Sistemi Intelligenti Avanzati
Corso di Laurea in Informatica, A.A. 2020-2021
Università degli Studi di Milano
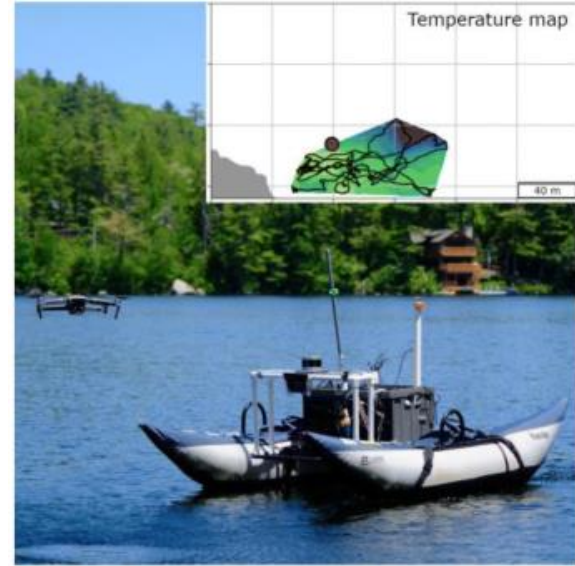
Introduction to Autonomous Mobile Robotics

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Autonomous mobile robots

What defines an autonomous mobile robot?

- Its architecture / configuration
  - Wheeled or legged
  - Humanoid
  - Fling – UAV, fixed wing
  - Water – ASV, underwater
  - …
- Its environment
  - Indoor (house, office, logistic, hospitals)
  - Outdoor (Field, marine, flying, space)
- Its tasks
  - Assistive / Collaborative (cleaning)
  - Patrolling / Surveillance
  - Urban Search and Rescue
- Its interaction with humans
  - Autonomous vs semi-autonomous
- Multi-robot

Autonomous mobile robots

What is an autonomous mobile robot?

An <u>agent</u> that autonomously moves inside a given <u>environment</u>, to perform a given <u>task</u>
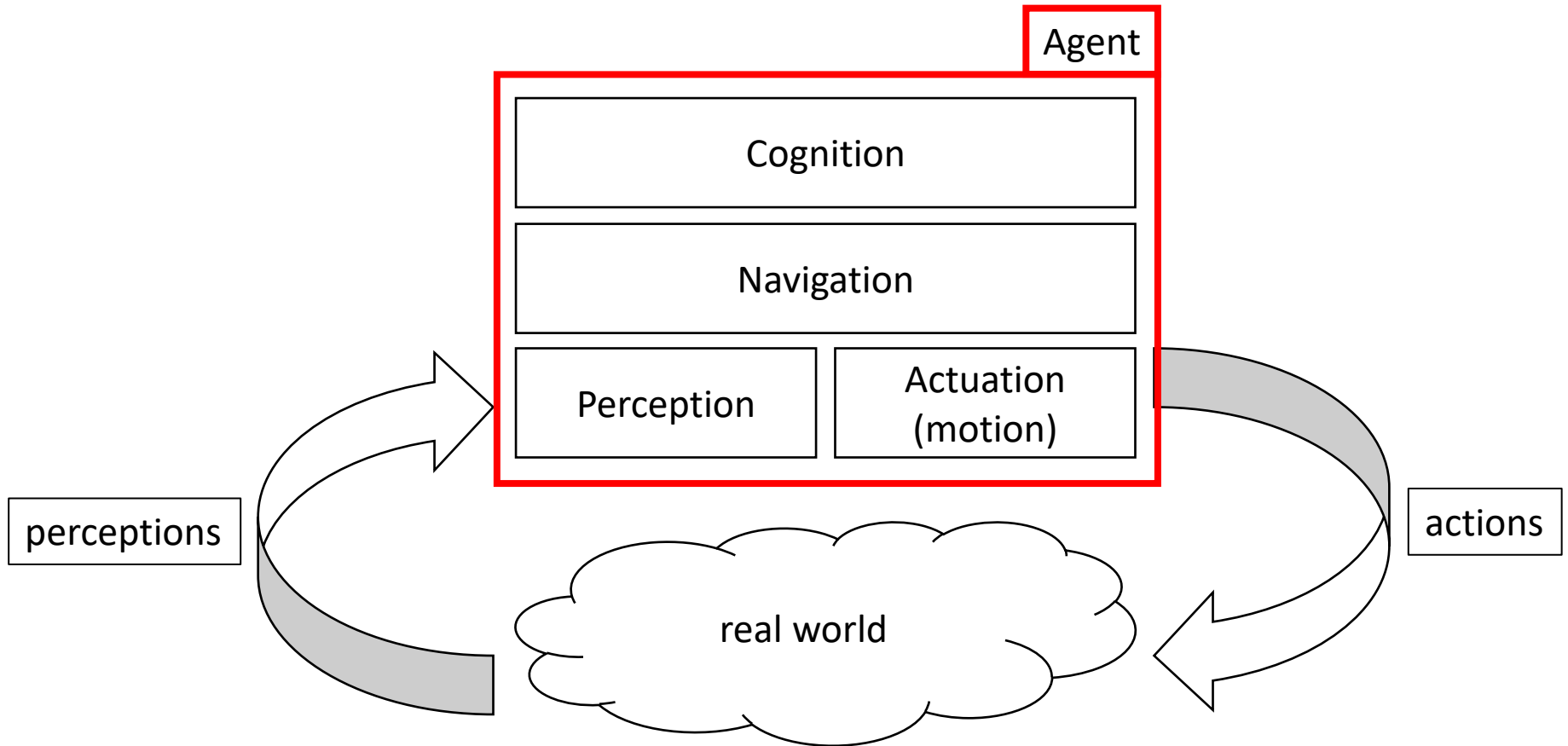
Robots as Agents

- *"[...] anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators."* [Russel, Norvig 1995]

- *"[...] a computer system that is situated in some **environment**, and that is capable of **autonomous action** in this environment in order to meet its delegated objectives."* [Wooldrige, 2009]

perceptions   Agent   actions
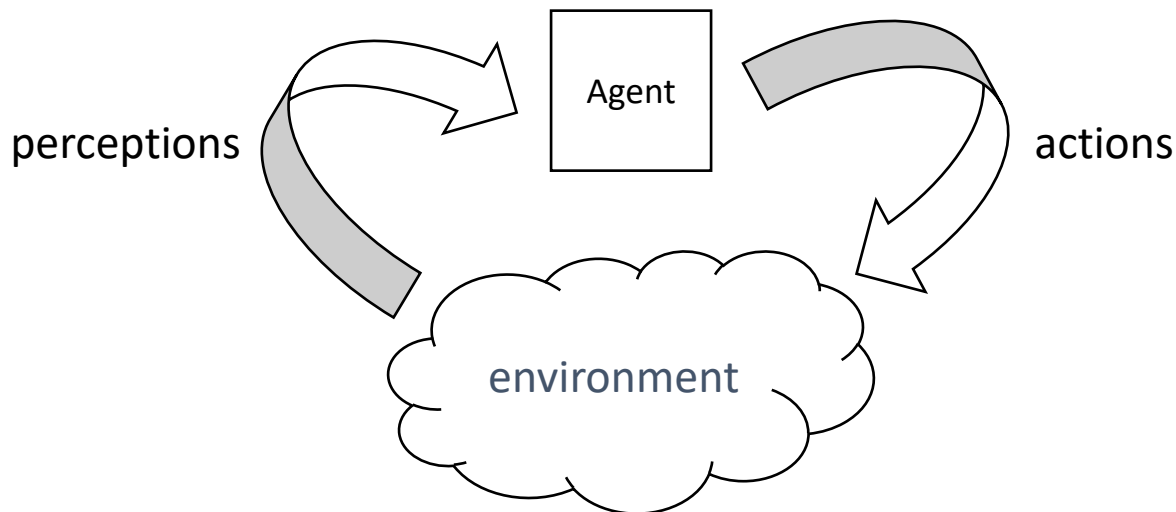
environment

Agents as mobile robots

Agents as mobile robots
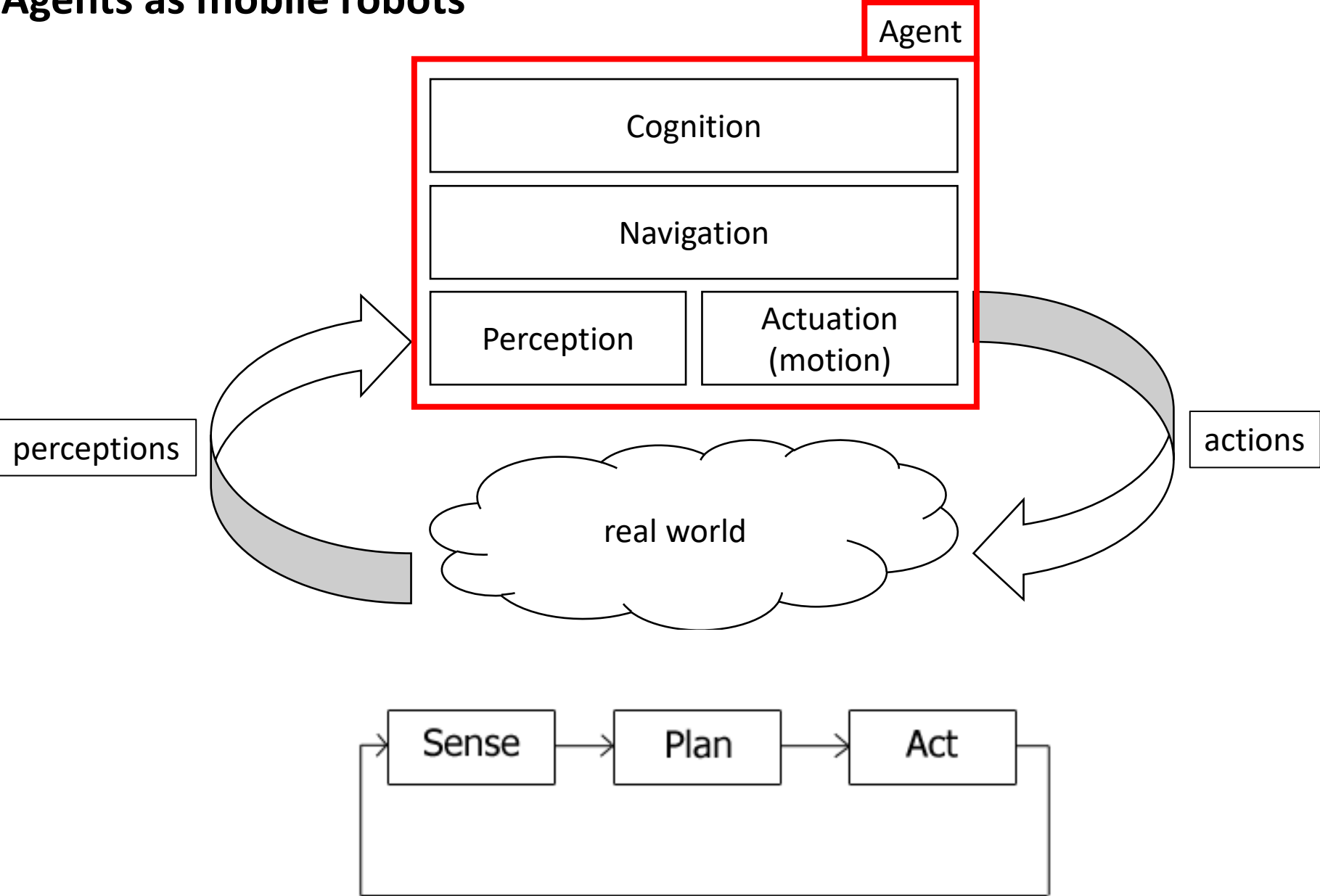
Environments and tasks

What we want robot to do? tedious, boring, hazardous, costly tasks that we do not want to do (or to help us in doing so)

Environments and tasks

What we currently have are robots that can perform repetitive simple tasks into controlled environments (e.g., industrial robots).

What we want is a sci-fi general AI robot capable of interacting with us and adapt to new challenges and tasks

Environments and tasks for robots
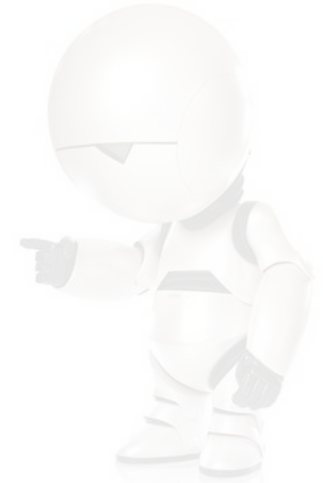
Despite costs (still quite high) manipulators are "commonly" used in manufacturing, but for performing repetitive and preprogrammed tasks…

Environments and tasks for robots

Despite costs (still quite high) manipulators are "commonly" used in manufacturing, but for performing repetitive and preprogrammed tasks…

…however their generalization to different settings (e.g. logistics, small manufacturing, …)

Environments and tasks for robots

Domestic robots are slowly coming, but even in this case they have limited abilities and they can perform only simple tasks (vacuum cleaners, lawnmowers, …)

Environments and tasks for robots

Autonomous driving cars are "almost" here, however:

- Driving in roads is a problem that is "easy" to be modeled

- How to do the last mile towards *really* having autonomous road vehicles is still unknown
(a lot of effort, and money, since 2010, no results)

Environments and tasks for robots
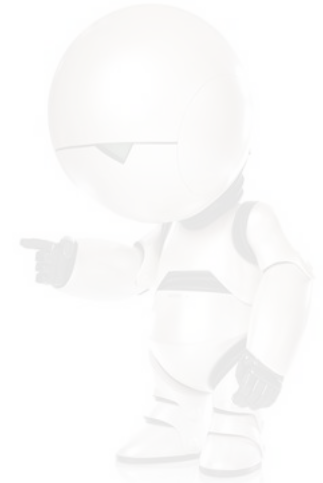
Broadly speaking: if we simplify the environment enough, and we simplify the robot's tasks enough, we can *have* autonomous robots…

…but there are still major limitations that prevents the widespread adoption of such machines.

(on the other side, general AI sci-fi robots are still sci-fi)

Limitations of Autonomous Robots

An <u>agent</u> that autonomously moves inside a given <u>environment</u>, to perform a given <u>task</u>

The major limitations of modern robots are due to the fact that a robots need to make *decisions* to adapt their behaviour to the *environment* towards reaching theirs *tasks*...

- *Embodiment* = is it related to limitation in the robot HW?

- *Cognition* = is it related to limitation in the robot reasoning / SW?

Limitations of Autonomous Robots

[Pieter Abbeel, 2008]

Limitations of Autonomous Robots

An <u>agent</u> that autonomously moves inside a given <u>environment</u>, to perform a given <u>task</u>

So it seems that, while we still have major limitations in terms of robots' actuation (wheels, arms, grippers) sensorial perception (sensors) and computational power (CPU/GPU,Memory) , the main limitation is still related to their cognition level, i.e. how to make decisions.

Limitations of Autonomous Robots

An <u>agent</u> that autonomously moves inside a given <u>environment</u>, to perform a given <u>task</u>

If we have to pick one major issues about modern autonomous robots, the main one is *perception*, as it involves the *interpretation* of sensed data in a meaningful way.

Thus, *mobility* is a critical aspects as depends on perception and interpretation (while, manipulators, have less strict requirements)

Towards Autonomous Robots

[Where to go next?]

[Where am I?]

[What is that?]

[What's my
battery status?]

?

[What are my tasks?]

[How do I go there?]

[What task is next?]

[What plan to do all
my tasks for today?]

[How to accomplish
this task?]
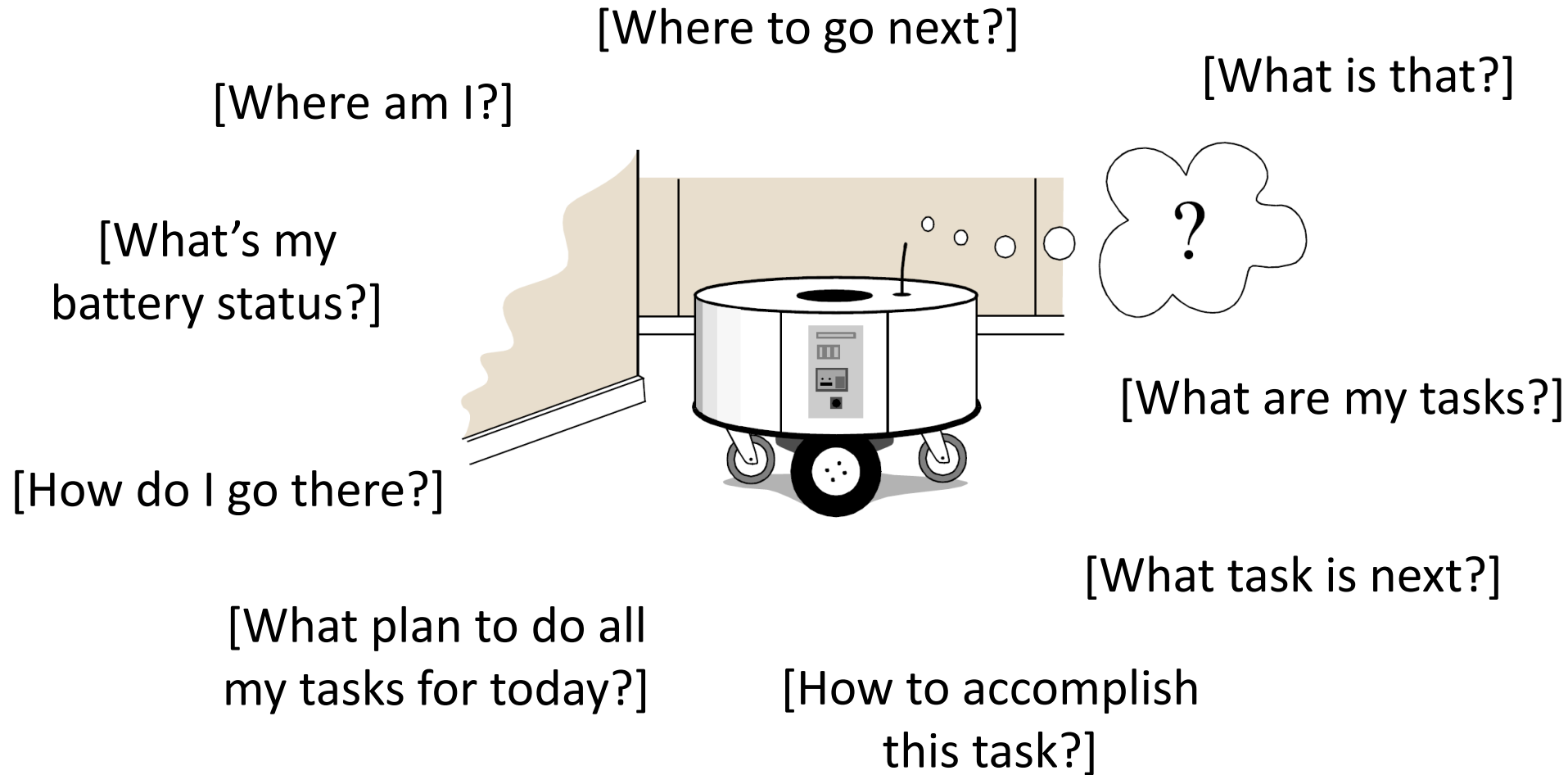
An autonomous mobile robot needs to solve different concurrent tasks

Towards Autonomous Robots

[Where am I?]

[Where to go next?]

[How do I go there?]

[How to accomplish this task?]

[What task is next?]

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[What is that?]
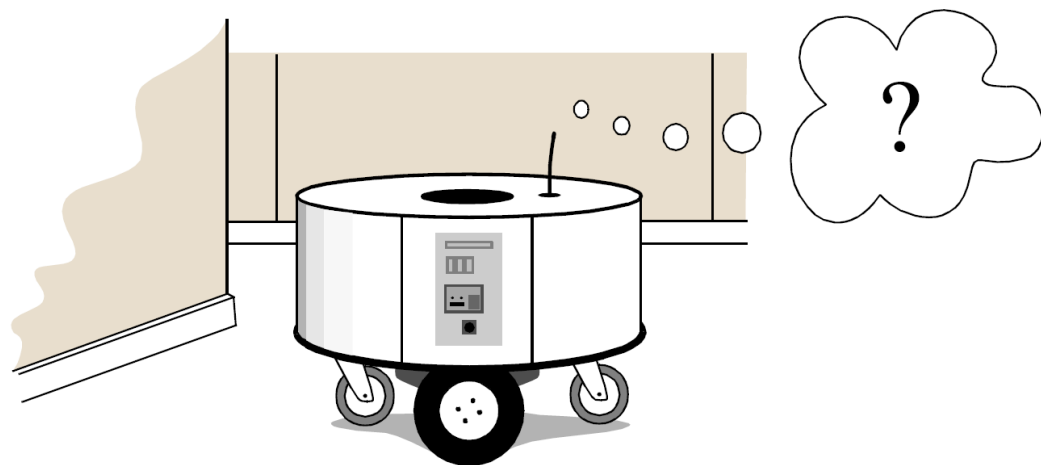
Divide et impera: divide robot functionalities in sub-problems, organize them at different level of abstraction, solve them separately, integrate

Towards Autonomous Robots

[Where am I?] [What's my battery status?] [What is that?] →

[Where to go next?]

[How do I go there?]

[How to accomplish this task?]

[What task is next?]

[What plan to do all my tasks for today?]

[What are my tasks?]

Adapt the execution to environmental changes, unexpected events, make robust solutions (e.g., self-driving cars)

Towards Autonomous Robots

[Where am I?]

[Where to go next?]

[How do I go there?]

Navigation and mapping and their subproblems:

Motion, mapping, localization, path planning, path execution

[How to accomplish this task?]

[What task is next?]

[What plan to do all my tasks for today?]

[What are my tasks?]

?

Towards Autonomous Robots

[Where am I?]

[Where to go next?]

[How do I go there?]

[How to accomplish this task?]

Task-related problems: manipulation, grasping, human-robot interaction, cleaning, patrolling, …

[What task is next?]

[What plan to do all my tasks for today?]

[What are my tasks?]

Towards Autonomous Robots

[Where am I?]

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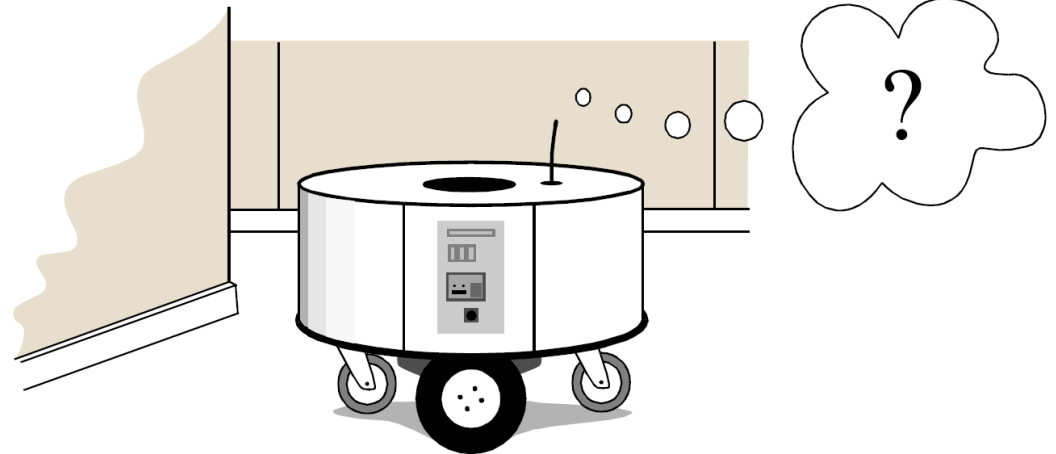
[What plan to do all my tasks for today?]

[What are my tasks?]

Agent

Cognition

Navigation

Perception	Actuation (motion)

?

Towards Autonomous Robots

[Where am I?]

[Where to go next?]
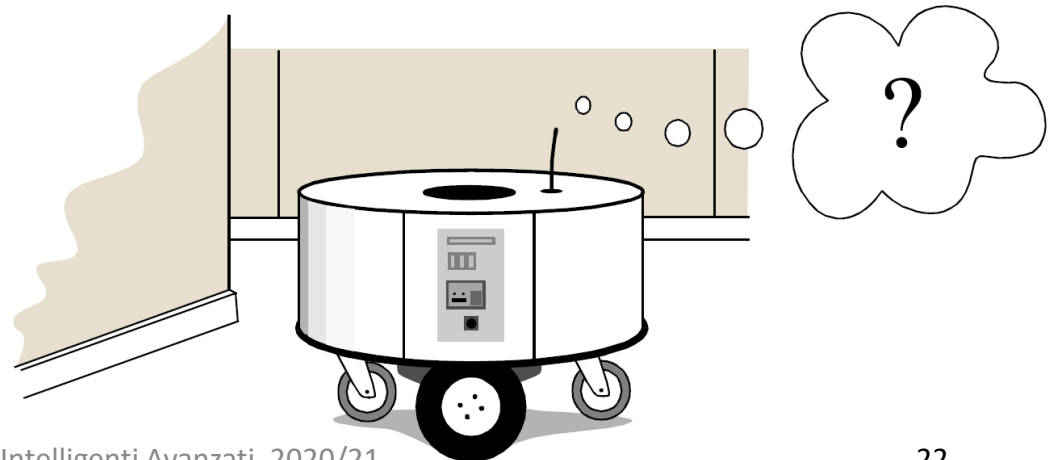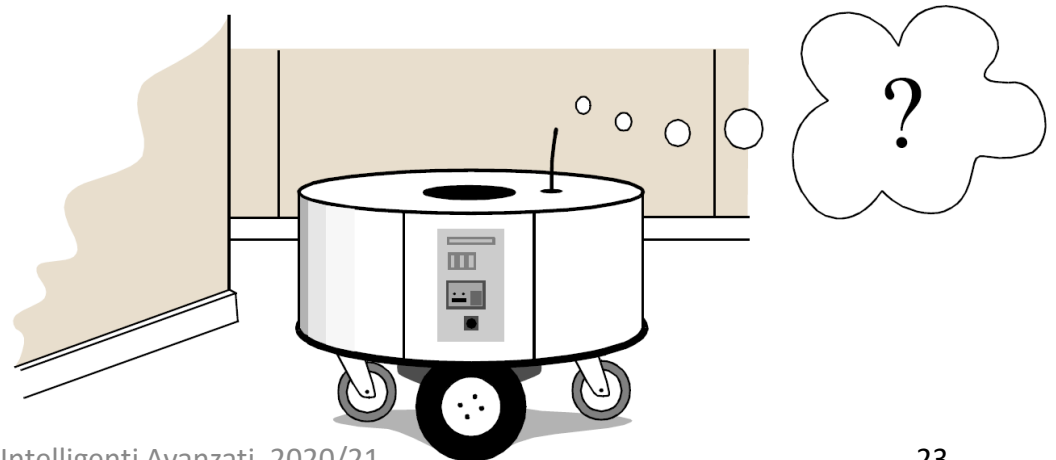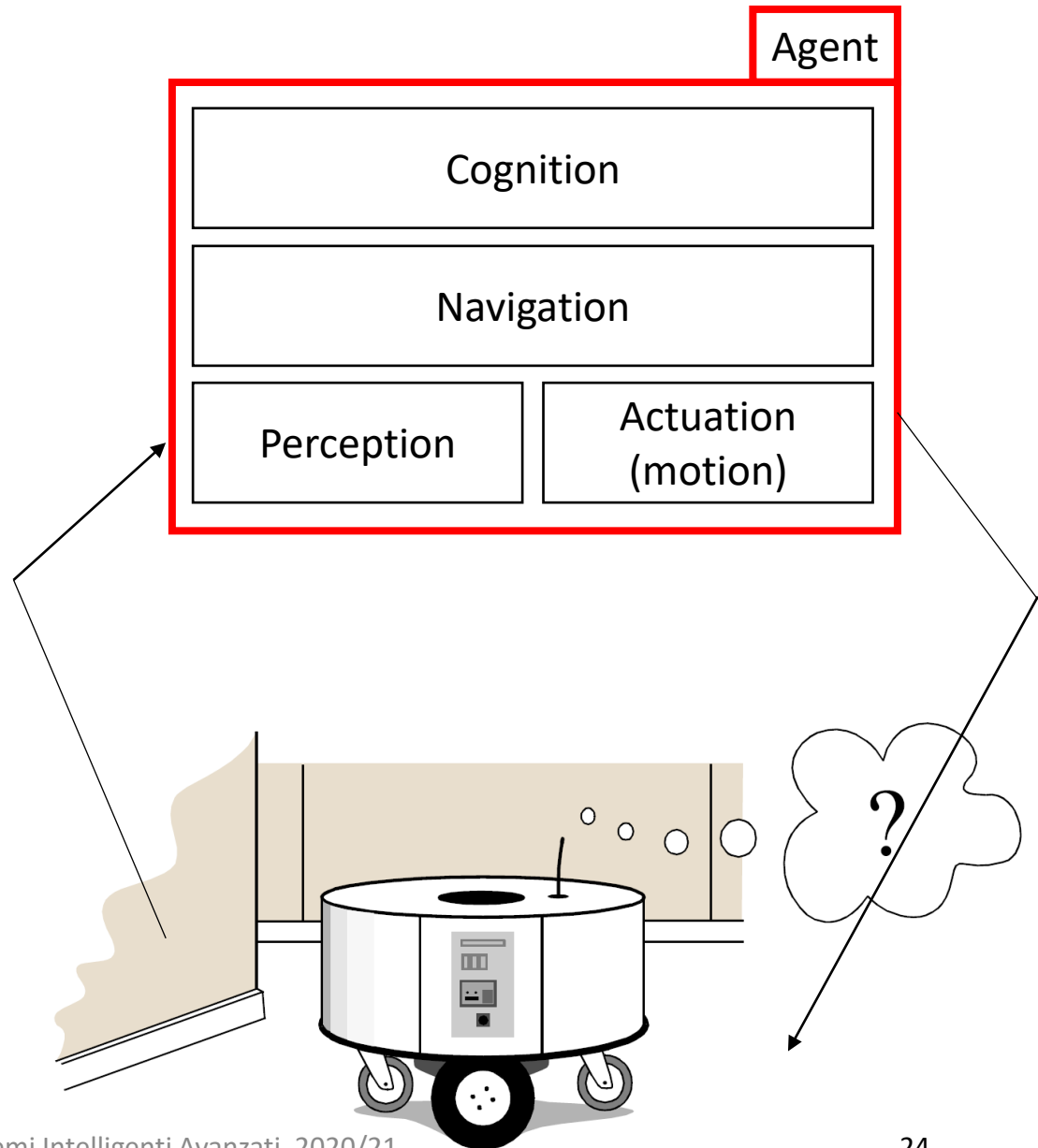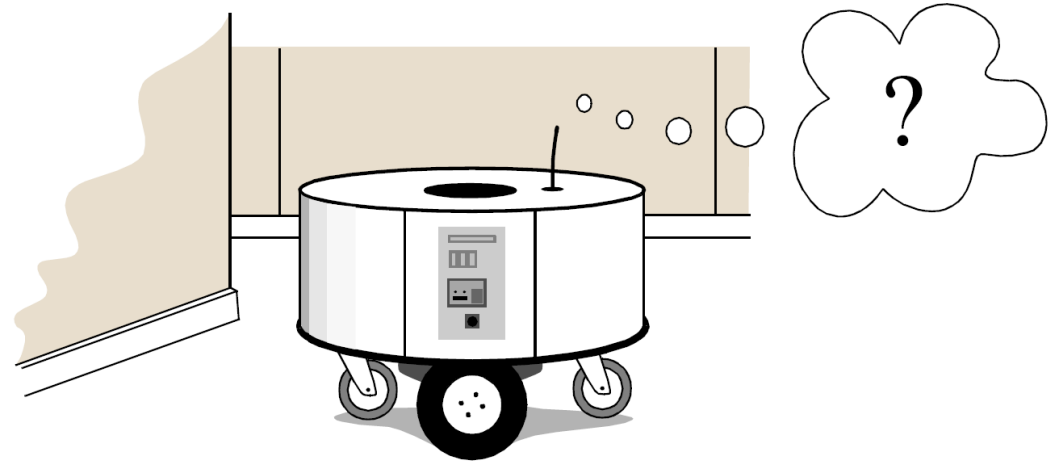
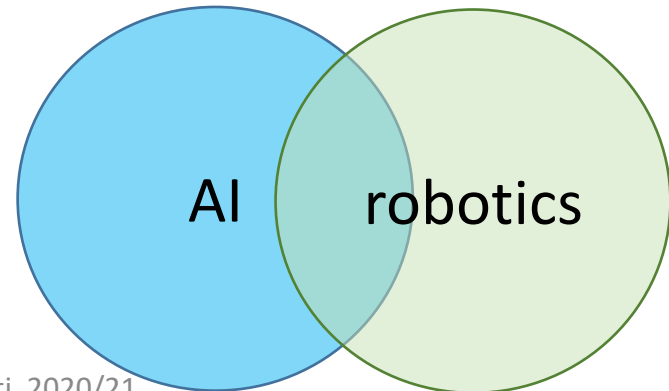[How do I go there?]

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Planning problems, AI for robotics

AI   robotics

SURVEYED AI-ENABLED LONG-TERM AUTONOMY ROBOT SYSTEMS.

Domain	Application Features								Duration	AI Areas						System
	Environment Variability	Task Diversity	Semantics	Dynamics	Partial Observability	Cost & Criticality	Interaction & Cooperation	Level of Autonomy		Navigation & Mapping	Perception	KR & Reasoning	Planning	Interaction	Learning	
Space	L	L	L	L	H	H	L	M	Years	○	●	−	●	○	−	Opportunity [9], [10]
									Years	○	●	−	●	○	−	IPEX [11]
Marine	M	L	L	M	H	H	L	H	Days	○	●	○	●	−	○	AUVs [12], [13]
									Months	○	○	−	○	−	−	Gliders [14]
Air	M	M	M	H	H	H	M	M	Days	○	●	○	○	−	−	AtlantikFlyer [15]
Field	H	M	L	M	H	M	M	M	Days	●	●	○	−	○	○	VT&R2 [16]
									Years	●	●	○	−	−	○	BearNav [17], [18]
Road	M	L	M	H	M	H	M	L	Days	○	●	●	○	−	○	VaMP [19]
									Days	○	●	○	○	−	○	ARGO [20]
									Months	○	●	○	○	−	○	PANS [21]
									Months	○	●	○	○	−	○	VIAC [22]
Service	H	H	H	L	H	L	H	M	Days	●	○	○	●	●	○	Rhino [23]
									Days	●	○	○	●	●	○	Minerva [24]
									Days	●	○	○	○	●	○	Willow Garage [25]
									Months	●	●	●	●	●	●	STRANDS [26]
									Years	●	●	●	●	●	●	CoBot [27]

Legend: L *low*, M *medium*, H *high*, − *not integrated*, ○ *partially integrated*, ● *fully integrated*

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Legend: L low, M medium, H high, — not integrated, ○ partially integrated, ● fully integrated

[Kunze et al., 2018]

SURVEYED AI-ENABLED LONG-TERM AUTONOMY ROBOT SYSTEMS.

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									Days	○	●	○	○	—	○	ARGO [20]
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Autonomous Robots at large

Mechanics

Kinematics

Control Theory

Signal Processing

Information Theory

Probability Theory

Artificial Intelligence

Computer Vision

Multi Agent Systems
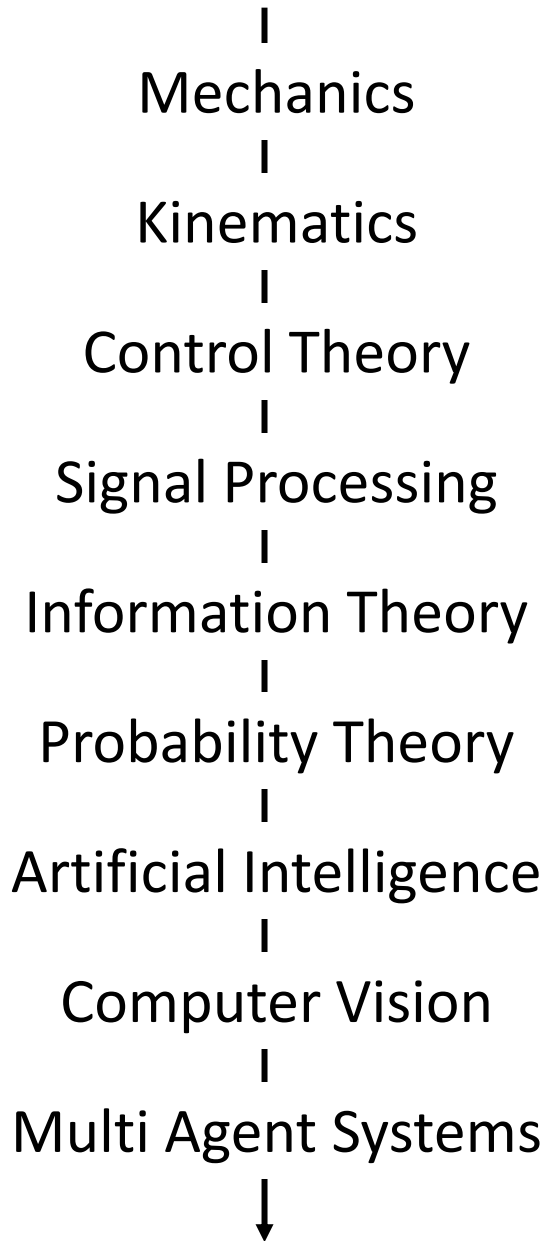
Multiple perspectives and fields involved, from HW to SW

There is no single solution on how to address this problem (robotics is still a young field)