TECHNISCHE UNIVERSITÄT CHEMNITZ

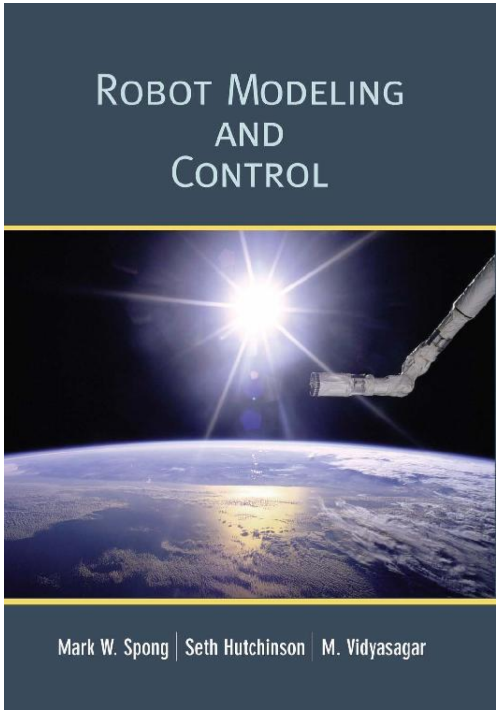
Artificial Intelligence & Neuro Cognitive Systems
Fakultät für Informatik

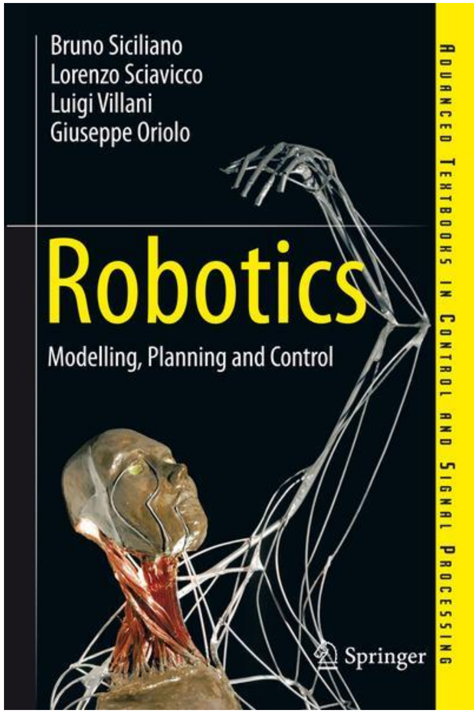
Introduction to Robotics

Dr.-Ing. John Nassour

10.10.2017

Suggested literature





General Information

- **Prerequisites**: Basic knowledge of Mathematics.

The Goal of the course

- This course gives an introduction to robotics, with a particular interest in biologically inspired robots; like humanoid robots.

- It presents different methods for programming robots to perform tasks that involve sensory motor interactions.

- The participants of the course will apply their knowledge in the Praktikum Robotik and program robots for different tasks.

Evaluation

- 25-minutes oral exam

Interaction

- Homework
- Oral presentation of a related scientific paper or topic (10 minutes)

Communication via email

Use **[Robotik]** in the subject filed of your emails.

Ex:

[Robotik] bla bla bla…

Please send me an email to add your contact on the list for the lecture slides and also for communication regarding the Robotik and the Praktikum.

Robotics

- **Robotics** is concerned with the study of those machines that can replace/assist human/animal beings in the execution of tasks, as regards both physical activity and decision making.

- In all robot applications, completion of a task requires the **execution of a specific motion** prescribed to the robot. The correct execution of such motion is entrusted to the **control system** which should provide the robot's **actuators** with the commands consistent with the **desired motion**.

- Motion control demands an accurate **analysis of the characteristics of the mechanical structure**, **actuators**, and **sensors**.

- **Modelling** a robot is therefore a necessary premise to develop motion control strategies.

Find the Challenge!

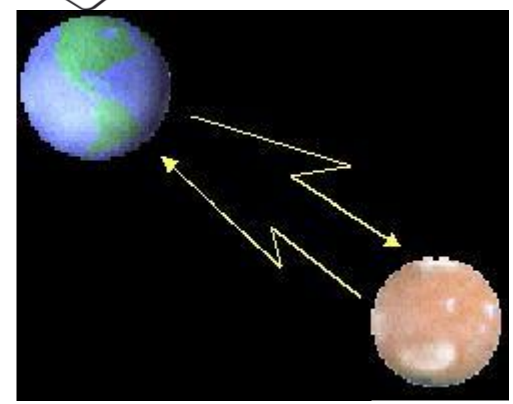
Find the Challenge!

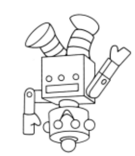
Find the Challenge!

Find the Challenge!

The **communication delay** that occurs in a one-way transmission:

Circuit	**Distance**	**Delay Time**
HF link (UK-NZ)	~20,000 km	0.07 s (67 ms)
Submarine cable(UK-NZ)	~20,000 km	0.07 s (67 ms)
Geosat Link (US-Aus)	~80,000 km	0.25 s
Earth-Moon	384,000 km	1.3 s
Earth-Mars	55 - 378 million km	3 - 21 minutes
Earth-Jupiter	590 - 970 million km	33 - 53 minutes
Earth-Pluto	~5800 million km	5 hours
Earth-Nearest Star	~9.5 million million km	4 years

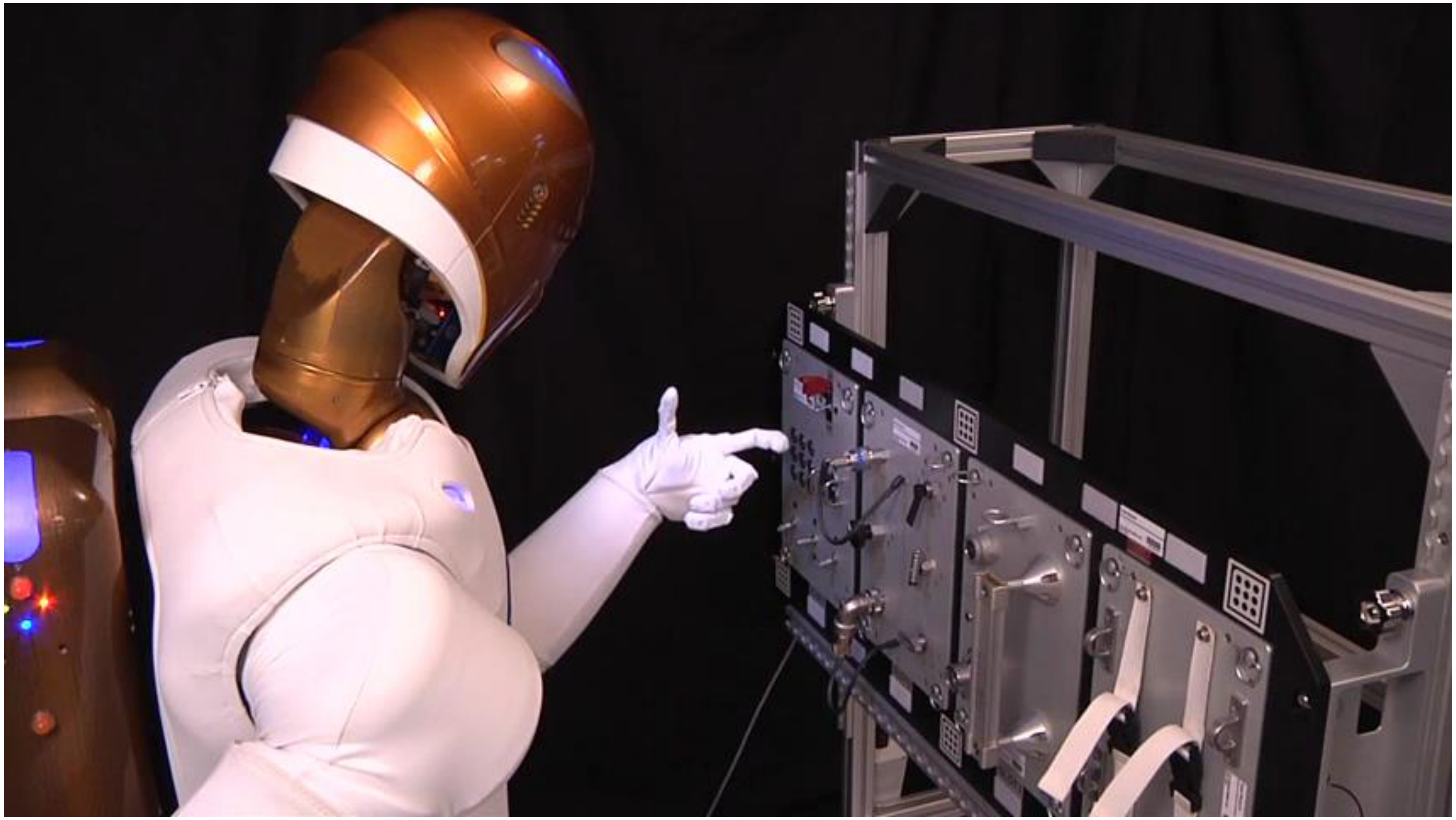




Find the Challenge!

- No model for the environment
- Interaction with the environment
- All terrain (friction, slopes, rough)
- Obstacle avoidance
- Path planning
- Autonomy

Find the Challenge!



Find the Challenge!

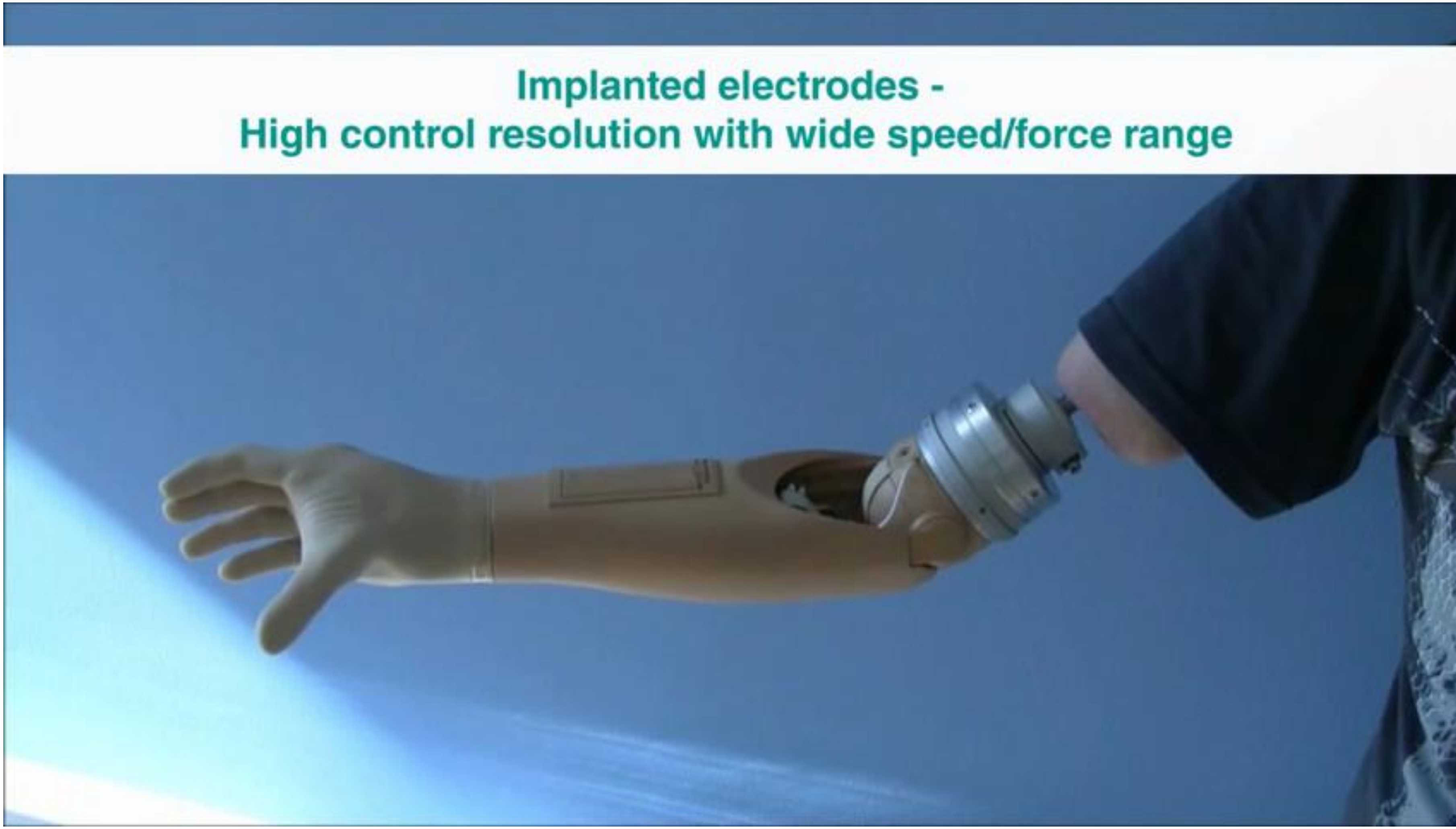
- Motor skills and capabilities
- Performance
- Speed

Find the Challenge!

Find the Challenge!

- Interact with human
- Safe interaction
- Reasoning
- Taking decision

Bionic Limbs: Find the Challenge!



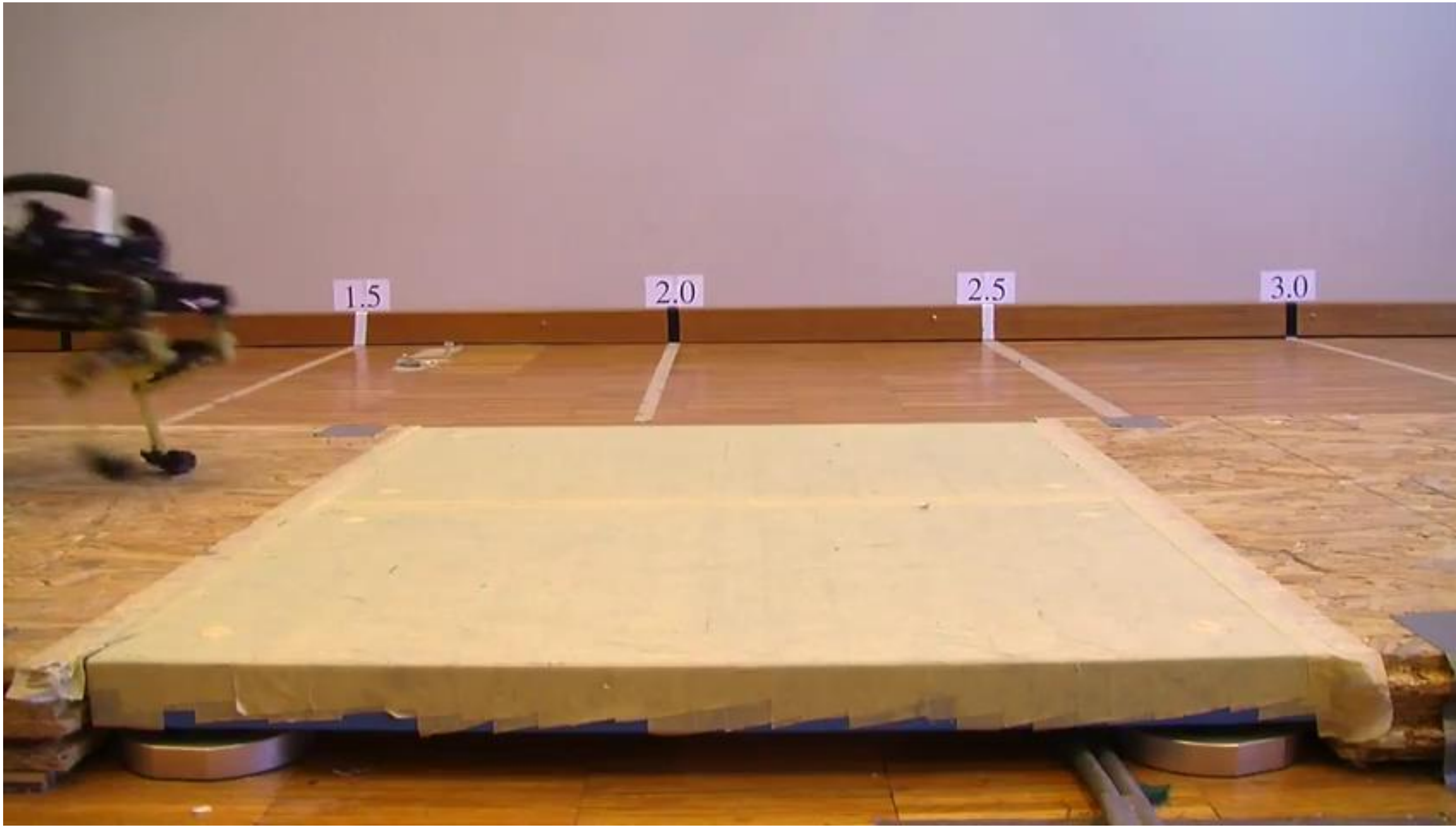
Find the Challenge!

- Interact with the environment
- Increase motor capabilities
- Make it lighter
- Transfer the sense into human
- Reduce the electromagnetic interference

Bionic Limbs

Bionic Limbs

Cheetah-cub Robot -EPFL



Motivation

Why Robots?

A group of 139 Japanese heroes from Tokyo went to help the first group of 50 people to Fukushima, into what seems obvious to be a suicide mission.

Not only humanoids can help

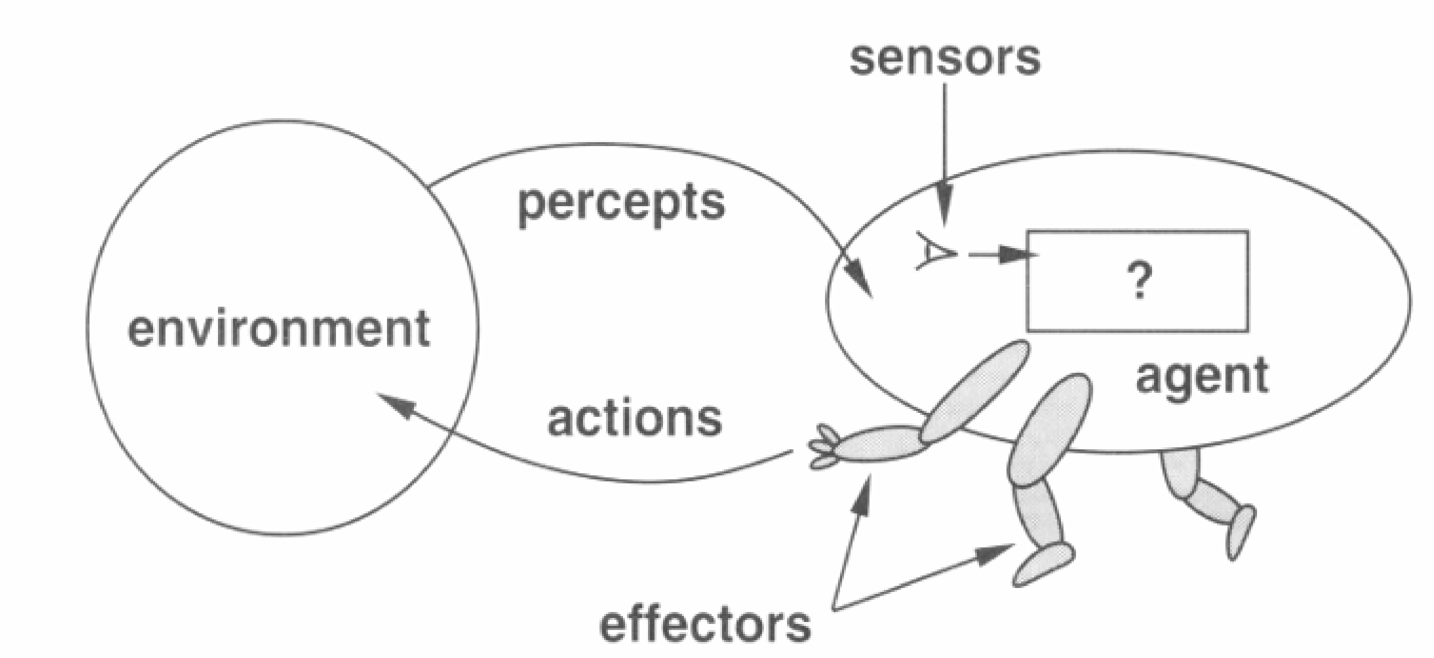
Two humanoids deal with toxic spills

Robots May Help Children with Autism

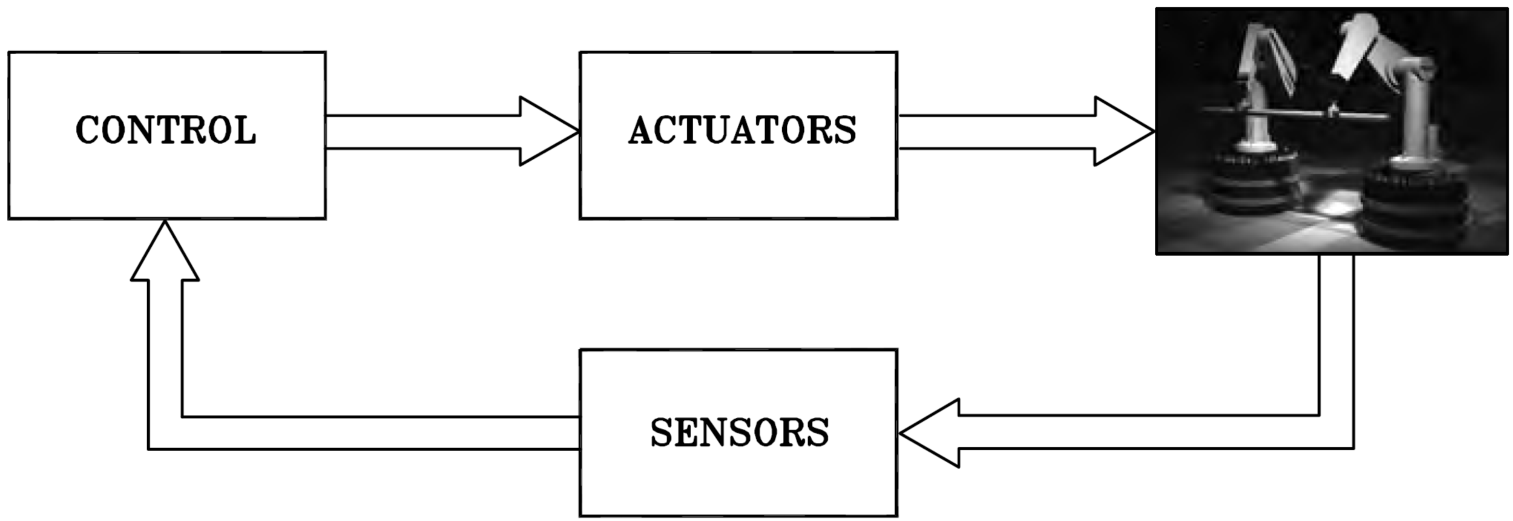
Motivation

Why Robots?

What is a Robot?



What is a Robot?



Components of a robotic system

Robot vs. Animals

Robot vs. Animals

Mechanical structure	Skeleton
Motor	Muscle
Sensor	Sense
Source of power	Food/Air
Computer	Brain
Program	Cognition

What is a Robot?

A **robot** is a **reprogrammable**, **multifunctional** manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

Definition by Robotic Industries Association

Classification

According to:

Classification

According to:

- **Application**

Classification

According to:

- **Application (industrial, medical, military, domestic robots,…)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- **Mobility**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- **Mobility (legged, wheeled, swimming, flying, non-mobile robots)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- **Interaction**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- **Interaction (interactive, non-interactive robots)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- **Autonomously**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- **Autonomously (fully-controlled, half-autonomous, autonomous robots)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- **Learning ability**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- **Learning ability (robots that learn, robots that does not)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- **Real vs. virtual robots**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- **Working environment**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- **Working environment (indoor, outdoor robots)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- Working environment (indoor, outdoor robots)
- **Sensation**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- Working environment (indoor, outdoor robots)
- **Sensation (robot that sense, robots that does not)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- Working environment (indoor, outdoor robots)
- Sensation (robot that sense, robots that does not)
- **Social interaction**

Classification

According to:

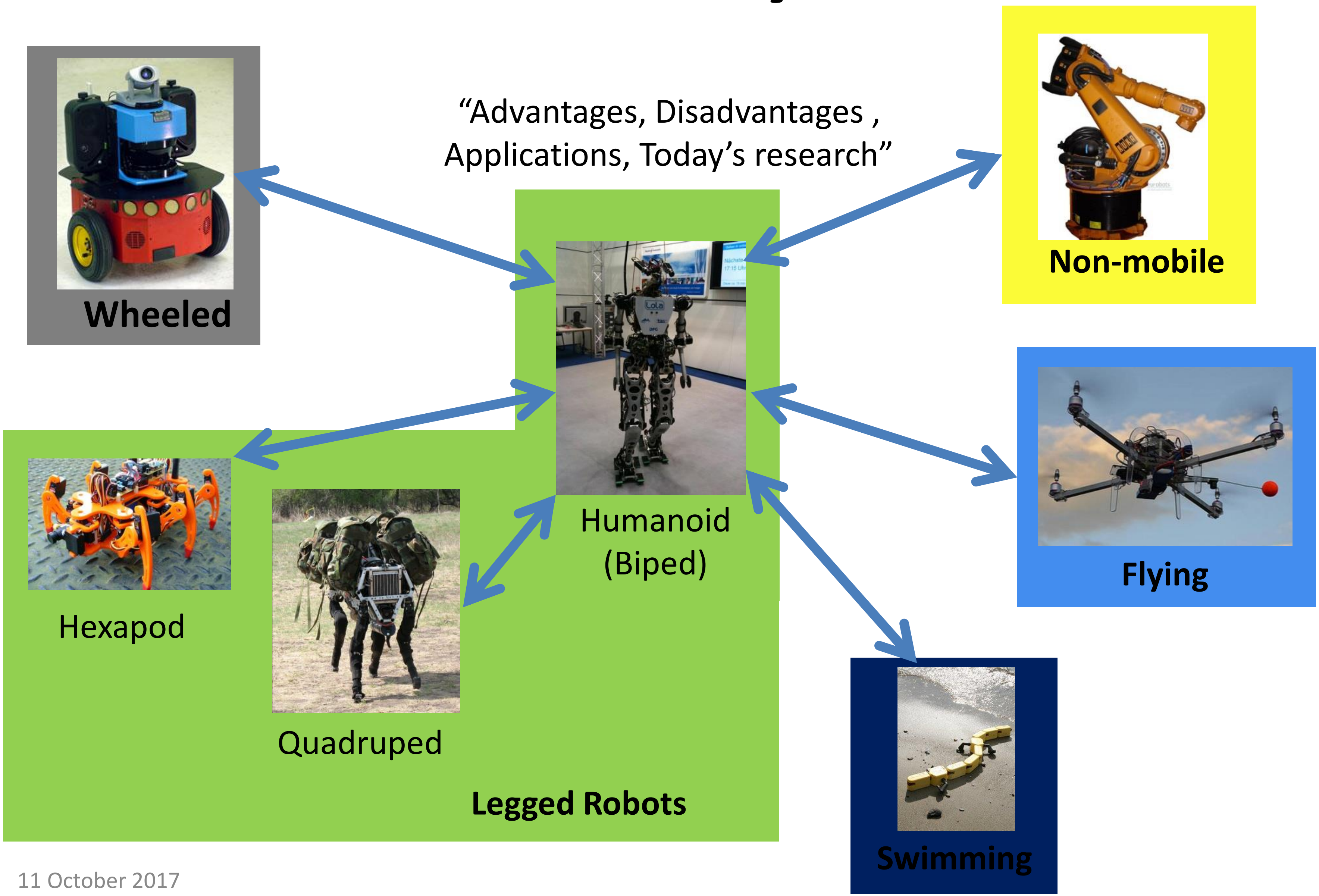
- Application (industrial, medical, military, domestic robots,…)
- Mobility (legged, wheeled, swimming, flying, non-mobile robots)
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- Working environment (indoor, outdoor robots)
- Sensation (robot that sense, robots that does not)
- **Social interaction (social, non-social robots)**

Classification

According to:

- Application (industrial, medical, military, domestic robots,…)
- **Mobility (legged, wheeled, swimming, flying, non-mobile robots)**
- Interaction (interactive, non-interactive robots)
- Autonomously (fully-controlled, half-autonomous, autonomous robots)
- Learning ability (robots that learn, robots that does not)
- Real vs. virtual robots
- Working environment (indoor, outdoor robots)
- Sensation (robot that sense, robots that does not)
- Social interaction (social, non-social robots)

Mobility



"Advantages, Disadvantages , Applications, Today's research"
Wheeled
Non-mobile
Humanoid (Biped)
Flying
Hexapod
Quadruped
Legged Robots
Swimming

Hexapod

Hexapod robots have a large number of real life applications, from crossing potentially dangerous terrain to carrying out search and rescue operations in hazardous and unpredictable disaster zones (Karalarli, 2003).


Hexapod

Advantages over wheeled, quadruped or bipedal robots: While **wheeled robots are faster on level ground than legged robots**, **hexapods are the fastest of the legged robots, as they have the optimum number of legs for walking speed** - studies have shown that a larger number of legs does not increase walking speed (Alexadre et al, 1991).

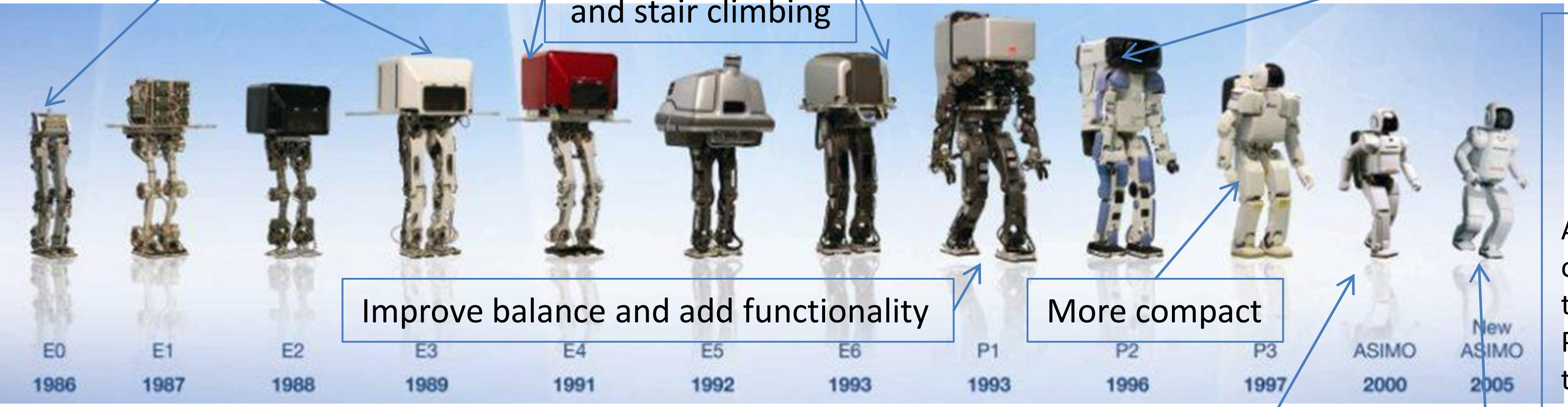
Humanoid Robots

Designed by **HONDA**

Simulate the walk of a human

Walk stabilization and stair climbing

More friendly design, improved walking, stair climbing -descending, and wireless automatic movements



Improve balance and add functionality

More compact

Run, walk on uneven slopes and surfaces, turn smoothly, climb stairs, and reach for and grasp objects. Voice and face recognition

?

Assisting the elderly or persons confined to wheelchair. Performing certain tasks that are dangerous to humans.

Humanoid Robots

Designed by **KAWADA Industries**

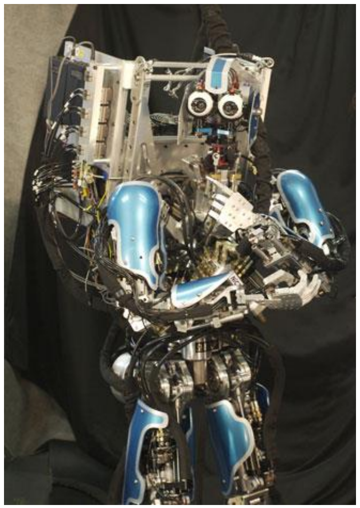
HRP

1997 2002 2007 2010 2009

HRP-4 **HRP-4C**

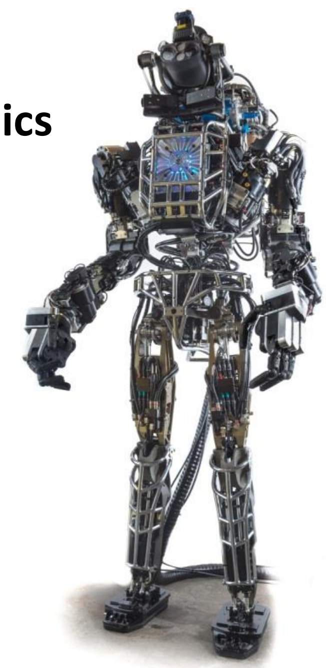
Humanoid Robots

Hydraulic actuation

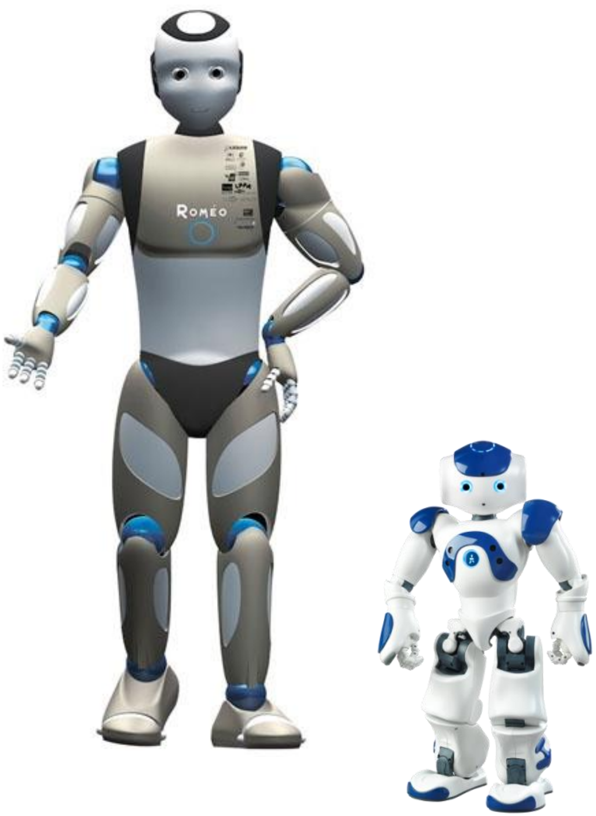


Robot name: **SARCOS**
Designed by **Advanced Telecommunications Research Institute International**
Hydraulic unit not embedded
Year: **2007**

Robot name: **ATLAS**
Developed by **Boston Dynamics**
Tall 1.88 m
Wight 150 kg
Extremely capable
Military purposes
Hydraulic unit not embedded
Unveiled on **June 2013**



Humanoid Robots



Robot name: **NAO / Romeo**
Developed by **Aldebaran Robotics**
Year: **2007/2014**
Domestic assistance purposes
Electrically actuated

Multidisciplinary Approach

Lets Build a Robot …

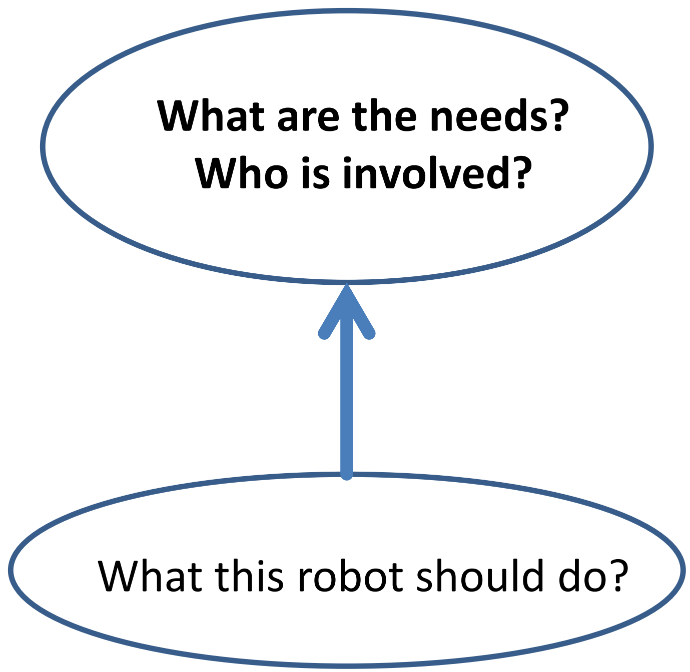
Multidisciplinary Approach

Lets Build a Robot …

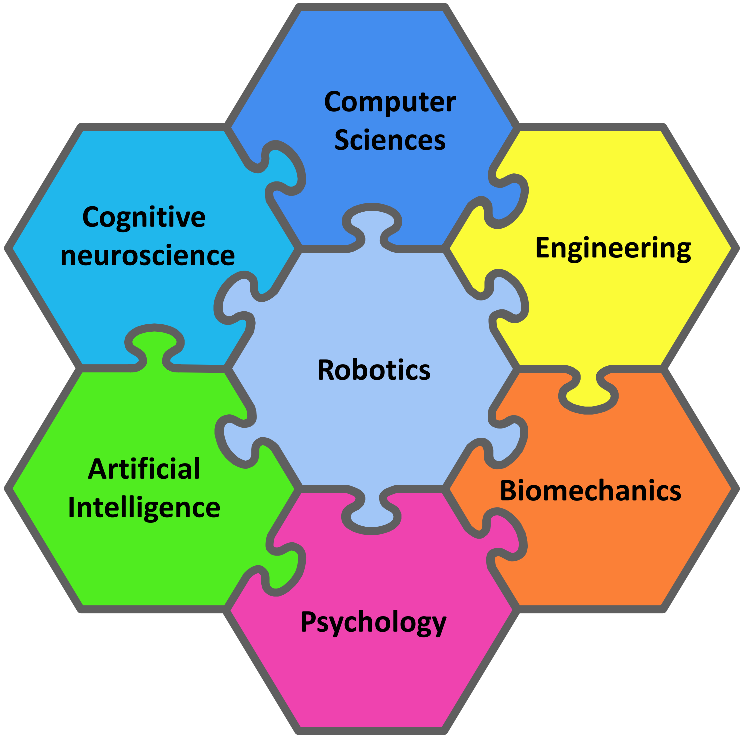
What this robot should do?

Multidisciplinary Approach

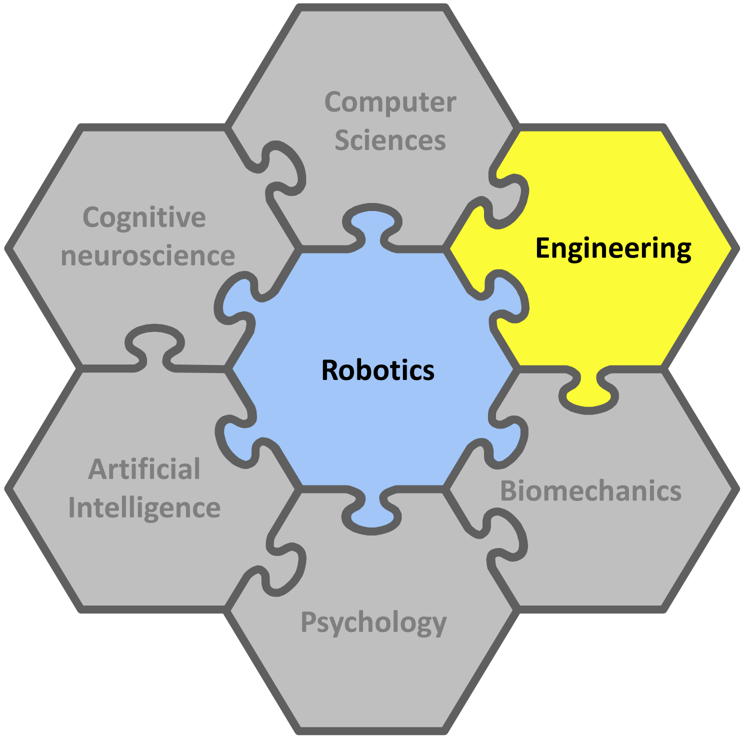
Lets Build a Robot …



Multidisciplinary Approach



Engineering



Engineering

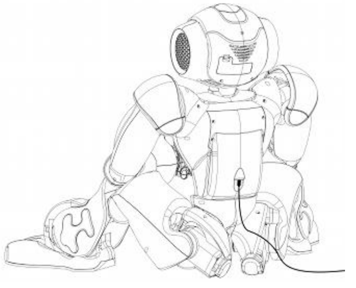
What robots need from Engineering?

Engineering

What robots need from Engineering?

- Source of power

Battery Li-ion
21.6 V/ 2.15 Ah
Puissance 27.6 W
Autonomy: 1h to 1h30
Duration of charging: 5h



Engineering

What robots need from Engineering?

- Source of power
- Electronics (Motor control & CPU & Bus communication)

Motherboard (Head):

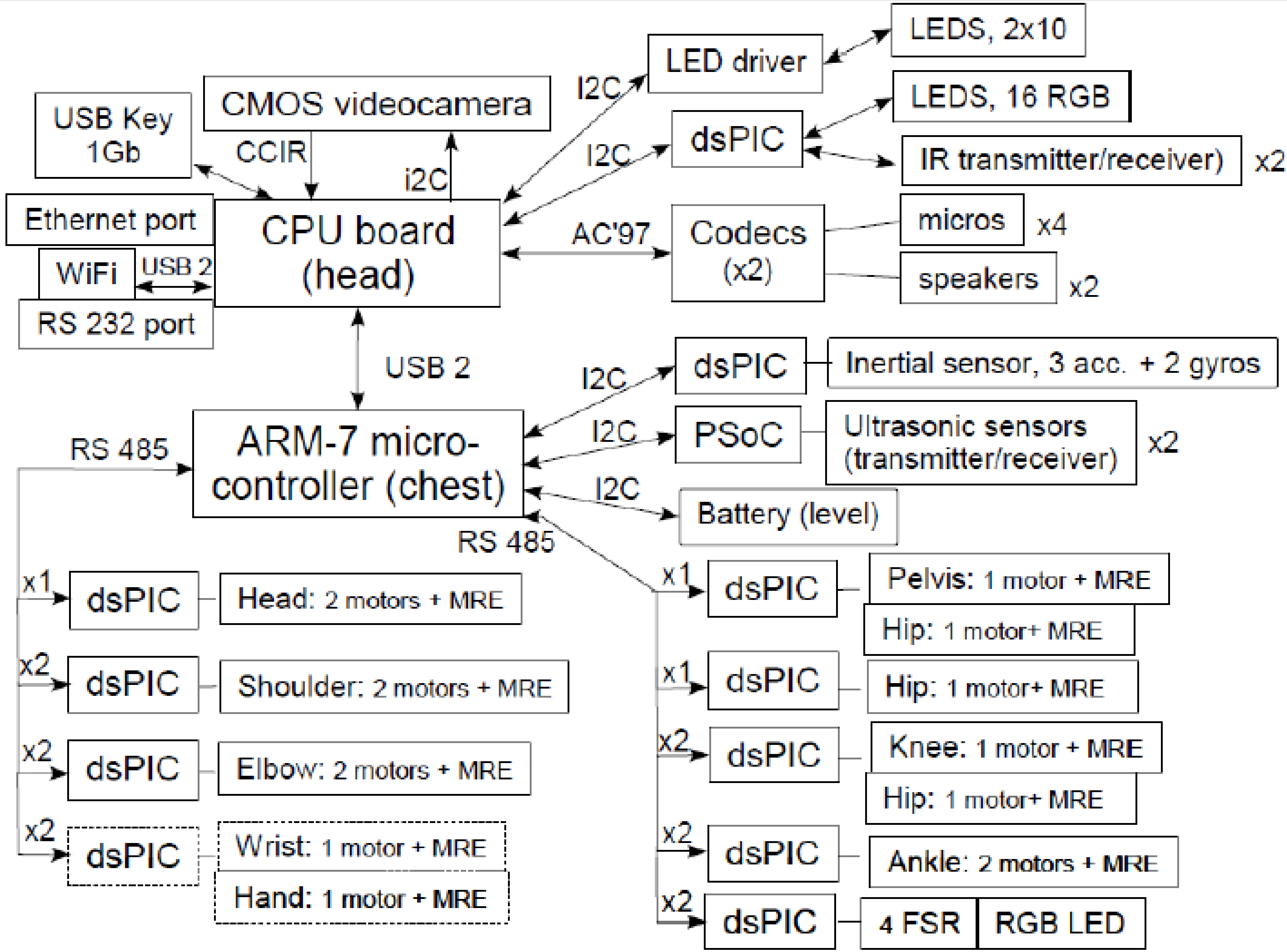
- **ATOM Z530 1.6GHz CPU**
- **1 GB RAM**
- **2 GB flash memory**
- **4 to 8 GB flash memory (user)**
- **Noyau linux, distrib. Gentoo**
- **Middleware naoqi**

Second CPU in the torso

- **Management motors/encoders**

Serial bus motors / sensors

Motor control cards (PID)


LEDS, 2x10
LED driver
I2C
LEDS, 16 RGB
CMOS videocamera
USB Key
1Gb
CCIR
I2C
dsPIC
IR transmitter/receiver)
x2
i2C
Ethernet port
CPU board
(head)
AC'97
Codecs
(x2)
micros
x4
WiFi
USB 2
speakers
x2
RS 232 port
USB 2
I2C
dsPIC
Inertial sensor, 3 acc. + 2 gyros
I2C
PSoC
Ultrasonic sensors
(transmitter/receiver)
x2
RS 485
ARM-7 micro-
controller (chest)
I2C
Battery (level)
RS 485
x1
dsPIC
Pelvis: 1 motor + MRE
x1
dsPIC
Head: 2 motors + MRE
Hip: 1 motor+ MRE
x1
dsPIC
Hip: 1 motor+ MRE
x2
dsPIC
Shoulder: 2 motors + MRE
x2
dsPIC
Knee: 1 motor + MRE
x2
dsPIC
Elbow: 2 motors + MRE
Hip: 1 motor+ MRE
x2
dsPIC
Wrist: 1 motor + MRE
x2
dsPIC
Ankle: 2 motors + MRE
Hand: 1 motor + MRE
x2
dsPIC
4 FSR
RGB LED

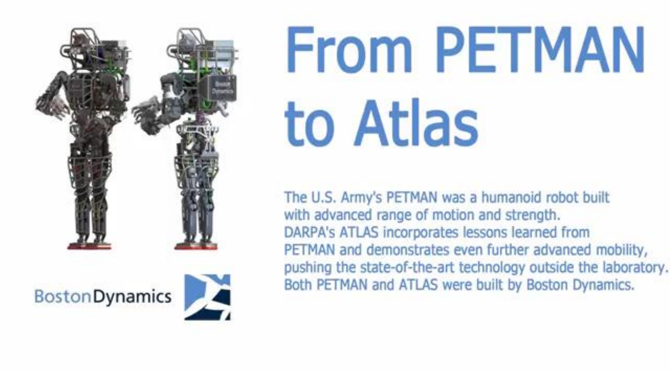
Engineering

What robots need from Engineering?

- Source of power
- Electronics (Motor control & CPU & Bus communication)
- Motorization

Pneumatic

Electric



Hydraulic

Engineering

What robots need from Engineering?

- Source of power
- Electronics (Motor control & CPU & Bus communication)
- Motorization

Electric

Advantages:

- Batteries embedded => motion **autonomy**
- Graphene batteries => **X10 energy density**
- Easy **control**
- **Lightweight**

Drawbacks:

- **Heating** of joints => needs a cooling system to increase working time
- **Rigid** joints, but **artificial compliance** can be introduced

Engineering

What robots need from Engineering?

- Source of power
- Electronics (Motor control & CPU & Bus communication)
- Motorization

Pneumatic/Hydraulic

Advantages:

- Much **larger** force/torque
- Can provide **natural** joint flexibility

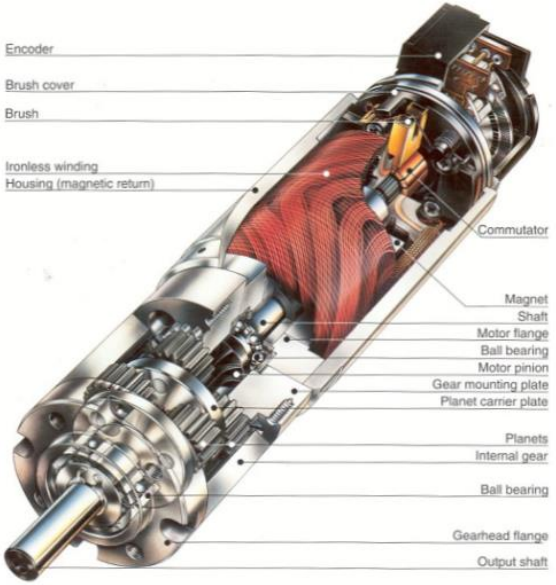
Drawbacks:

- Noisy
  Problem of leaks
- Bulkiness, and heavy weight if power source embedded
- Often, power source **not embedded** (most existing hydraulic humanoids get power from external source)
- **Control** design more **difficult**

Engineering

What robots need from Engineering?

- Source of power
- Electronics: Motor control & CPU & Bus communication
- Motorization
- Mechanical transmissions



Motors

There are 3 types of motor in NAO - V. 4.0:

	Motor type 1	**Motor type 2**	**Motor type 3**
Model	22NT82213P	17N88208E	16GT83210E
No load speed	8 300 rpm ±10%	8 400 rpm ±12%	10 700 rpm ±10%
Stall torque	68 mNm ±8%	9,4 mNm ±8%	14,3 mNm ±8%
Nominal torque	16.1 mNm	4.9 mNm	6.2 mNm

Speed Reduction ratio

For each motor, there are several types of speed reduction ratio:

	Motor type 1	**Motor type 2**	**Motor type 3**
Type A	201.3	50.61	150.27
Type B	130.85	36.24	173.22

Motors

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Speed Reduction ratio

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	Motor type 1	**Motor type 2**	**Motor type 3**
Type A	201.3	50.61	150.27
Type B	130.85	36.24	173.22

Calculate the angular velocities of the two joints: ‘HeadYaw’ and ‘HeadPitch’ that corespond to no load speeds?

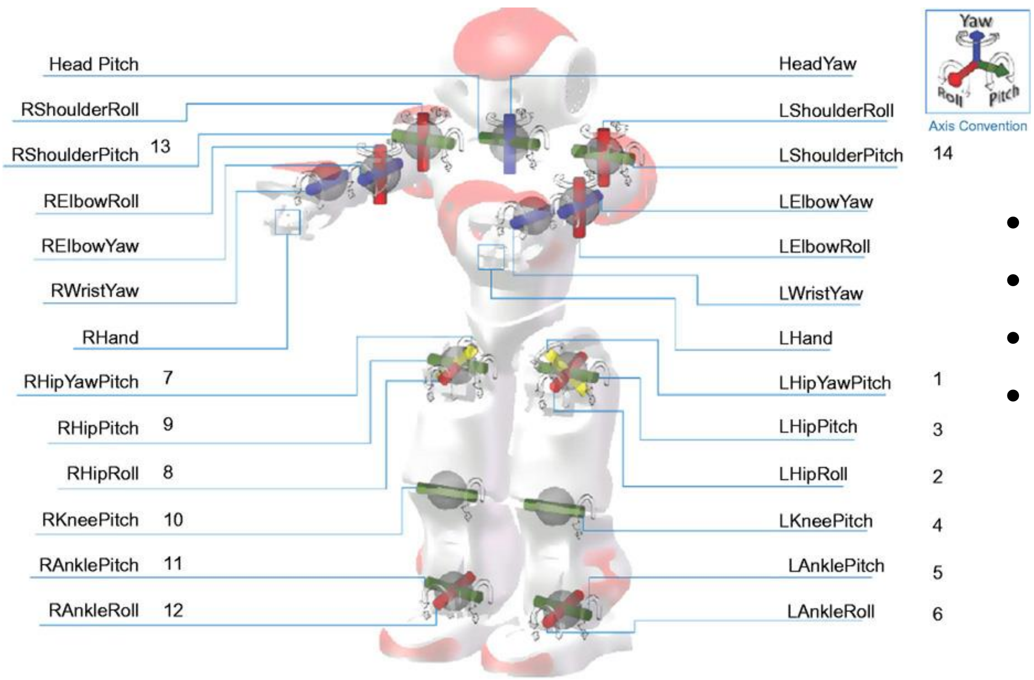
Head

Joints	**Motor**	**Reduction ratio**
HeadYaw	Type 3	Type A
HeadPitch	Type 3	Type B

Engineering

What robots need from Engineering?

- Source of power
- Electronics: Motor control & CPU & Bus communication
- Motorization
- Mechanical transmissions
- Design: Degrees of freedom DOF & Kinematics & Joint Layout

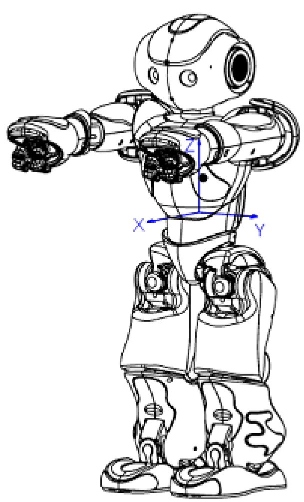


- Reachable space
- Where is the best place to put the motor?
- What are the axis?
- How many motor we need for each joint?

Engineering

What robots need from Engineering?

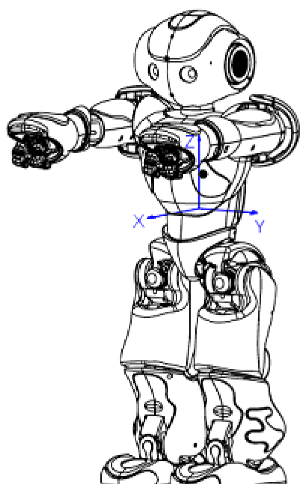
- Source of power
- Electronics: Motor control & CPU & Bus communication
- Motorization
- Mechanical transmissions
- Design: Degrees of freedom DOF & Kinematics & Joint Layout
- Sensors

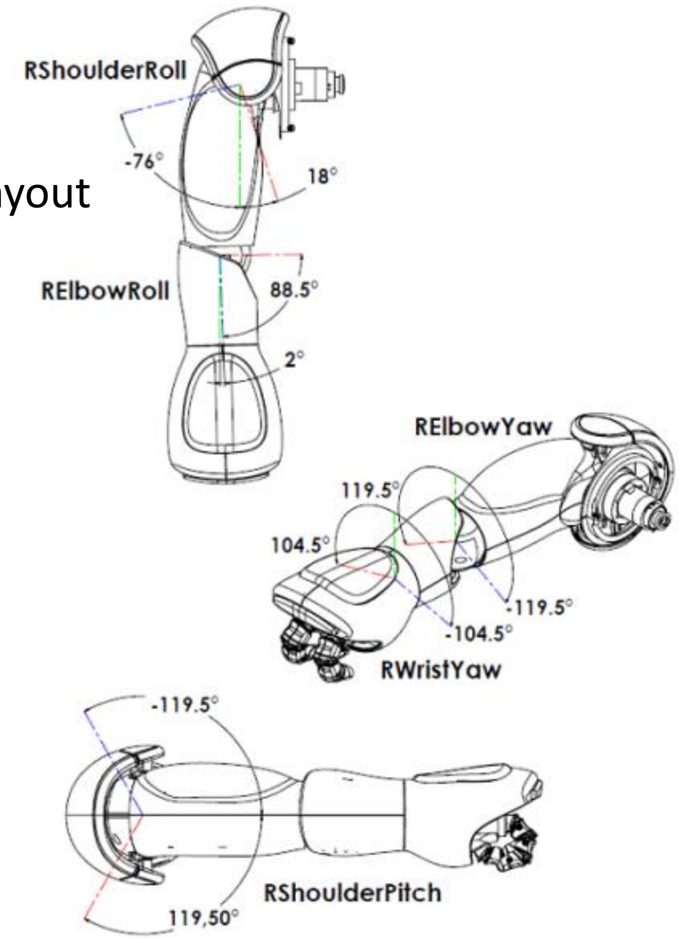


Engineering

What robots need from Engineering?

- Source of power
- Electronics: Motor control & CPU & Bus communication
- Motorization
- Mechanical transmissions
- Design: Degrees of freedom DOF & Kinematics & Joint Layout
- Sensors (**Proprioceptive**

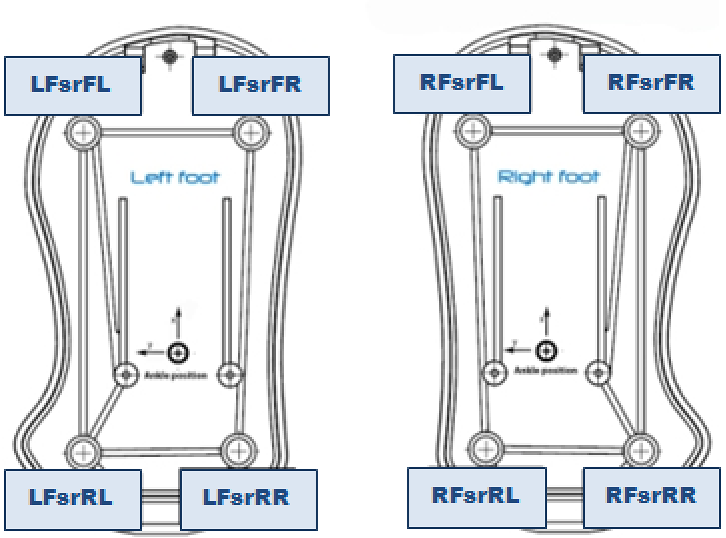




Engineering

What robots need from Engineering?

- Source of power
- Electronics: Motor control & CPU & Bus communication
- Motorization
- Mechanical transmissions
- Design: Degrees of freedom DOF & Kinematics & Joint Layout
- Sensors (Proprioceptive , **Exteroceptive**)



Example:

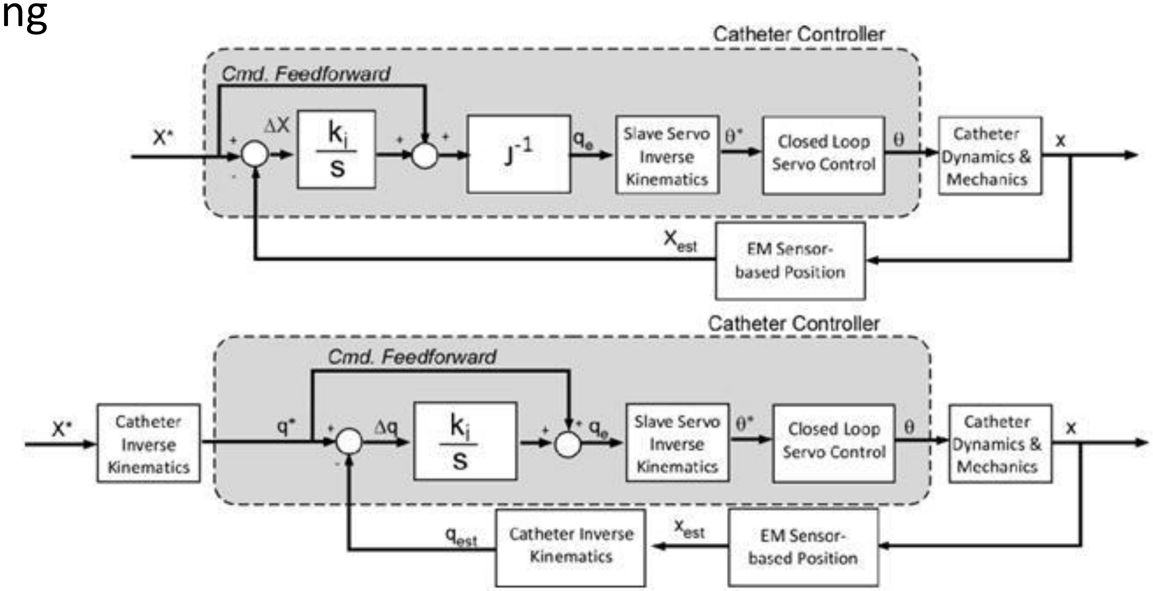
Force Sensitive Resistors:
These sensors measure a resistance change according to the pressure applied.

The FSR located on the feet have a working range from 0 N to 25 N.

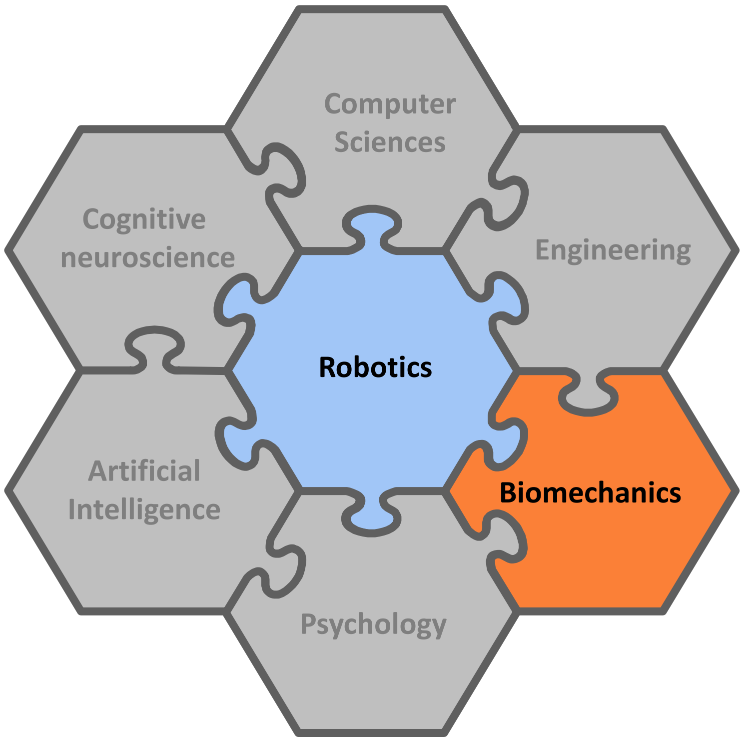
Engineering

Control

- Low level: regulation loop sensor motor e.g. PID
- Kinematic model (Cartesian trajectory level: **position control**)
- Differential kinematic model (**velocity control**)
- Dynamical model (**force / torque control**)
- Trajectory generation/planning
- Stability analysis



Bio-inspired mechanics



Bio-inspired mechanics

- Artificial muscles

Hopping Mechanism with Knee Actuated

It expands radially and contracts axially when inflated, while generating high pulling forces along the longitudinal axis.

- High torque/weight and power/weight ratios
- Muscles' natural compliance
- The actuator can be positioned at the joint without complex gearing mechanisms
- Shock absorbance during impact.

- The generated force is highly non-linear, that make it difficult to control

Suggested reading:
Masahiko Osada, Tamon Izawa, Junichi Urata, Yuto Nakanishi, Kei Okada, and Masayuki Inaba. Approach of "planar muscle" suitable for musculoskeletal humanoids, especially for their body trunk with spine having multiple vertebral. IEEE Humanoids, pages 358-363. 2011

Bio-inspired mechanics

- Artificial muscles
- Compliance

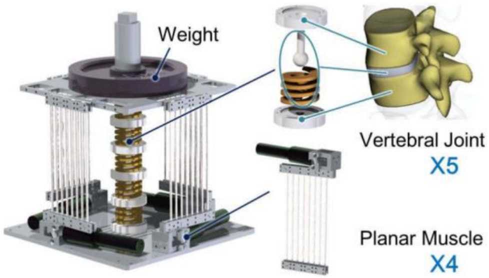
Stiff actuator (non-compliant actuator) is a device, which is able to move to a specific position or to track a predefined trajectory. Once a position is reached, it will remain at that position, whatever ***the external forces exerted on the actuator*** (within the force limits of the device).

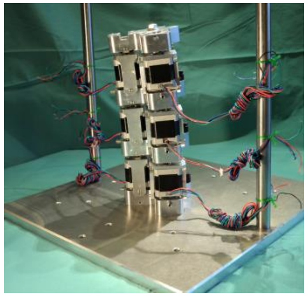
Compliant actuator on the other hand will allow deviations from its own equilibrium position, depending on the applied external force.

Bio-inspired mechanics

- Artificial muscles
- Compliance
- Vertebral column



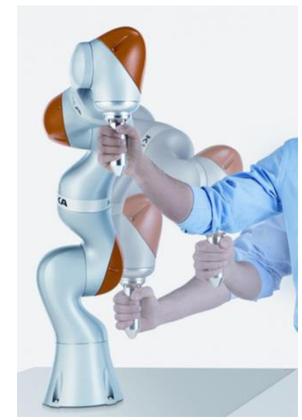
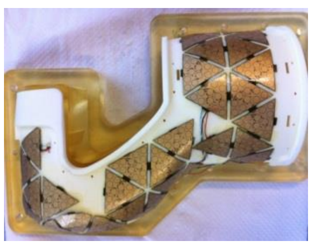



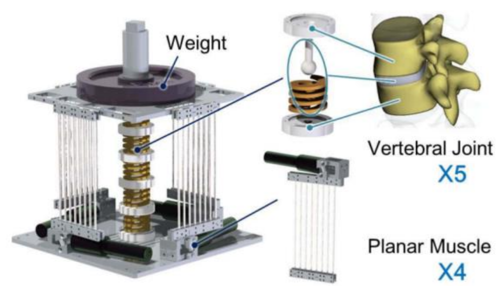


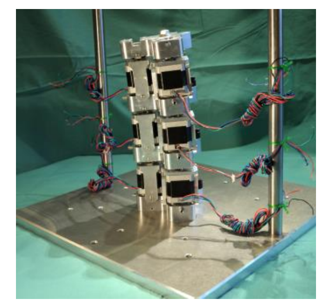
Bio-inspired mechanics

- Artificial muscles
- Compliance
- Vertebral column
- Tactile sensitive skin
  (cover the whole body, multimodality)





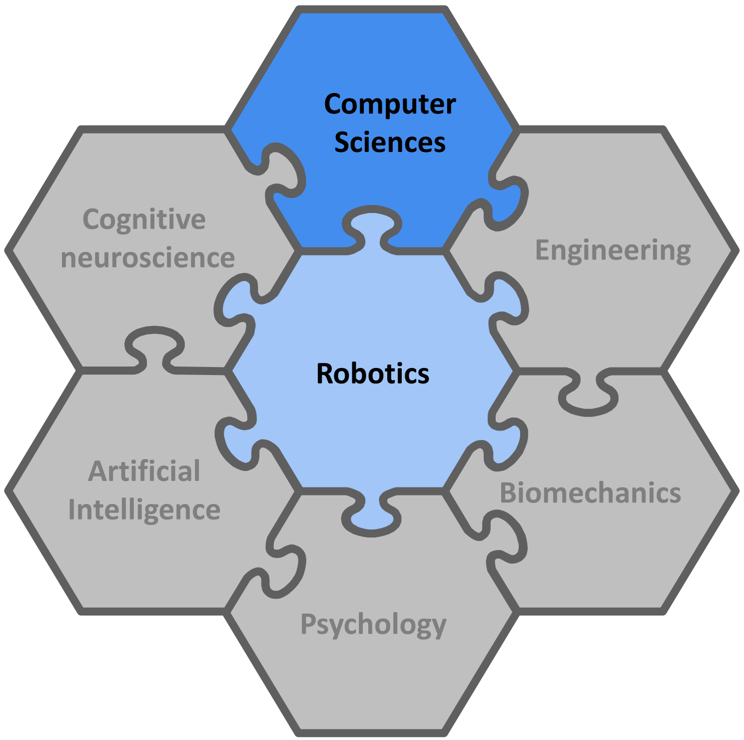


Video

Suggested reading:
Ravinder S. Dahiya, Philipp Mittendorfer, Maurizio Valle, Gordon Cheng and Vladimir Lumelsky. Directions Towards Effective Utilization of Tactile Skin - A Review. IEEE SENSORS JOURNAL, 2013

Computer Sciences

What robots need from Computer Sciences?



Computer Sciences

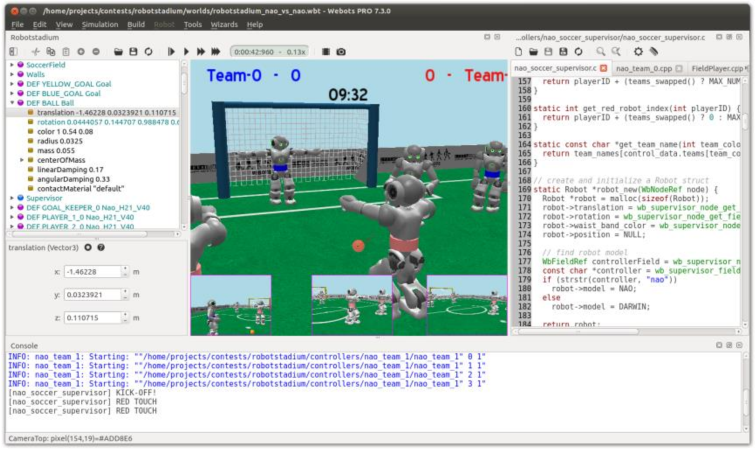
What robots need from Computer Sciences?

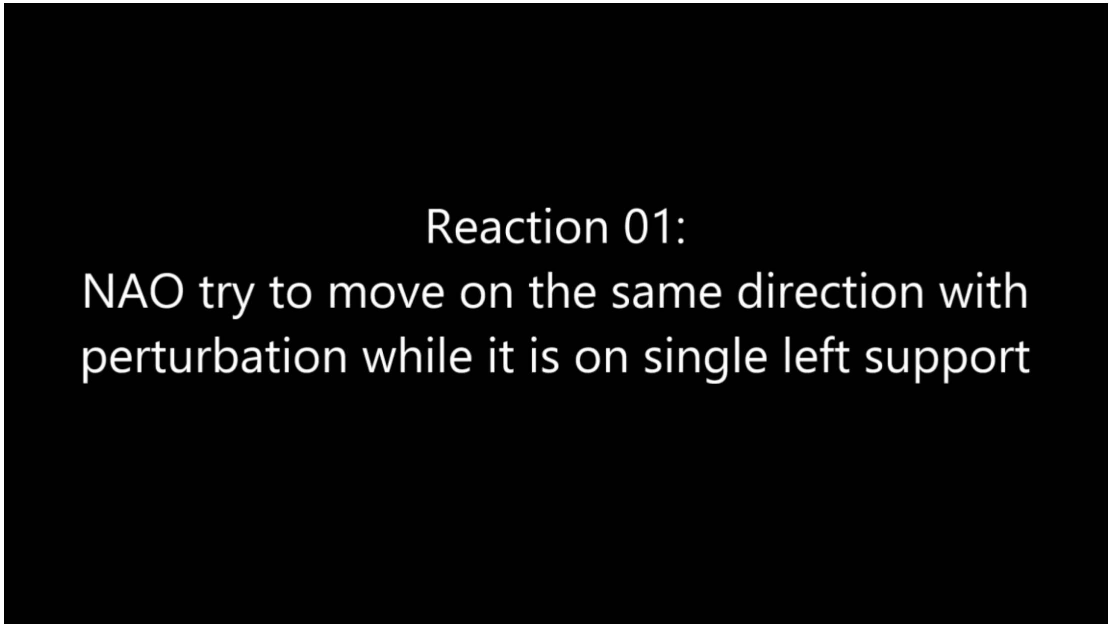
- Programming languages

Computer Sciences

What robots need from Computer Sciences?

- Programming languages
- Simulation Environments





Computer Sciences

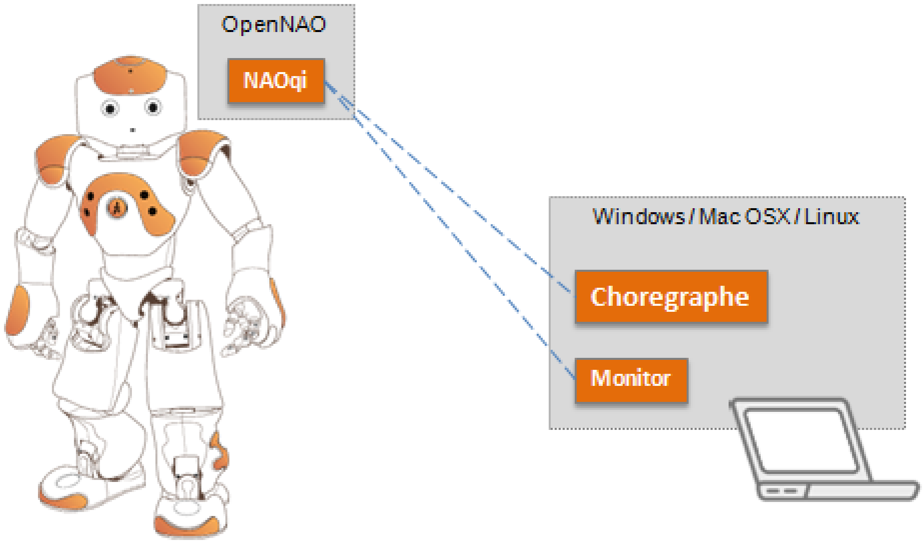
What robots need from Computer Sciences?

- Programming languages
- Simulation Environments
- Software development kits (SDK)

Computer Sciences

What robots need from Computer Sciences?

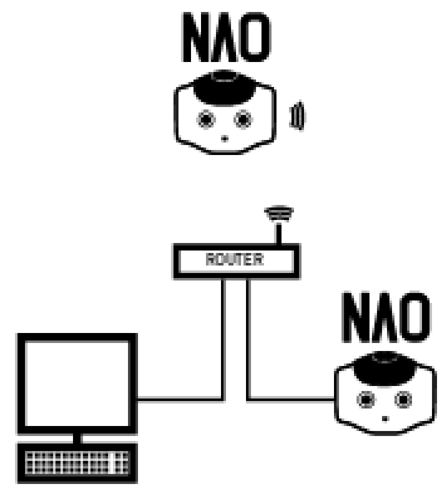
- Programming languages
- Simulation Environments
- Software development kits (SDK)
- Embedded software



Computer Sciences

What robots need from Computer Sciences?

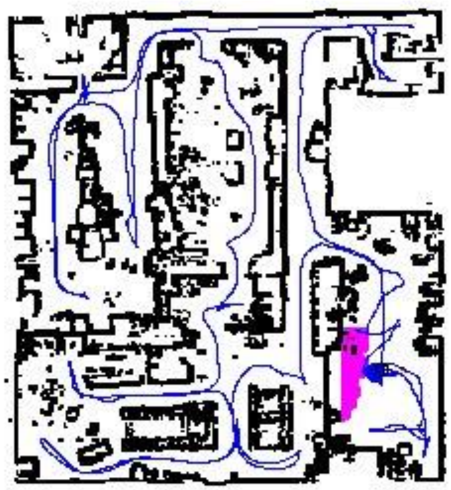
- Programming languages
- Simulation Environments
- Software development kits (SDK)
- Embedded software
- Networking



Computer Sciences

What robots need from Computer Sciences?

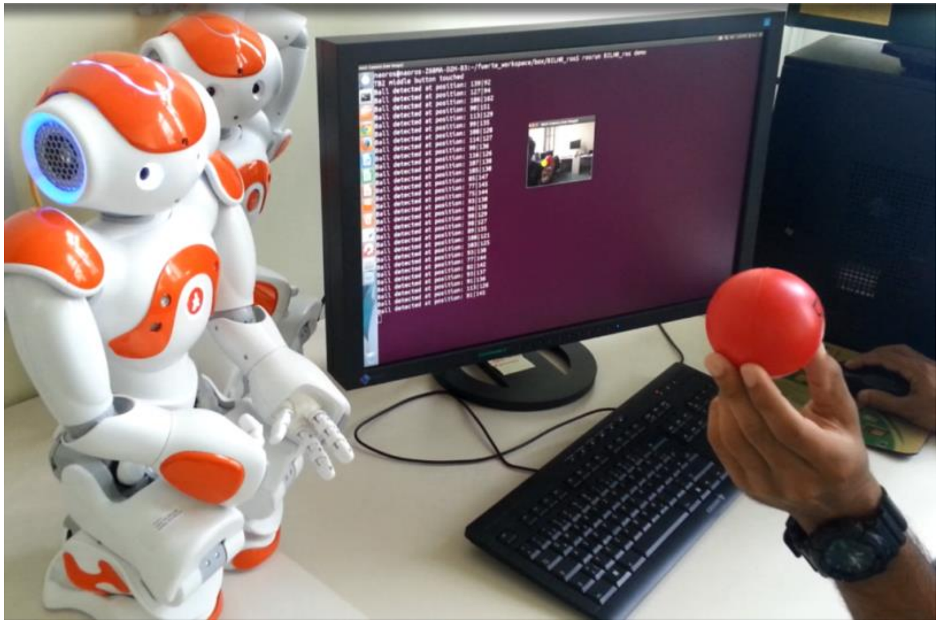
- Programming languages
- Simulation Environments
- Software development kits (SDK)
- Embedded software
- Networking
- Navigation
- Localization and mapping



Computer Sciences

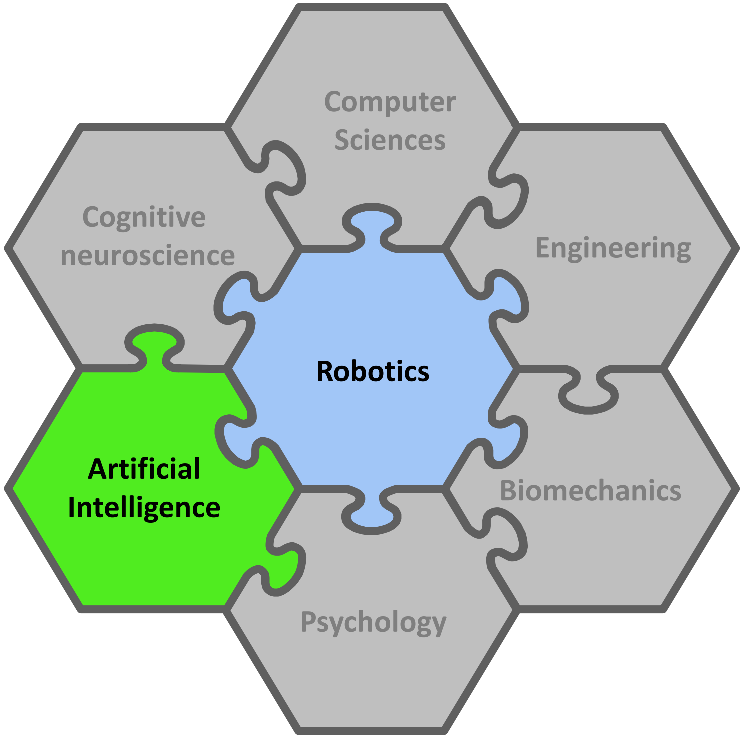
What robots need from Computer Sciences?

- Programming languages
- Simulation Environments
- Software development kits (SDK)
- Embedded software
- Networking
- Navigation
- Localization and mapping
- Vision



Artificial Intelligence

Why robots need AI?



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Artificial Intelligence

Why robots need AI?

- Interaction with people

Artificial Intelligence

Why robots need AI?

- Interaction with people
- Deal with unexpected changes

Artificial Intelligence

Why robots need AI?

- Interaction with people
- Deal with unexpected changes

They must be able to do:

Artificial Intelligence

Why robots need AI?

- Interaction with people
- Deal with unexpected changes

They must be able to do:

- Voice recognition

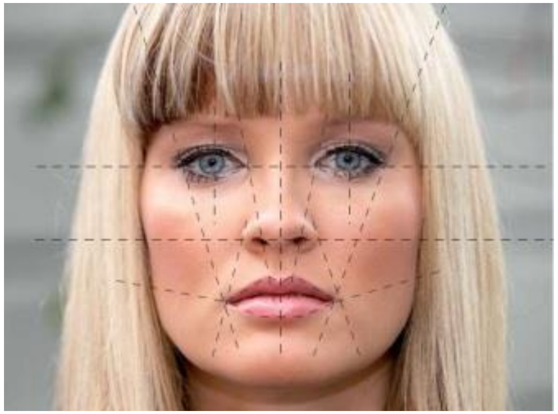
Artificial Intelligence

Why robots need AI?

- Interaction with people
- Deal with unexpected changes

They must be able to do:

- Voice recognition
- Face recognition



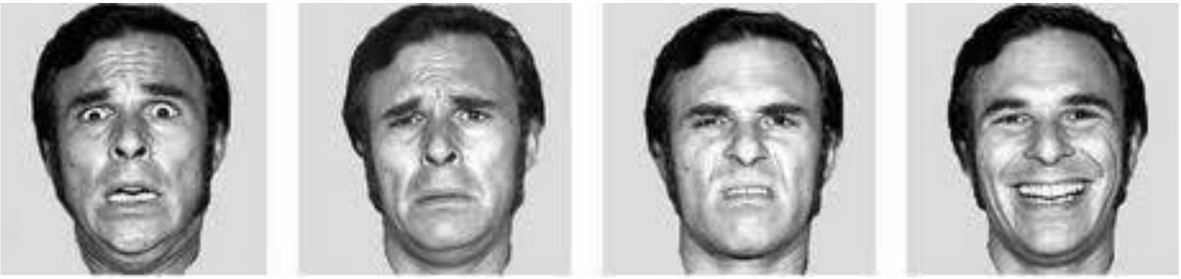
Artificial Intelligence

Why robots need AI?

- Interaction with people
- Deal with unexpected changes

They must be able to do:

- Voice recognition
- Face recognition
- Emotion recognition



Artificial Intelligence

Why robots need AI?

- Interaction with people
- Deal with unexpected changes

They must be able to do:

- Voice recognition
- Face recognition
- Emotion recognition
- Event-driven decision making

Artificial Intelligence

Why robots need AI?

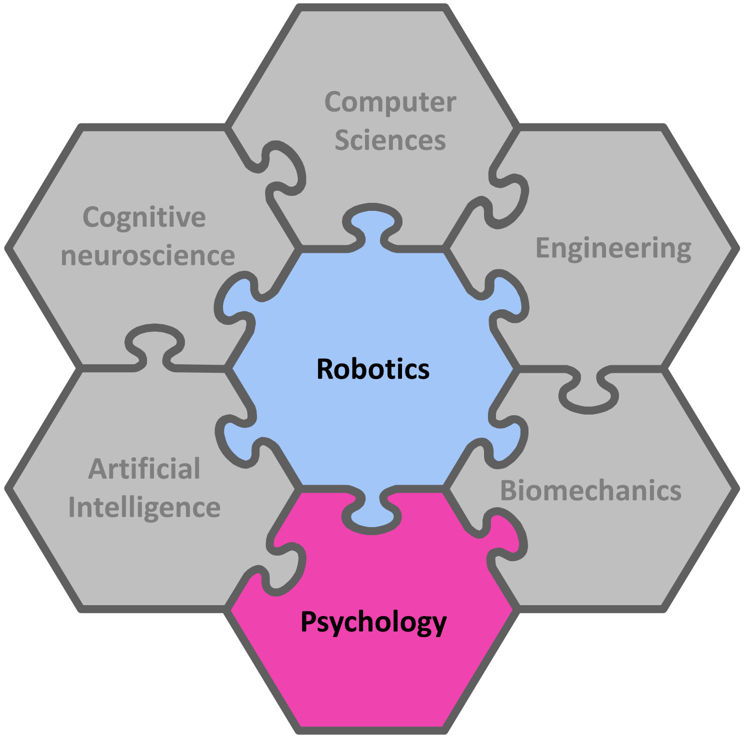
- Interaction with people
- Deal with unexpected changes

They must be able to do:

- Voice recognition
- Face recognition
- Emotion recognition
- Event-driven decision making
- Reasoning capabilities

Psychology

Why robots need Psychology?



Psychology

Why robots need psychology?

- Be acceptable by human
  (assist elderly and disabled)
- Generate Human behavior

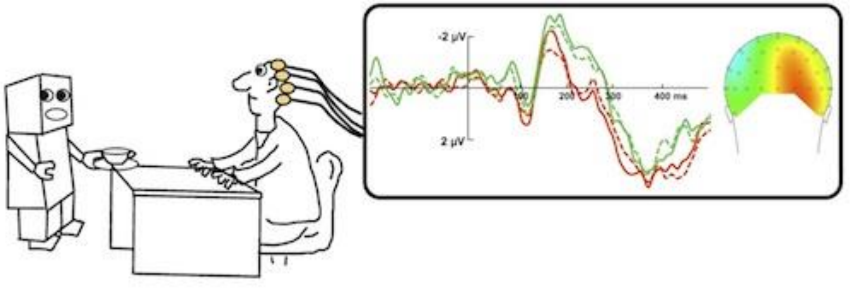
Psychology

Why robots need psychology?

- Be acceptable by human
  (assist elderly and disabled)
- Generate Human behavior

What robots need from psychology?

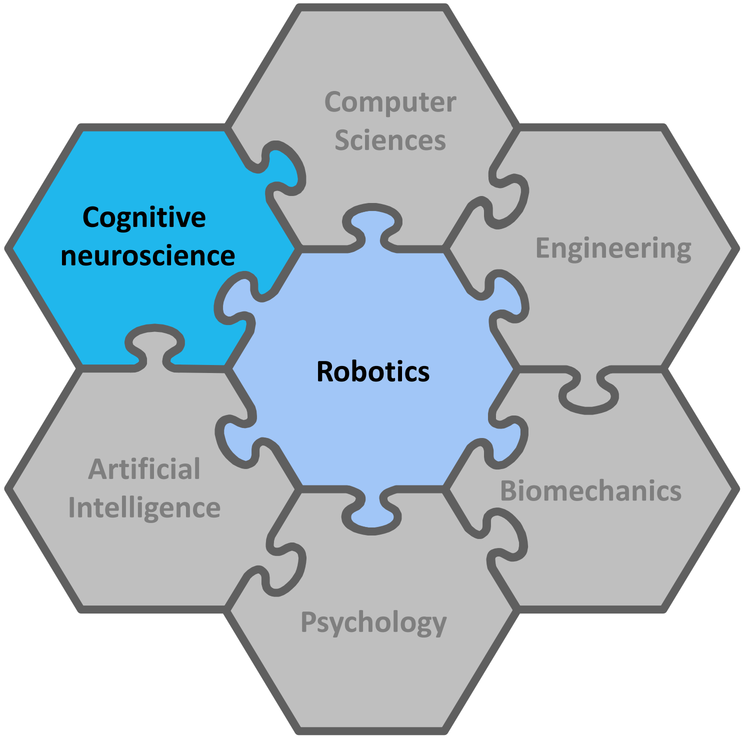
- Reacting to humans' social signals
- Following norms of human behavior
- New designs



Source: PD Dr. **Agnieszka Wykowska**
Dept. Psychology, Ludwig-Maximilians-Universität
& ICS Technische Universität München

Cognitive Neuroscience

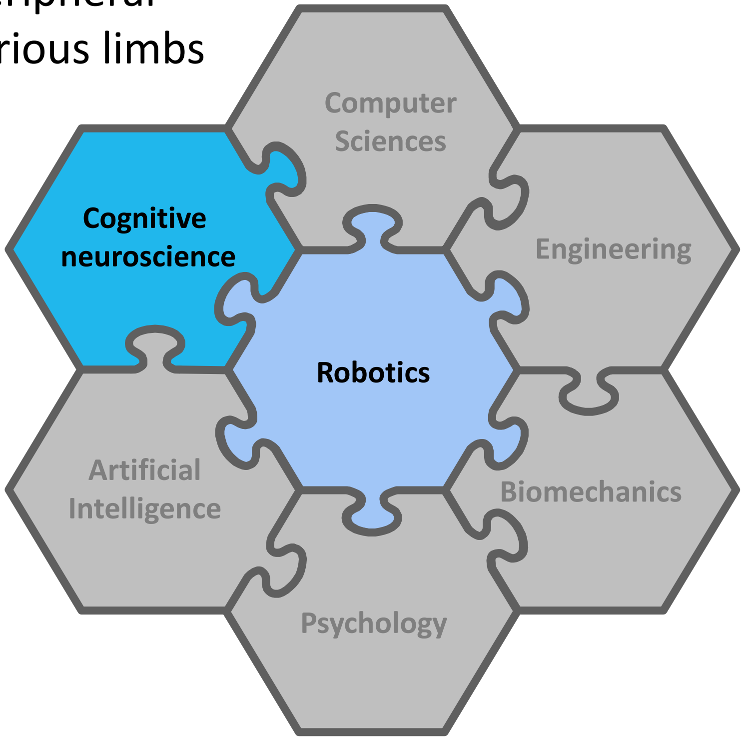
Why robots need Cognitive Neuroscience?



Cognitive Neuroscience

Centralization

1662: **Descartes** recognized the need to convey peripheral signals to a **central point**, so that the actions of various limbs could be coordinated.



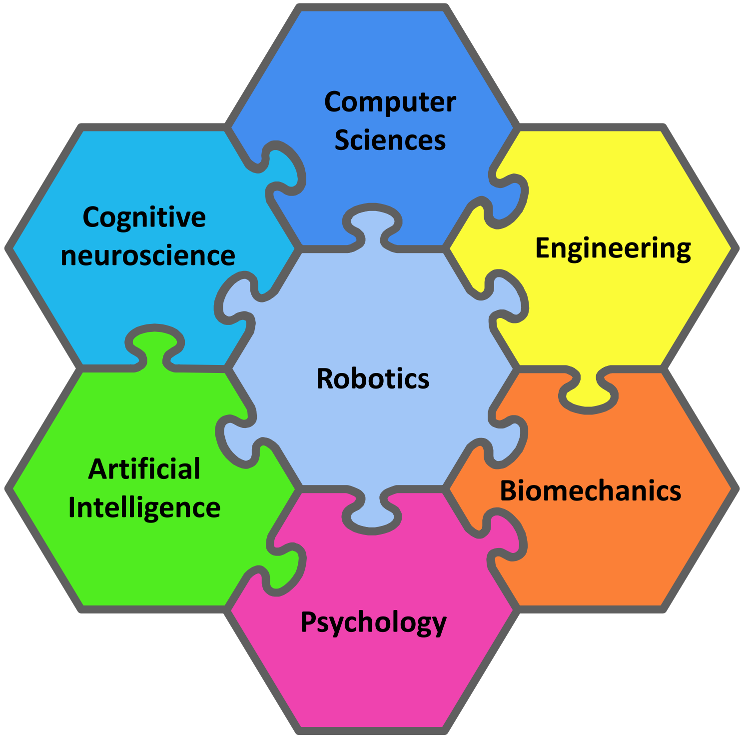
Cognitive Neuroscience

Why robots need Cognitive Neuroscience?

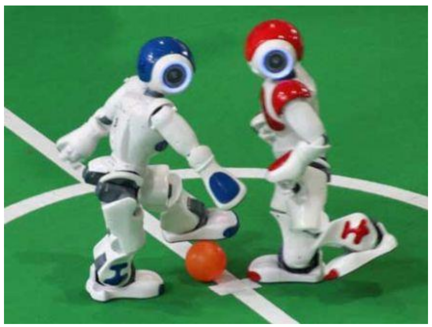
- Perception, Recognition
- Motor coordination
- Attention (e.g. eye movement)
- Learning , Adaptation
- Planning
- Decision making

By studying the neural activation and the behavioral consequences of the brain damages, cognitive neuroscience promises to delineate the connections between the brain anatomy and the functionality of the human mind that is studied in cognitive psychology.

Today's Limitation



Today's Limitation



Sensors !
Actuators!
Balance control loop !

Intelligence!
Strategies!
Coordinated reactions!

Not yet possible

Today's Limitation

Cognition & Robotics

Recent debates in Cognitive Robotics bring about ways to seek a definitional connection between **cognition** and **robotics**, ponder upon the questions:

euCognition

www.euCognition.org

EUCog - European Network for the Advancement of Artificial Cognitive Systems, Interaction and Robotics

Cognition & Robotics

Recent debates in Cognitive Robotics bring about ways to seek a definitional connection between **cognition** and **robotics**, ponder upon the questions:

Do robots need cognition?

Does cognition need robot?

Cogsys 2012

Cognition & Robotics

Recent debates in Cognitive Robotics bring about ways to seek a definitional connection between **cognition** and **robotics**, ponder upon the questions:

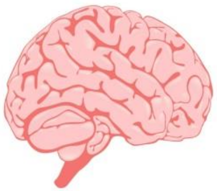
Do robots need cognition?

Some robots **do not need** cognition, and others **do**.
Robots that interact with **living organisms** need to understand their **behaviors** (e.g. human robot interaction).

Does cognition need robot?

Cogsys 2012

Cognition & Robotics

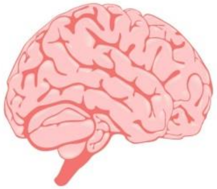


Cognition says to Robot:

Suggested reading:

- Yasuo Kuniyoshi, Yasuaki Yorozu, Yoshiyuki Ohmura, Koji Terada, Takuya Otani, Akihiko Nagakubo, Tomoyuki Yamamoto. From Humanoid Embodiment to Theory of Mind. *Embodied Artificial Intelligence, Springer Berlin / Heidelberg,* 2004*, 3139*, 202-218
- Michael Arbib. Action to Language via the Mirror Neuron System. *Cambridge University Press,* 2006, 566 pages

Cognition & Robotics



Cognition says to Robot:

You have everything to learn from us, and we have nothing to learn from you!

(Michael Arbib)

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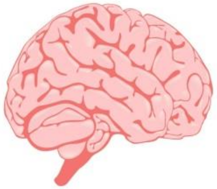
Cognition & Robotics



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The robot replys:

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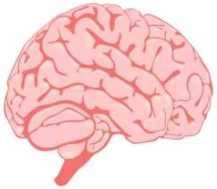
Cognition & Robotics



Cognition says to Robot:

You have everything to learn from us, and we have nothing to learn from you!

(Michael Arbib)

The robot replys:

Cognitive scientists probably need a physical experiment platform like a robot that has Quantifiable and Measurable Capabilities in Appropriate Dimensions to solve their scientific problem that cannot be solved by simulation.

(Michael Arbib)

Suggested reading:

- Yasuo Kuniyoshi, Yasuaki Yorozu, Yoshiyuki Ohmura, Koji Terada, Takuya Otani, Akihiko Nagakubo, Tomoyuki Yamamoto. From Humanoid Embodiment to Theory of Mind. *Embodied Artificial Intelligence, Springer Berlin / Heidelberg,* 2004*, 3139*, 202-218
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Robotics

- Modelling
- Planning
- Control

Robotics

- **Modelling**
- Planning
- Control

Modelling

- **Kinematic** analysis of the mechanical structure of a robot concerns the description of the motion with respect to a fixed reference Cartesian frame by ignoring the forces and moments that cause motion of the structure.

- It is meaningful to distinguish between **kinematics** and **differential kinematics**.

- With reference to a robot manipulator, ***kinematics*** describes the analytical relationship between the joint positions and the end-effector position and orientation.

- ***Differential kinematics*** describes the analytical relationship between the joint motion and the end-effector motion in terms of velocities, through the manipulator Jacobiann.

Modelling

- The formulation of the kinematics relationship allows the study of two key problems of robotics, namely, the ***direct kinematics*** problem and the ***inverse kinematics*** problem.

- The ***direct kinematics*** concerns the determination of a systematic, general method to describe the end-effector motion as a function of the joint motion.

- The ***inverse kinematics*** concerns the inverse problem; its solution is of fundamental importance to transform the desired motion, naturally prescribed to the end-effector in the workspace, into the corresponding joint motion.

- The availability of a manipulator's kinematic model is also useful to determine the relationship between the ***forces*** and ***torques*** applied to the joints and the forces and moments applied to the end-effector.

Modelling

- ***Robot dynamics*** is concerned with the relationship between the **forces** acting on a robot mechanism and the **accelerations** they produce.

- Typically, the robot mechanism is modelled as a rigid-body system, in which case robot dynamics is the application of rigid-body dynamics to robots.

- The two main problems in robot dynamics are:
  - ***Forward dynamics***: given the forces, work out the accelerations.
  - ***Inverse dynamics***: given the accelerations, work out the forces.

$$\vec{F} = m.\vec{a}$$

Modelling

- ***Kinematics*** of a manipulator represents the basis of a systematic, general derivation of its ***dynamics***, i.e., the equations of motion of the manipulator as a function of the forces and moments acting on it.

- The availability of the ***dynamic model*** is very useful for
  - mechanical design of the structure
  - choice of actuators (e,g. How much torque they have to produce!)
  - determination of control strategies
  - computer simulation of manipulator motion.

Robotics

- Modelling
- **Planning**
- Control

Planning

- With reference to the tasks assigned to a manipulator, the issue is whether to specify the motion **at the joints** or directly **at the end-effector**.

- In material handling tasks, it is sufficient to assign only the pick-up and release locations of an object (**point-to-point motion**), whereas, in machining tasks, the end-effector has to follow a desired trajectory (**path motion**).

- The goal of **trajectory planning** is to generate the timing laws for the relevant variables (joint or end-effector) starting from a concise description of the desired motion (e,g. writing a straight line with a robotic arm.).

Planning

- **The motion planning** problem for a mobile robot concerns the generation of trajectories to take the robot from a given initial configuration to a desired final configuration.

- Whenever **obstacles** are present in a mobile robot's workspace, the planned motions must be safe, so as to **avoid collisions**.

Robotics

- Modelling
- Planning
- **Control**

Control

- Realization of the motion specified by the control law requires the employment of **actuators** and **sensors**.
- the **hardware/software architecture** of a robot's **control system** is in charge of implementation of **control laws** as well as of interface with the operator.

Control

- The problem of robot manipulator control is to find **over time the forces and torques** to be **delivered by the joint actuators** so as to ensure the execution of the **reference trajectories**.

- This problem is quite **complex**, since a manipulator is an articulated system and, as such, **the motion of one link influences the motion of the others**.

Control

- The synthesis of the joint forces and torques cannot be made on the basis of the sole knowledge of the **dynamic model**, since this does not **completely describe** **the real structure**.
- Therefore, manipulator control is entrusted to the closure of **feedback loops**; by computing the deviation between the reference inputs and the data provided by the proprioceptive sensors, a feedback control system is capable of satisfying accuracy requirements on the execution of the prescribed trajectories.

Conclusion

- Why robots?

  Assistance robotics (elderly, a person confined to a bed or a wheelchair, …).

  Performing certain tasks that are dangerous to humans (fighting fires, cleaning up toxic spills, …).

- Robots are classified according to different rules.

- Building robots should follow multidisciplinary approach.

- Robotics research may overcome some of its limitations in term of autonomy and intelligent capabilities if it gets closer to neuroscience.

- Robotics: Modelling, Planning and Control.

References

1. Yasuo Kuniyoshi, Yasuaki Yorozu, Yoshiyuki Ohmura, Koji Terada, Takuya Otani, Akihiko Nagakubo, Tomoyuki Yamamoto. From Humanoid Embodiment to Theory of Mind. *Embodied Artificial Intelligence, Springer Berlin / Heidelberg,* 2004*, 3139*, 202-218
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