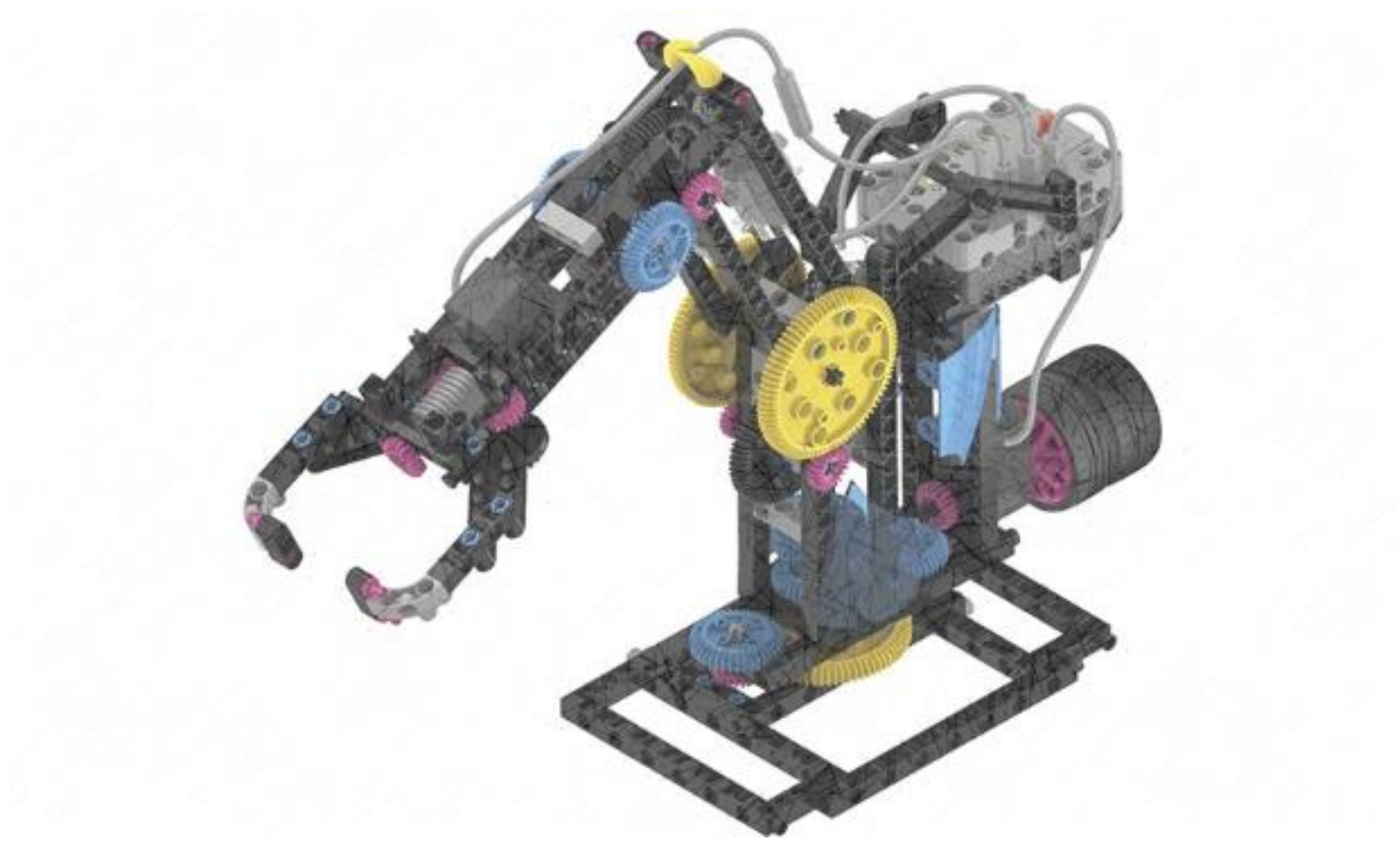
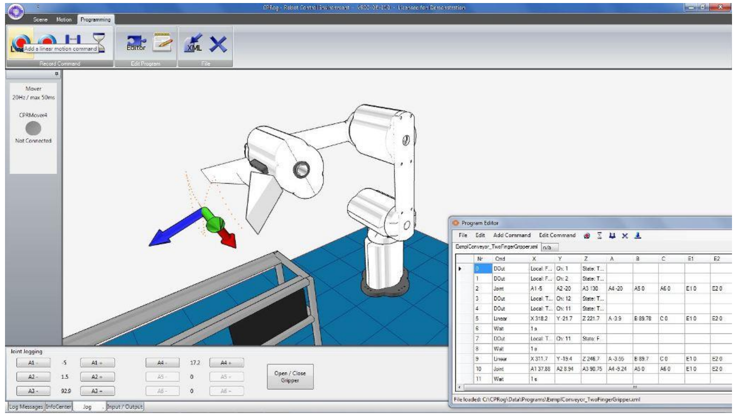
Introduction to Robotics

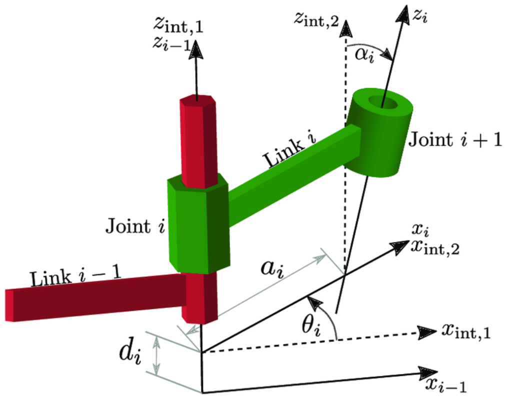


Structure of the class

- Introduction to Robotics and fields of applications (no tutorial)
- Intro to robotics components and architectures (Tutorial on Grubler Formula and basic mechanics)
- Rigid Motion and Homogeneous Transformations (Tutorial on rotation matrixes and basic geometry)
- Forward Kinematics (Tutorial on DH)
- Inverse Kinematics (Tutorial on Jacobians and again DH 1)
- Differential Kinematics (Intro to ROS)
- Motion Planning (Intro to ROS)
- Forward Dynamics (Tutorial on Lagrangian Formulation 1)
- Inverse Dynamics (Tutorial on Lagrangian Formulation 2)
- Robot Control (Tutorials on stability and more on control theory)
- Mobile Robotics (Practice tutorial in Lab with Holger)

https://www.ros.org/





UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

Meeting and Consultation

Nicola

Francesco

Ryan

Holger

Send an email before and pass by ZITI (Im Neunheimerfeld 368) 4^{th} and 5^{th} floor.

Lorenzo Masia (Room521 5^{th} Floor) lorenzo.masia@ziti.uni-heidelberg.de

Nicola Lotti nicola.lotti@ziti.uni-heidelberg.de

Francesco Missiroli francesco.missiroli@ziti.uni-heidelberg.de

Holger Dieterich holger.dieterich@ziti.uni-heidelberg.de

Ryan Alicea ryan.alicea@ziti.uni-heidelberg.de

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

Examination

Written examination (2.5 hours)
15-20 questions on exercises and theory explained and discussed in the classes over the semester.
3 homeworks to be completed to access the exam

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

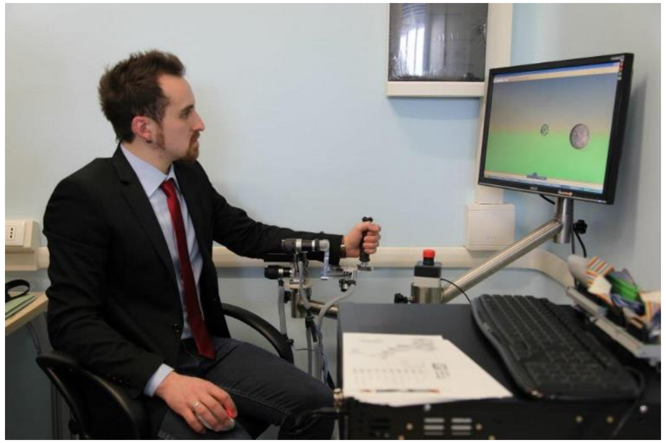
Master Thesis (min 6 months)

Visit here to know what I do for living under “Projects” page:

www.lorenzomasia.com

Research

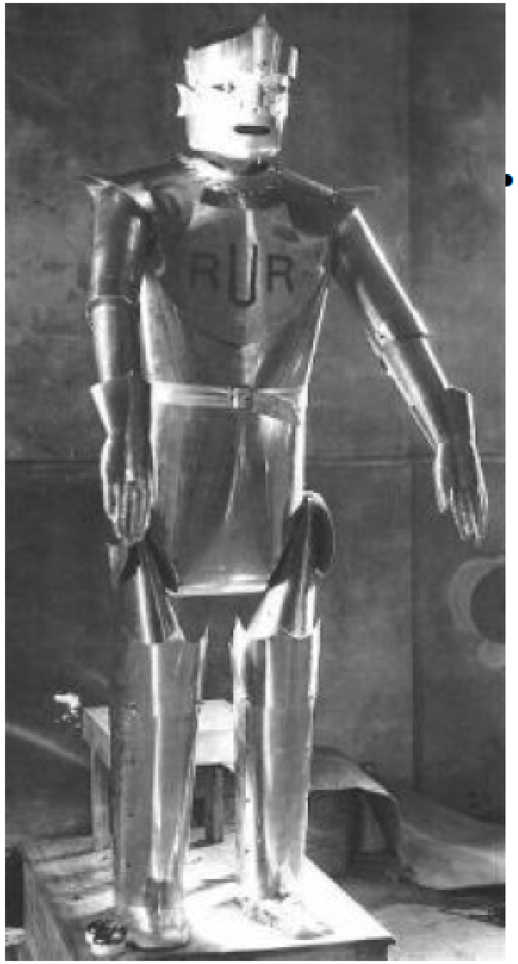
- Robot-Aided Rehabilitation
- Soft Wearable Exosuits
- Bio-Robotic Design
- Human Machine Interaction
- Control System Engineering
- Virtual Reality & Haptics
- Intelligent Actuators Design



Requested skills (one at least)

- Programming MatLab, C, C++
- Mechanical Design CAD
- Clinical Data Analysis
- Statistics

Woher kommt das Wort „Roboter“?



- erfunden von Karel Capec (tschechischer Schriftsteller):

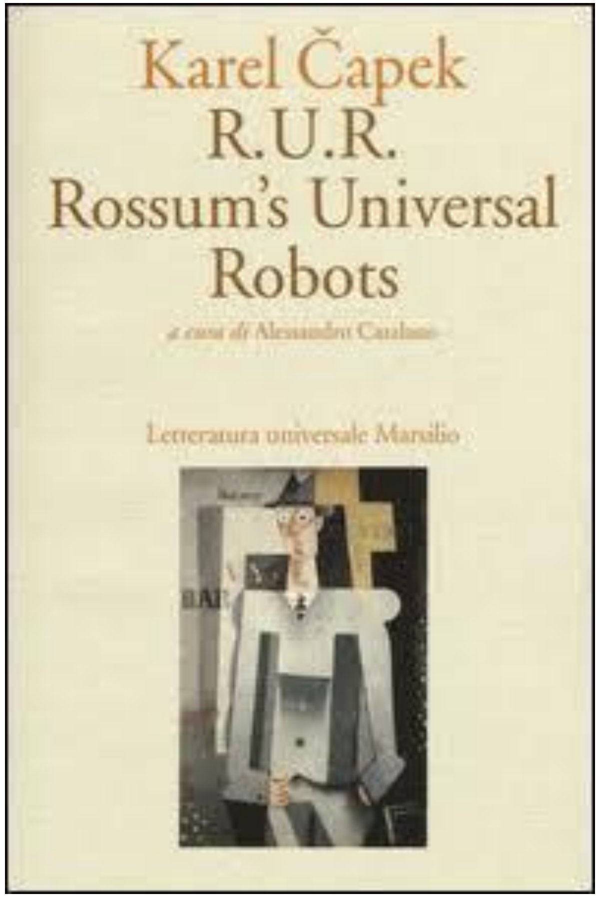
  schrieb 1923 das Schauspiel R.U.R (Rossum‘s Universal Robots)

  „Robota“ = Fronarbeit

robot

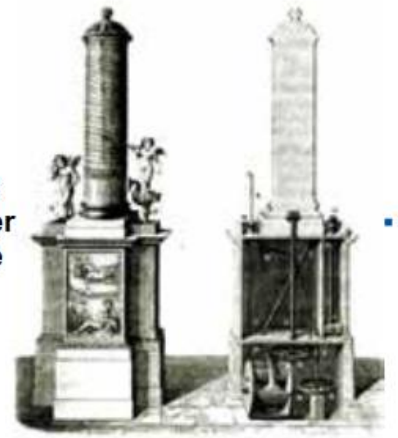
***Robota*: «hard work»**

The term was first introduced by the Czeck playwrigth Karel Kapek in 1920 in his play drama **R.U.R. (Rossumovi univerzální roboti).**



History of Robots

250 B.C.
Ctesibius of Alexandria build **organs and water clocks with moveable figures**



1495
Leonardo da Vinci designed and **possible built the first humanoid robot**.

1738
Jacques de Vaucanson built **several automata**: flute player, drum player and a duck (could quack, flap its wings and eat)

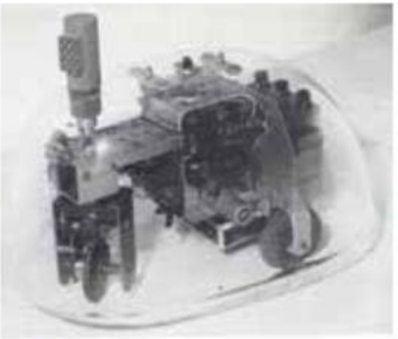
1865
John Brainerd created the **Steam Man**, apparently to pull things.

1885
Frank Reade Jr build the **Electric Man**

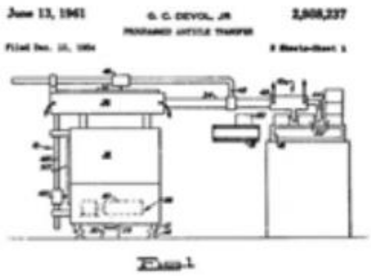
History of Robots

1938
Westinghouse created ELEKTRO, **a human-like robot** that could walk, talk and smoke.

1948
Grey Walter created his first robots: Elmer and Elise known as **the turtle robots**.



1954
George Decol designd the **first programmable robot** „Universal Automation“



1963
The Rancho Arm ist the **first computer controlled artificial robotic arm**.

History of Robots

1966
Joseph Weizenbaum wrote the famouse Eliza program. **The program simulates a psychoanalist** by reqhrasing many of the user's questions.

1969
Victor Scheinman created the Standford Arm, which was the **first successful electrically-powerd, computer-controlled robot arm**.

1970
SRI International created Shakey, which is the **first robot controlled by artificial intelligence**

1975
PUMA was developed by Victor Scheinman. It is **widly used** in industrial robots.

History of Robots

1989
The Mobile Robots Group at MIT created Genghis, a walking robot.

1996
Honda created P2, which was the **first self-regulating, bepedal humanoid robot.**

1997
NASA's Pathfinder landed in Mars.

2010
Robonaut 2 was launched to the space station. It is the **first humanoid robot in space**.

History of Robots

Laws of Robotics by Asimov (1942/1950)

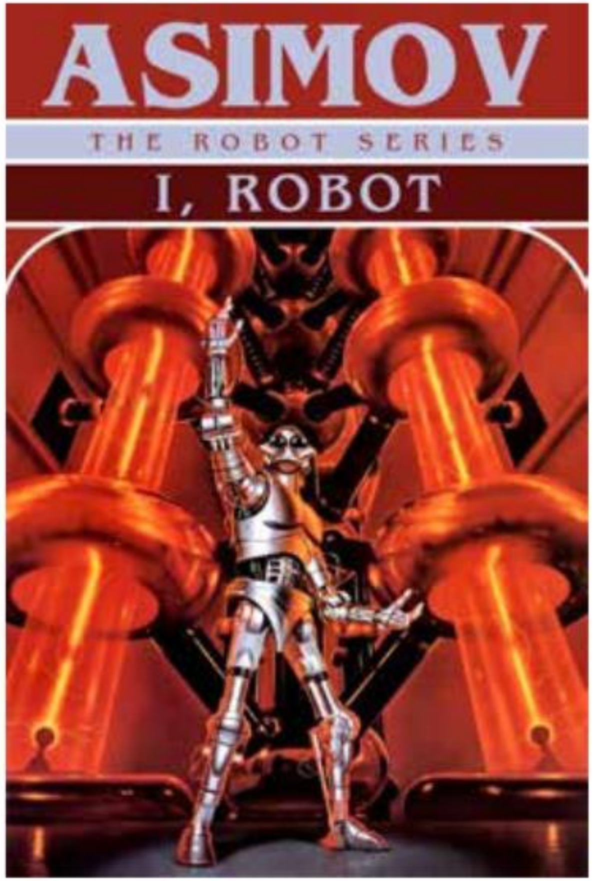
Asimov proposed three “Laws of Robotics” and later added the “zeroth law”

Law 0*: A robot may not injure humanity or through inaction, allow humanity to come to harm*

Law 1: A robot may not injure a human being or through inaction, allow a human being to come to harm, unless this would violate a higher order law

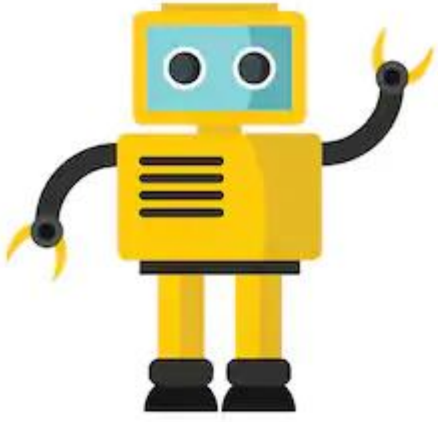
Law 2: A robot must obey orders given to it by human beings, except where such orders would conflict with a higher order law

Law 3: A robot must protect its own existence as long as such protection does not conflict with a higher order law



Source: https://lf420.deviantart.com

Application in robotics



It is a multi-disciplinary domain. The different branches occupied in the development of Robotics are:

- **Mechanical Engineering**: Deals with the machinery & structure of the Robots.
- **Electrical Engineering**: Deals with the controlling & intelligence (sensing) of Robots.
- **Computer Engineering**: Deals with the movement development and observation of Robots.

“a robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks”

Definition of Robotics

The word “robot” was coined by the Czech novelist Karel Capek in 1920 play titled Rassum’s Universal Robots (R.U.R.). “Robot” in Czech is a word for worker or servant.

THE ROBOTICS INSTITUTE

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.
[Robot Institute of America, 1979]

"automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications"
[ISO 8373:2012 definition of industrial robots]

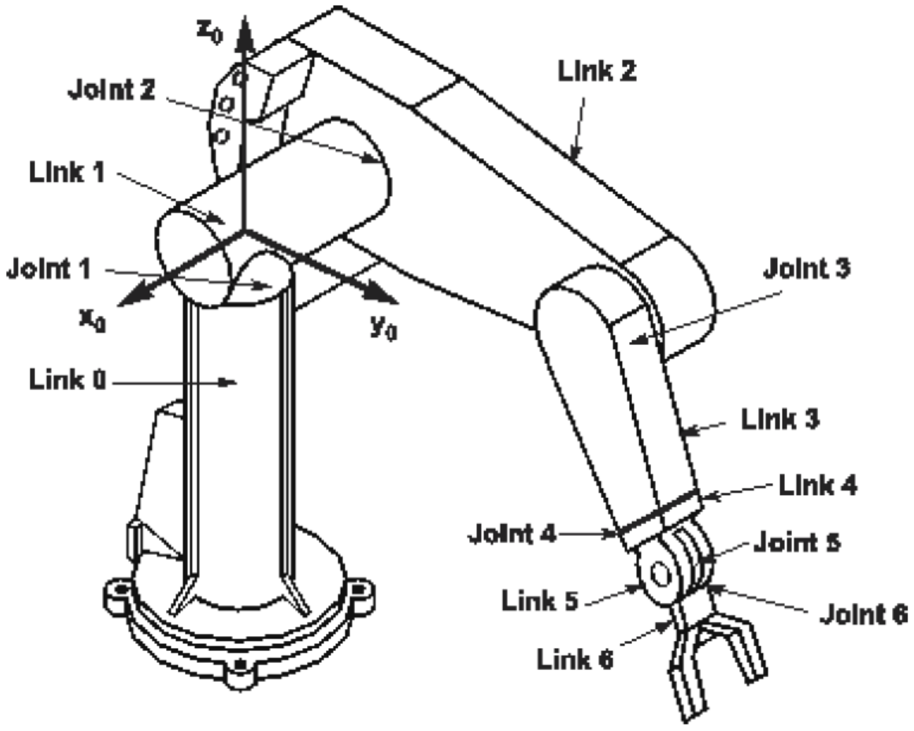
ISO

IFToMM

Scientific and engineering field of the design, construction and application of robots, that under automatic control performs operations such as handling and locomotion.
[IFToMM]

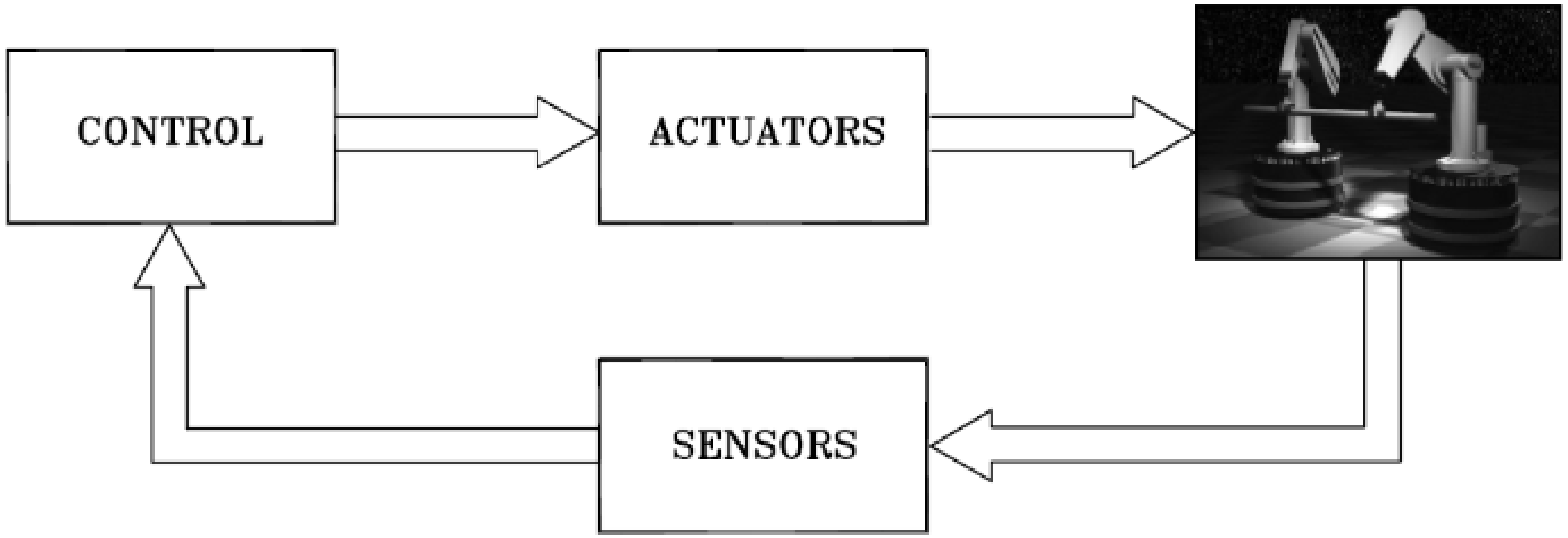
robot

RIA *(Robotic Institute of America)*
"A robot is a ***programmable multifunctional mechanism*** *designed to move material, part or tools, or specialized devices through variable programmed motion for the perfomance of a variety of tasks".*



Main structure

- sensors used to perceive the surrounding environment;
- actuators, e.g. servomotors, to interact with the environment;
- a control structure i.e. the brain of the robot;
- the mechanical structure of the robot itself.

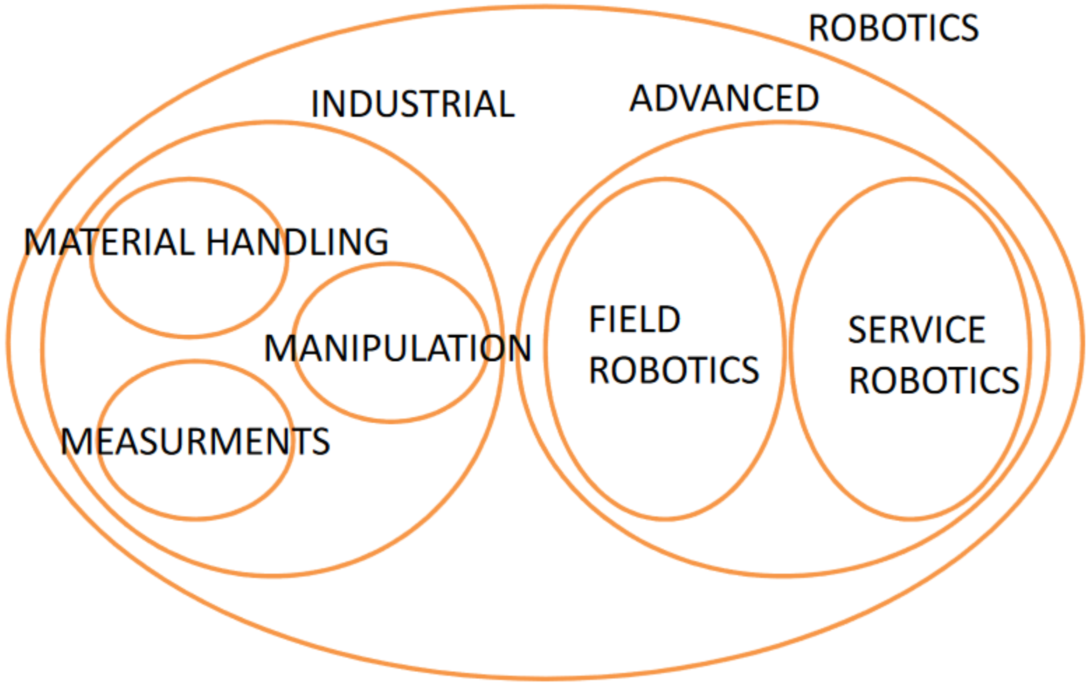


Classification according to the working environment

Robotics can be divided into industrial and advanced.

Industrial robotics is located in a structured environment whose geometrical or physical characteristics are mostly known a priori. Three main working areas can be identified: material handling, manipulation and measurements.

Advanced robotics operates in unstructured environments, whose geometrical or physical characteristics would not be known a priori. It can be further divided into field robotics, i.e. the working environment is not safe, and service robotics, i.e. its scope is to improve quality of life



https://www.staubli.com/de/robotik/
http://new.abb.com/products/robotics/de
http://www.kuka-robotics.com

Definition of an Classical Industrial Robot

An industrial robot is a multipurpose manipulator that is automatically controlled:

- Three or more axes
- (Re)programmable:
  - Translations and Rotations
  - Movement pattern
  - Possibly sensor guided
- Can be equipped with different end-effectors for industrial applications:
  - Gripper
  - Tools
  - Sensors
  - …

Industrial Robots

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

https://avenue.cllmcmaster.ca
http://www.tuvie.com
http://www.popularmechanics.com
https://www.theengineer.co.uk
http://itelemedicine.com

www.popularmechanics.com
https://www.wsj.com/
http://www.engineering.com
www.engineering.com

Advanced Robotics

- Extreme Environments
- Medical Robotics
- Home Cleaning
- Agriculture
- Lawn Mowing
- Food Industry
- Mine Exploration
- De-Mining
- Civil and Naval Construction
- Automatic Refueling
- Public Ground Guide
- Fire Fighting
- Inspection and Surveillance
- Emergency Rescue
- Entertainment
- Humanoids





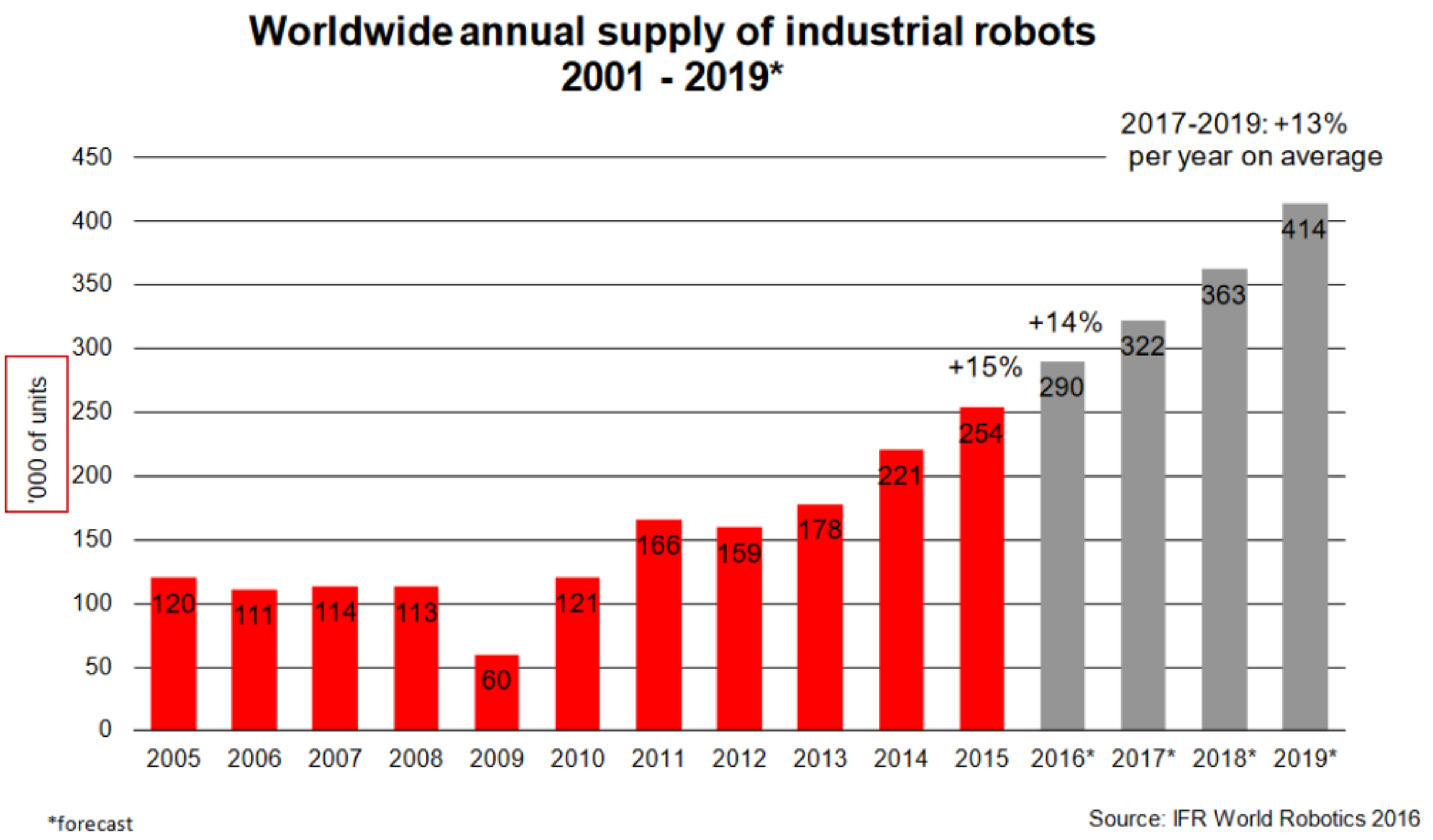




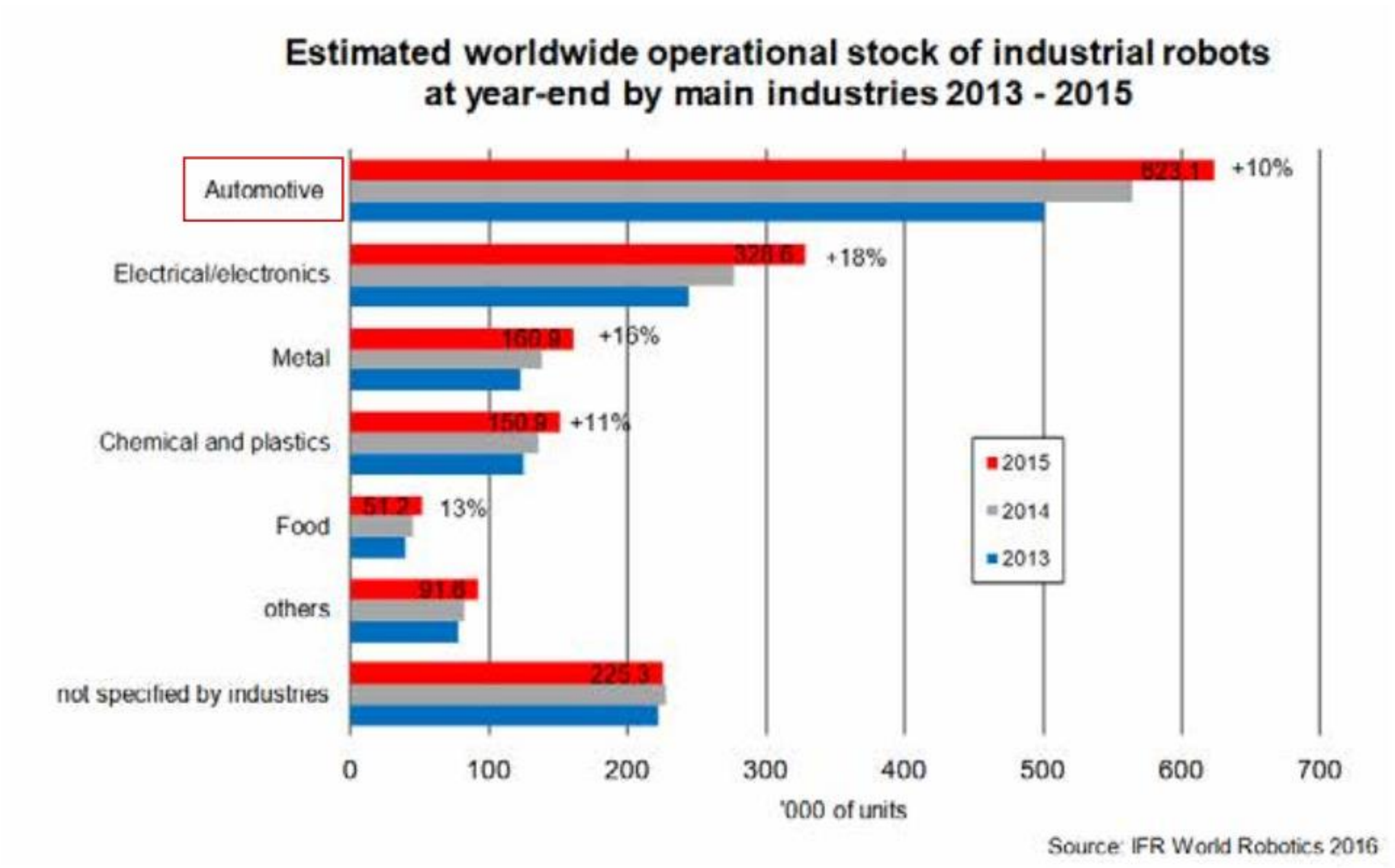




World Robotics Market

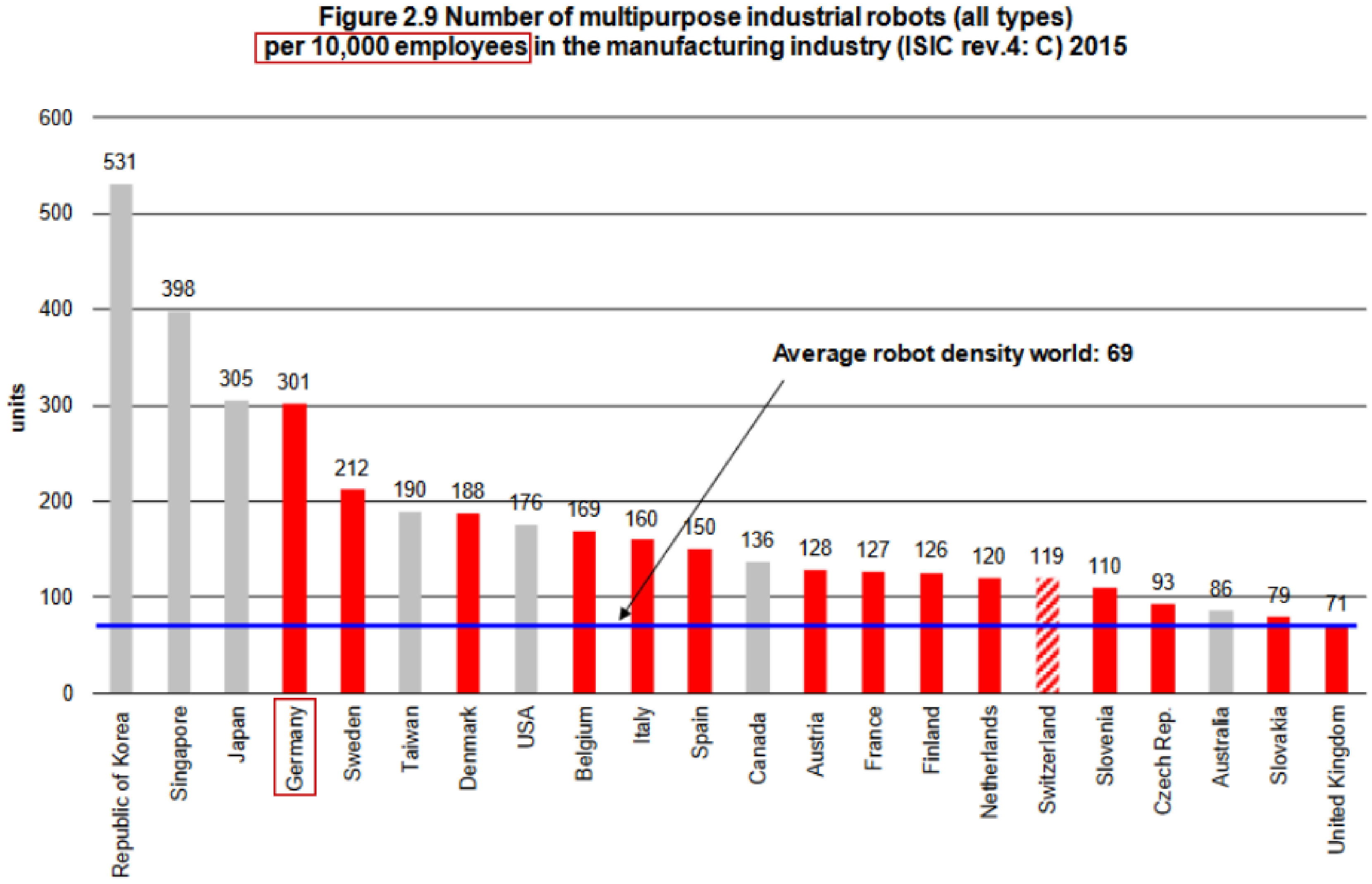


World Robotics Market



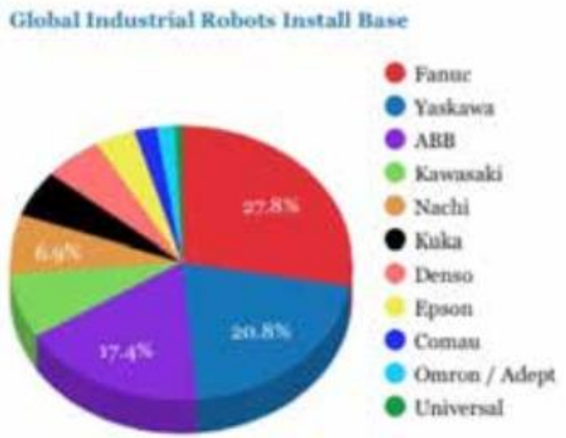
UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

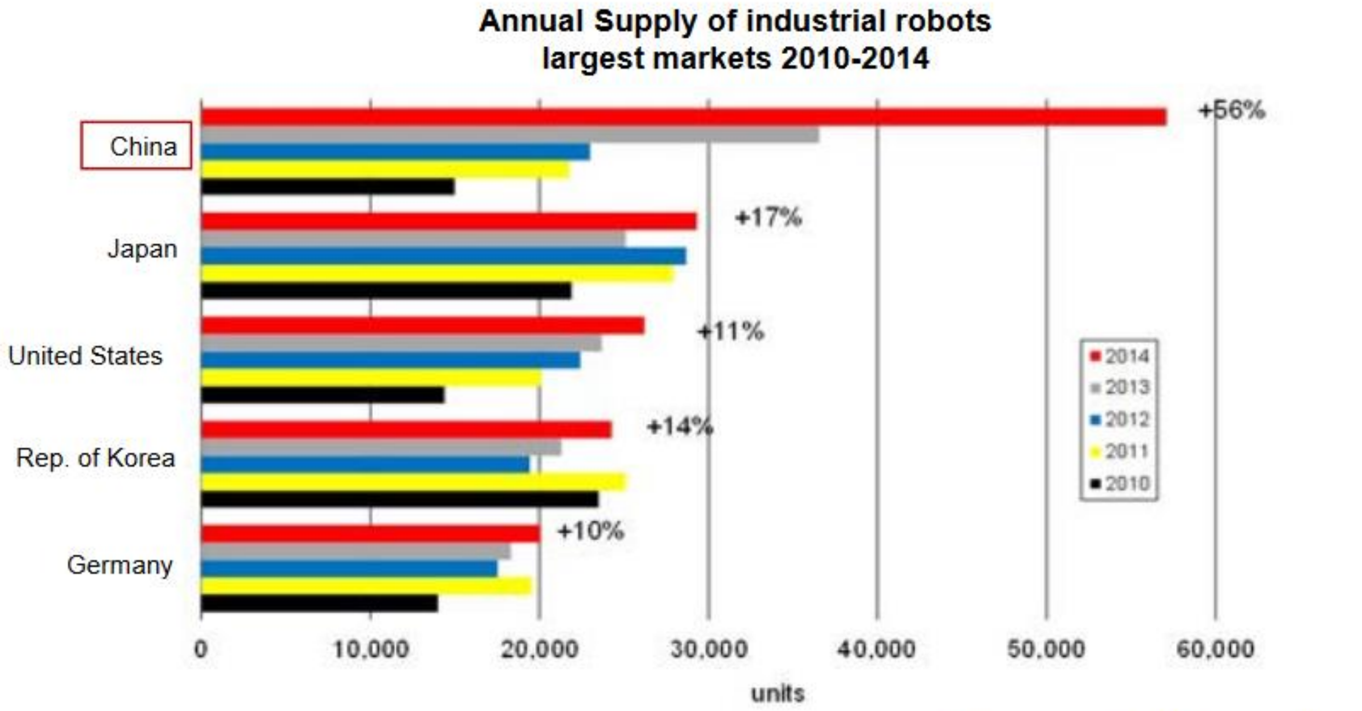
World Robotics Market



World Robotics Market

2014: **75%** of world supply goes to **5** markets





Source: IFR World Robotics 2015

http://www.bmwblog.com
https://www.technologyreview.com
https://www.roboticsbusinessreview.co

Robots: Requirements and Application Scenario

Why do we need robots?

- **4D Environments**
  - Dangerous
  - Dirty
  - Difficult
  - Dull

- **4A Tasks**
  - Automation
  - Augmentation
  - Autonomous
  - Assistance

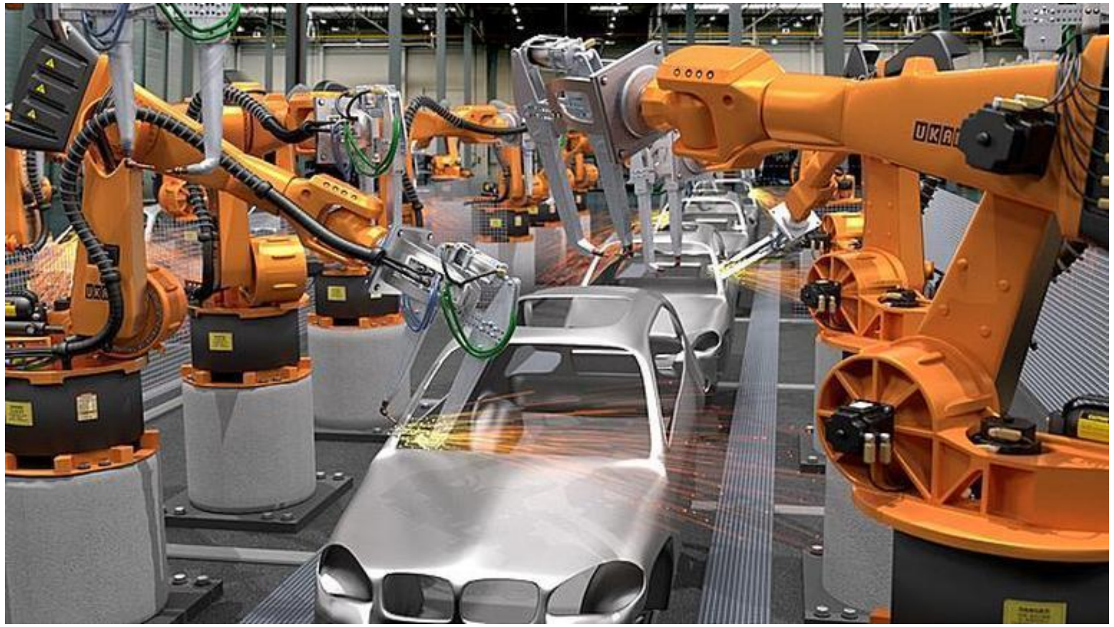
BMW
Car production line

Yumi, ABB
The world's first truly collaborative

Phoenix
Robotic exoskeleton ($40,000)

Kiva, Amazon
Logistic Robots

Industrial: The traditional industrial robot consists of a manipulator arm designed to perform repetitive tasks. An example is the Unimate, the grandfather of all factory robots. This category includes also systems like Amazon's warehouse robots and collaborative factory robots that can operate alongside human workers.

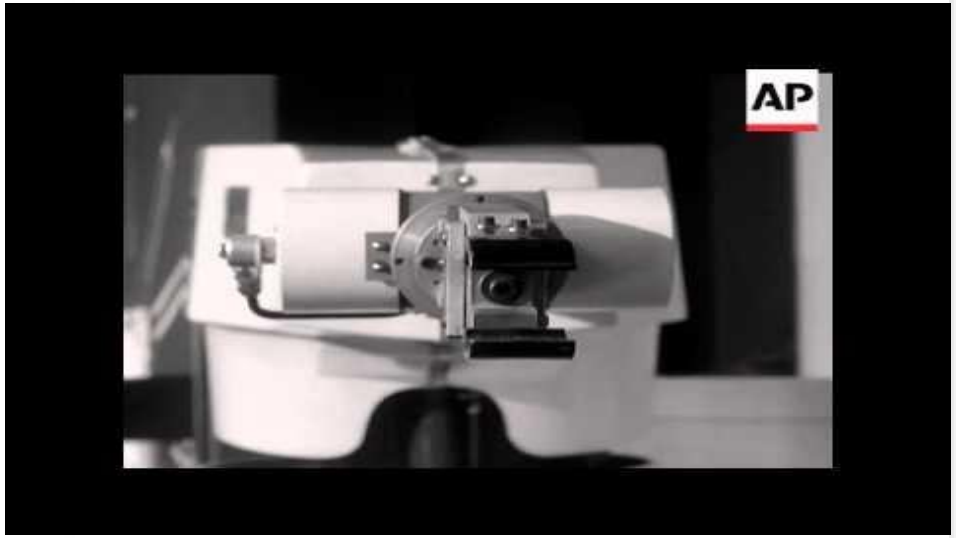


https://www.youtube.com/watch?v=hxsWeVtb-JQ

Origin and evolution toward industrial robot: The first industry robot

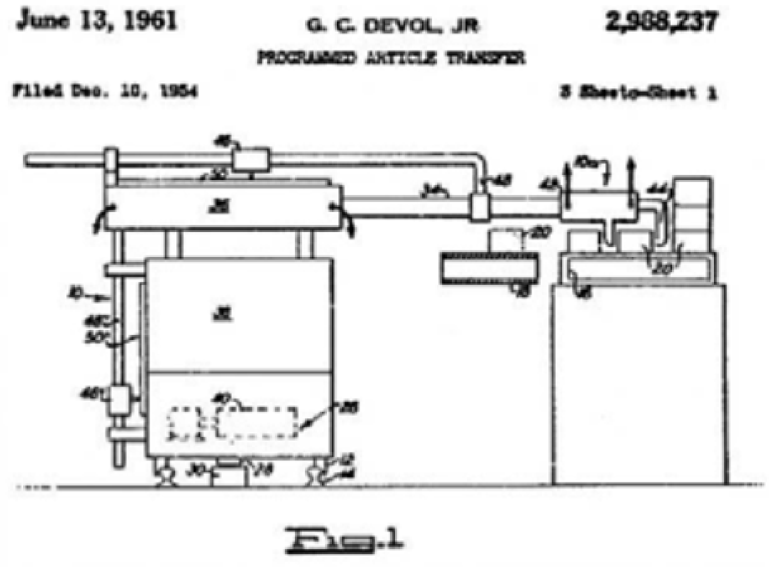
with respect to the ancestors, robot manipulators must…

- Flexibility of use
- Adaptability to a priori unknown conditions
- Accuracy in positioning
- Repeatability of operation



The first Unimate was installed at a GM plant in Trenton, New Jersey (1961)

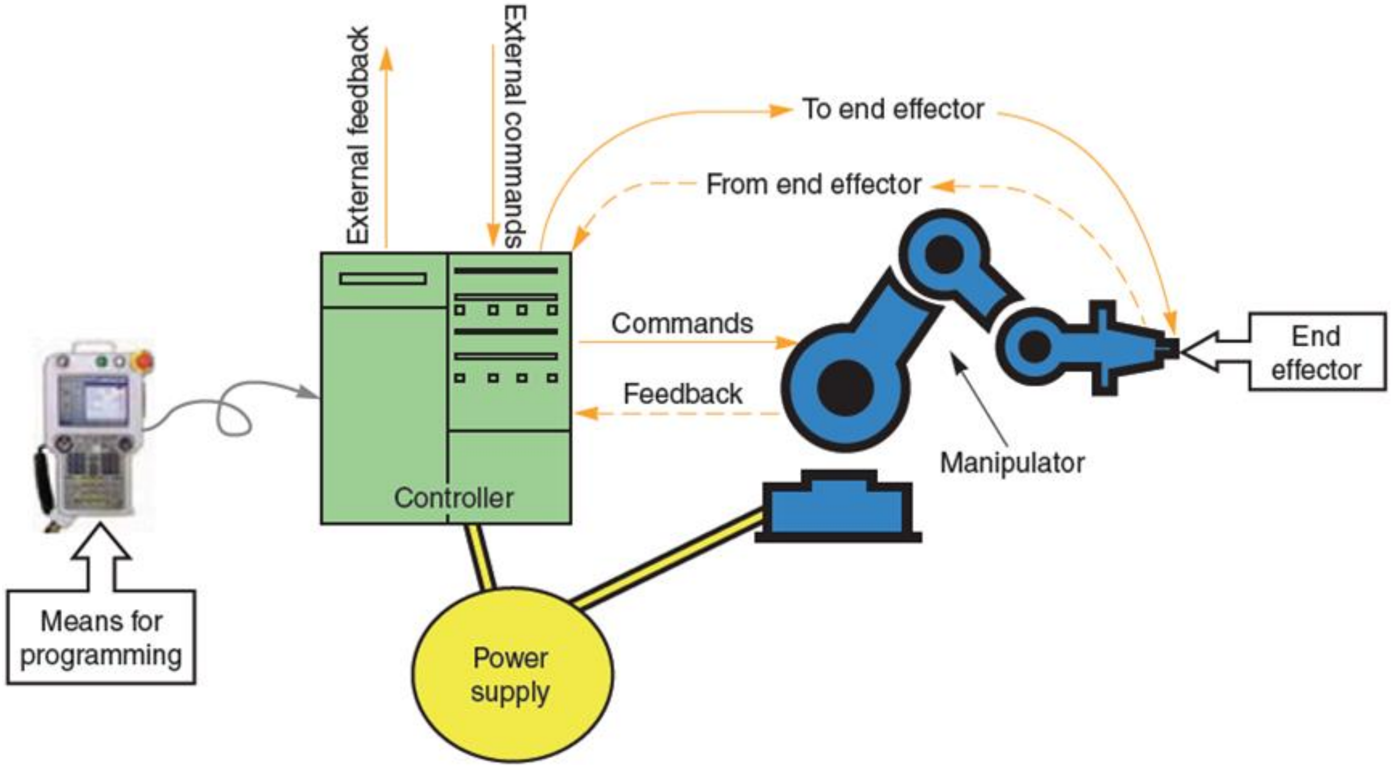
George Devol and Joseph Engelberger
(Unimation. Inc.)



Programmed Article Transfer
Patent Number: 2,988,237
(Applied, 1954; Issued, 1961)

UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

Anatomy of an industrial robot



Origin and evolution toward industrial robot: Milestones of Robot Manipulators

ASEA, IRB6
(1973)

The first fully electric, microprocessor controlled

Programmable Universal Machine for Assembly (PUMA)
(1978)

6 revolute joints with human-like dexterity

Hirata AR-300
(1978)

First SCARA robot

Demaurex, Switzerland
(1992)

The first Delta robot packaging application to Roland

Industrial applications

- **Typical industrial applications**

1) Arc welding
2) Spot welding
3) Material handling
4) Machine Tending
5) Spray painting and coating
6) Picking, Packing, and Palletizing
7) Assembly
8) Laser cutting, welding, and Polishing
9) Gluing, sealing, spraying materials
10) Other Processes (Inspection, waterjet)











UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

https://www.youtube.com/watch?v=fH4VwTgfyrQ&t=140s

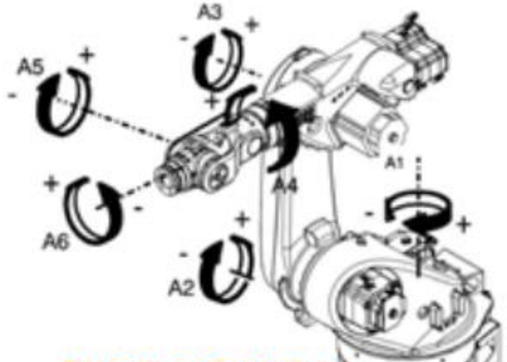
Industrial applications: The construction of a KUKA KR 500 R2830

Main Components of KUKA robot system:

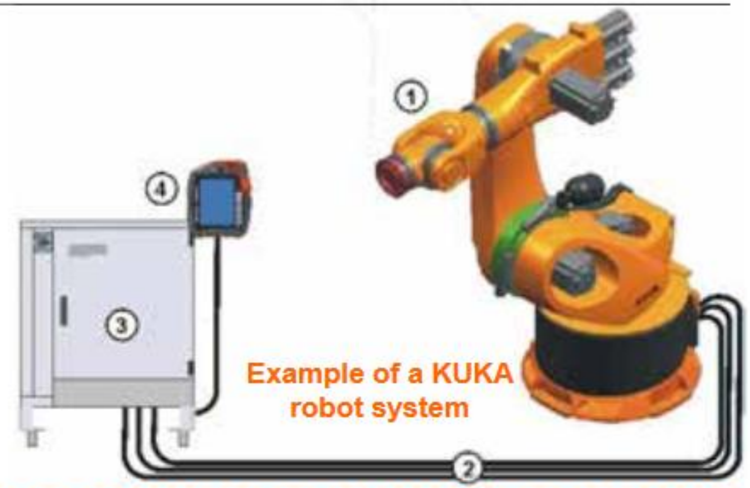
1. **Robot**
    1) Arm
    2) Electrical installations
    3) Rotating column
    4) Base frame
    5) Counterbalancing system
    6) In-line wrist
    7) Link arm
2. **Connecting cables**
3. **Robot controller**
4. **smartPAD teach pendant**

Others:

1. **Software**
2. **Options, accessories**

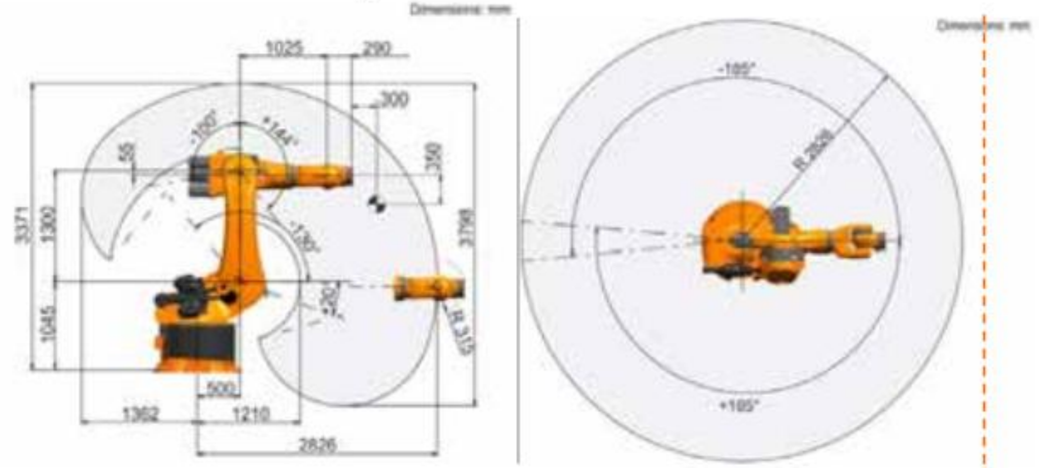


Direction of rotation of robot axes

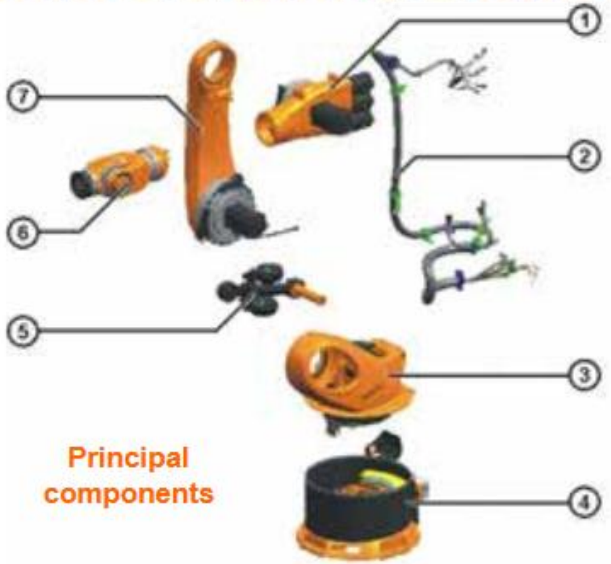


Example of a KUKA robot system

Source: https://www.kuka.com/



KR 500 working envelope , side view & top view



Principal components

Industrial applications: Inside of a KUKA, Robot

KUKA

KR AGILUS sixx

Payload [kg]: 3 – 10;
Reach [mm]: 706,7 – 1101;

KUKA

KR5

Payload [kg]: 5;
Reach [mm]: 1412;

How is made an industrial robot

https://www.youtube.com/watch?v=mADNlV1yCSo

End-effector

Definition End-effector:

Device that attaches to the wrist of the robot arm and enables the general-purpose robot to perform a specific task

- The end-effector means the last link (or end) of the robot
- In a wider sense, an end-effector can be seen as the part of a robot that interacts with the environment
- (That does not refer to the wheels of mobile robot or the feet of a humanoid robot which are not end effectors – they are part of the robot's mobility)

What could the robot do without End-effector?

Two types:
Grippers to grasp and manipulate objects (e.g. parts) during work cycle

Tools to perform a process, e.g., spot welding, spray, painting, 3D Printing, milling, cutting, measure

https://www.youtube.com/watch?v=5UkB7CbY2Uc

End-effector applications

Milling/Drilling

Specifications:
- Flexible Process, high Degree of Freedom, large work-pieces

Requirements:
- Precise trajectories required
- Positioning and orienting the milling tool
- Higher Degree of Freedom Robots

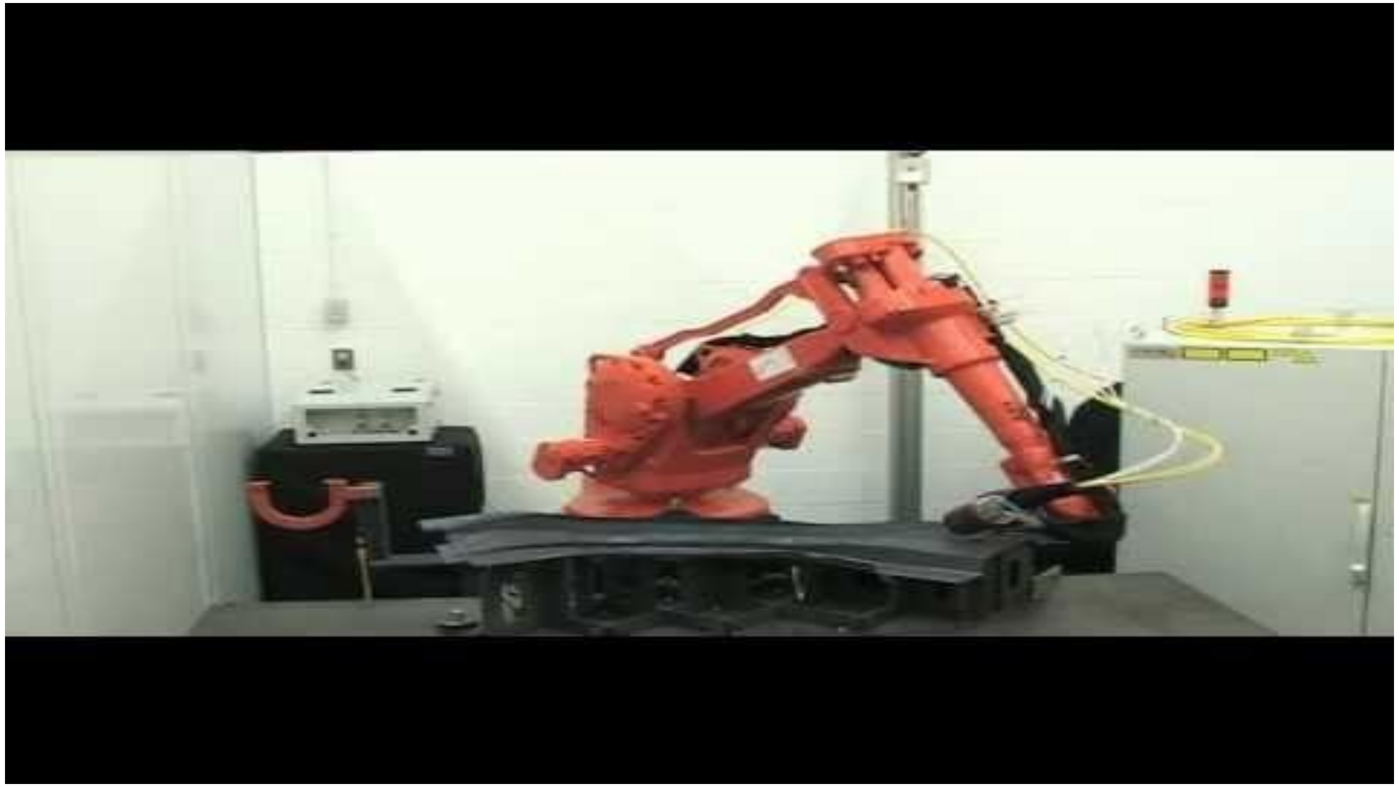
Problems:
- Lack of robot stiffness depending on the robot positioning in the Cartesian space

Solutions:
- Using free degree of freedom to optimize the stiffness over the desired milling path

https://www.youtube.com/watch?v=7k20Zp5aPjY

End-effector applications

Laser cutting



Specifications:

- Flexible laser orientation

Requirements:

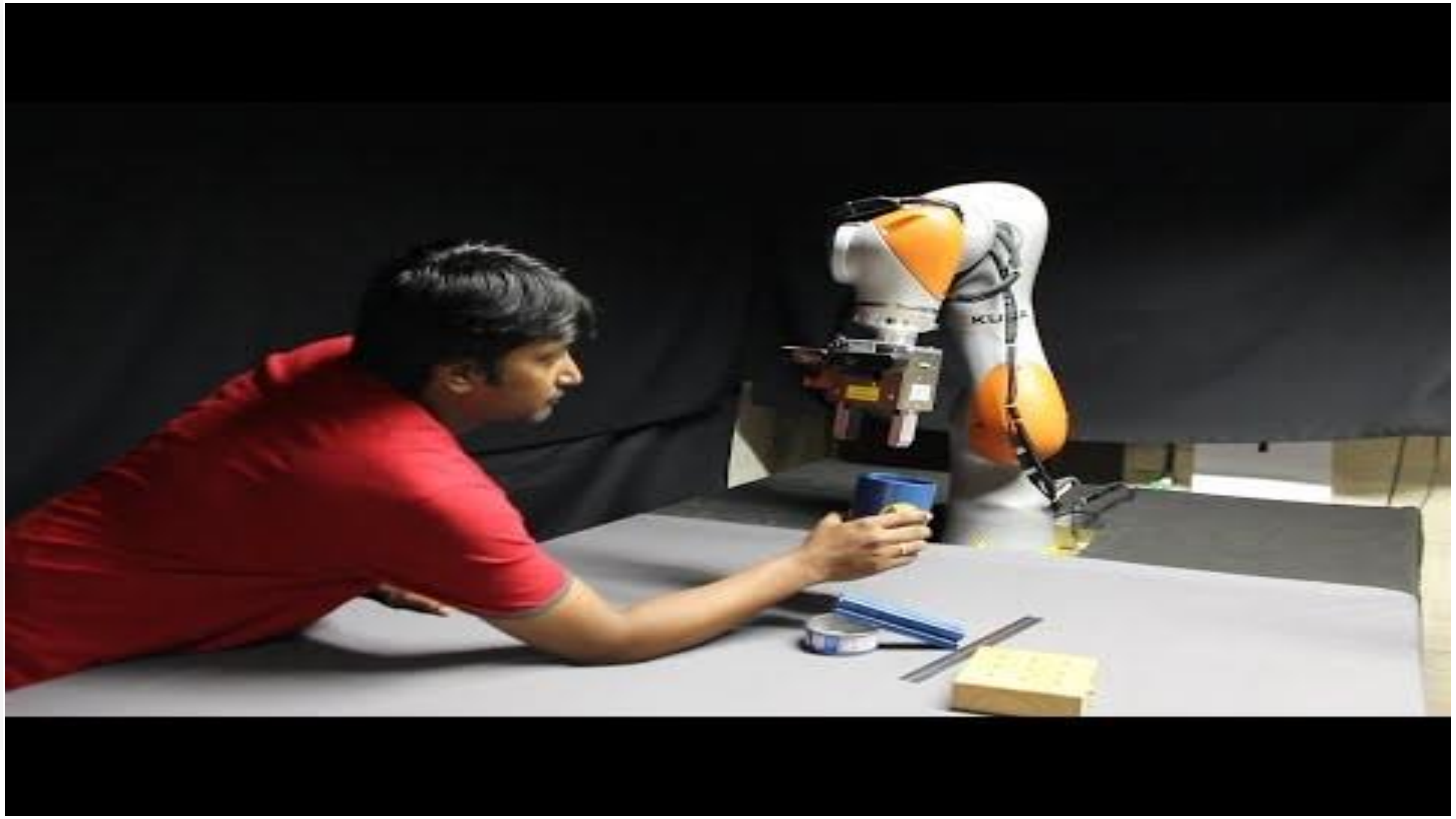
- Precise trajectories required
- Positioning and orienting the laser
- Higher Degree of Freedom Robots

Challenges:

- High accuracy required (use free Degree of Freedom for Optimization) https://www.youtube.com/watch?v=kzG-TxT4wd8

End-effector applications

Grasping



Specifications:
- Adaptive gripper position

Requirements:
- Reliable gripping of components
- Adaption to unknown object positions
- Sensitive Gripping process for different objects

Challenges:
- Identification of reliable object position and grasping pose
- Feedback about successful gripping operation
- Economic Pick and Place speed

https://www.youtube.com/watch?v=xqRbHCCdFB8

End-Effector Sensors

Applied Robotics™ Solutions in reach | ATI Industrial Automation | JR3 Multi-Axis Load Cell Technologies | ROBOTIQ

- Force-torque Sensors
  - Installed between the robot and the tool that interacts with the part
  - Measure the force and torque that the robot applies to the part through the tool
- Collision Sensors
  - To prevent damaging the robotic tooling and the parts being processed
  - Can disengage or send a message to the robot to stop at any moment when a collision is detected
- Vision Sensors
  - Video camera (2D), detecting movement to localization of a part
  - 3D vision system with 2 cameras at different angles or laser scanner
- Safety Sensors
  - Industrial robots in collaborative mode
  - Slow the robot down once a worker is in a vertain area and stop once the worker is too close
- Measurement probes

https://www.youtube.com/watch?v=EMvvB-_V0Eo
https://www.youtube.com/watch?v=9Wof8g-OO3w
https://www.youtube.com/watch?v=xjvzhvMTdTc

Tool Changer

Automatic tool changer for flexible, multi-tool applications which use only one robot.

https://www.youtube.com/watch?v=kDP-oofDn4w

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

https://www.youtube.com/watch?v=I-M1x6aWPs8

Industrial applications: How to use industrial robot

Industrial robot animation: Programming methods

Programming a robot

⇩ Online-Programming
- ⇩ Play-back
- ⇩ Teach-in

⇩ Offline-Programming

These are the way to program a robotic system for specific tasks.

https://www.youtube.com/watch?v=neWc5I9IdQ4

Top Industrial Robots

Human Robot Collaboration

https://www.youtube.com/watch?v=XVGfBgOhaqw

Classification of Robotic Structures

- Kinematic Topology Classification

Serial kinematic topology

- *Drives and links are connected serially*
- *All drives and links must be actuated by the preceeding drives*
- *There is only one kinematic chain from the ground frame (base) to the TCP*

Parallel kinematic topology

- *Several serial link & joint chains with one drive each are connected in parallel between the ground frame (base) and the TCP*
- *The drives are attached directly to the base and do not undergo any motion*
- *There is at least one closed kinematic chain*

Classification of Robotic Structures

- Kinematic Topology Classification

Serial kinematic topology

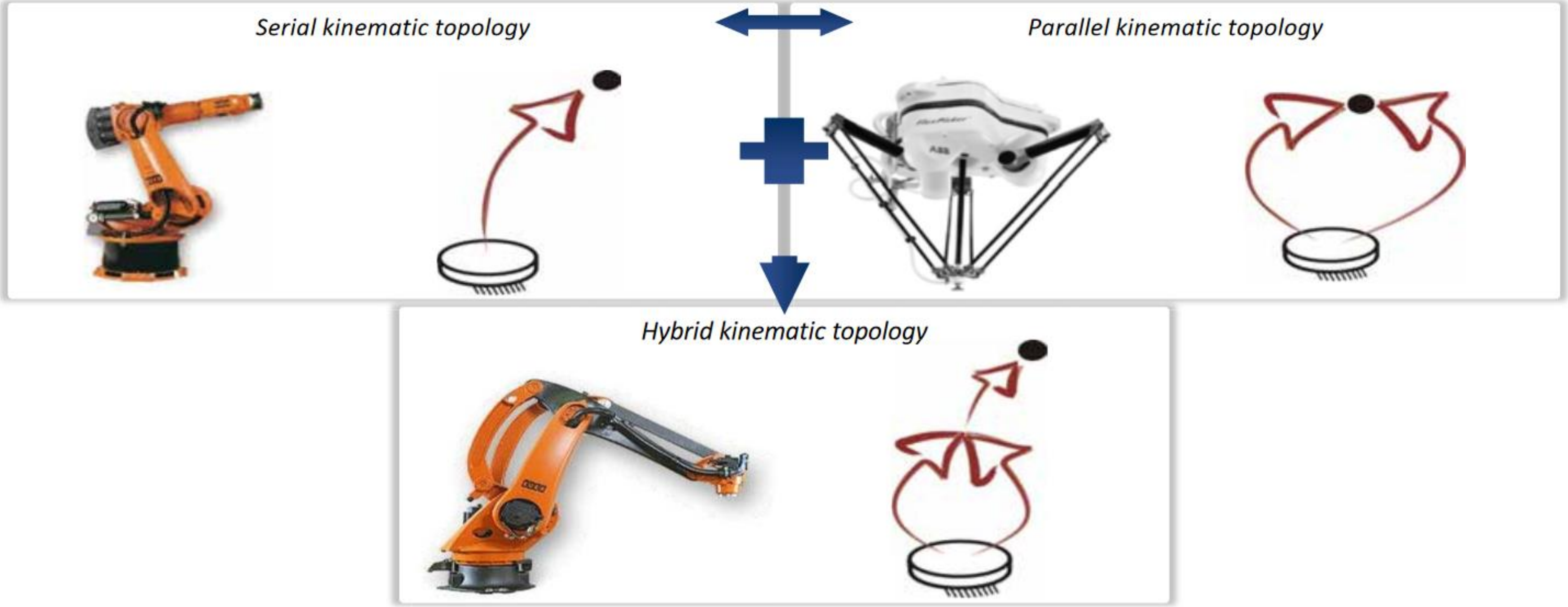
- *Large Workspace and easy maneuverability in a compact design space*
- *High payload requires large drives and sturdy links*
- *Moderate precision and dynamic performance*
- *Comparatively low stiffness due to the open kinematic chain*

Parallel kinematic topology

- *Small Workspace compared to the design space*
- *High payload and very good dynamic behavior with comparably small drives*
- *Very good precision due to the closed kinematic chains*
- *High precision even with lightweight design*

Classification of Robotic Structures

- Kinematic Topology Classification



Industrial Robots: Kinematic Structures

Serial and Parallel Manipulators

KUKA, KR 1000 titan

Serial kinematic chain
with rigid links connected by revolute joints

FANUC Robots, M-2000iA

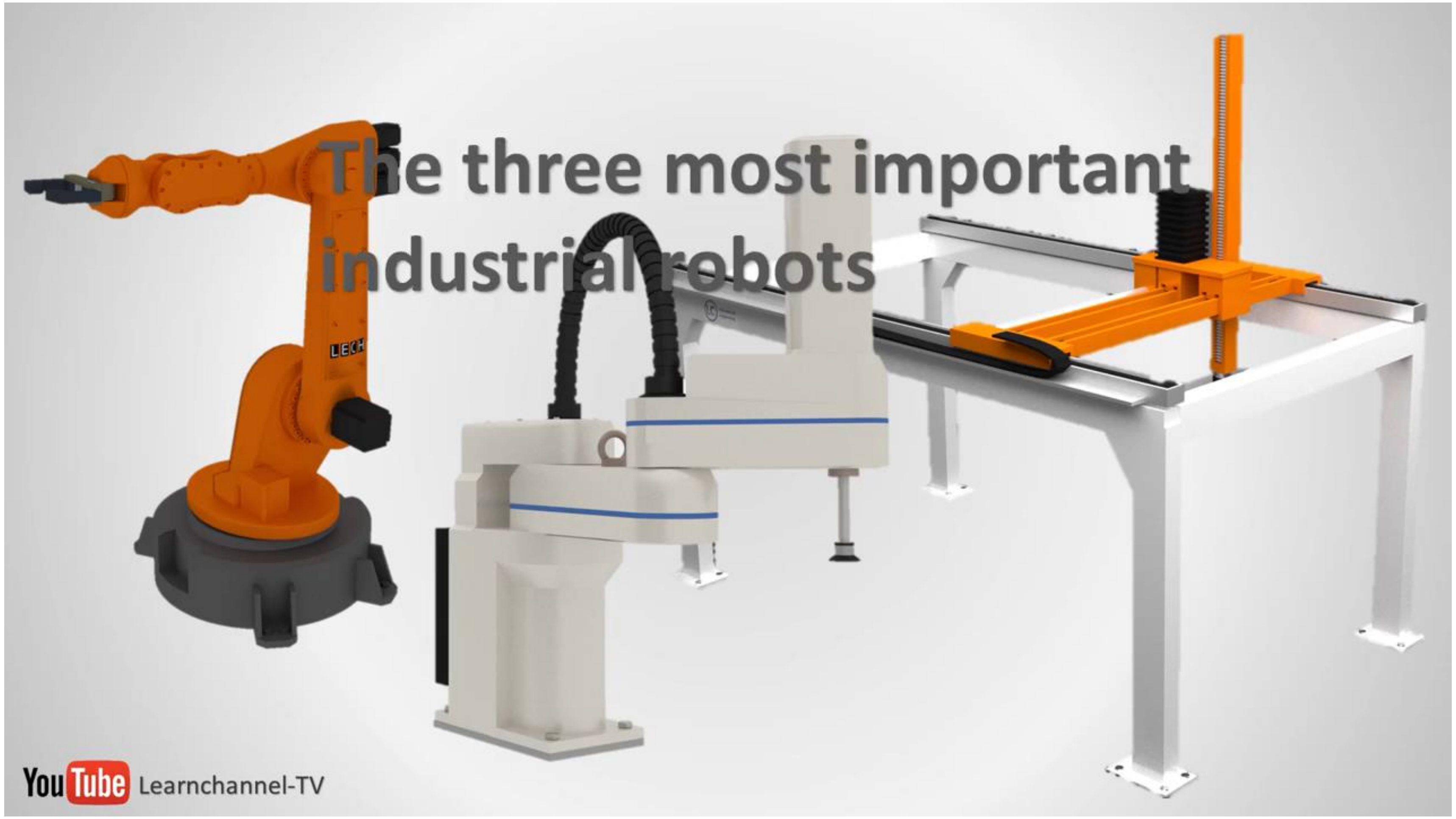
Close kinematic chain
with partial closed-loop plane kinematic chain formed a Parallelogram Five-bar Mechanism

FANUC, F-200iB

Parallel kinematic chains
Stewart Platform with six electronic telescopic rods

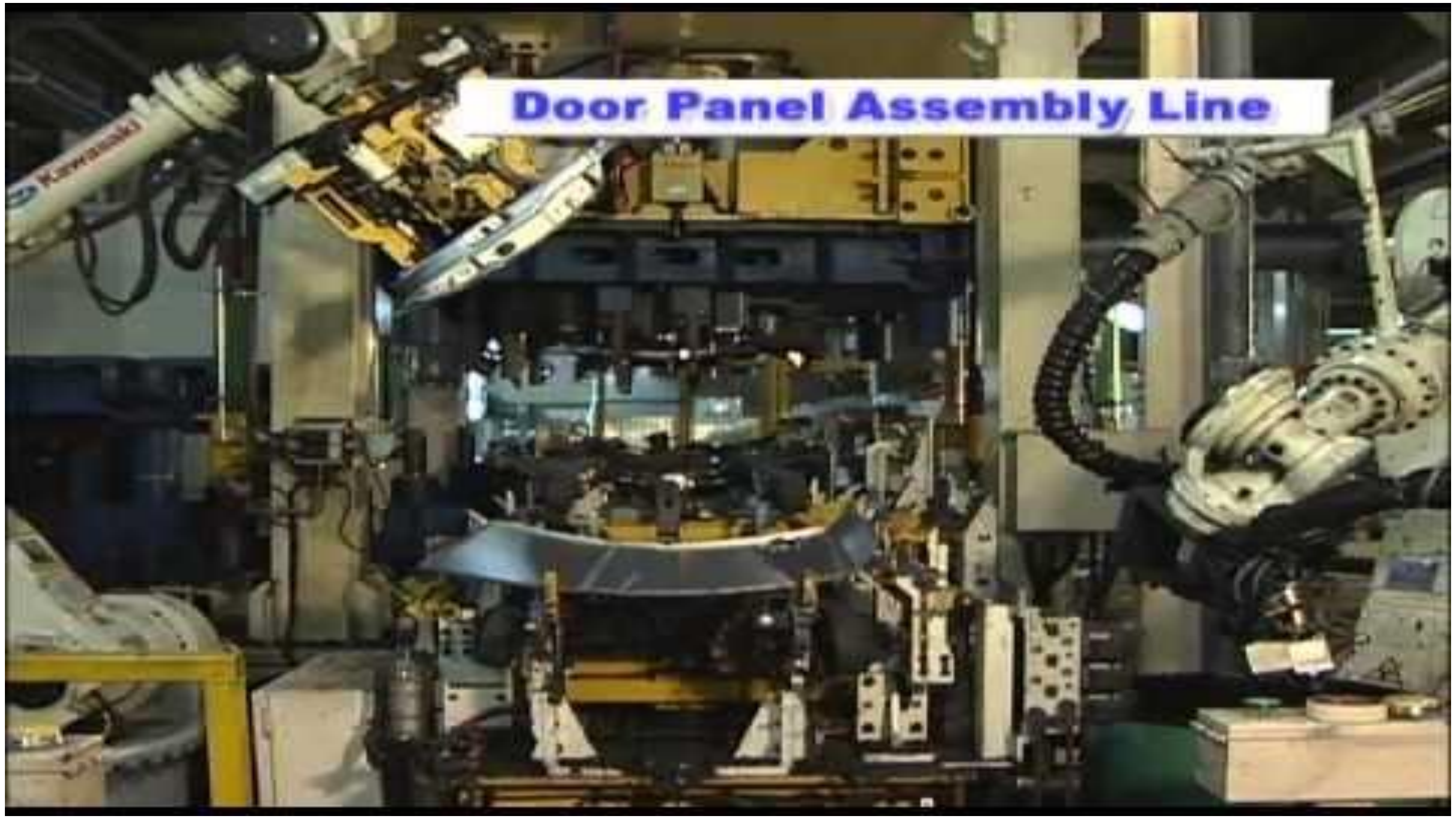
https://www.youtube.com/watch?v=FORcPhBaa50&list=PLKyLX1dBFAo2hTHojzmOQOqjcHwTvWvLX

Most important robots

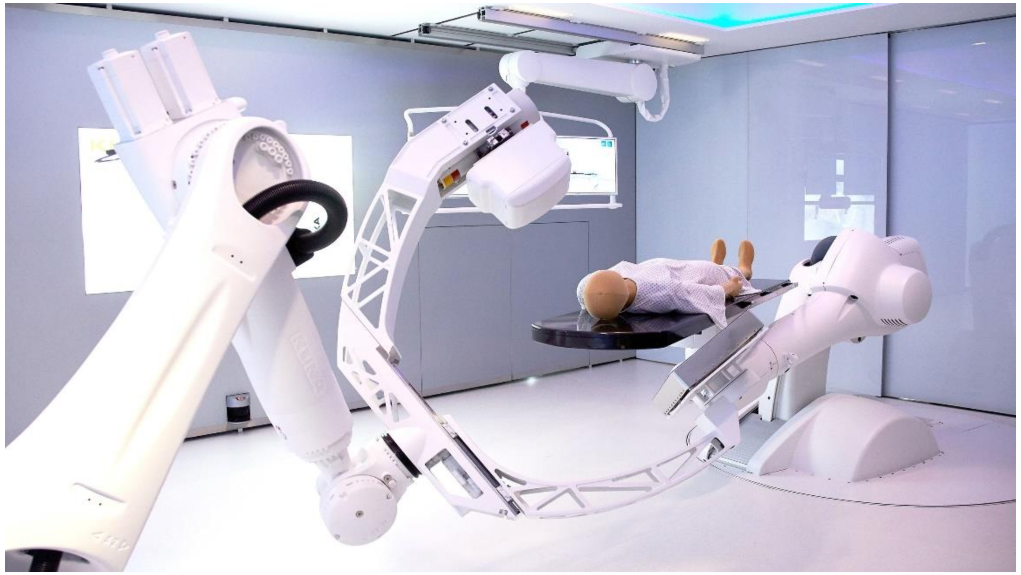


Example of production line

Typical applications of **industrial robots** include welding, painting, ironing, assembly, pick and place, palletizing, product inspection, and testing, all accomplished with high endurance, speed, and precision.



Medical: Medical and health-care robots include systems such as the da Vinci surgical robot and bionic prostheses, as well as robotic exoskeletons. A system that may fit in this category but is not a robot is Watson, the IBM question-answering supercomputer, which has been used in healthcare applications.

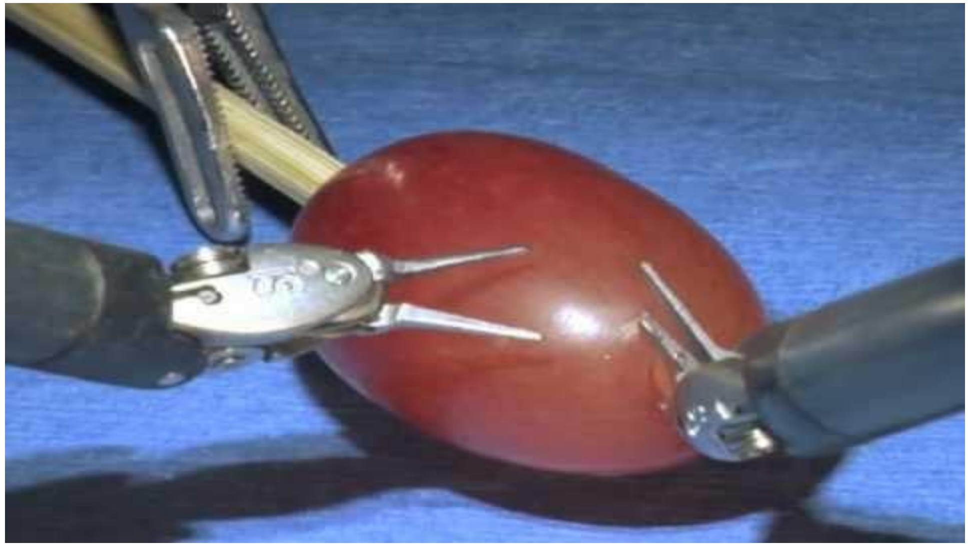


Robotic imaging and automated surgery

https://www.youtube.com/watch?v=XhvHU99ib0o

UNIVERSITÄT HEIDELBERG
ZUKUNFT
SEIT 1386

Tele-operated surgical system



- Master Slave configuration
- High accuracy in movement
- Stereoscopic console
- No haptic feedback
- Safety is done by scaling surgeon´s movement

https://www.youtube.com/watch?v=CacWd64RJhM

UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

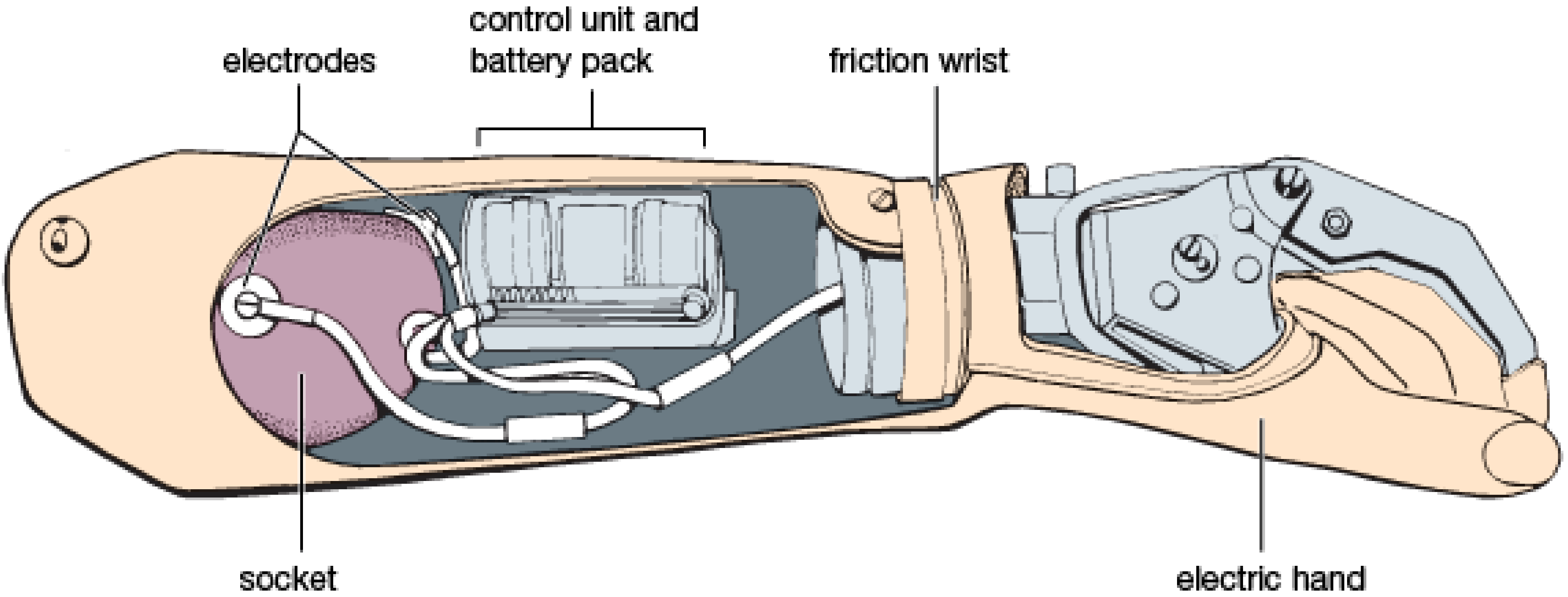
Myoelectric control and prosthetics

ottobock.

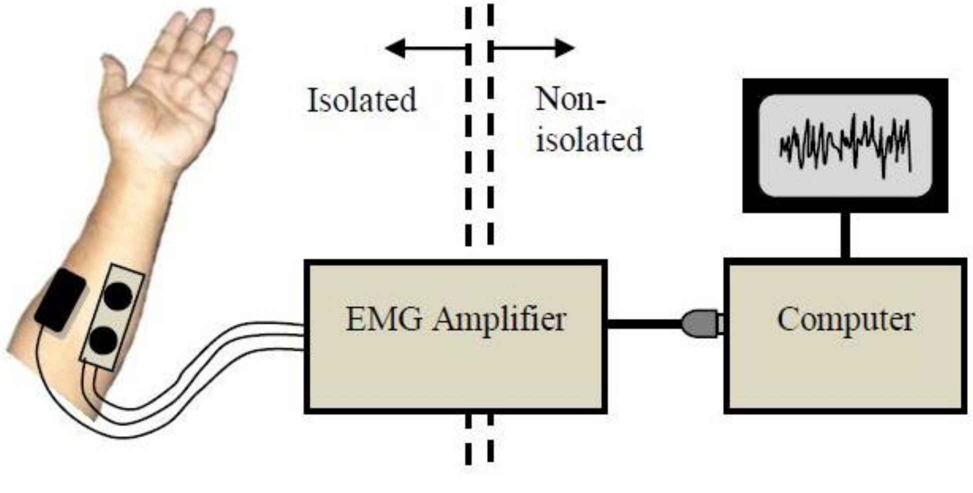
ÖSSUR®
LIFE WITHOUT LIMITATIONS

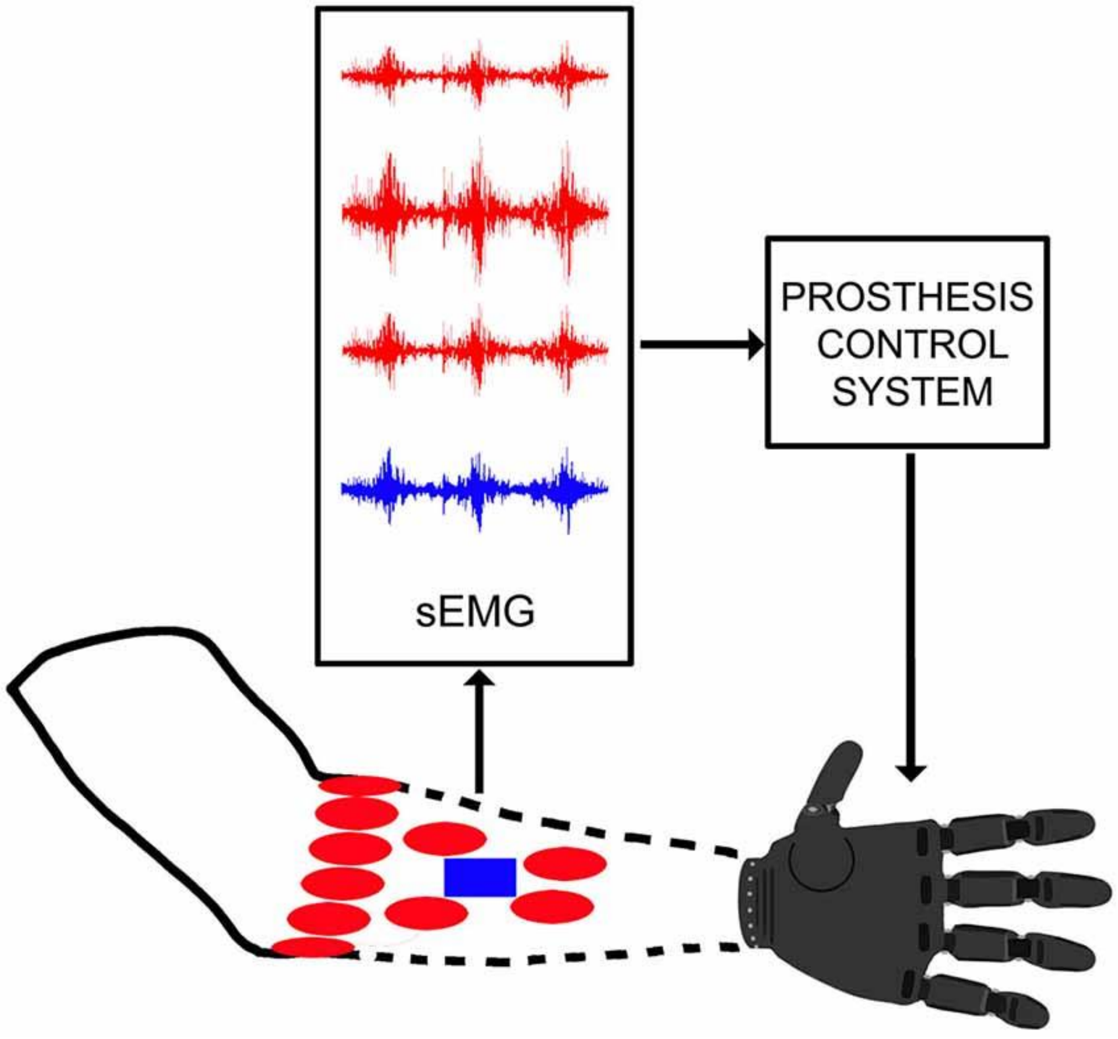
How is made a prostheses?

Parts of a below-elbow myoelectric prosthesis



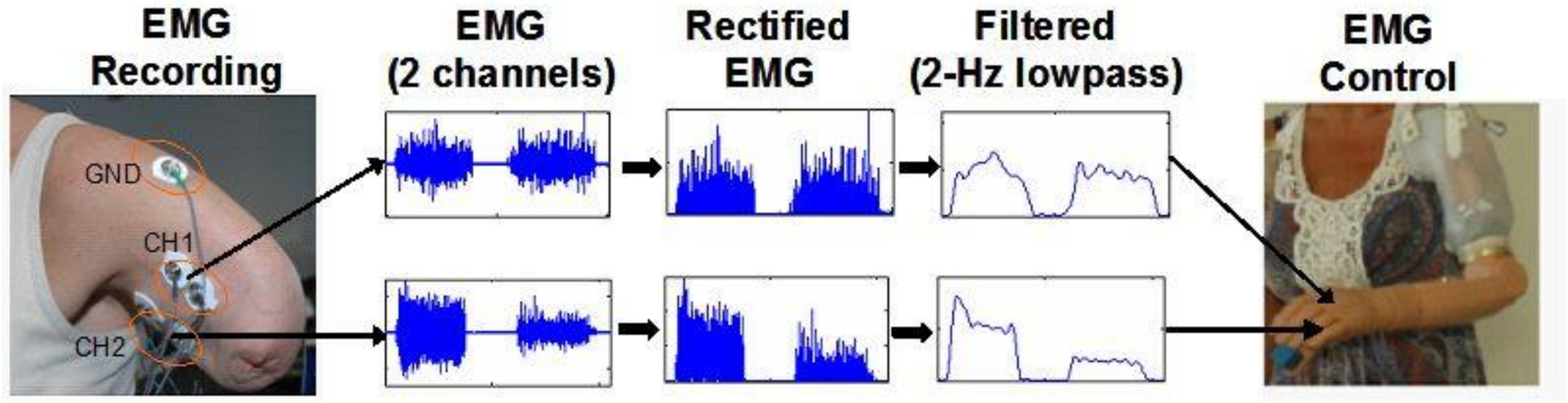
Raw Signals from muscles



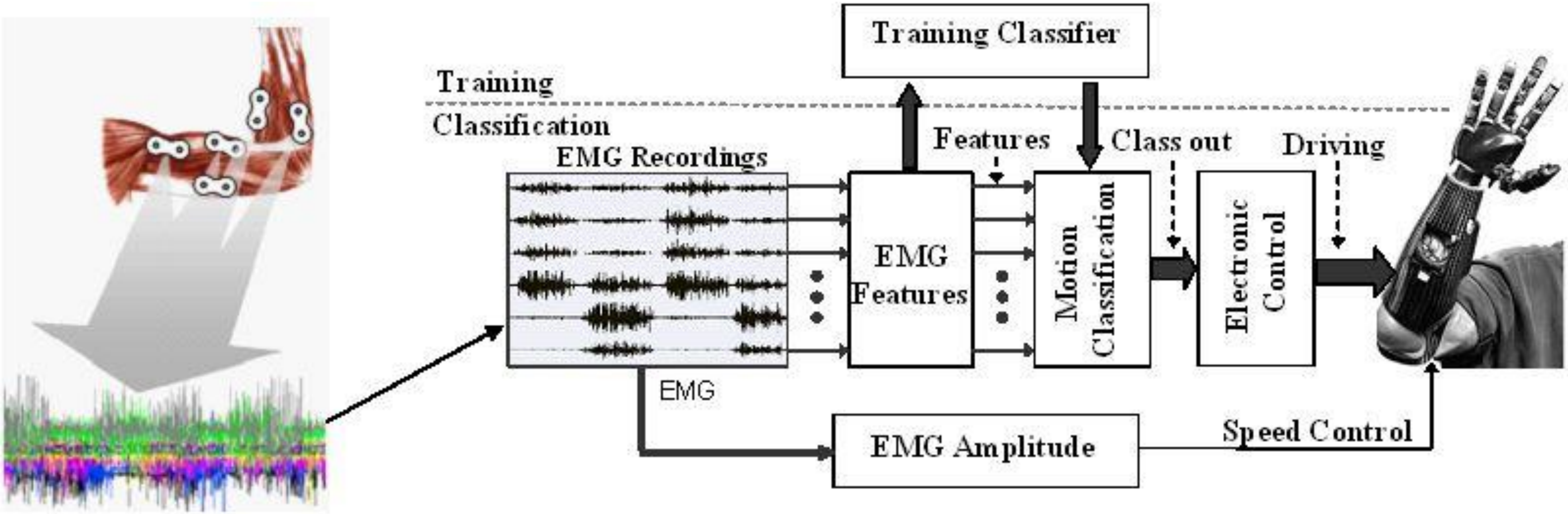


Wireless signals

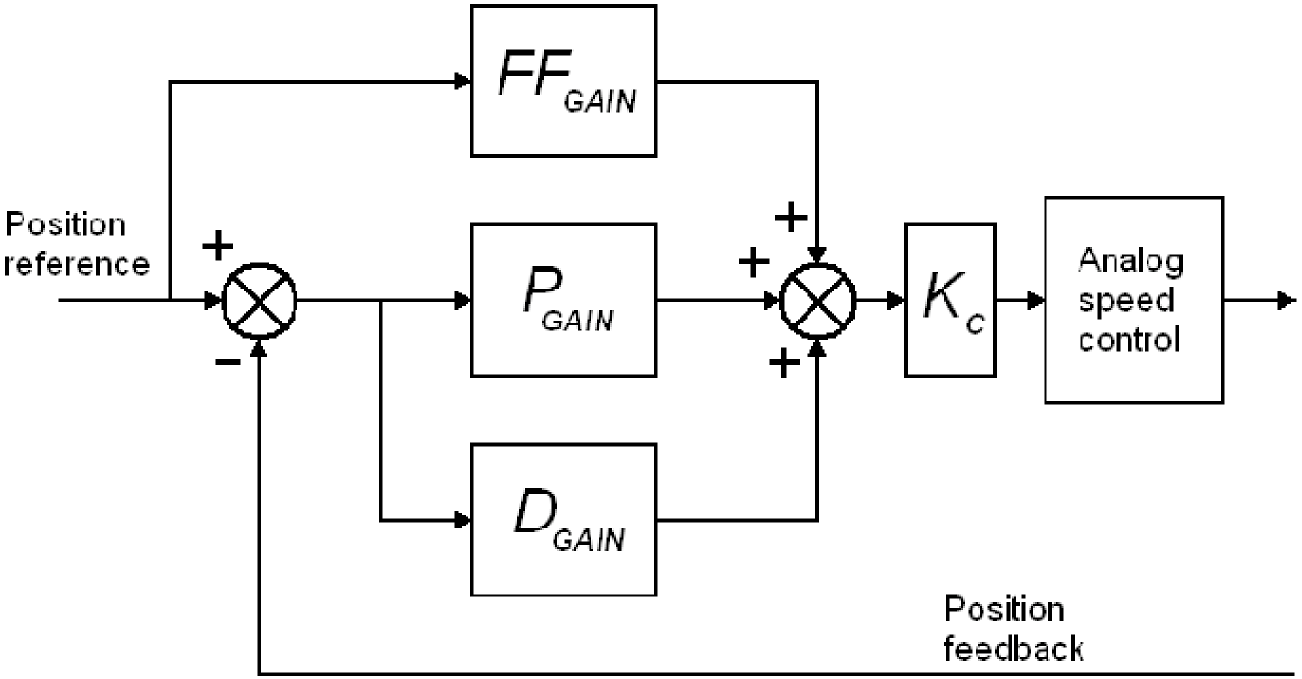
Detection of Muscle signals



Myoelectric control and classification



Typical controller for prostheses



http://research.vuse.vanderbilt.edu/cim/research_arm.html

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

VANDERBILT SCHOOL OF ENGINEERING

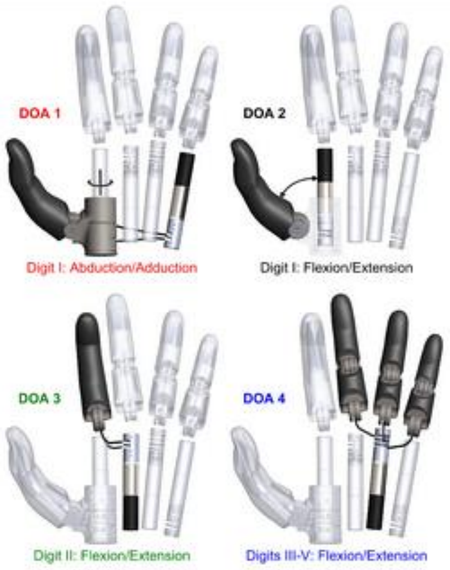
Background

- The human hand is highly articulated, possessing approximately twenty major degrees of freedom which allow it to execute a wide variety of grasps and postures
- Traditional hand prostheses possess only a single degree of freedom

- The majority of upper extremity amputations are the result of traumatic injury, and tend to effect a relatively young and active population
- Amputee surveys indicate that greater articulation and functionality are among their top priorities for prosthetic development
- Functionality may be indicated by the ability to perform the activities of daily living, which determines an individuals level of independence and quality of self-care
- Recent technological advances have made possible multigrasp prosthetic hands which have enhanced potential to restore normal biomechanical function

- *The full realization of this potential requires the development of an effective multigrasp control interface which enables the user to access the capability of the multigrasp prosthesis in an intuitive, reliable, and robust manner*

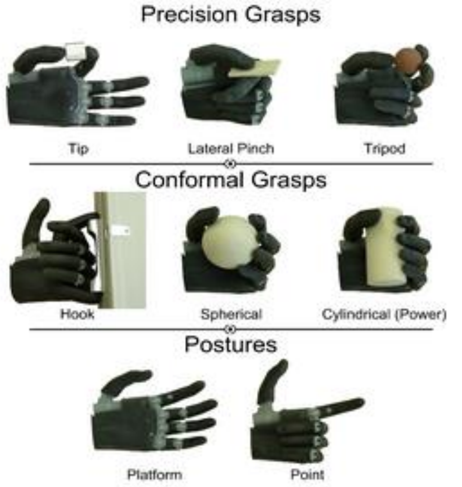
Structure and Actuation



Schematic of each DoA and the corresponding DoFs

- 4 motor/pulley systems drive 9 degrees of freedom (DoF) via tendon actuation
- Fully actuated DoFs in digits I and II facilitate precision grasping
- Underactuated DoFs in digits III-V facilitate conformal grasping
- 2-way clutch on each motor unit maintains constant force with no electrical power
- Commutation and position control for brushless motors provided by integrated servoamplifier
- Battery and high level control located in socket
- Structure composed of two materials built with additive manufacturing:
  - ABS-like skeleton for support and strength
  - Rubber-like skin for appearance and grip

Grasps and Postures



Prosthesis performing the 8 grasps and postures typically used for most ADLs

Assembled hand with cover removed:
Left: bottom of hand with 4 brushless DC servomotors
Right: top of hand with servoamplifier circuit board

Hand Specifications

Mass:	546 g
Length:	20 cm 85th Percentile Male
Breadth:	8.9 cm 35th Percentile Male
Max Grip Force:	45 N
Battery Life:	~2100 grasps

- Mass includes motor and servoamplifier, but not battery
- Length measured from base of palm to tip of digit III
- Breadth measured across widest portion of palm
- Max grip force based off measurements shown in fingertip plot
- Battery life estimated from the average power required for one grasp and the capacity of the Li-Po battery used

Functional Assessment (SHAP)		
Index of Function		87
Functionality Profile (FP)	Pow.	85
	Sph.	90
	Ext.	90
	Trip.	82
	Lat.	89
	Tip	78

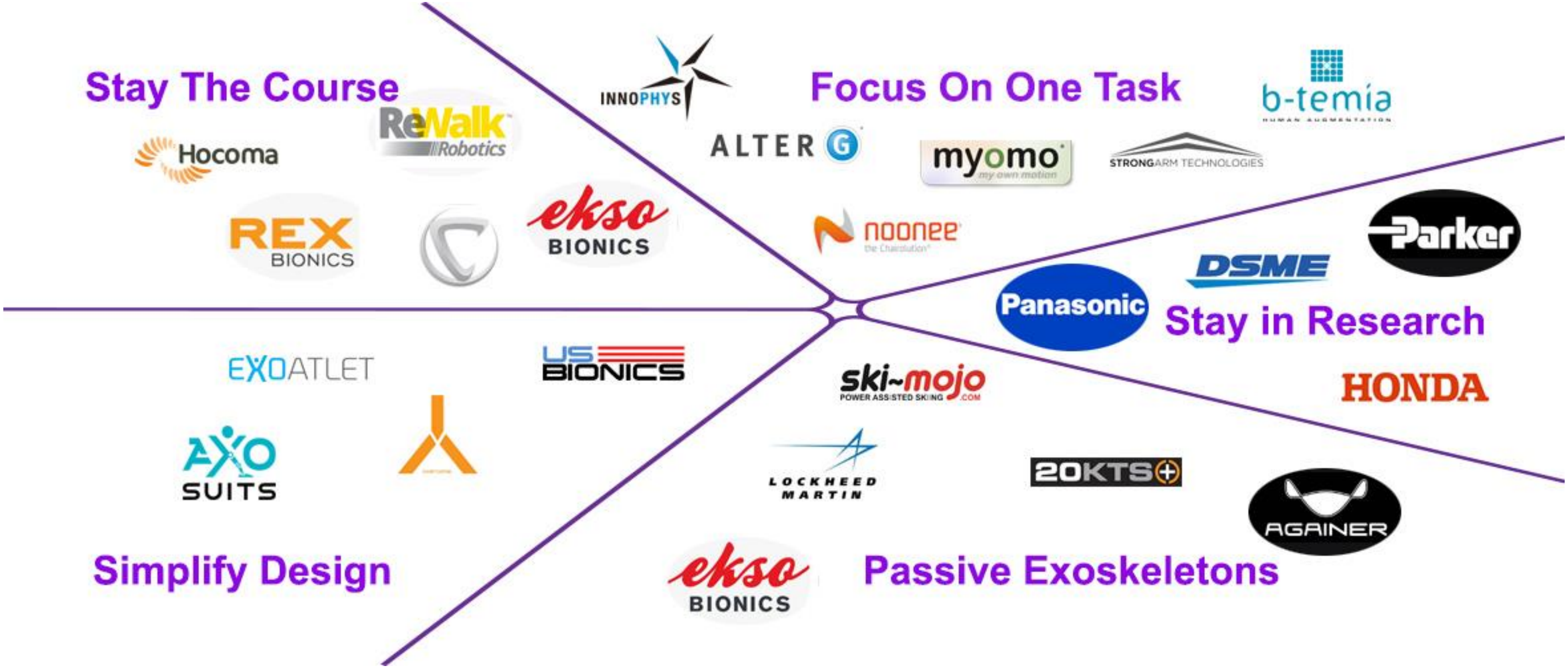
The "Deus Ex Machina" of Prosthetics
Hugh Herr (MIT)

https://www.youtube.com/watch?v=PLk8Pm_XBJE

Exoskeletons: Robotic exoskeletons can be used for physical rehabilitation and for enabling a paralyzed patient walk again. Some have industrial or military applications, by giving the wearer added mobility, endurance, or capacity to carry heavy loads.

- Designed of human assistance in clinical scenarios or for human augmentation.
- They use electromechanical actuators in parallel with the human biomechanics.
- The control is mostly based on passive motion because it is designed for complete SCI (spinal cord injury) patients or sever stroke.

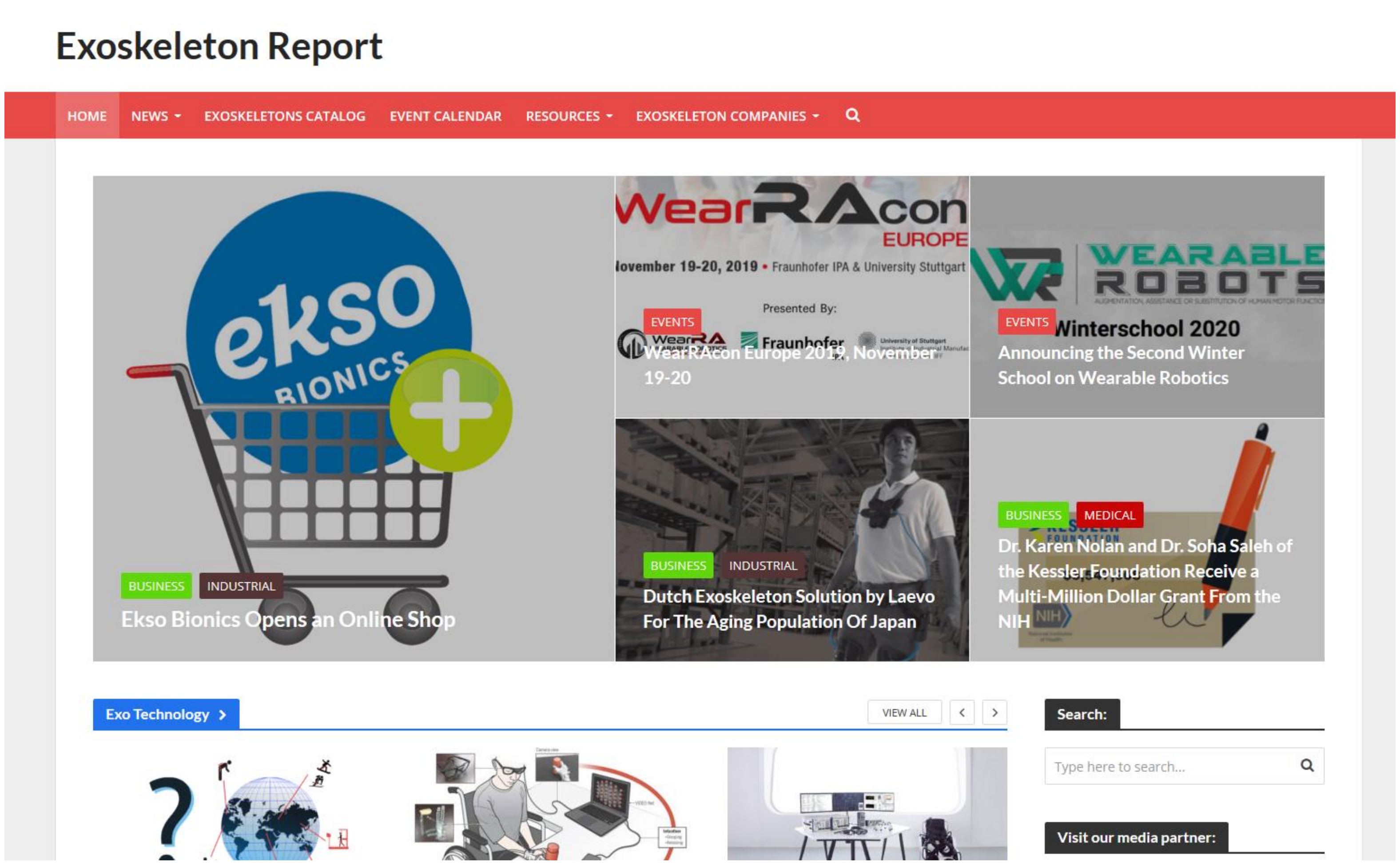
Commercial exoskeletons



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

An interesting website

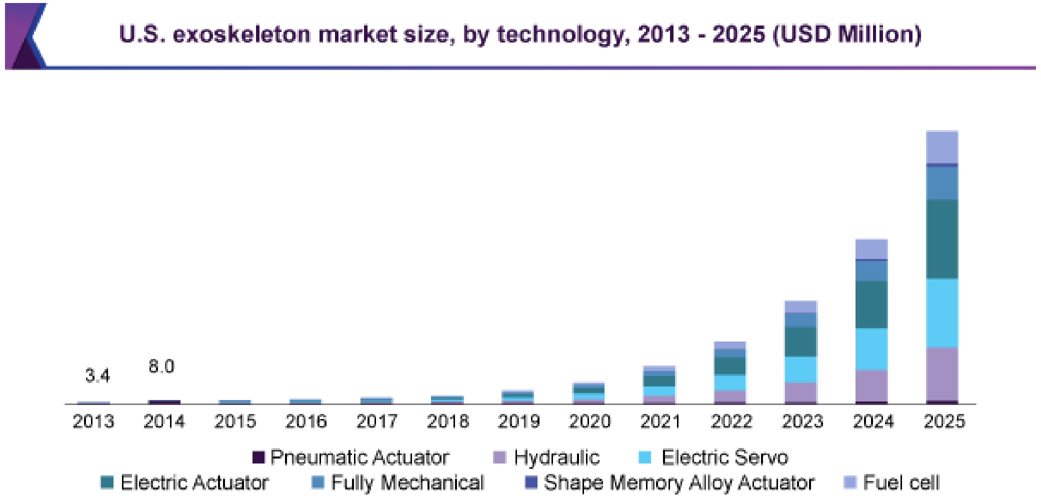
https://exoskeletonreport.com/

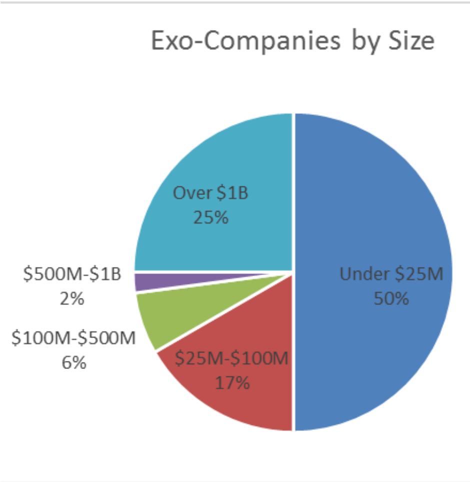


UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

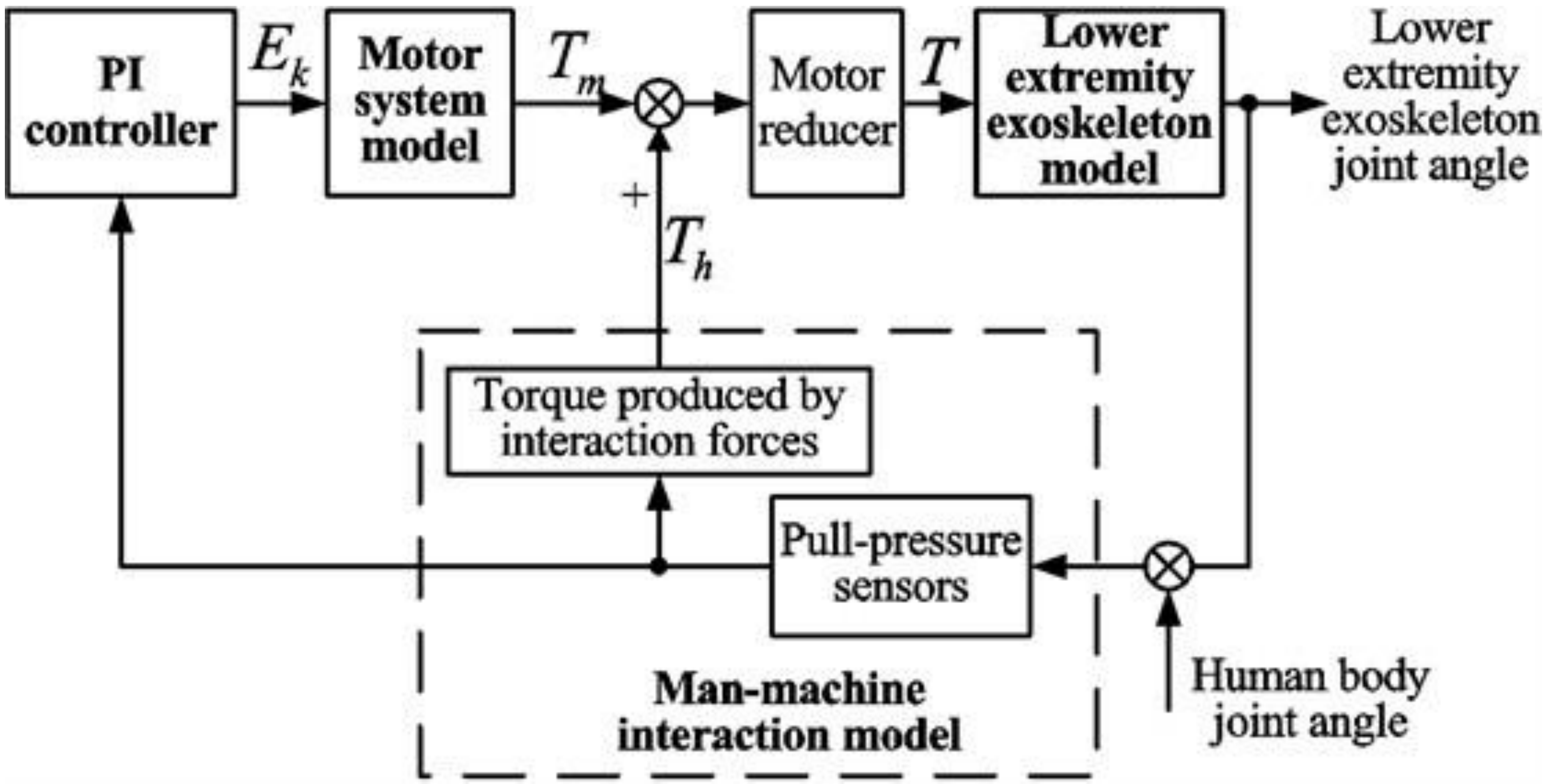
Example of lower limb exos

https://www.youtube.com/watch?v=nKv81nGJ0tM



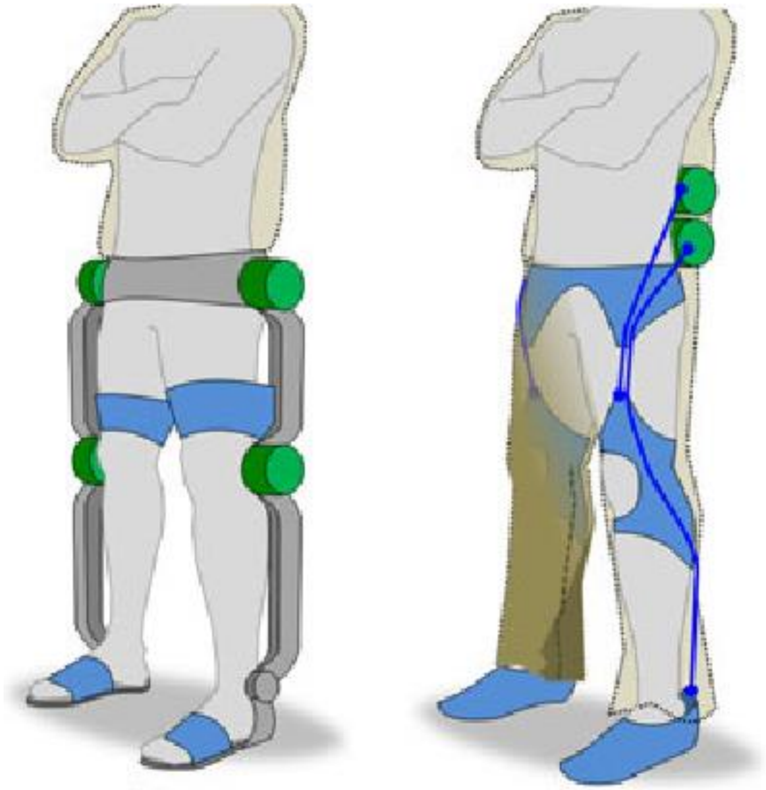


How is it controlled a lower limb exos?



Exoskeleton in production (sci-fi for now)

Exosuits (check Harvard Biodesign Lab)

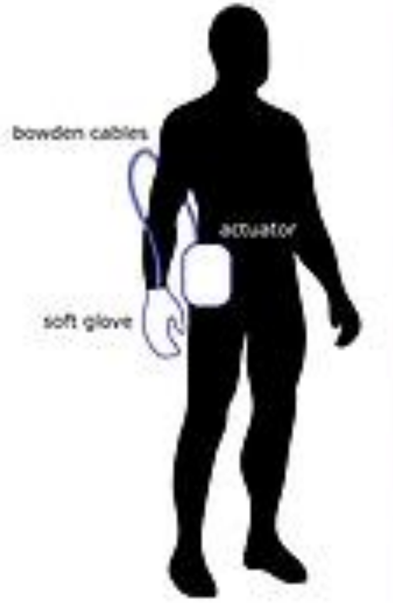


https://www.youtube.com/watch?v=aeDm5yFYt10

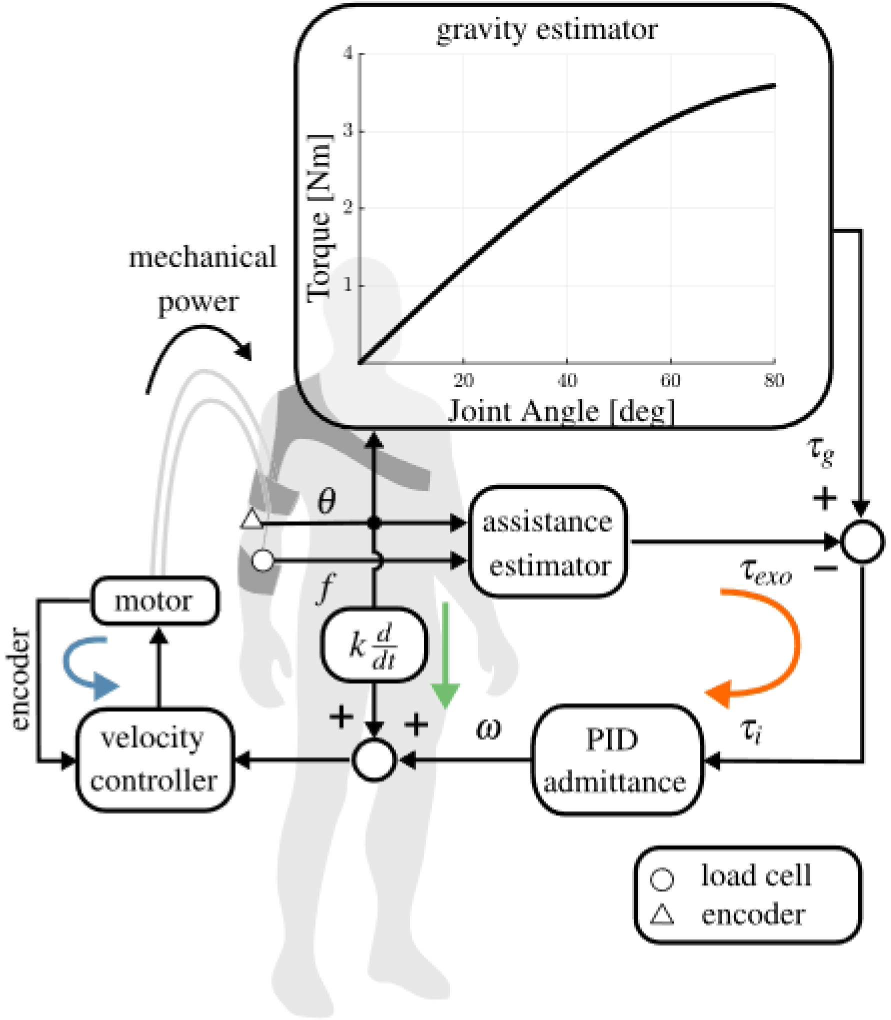
UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

Exosuits (in Heidelberg)

https://www.lorenzomasia.com/projects

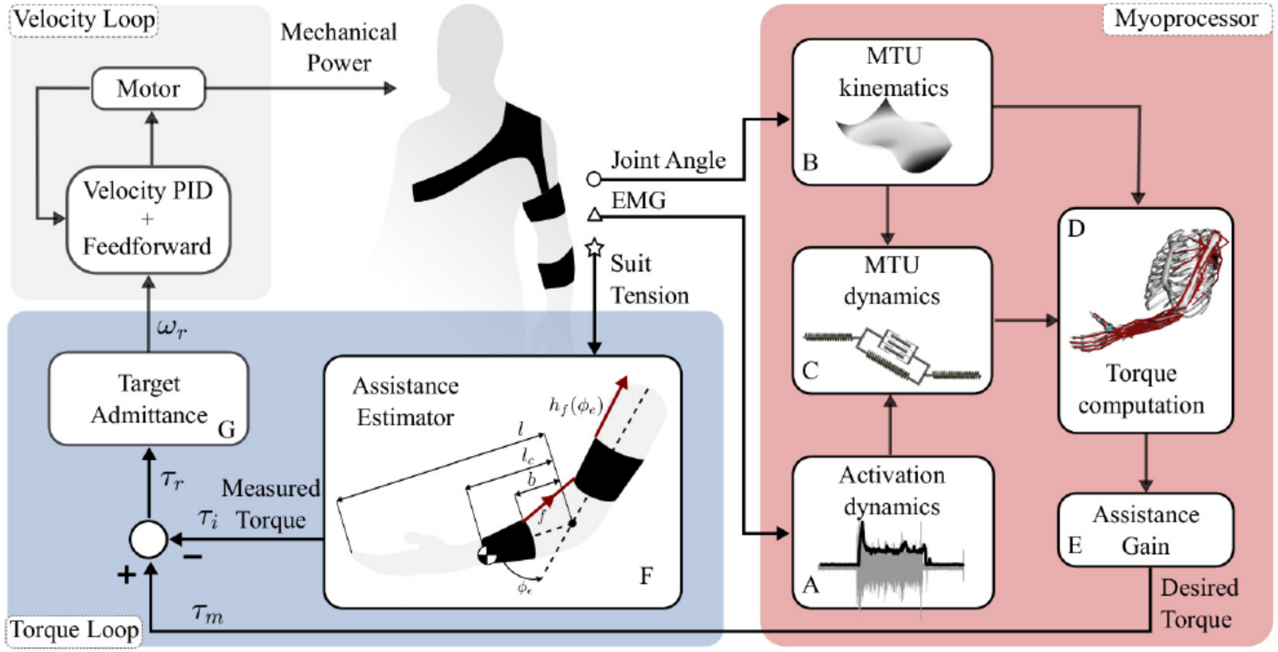


Controlling an exosuit

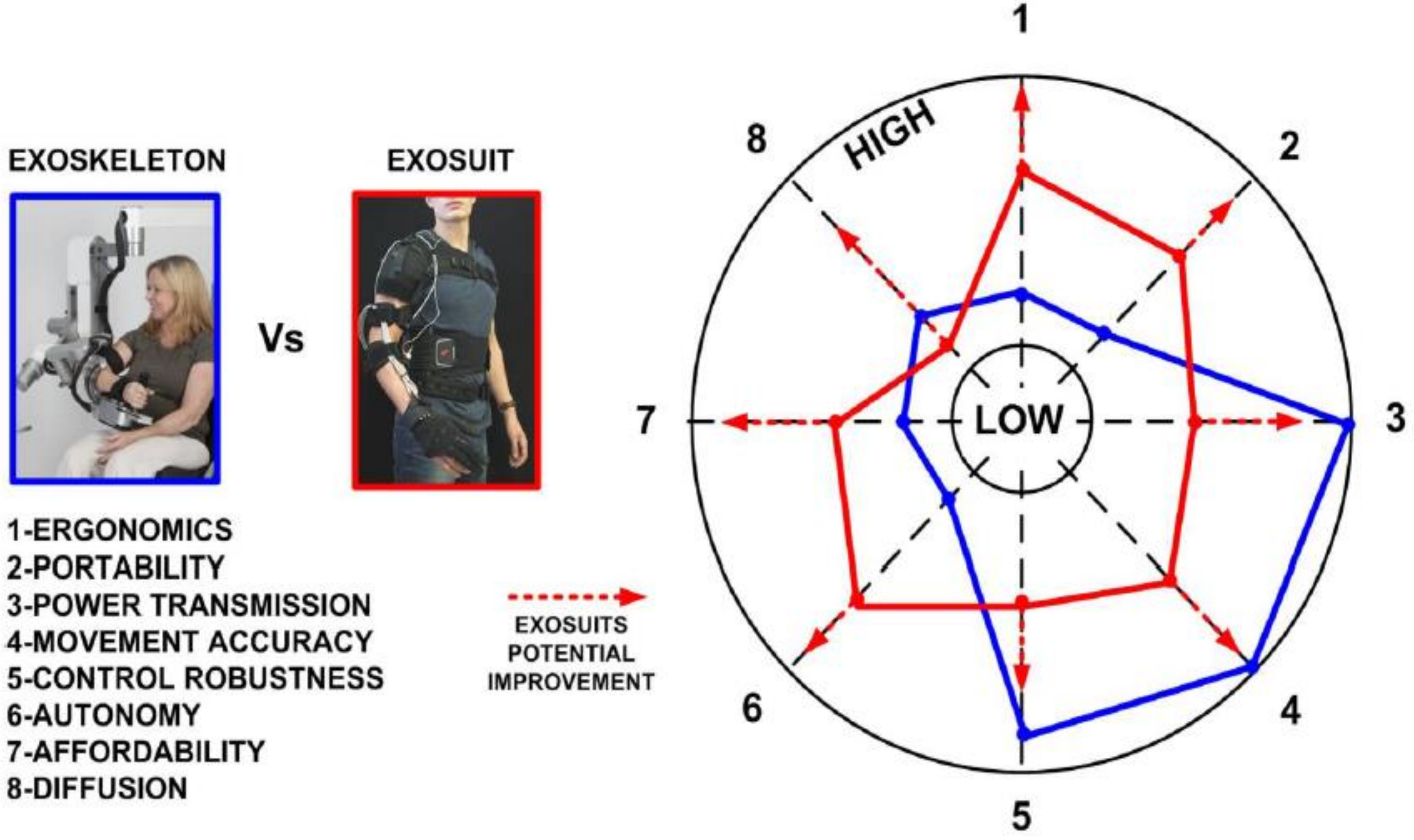


UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

Controlling an exosuit via EMG



Exoskeletons Vs Exosuit



Human machine interaction controller

https://www.youtube.com/watch?v=F1zXnPDfTgM&fbclid=IwAR1_3gX
tP6Vyzrgd7rXBP5tDD7HQgvHIqUiHnj0x5UbhOB085QUqyd7xYTg



Research: The vast majority of today's robots are born in universities and corporate research labs. Though these robots may be able to do useful things, they're primarily intended to help researchers do, well, research. So although some robots may fit other categories described here, they can also be called research robots.

These kind of platforms are developed for universities and labs.
The idea is to share technology for implementing new control schemes and new hardware.

Icub (IIT, Italy)

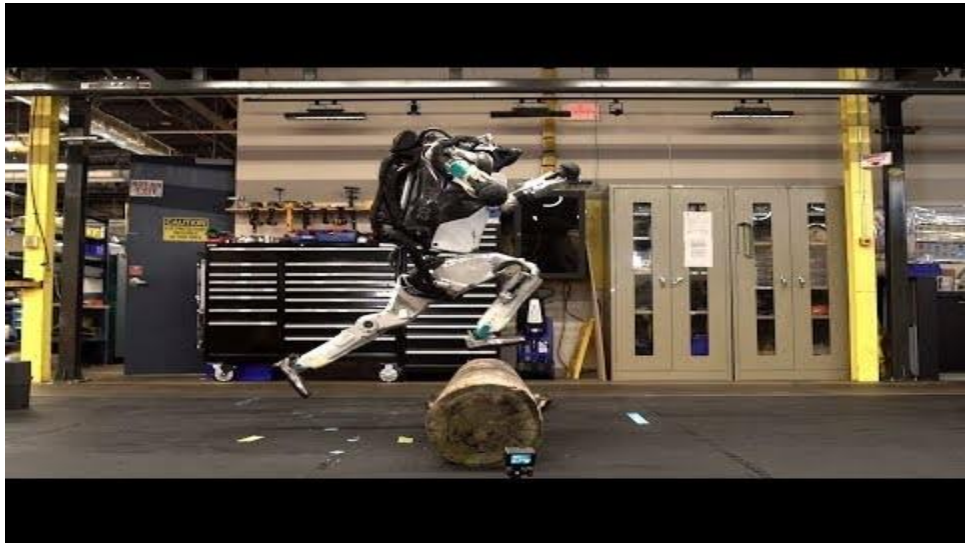
https://www.youtube.com/user/robotcub

http://www.icub.org/

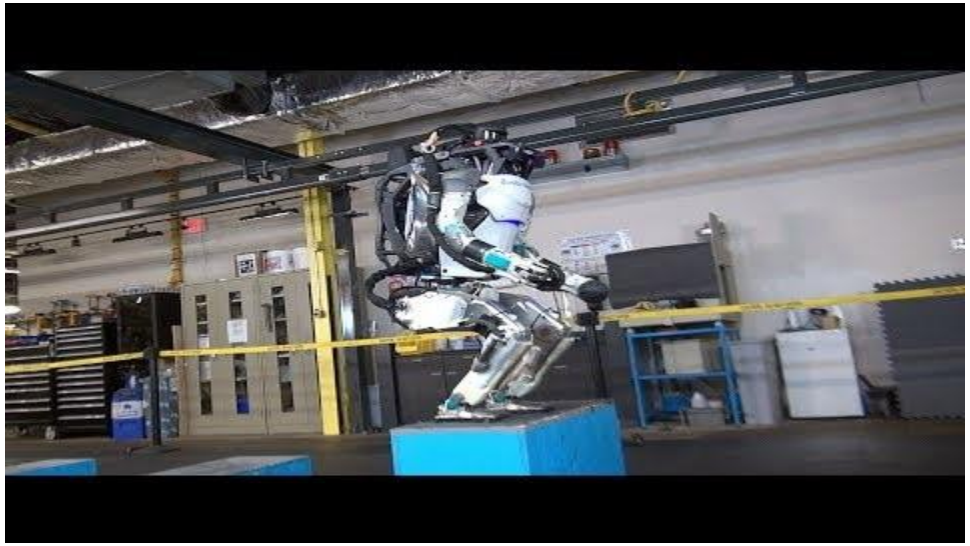
Example: Agility Robotics (US)

https://www.youtube.com/channel/UCN-StetwWuVYf-MU2_NVj4A

Humanoids (Boston Dynamics, US)

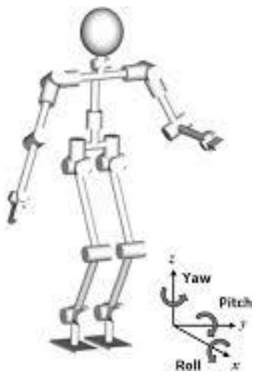


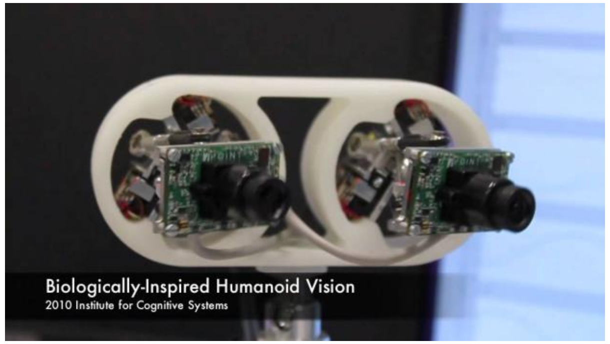
https://www.youtube.com/watch?v=LikxFZZO2sk

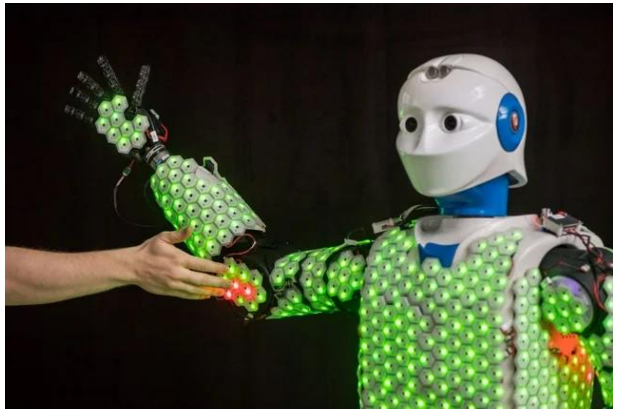


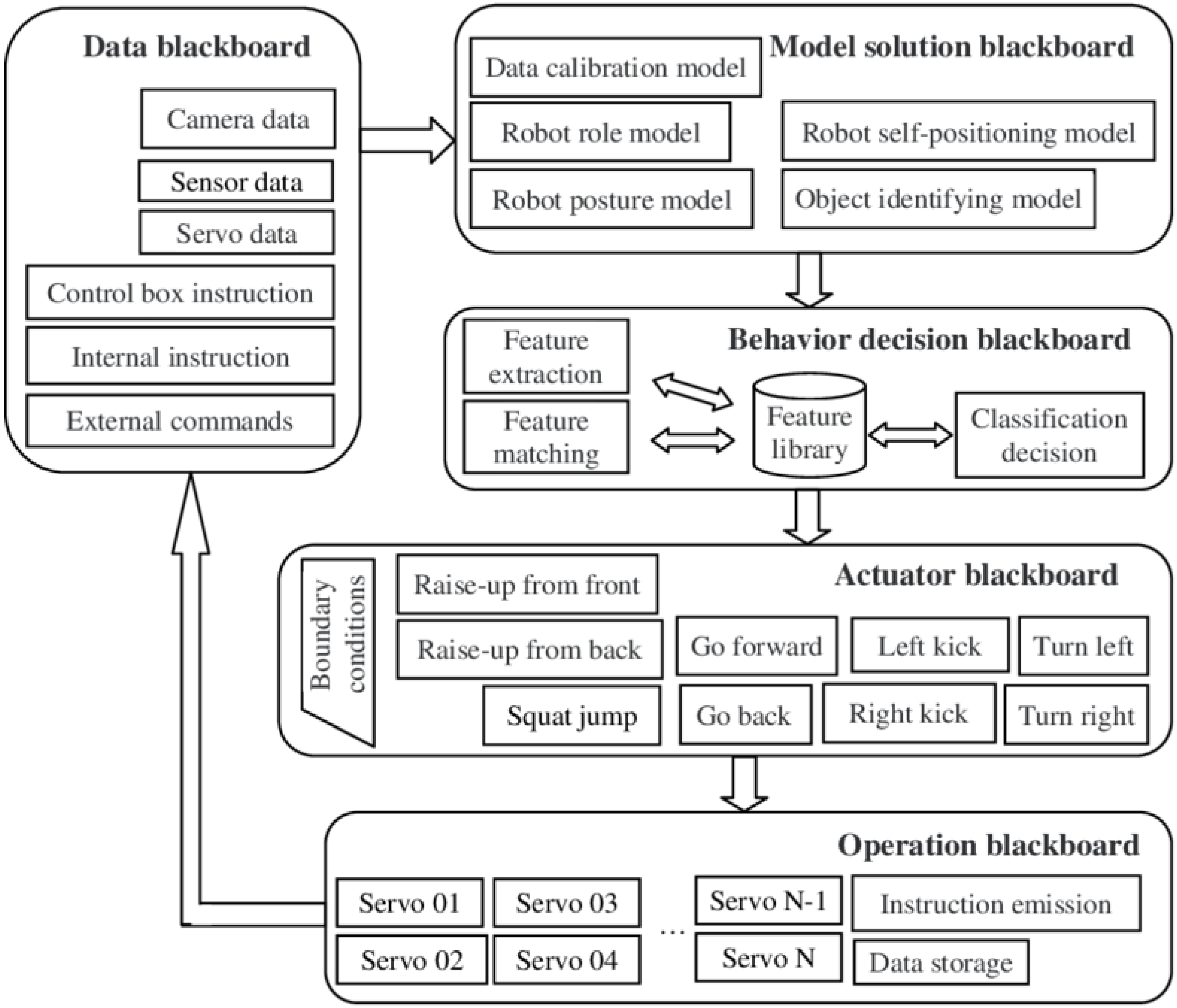
https://www.youtube.com/watch?v=fRj34o4hN4I

Humanoid controller (example)











Humanoids: This is probably the type of robot that most people think of when they think of a robot. Examples of humanoid robots include Honda's Asimo, which has a mechanical appearance, and also androids like the Geminoid series, which are designed to look like people.

https://www.youtube.com/watch?v=7F43R8ghTiU

Entertainment: These robots are designed to evoke an emotional response and make us laugh or feel surprise or in awe. Among them are robot comedian RoboThespian, Disney's theme park robots like Navi Shaman, and musically inclined bots like Partner.

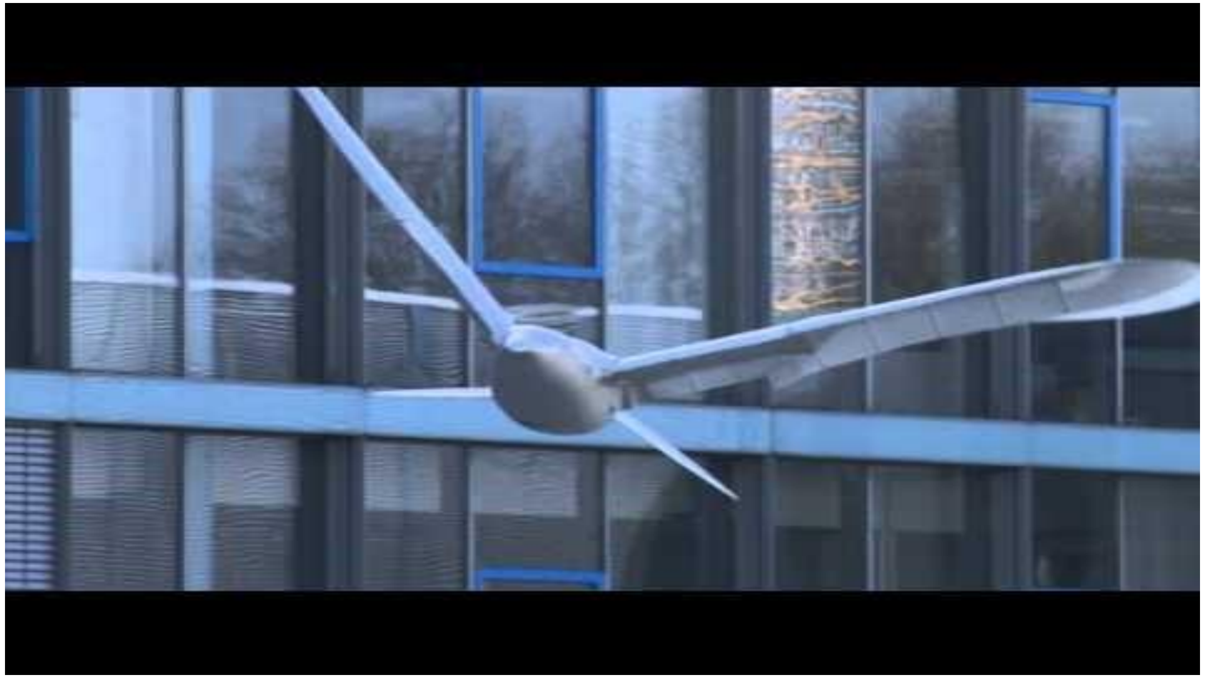
https://www.youtube.com/watch?v=EzjkBwZtxp4

Aerospace: This is a broad category. It includes all sorts of flying robots—the SmartBird robotic seagull and the Raven surveillance drone, for example—but also robots that can operate in space, such as Mars rovers and NASA's Robonaut, the humanoid that flew to the International Space Station and is now back on Earth.

Drones: Also called unmanned aerial vehicles, drones come in different sizes and have different levels of autonomy. Examples include DJI's popular Phantom series and Parrot's Anafi, as well as military systems like Global Hawk, used for long-duration surveillance.

Bio-inspiration and biomimetics

https://www.youtube.com/user/FestoHQ



https://www.youtube.com/watch?v=BaDz12Yt0rw

https://www.youtube.com/watch?v=nnR8fDW3Ilo

Disaster Response: These robots perform dangerous jobs like searching for survivors in the aftermath of an emergency. For example, after an earthquake and tsunami struck Japan in 2011, Packbots were used to inspect damage at the Fukushima Daiichi nuclear power station.

Conceived for exploring and intervening in location which are hazardous of inaccessible to humans.
Usually are designed to be operated remotely with limited decision authority

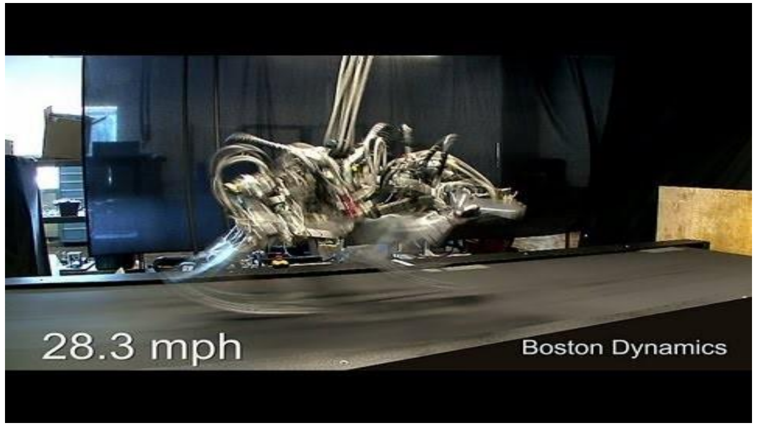
https://www.youtube.com/watch?v=sD9okFLvzV8

https://www.youtube.com/watch?v=_mFg0Md5qG4

Military & Security: Military robots include ground systems like Endeavor Robotics' PackBot, used in Iraq and Afghanistan to scout for improvised explosive devices, and BigDog, designed to assist troops in carrying heavy gear. Security robots include autonomous mobile systems such as Cobalt.

https://www.youtube.com/watch?v=wXxrmussq4E

https://www.youtube.com/watch?v=Zzgz52KmCag



https://www.youtube.com/watch?v=chPanW0QWhA



Education: This broad category is aimed at the next generation of roboticists, for use at home or in classrooms. It includes hands-on programmable sets from Lego, 3D printers with lesson plans, and even teacher robots like EMYS.



Underwater: The favorite place for these robots is in the water. They consist of deep-sea submersibles like Aquanaut, diving humanoids like Ocean One, and bio-inspired systems like the ACM-R5H snakebot.



Consumer: Consumer robots are robots you can buy and use just for fun or to help you with tasks and chores. Examples are the robot dog Aibo, the Roomba vacuum, AI-powered robot assistants, and a growing variety of robotic toys and kits.



Education: This broad category is aimed at the next generation of roboticists, for use at home or in classrooms. It includes hands-on programmable sets from Lego, 3D printers with lesson plans, and even teacher robots like EMYS.

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

The end!