Computational Intelligence

LMU Munich
winter term 2024/2025

Thomas Gabor
Claudia Linnhoff-Popien

Exam Registration via moodle

Early Exam

The early exam will take place on **Thursday, February 6th 2025**, in the buildings **Geschwister-Scholl-Platz 1** and **Theresienstr. 39**. Rooms are listed below, room allocation will be announced after registration has ended. The exam takes place from 18:15 to 20:15, writing time is 90 minutes. We will **start the exam 18:30**! Please plan for enough time before and after the exam!

The exam (like the exercises and the slides) will be given fully in English. All answers can be given in English or German. You are allowed to bring a dictionary (unmarked and unaltered, of course). No other aids (including calculators) are permitted. Proof of student immatriculation and a photo ID (the LMU card is both in one) are required for participation.

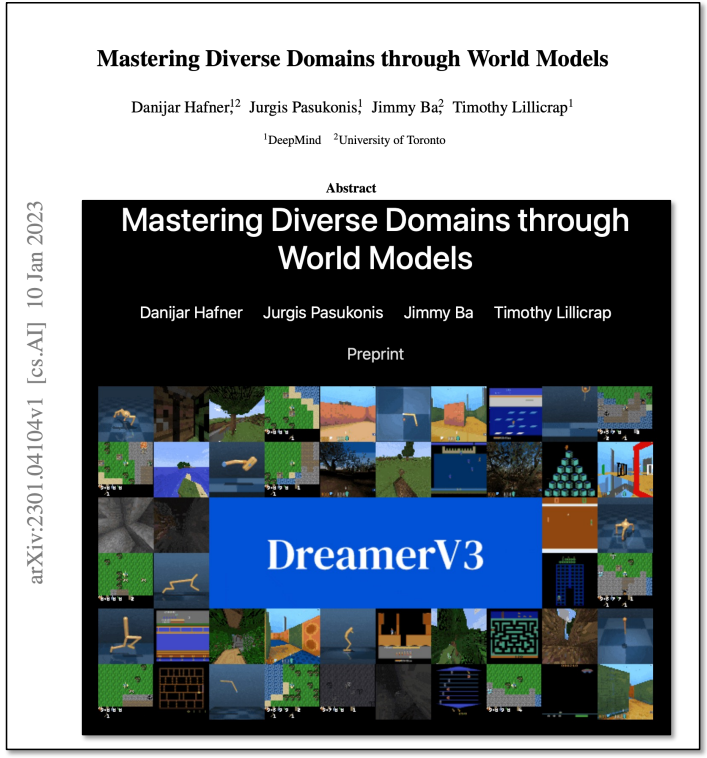
Rooms:

- **Geschwister-Scholl-Platz 1, M 218**
- **Theresienstr. 39, C 123**
- **Theresienstr. 39, B 138**

Reading Exercise #4
Discussion on 2025-01-16

Danijar Hafner, Jurgis Pasukonis, Jimmy Ba, Timothy Lillicrap.
Mastering Diverse Domains Through World Models.
arXiv, 2023.

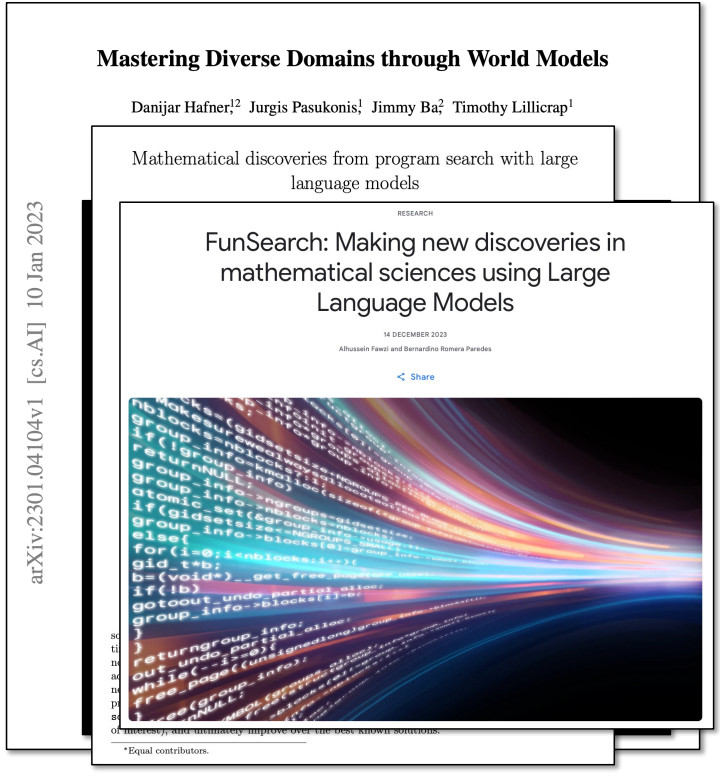
You might also have a look at the accompanying blog post:
https://danijar.com/project/dreamerv3/



Reading Exercise #4
Discussion on 2025-01-16

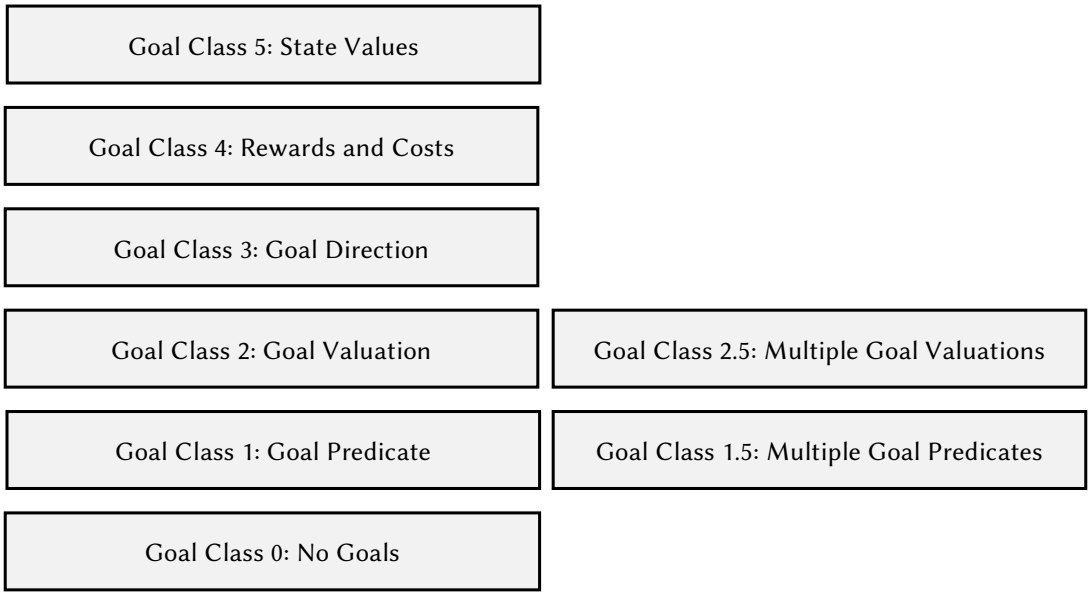
Danijar Hafner, Jurgis Pasukonis, Jimmy Ba, Timothy Lillicrap.
Mastering Diverse Domains Through World Models.
arXiv, 2023.

Romera-Paredes et al.
Mathematical Discoveries from Program Search with Large Language Models.
Nature, 2023.



Reinforcement Learning

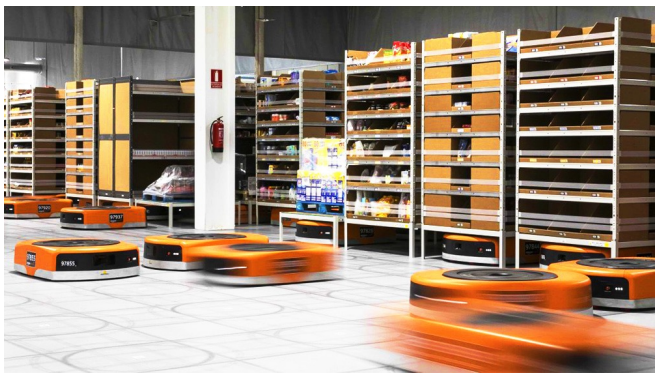
The Goal Class Hierarchy



https://stablediffusionweb.com

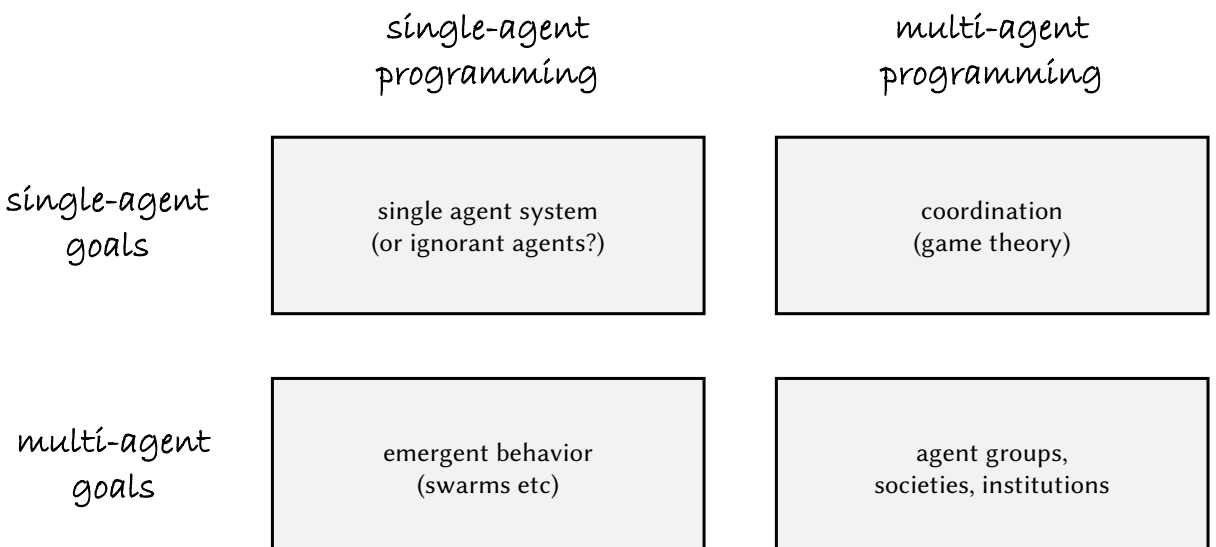
Multi-Agent Applications

https://stablediffusionweb.com/prompts



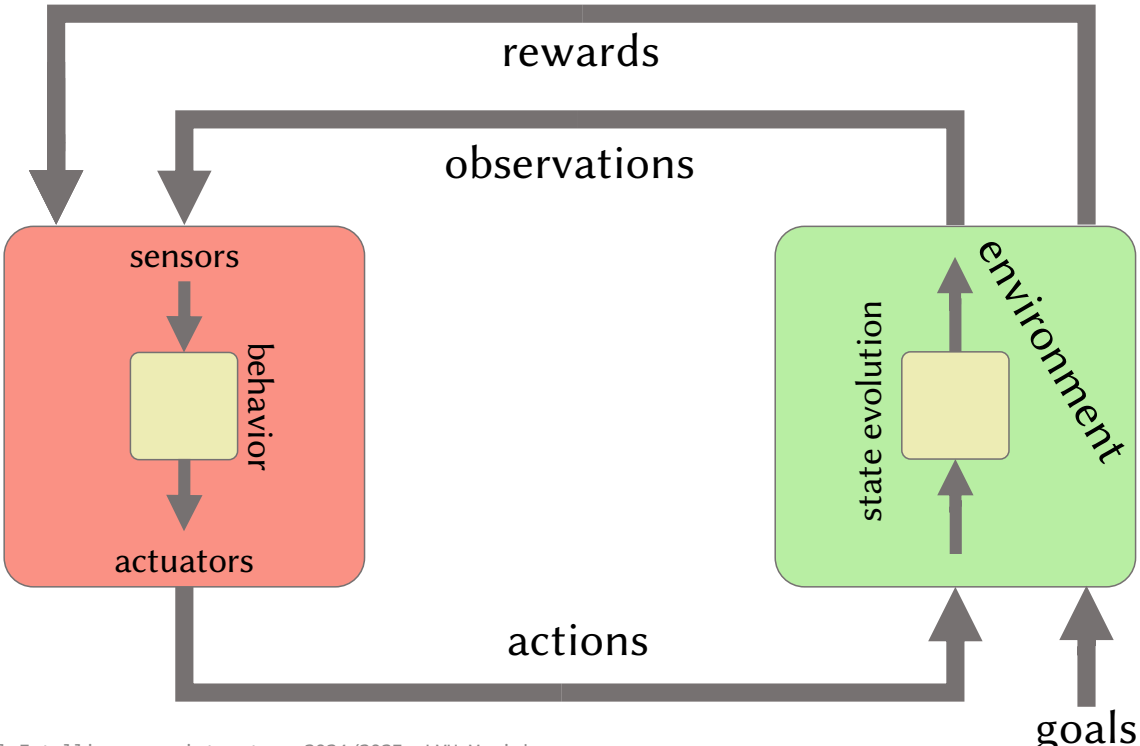
https://aws.amazon.com/de/solutions/case-studies/amazon-robotics-case-study/

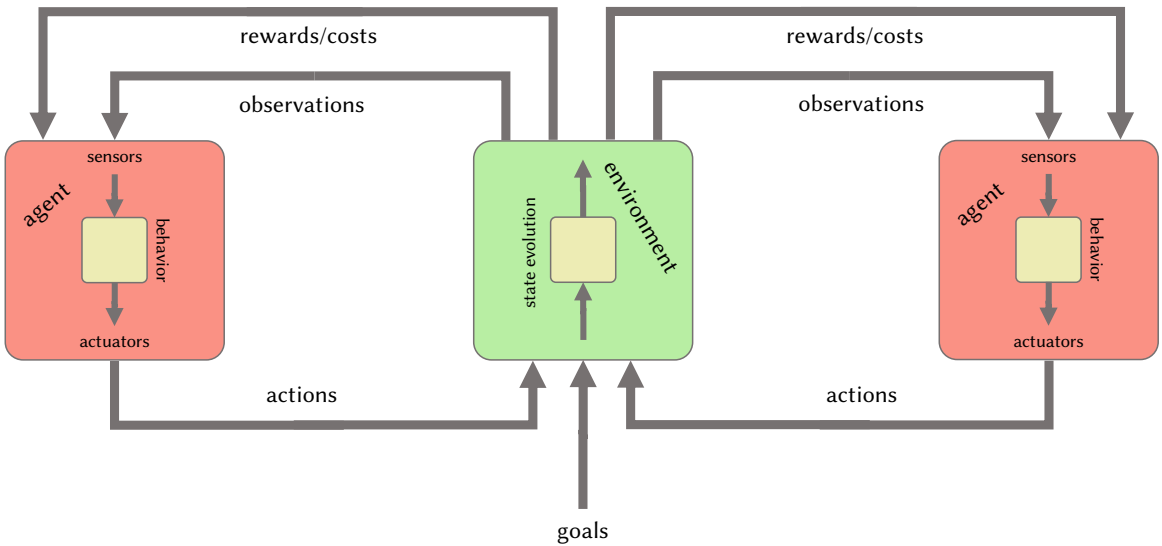
https://aaai.org/Conferences/AAAI-19/invited-speakers/
Speaker: Cynthia Breazeal
Title: „Living and Flourishing with AI“


single-agent programming
multi-agent programming
single-agent goals
multi-agent goals
single agent system (or ignorant agents?)
coordination (game theory)
emergent behavior (swarms etc)
agent groups, societies, institutions

Multi-Agent Systems

Why?


rewards
observations
sensors
behavior
actuators
state evolution
environment
actions
goals


rewards/costs
observations
sensors
agent
behavior
actuators
actions
environment
state evolution
goals
rewards/costs
observations
sensors
agent
behavior
actuators
actions

Definition 12 (multi-agent system)**.** Let $G = \{G^{[1]}, ..., G^{[N]}\}$ be a set of $|G| = N$ agents with observation spaces $\mathcal{O}^{[i]}$ and action spaces $\mathcal{A}^{[i]}$ controlled by policies $\pi^{[i]}$ for all $i = 1, ..., N$, respectively. The multi-agent system G then takes a joint action $a \in \mathcal{A}$ with $\mathcal{A} = \mathcal{A}^{[1]} \times ... \times \mathcal{A}^{[N]}$ after making a joint observation $o \in \mathcal{O}$ with $\mathcal{O} = \mathcal{O}^{[1]} \times ... \times \mathcal{O}^{[N]}$ based on the joint policy $\pi(o^{[1]}, ..., o^{[N]}) = (a^{[1]}, ..., a^{[N]})$ where $a^{[i]} = \pi^{[i]}(o^{[i]})$ for all i.

Multi-Agent Systems as a Paradigm for Distributed Programming

Multi-Agent Systems as a Paradigm for Distributed Programming

$$\begin{aligned} \mathit{GreetingRobot}(\_) = \; & \mathit{good\_morning}.\overline{\mathit{morning}}.\mathit{GreetingRobot}(\text{“happy”}) \\ & + \mathit{morning}.\mathit{GreetingRobot}(\text{“happy”}) \end{aligned}$$

$$\mathit{HappyMultiAgentSystem} = \mathit{GreetingRobot}(\text{“sad”}) \mid \overline{\mathit{good\_morning}}.\mathit{GreetingRobot}(\text{“angry”})$$

Swarm Intelligence

local programming => emergent behavior

Experiment Time!

Experiment Time!

http://10.181.179.137:80

How many balls are in this jar?
[range 1 – 200]

`http://10.181.179.137:80`

How many balls are in this jar?
[range 1 – 200]

22

How many bricks are in this jar?
[range 1 – 200]

http://10.181.179.137:80

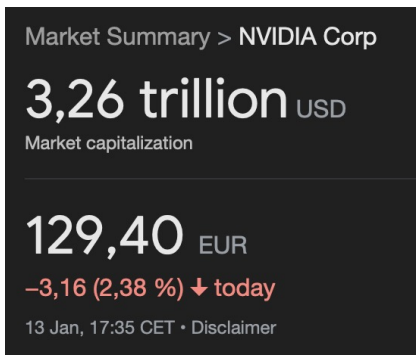
How many bricks are in this jar?
[range 1 – 200]

What is NVIDIA's current market cap in 100 Billion US$? [range 1 – 200]

http://10.181.179.137:80

What is NVIDIA's current market cap in 100 Billion US$? [range 1 – 200]

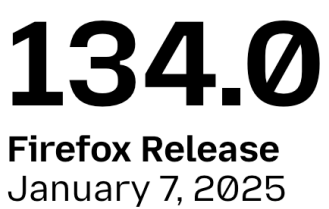
32,6



What is the current major release version of Mozilla Firefox?
[range 1 – 200]

`http://10.181.179.137:80`

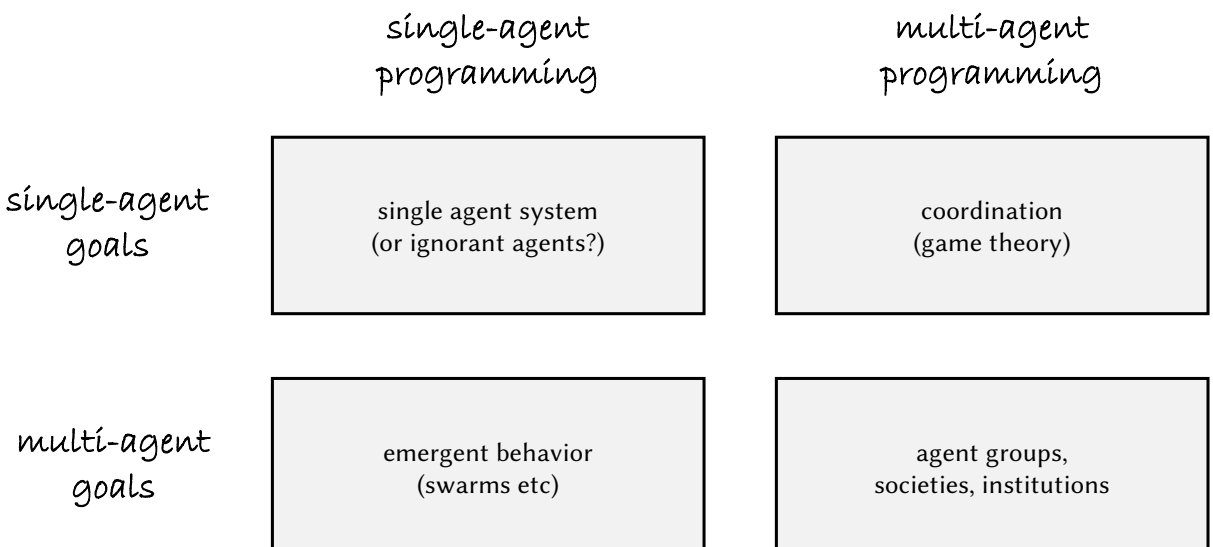
What is the current major release version of Mozilla Firefox?
[range 1 – 200]



https://www.mozilla.org/en-US/firefox/134.0/releasenotes/

Swarm Intelligence

it's all about goals...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Game Theory

"What do we do so that I get the most reward?"

Definition 13 (normal-form game)**.** Let $G = \{G^{[1]}, ..., G^{[N]}\}$ be a set of $|G| = N$ agents. Let $\mathcal{A} = \mathcal{A}^{[1]} \times ... \times \mathcal{A}^{[N]}$ be the space of joint actions where $\mathcal{A}^{[i]}$ is the set of actions available to agent $G^{[i]}$ for all i. Let $\chi : \mathcal{A} \to \mathcal{T}$ be a utility function for the joint action space $\mathcal{A}$ and the joint target space $\mathcal{T} = \mathcal{T}^{[1]} \times ... \times \mathcal{T}^{[N]}$ where $\mathcal{T}^{[i]}$ is the target space of agent $G^{[i]}$ for all i. Unless stated otherwise, the utility χ is to be maximized. From χ we can derive a set of single-agent utility functions $\chi^{[i]} : \mathcal{A} \to \mathcal{T}^{[i]}$ for all i. A tuple $(G, \mathcal{A}, \mathcal{T}, \chi)$ is called a *normal-form game*.

Definition 14 (common-payoff game)**.** A normal-form game $(G, \mathcal{A}, \mathcal{T}, \chi)$ is a *common-payoff game* iff for any two agents $G^{[i]}, G^{[j]}$ and for any joint action $a = (a^{[1]}, ..., a^{[N]}) \in \mathcal{A}$ it holds that $\chi^{[i]}(a) = \chi^{[j]}(a)$.

Definition 15 (zero-sum game)**.** A normal-form game $(G, \mathcal{A}, \mathcal{T}, \chi)$ is a *zero-sum game* iff for any joint action $a = (a^{[1]}, ..., a^{[N]}) \in \mathcal{A}$ it holds that

$$\sum_{i=1}^{|G|} \chi^{[i]}(a) = 0.$$

Rock-Paper-Scissors

	R	P	S
R	0,0	+1,-1	-1,+1
P	+1,-1	0,0	-1,+1
S	-1,+1	+1,-1	0,0