Autonomous agents
Lecture 2, 20160121

Sensors, actuators, and processors

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- After this lecture you should be able to
  - Define and list various robot types in detail
  - Describe the uncanny valley phenomenon
  - Describe how IR sensors work
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Robot types

Manipulator (robotic arm)

Mobile robot

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Taxonomy of mobile robots

- Wheeled robots
- Walking robots
  - Non-humanoid
  - Humanoid
    - Androids
- Swimming robots
- Flying robots

Wheeled robots (examples)

Pioneer, with a sonar array and a laser range finder

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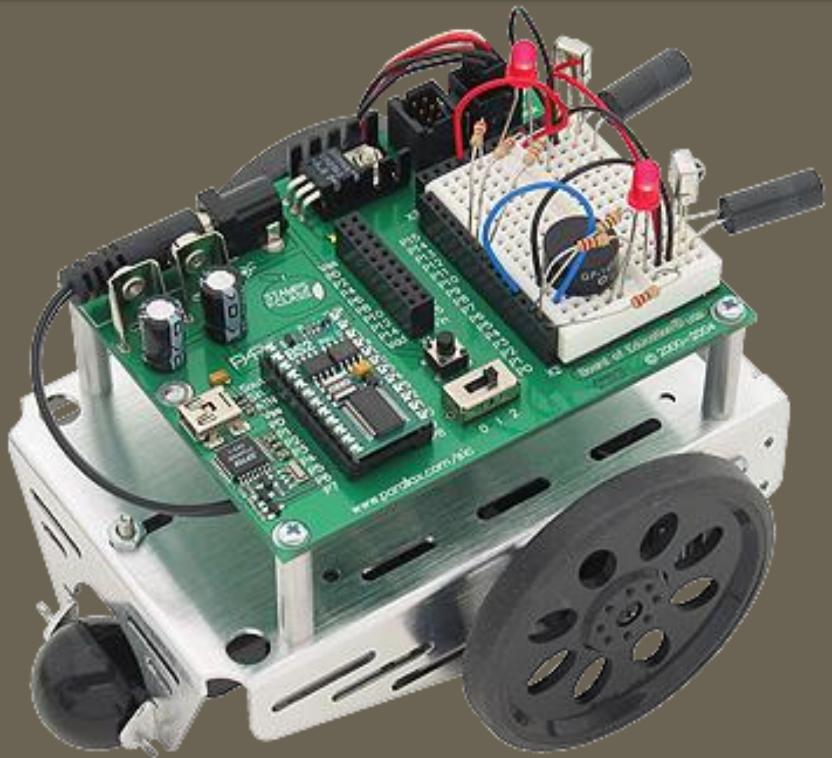
Wheeled robots (examples)

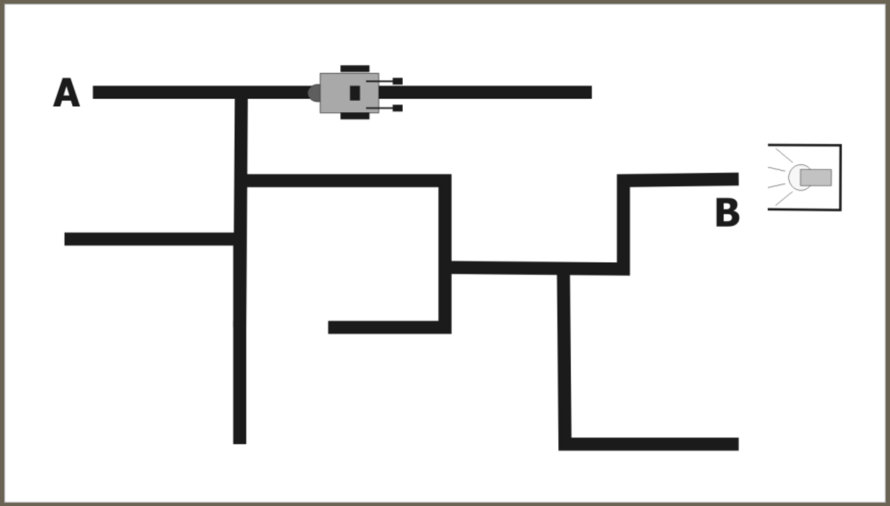
Our research robot (with 3 IR sensors and a laser range finder)

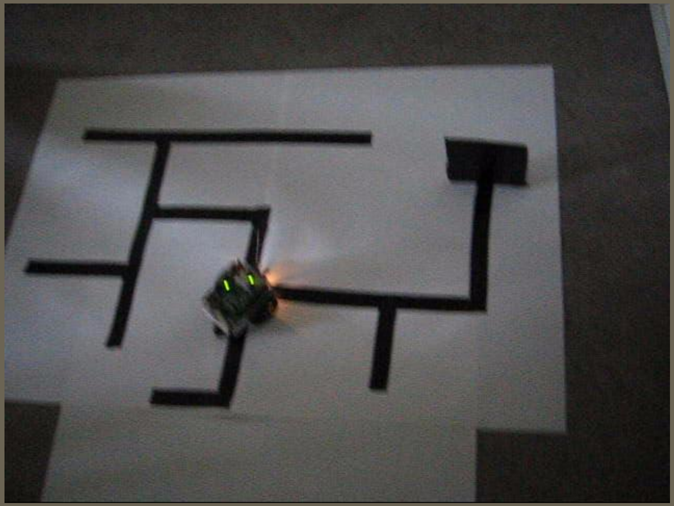
Wheeled robots (examples)



Boe-bot

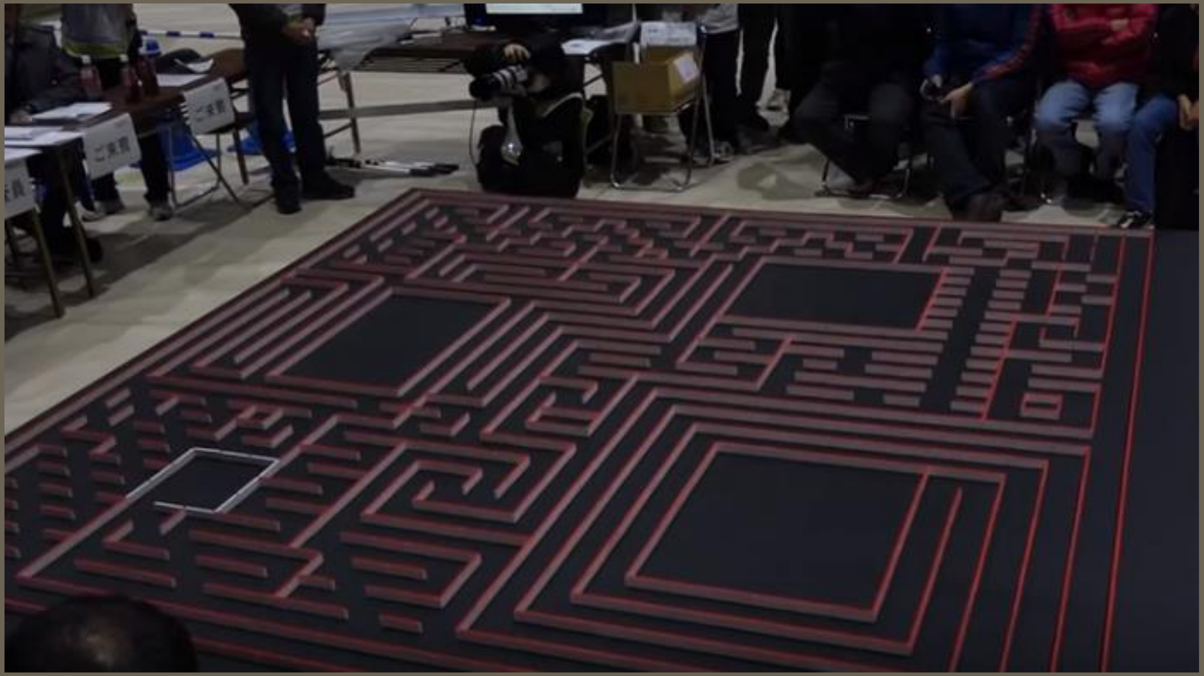
Wheeled robots (examples)





Boe-bot

Wheeled robots (examples)



Really fast maze-solving robot …

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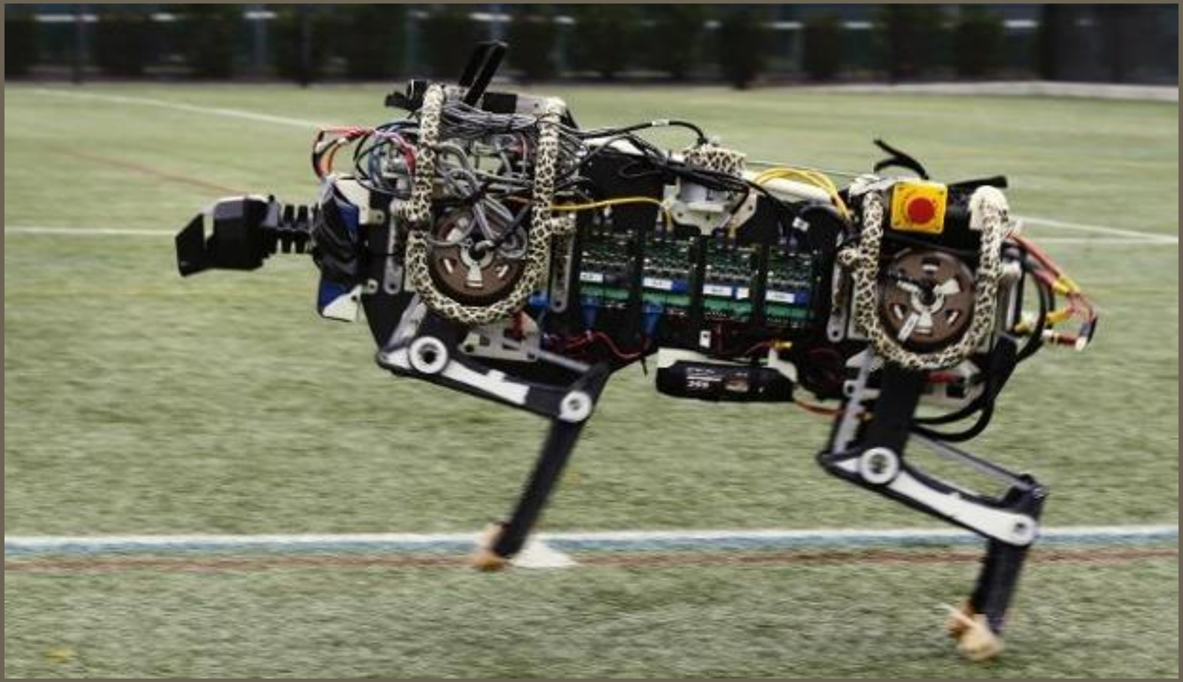
Non-humanoid walking robots (examples)

Quadruped robot with Arduino microcontroller

Non-humanoid walking robots (examples)



MIT Cheetah

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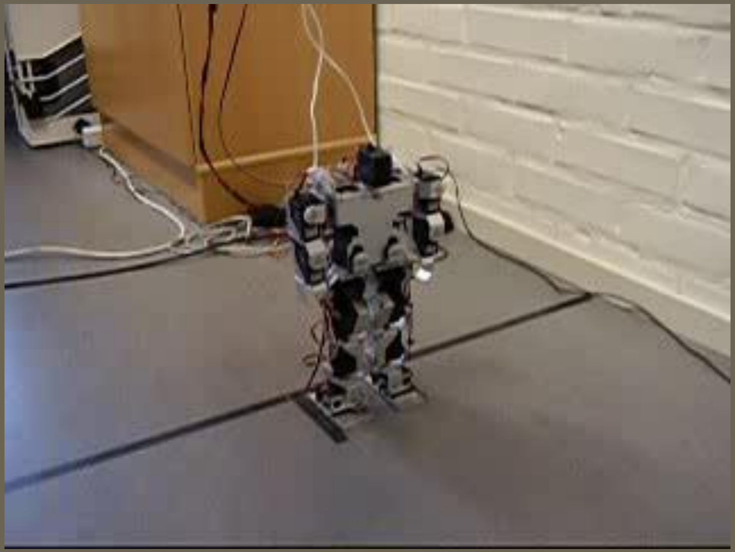
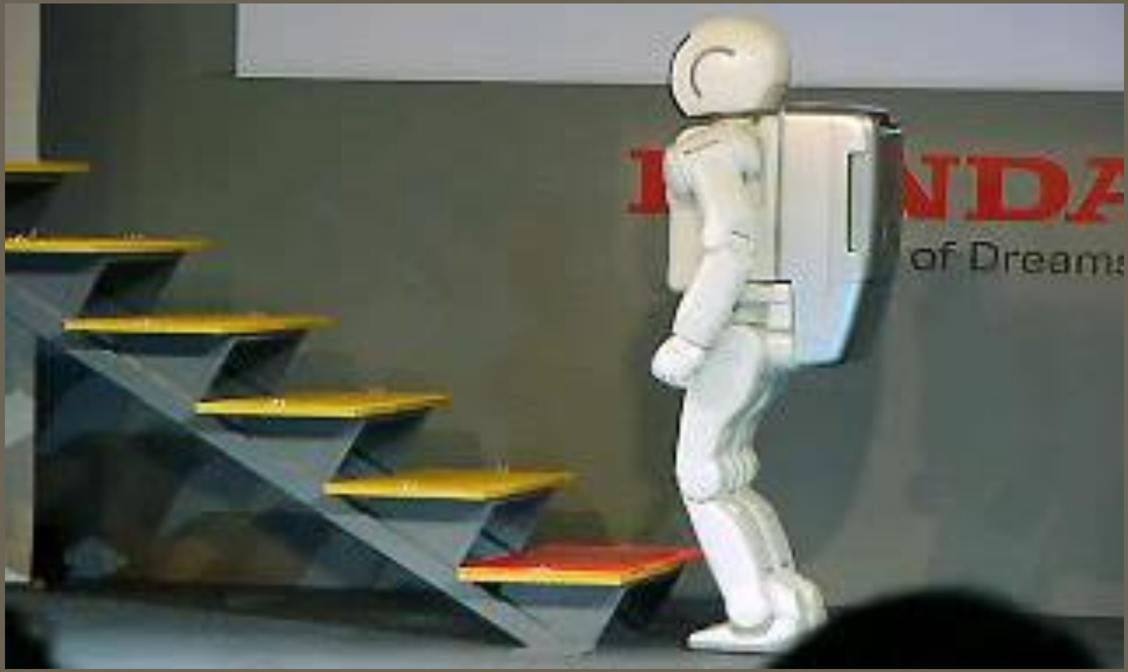
Humanoid robots (examples)

- Humanoid robot: A robot with an approximately human shape.



Kondo robot (previously used in the Humanoid robotics course)

Humanoid robots (examples)



ASIMO

Humanoid robots (examples)

NAO

Androids (examples)

- Android: Robots that try to mimic human appearance in every aspect (skin, hair, facial expressions etc.)

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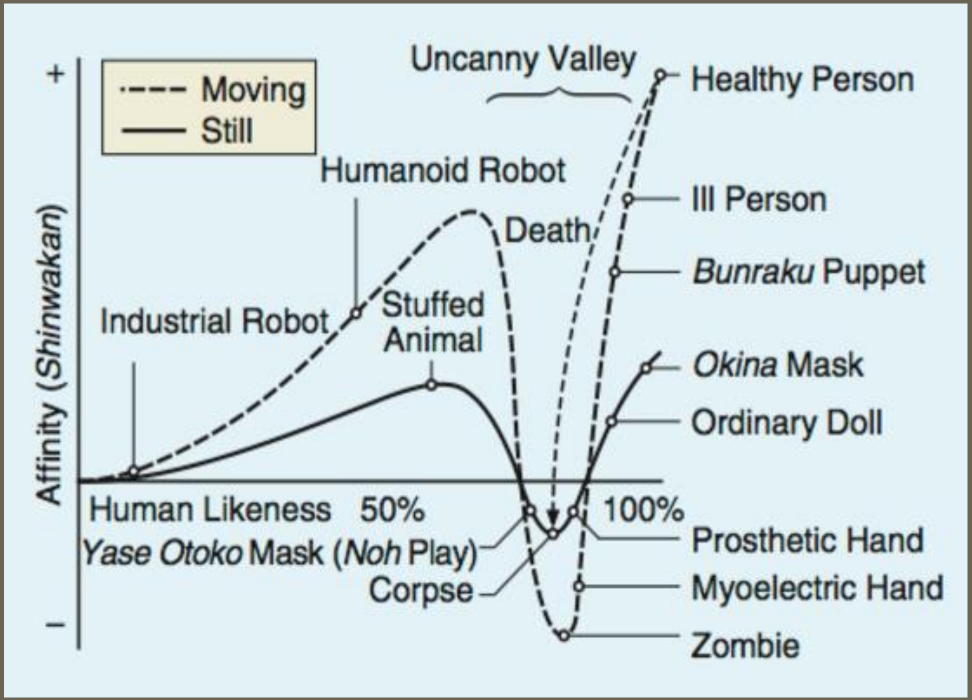
Uncanny valley

- Suggestion (by M. Mori, 1970)
  - Emotional response towards a robot increasingly positive as human likeness is increase, until ...
  - ...a certain level (the *uncanny valley*) where the robot is instead provokes strongly negative emotions (reinforced by the movements of the robot) until...
  - ...a level at which it is virtually indistinguishable from a real human.

Uncanny valley



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Construction material

- For small (light) robot, aluminium is often used – this material is sturdy, yet light-weight and easy to work with.

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Sensors

- Many different types exist. Examples
  - Infrared (IR) sensors
  - Digital optical encoders (measure wheel rotation)
  - Ultrasound (sonar) sensors
  - Laser range finders
  - Cameras
  - Touch sensors
  - Accelerometers (measure acceleration)
  - Gyro(scopes) (measure orientation and rotation)
  - Compasses (measure direction)

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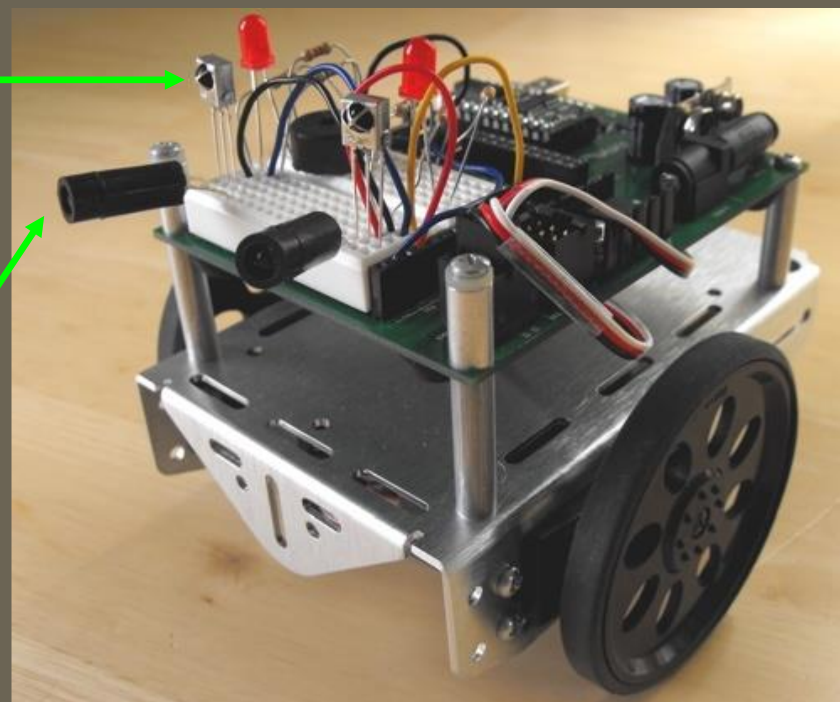
Simple IR proximity sensor

Receiver (Photodetector)

Emitter (IR LED)



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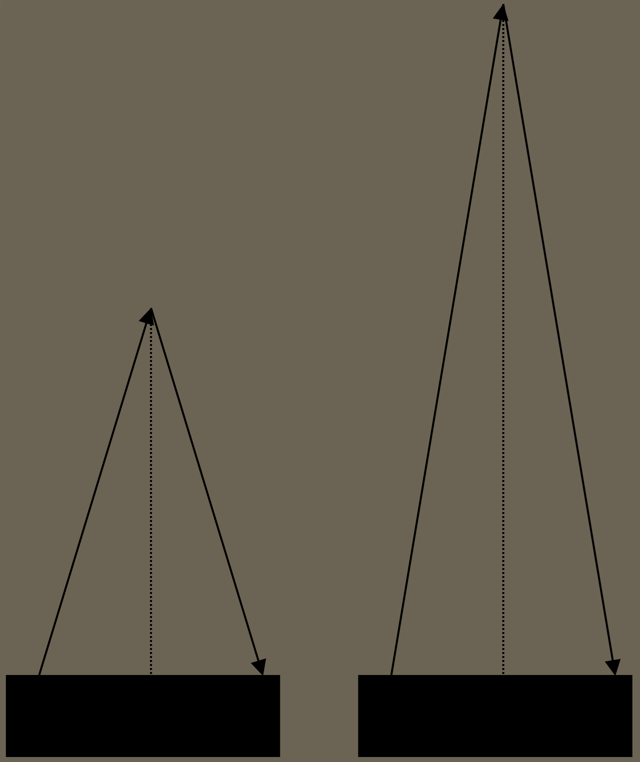
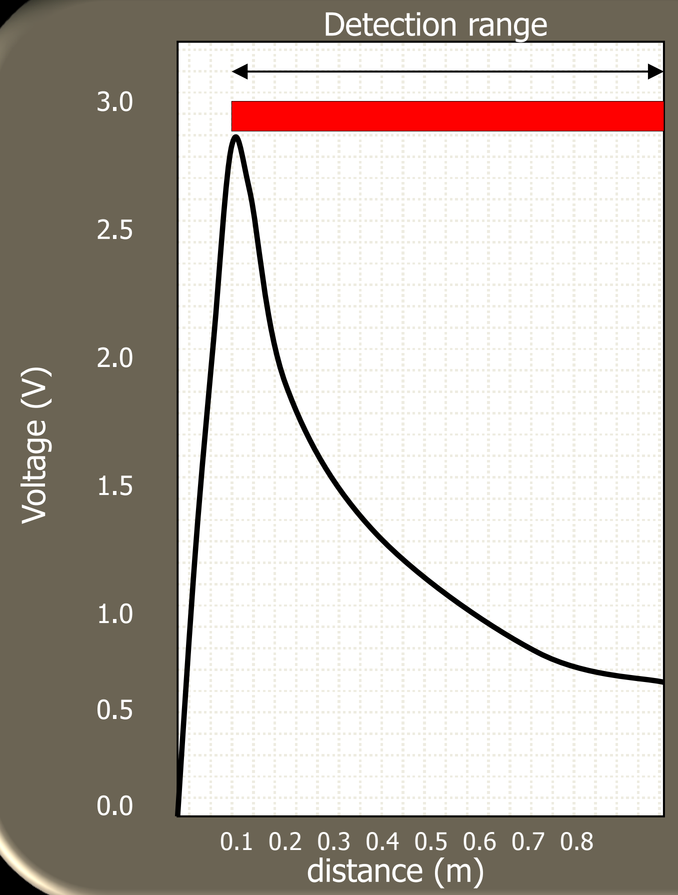
IR distance sensor

Sharp GP2D12 IR sensor



IR distance sensor

- Schematic voltage characteristics
- Effective detection range from around 0.1 m out to around 0.5 – 1.0 m (depending on the type of IR sensor).
- Drawback with IR sensors: Strong light sensitivity



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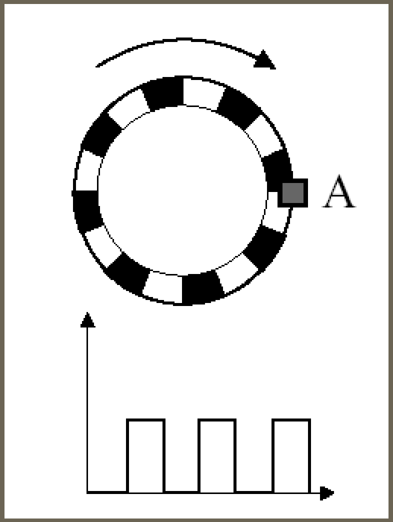
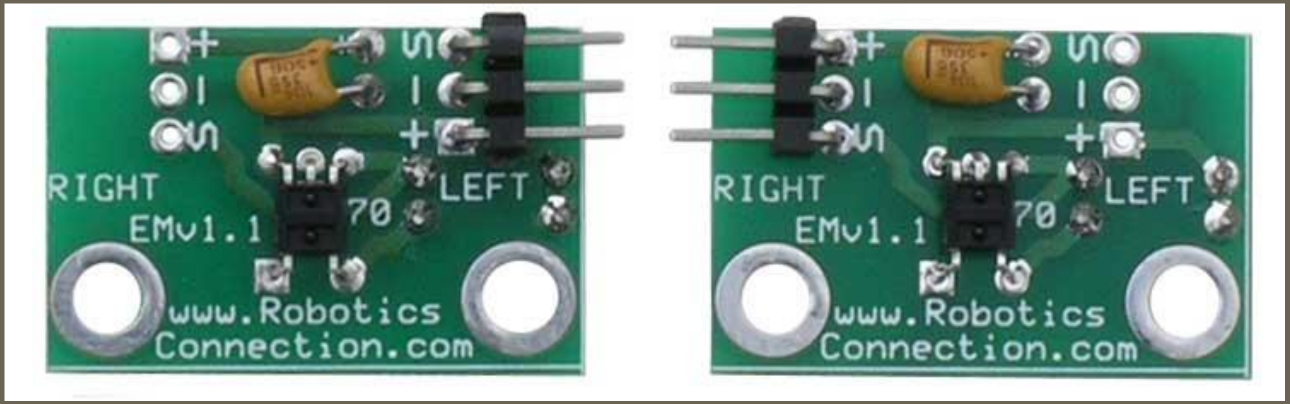
Digital optical encoders

- Measure wheel rotation
  - Rotating disc with alternating transparent and opaque regions.
  - Light emitter and receiver.
- Count the number of interuptions of the beam => possible to deduce wheel rotation.



- Preferably mounted before the gear box for better accuracy (more rotations (of the motor axis) per wheel rotation, than if mounted directly on the wheel axis).

Digital optical encoders



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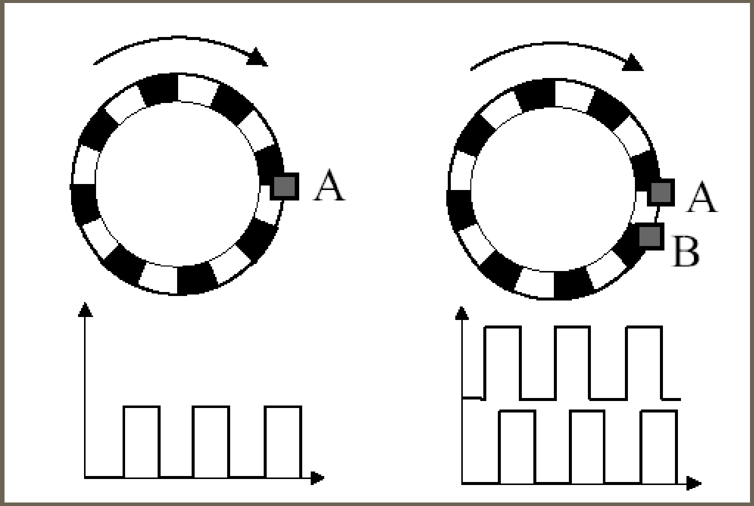
Digital optical encoders

- Direction of motion can be deduced by using a second encoder, mounted ¼ out of phase with the first one (so called quadrature encoding)



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Ultrasound (sonar) sensors

- Sends out ultrasound beam and listens to the echo
- Rely on time-of-flight measurements

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Laser range finders (LRFs)

- An LRF sends out a beam of laser light and detects the echo.
- Rotating laser: Measures many (usually around 1000) different directions.
- High accuracy, typically ± 1 mm or so.
- Range from 4 m up to hundreds of meters.

Laser range finders (LRFs)

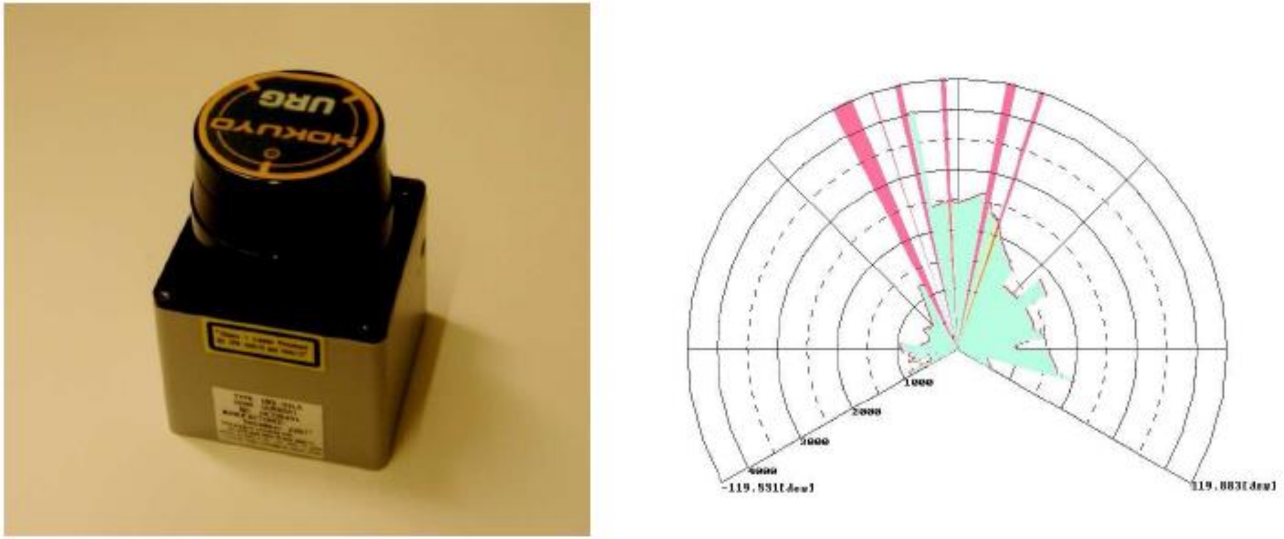
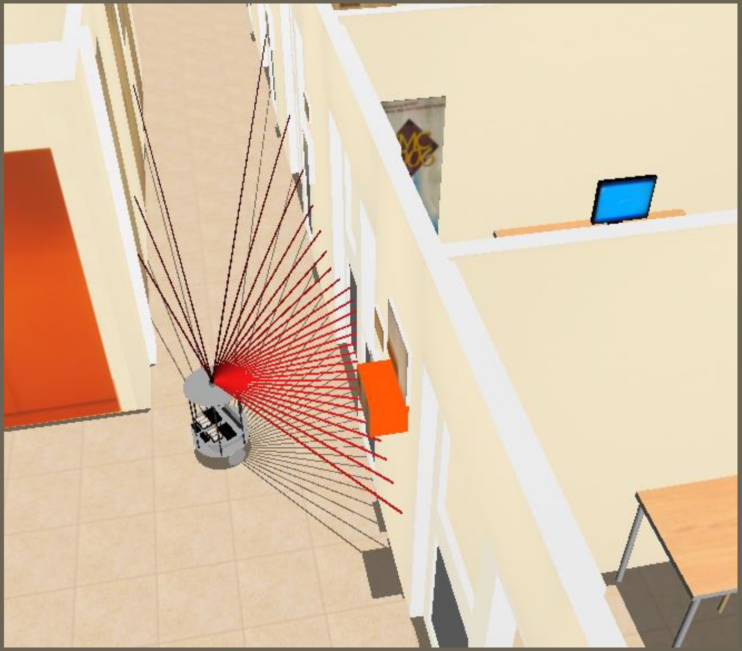
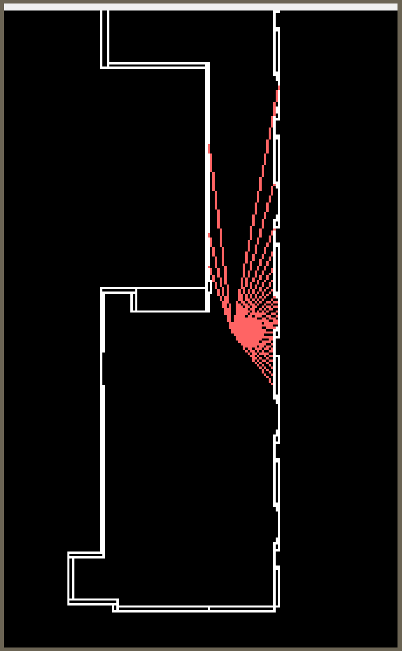


Figure 1.8: *Left panel: A Hokuyo URL-04LX laser range finder. Right panel: A typical reading, showing the distance to the nearest object in various directions. The pink rays indicate directions in which no detection is made. The maximum range of the sensor is 4 m.*

Laser range finders (LRFs)





Laser rays (that hit an object) are shown in red.

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Robot actuators

- Typically DC motors
- Common type: Servo motor = DC motor with control electronics and a gear box.

DC motor

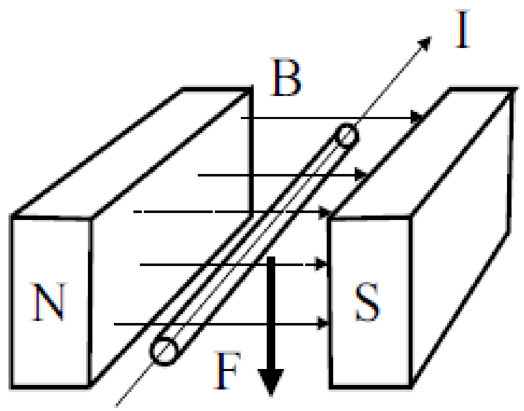

Figure 1.11: *A conducting wire in a magnetic field. B denotes the magnetic field strength and I the current through the wire. The Lorentz force* **F** *acting on the wire is given by* $\mathbf{F} = \mathbf{I} \times \mathbf{B}$.

DC motor

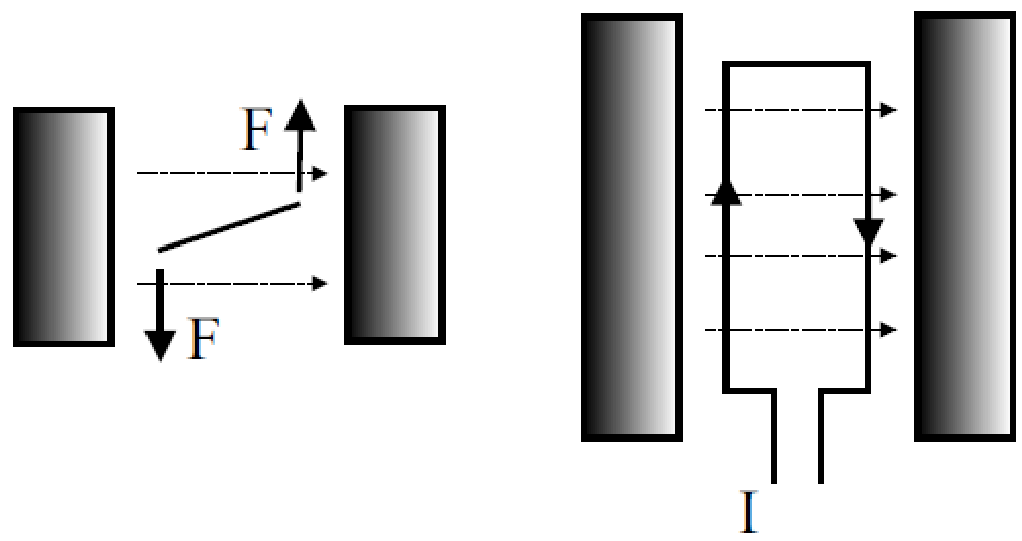

Figure 1.12: *A conducting loop of wire placed in a magnetic field. Due to the forces acting on the loop, it will begin to turn. The loop is shown from above in the right panel, and from the side in the left panel.*

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DC motor

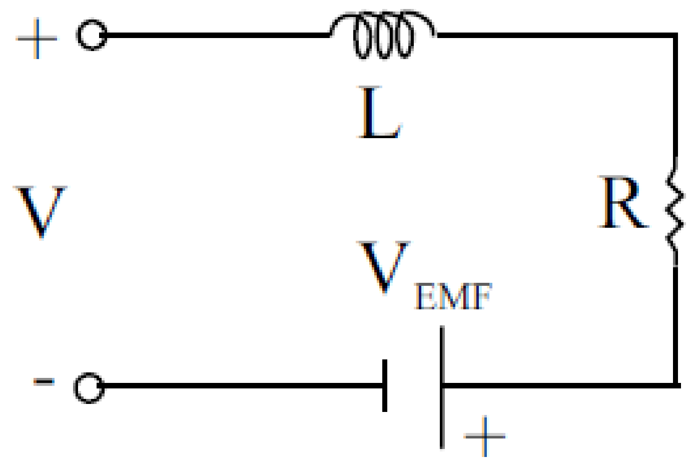

Figure 1.13: *The equivalent electrical circuit for a DC motor.*

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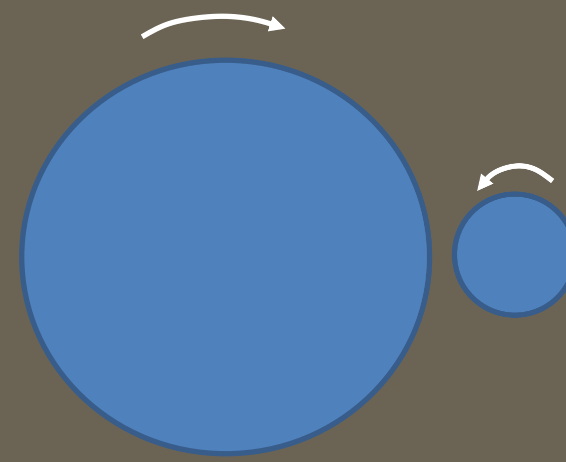
Gear box

- Typically, a DC motor can rotate with high speed but generates a low torque.
- The opposite is needed for a wheeled robot!
- Solution: Add a gear box.



$$\tau_{\mathrm{out}} = G\tau \qquad \omega_{\mathrm{out}} = \frac{1}{G}\omega$$

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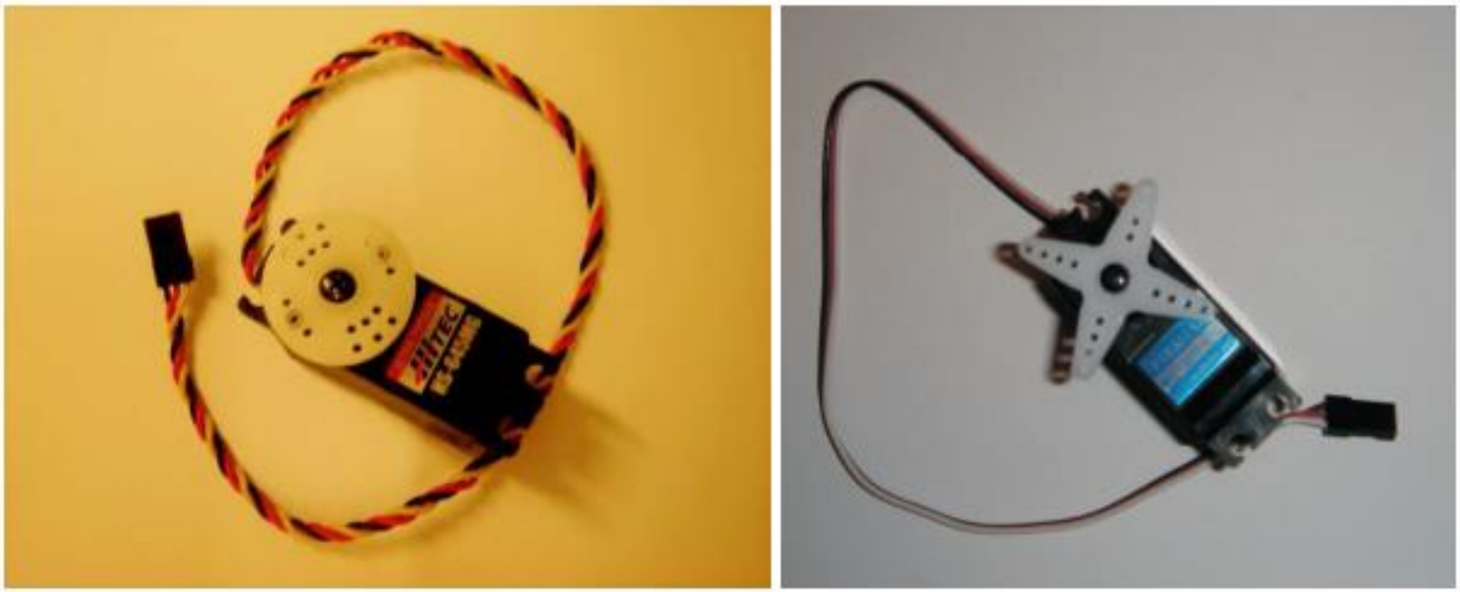
Servo motor



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Servo motor

- Uses pulse-width modulation (PWM) to determine set position.

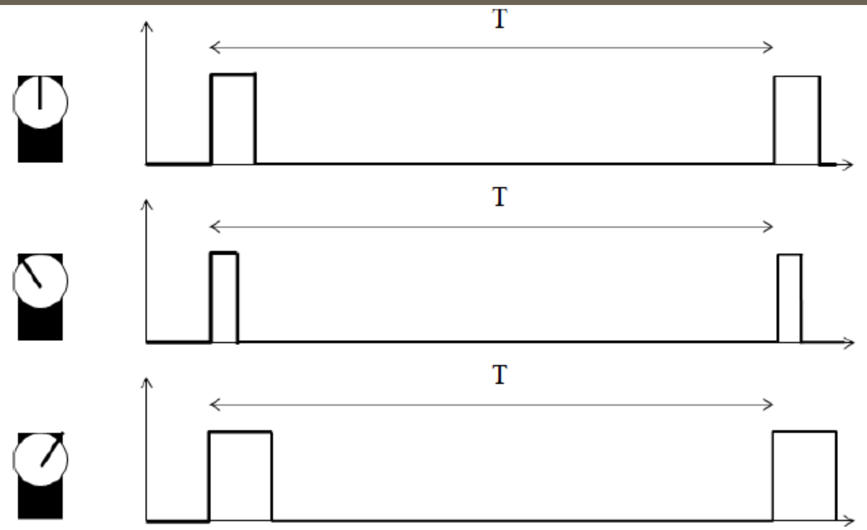

Figure 1.15: *Pulse width modulation control of a servo motor. The lengths of the pulses determine the requested position angle of the motor output shaft. The interval betwwn pulses (typically around 20 ms) is denoted T.*

Servo motor

- Modified servo motors (for wheeled robots): Here, the pulse width instead determines the desired rotation speed (which can also be negative) of the motor.

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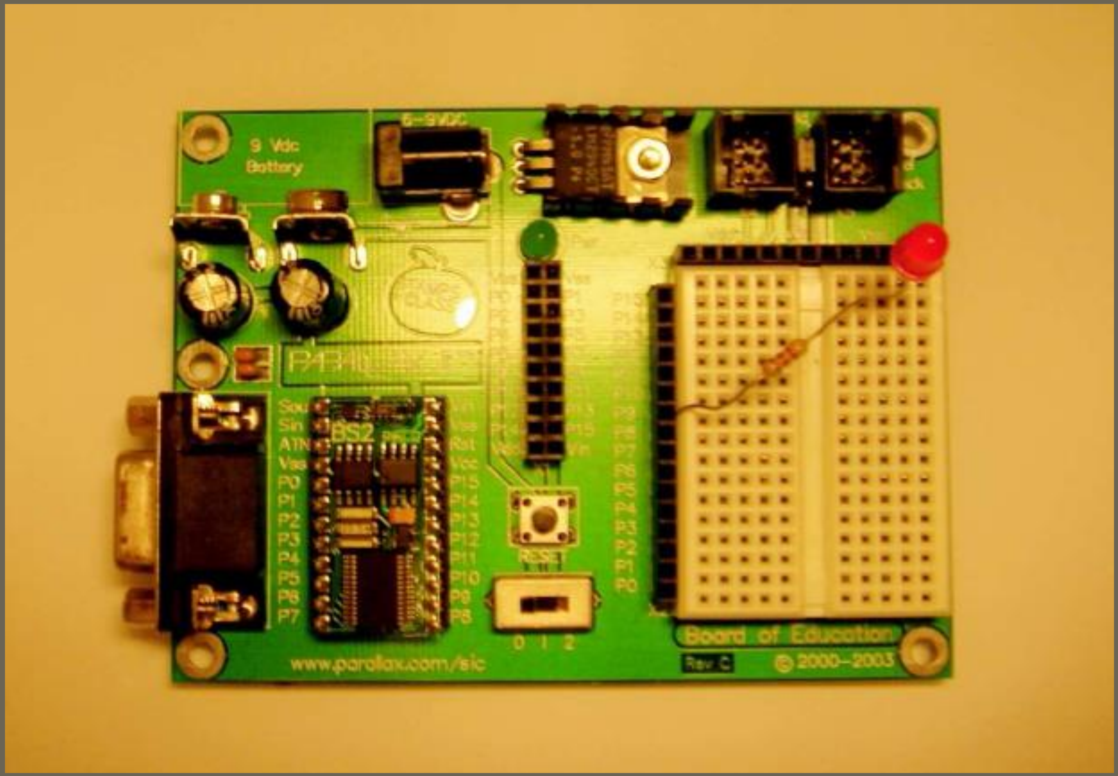
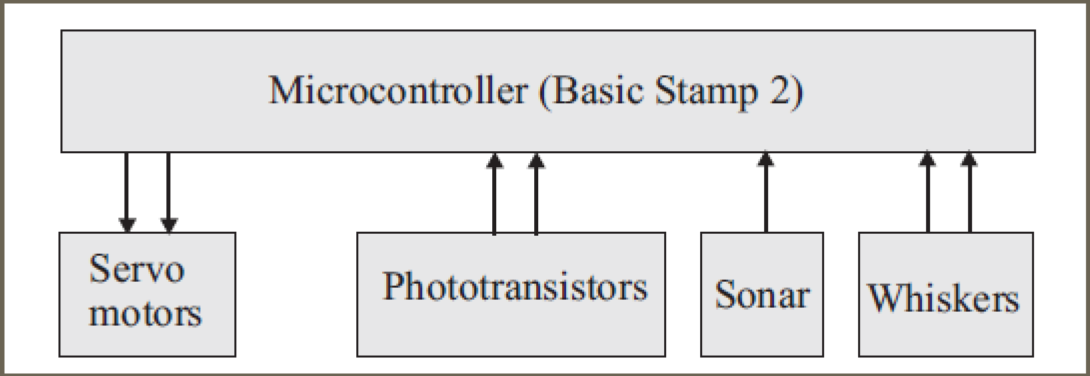
Microcontrollers

- A **microcontroller** is a small computer, attached to a **microcontroller board.**
- The microcontroller board offers various input and output channels for communication with other devices (sensors, actuators etc.)
- For quick testing, a solderless board can be used.

Microcontrollers

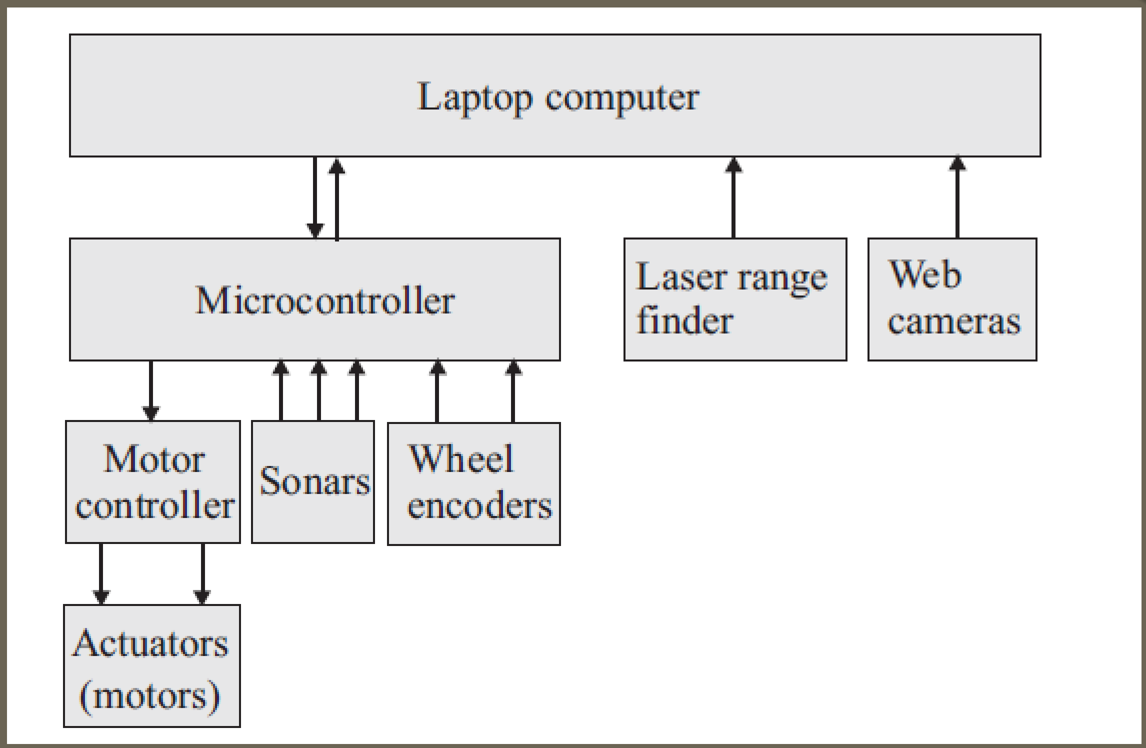


Robot architectures



Simple robot (e.g. Boe-bot)

Robot architectures



Advanced robot (generic example)