Module Image

Montpellier, 29 avril 2015

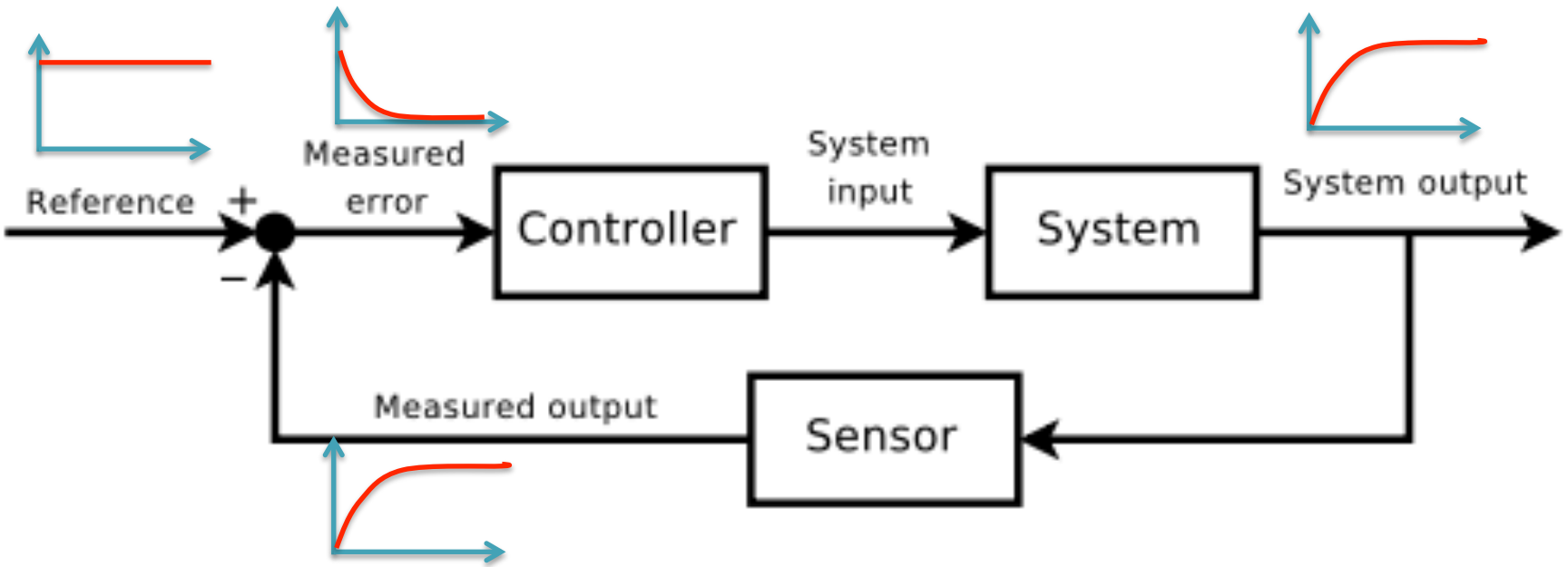
See and move: vision-based robot control

Andrea Cherubini

Robots are Autonomous!!

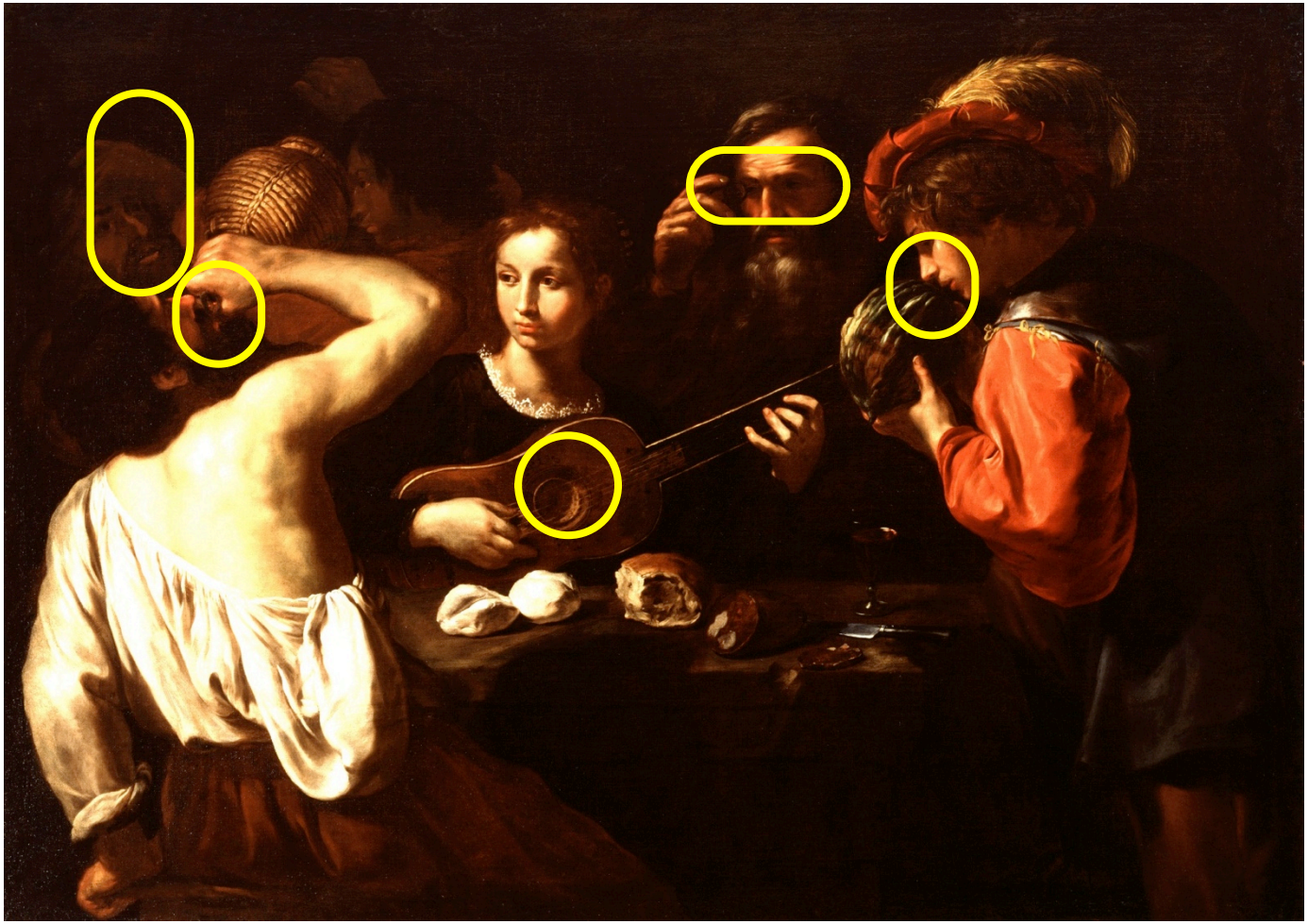
This is not a robot!!

Feedback control is “a must”



The five senses [Aristotle, ca. 300 BC]

[Encyclopedia Britannica, 2007]
In terms of complexity, the amount of brain area used:



1) vision
2) auditory
3) touch
4) smell
5) taste

Pietro Paolini - Allegory of the Five Senses, ca. 1630

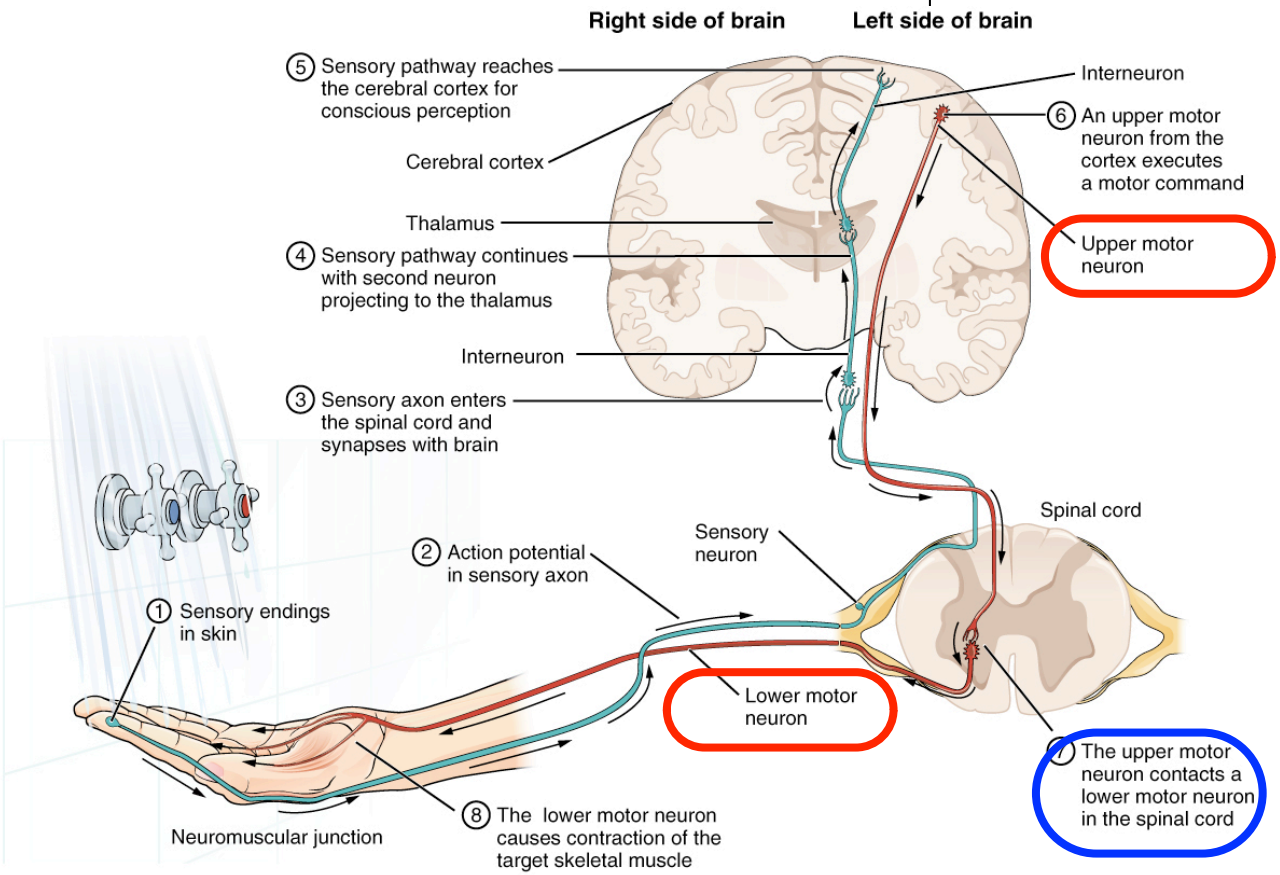
The ‘sense’ of vision for robots

Sensorimotor

Act

Cognitive

Understand



Control

Observation

The ‘sense’ of vision for robots

Sensorimotor

Act

Control

Cognitive

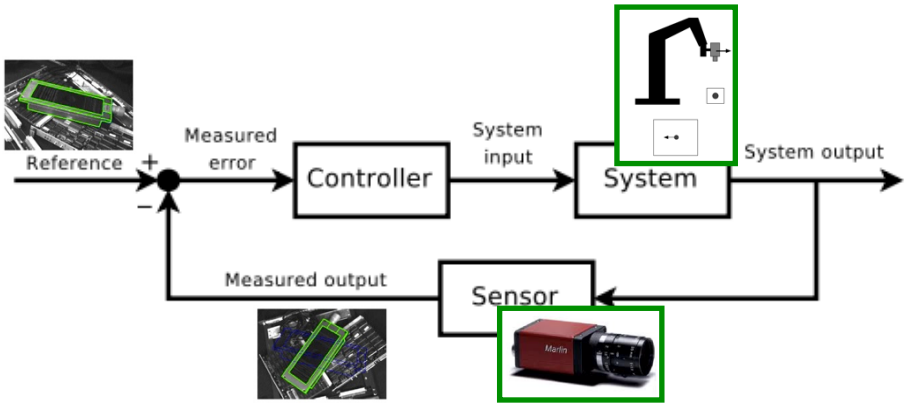
Understand

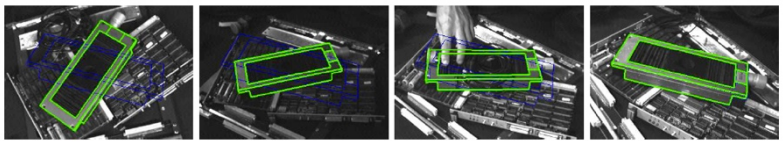
Observation

The ‘sense’ of vision for robots

Sensorimotor

Act





control theory, visual tracking

Control

Cognitive

Understand

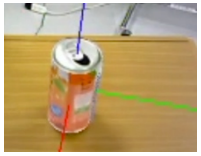
learning, probabilities, classifiers

Observation

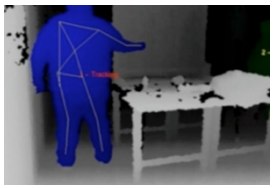
Robotics features plenty of visual…

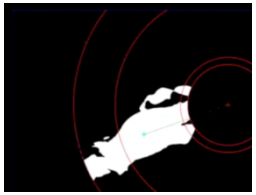
PROBLEMS

- object recognition

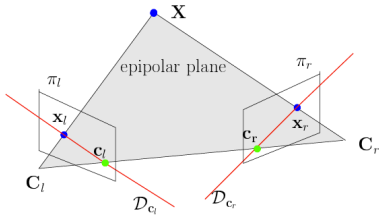


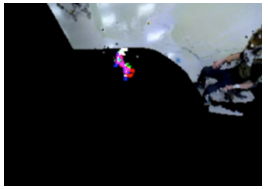
- human tracking





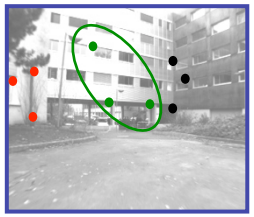
- structure from motion

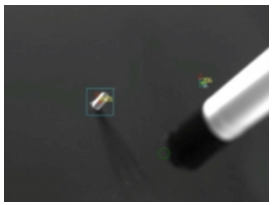




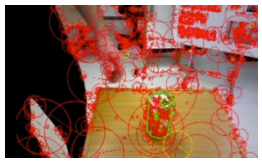
TECHNIQUES

- appearance-based
natural features are used





- model-based requires a 3D model (e.g. CAD)



Outline

- Robots
- Sensors
- Image processing
- Computer vision
- Robot control
- Example applications

- **Robots**
- Sensors
- Image processing
- Computer vision
- Robot control
- Example applications

Robot applications

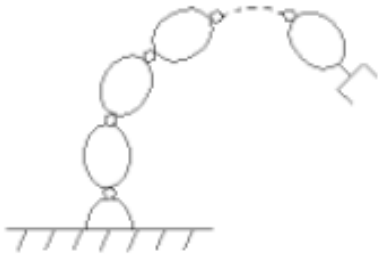
- industrial
- underwater
- aerial
- spatial
- urban mobility
- search & rescue
- medical
- assistive

  etc…

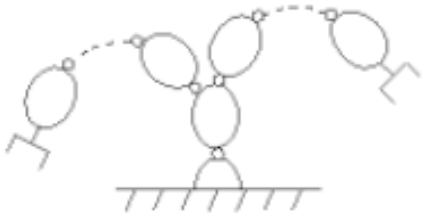
Robot designs

- serial manipulators
- parallel manipulators
- humanoids
- legged
- wheeled

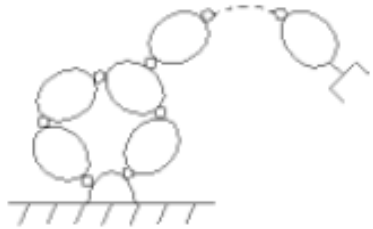
Mechanisms



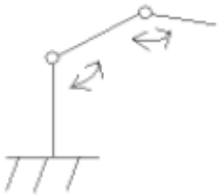
Open chain



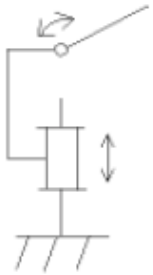
Tree chain



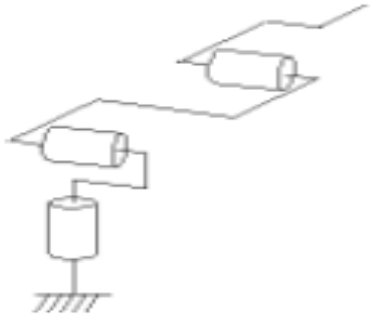
Closed chain



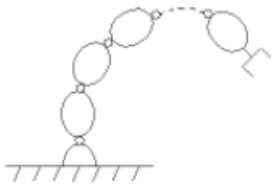
2 DOF (RR)



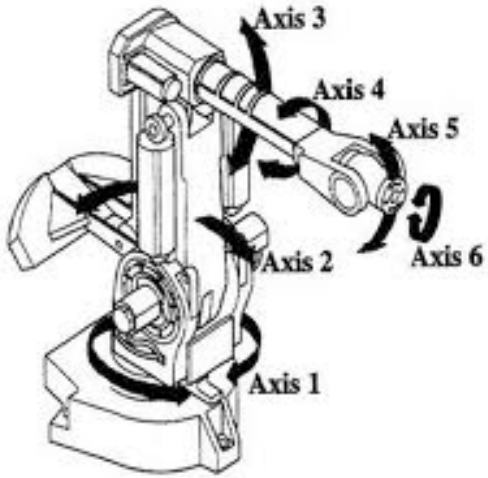
2 DOF (TR)

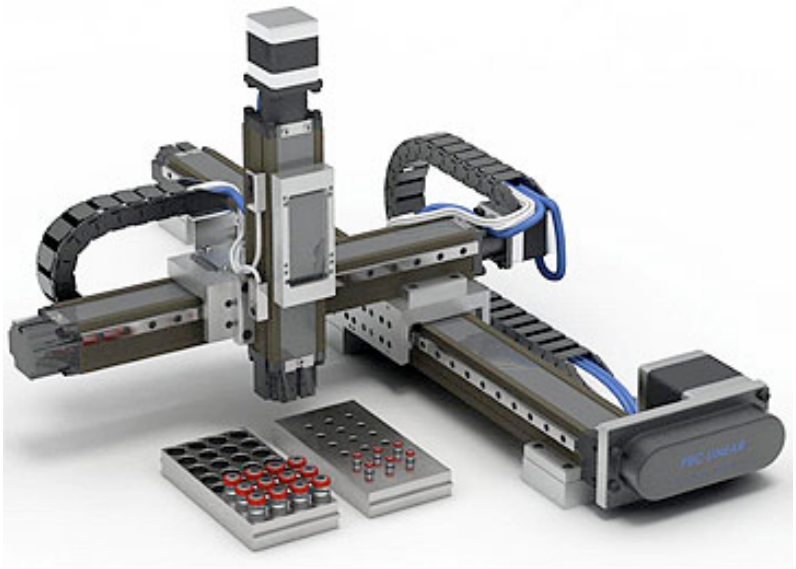


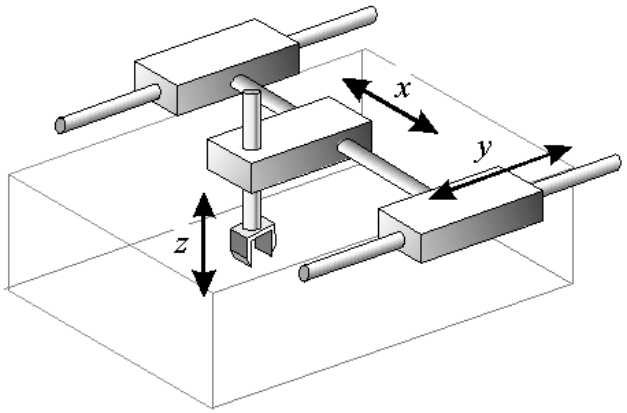
3 DOF (RRR)



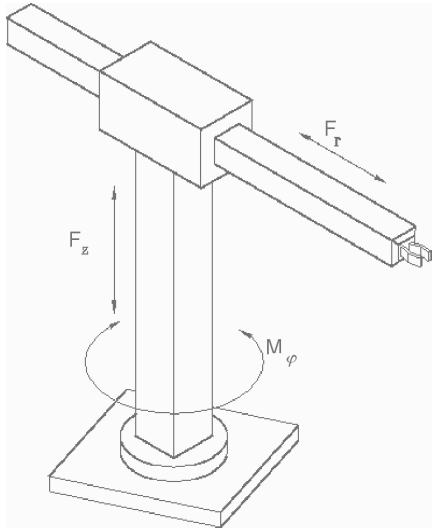
Serial manipulators

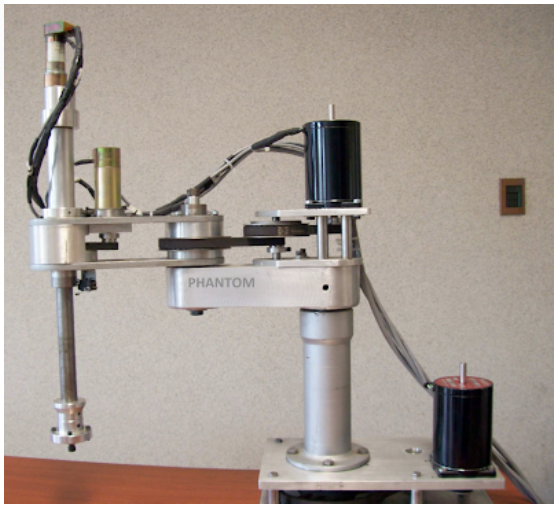


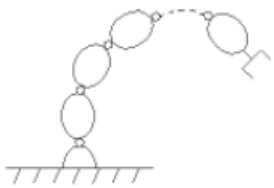




Serial manipulators





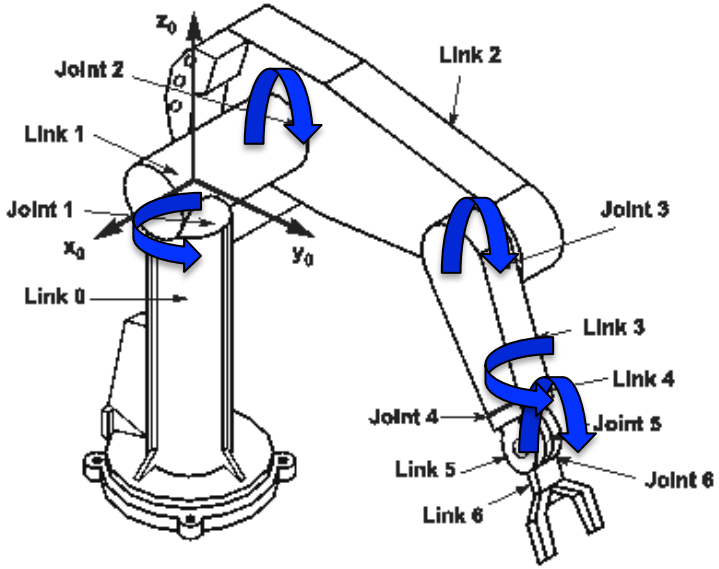


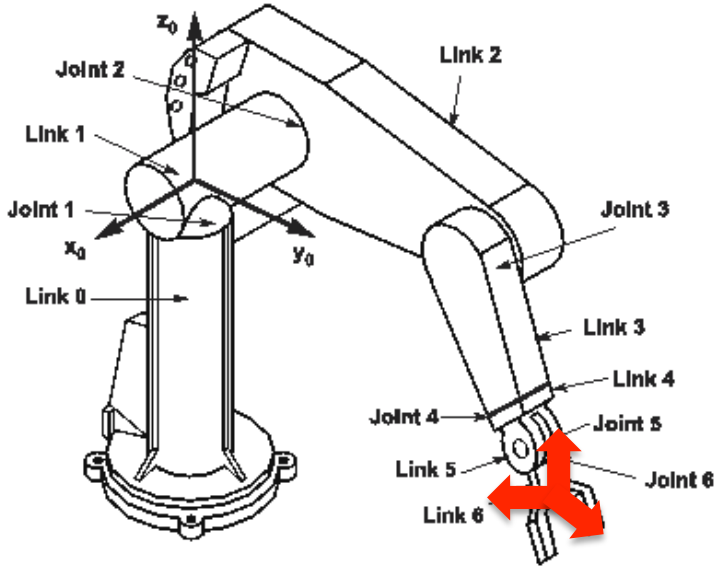
Serial manipulators

Direct kinematics vs Inverse kinematics

task defined in the joint space

task defined in the cartesian space

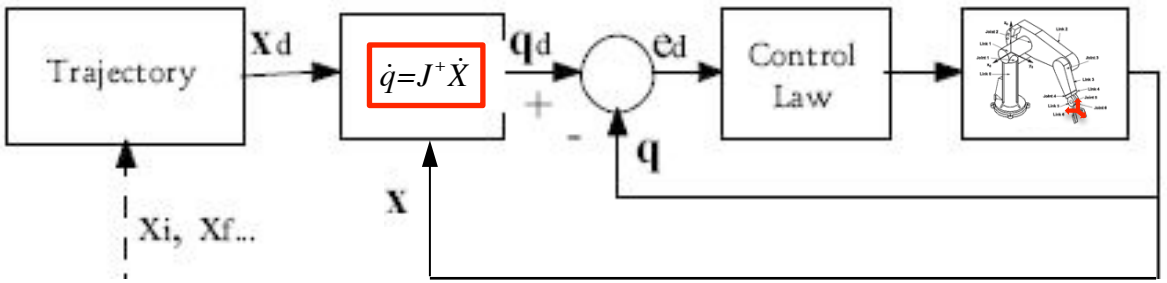




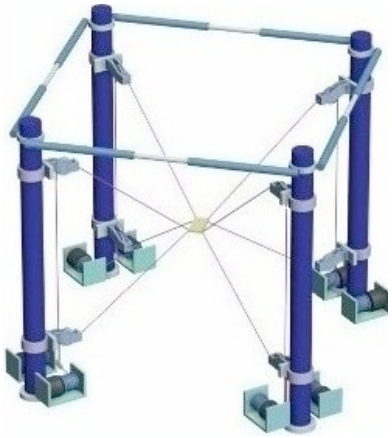
$$x_i = f_i(q_1, q_2, \ldots, q_n)$$

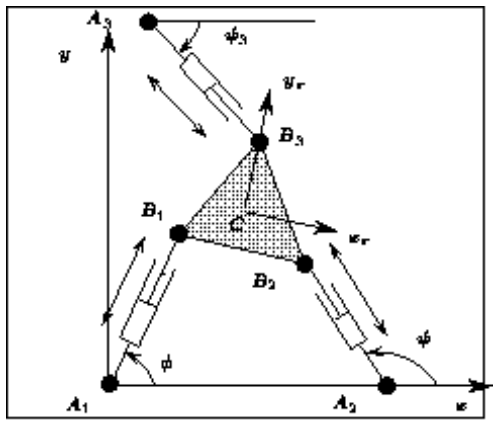
$$\begin{pmatrix} \dot{x}_1 \\ \vdots \\ \dot{x}_n \end{pmatrix} = \begin{pmatrix} \frac{\partial f_1}{\partial q_1} & \cdots & \frac{\partial f_1}{\partial q_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_n}{\partial q_1} & \cdots & \frac{\partial f_n}{\partial q_n} \end{pmatrix} \begin{pmatrix} \dot{q}_1 \\ \vdots \\ \dot{q}_n \end{pmatrix}$$

$$\underline{\dot{X}} = J\,\underline{\dot{q}}$$

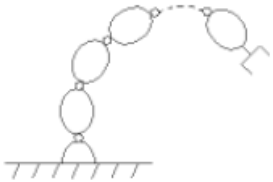


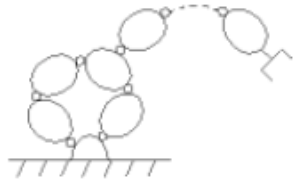
Parallel manipulators

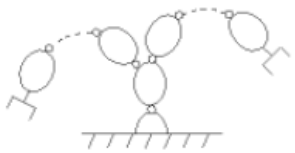




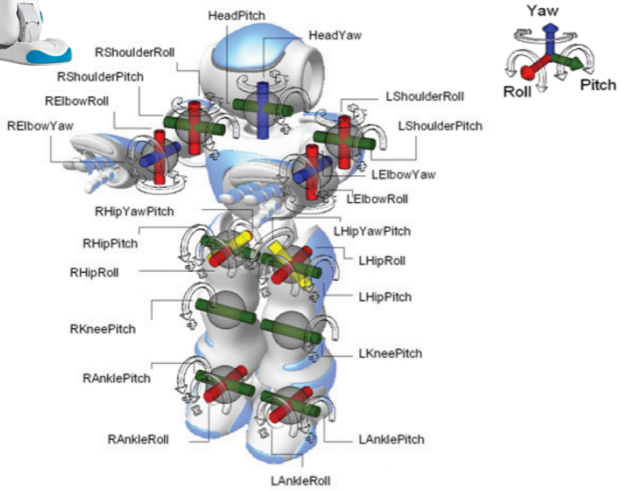
Visual control of manipulators

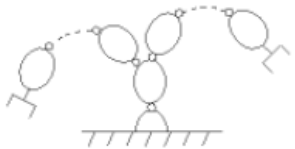






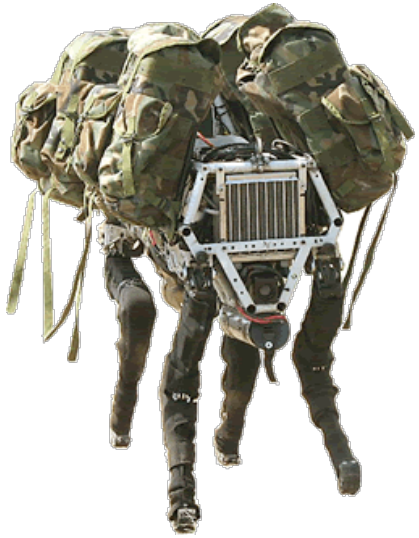
Humanoid robots

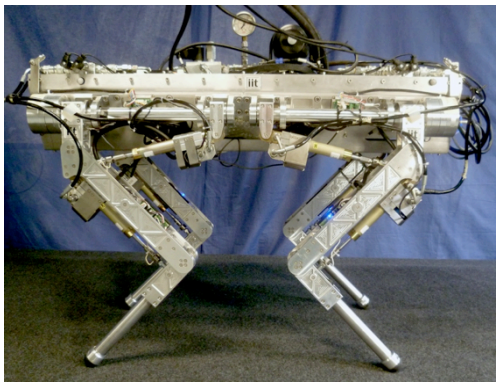


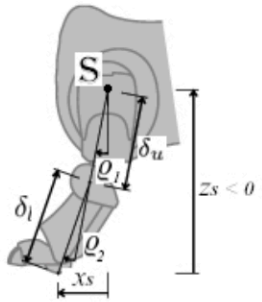


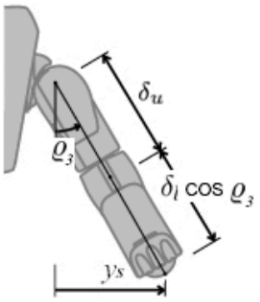
Humanoid visual control

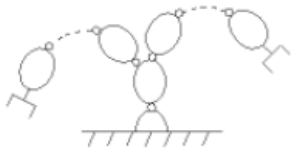
Legged robots





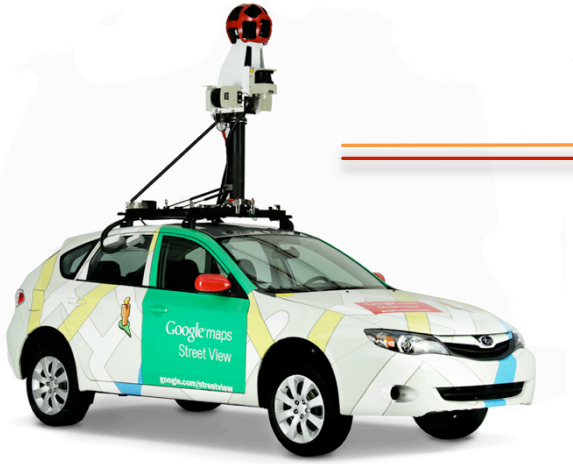


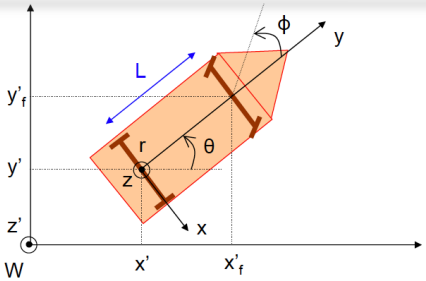


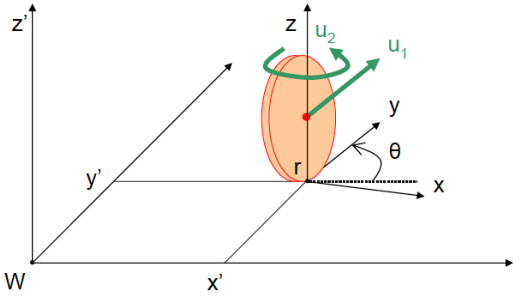


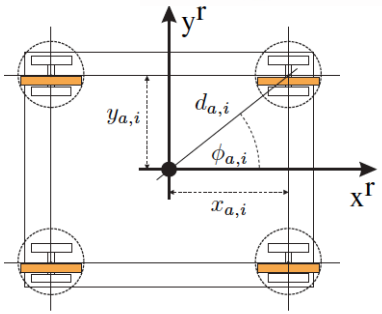
Legged robot visual control

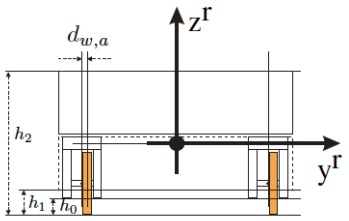
Wheeled robots

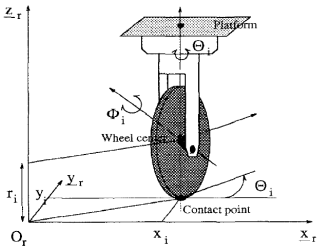


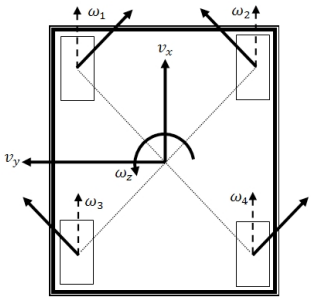












Visual navigation

- Robots
- **Sensors**
- Image processing
- Computer vision
- Robot control
- Example applications

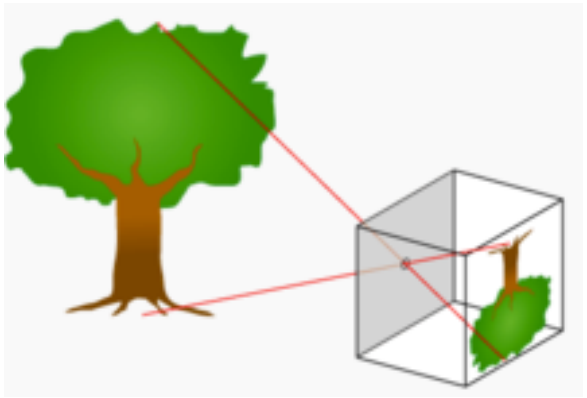
Sensors

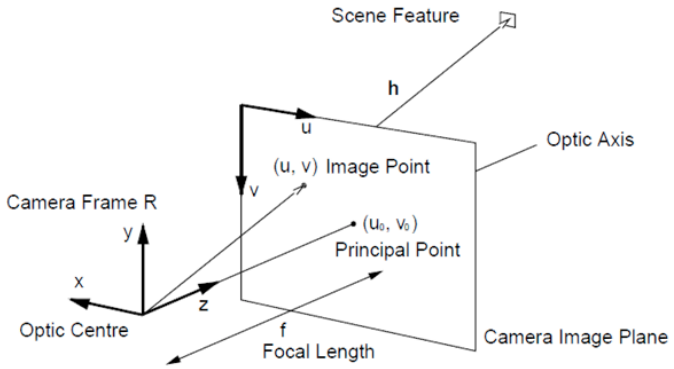
CAMERAS
- monocular
- wide field of view
- stereo pair
- RGB-D (image+depth)

OTHER
- rangefinders
- tactile

Monocular camera

Pinhole model



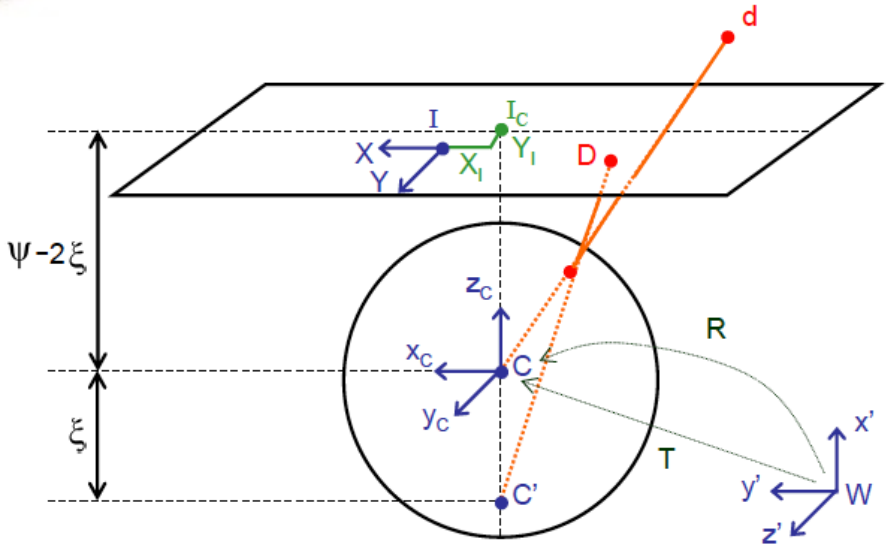


$$\begin{bmatrix} u \\ v \end{bmatrix} = \frac{1}{Z} \begin{bmatrix} f & 0 & u_0 \\ 0 & f & v_0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix}$$

Wide field of view cameras

Fisheye

Central catadioptric



Stereo pair

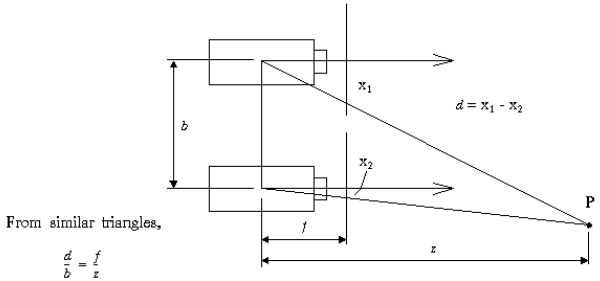
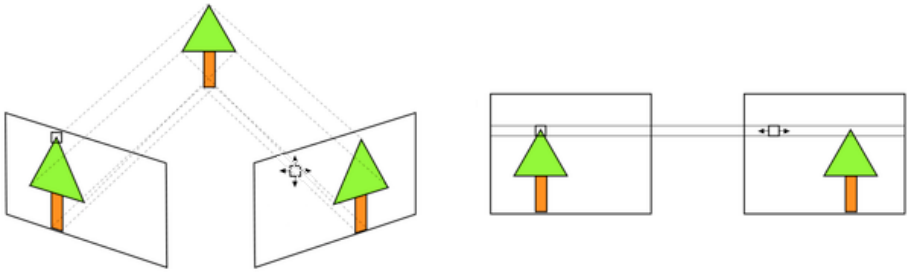
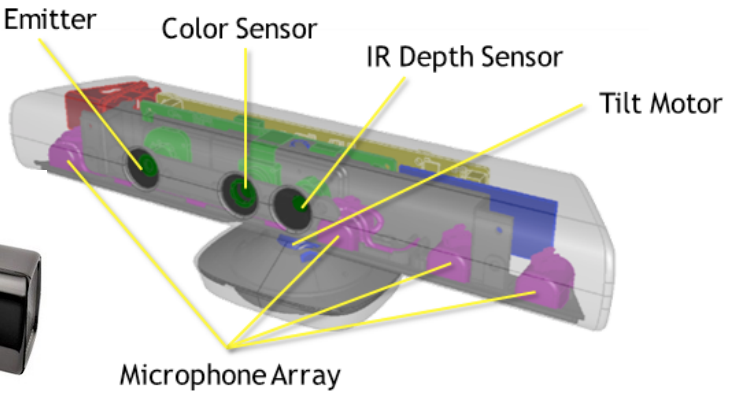
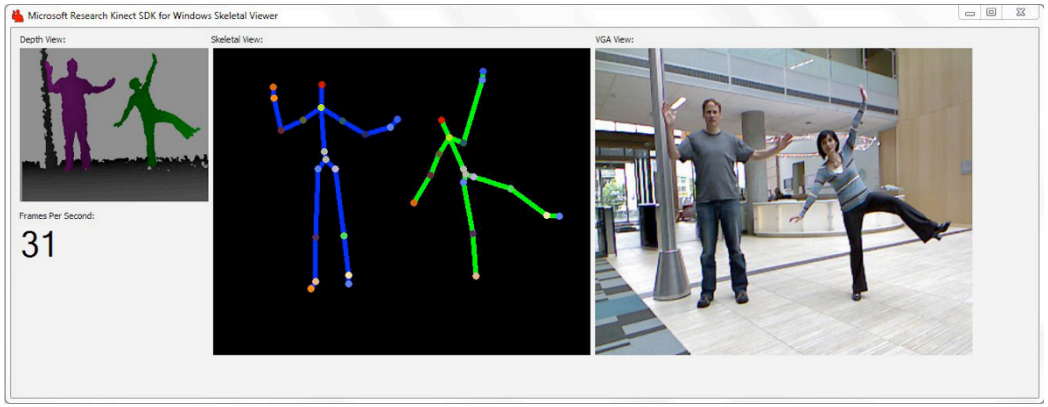


Figure 9. Relationship between the baseline b, disparity d, focal length f, and depth z



RGB-D cameras



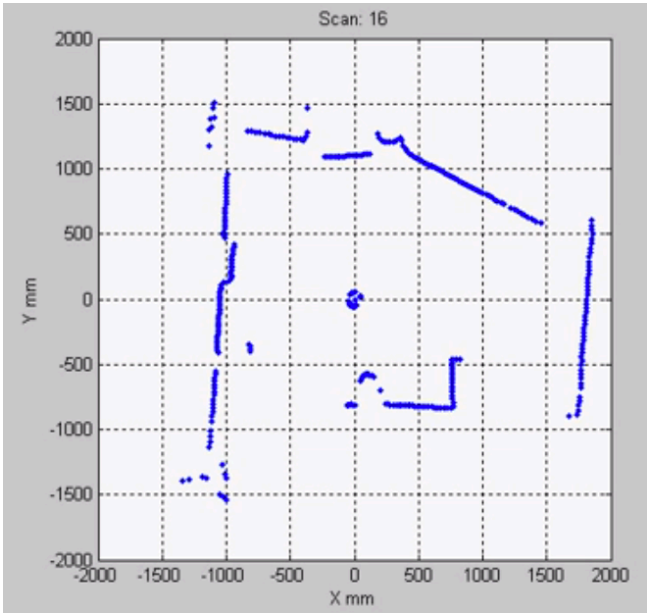


Rangefinders

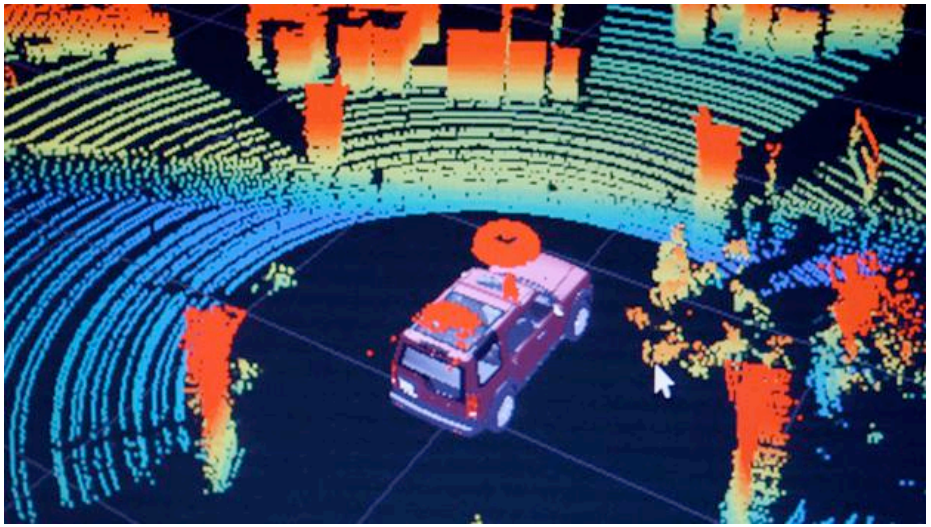
radar

sonar

lidar



2D maps



3D maps (point clouds)

Rangefinders

Tactile sensors