BLG456E
Robotics
Introduction

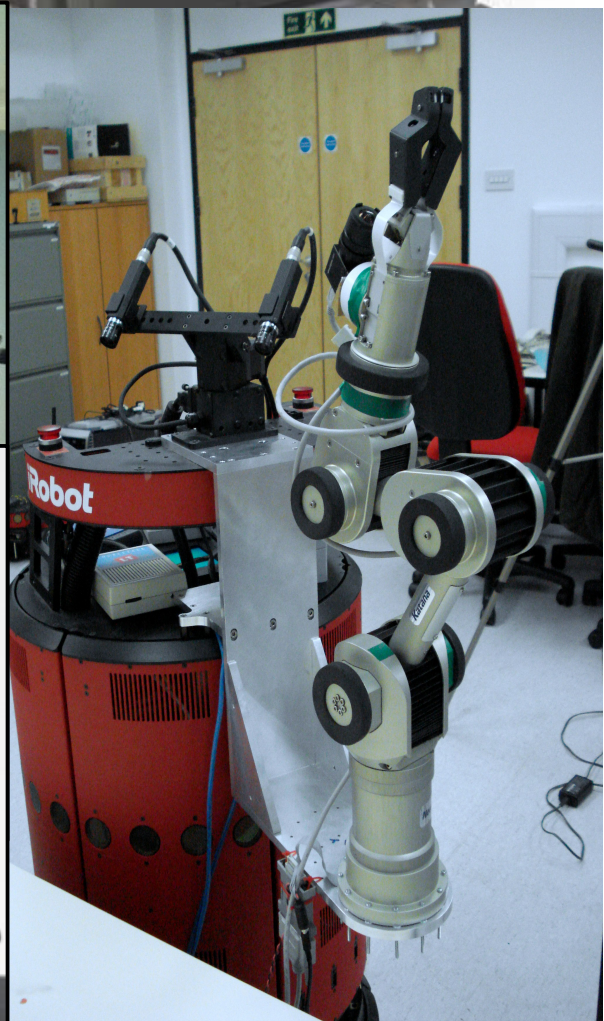
Lecture Contents

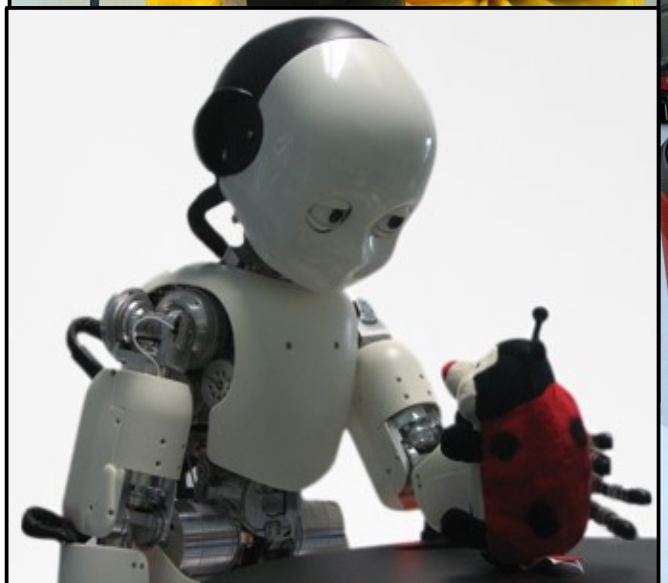
- Why and what robotics.
- Course plan.
- Robot basics.
  - Basic approach.
  - Definitions & a little history.
  - Main problems in robotics.

Lecturer:	Damien Jade Duff
Email:	djduff@itu.edu.tr
Office:	EEBF 2316
Schedule:	http://djduff.net/my-schedule
Coordination:	http://ninova.itu.edu.tr/Ders/4709

Autonomous Robotics

- Building artificial systems that are:
  - **Embodied.**
  - **Acting.**
  - **Problem-solving.**
- Why do this?
  - **Applications!**
  - **Cognitive models.**





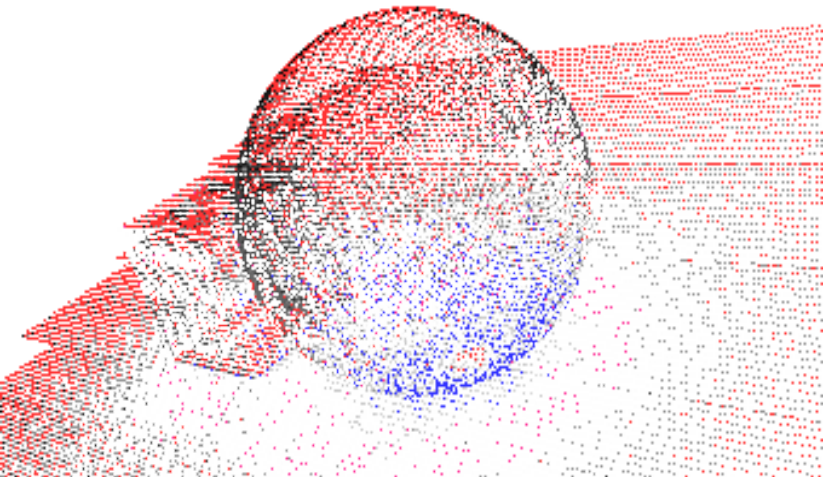
Why robots?

Image by Maas Digital LLC for Cornell University and NASA/JPL

- Example applications:
  - Human assistance in office and home.
  - Waste site exploration, construction.
  - Search and rescue.
  - Dynamic industrial processes.
  - Automated experimentation.
  - Manufacturing.
  - Warehousing and transportation.
  - Environmental monitoring, agriculture and surveillance.

Why robots?

Meers & Ward 2004

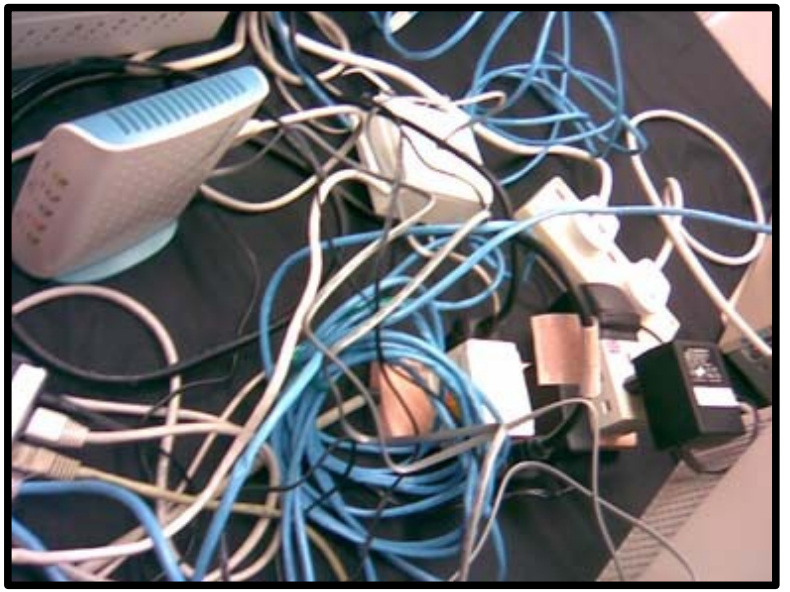


- Other areas that benefit:
  - Augmentation
  - Machine intelligence
  - Semi-autonomous systems
  - Cognitive science
  - Lots more.

What tasks **should** robots do?

What tasks **should** robots do?

What tasks **should** robots do?



What tasks **should** robots do?

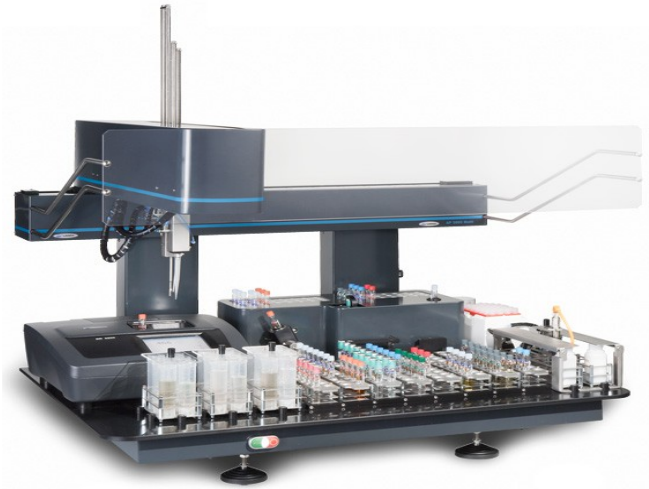
What tasks **should** robots do?

What tasks **should** robots do?

What kinds of robots are there?

Current robots

- Manipulators:
  - Factory assembly line.
  - International Space Station.
  - Laboratory robots.

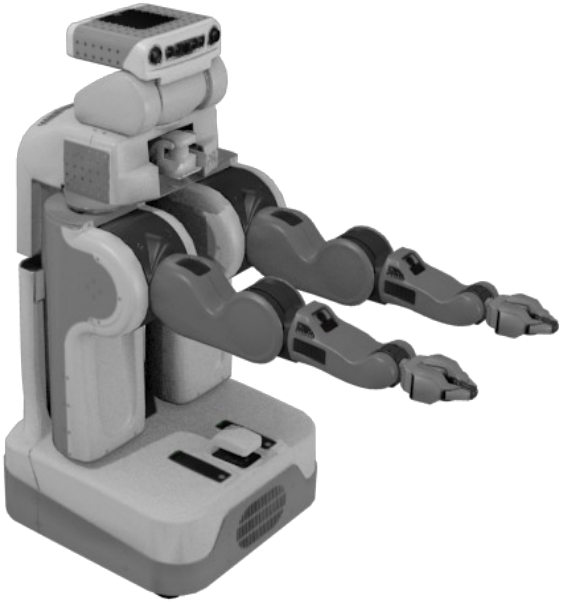


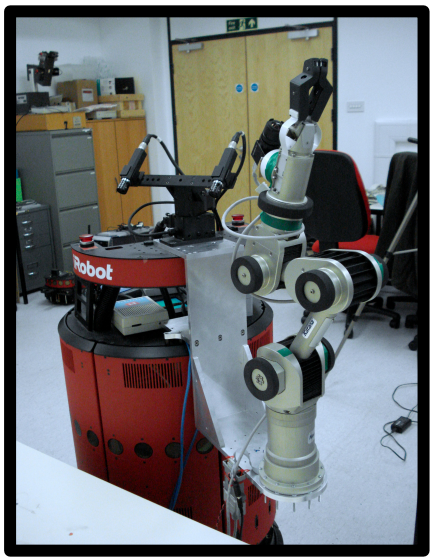
Current robots

- Mobile robots:
  - Unmanned Ground Vehicles (UGV/ULV).
  - Unmanned Air Vehicles (UAV).
  - Autonomous Underwater Vehicles (AUV).
  - Planetary rovers.

Current robots

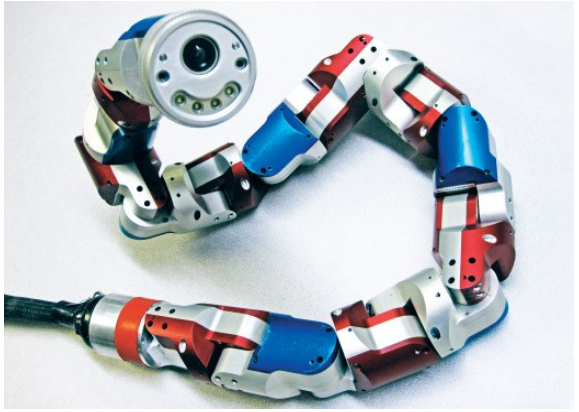
- Mobile manipulators.





Current robots

- Other (weird & wonderful) robots:
  - Humanoid robots.
  - Bio-inspired robots.
    - E.g. snakes, flies, geminoids.
  - Self-assembling.



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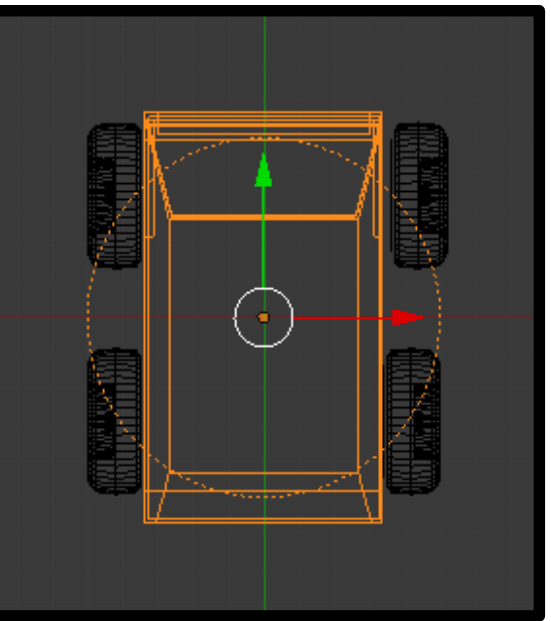
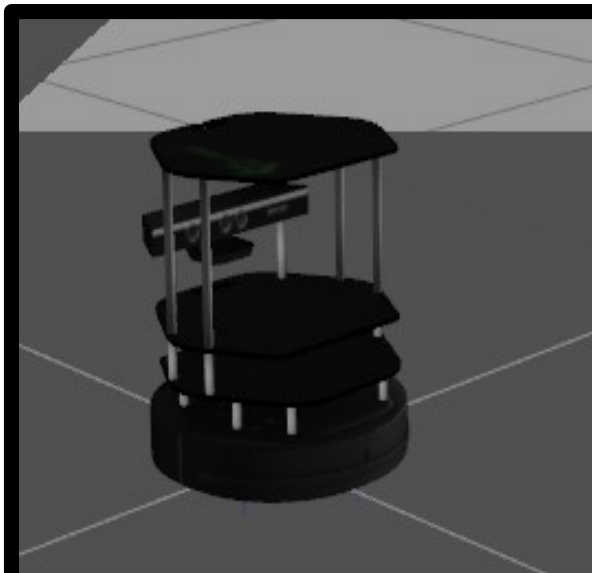
Course approach

- **Practical** application of the theory of robotics.
  - Focus on **autonomous mobile robots in 2D**.
- Theory → Practice.
- Apply:
  - Estimation, planning, probability, control, calculus, planning, dynamics, kinematics, geometry, software architecture, etc...

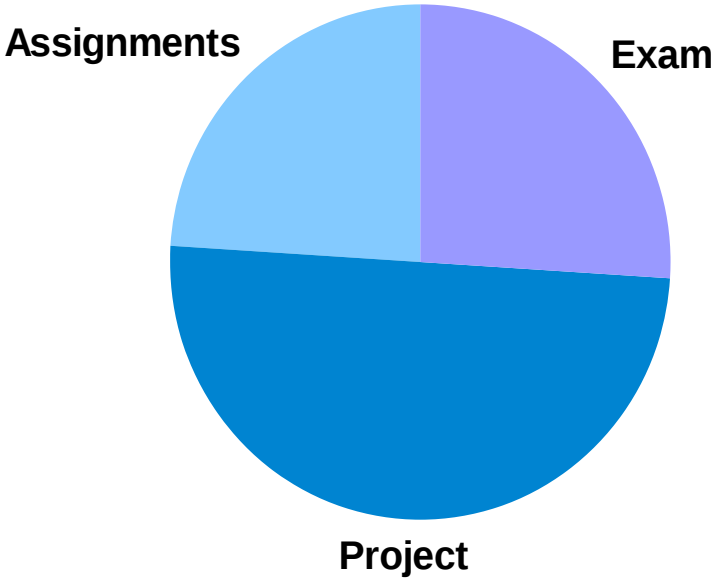


Exercises + Project

- Mostly in simulation (ROS + Gazebo).
- Some real robots available.

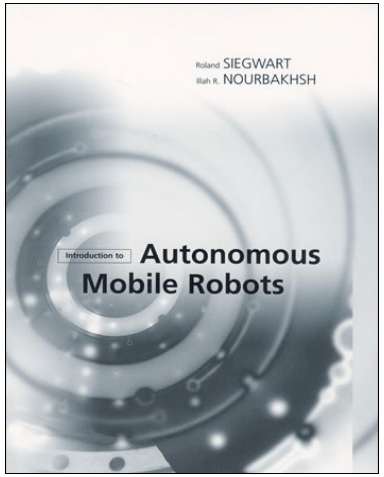


Assessment



- 2 assignments (24%).
  - **VF requirement**: Submit both (≥ 20% counts).
  - **VF requirement**: Average grade ≥ 30%.
  - Practical fundamentals.
  - Start NOW.
- Project (50%).
  - **VF requirement**: Grade more than 30%.
  - In a group.
  - Proposal a requirement.
  - *Implement a solution, in simulation or on a real robot.*
  - Work package interim submission.
  - Report, demo & video.
- Final (26%).
  - Conceptual understanding.
  - Maths applied to robot problems.

Textbooks



Main:

Introduction to Autonomous Mobile Robots

Roland Siegwart and Illah Nourbakhsh, The MIT Press, 2004

Electronic version available & in library.

Extra reading:

Springer Handbook of Robotics

Bruno Siciliano and Oussama Khatib, Springer, 2008.

Electronic version available in library.

Planning Algorithms

Steven M. LaValle, Cambridge University Press, 2006.

Electronic version available online.

Computational Principles of Mobile Robotics

Gregory Dudek, Michael Jenkin, Cambridge University Press, 2010.

Electronic version available online.

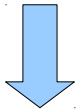
Weekly Plan

Week	Topic	Assignment
	Part I – Reactive Robotics	
1	Intro to robotics & ROS	
2	*Holiday*	
3	2D mobile robot kinematics & ROS	
4	2D mobile robot kinematics & ROS	Assignment 1
5	Basic control & learning	Proposal
	Part II – Cognitive Robotics	
6	Estimation & Localization	
7	*Holiday*	
8	Map estimation & SLAM	Assignment 2
9	Path planning	
10	Model learning & simulation	Project WP1
	Part III – Advanced Topics	
11	Robot vision + robot audition (guest)	
12	Adv. Locomotion/kinemat. + cognitive robotics (guest)	
13	3D geometry/dynamics + human-robot interaction (guest).	

Project summary

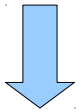
Teams of 3.

"Make a robot do something cool".



Suggested approach:

- Choose a platform (e.g. Turtlebot).
- Choose a problem (e.g. Path-planning in a cluttered room).
- Choose a solution or two (e.g. RRT-Star).
- Choose an evaluation (e.g. traversal speed)



"Solve the path-planning problem on the Turtlebot using RRT-Star and evaluate speed of traversal"

Project summary Step-by-step.

- Step 1: Proposal (week 5):
  - We want to make robot A do X using method Y..
  - We will measure the goodness of our solution by doing Z.
- Step 2: Work package 1 (week 10):
  - Face-to-face meeting & short report.
  - Evaluated against proposal's expectations for WP1.
- Step 3: Demo (week 14):
  - This is the robot, the problem and our solution.
  - This is how it works.
- Step 4: Report/Video (week 15):
  - Details of robot, problem & solution.

Assignments

- Assignment 1 (week 4).
  - Obstacle-avoiding robot in ROS/Gazebo (Turtlebot).
- Assignment 2 (week 8).
  - Mobile robot control in ROS/Gazebo (Turtlebot).

(compulsory > 20%)

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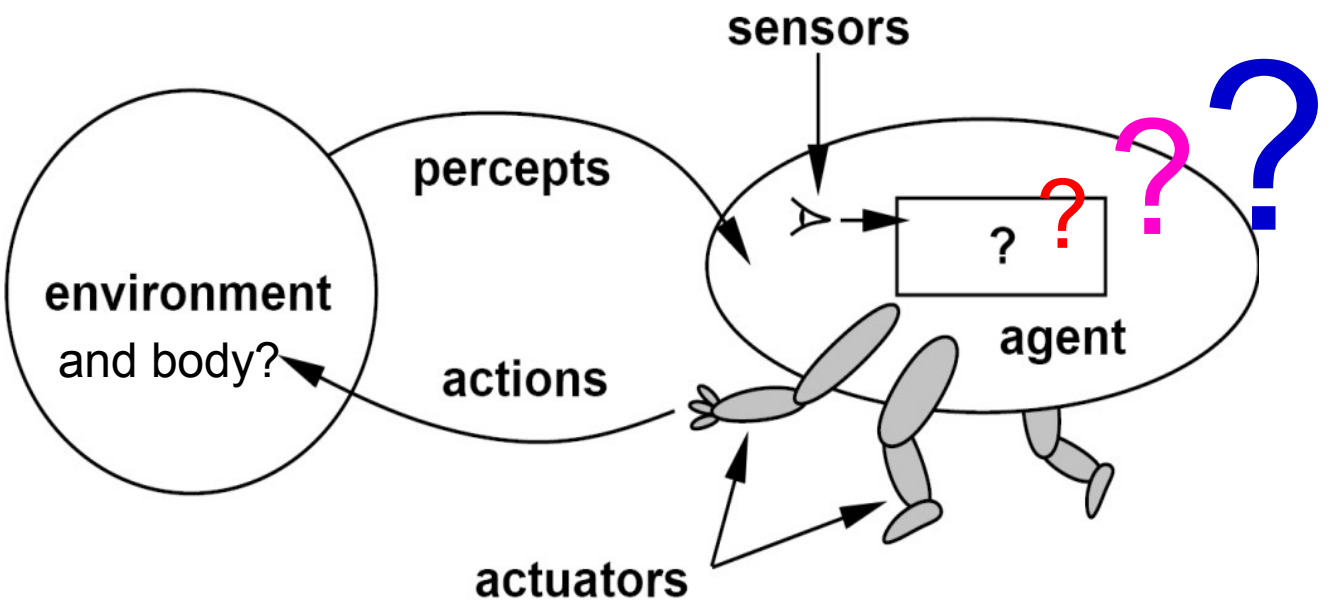
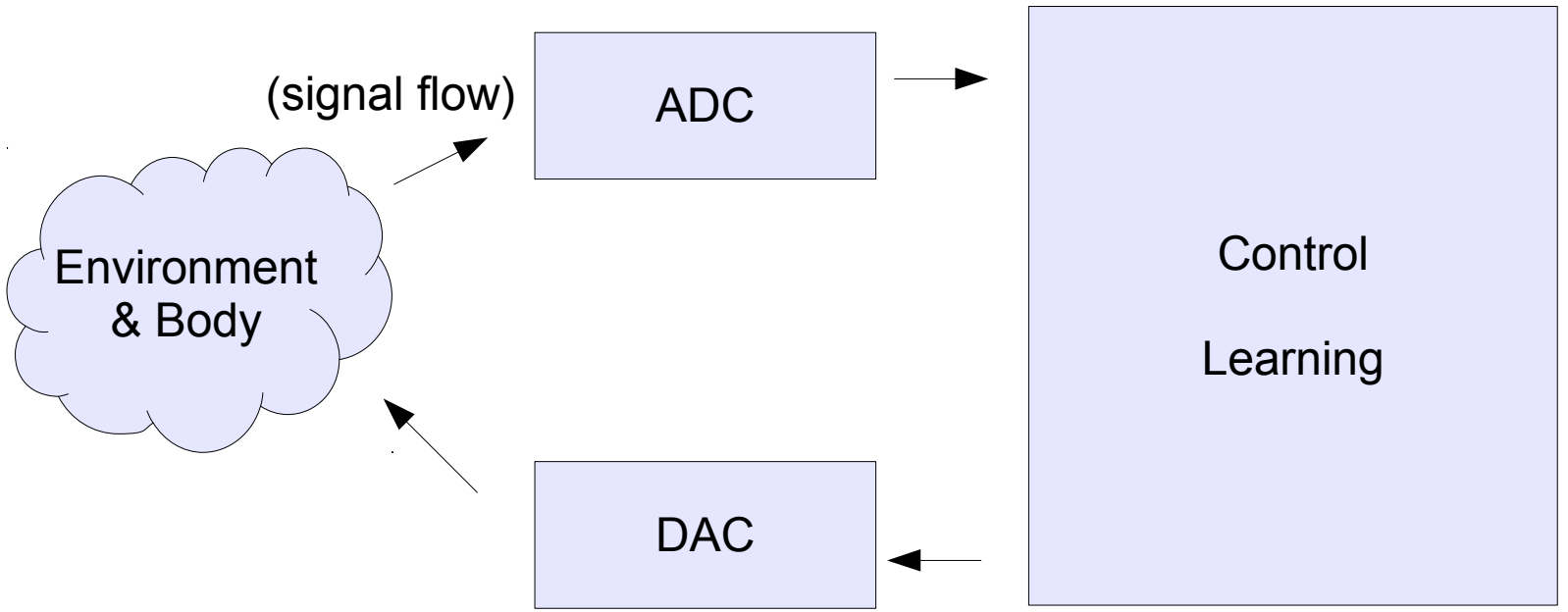
The computational problem of autonomous robotics



$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

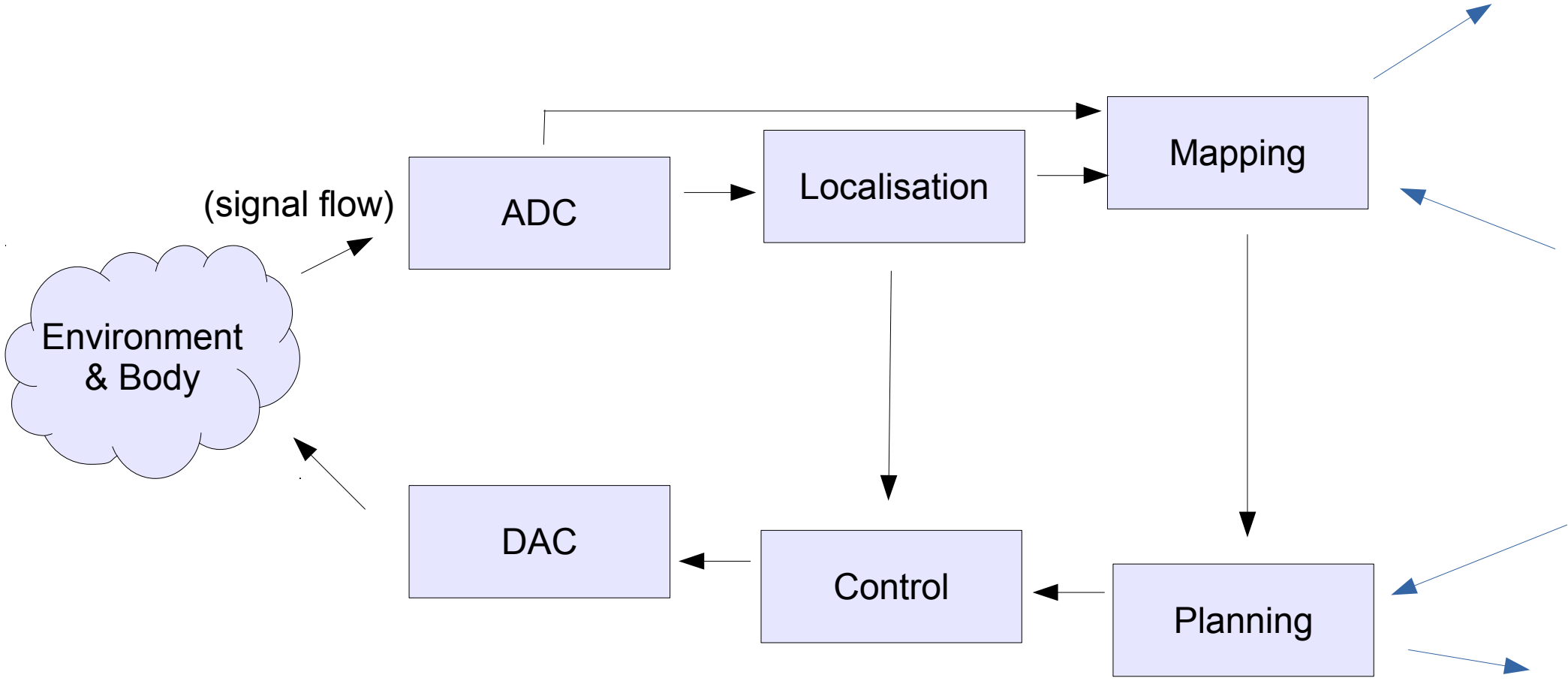
Reactive/learning approach

(sense-act+learn)



Cognitive approach

(sense-represent-decide-act)



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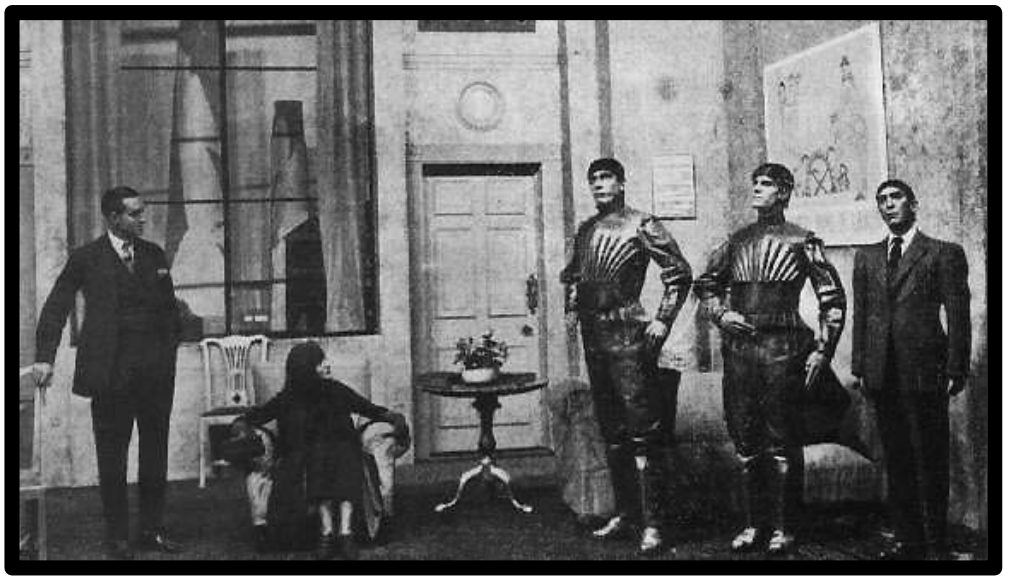
Robot etymology

Karel Capek: *R.U.R. (Rossum's Universal Robots), 1921*

- "*Obligatory Work*" (Czech)
- More like clones.



Robot definition

- "*A robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, or specialized devices through variable programmed motions for the performance of a task*" (Robotics Industry Association)
- Maja Mataric's definition, 2007

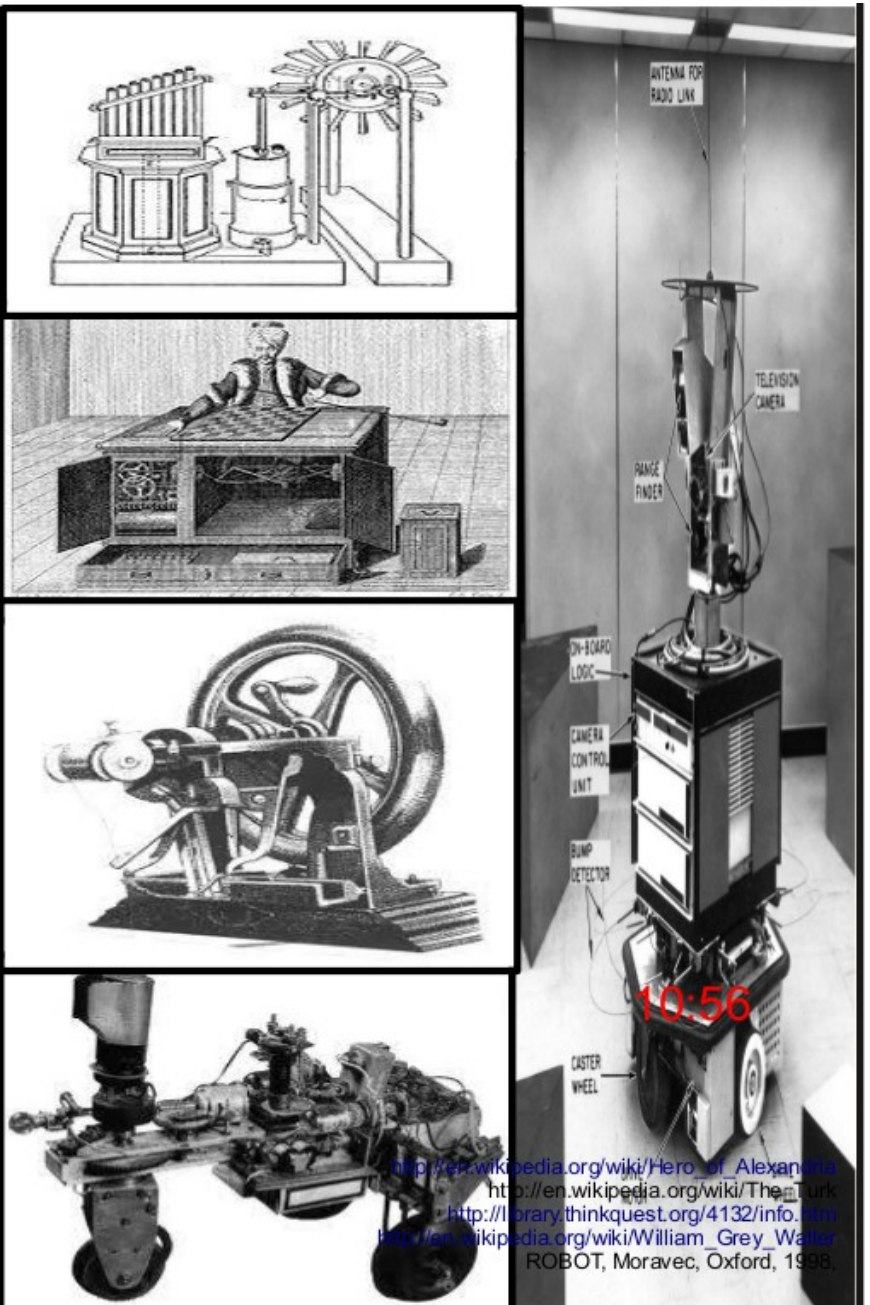
  An autonomous system which
  - exists in the physical world.
  - can sense the environment.
  - act on it.
  - to achieve its goals.

Robot definition

- Is a thermostat a robot?
- Is a food processor a robot?
- Is a worm a robot?
- Is a human a robot?

Autonomous Robots?

Milestones in Robotics



- Automatons: e.g. Heron of Alexandria 10-70.
- Mechanical Turk 1770.
- Industrial revolution 18th – 19th century.
- Grey Walter's Turtles 1948-1949.
- Stanford's Shakey 1966-1972.
- 21st century abundance.

http://en.wikipedia.org/wiki/Hero_of_Alexandria
http://en.wikipedia.org/wiki/The_Turk
http://library.thinkquest.org/4132/info.htm
http://en.wikipedia.org/wiki/William_Grey_Walter
ROBOT, Moravec, Oxford, 1998,

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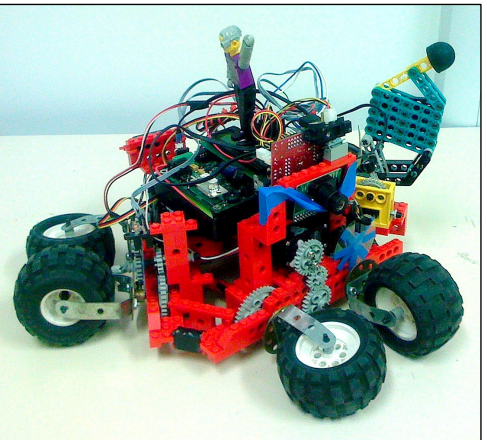
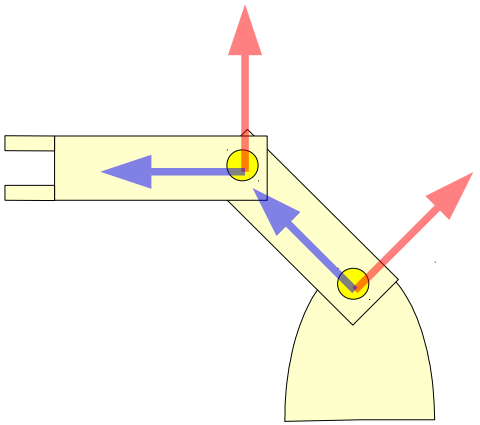
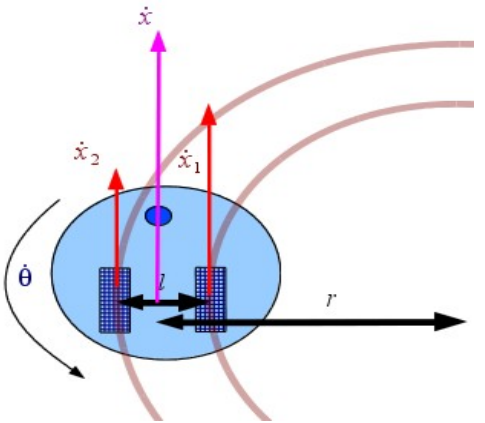
Main problems in robotics: Kinematics

- Kinematics:
  - "*The study of (instantaneous) motion*".
- E.g.
  - Joint angles → *effector* position (**forward kinematics**)
  - Effector position → joint angles (**inverse kinematics**).
  - Wheel motion & steering ←→ angular/linear motion.

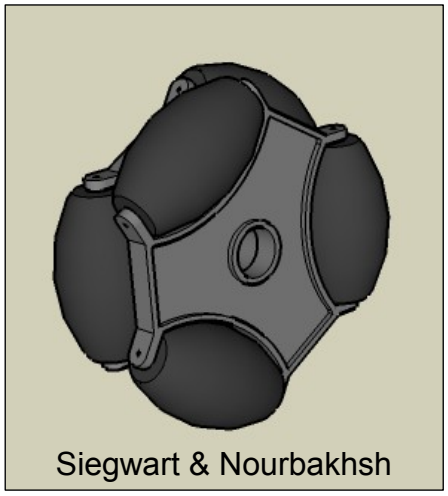






Main problems in robotics: Dynamics

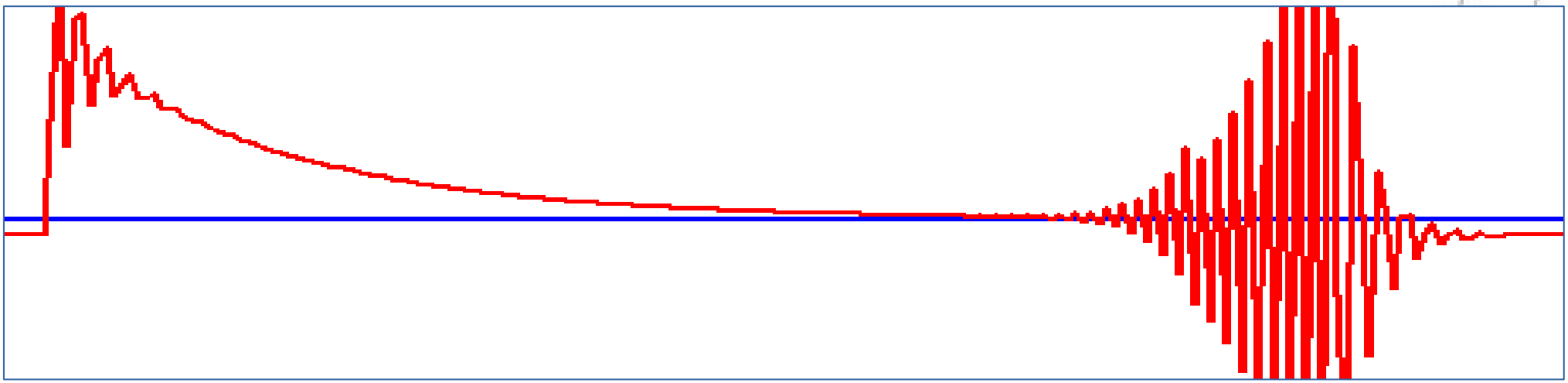
- Dynamics:
  - "*The study of motion and the causes of motion*".
- E.g.
  - Robot finger torques → applied force.
  - Desired car motion → engine torque.


Siegwart & Nourbakhsh

http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/ping-pong-robot-learns-by-doing

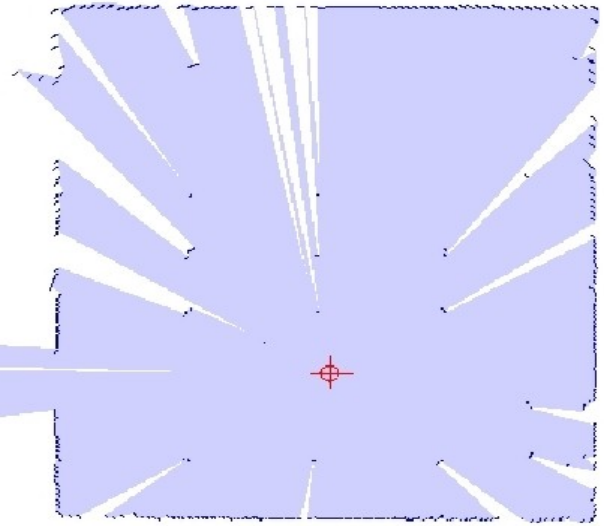
Main problems in robotics: Control

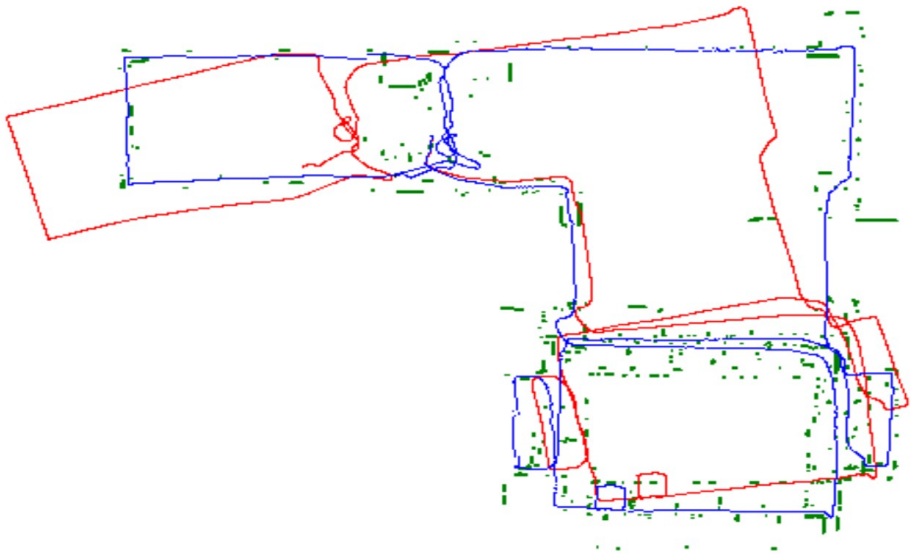
- Control:
  - *"The (mathematical) study of getting dynamical systems to behave in desirable ways."*
- E.g.
  - Turn steering wheel to go in straight line.
  - Apply correct force to lift a box.



Main problems in robotics: Localisation

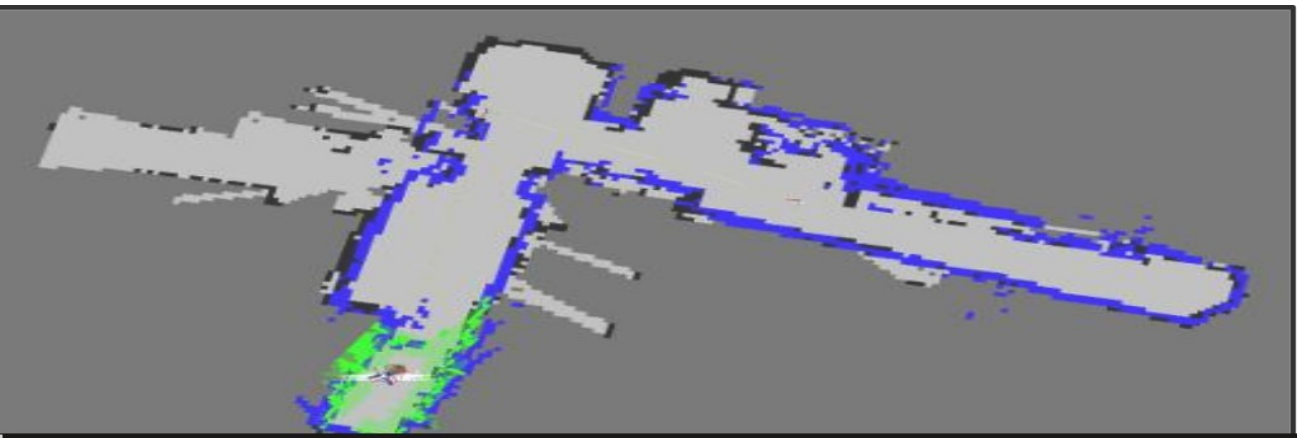
- Localisation:
  - Finding the robot's pose in a known area.
- E.g.
  - Odometry & laser scans → car location.





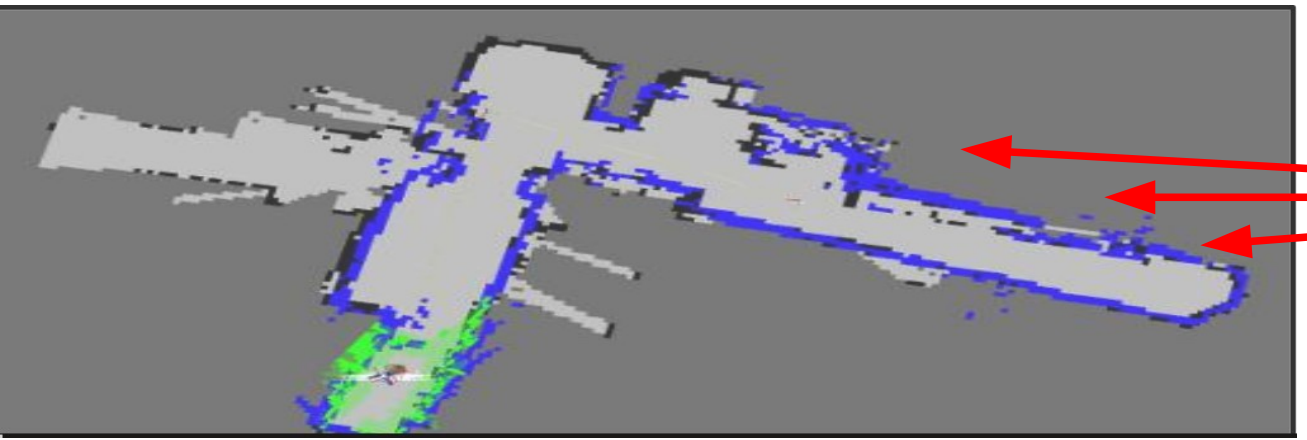
Main problems in robotics: Mapping

- Mapping:
  - Building a known-world map.
- E.g.
  - Odometry & laser scans → occupancy map.



Main problems in robotics: SLAM

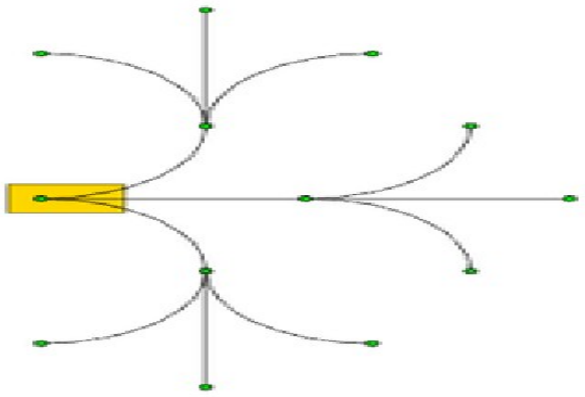
- Simultaneous Localisation And Mapping (SLAM).
- E.g.
  - Odometry & laser scans → occupancy map AND location.

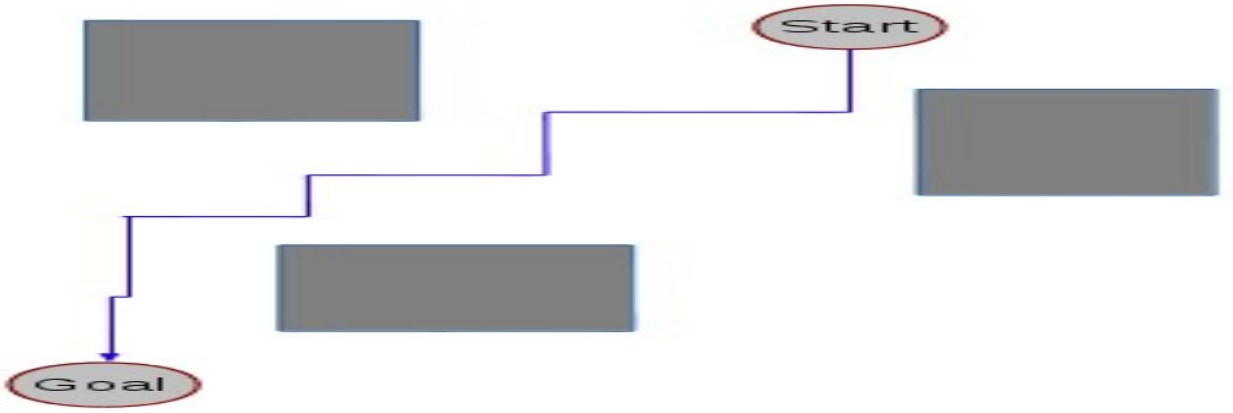


?

Main problems in robotics: Motion planning

- Motion planning:
  - “The study of paths that robots can take to get to a goal”.
- E.g.
  - Move a robot arm past an obstacle.
  - Move my car through a crowded arena.



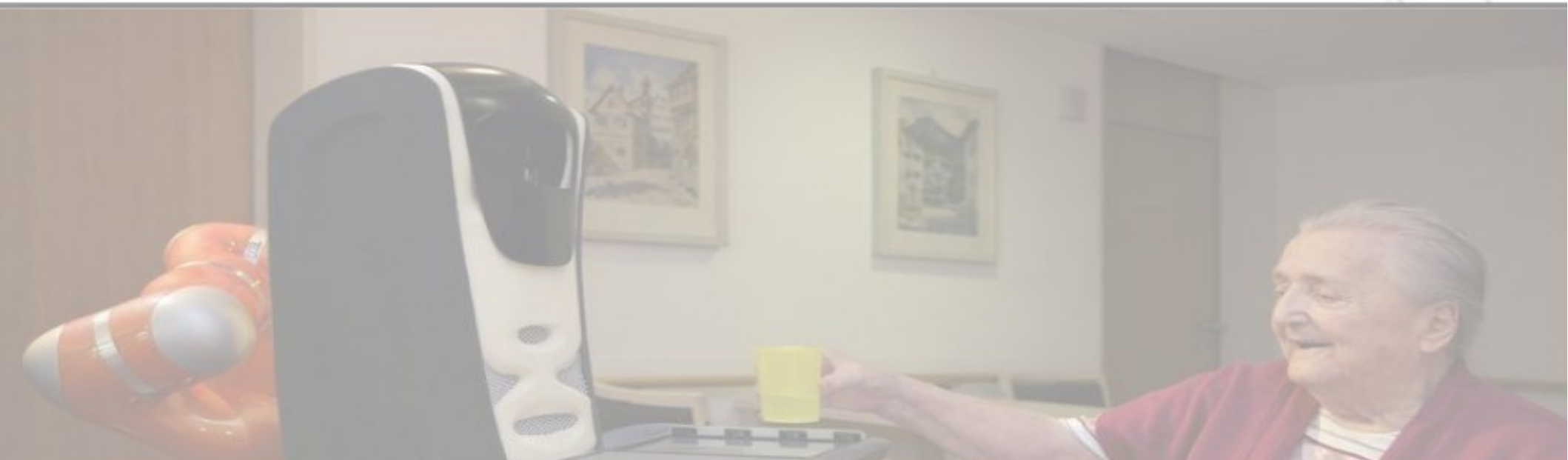


Main problems in robotics: Task planning

- Task planning:
  - “The study of sequences of actions that robots can take on objects to achieve a particular goal”.
- E.g.
  - Warehousing strategies & stacking.
  - Cooking a meal.

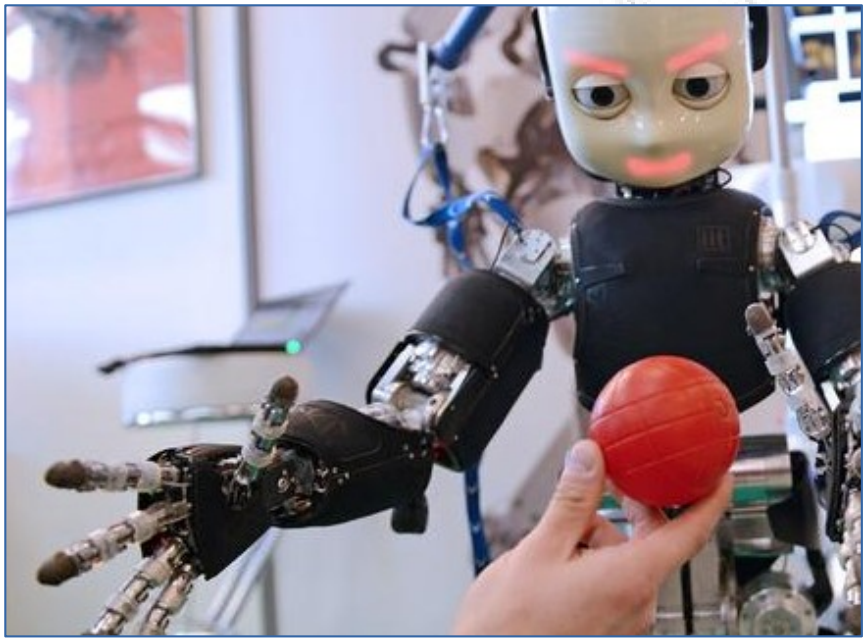
Main problems in robotics: People-centered

- Speech recognition & generation.
- Action, intention detection.
- Safety & soft robotics.
- Being useful & making people comfortable.



Main problems in robotics: Learning

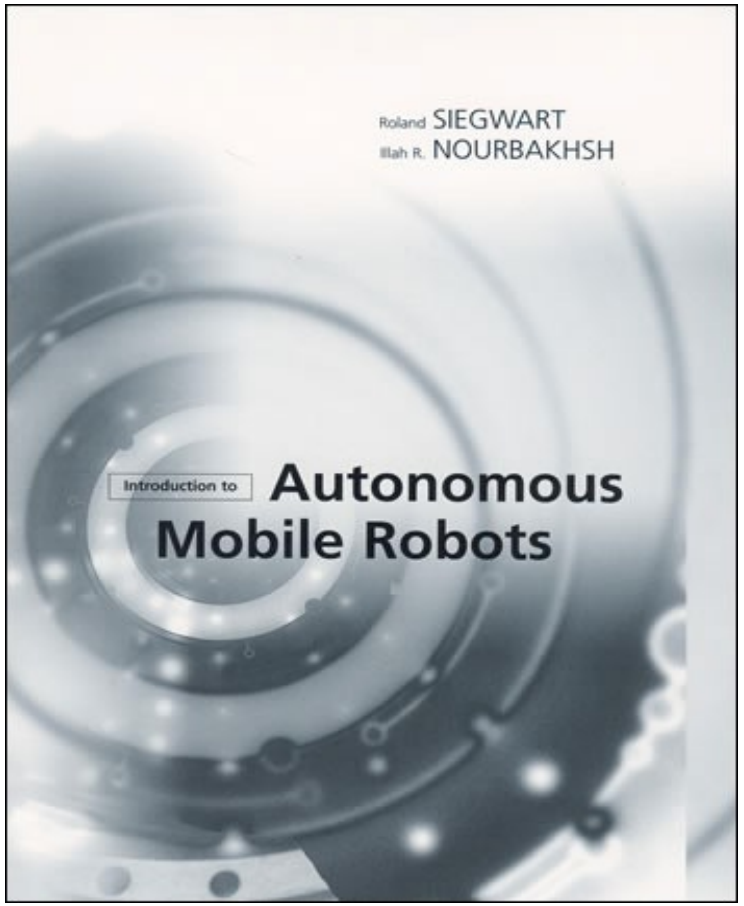
- Policy learning.
- Temporal-difference learning.
- Object learning.
- Adaptive control.
- Developmental robotics.
- Visual learning.
- Etc.



Readings

Siegwart & Nourbakhsh Chapter 1.

(Introduction)



“When we try to pick out anything by itself
we find that it is bound fast by
a thousand invisible cords that cannot be broken,
to everything in the universe.”

John Muir

Ecologist

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Review

- What is a robot?
- What was the first robot?
- What is the difference between reactive robotics and cognitive robotics?
- What is “control”?
- What is “kinematics”?
- What is “localisation”?
- What is “soft robotics”?