Autonomous Robotics: Action, Perception and Cognition: Introduction

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What comes to your mind when you hear the word “robot”

- Google search “robot” (21 apr 2020)

Nao (robot) - Wikipedia
en.wikipedia.org

more productive than human workers ...
information-age.com

Future Robots and Ensuring Human S...
blogs.3ds.com

Robots have jumped, raced and rolled a ...
cnet.com

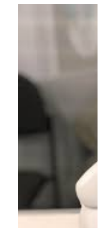
H
b

fight the coronavirus in China ...
businessinsider.com

Social robot - Wikipedia
en.wikipedia.org

China says AI robots won't lead to ...
techinasia.com

Could robots be marking your homework ...
bbc.com



CES 2020 v
cnet.com

Humanoid robot job apocalypse — or a ...
pri.org

Here are the coolest robots of 2019 s...
thegadgetflow.com

extend the scope of IoT applications ...
networkworld.com

The time for putting up with stupid ...
cosmosmagazine.com

Eight cute and
dezeen.com

Japanese-Israeli venture offers robots ...
timesofisrael.com

Robots Might Make Human Workers More ...
bloomberg.com

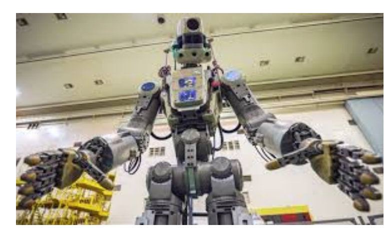
NAO the humanoid and pro...
softbankrobotics.com

Will Robots Rob Us From Our Jobs?
industrywired.com

Robots.txt Datei fürs SEO ...
neilpatel.com

Why Ethical Robots Might Not Be Such...
spectrum.ieee.org

Robots could learn to recognise human ...
techxplore.com

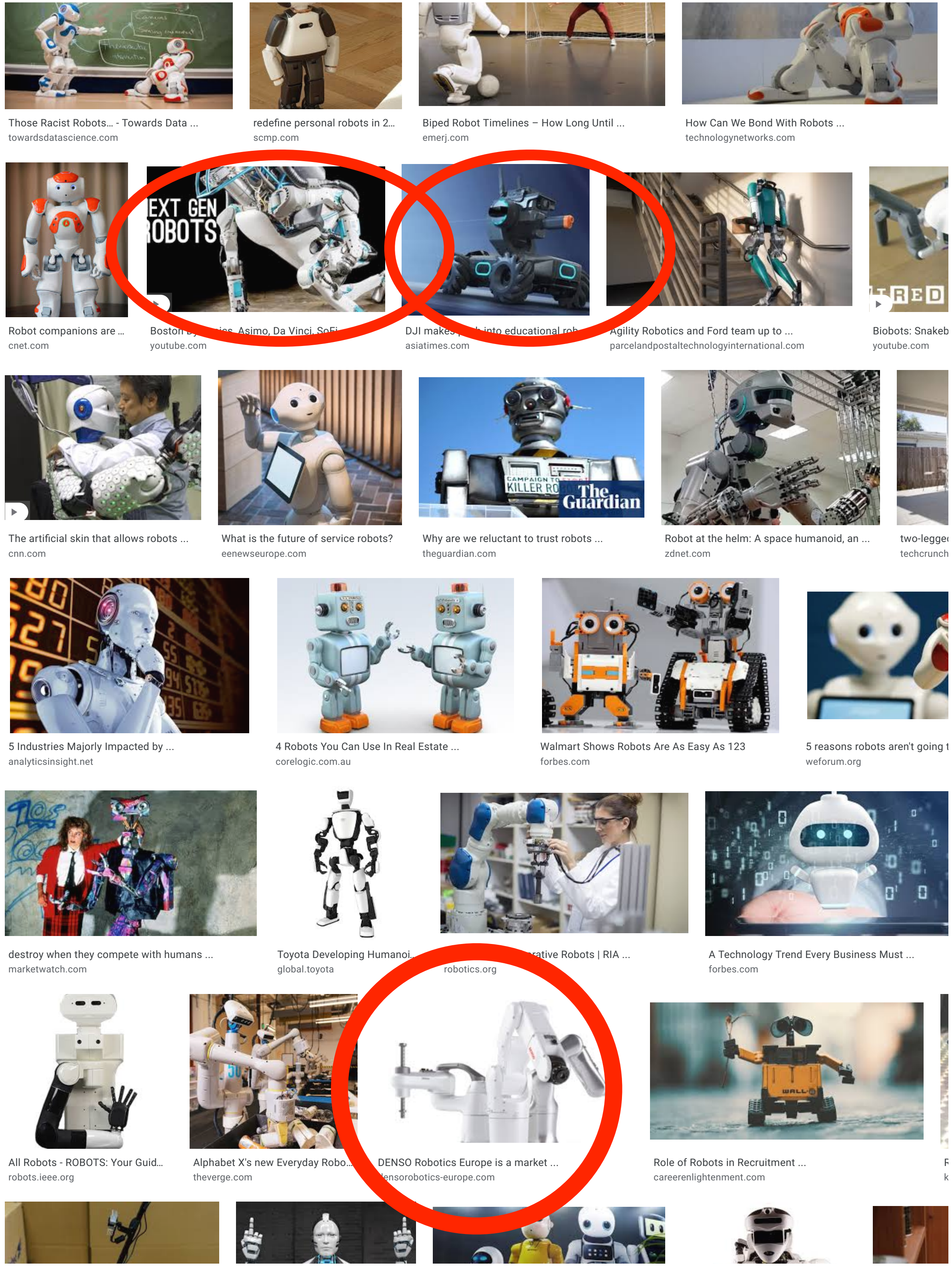


Russia and robots: Steel junk or a ...
bbc.com

- => Humanoids (or anthropomorphic) robots page 2

legged robot

compliant arms



vehicle

no regular industrial robot on first 4 pages

in reality, industrial robots are much more common today than humanoids or autonomous vehicles

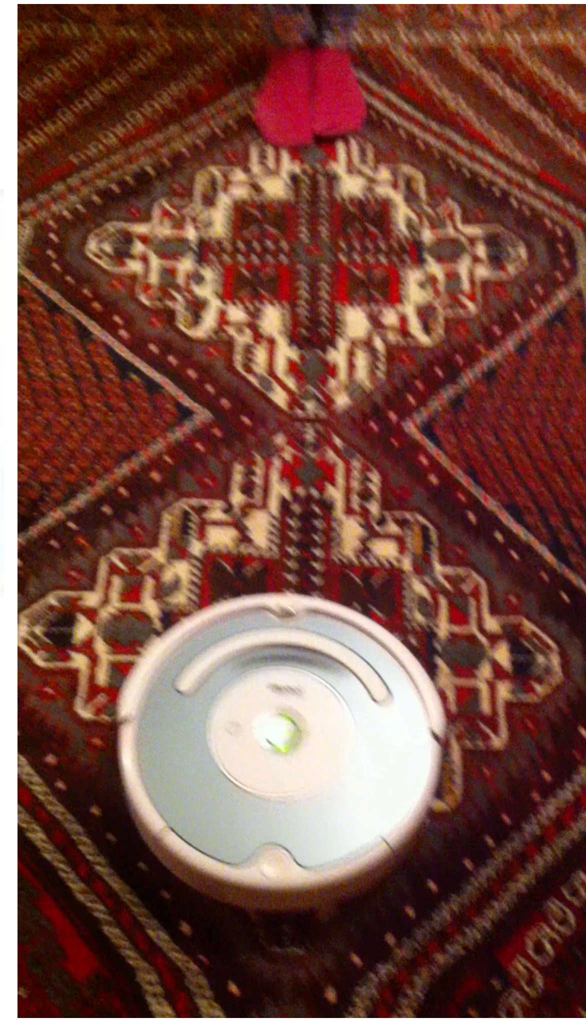
- fundamentally, all factory automatization is a form of robotics: "programmable" machines…

Survey of kinds of robots

- other than humanoid or industrial

simple, single-task autonomous vehicles

Figure 5.5. Examples of service robots.



[photo credits: WTEC final report 2006]

some of our own (older) autonomous vehicles

outdoor vehicles

(a) (b)

Figure 2.3. Agricultural robotic vehicle (Int Harv, U.S.) (a). Mining haul truck (ACFR, Australia) (b).

Figure 2.1. NASA Mars Rover (NASA Jet Propulsion Laboratory (JPL)).

cars: autonomous driving

legged robots

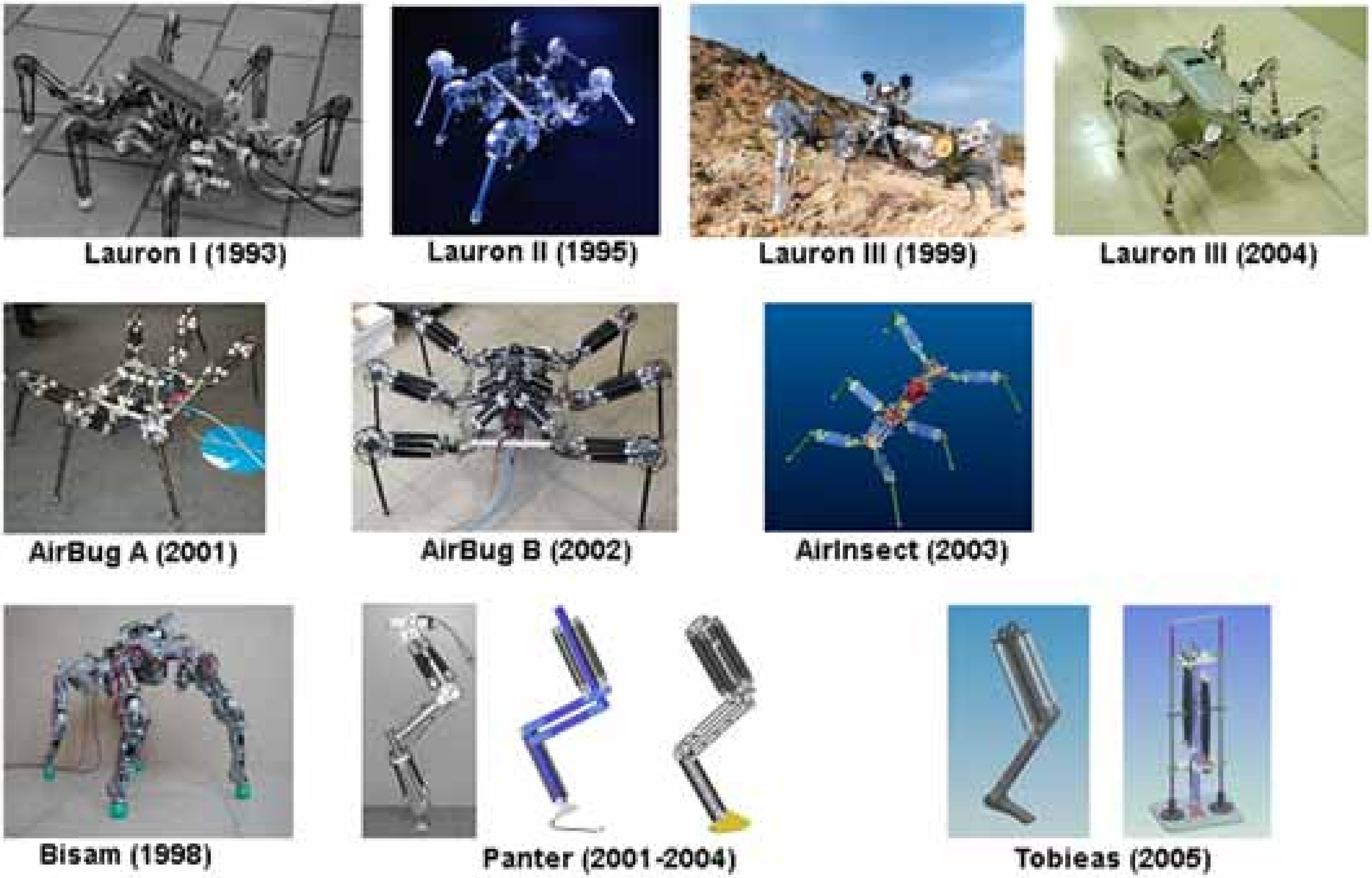
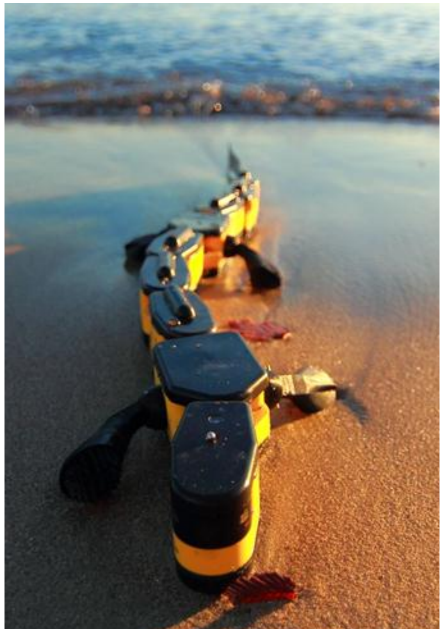
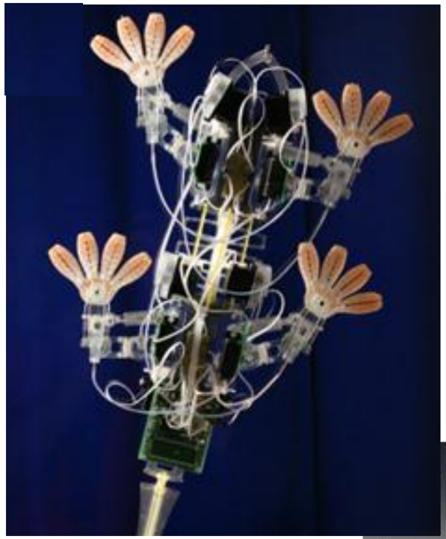
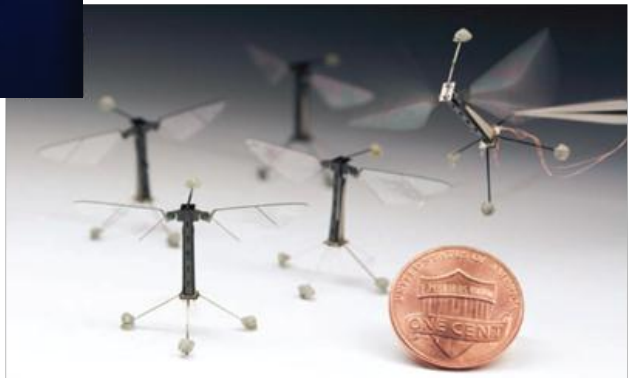


Figure C.58. The walking machines built by Dillmann's group.

biologically inspired robotics







snakes, crawlers, climbers

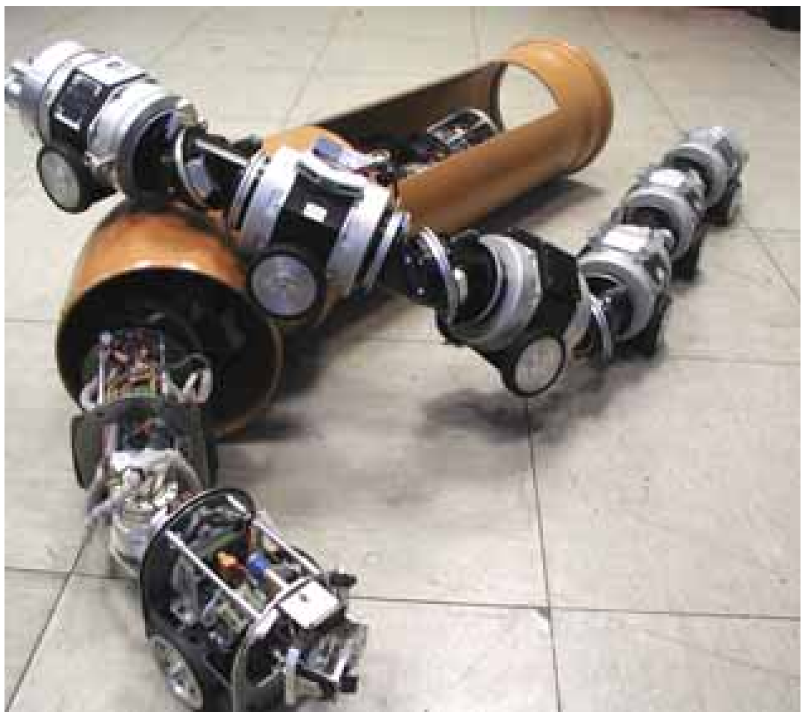


Figure C.57. Inspection robot.

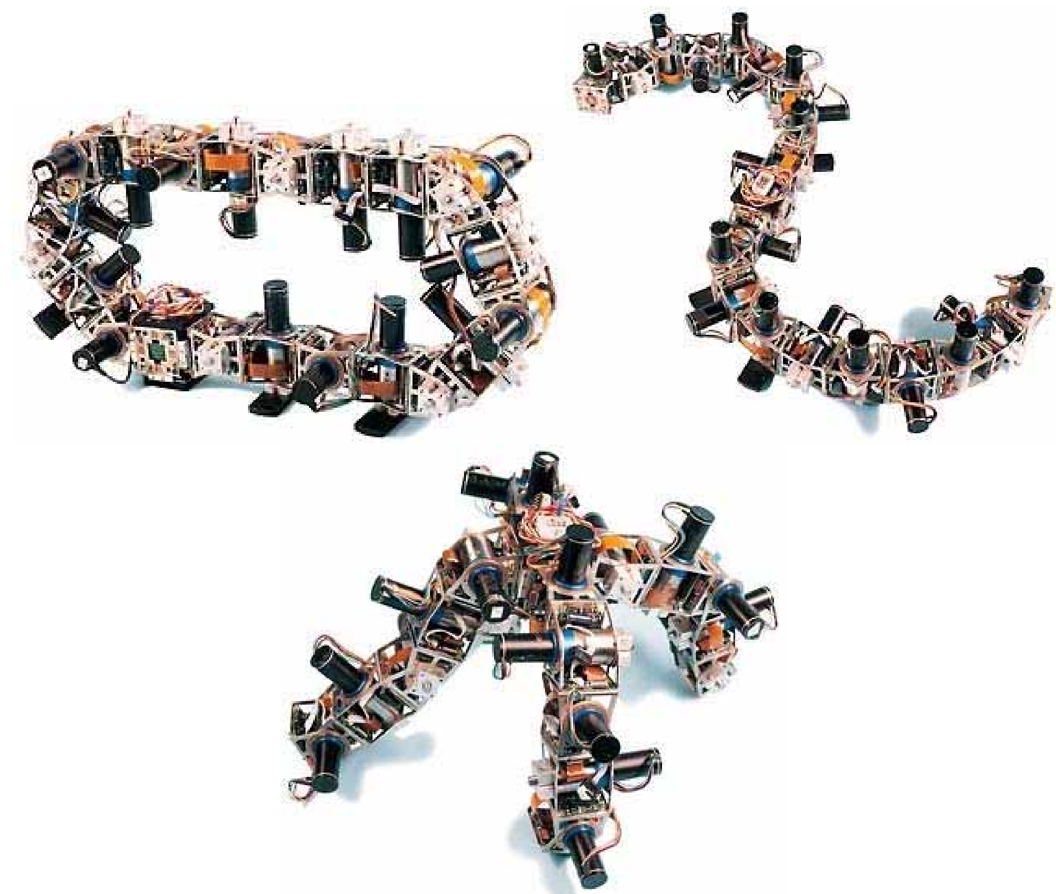


Figure 7.2. Robotic modules can be reconfigured to "morph" into different locomotion systems including wheel-like rolling system (left), a snake-like undulatory locomotion system (right), a four-legged walking system (bottom).

underwater vehicles, ships

Figure 2.2. IFREMER ASTER autonomous underwater vehicle.

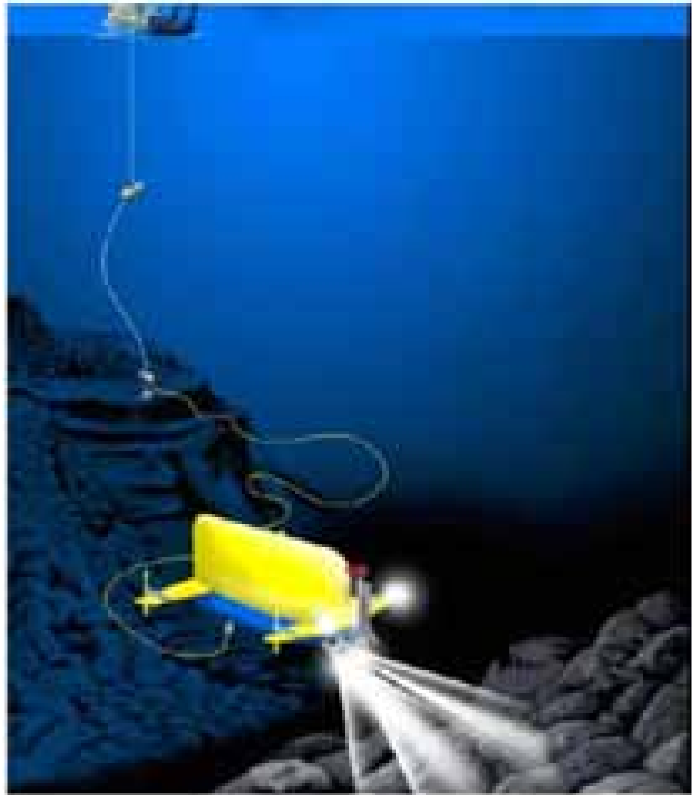
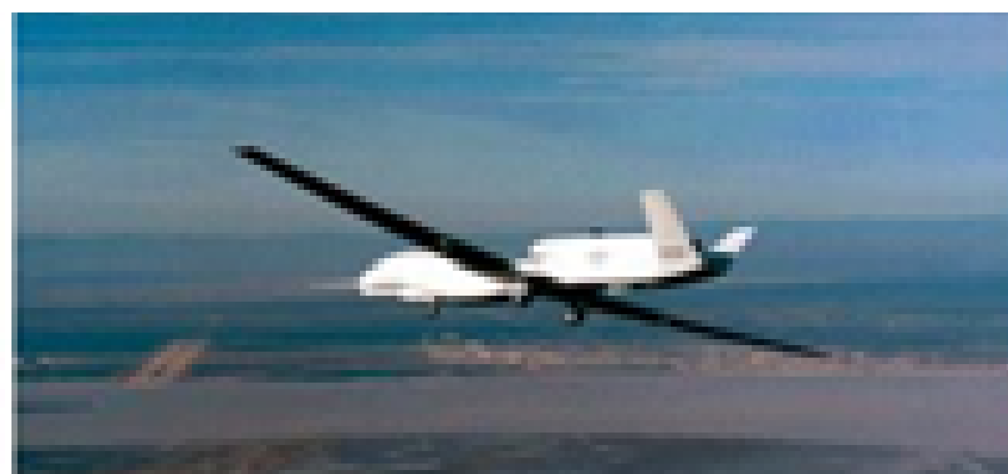


Figure 2.11. HROV (Hybrid ROV) project (Johns Hopkins University (JHU) and Woods Hole (WHOL), U.S.).

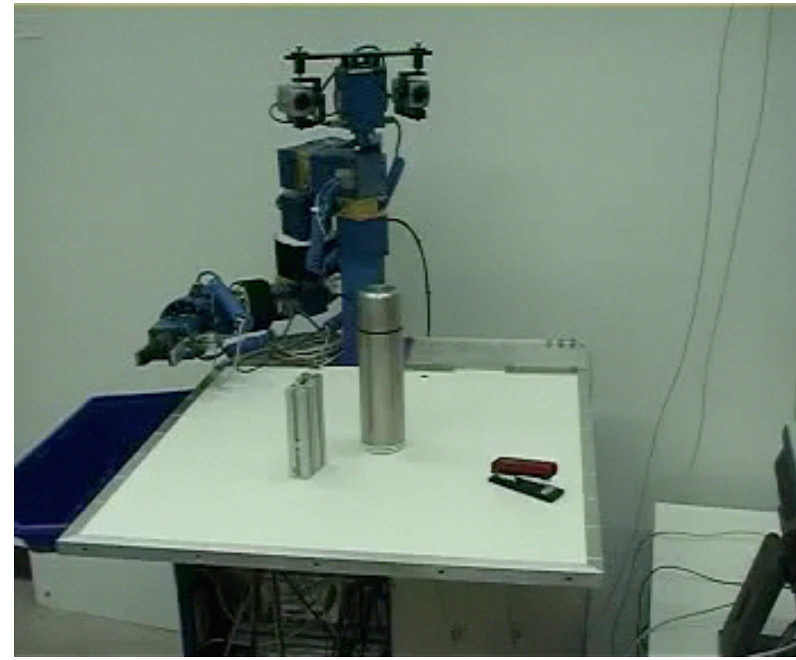
airborne robots

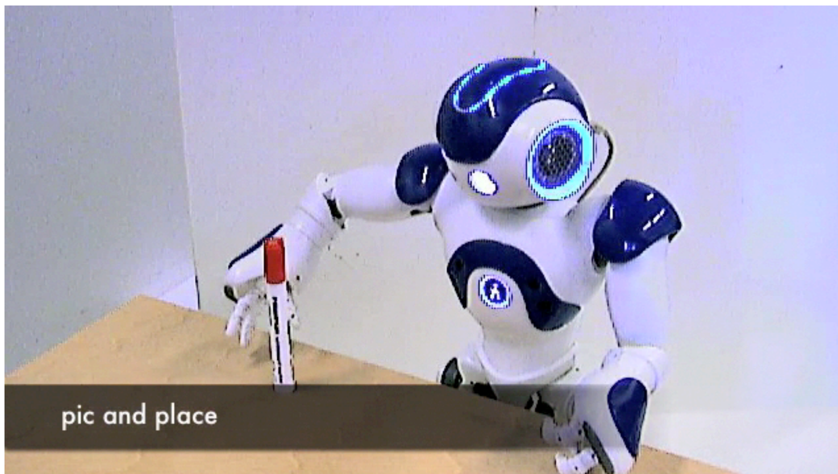


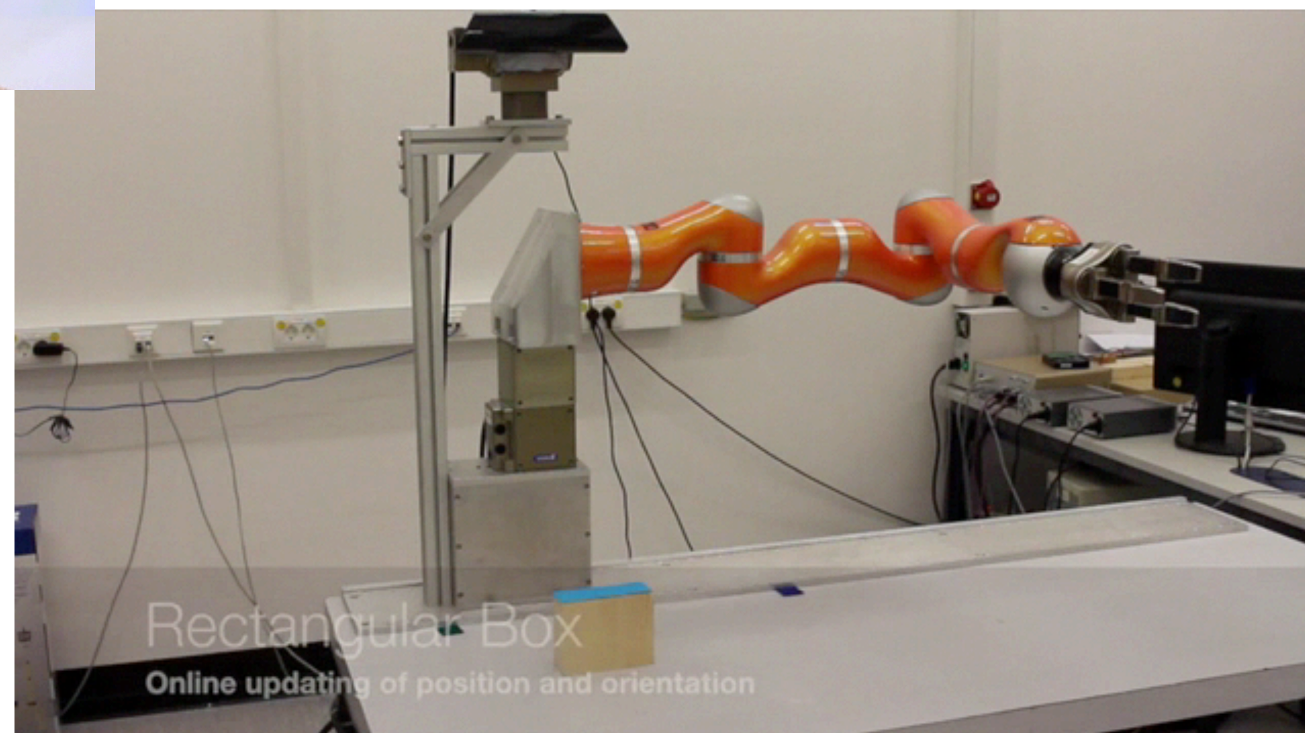
robotic manipulators, hands

Figure 4.10. Dexterous arms at DLR, NASA and UMASS.

some of our own robotic manipulators



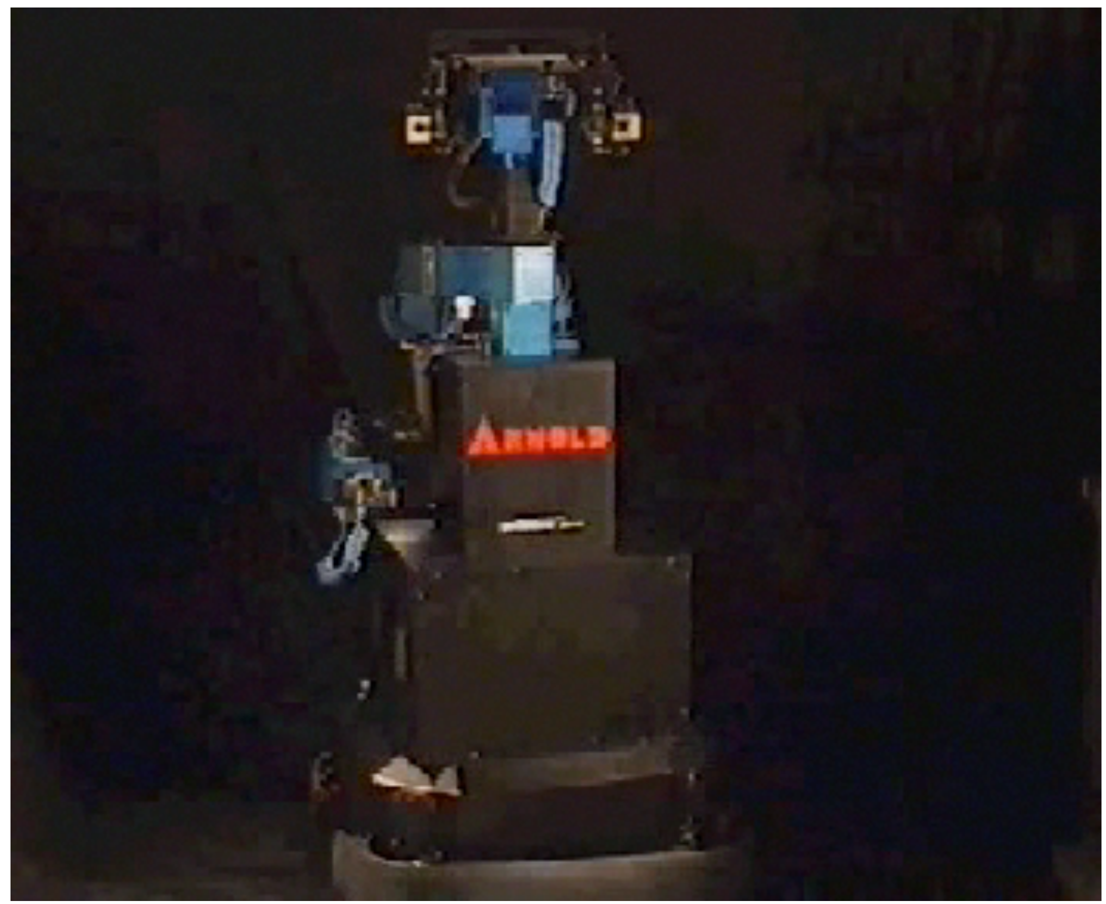




mobile robot manipulators

Figure C.28. Dexterous arm on mobile base, opening door (left), robot passing through doorway (right).

our own mobile robot manipulator



[Arnold: 1998-2000]

autonomous robotics

- *auto-nomos*: giving laws to oneself
- minimally: autonomous robots generate behavior based on sensory information obtained from their own on-board sensors
- in contrast to industrial robots that are programmed in a fixed and detailed way

autonomous robotics

- but: even an industrial robot uses autonomous control to reach its programmed goals…
- => autonomy is expected to go beyond control, include decisions=qualitative change of behavior
    - e.g. avoid obstacle to the left vs. to the right
    - e.g., reach for one object rather than another

autonomous robotics

- but: we do not expect autonomous robots to just do whatever “they want”… we expect to give them “orders”

autonomous robotics

- autonomy as a "programming interface":
  - give instructions to a robot at a high level, in regular human language and gesture in a shared environment…
  - … and let the autonomous robot deal with the "details" of how to achieve goals

why autonomous robots?

why autonomous robots?

- ideas I hear from lay-people
  - to clean up, to serve drinks..
  - just generally cool..
  - robot soldiers..

toy/entertainment/animation

- including therapy (autism)

assistance robotics

- at home, in the work place
- collaborate with human users

autonomous vehicles

- …. well, for autonomous transport…

[Amazon robotized warehouse]

military, fire fighting, rescue

- the “ideal” application because desire to remove human agent from the scene is consensual …
- much research

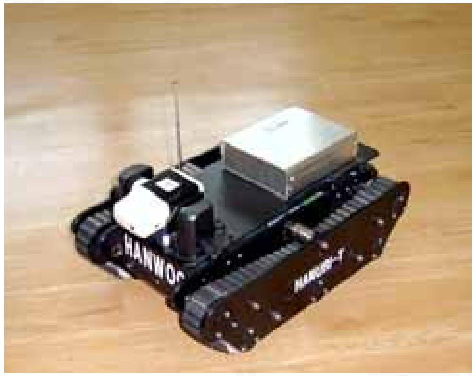
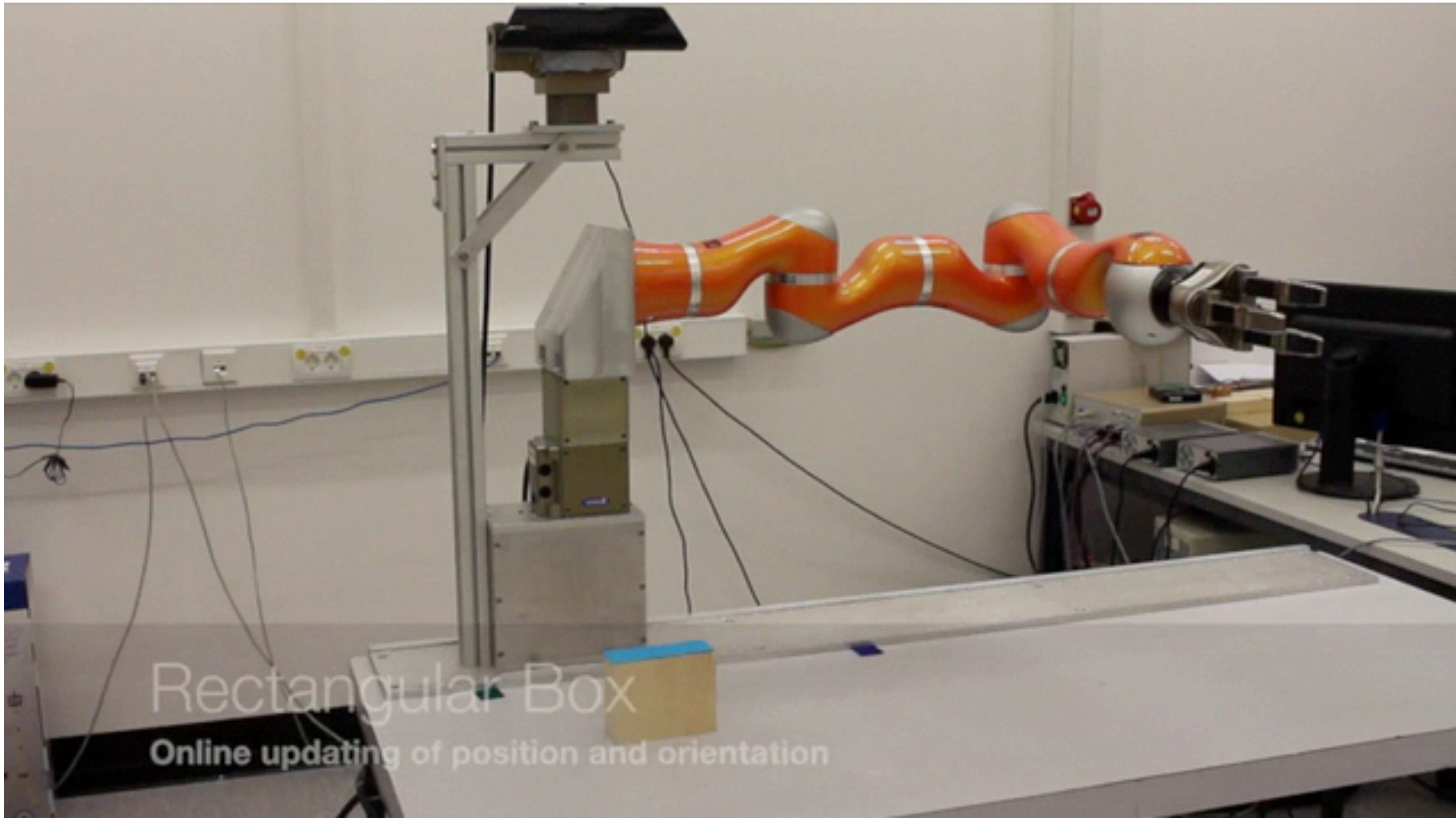


Figure B.11. Military Robot.

(robot ethics…interesting topic)

- may a military robot decide autonomously to shoot
  - …. navy ships do that already…
- may a autonomous car decide between avoiding a pedestrian and preventing danger for car occupants?
  - fundamental problem: off-loading decisions from user to designer …

autonomous robotics as a “playground” of research



autonomous robotics as a “playground” of research

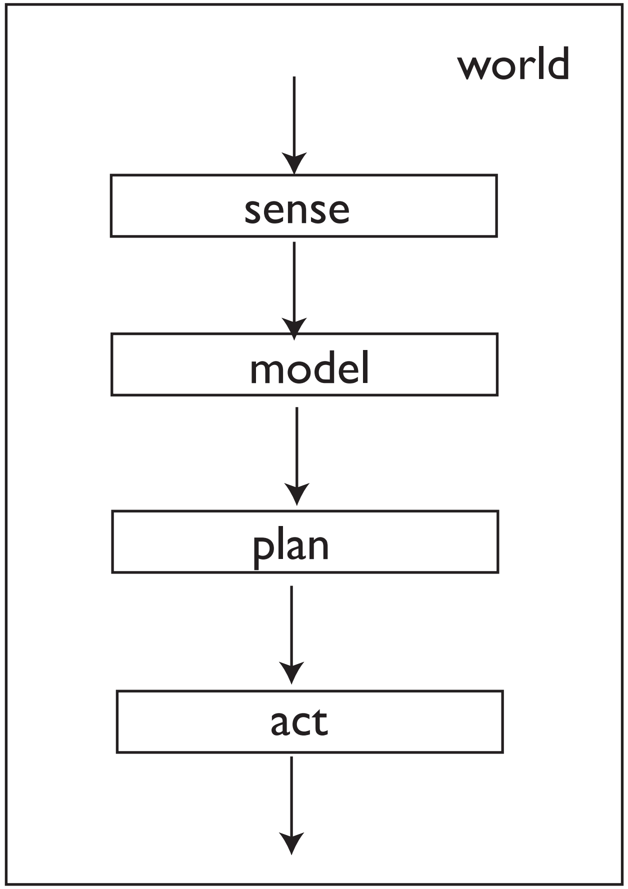
- modern engineering models systems, treating the remainder stochastically…. autonomous robotics act in natural environments that are difficult to model

autonomous robotics as a "playground" of research

- modern engineering uses modular design that limits the range over which modules interact/interfere…autonomous robotics: requires system integration

autonomous robotics as a "playground" of research

- highly interdisciplinary field
  - sensing
  - perception
  - mechanics
  - control
  - AI/planning
  - embedded computing
  - communication / data security
  - user interfaces



State of the art

- Sustained research effort over decades…
  - fast embedded computation has made many classical algorithms feasible that used to be not viable
- Autonomous vehicles
  - breakthroughs due to laser range finders… probabilistic approaches… machine learning
  - but hit a wall in the last percent..

State of the art

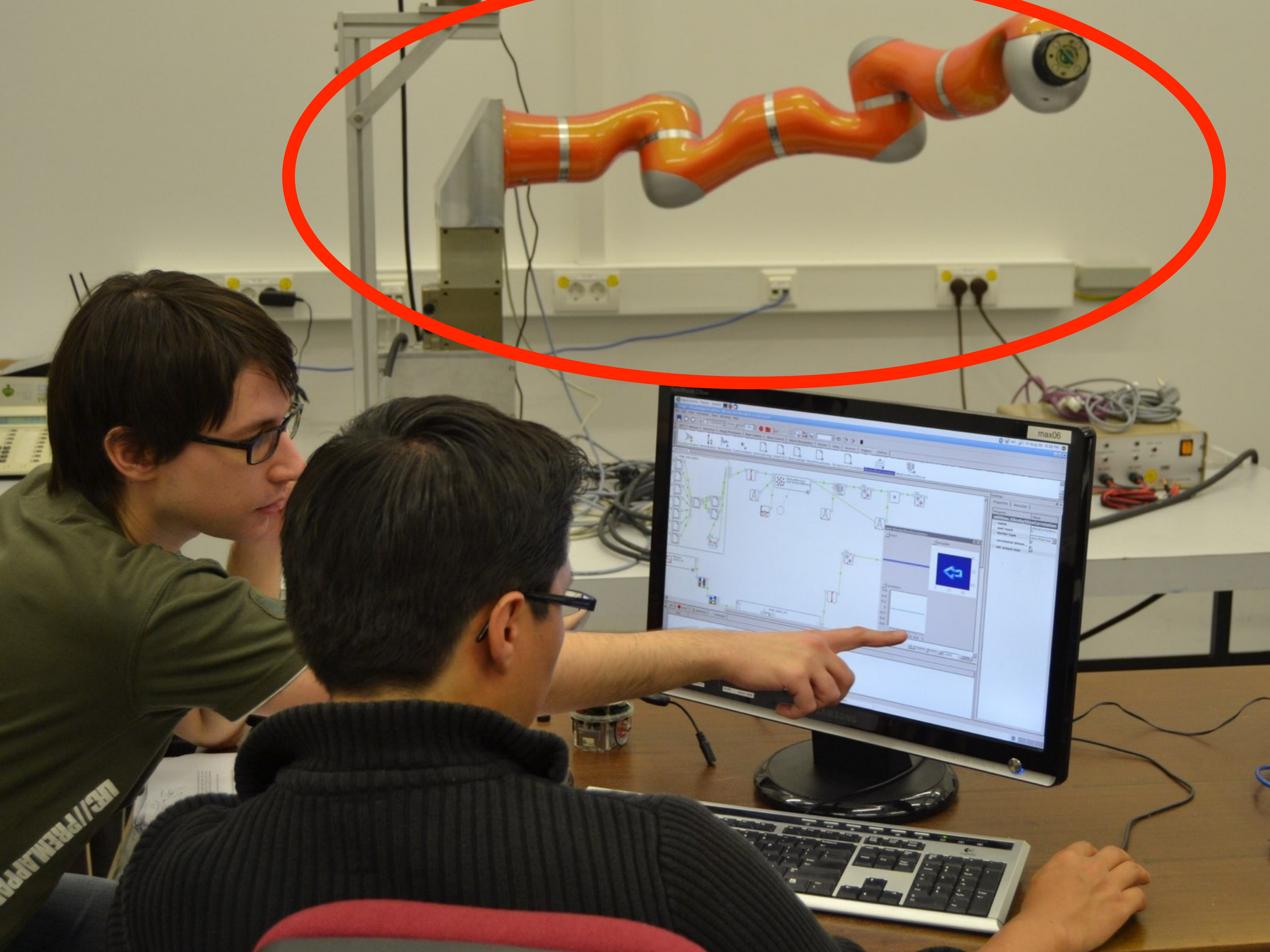
- Robot vision for manipulation
  - after decades of slow progress, push from deep learning
  - but no breakthrough
- Robotic manipulators
  - classic compliant reaching/grasping still struggling after decades
  - physical interaction as a bottleneck
  - suction cup based reaching/sorting in limited scenarios is practical and deployed

4 core problems/challenges

- perception
- interacting with humans
- background knowledge
- movement generation

(1) perception

- no autonomy without perception
- perception is NOT estimating the stimulus
- it is learning about the environment and extracting meaning=that what enables action


max06

core problems of perception

- detection/classification… invariance
- attention: search!
- estimation: pose

=> WS lecture course

perception SoA

- perception for vehicles: much progress in SLAM and variants
  - exploiting multiple/low level sensors
- perception for arms:
  - a return to computer vision driven in part by Deep NN which derives its success from having many examples to learn from and aiming to extract little information (e.g. label only)
  - robotic settings conditions differ: limited number of objects/examples from which more information must be extracted (e.g. pose)

(2) interaction with humans

- in part also a problem of perception
  - e.g. in perceptually grounding language
  - not a solved problem in general
- joint attention
- intention perception
- linking to background knowledge

- e.g., "the red cup to the left of the green cup" …

=> WS lecture course

(3) background knowledge

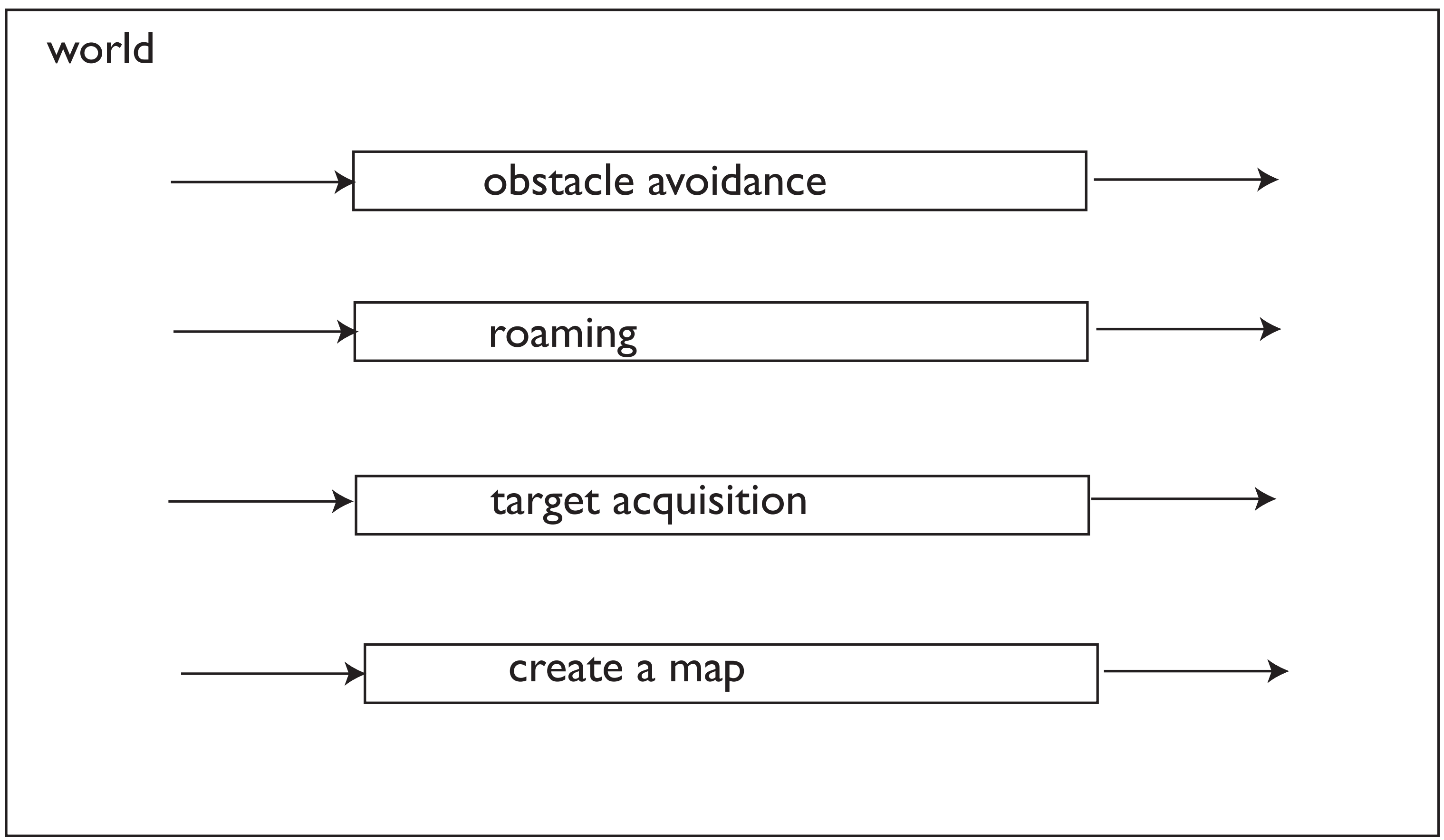
- implicit knowledge about how the world works
  - how to open a door
  - that milk is in the fridge
  - how to grasp a glas vs. a cup vs. a spoon
  - how to grasp an object to achieve a particular goal
  - to clear space before moving something to a new place…

background knowledge

- background knowledge is a core problem of classical artificial intelligence
  - knowledge representations
  - reasoning
  - action planning
  - architectures

background knowledge

- implicit background knowledge in behavior based robotics… the background is in the individual skills and how they are connected



background knowledge

- autonomously acquiring back-ground knowledge continues to be a challenging research frontier…
  - online learning
  - continuous learning
  - autonomous learning

(4) movement generation

- the core robotic problem that this lecture course primarily focusses on

movement generation

- classical approach
  - world models enable motion planning
  - plant models enable control
  - we will review these at textbook level…
- but:
  - this places demands on perception and on modeling of plant/objects that are not achieved in the real world
  - unclear if this works for soft/compliant actuation needed to safely interact with humans and real world objects
  - limited for human like movement

alternative approach

- movement generation inspired by analogies with human (biological) movement generation
  - integration of spatial orientation (navigation) and movement generation
  - planning by dynamical systems: control-like
  - timing/coordination
- confronting the problem of soft visco-elastic actuators: muscles
- => main emphasis of this course

Particular perspective of the course

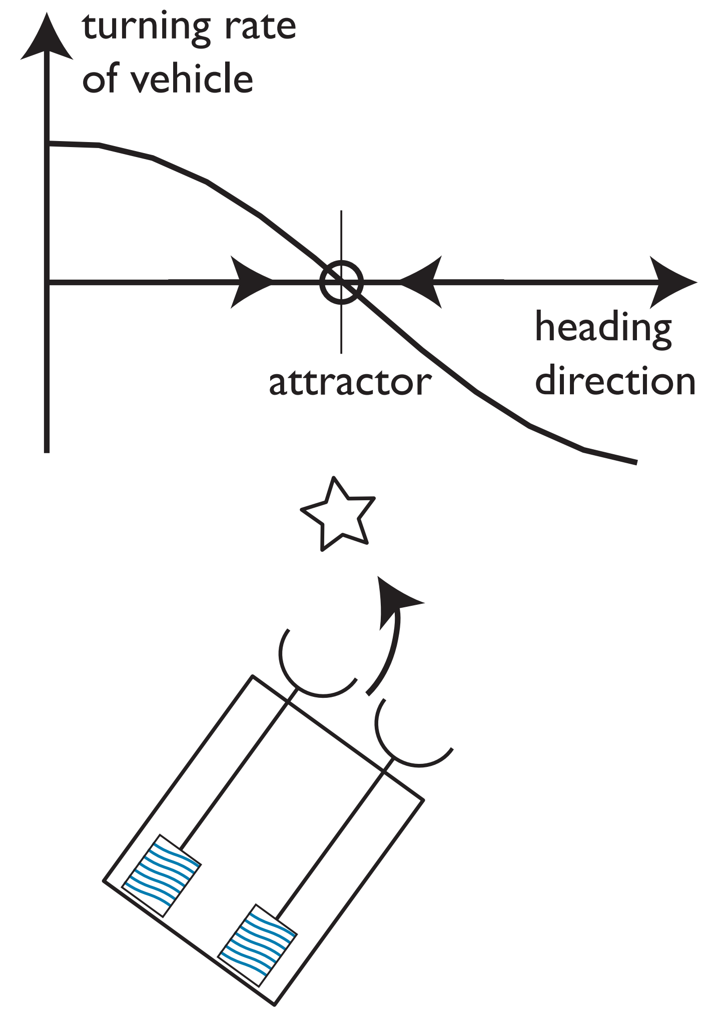
- autonomous robotics as a research field that interacts with the theory of cognitive systems
- 1) robots as examples of such systems… from which we learn about key problems
  - => integrative framework of dynamical systems
- 2) robots as tools to test neural models of cognition and behavior…
  - => proof of concept
  - => heuristic: source of ideas/discovery of problems

Particular perspective of the course

- this course is NOT a standard introduction into autonomous robotics from a technical point of view
- although it provides some elements of that through
  - a review of approaches to vehicle path planning
  - a review of concepts in robotic manipulators, planning, and control

Particular perspective of the course

- the dynamical systems perspective
  - neural dynamics => WS course on Neural Dynamics
  - “behavioral dynamics” ...



Syllabus

- dynamical systems tutorial
- vehicles: path planning
  - attractor dynamics approach
  - other approaches
  - analogy to navigation in humans and animals
- robot arms
  - kinematics, degree of freedom problem
  - dynamics, control
  - timing
  - movement generation with muscles