Introduction to Autonomous Agents 2008

2008-01-22

Lecture 1

What you will learn...

- The fundamentals of **behavior-based robotics** and **evolutionary robotics**
- The basics of **robot hardware**: sensors, actuators, and microcontrollers
- The basics of **rational decision-making**
- The basics of **animal behavior** and its relevance for autonomous agents
- The basics of **learning and adaptive behavior** for autonomous robots
- Elementary **robot construction**

Why you should take this course:

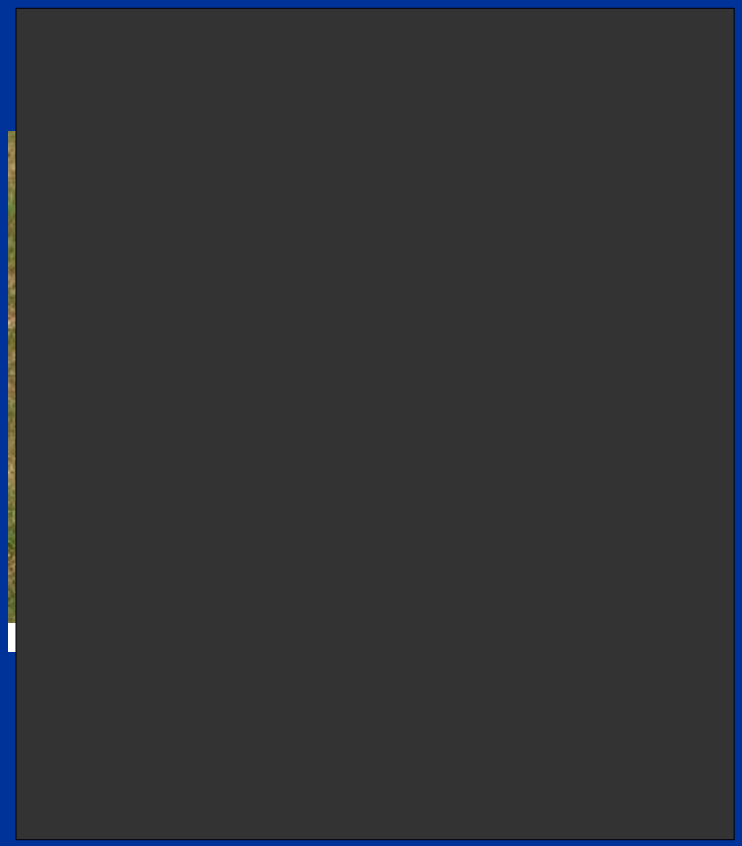
- Intelligent systems for decision-making and adaptive control are becoming increasingly **important** in industry
- In particular, **autonomous robots** are likely to appear in more and more applications in the near future
- The course is **multidisciplinary**, involving methods from many different fields of science and engineering
- It's really **fun** to work with autonomous robots ☺

Autonomous robots

- Intended to move around freely in **unstructured environments**, operating without continuous human guidance.
- Confronted with similar problems as biological organisms. Rapid **reactions** and **adaptive behavior** are often necessary
- Such robots are commonly developed in a **biologically inspired** framework, using behavior-based methods.

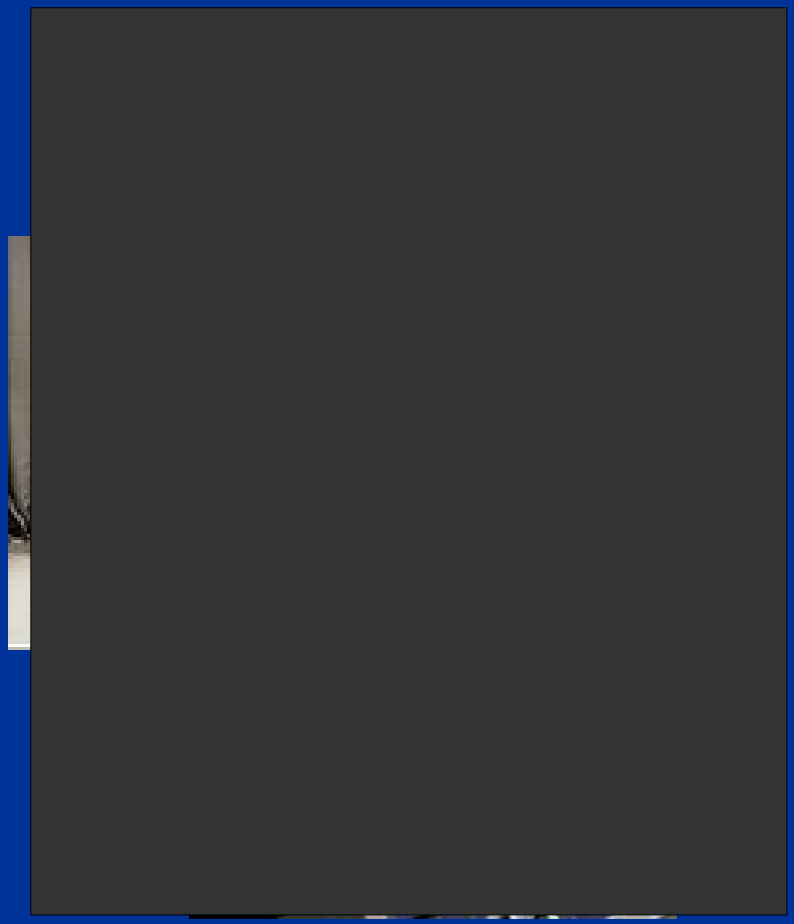
Autonomous robots

- Typical applications (today)
  - Entertainment
  - Vacuum cleaning
  - Lawn mowing
  - Internal transportations
  - Planetary exploration



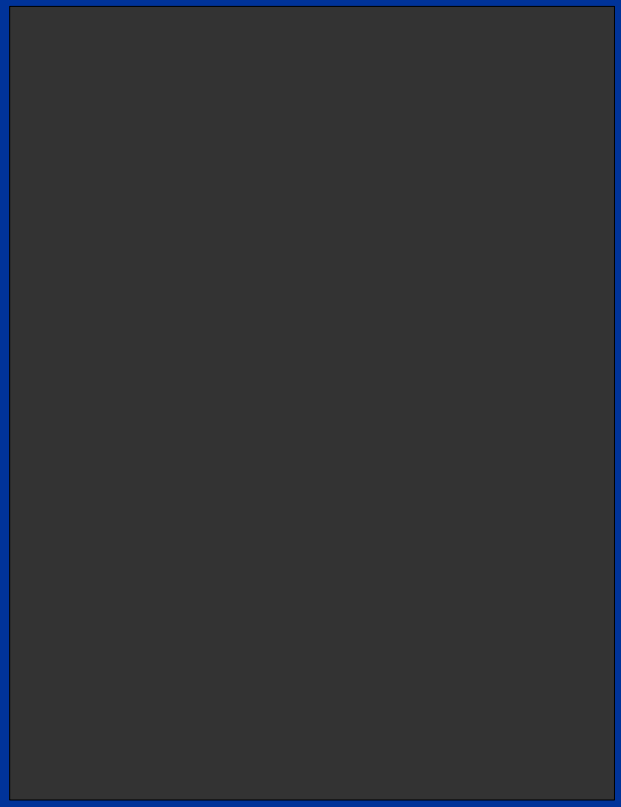
Autonomous robots

- Typical applications (future)
  - Domestic service robots
  - Elderly care
  - Construction
  - Space applications (Extravehicular activity, EVA)
  - etc. etc.



Autonomous robots

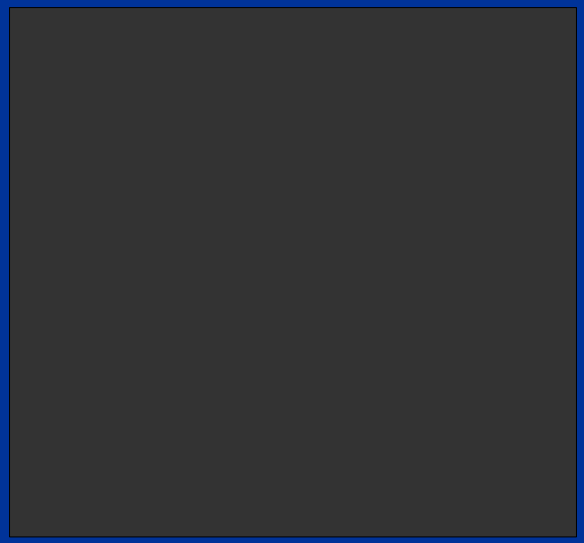
- More examples...
  - Honda Asimo

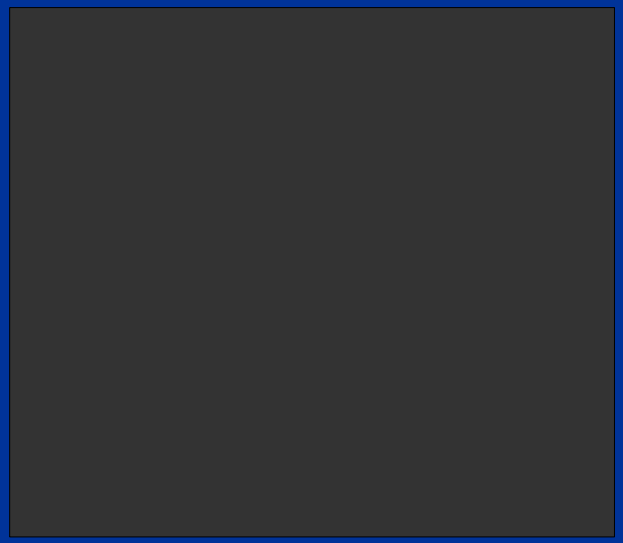


  - However, humanoid robots will be considered in the Humanoid robotics course ...

Autonomous robots

- In this course we will focus on wheeled robots.
- In particular, we will construct a small two-wheeled robot in the 4:th quarter.



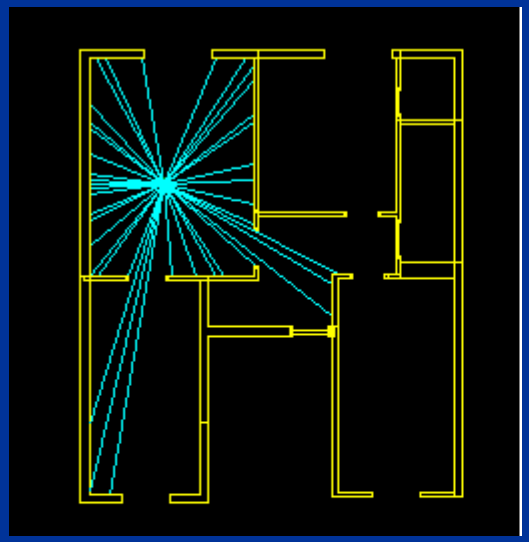


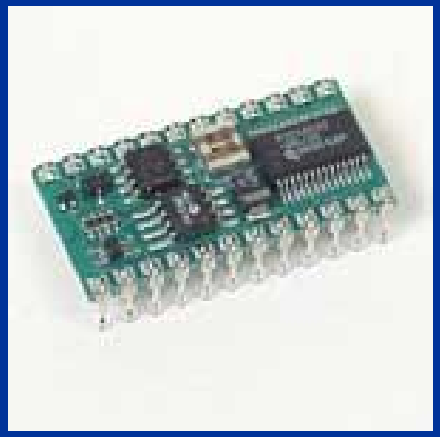
Course contents, Part I

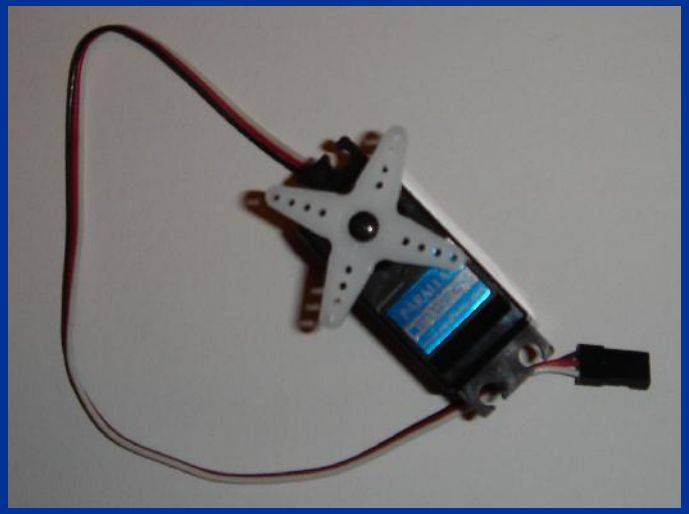
- Quarter 3: Theory and robot simulations
  - Lectures
  - Home problems: theory and programming
  - Written exam
- A walktrough...

Robot hardware

- We will begin by a brief introduction to some of the main components in real robots:
  - Microcontrollers
  - Actuators
  - Sensors

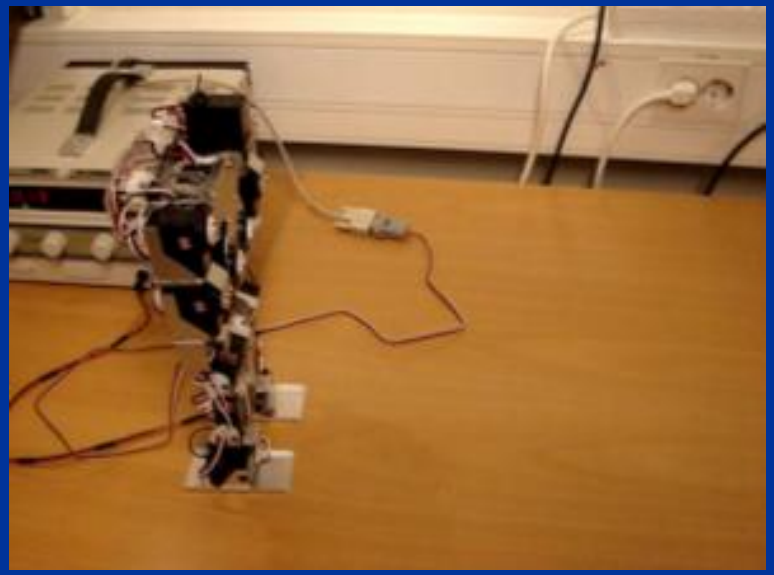




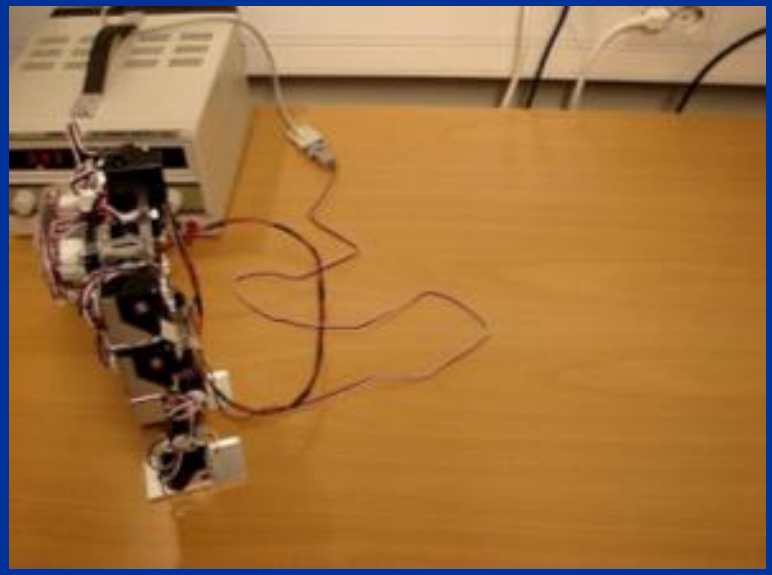


Example of servo motor usage

- Full-body motions:



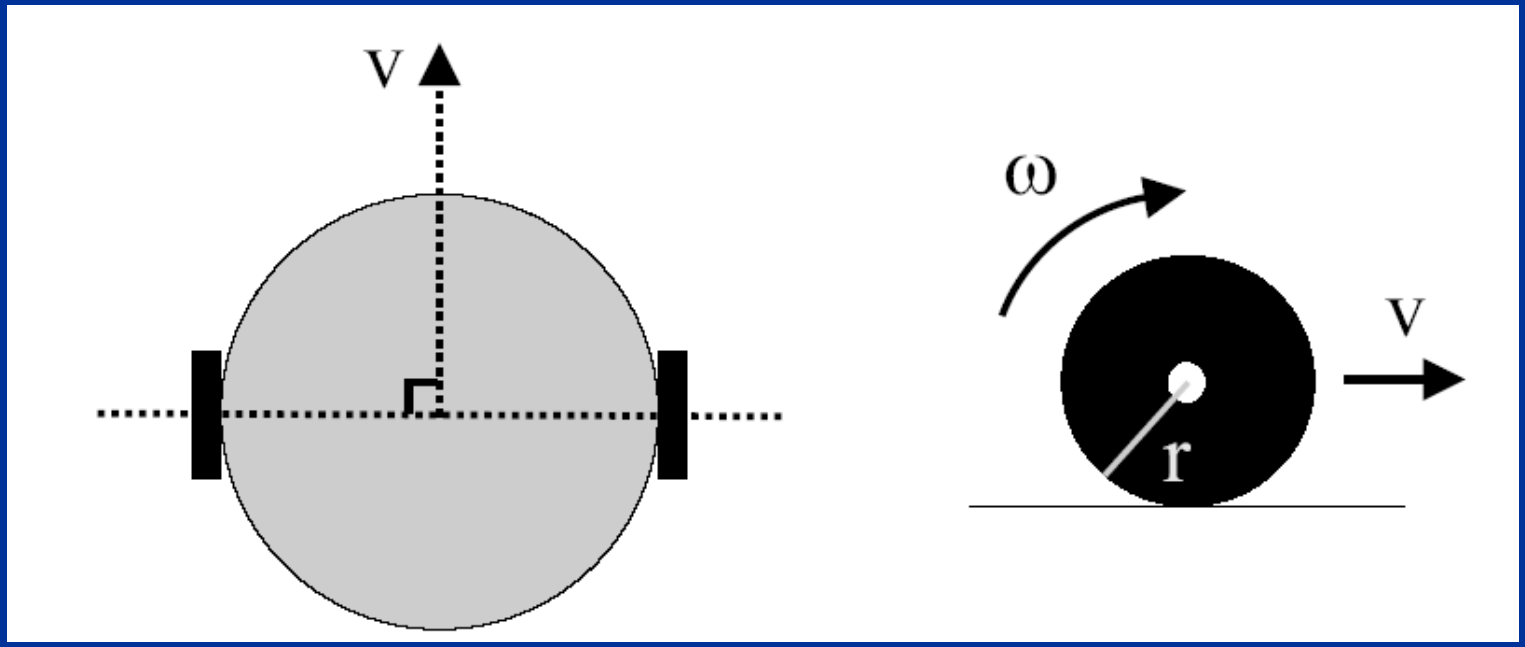
Sommersault motion



Push-ups

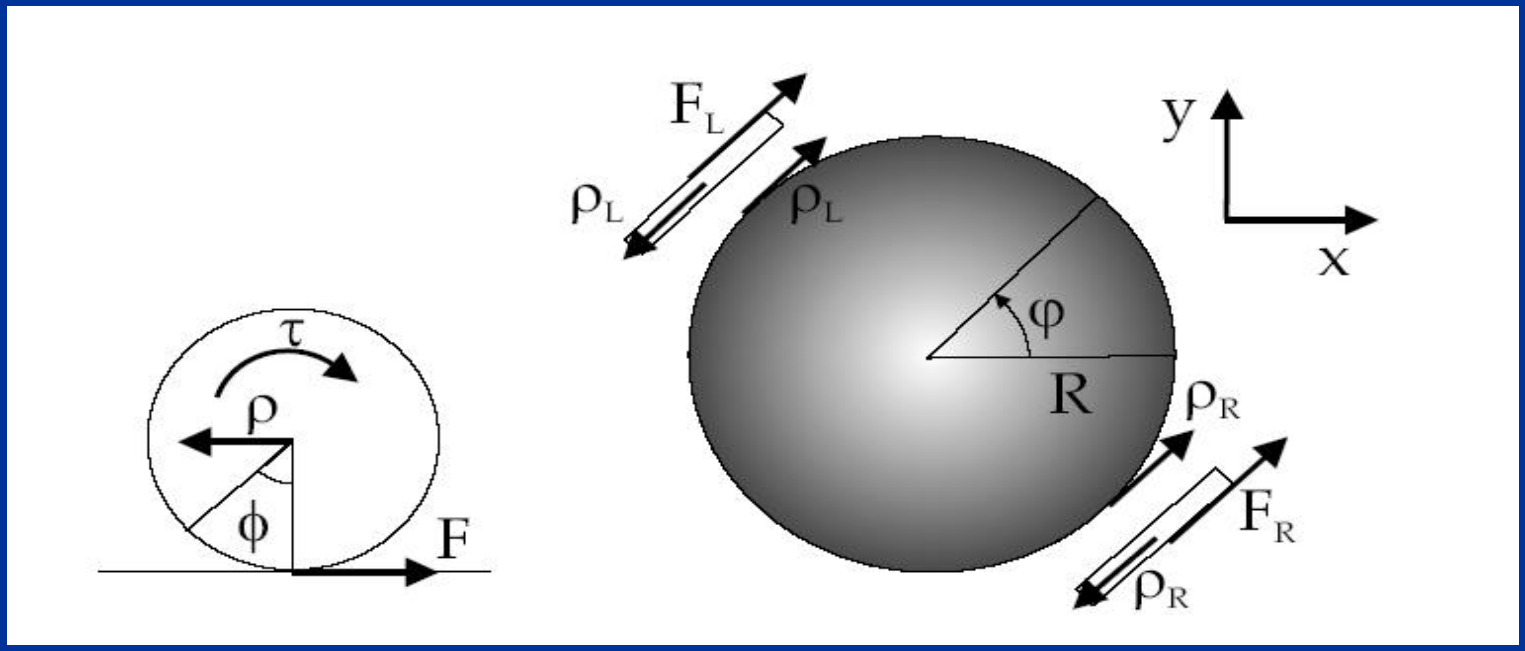
Robot kinematics and dynamics

- Kinematics:
  - Determining the range of possible motions for a robot given the various constraints limiting the freedom of motion, and without taking into account the forces that cause the motion.



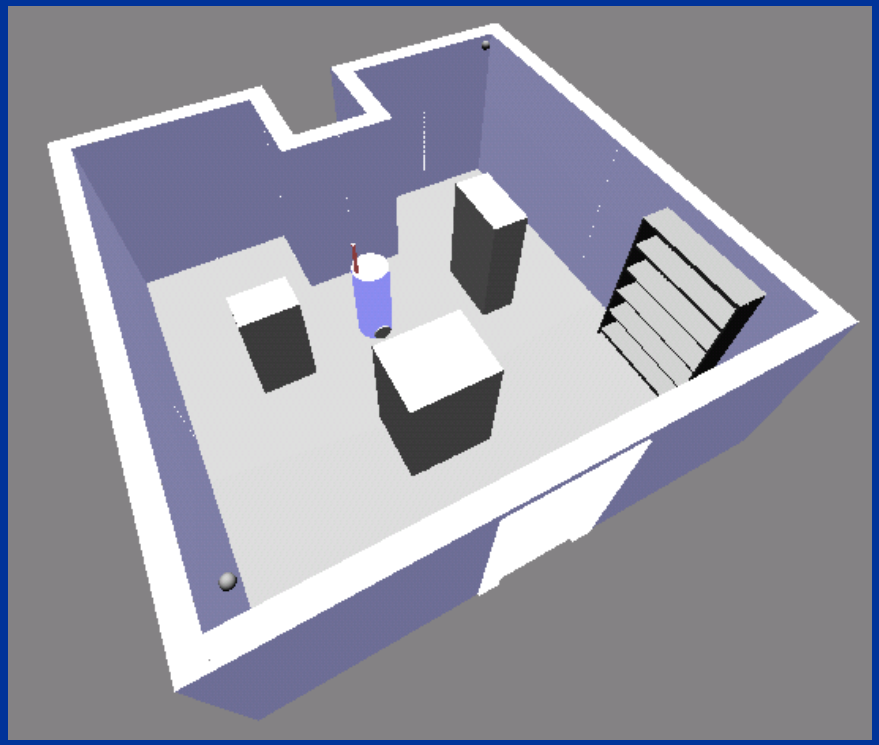
Robot kinematics and dynamics

- Dynamics:
  - Determining the motion of a robot under the action of forces (and torques).



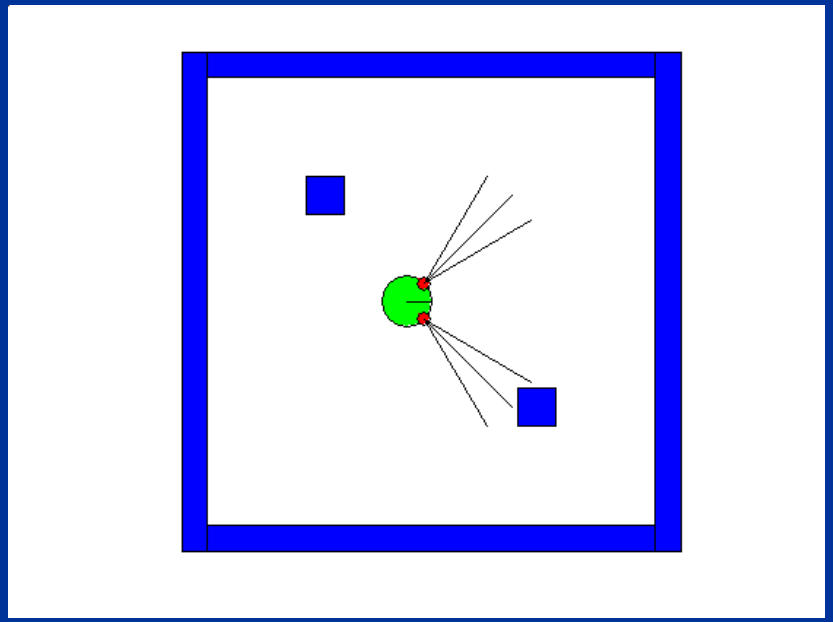
Simulation of autonomous robots

- We will study simulated two-wheeled differentially steered robots
- The simulations will include models of sensors and actuators
- The important issue of making simulations realistic (i.e. transferable to a real robot) will be studied



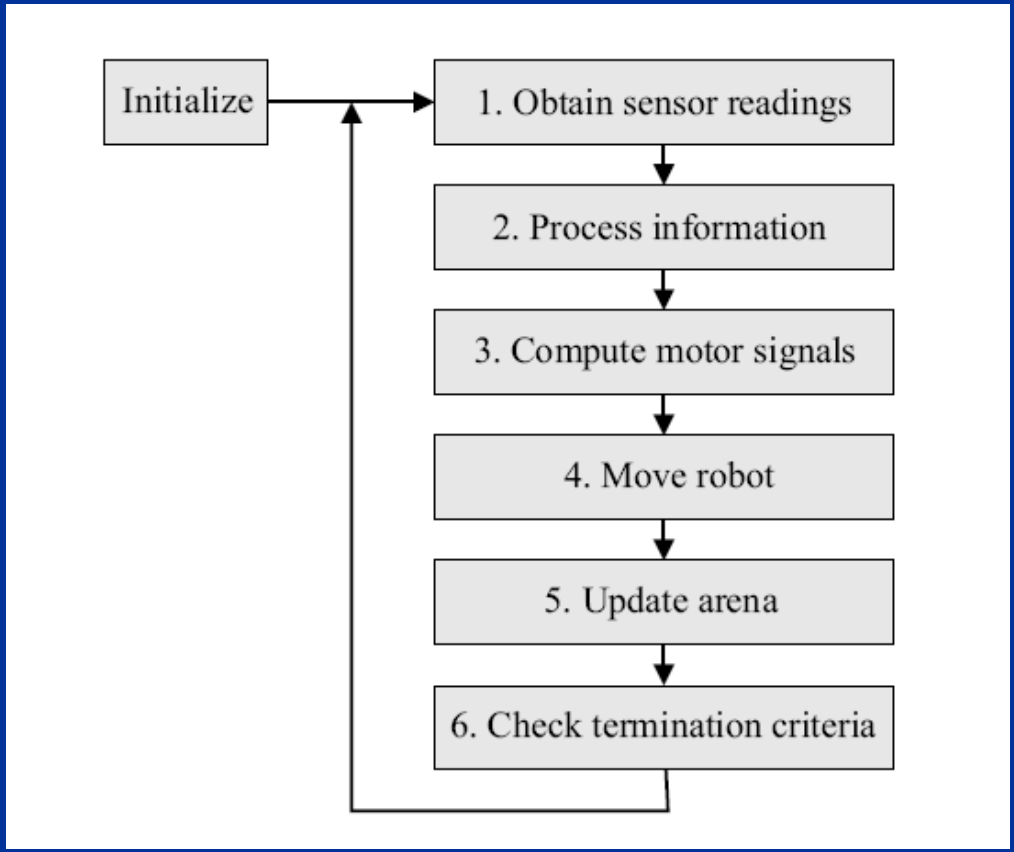
Simulation of autonomous robots

- For our simulations, we will use a Matlab simulator, ARSim
- The simulator allows the user easily to modify the setup of:
  - the robot
  - the arena in which it operates



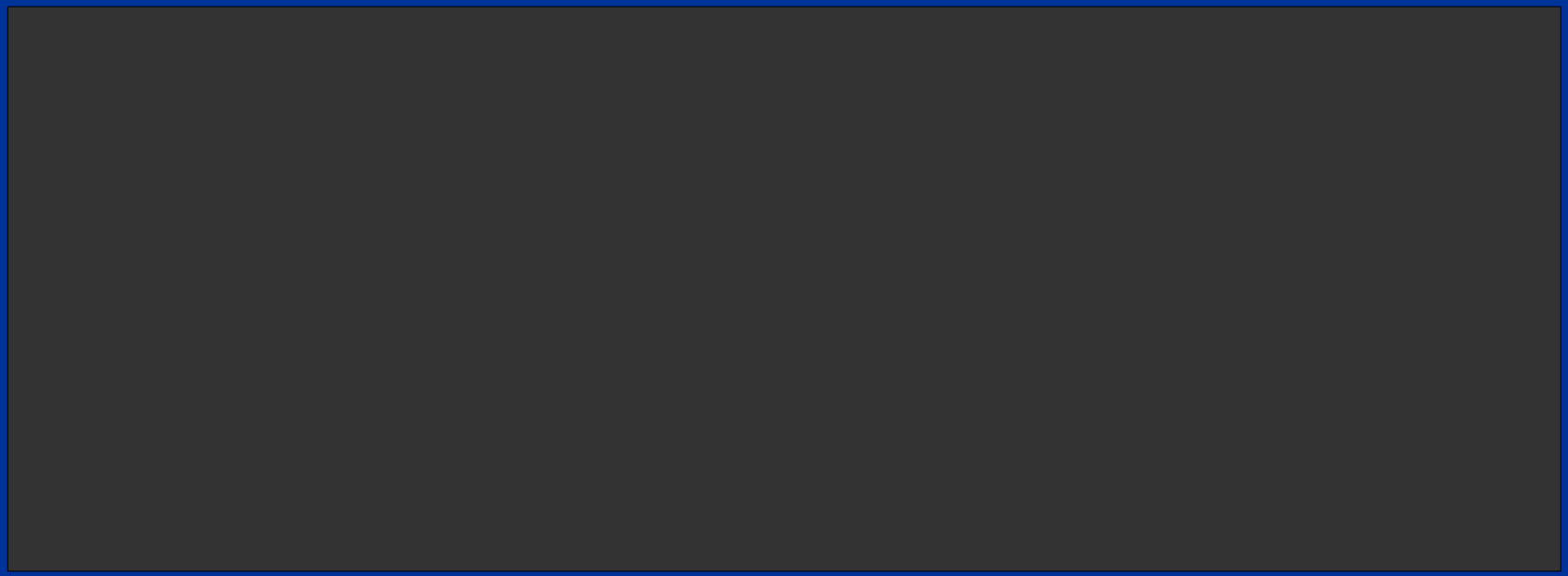
Simulation of autonomous robots

- Basic flow of a single-robot simulation

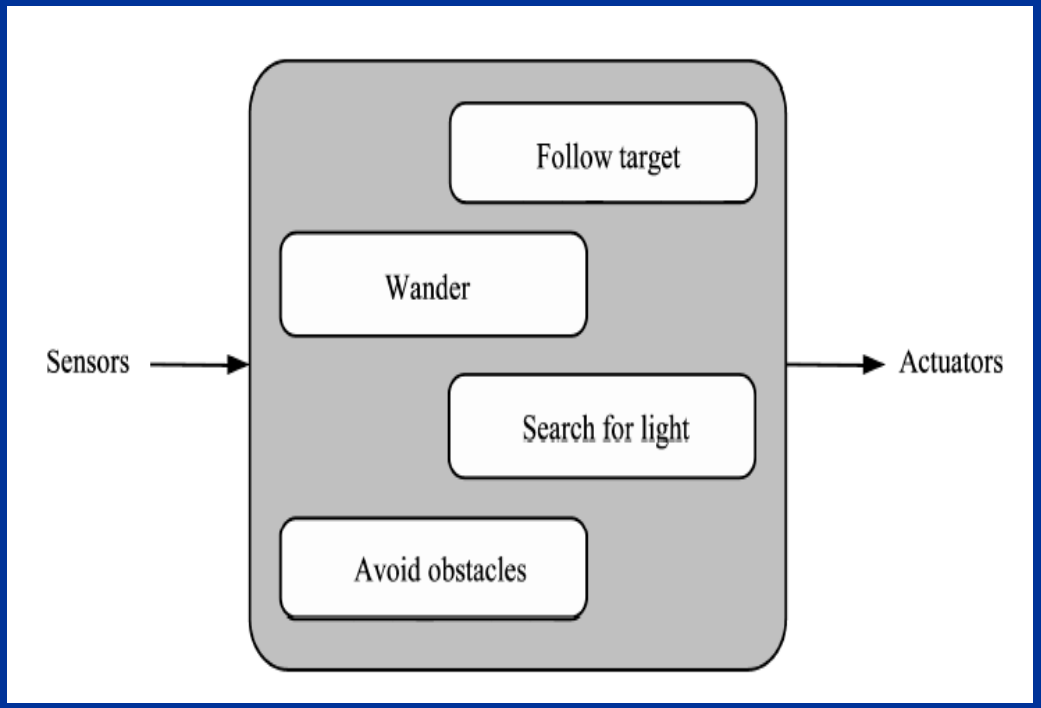


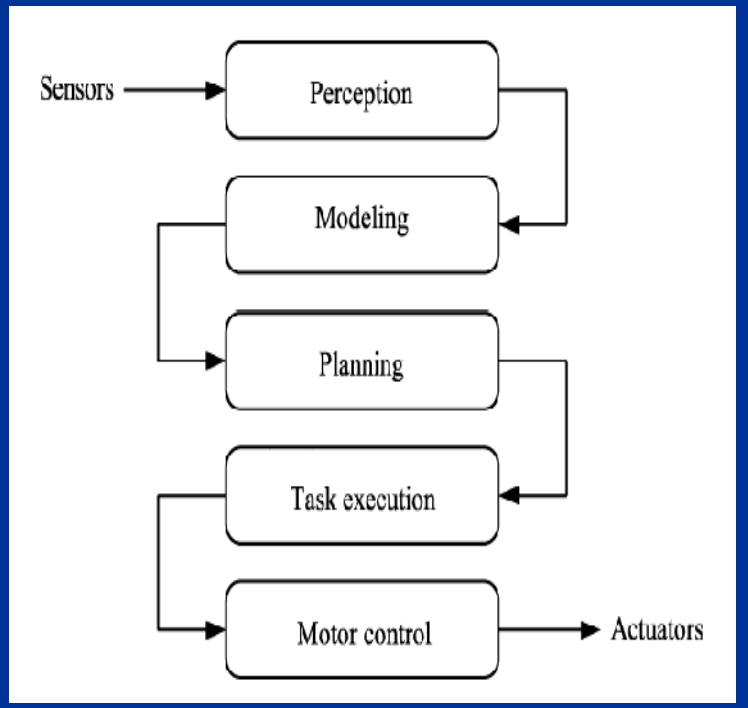
Animal behavior

- Brief introduction concerning animal nervous systems, and ethology (animal behavior) will be given
- Basic behaviors, such as reflexes and fixed-action patterns will be discussed



Behavior-based robotics



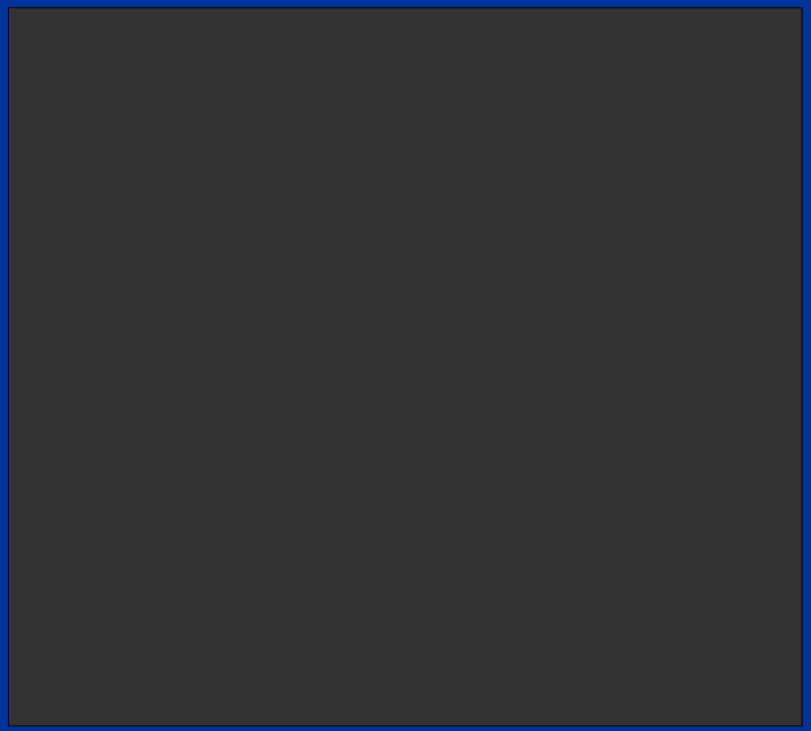


BBR vs. Classical AI

Behavior-based robotics (BBR)

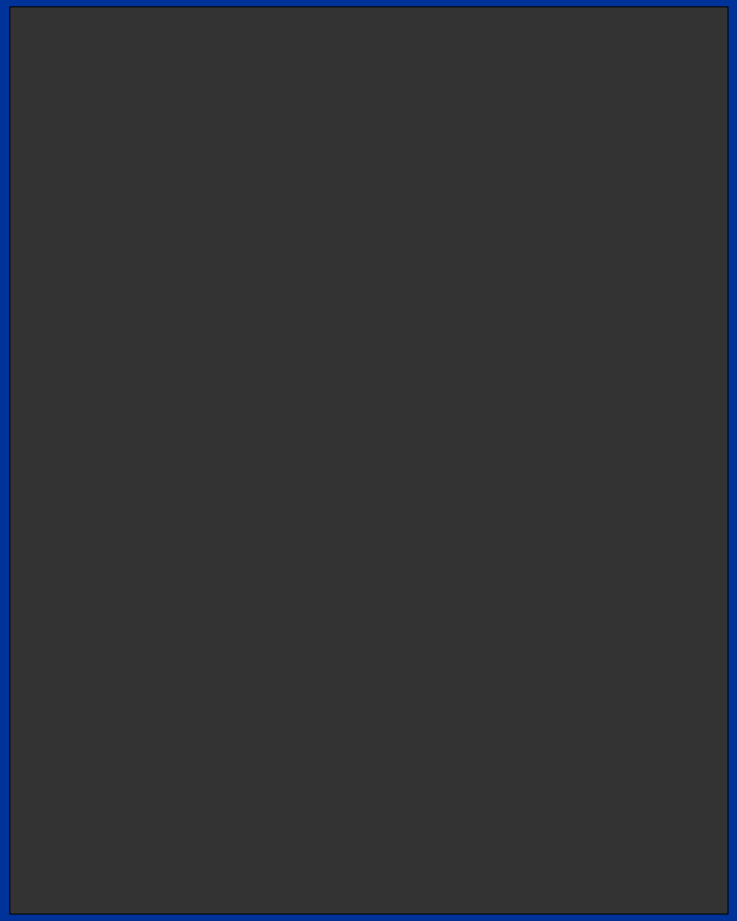
- Various architectures for behavior-based robots, such as ANNs and if-then-else-rules will be considered

- Methods for generating basic behaviors, such as *exploration*, *collision avoidance* etc. will be studied

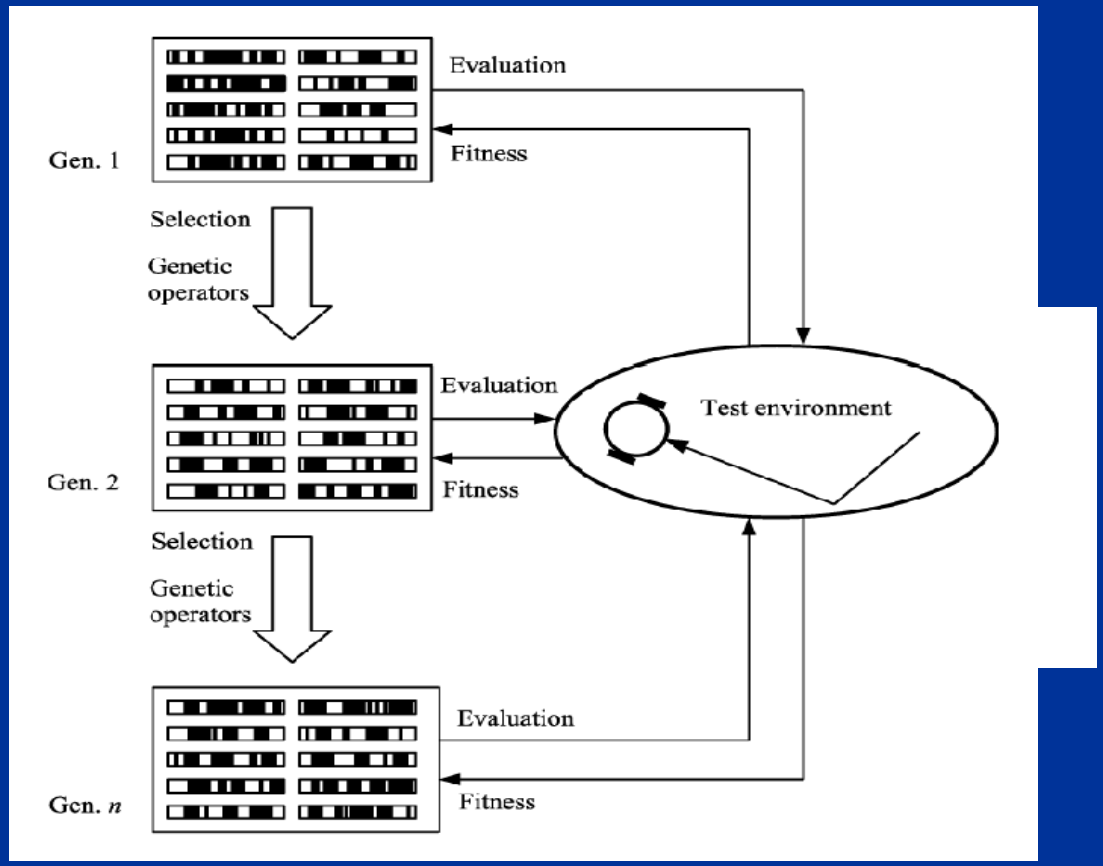


Evolutionary robotics (ER)

- Evolutionary robotics, i.e. the generation of robotic brains (or bodies) by means of evolutionary algorithms, will be considered as well.
- A simulator (ERSim), based on the ARSim Matlab simulator will be used in the experiments.



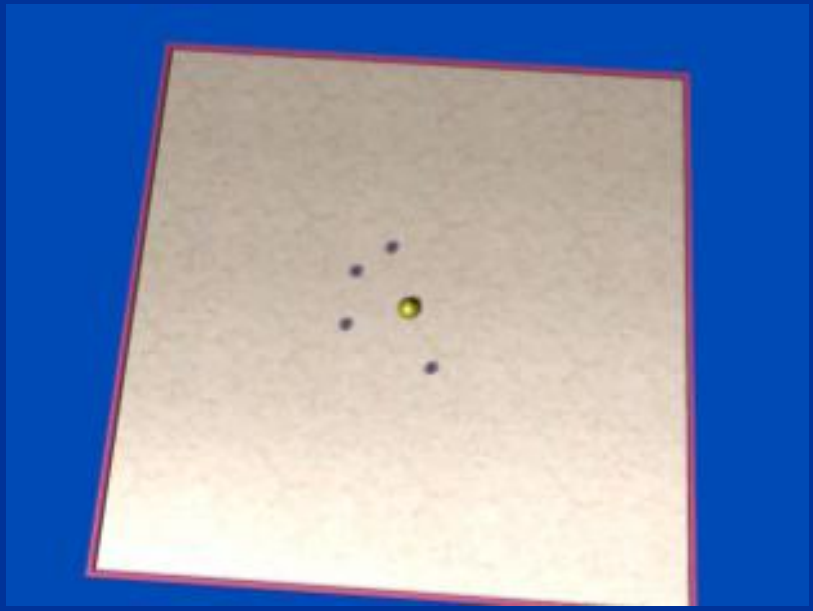
Evolutionary robotics



- Basic flow of evolutionary robotics

Evolutionary robotics

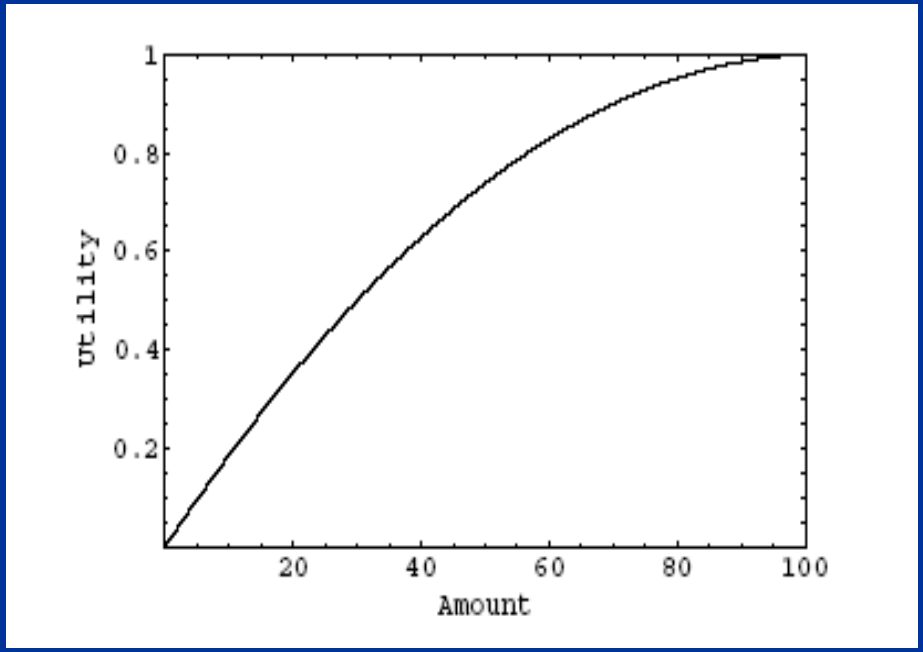
- Generation of basic behaviors by means of evolutionary algorithms will be studied:



- Example: Garbage collection

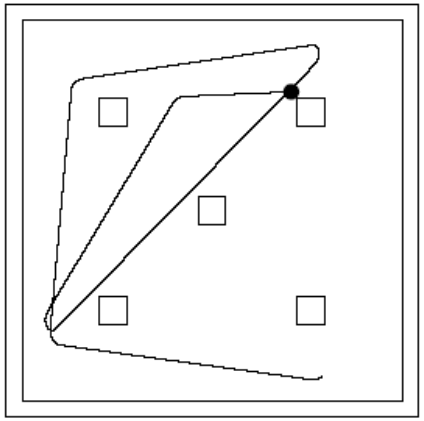
Rational decision-making

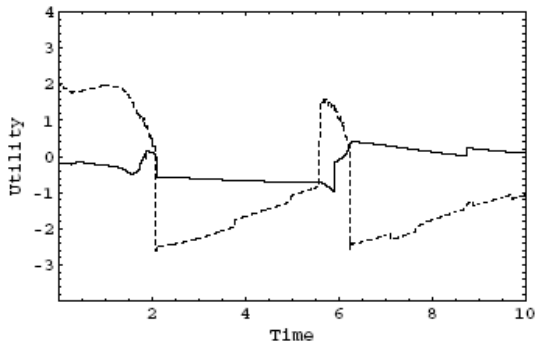
- The theory of **rational-decision making** (von Neumann & Morgenstern) will be considered.
- The concepts of **utility** and **rational agents** are central.
- Biological examples will be used to illustrate the principles of rational decision-making.

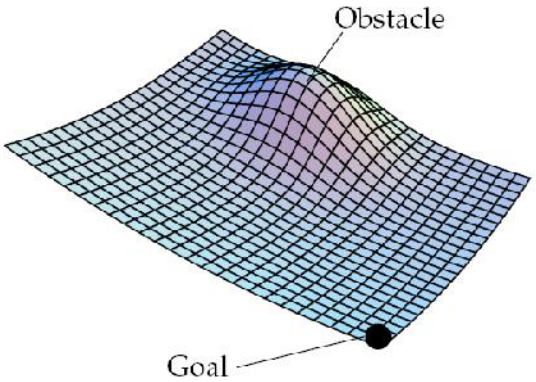


Behavioral organization in robots

- **Behavioral organization** (behavior selection) allows one to move from simple behavior-based robotic brains to complex ones, particularly in motor tasks, e.g. navigation.
- Two classes of methods will be considered: **arbitration methods** and **cooperative methods**

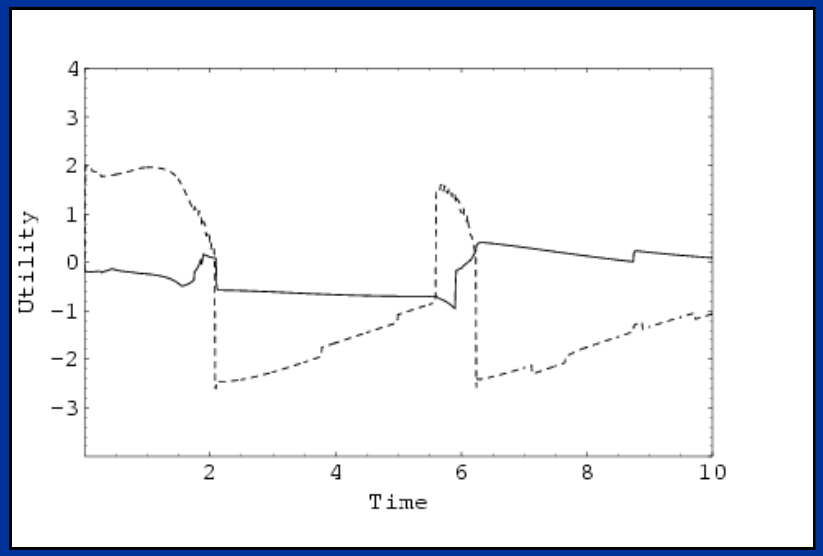


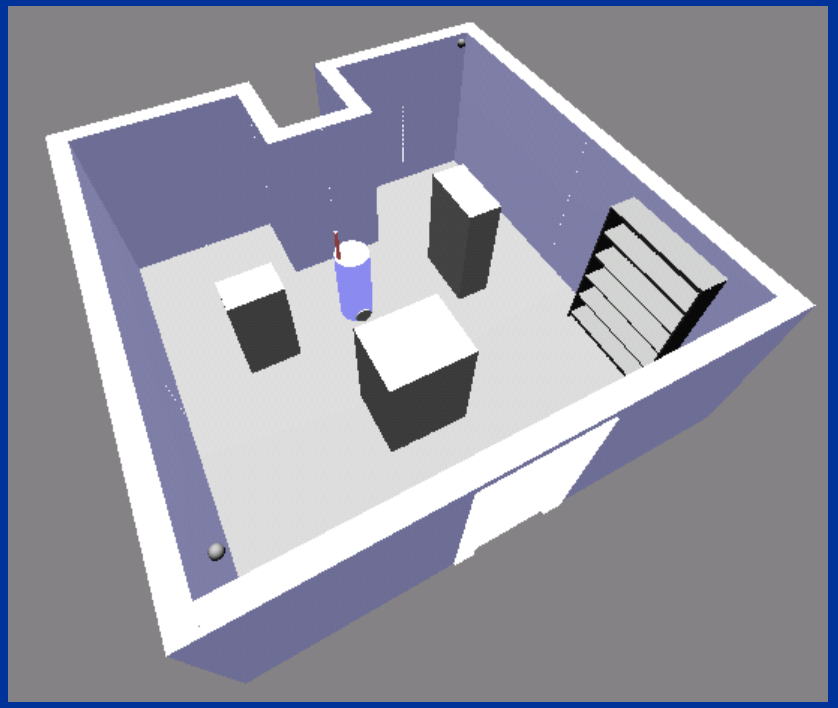




Example: behavioral selection for simple exploration

- Two behaviors to be organized:
  - B1: Straight-line navigation
  - B2: Obstacle avoidance

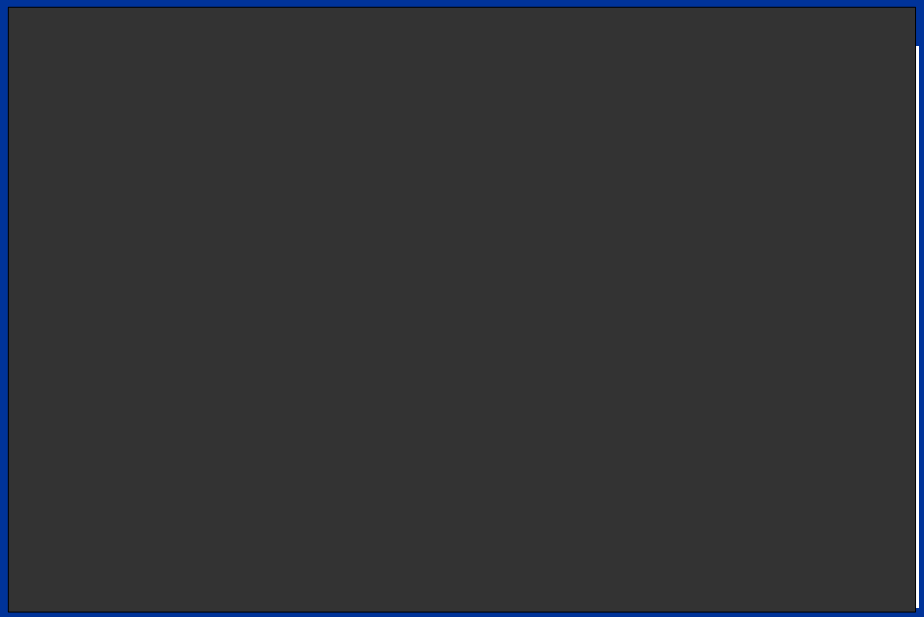


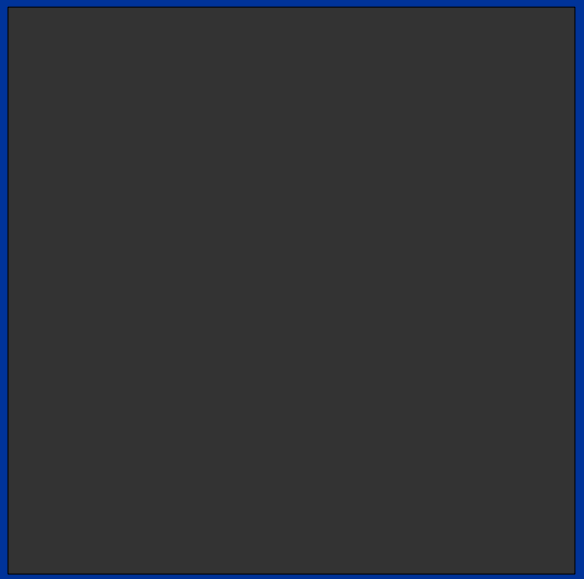


Learning in animals and robots

- **Learning** deals with the modification of the brain of an animal (or a robot) during the life time of the individual.

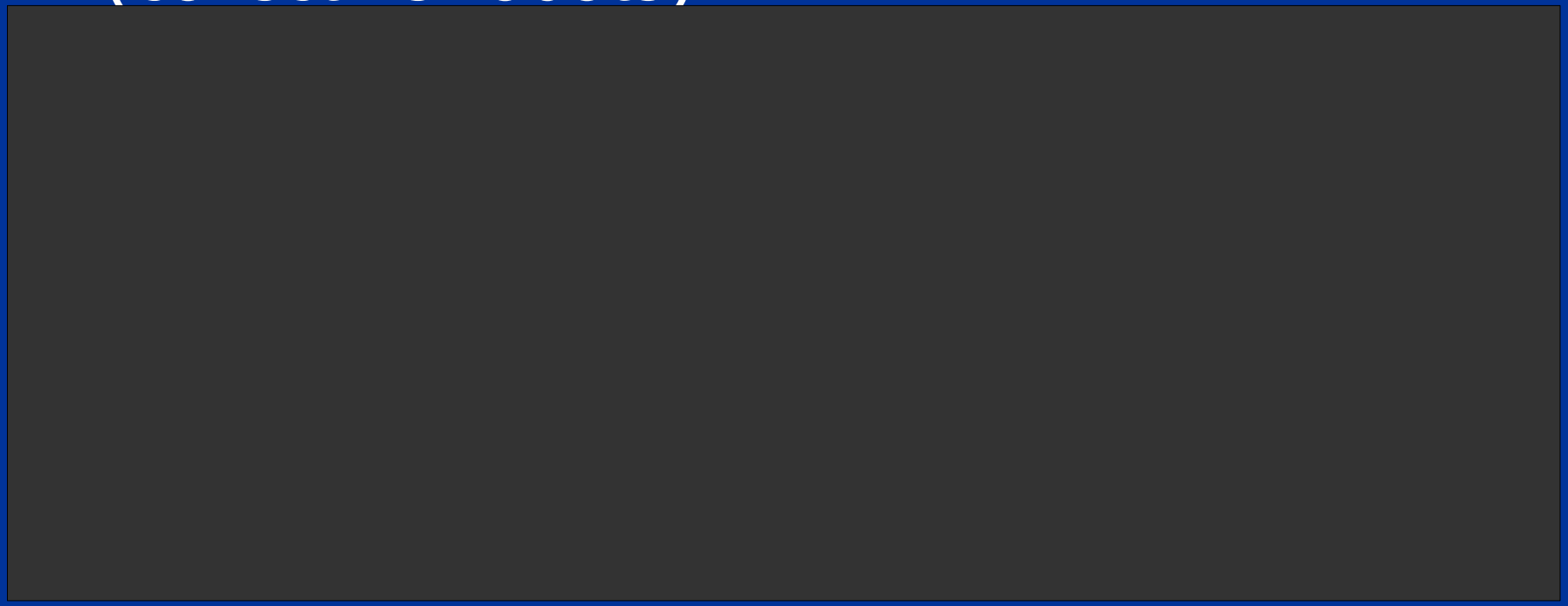
- The relation between evolution (adaptation) and learning will be studied, as will the concepts of short-term and long-term memory.





Multirobot applications

- Division of labour in a group of robots inspired by ant's foraging behavior (collective robots).

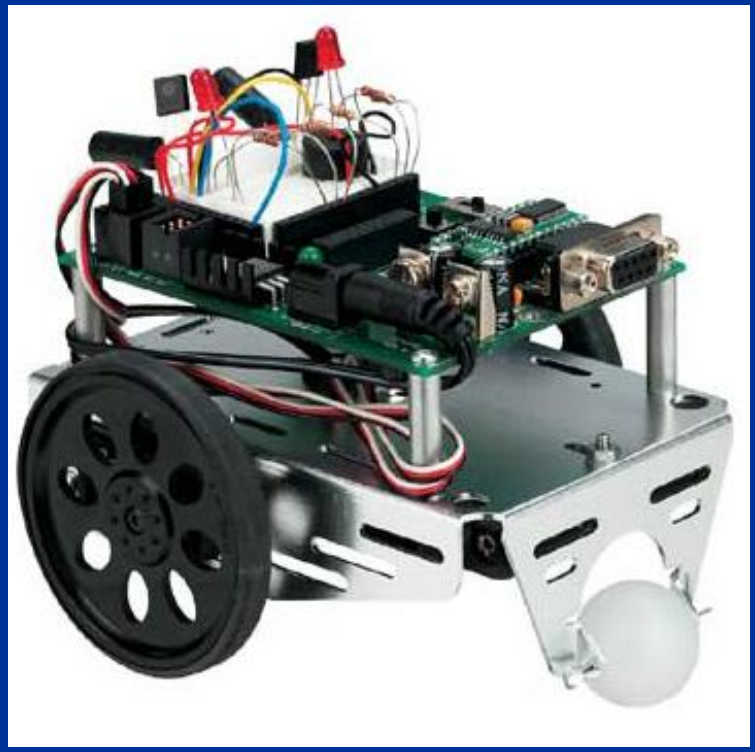


Course contents, Part II

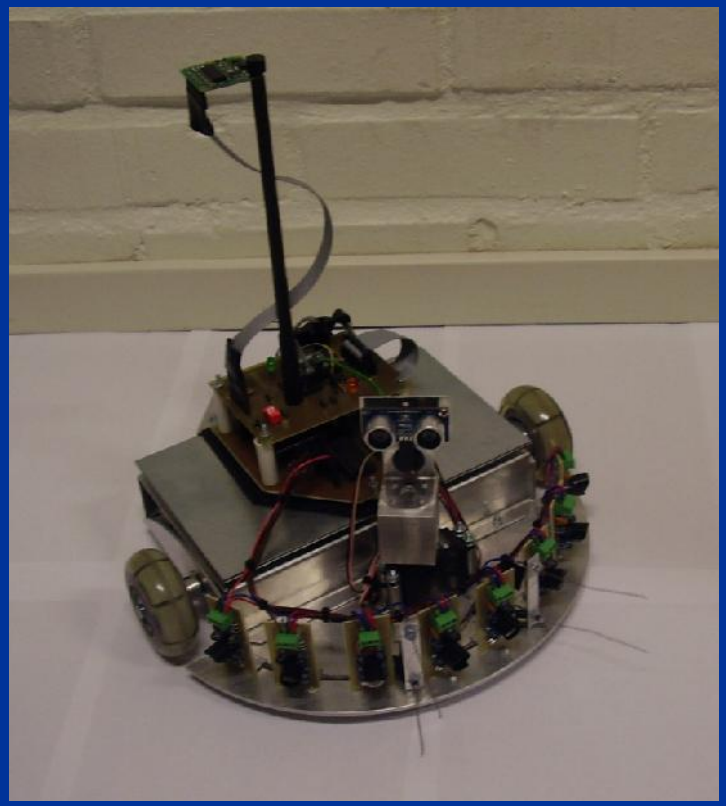
- Quarter 4: Robot construction part.
  - Group work
  - Robot design (given certain tasks)
  - Implementation
- **Mandatory** robot activities!
- A walktrough...

Platform: The Boe-Bot® robot

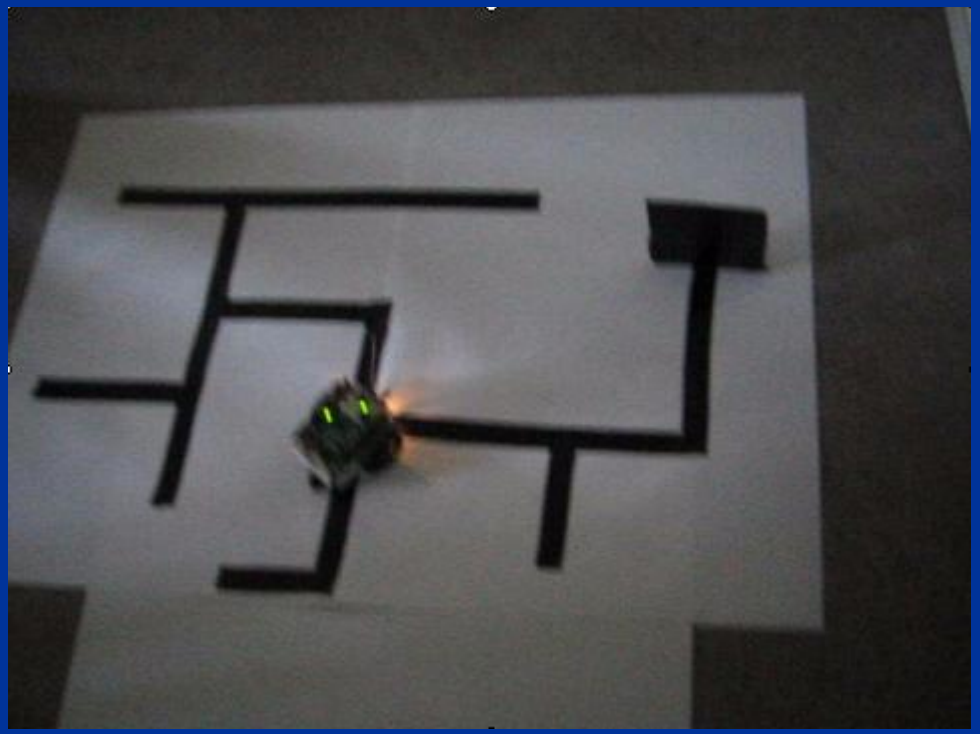
- Developed by Parallax Inc.
- Learn about
  - sensors
  - servo motors
  - microcontrollers
- Apply the theory from part I.
  - Implementation
- Groups of 4-6 students
- Use it out-of-the-box, or use your **creativity**!



Example: creative robots



An example from last year...



Topics

- Course introduction, introduction to autonomous robots.
- Kinematics, dynamics, and sensors of autonomous robots.
- Simulation of autonomous robots.
- Decision-making system of robots.
- Animal behavior: Lessons for robotics.
- Behavior-based robotics: Generating robot behaviors.
- Evolutionary robotics: Evolving basic behaviors.
- Utility theory and rational decision-making.
- Behavior organization in autonomous robots.
- Control system of robots (I+II)
- Information system of robots.
- Learning and adaptive behavior in animals and robots.
- Multi-robot applications.
- Robot construction.

Course information

- **Lecturer:** Krister Wolff
  - phone: 772 3625, email: krister.wolff@chalmers.se
- **Course assistant:** David Sandberg
  - phone: 772 3696, email: david.sandberg@chalmers.se
- **Examiner:** Mattias Wahde
  - phone: 772 3727, email: mattias.wahde@chalmers.se

Course information

- The course runs over 2 quarters. In order to complete the course, you must participate during both quarters!
- All parts are **mandatory**, i.e. home problems, written exam, and robot activities!
- Check the course homepage **regularly** for information:

http://www.am.chalmers.se/~wolff/AA/AutonomousAgents.html

- Detailed information regarding the robot construction part will come later

Course information

- Course literature (part I):
  - 1. Wahde, M.: *An introduction to autonomous robots* (lecture notes). Will be made available for download shortly.
  - 2. Xie, M. -- *Fundamentals of robotics - linking perception to action*. Available at Cremona bookstore.
  - 3. Various scientific papers
    (web links or printouts will be made available during the course)

Course information

- Course literature (part II):
  - 4. Lindsay, A.: *Robotics with the BoeBot - Student guide v2.2*, Available for download at www.parallax.com.
  - 5. The BasicX Manual: *BX-24 Documents*. Available for download at www.basicx.com.
  - 6. Various additional materials, which will be annonced in the beginning of Lp IV.

Course information

- Teaching hours and locations:
  - **3rd quarter** (Janunary 21 - March 7):
    Tuesday 10.00 - 11.45, MC
    Friday 13.15 - 15.00, MC
  - **4th quarter** (March 31 - May 23):
    Tuesday 08.00-11.45, F7105A (ET-lab).

Course information

- Examination: Maximum total score is 50, divided according to
  - Two sets of home problems, 3rd quarter (25p maximum)
  - A written exam (by the end of the 3rd quarter, 25p maximum)

- Robot construction project give no points, but is **mandatory** to do. However, you *may* recieve two extra points for creativity.

- Regarding the home problems: You may discuss with other students, but you **must** hand in your **OWN** solution!

Course information

- Prerequisites:
  - You do *not* need to know about autonomous robots, neither simulations nor hardware.
  - You *should be* familiar with evolutionary algorithms, Matlab programming, basic physics (mechanics, electrical engineering) and artificial neural networks.

Course information

- Note: In order to **register** for the course, each student *must* send an email to krister.wolff@chalmers.se with his/her *name*, *affiliation* (i.e. cas, cth, gu, or other), and *civic registration number* (personnummer).

- Use *one single email address* throughout the course, with your full name (e.g. "Anders Andersson") in the "From" field, no nicknames! Use Western characters (no Chinese, Russian etc.)!

- Important information will be distributed via email!

Course information

- Course Evaluations - CAS
  - Three volunteers, please!
  - Compensation will be paid from Chalmers: 200-300 SEK

Course information

- Don't hesitatie to ask questions, any time:
  - You may come to my office (behind Café Bulten, walk up one floor).
  - Call me (031-7723625)
  - Send emails
- But check the web page first, please!

Reading Guidance

- **Lecture 1:** Course introduction, introduction to autonomous robots:
  - MW: p. 1-2:
    - 1 Autonomous robots; *important*
  - MX p. 1-26:
    - 1.1 Introduction; *important*
    - 1.3 Factory automation; *briefly*
    - 1.4 Impact of industrial robots; *briefly*
    - 1.5 Impact of humanoid robots; *briefly*
    - 1.6 Issues in robotics; *important*