Autonomous Robotics: Action, Perception and Cognition

Gregor Schöner
Institute for Neural Computation
Theory of Cognitive Systems
gregor.schoener@rub.de

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

- Google search “robot” (10 apr 2018)

robot

2

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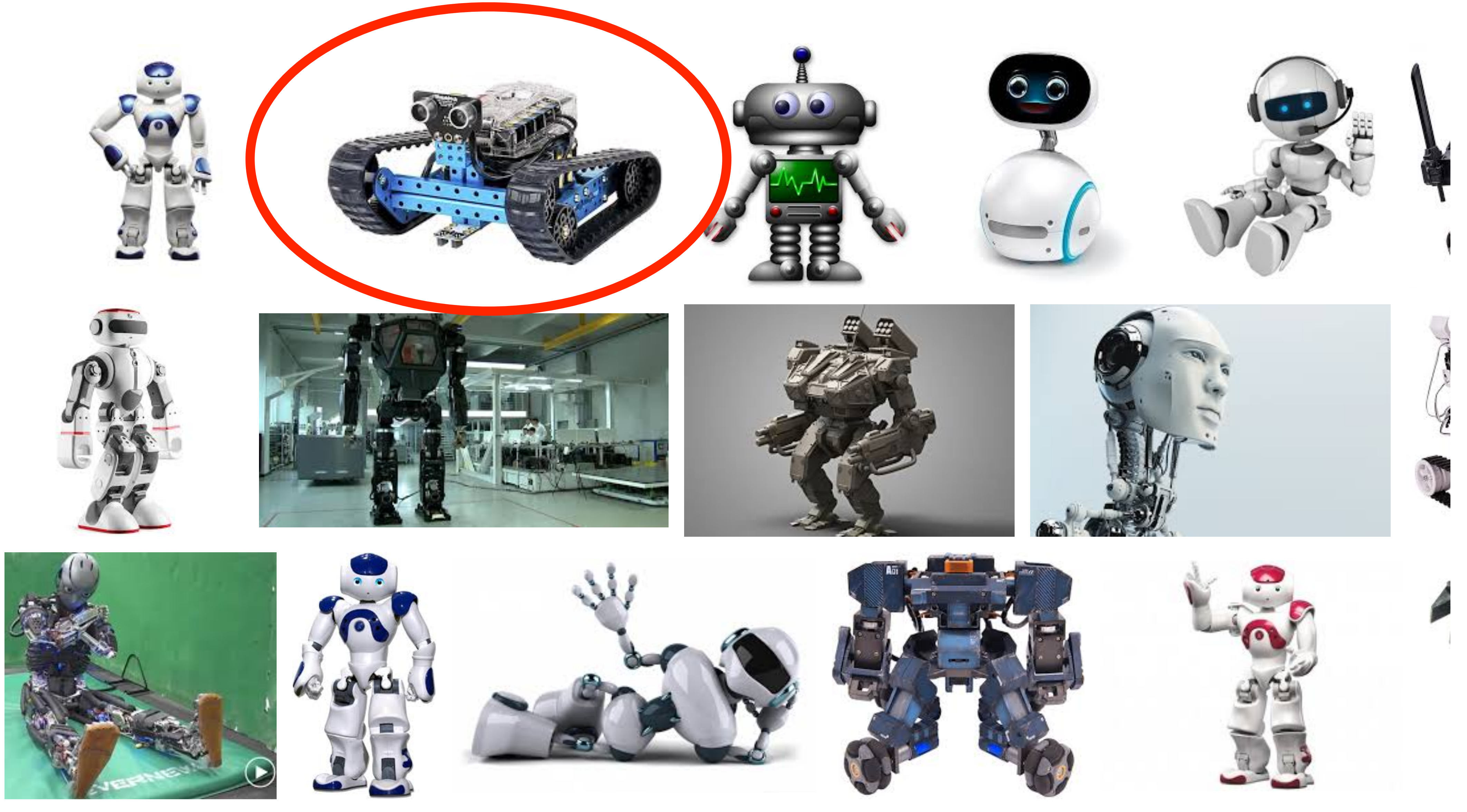
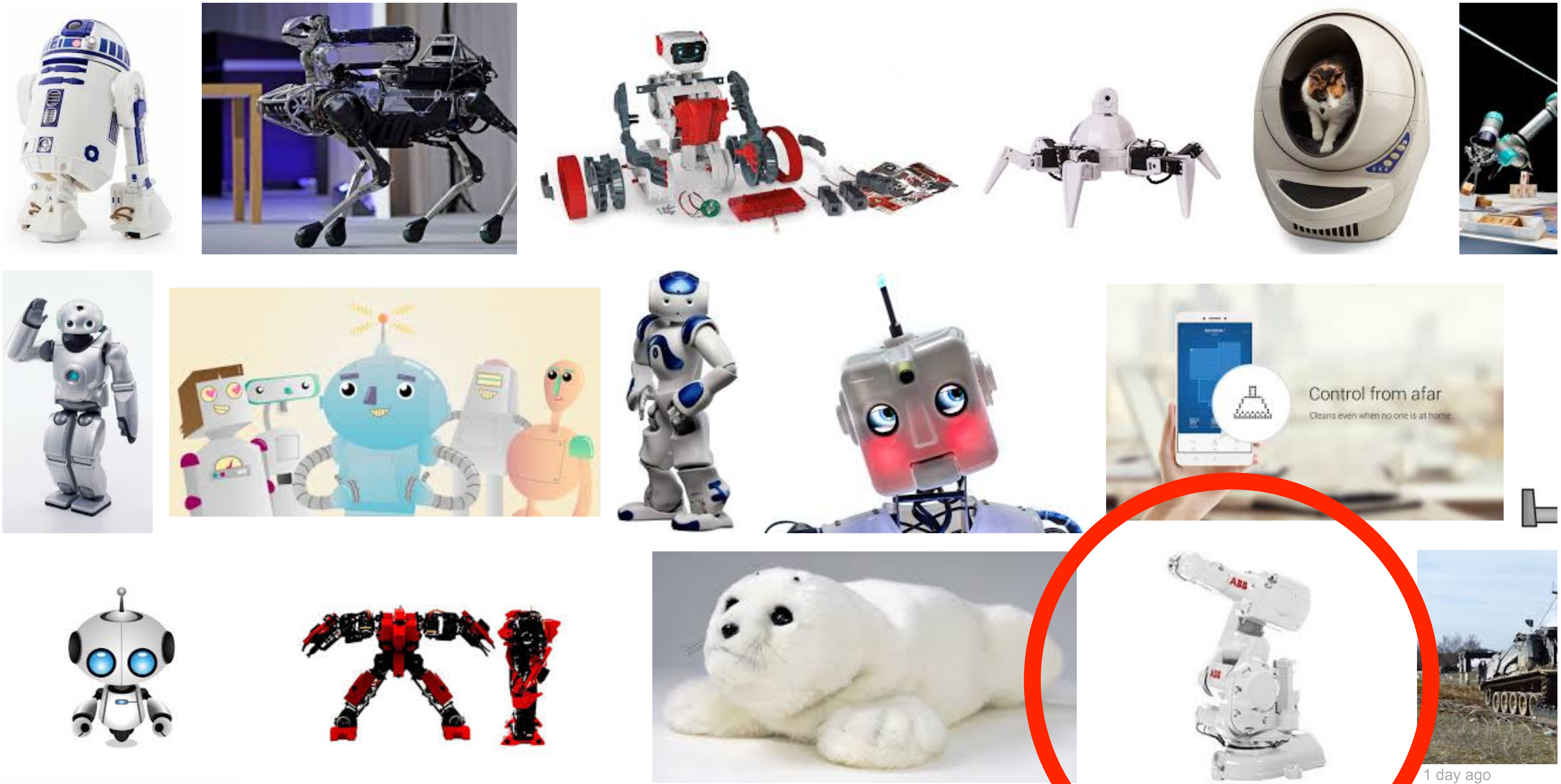
human | real life | mech | cartoon | sci fi | fantasy | cyborg | alien | pokemon | military | humanoid | homemade | steampu

- => Humanoids (or anthropomorphic) robots



 => vehicles



industrial robot on page 5

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

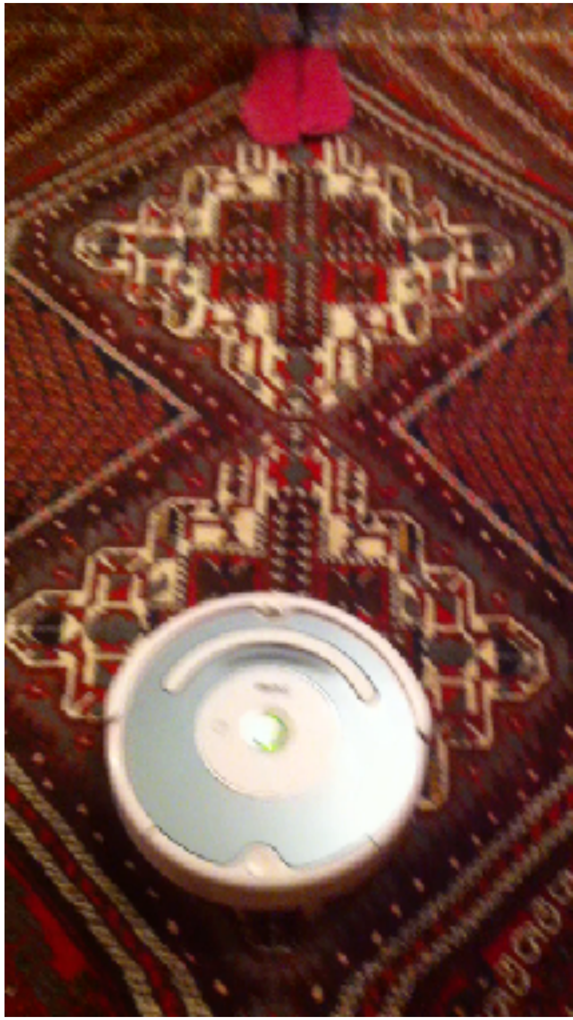
- fundamentally, all factory automatization is a form of robotics: "programmable" machines…

examples 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

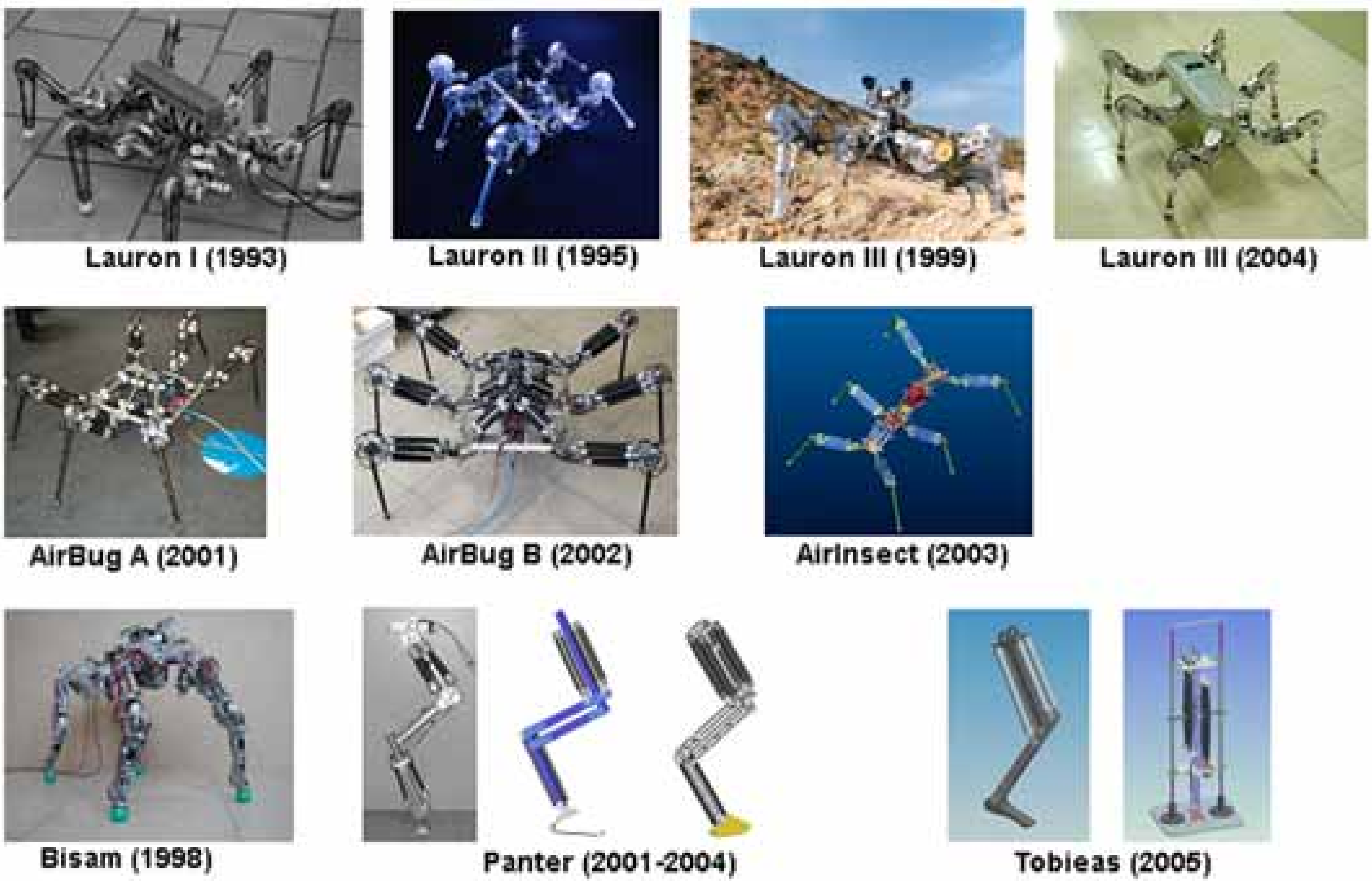
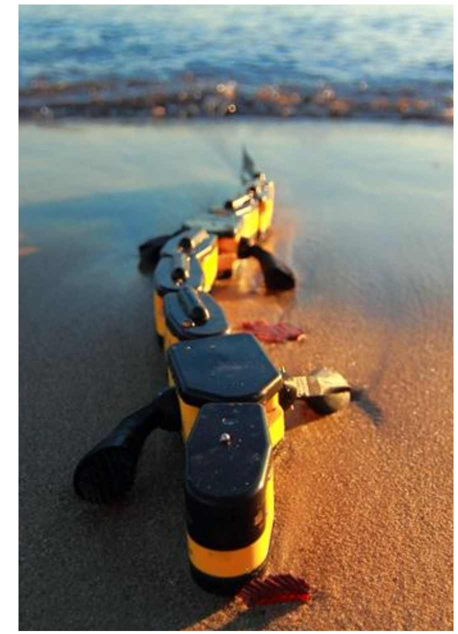
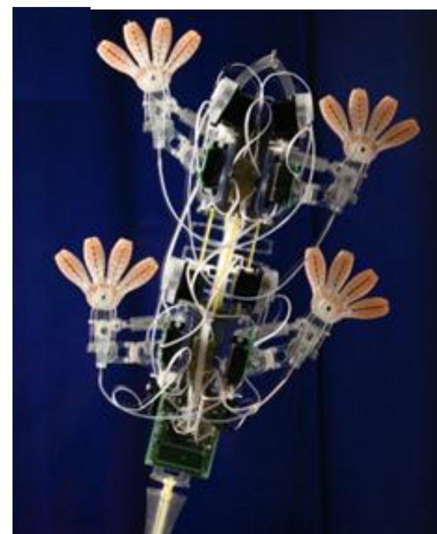
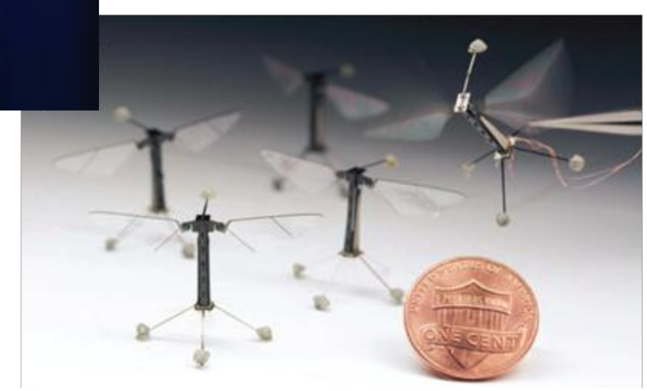


Figure C.58. The walking machines built by Dillmann's group.

biologically inspired robotics







snakes, crawlers, climbers

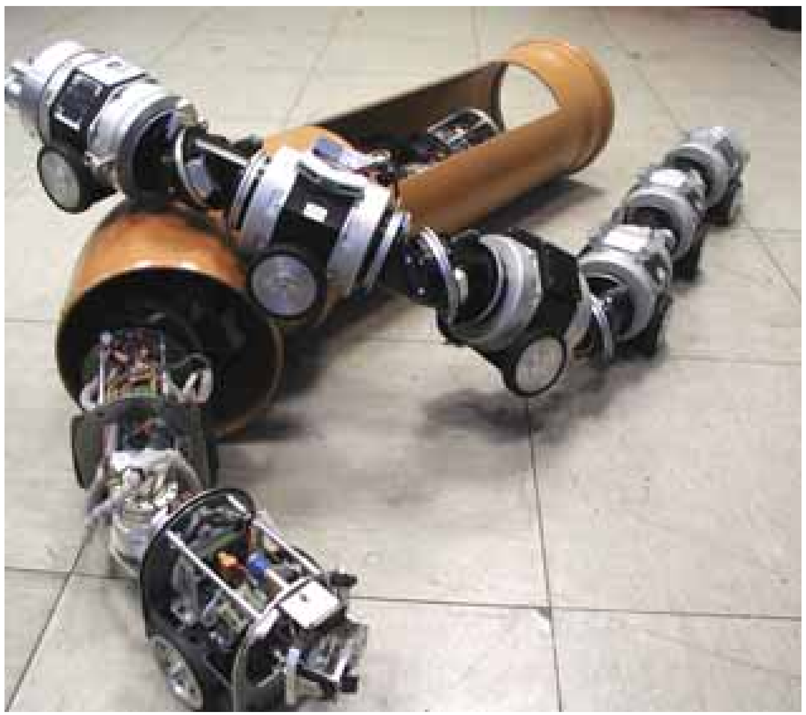


Figure C.57. Inspection robot.

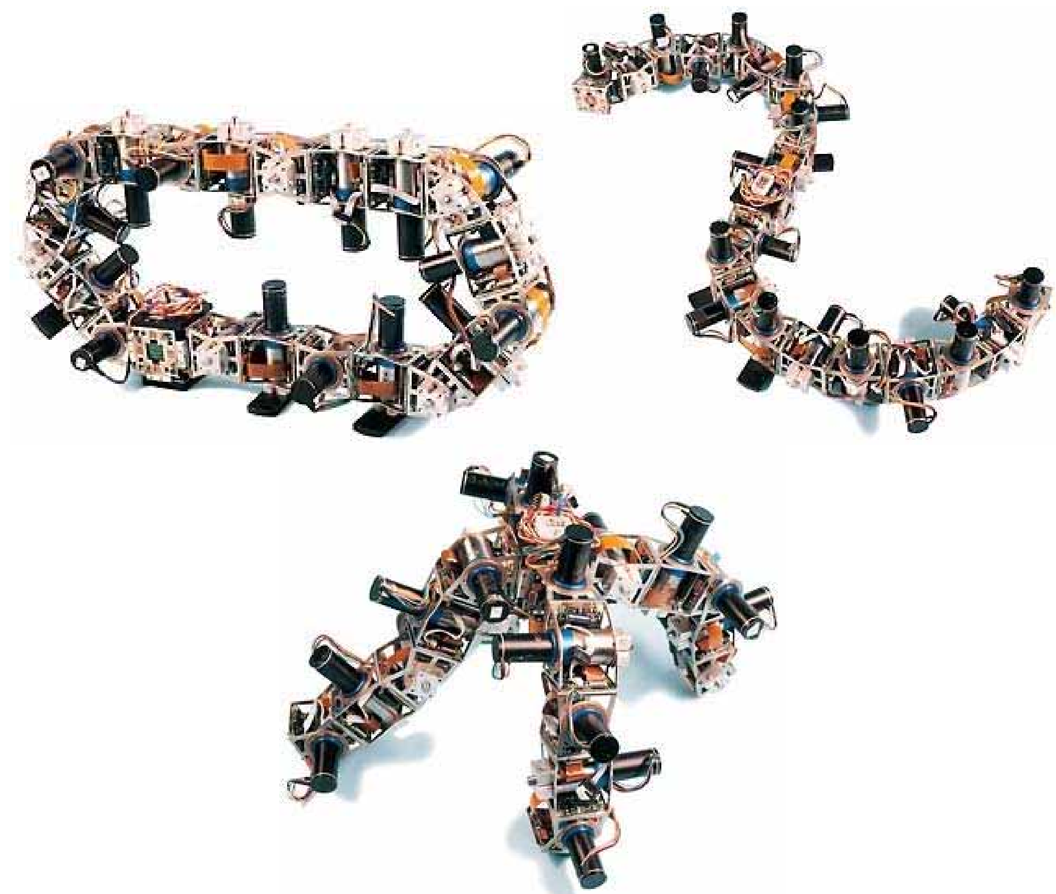


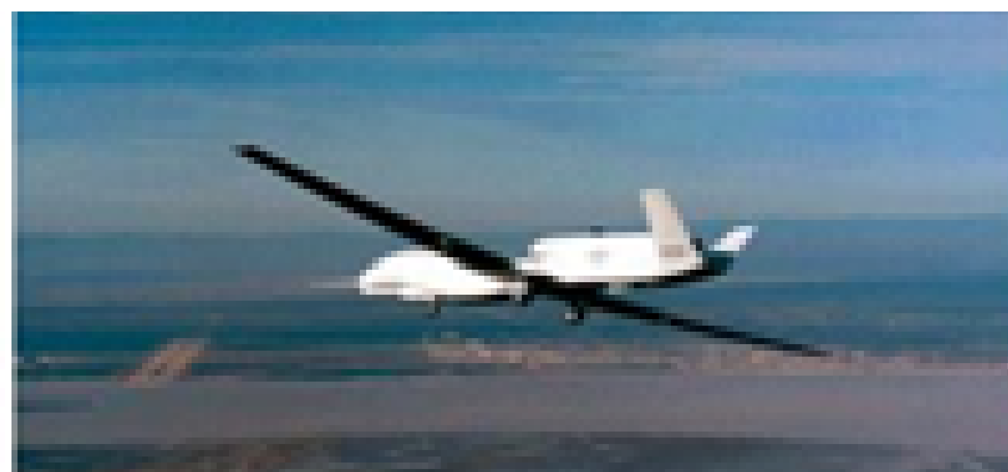
Figure 7.2. Robotic modules can be reconfigured to “morph” into different locomotion systems including wheel-like rolling system (left), a snake-like undulatory locomotion system (right), a four-legged walking system (bottom).

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.).

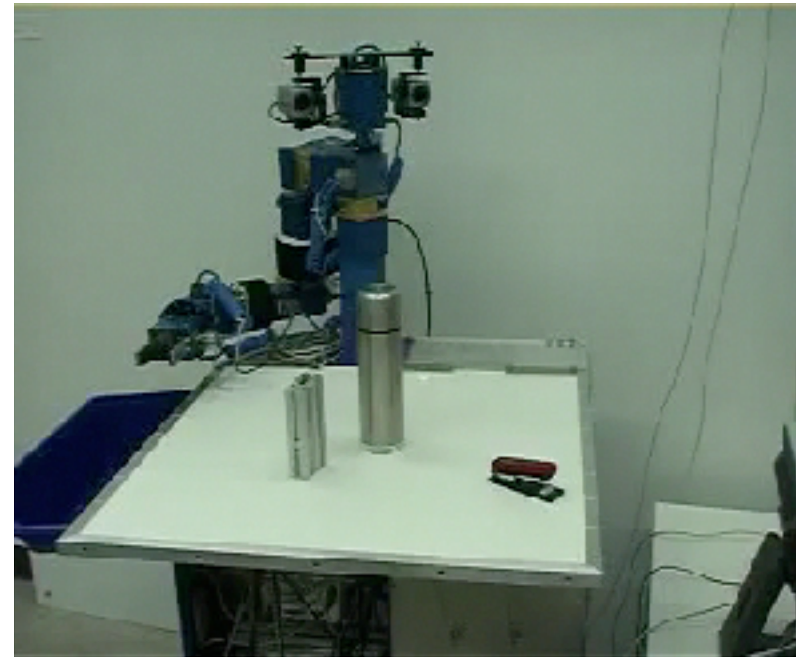
airborne robots

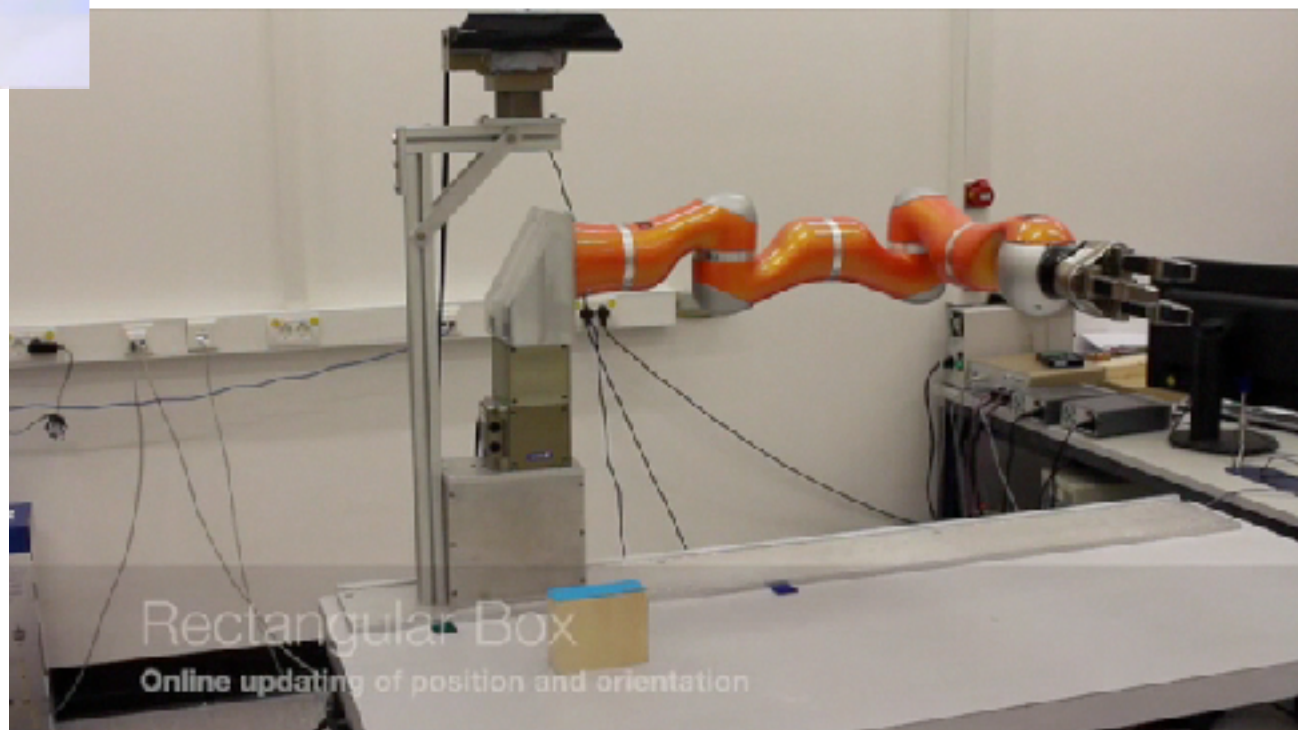


robotic manipulators, hands

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 “order”

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?

- asked my then 18 year old son…
  - to clean up, to serve drinks
  - but they are just generally cool too..
  - .. (after some hesitation)… in the military

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

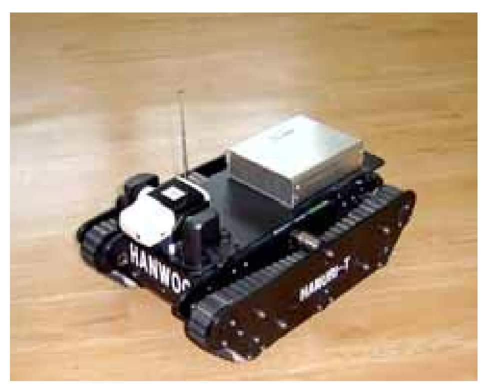
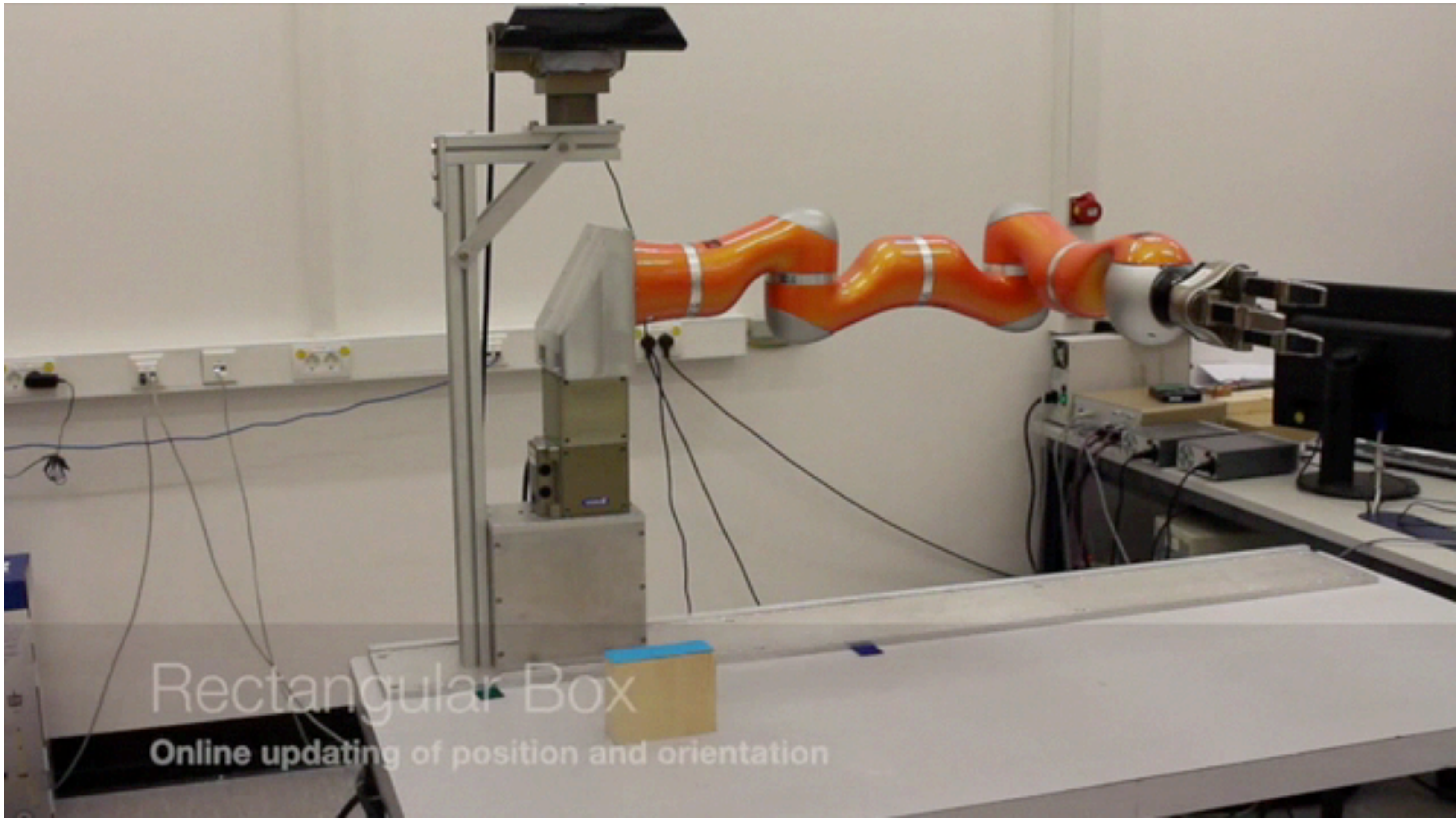


Figure B.11. Military Robot.

(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

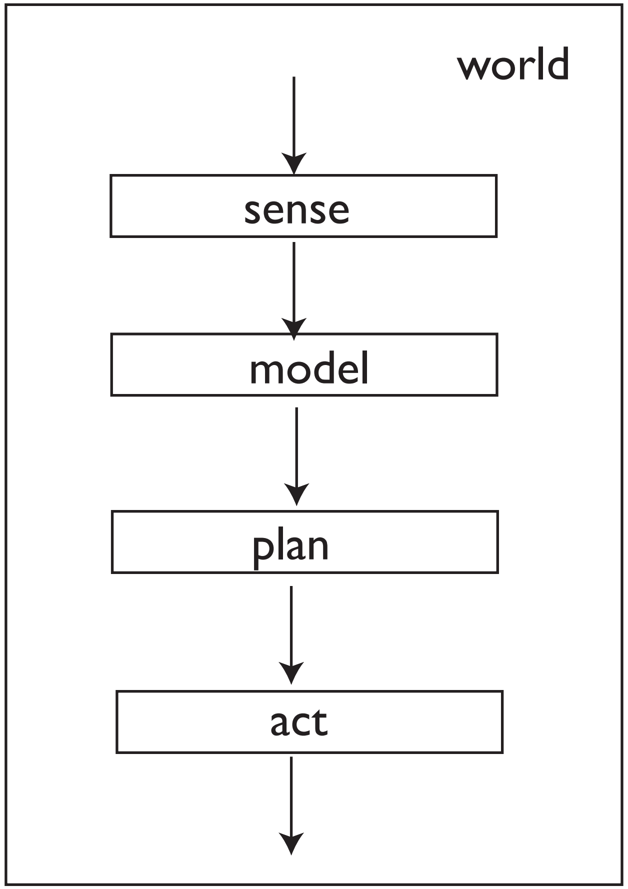
- modern engineering models systems, treating the remainder stochastically…. autonomous robotics act in natural environments that are difficult to model
- autonomous robotics: highly interdisciplinary
- modern engineering uses modular design that limits the range over which modules interact/interfere…autonomous robotics: requires system integration

state of the art: current explosion

- through maturation of technology
- fast computation makes approach real-time that used to be not viable
- laser range finder
- modern software engineering facilitates programming
- … many detailed and specific improvements

what is entailed in designing an autonomous robot?

- sensors
- signal processing, digitization
- perception: estimation, detection, classification
- action planning
- communication, data security
- optimal control, control
- mechanics, actuators



=> an interdisciplinary task

4 core problems/challenges

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

(1) perception

- no autonomy without perception
- main channel: visual perception

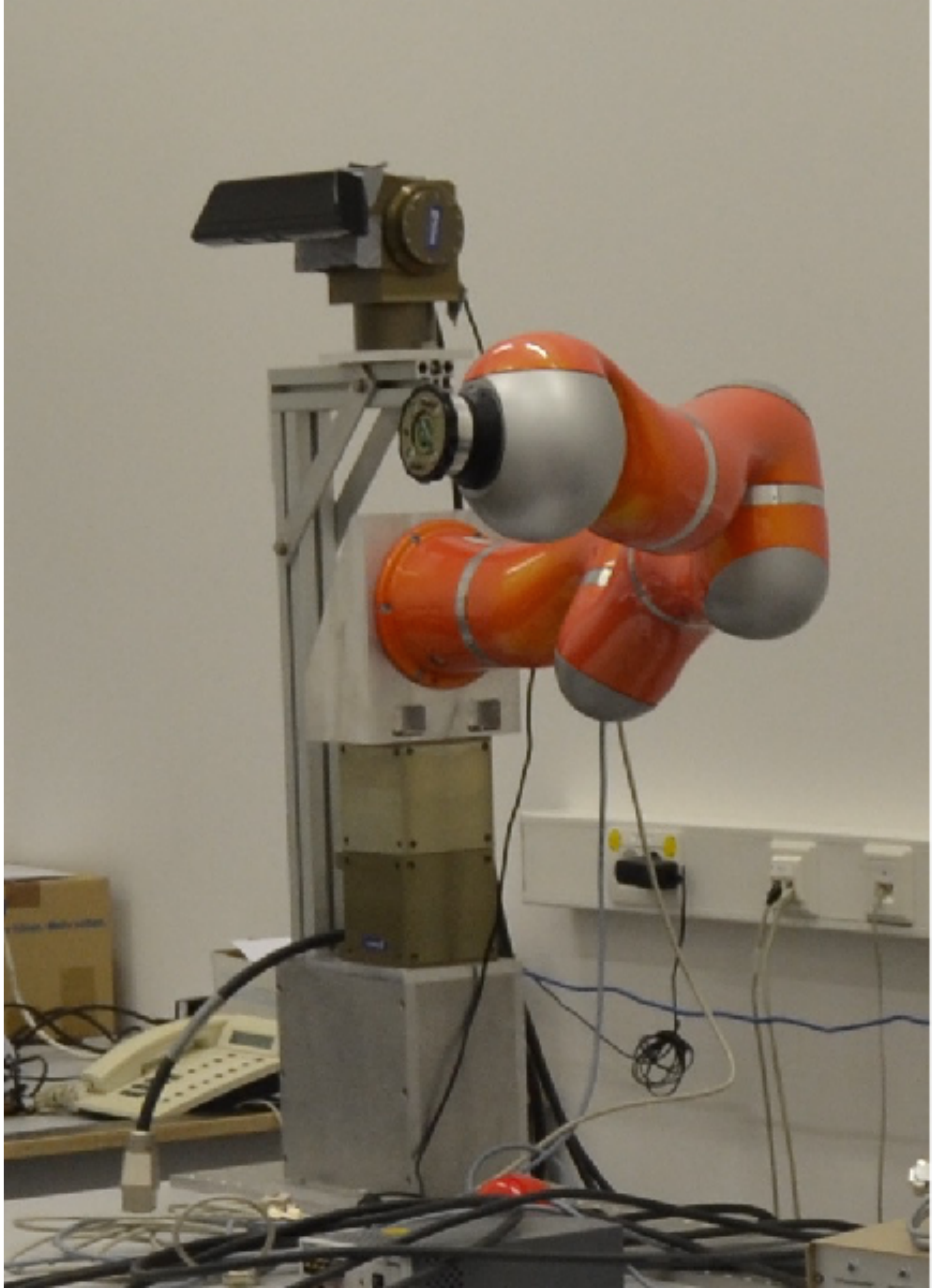
what is perception?

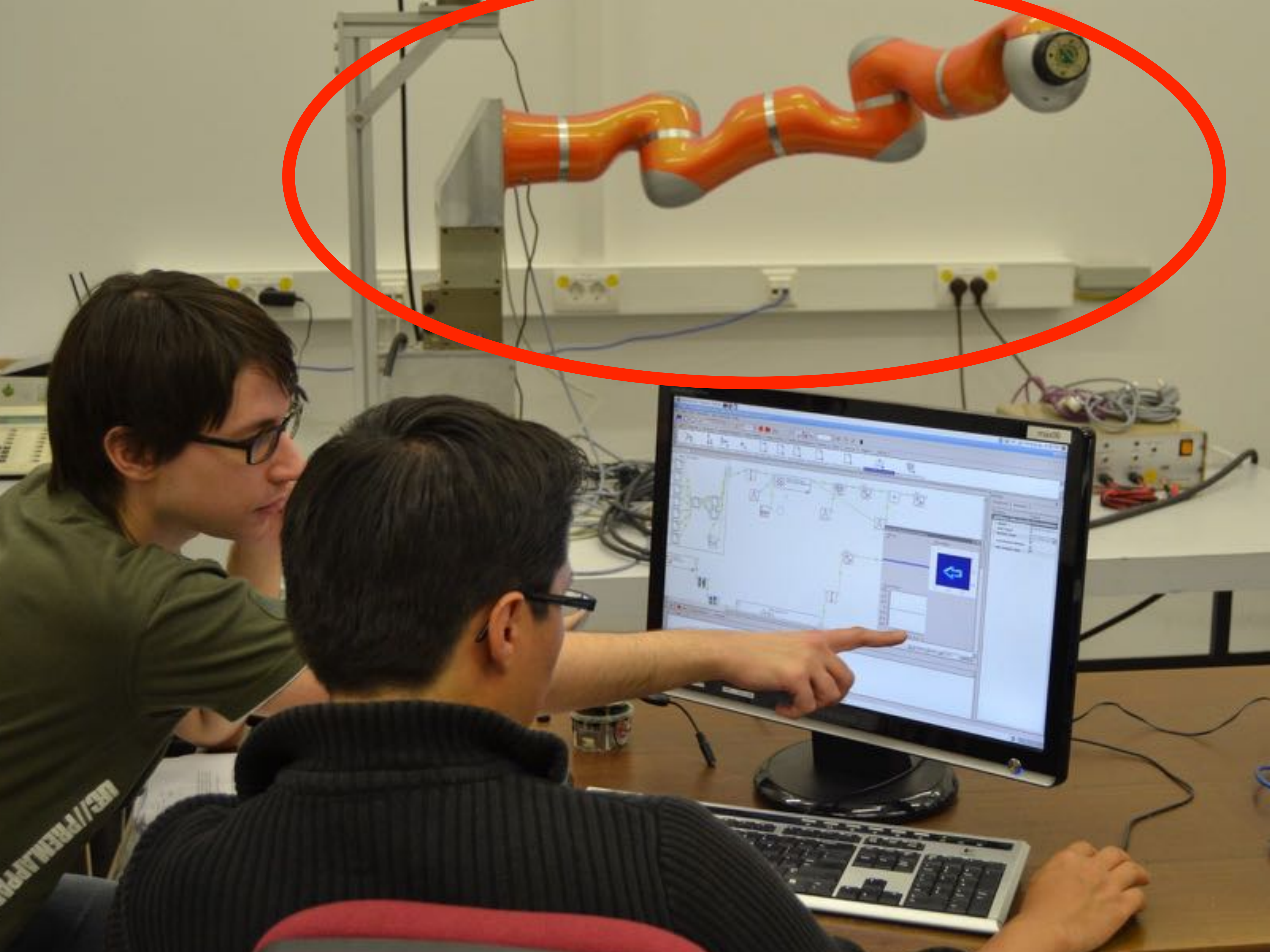
what is perception?

- we do not perceive the stimulus but the world and meaning
- seeing is active:
  - bring objects into the attentional foreground
  - see to answer questions

what is perception?

- attention
- segment
- recognize (invariantly)
- estimate (pose)





(2) interaction with humans

- in part a problem of perception as well…
- including perceptually grounding language
  - e.g.,“the red cup to the left of the green cup“ …

research issues

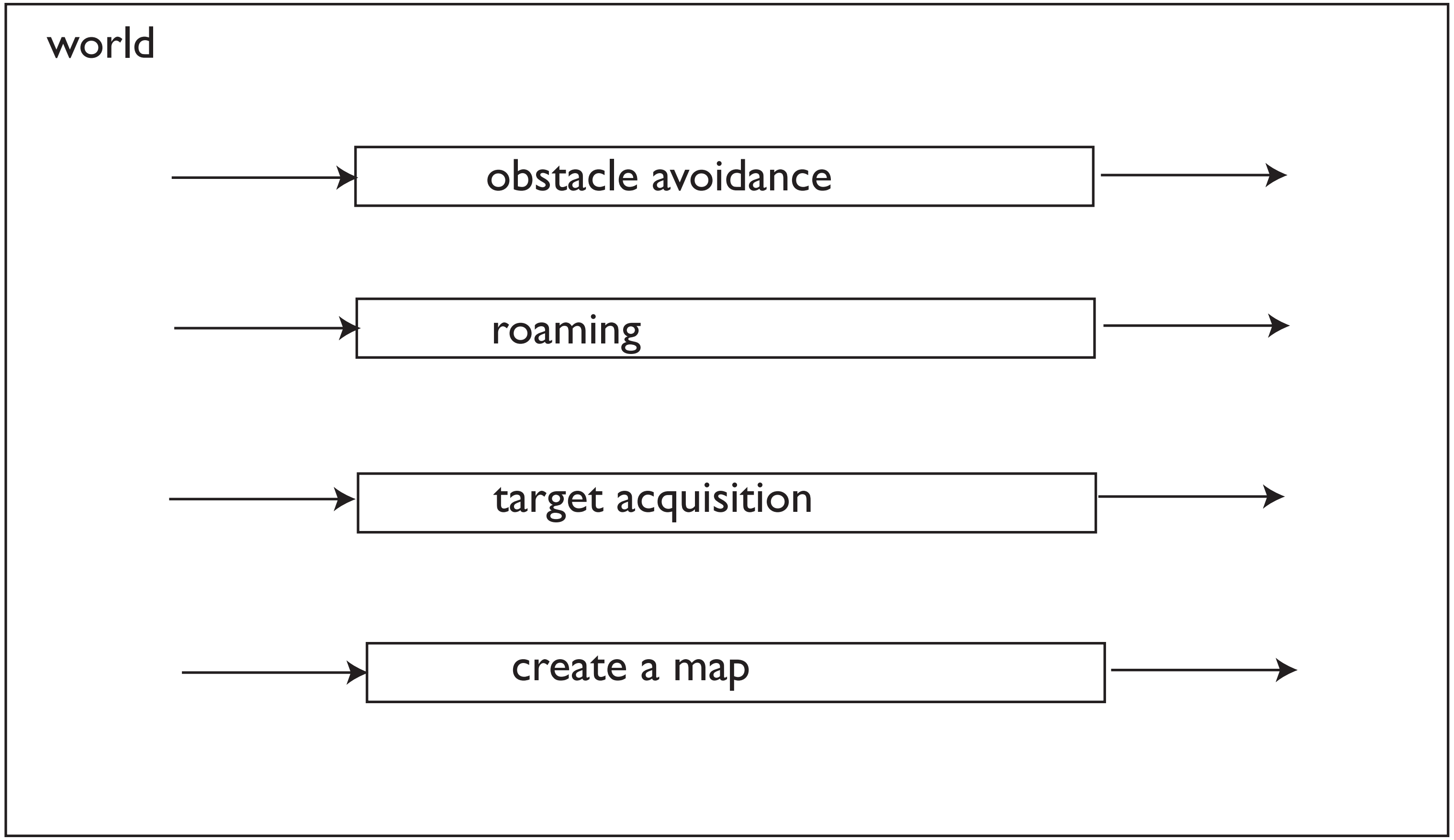
- perceptually grounding language
- intention perception
- gesture recognition
- joint attention
- dialogue management
- emotion recognition

(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…
- John Searle call this “background” (knowledge, skills)

- “background” is where the traditional approach to artificial intelligence was positioned
    - knowledge bases
    - reasoning
    - action planning
    - architectures

- behavior based robotics / behavioral organization



research

- special solutions designed/programmed "by hand"
- autonomous learning from experience… largely unsolved
- analogy with human nervous system whose structure reflects "knowledge" about how the world works…

(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

research

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

autonomous robotics inspired by analogy to human movement

- learning from how human movement is organized: properties, principles
- => an analogy robotics/organism at a more abstract level than in “neural dynamics”

Rough plan of course

- attractor dynamics approach to motion planning: vehicles
- [dynamical systems tutorial]
- coordination and timing
- attractor dynamics approach to reaching movements
- dynamic movement primitives
- behavioral organization
- motor control