Autonomous Robotics: Action, Perception and Cognition

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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

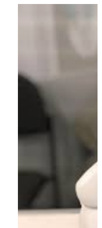
H
b

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

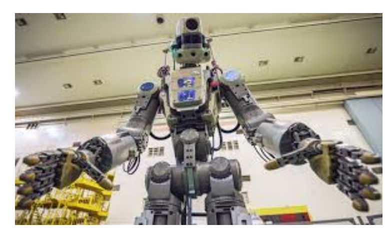
NAO the humanoid and pro...
softbankrobotics.com

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

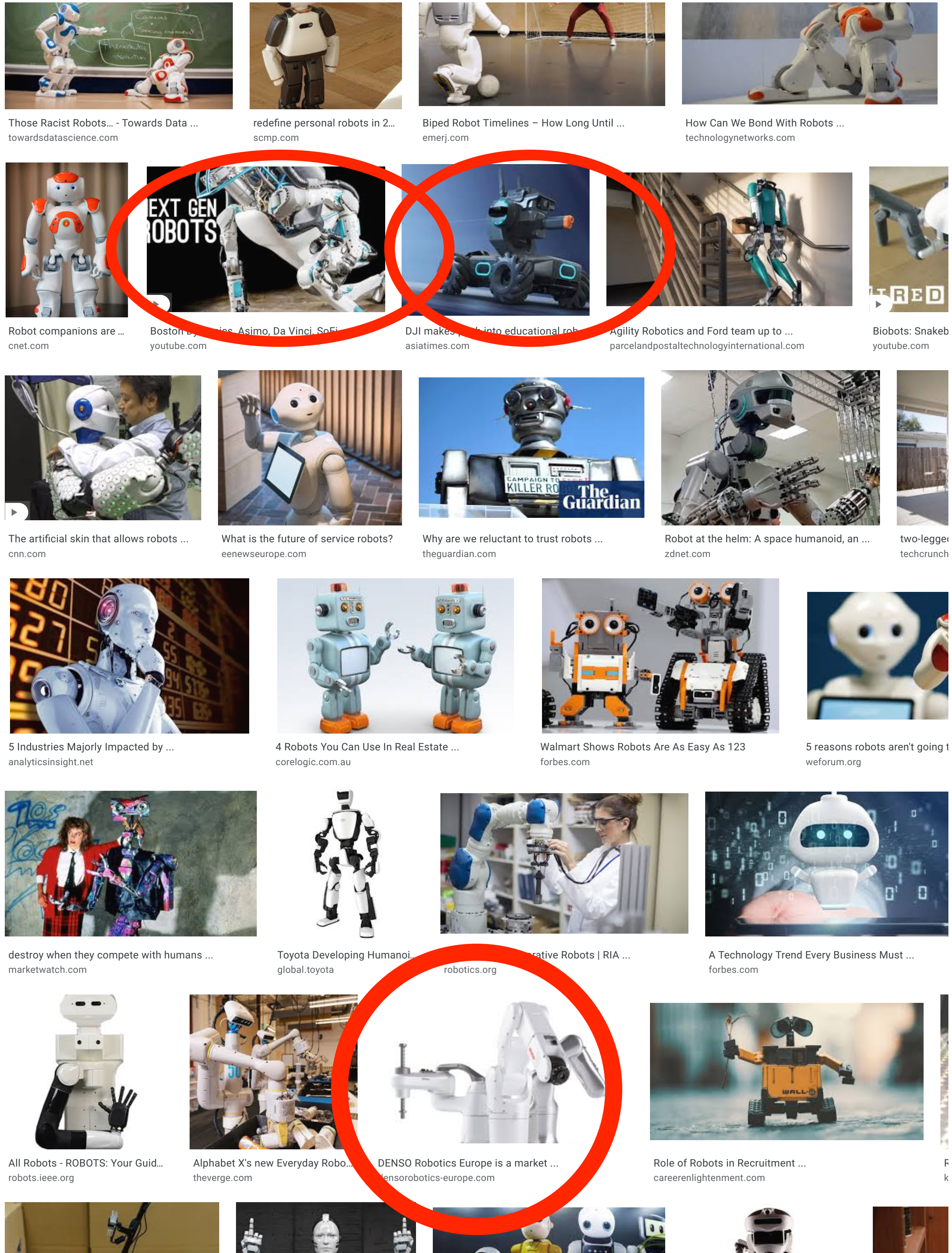
Robots could learn to recognise human ...
techxplore.com



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

- => Humanoids (or anthropomorphic) robots page 2

legged robot



vehicle

compliant arms

on regular industrial robot on first 4 pages

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

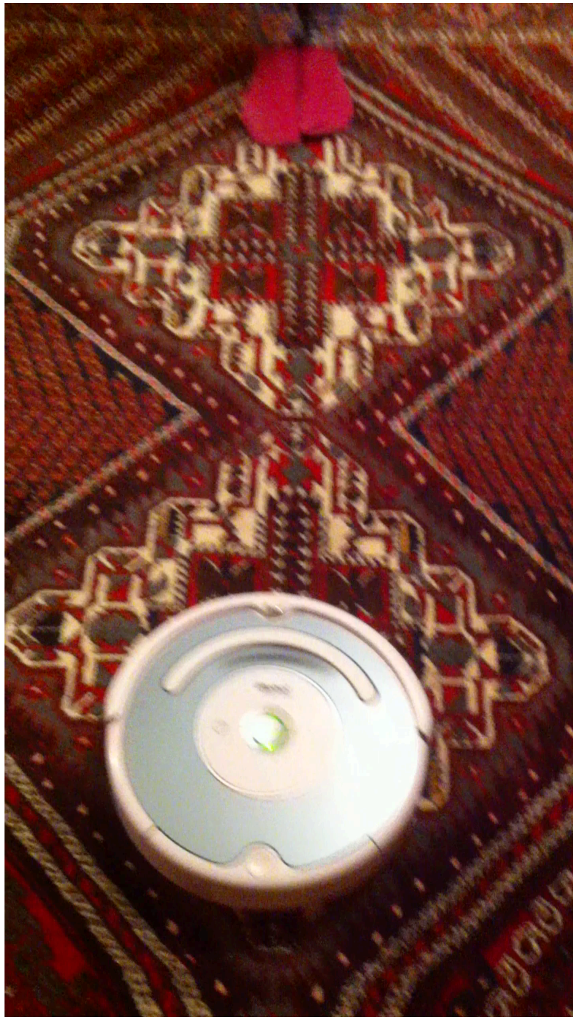
- fundamentally, all factory automatization is a form of robotics: “programmable” machines…

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

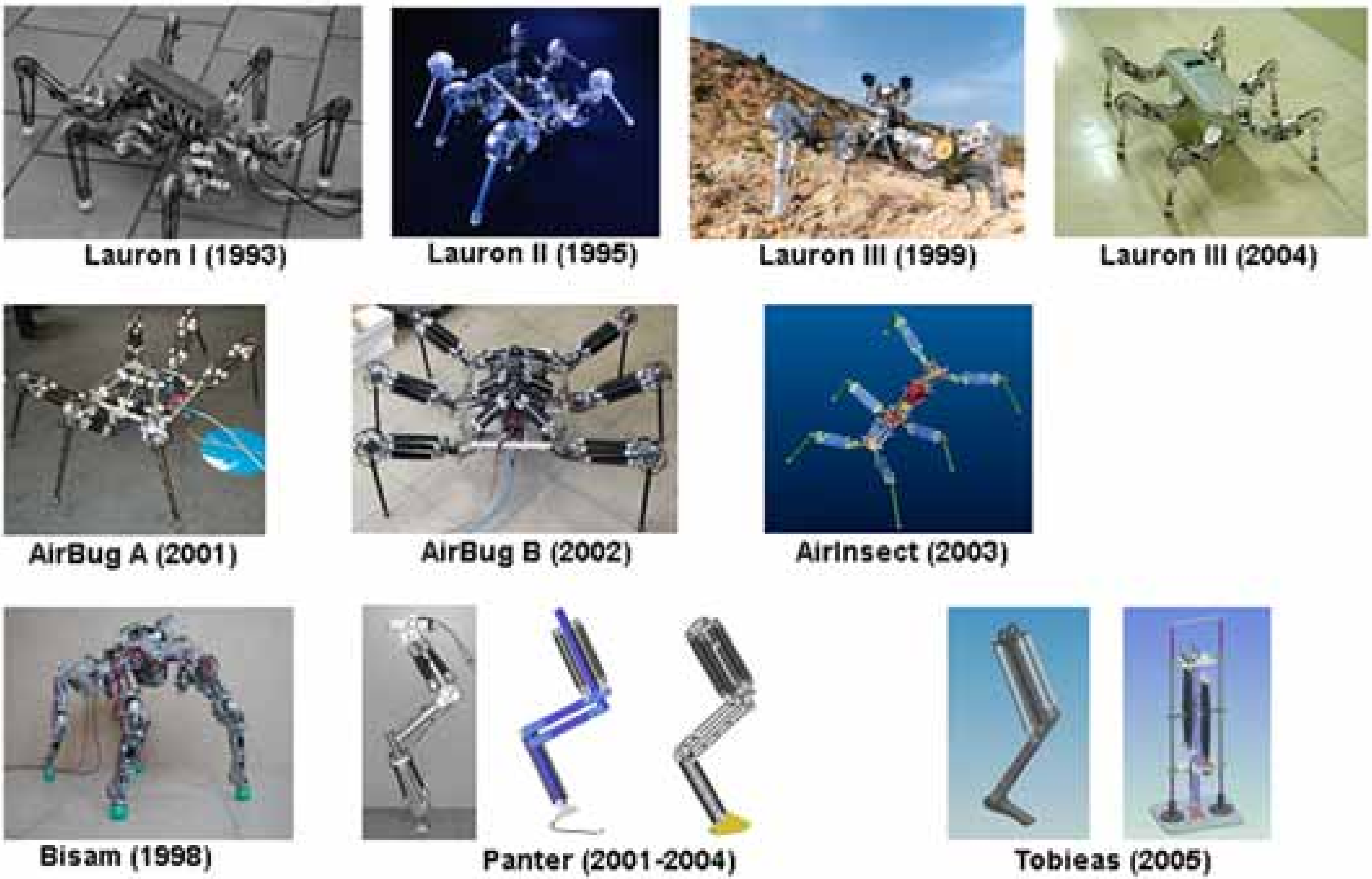
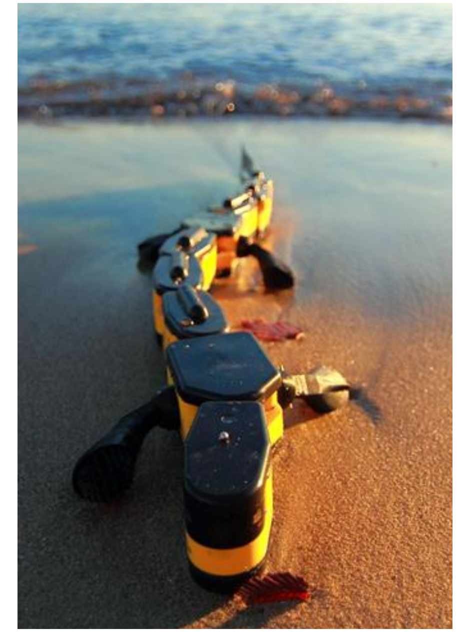
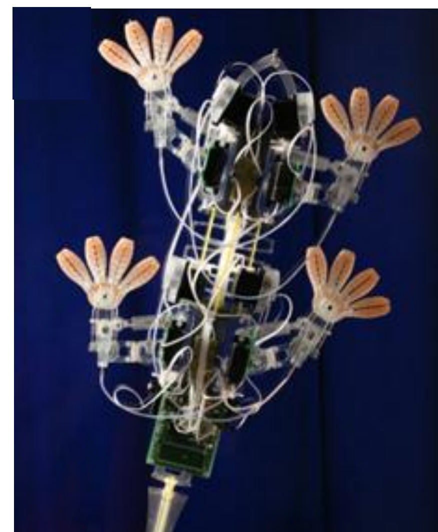


Figure C.58. The walking machines built by Dillmann's group.

biologically inspired robotics





snakes, crawlers, climbers

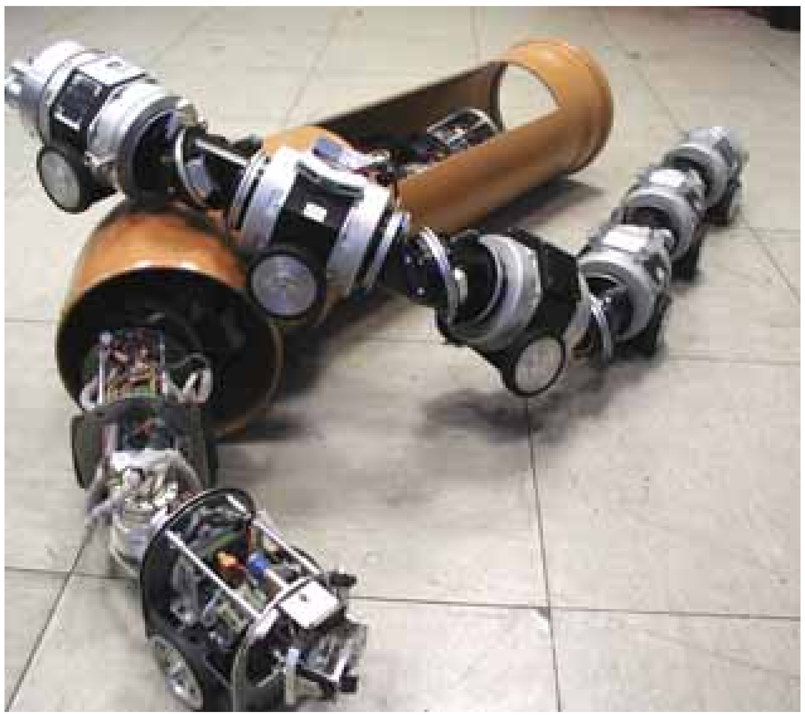


Figure C.57. Inspection robot.

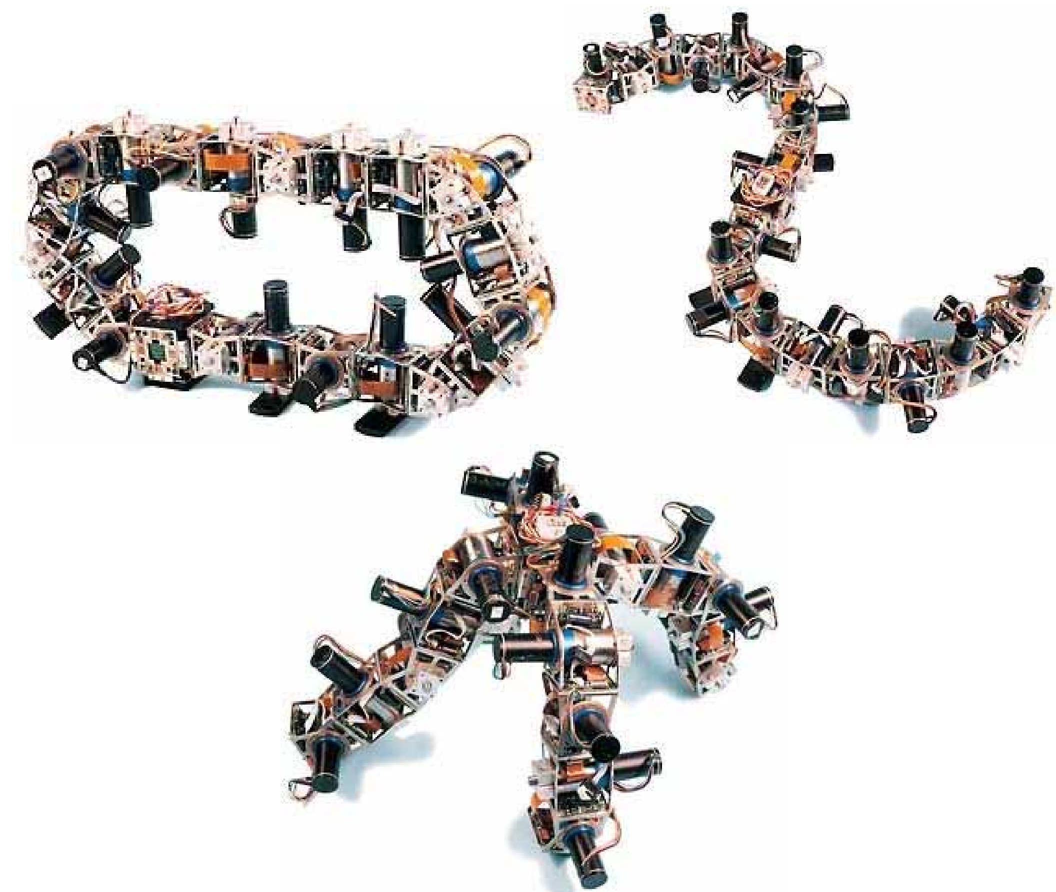


Figure 7.2. Robotic modules can be reconfigured to “morph” into different locomotion systems including wheel-like rolling system (left), a snake-like undulatory locomotion system (right), a four-legged walking system (bottom).

underwater vehicles, ships

Figure 2.2. IFREMER ASTER autonomous underwater vehicle.

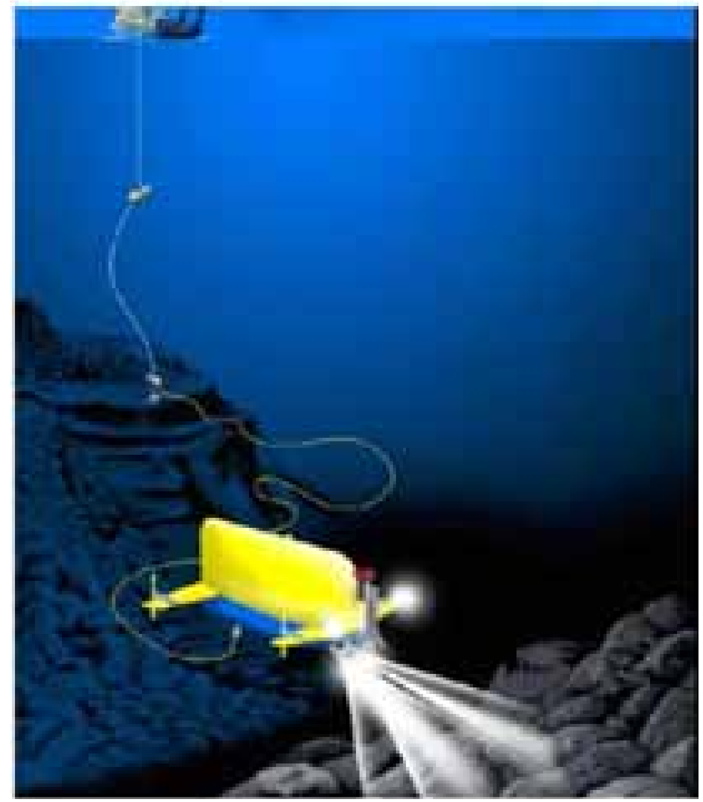
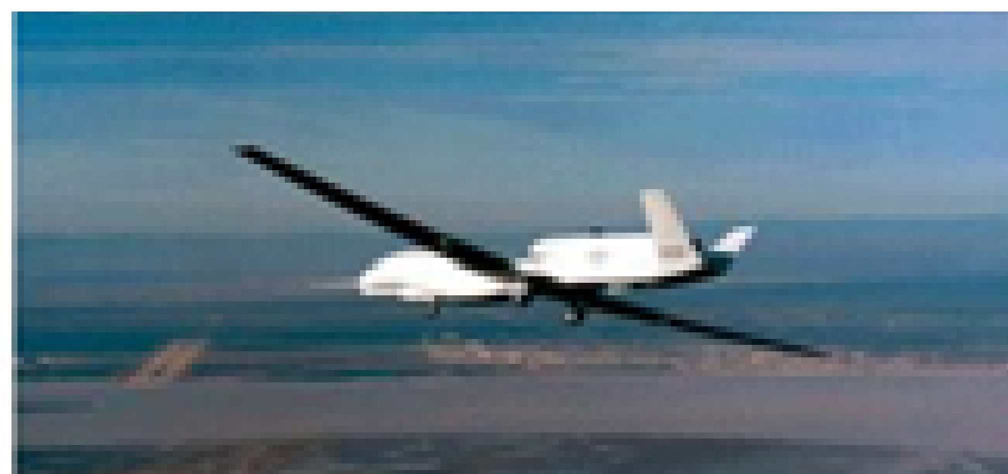


Figure 2.11. HROV (Hybrid ROV) project (Johns Hopkins University (JHU) and Woods Hole (WHOL), U.S.).

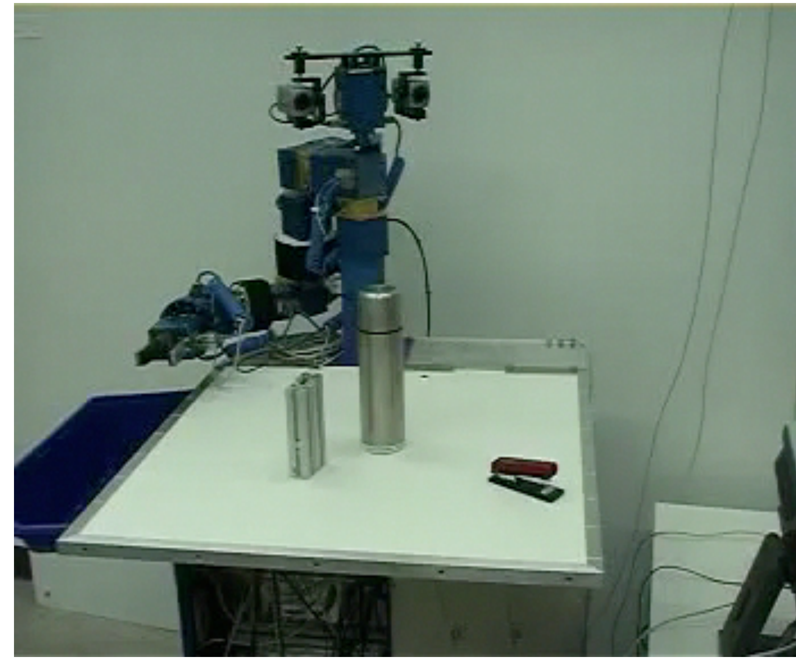
airborne robots

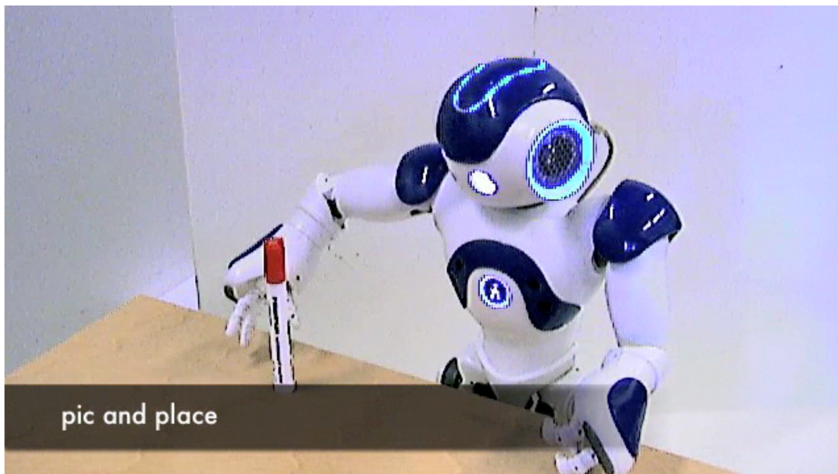


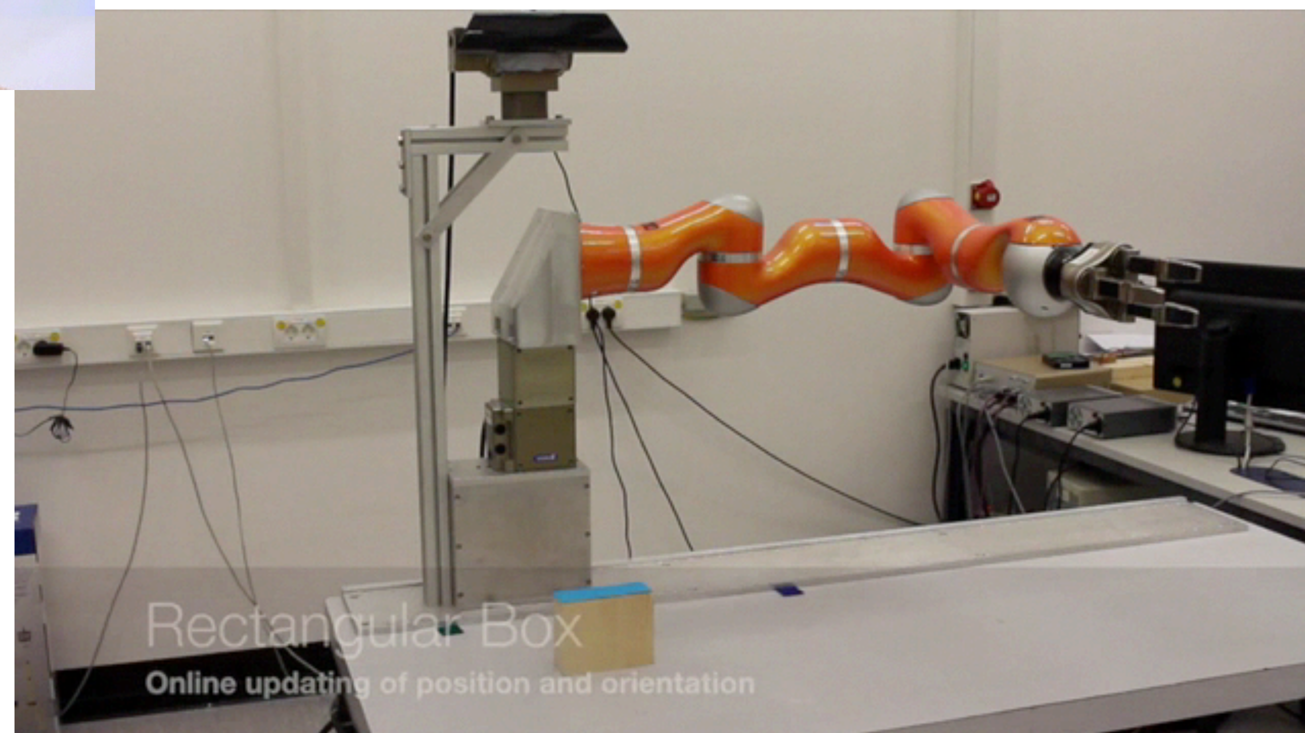
robotic manipulators, hands

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

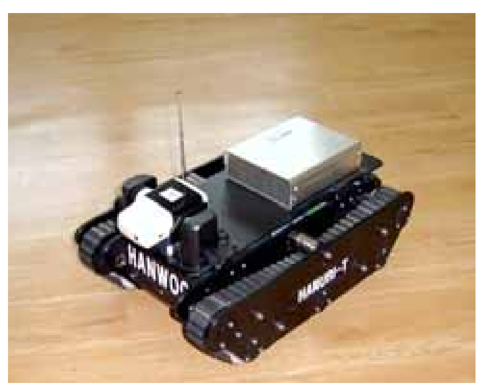
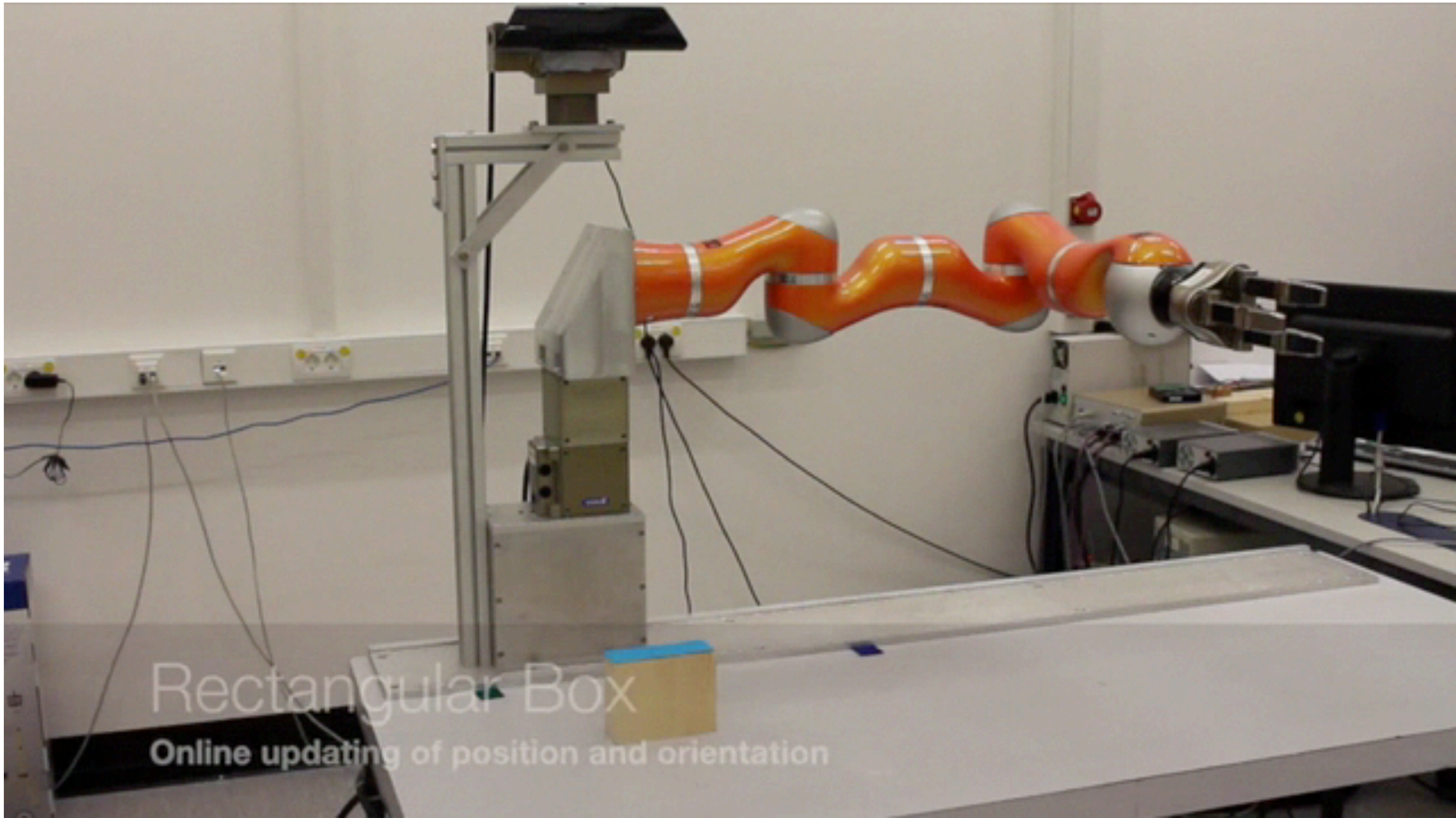


Figure B.11. Military Robot.

(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

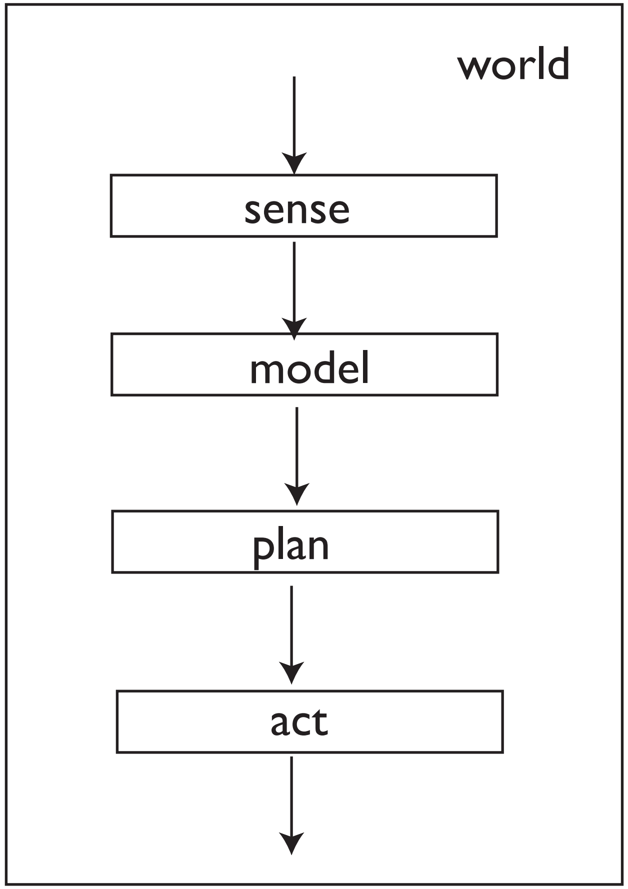
- modern engineering models systems, treating the remainder stochastically…. autonomous robotics act in natural environments that are difficult to model

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: current explosion

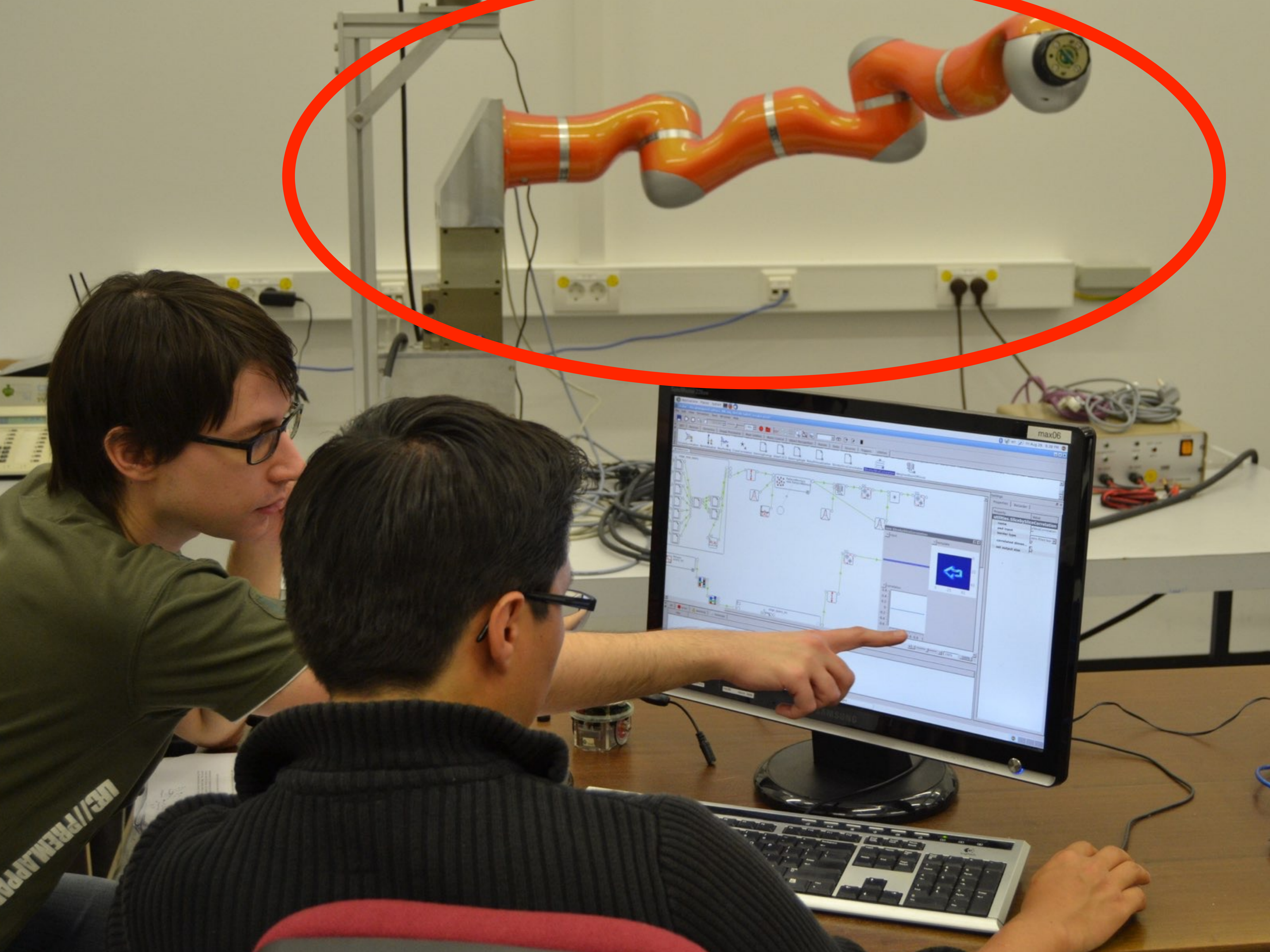
- fast computation makes approach real-time that used to be not viable
- laser range finder… probabilistic approaches
- modern software engineering facilitates programming
- … through maturation of technology

4 core problems/challenges

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

(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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(I) perception

- 4 core problems of perception
  - attention
  - recognition/classification
  - segmentation
  - estimation

=> WS lecture course

(1) perception

- much progress in SLAM and variants
  - exploiting multiple/low level sensors
- much progress in computer vision
  - driven in part by Deep NN
  - but not as successful in robotic settings: where we have much experience with few objects rather than little experience with many objects

(2) interaction with humans

- in part a problem of perception as well…
- perceptually grounding language
- intention perception
- gesture recognition
- joint attention
- dialogue management
- emotion recognition

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

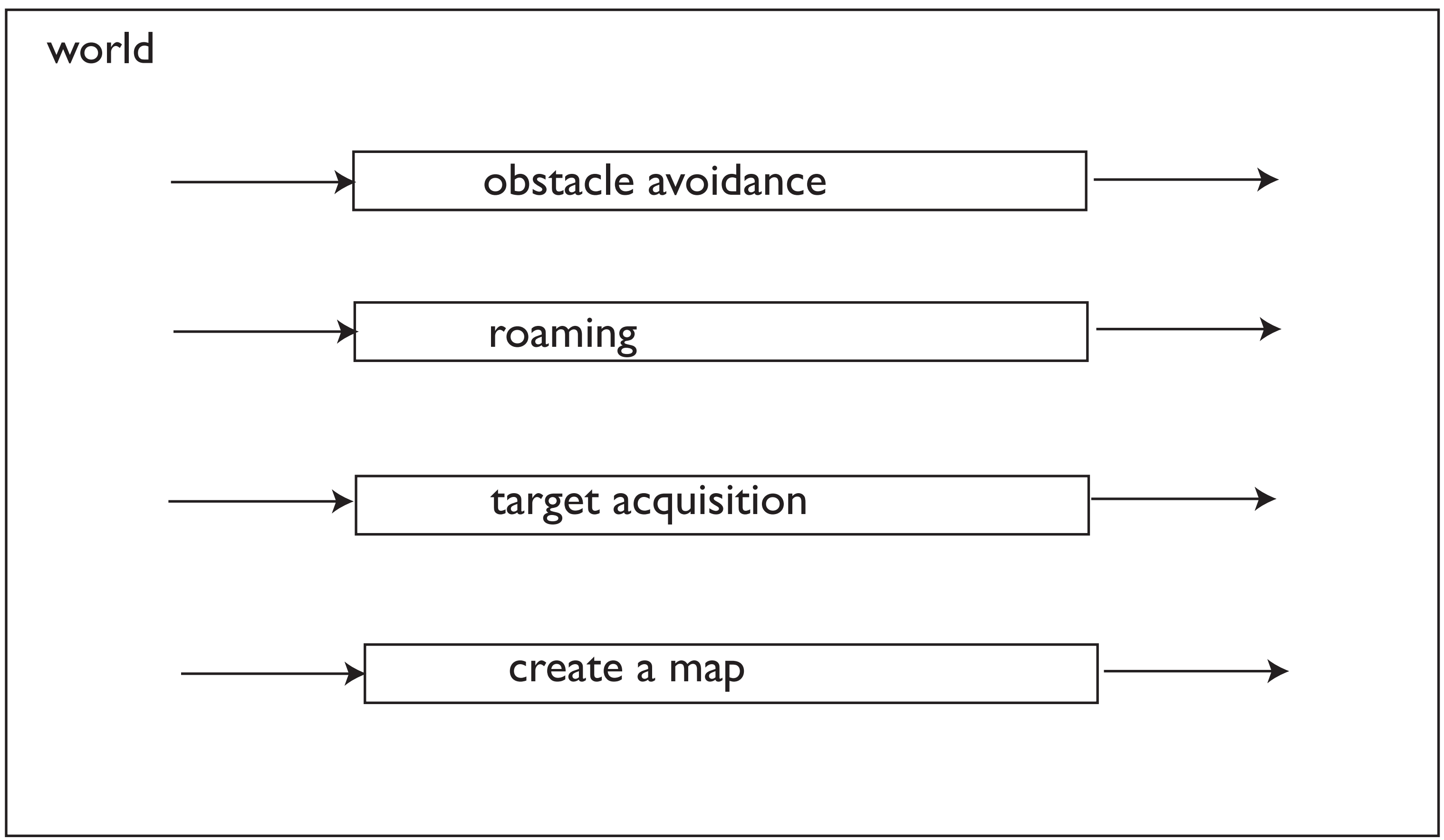
=> WS lecture course

(3) back-ground knowledge

- implicit knowledge 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” is a core problem of classical artificial intelligence
    - knowledge bases
    - reasoning
    - action planning
    - architectures

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



(4) movement generation

- classical approach
  - motion planning based on precise world models
  - using optimal control to address control problems…
- but:
  - high demands on perception and on modeling of plant/ objects
  - unclear if it works for soft actuation for safe interaction with humans
  - need for flexible, human like movement and movement sequences

this is what we'll cover a lot

- exploit analogies with human movement coordination, movement primitives
- exploit analogy with muscle: soft visco-elastic actuators

Particular perspective of the course

- We look at autonomous robotics as a research field that interacts with the theory of cognitive systems
- 1) robots as examples of such systems… learn about principle problems here
  - => integrative framework of dynamical systems
- 2) robots as tool to test neural models of cognition and behavior…
  - => proof of process account and source of ideas/ discovery of problems

Particular perspective of the course

- dynamical systems
  - “behavioral dynamics” ...
  - neural dynamics => WS course on Neural Dynamics
  - but we will touch on some aspects of neural dynamics in the “rate code” picture …
  - (while the WS is focussed mainly on the space code/ population picture)

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

Syllabus

- dynamical systems tutorial
- vehicles: path planning
  - attractor dynamics approach
  - other approaches
- robot arms
  - kinematics
  - dynamics
  - inverse kinematics

Syllabus

- timing
  - coordination
  - movement primitives
  - a neural architecture of movement
- motor control
  - principles of control
  - human motor control
  - muscles and reflexes