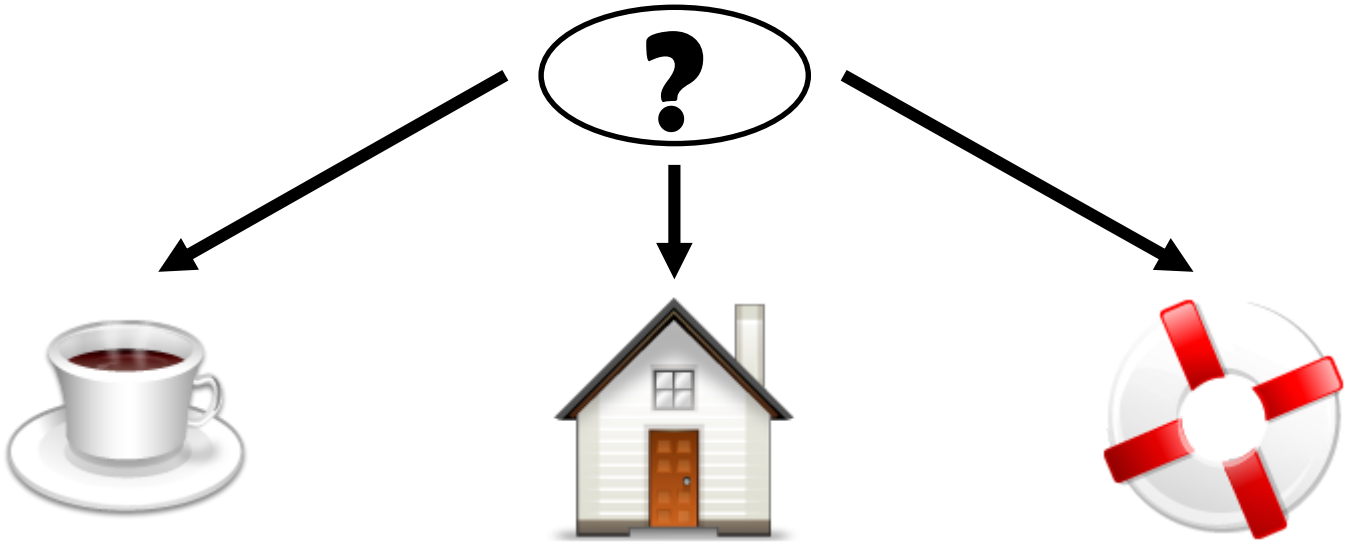

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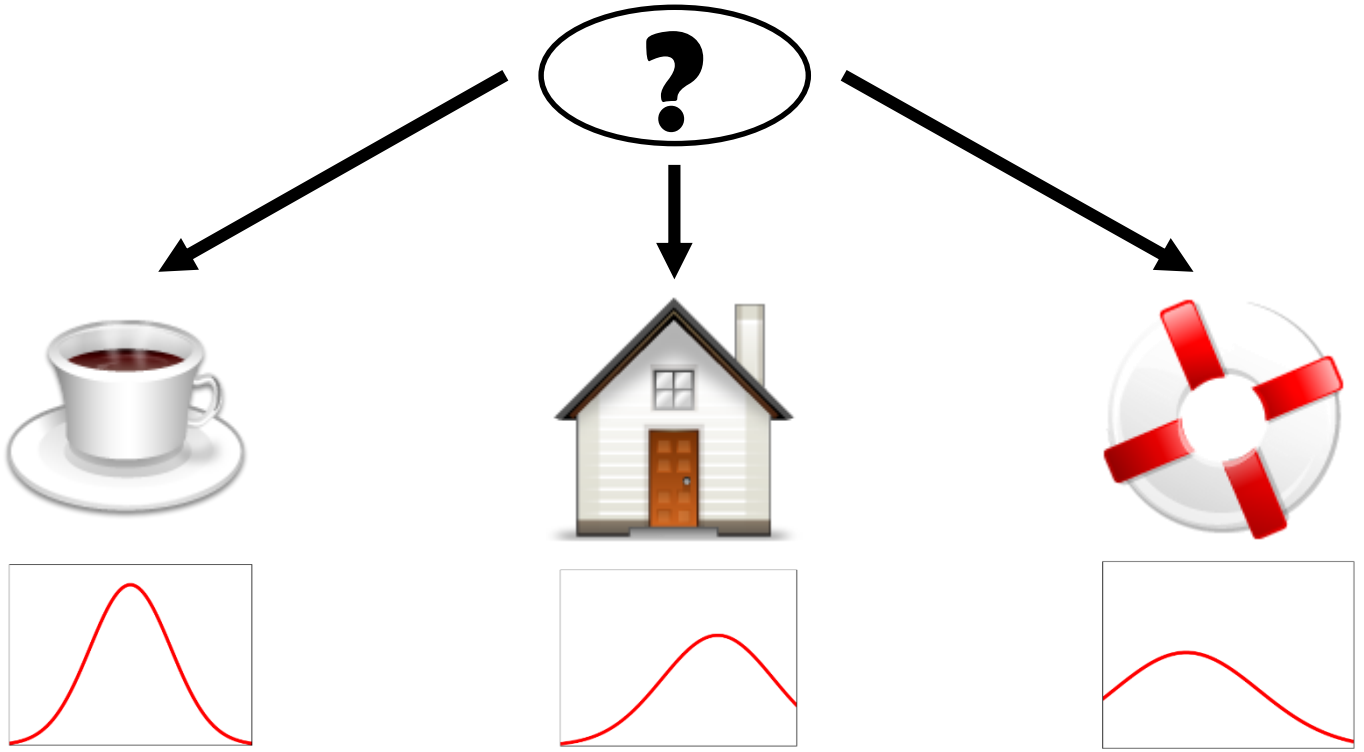

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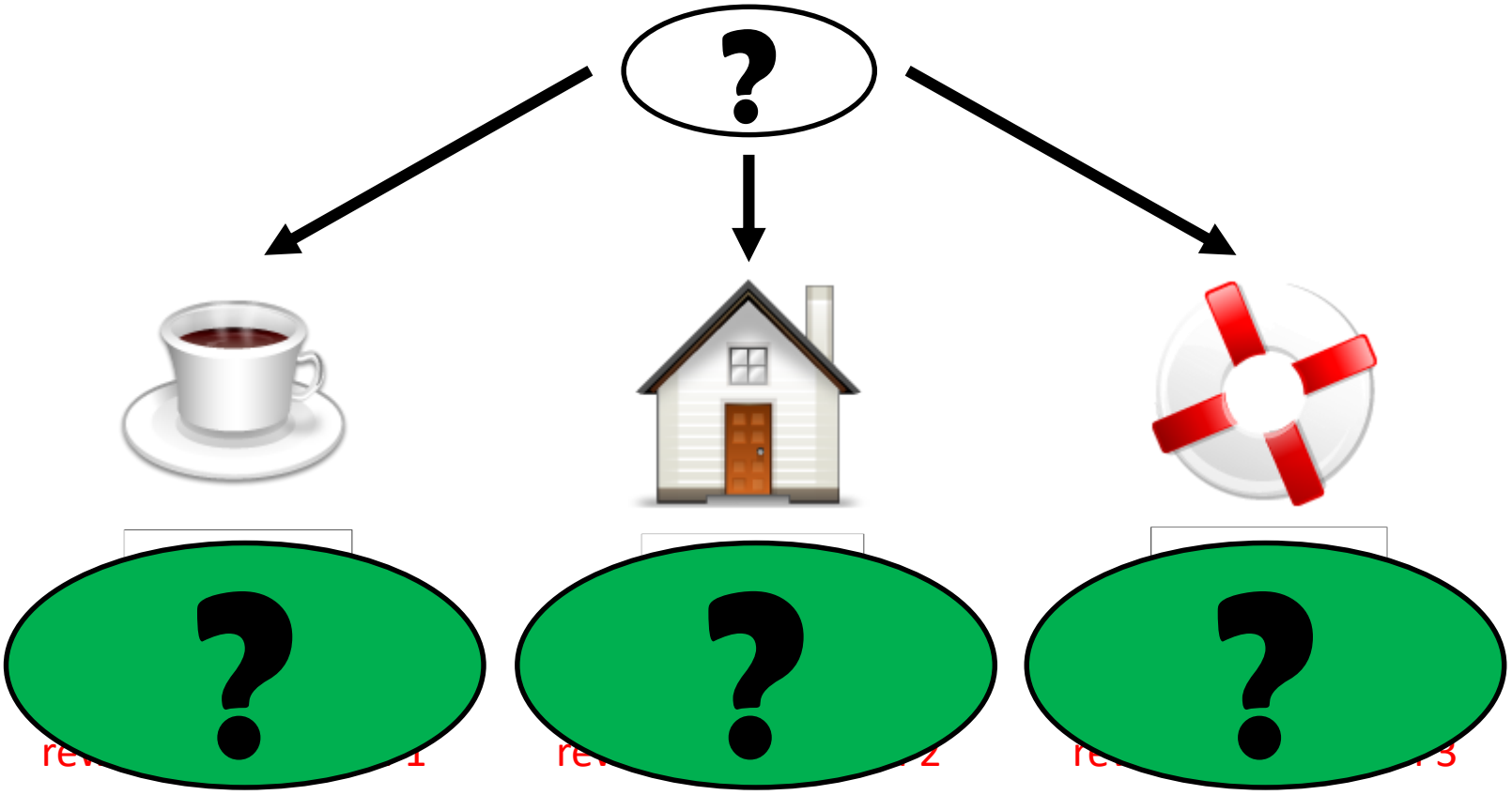


Multi-Armed Bandits

- **Multi-Armed Bandit**: situation, where you have to learn how to make a good (long-term) choice

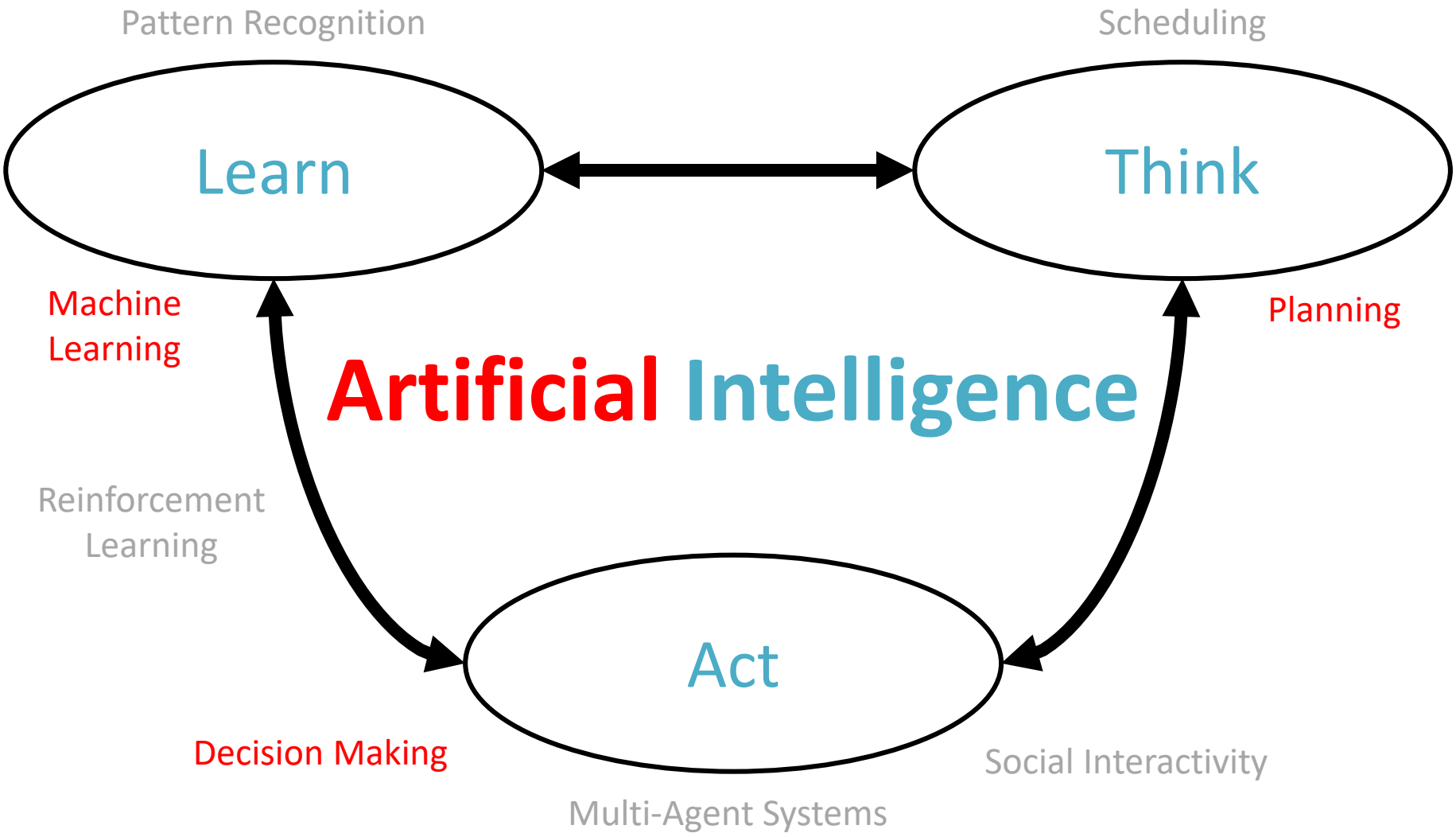
- **Explore** choices to gather information (= Exploration)
  - Example: random choice

- **Prefer** promising choices (= Exploitation)
  - Example: greedy choice (e.g., using `argmax`)

- A good Multi-Armed Bandit solution should **always** balance between Exploration and Exploitation

Decision Making Challenges and Outlook

- Sequential Decision Making
- Problem Complexity
- Sparse/Delayed Feedback
- Sample Efficiency
- Uncertainty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Thank you!