INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

From Industrial to Cloud Robots

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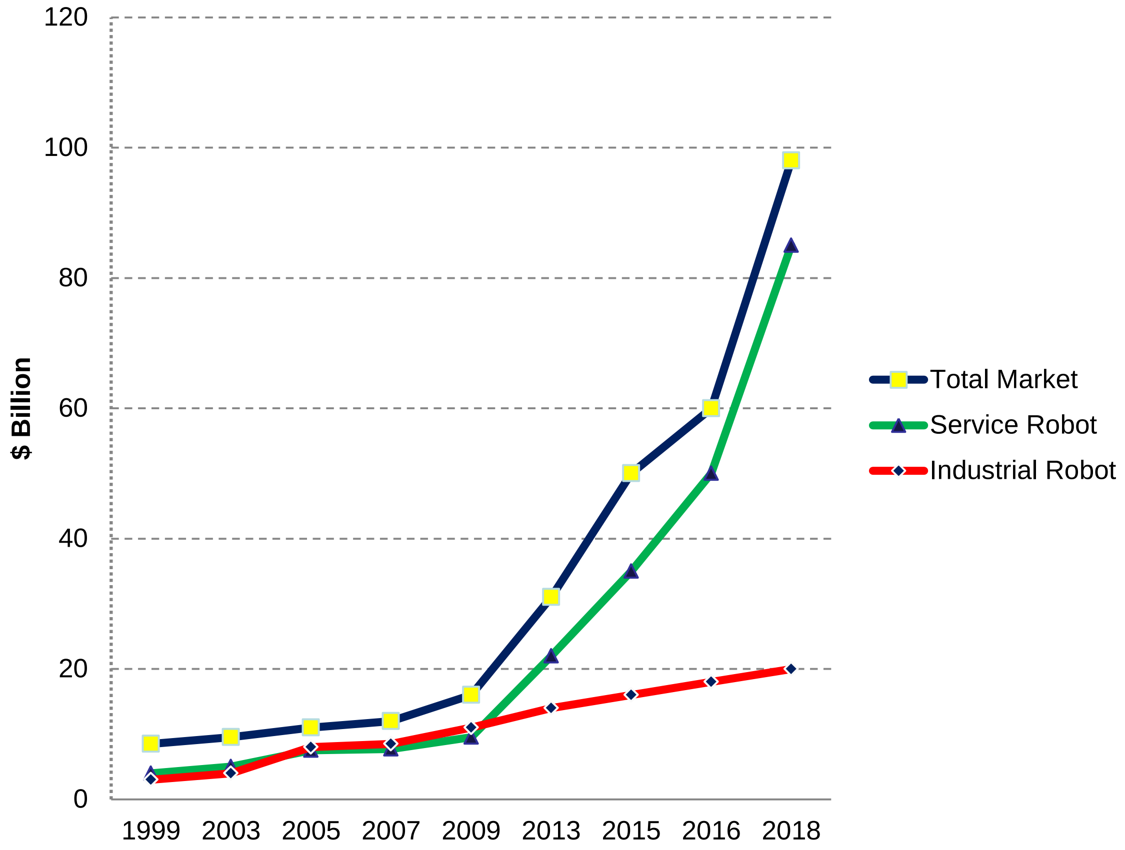
Tato prezentace je spolufinancována Evropským sociálním fondem a státním rozpočtem České republiky.

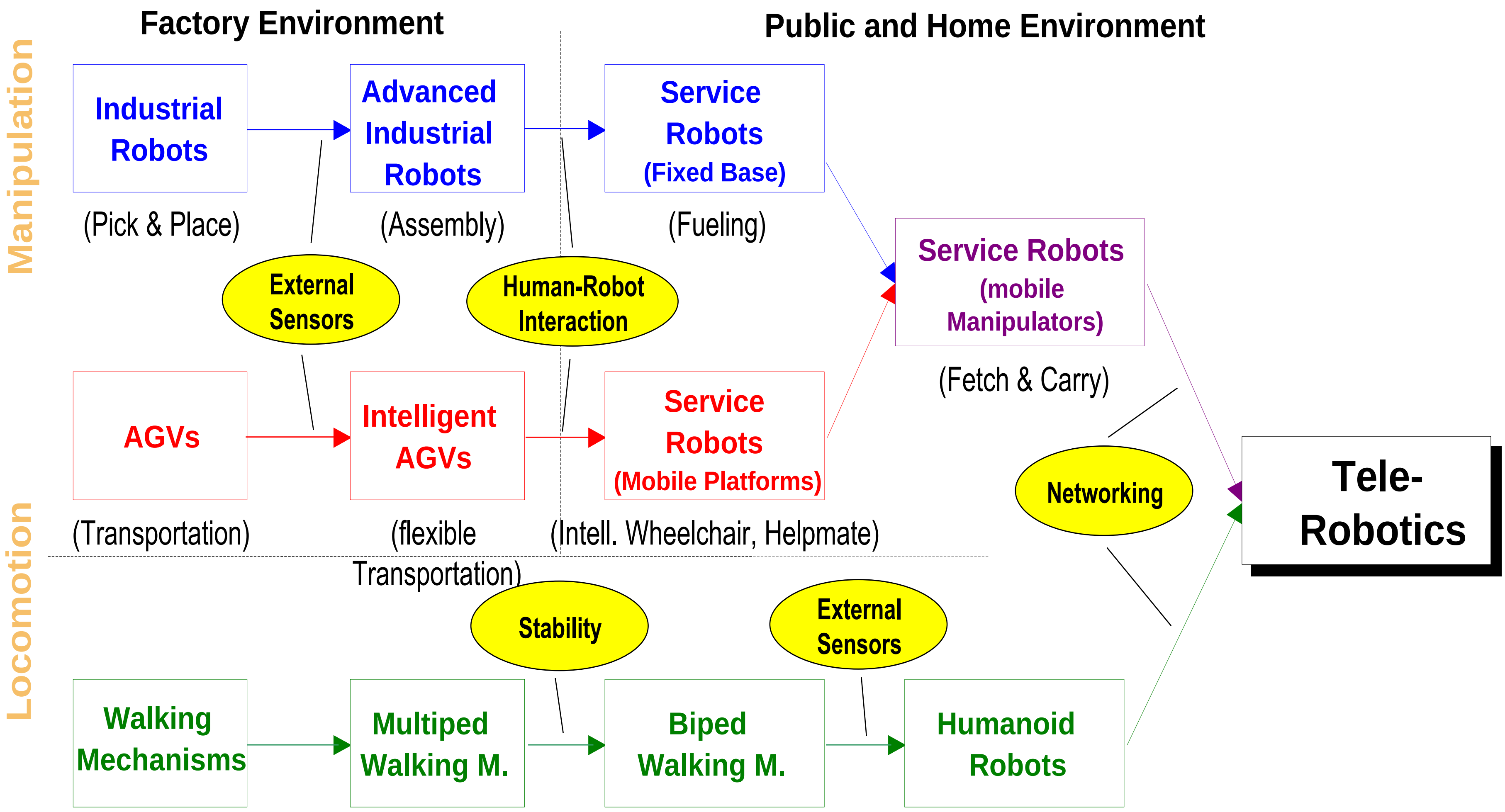
ROBOTS

Global Robot Market Outlook

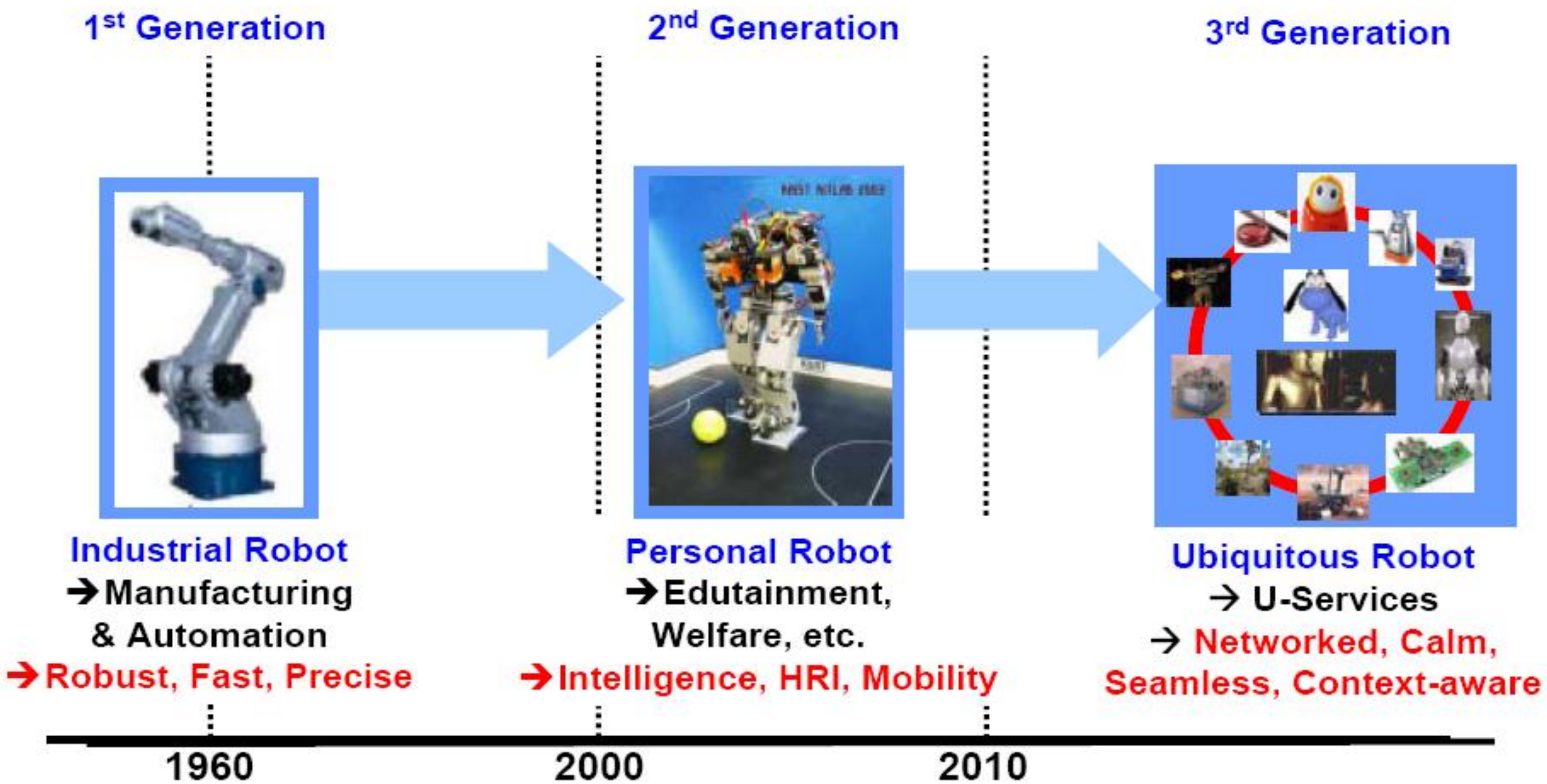
(Ministry of Knowledge and Economy of South Korea, 2011)



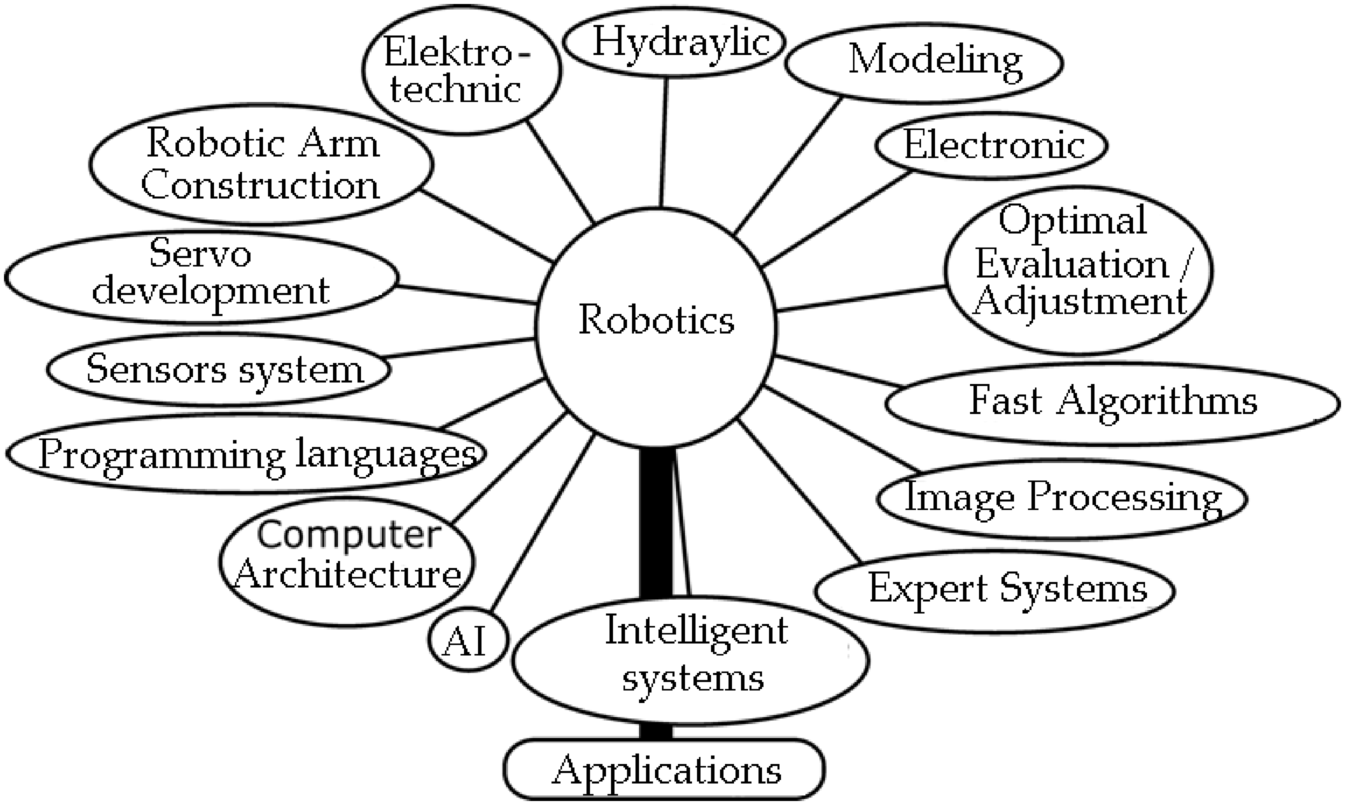
From industry- to service robots



Development Trends in Robotics

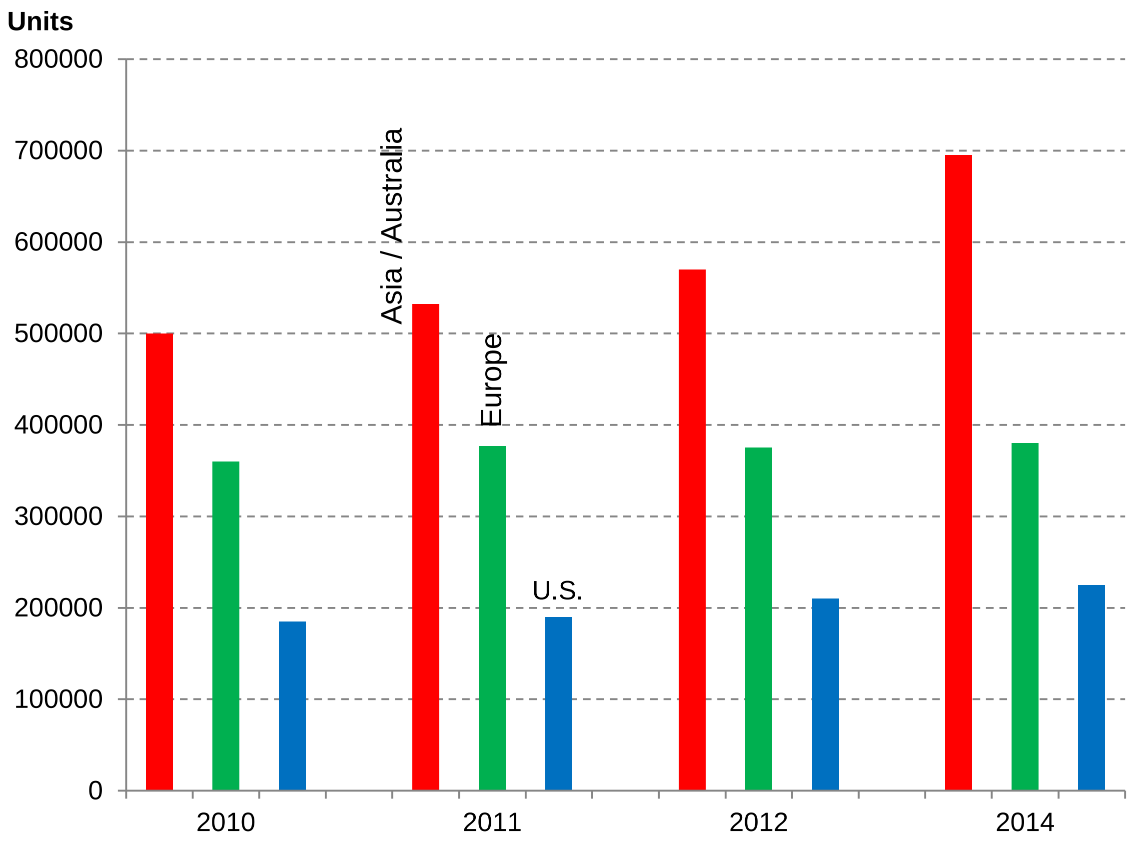


Robot: A mechatronic system



INDUSTRIAL ROBOTS

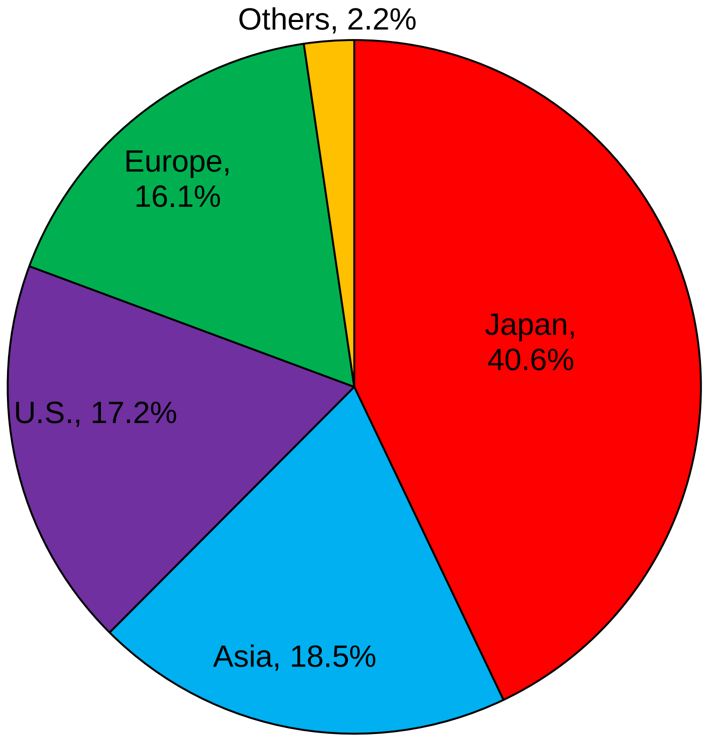
Estimated Global Operational Stock of Industrial Robots 2010 and Forecast for 2011-2014
(IFR, Industrial Robot and Forecast, 2011)



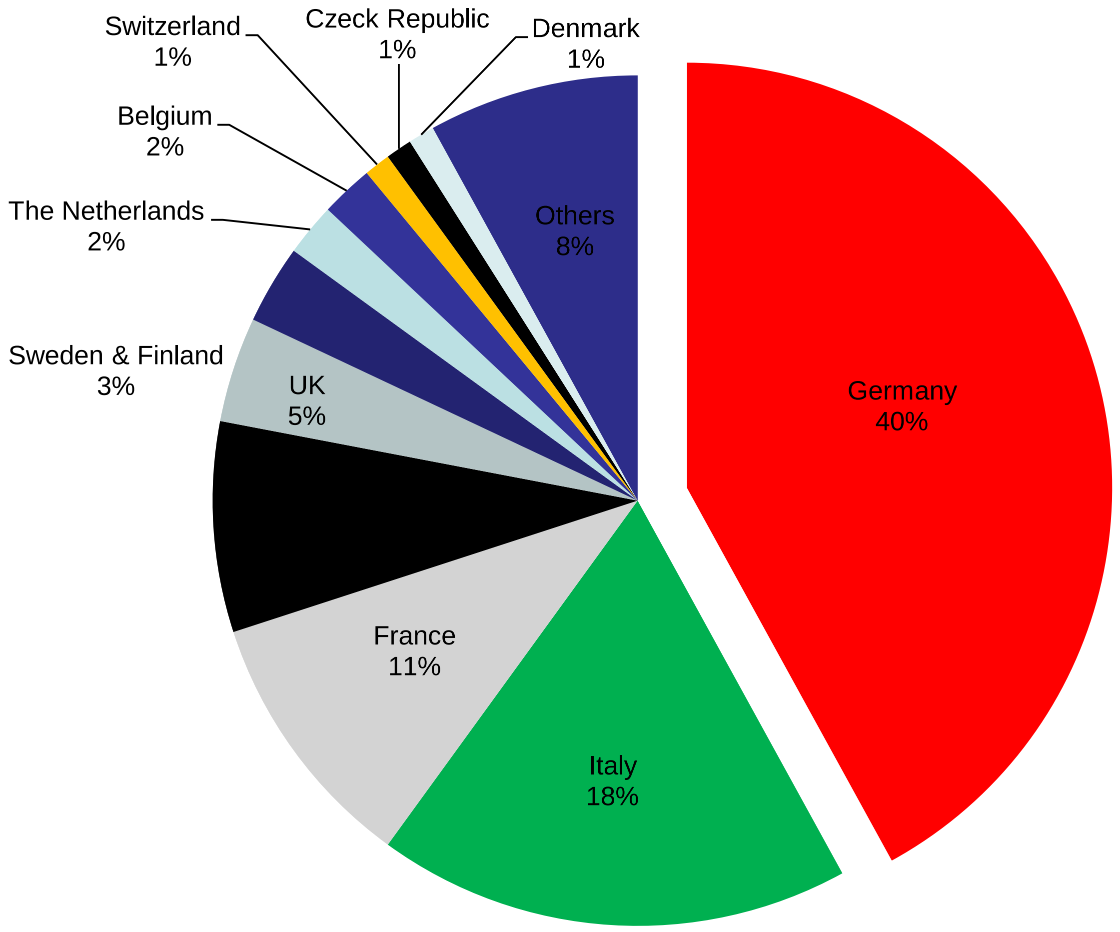
Estimated Operational Stock of Multipurpose Industrial Robots at Year-End in Selected Countries-Number of Units (IFR, Industrial Robot, 2011)

Country	2009	2010	2011	2014
America	**172,141**	**179,785**	**189,200**	**229,000**
North America (Canada,Mexico,USA)	166,183	173,174	181,300	216,600
Central and South America	5,958	6,611	7,900	12,400
Asia/Australia	**501,422**	**498,933**	**539,900**	**695,000**
China	37,312	52,290	71,200	155,600
India	4,079	4,855	5,800	13,000
Japan	332,720	285,800	276,200	262,000
Republic of Korea	79,003	101,080	123,150	169,300
Taiwan	24,365	26,896	29,800	40,400
Thailand	7,185	9,635	12,700	25,100
other Asia	16,758	18,377	21,050	29,600
Europe	**343,661**	**352,031**	**360,700**	**376,000**
France	34,099	34,495	33,800	31,400
Germany	144,133	148,195	153,100	158,300
Italy	62,242	62,378	61,800	58,400
Spain	28,781	28,868	28,900	26,800
United Kingdom	13,923	13,519	13,100	11,800
Central and Eastern Europe	11,470	13,761	17,100	28,300
other Europe	49,013	50,815	52,900	61,000
Africa	**1,973**	**2,232**	**2,600**	**3000**
Total	**1,019,197**	**1,032,981**	**1,092,400**	**1,303,000**

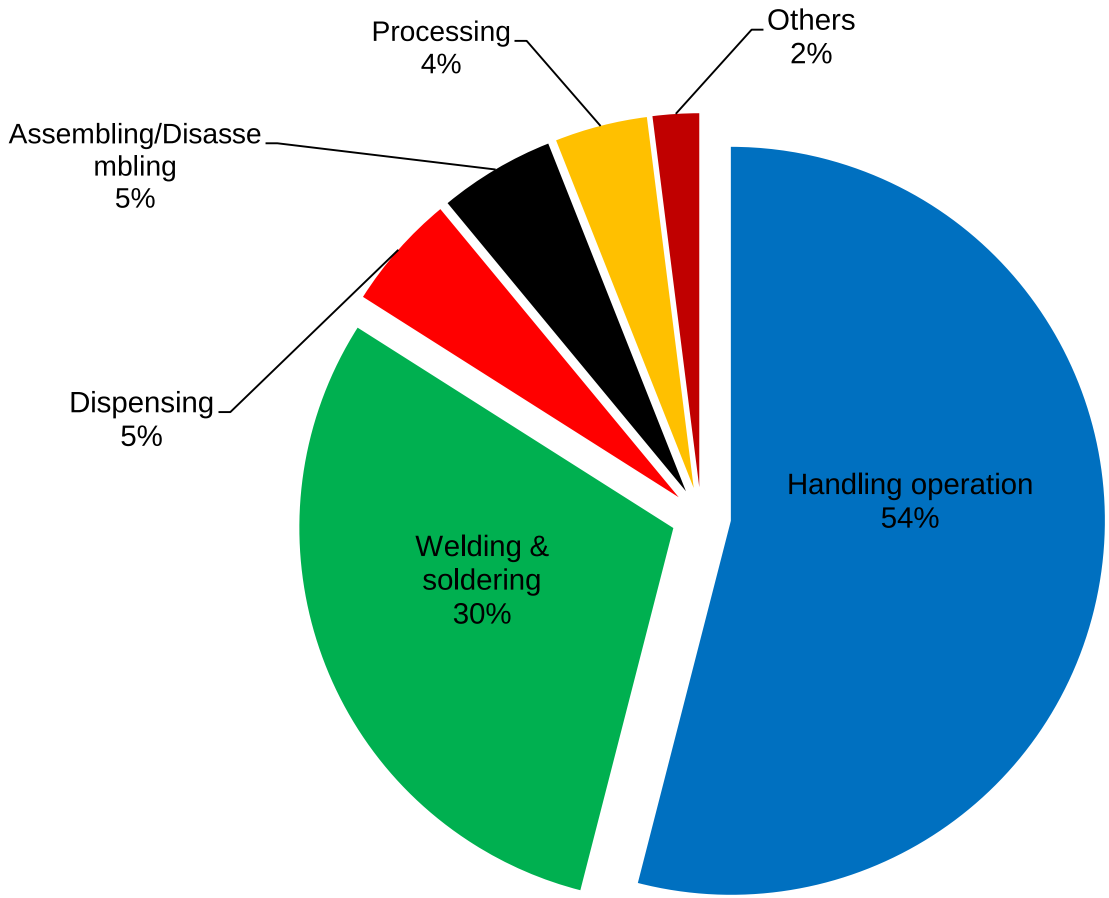
Global Demand for Robots (Fuji-Keizai Co., Ltd., 2011)



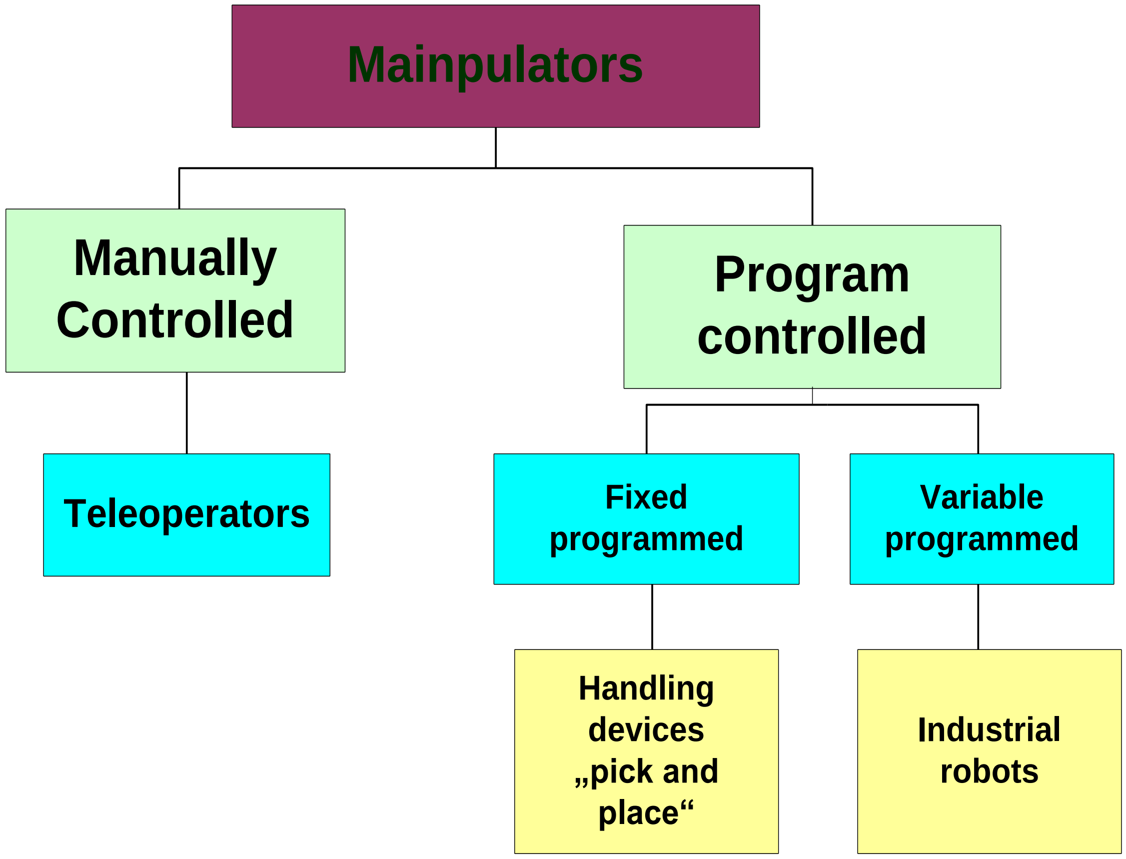
Industrial Robots in Europe



Industrial Robot Tasks in Europe



Manipulator



Definition of multi purpose manipulating Industrial robot

Manipulating industrial robots as defined by ISO 8373:

An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications

KUKA - Germany

Payload : 180 kg

Payload : 500 kg

ABB - Sweden

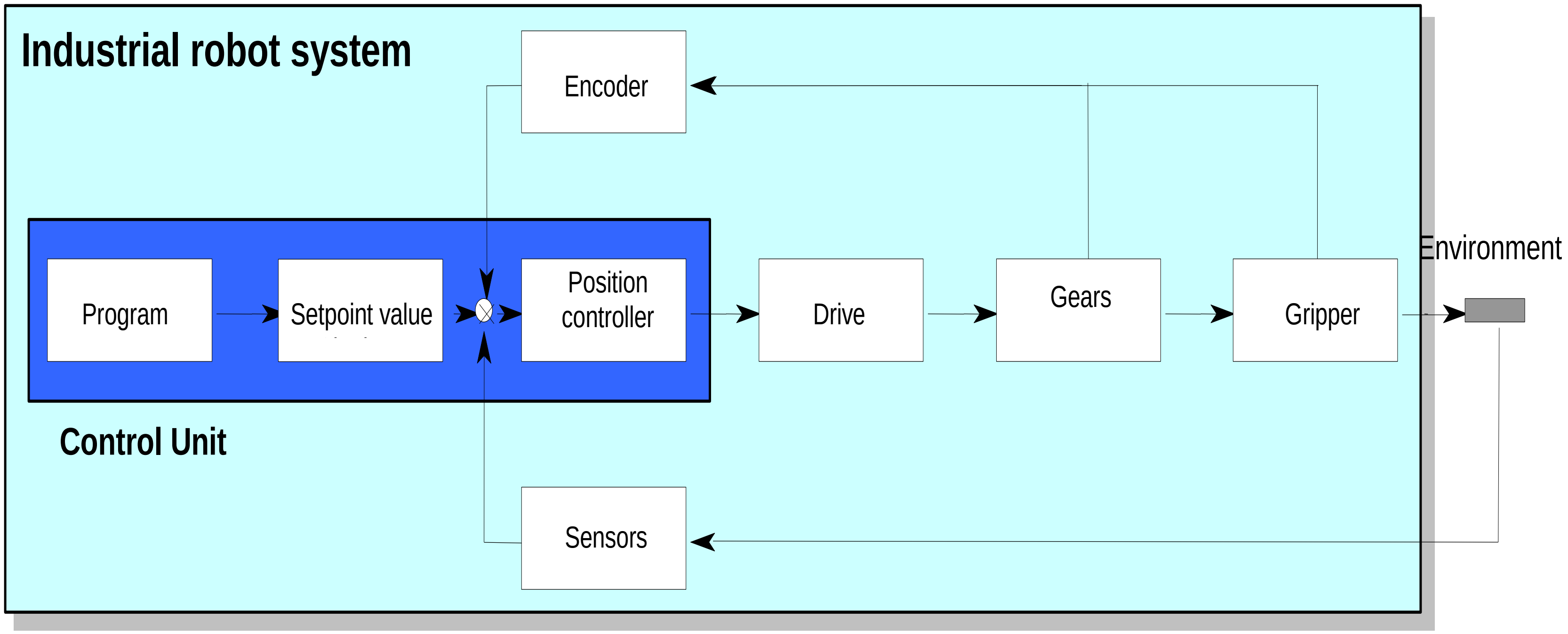
Payload : 500 kg

Payload : 1 kg
Repeatability : 0.1 mm

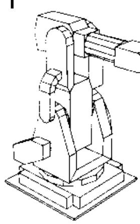
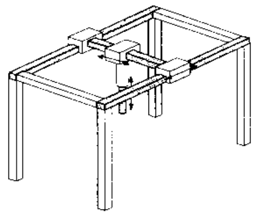
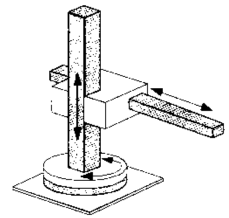
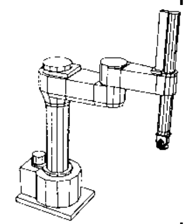
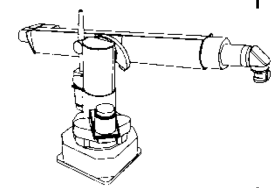
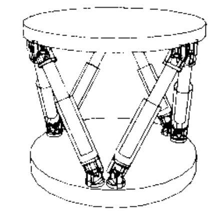
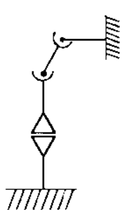
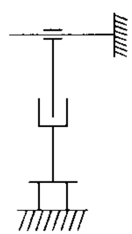
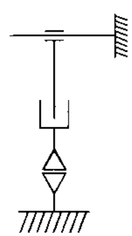
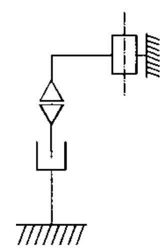
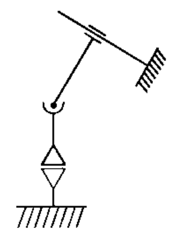
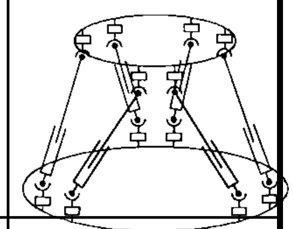
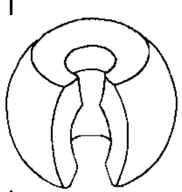
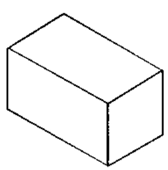
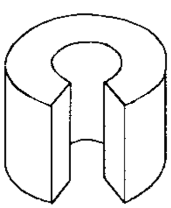
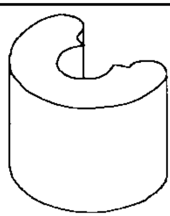
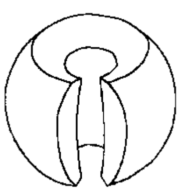
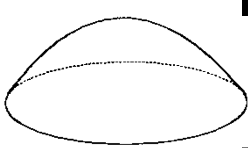
Components of a robot system

- Mechanical Arm
  Robot joint, wrist, base; sufficient structural stability with the payload
- Drive systems
  Motor, Hydraulic, Pneumatic Drive, Gear, Break
- Control system
  Interface to operator; Control of robot‘s joint
- End-effector, End-of-Arm Tooling (EOAT)
  Special Tools; adapted to the application; Gripper, etc.
- Programming tool
  Teach-Panel, Movement of joints, Record of points, Generation of Programs, Not-Stop, and others.

Block diagram of an IR-System



Robot Configurations

Name	J o i n t s- Robot	Cartesian Robot	Cylindrical Robot	SCARA Robot	Spherical Robot	Parallel Robot
Scheme						
Kinematics						
Workspace						

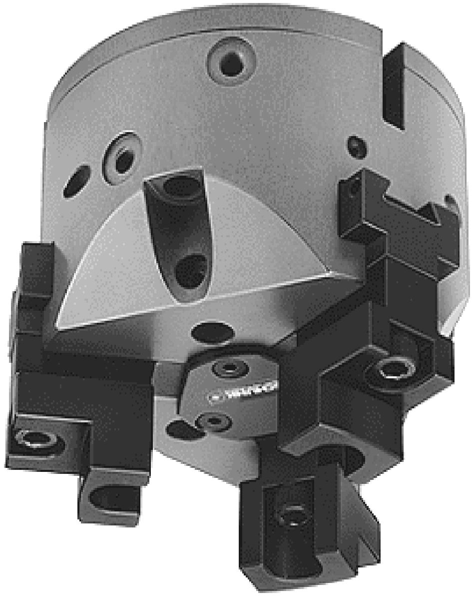
Drive Systems for Industrial Robots

	Advantages	Disadvantages
Electric	• Uniform and simple components • Signal transfer without delay • Getting energy is easy	• Small Force and Torque • Expensive explosion protection
Pneumatic	• Explosion protection • Many possibilities for the combination • cheap	• Finite transmission line • Energy source will be lost. Energy source should be clean. Energy source should be generated. • Noise
Hydraulic	• High Force and Torque	• Generation of heat • Pollution of the environment in case of leakage

Gripping Devices

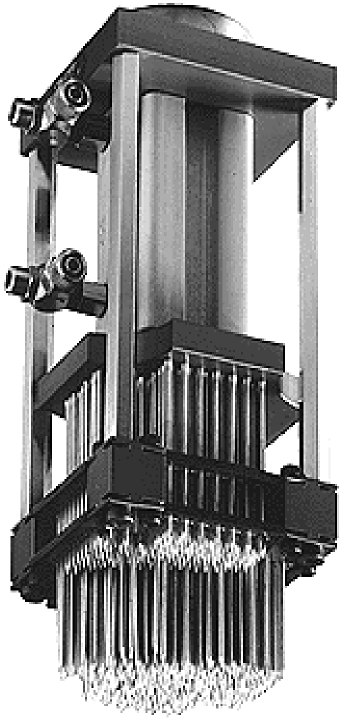
- Interface between IR and work piece
- Gripping Device = „*Part of a handling device which to grasp an object, usually the work part, and hold it during the robot work cycle.*
  - *Holding method: mechanical (for example, finger), suction cups, magnets, etc.*
- In practice special solutions for few distinct applications
  - å Flexibility of the whole system reduced

Gripping Devices



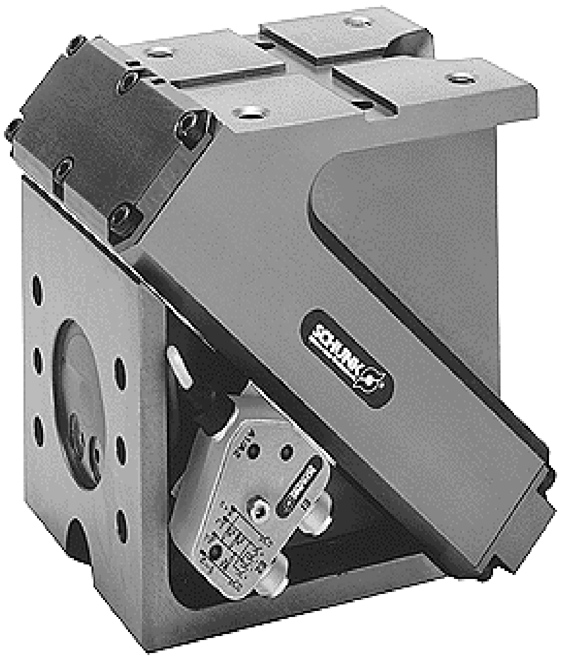
3-Finger-Centric gripper

2-Finger-Angle gripper

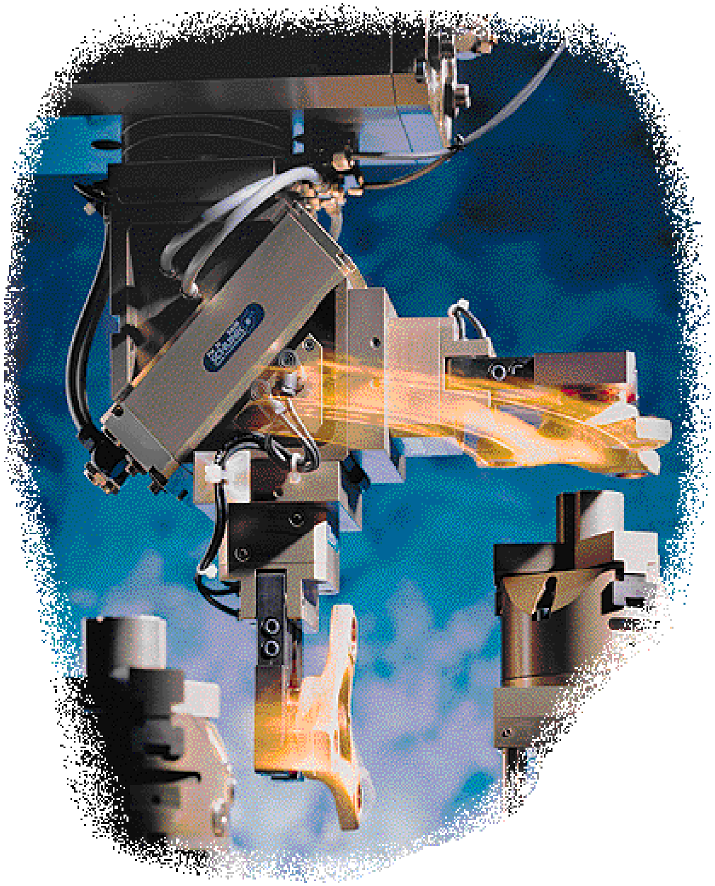


Needle gripper

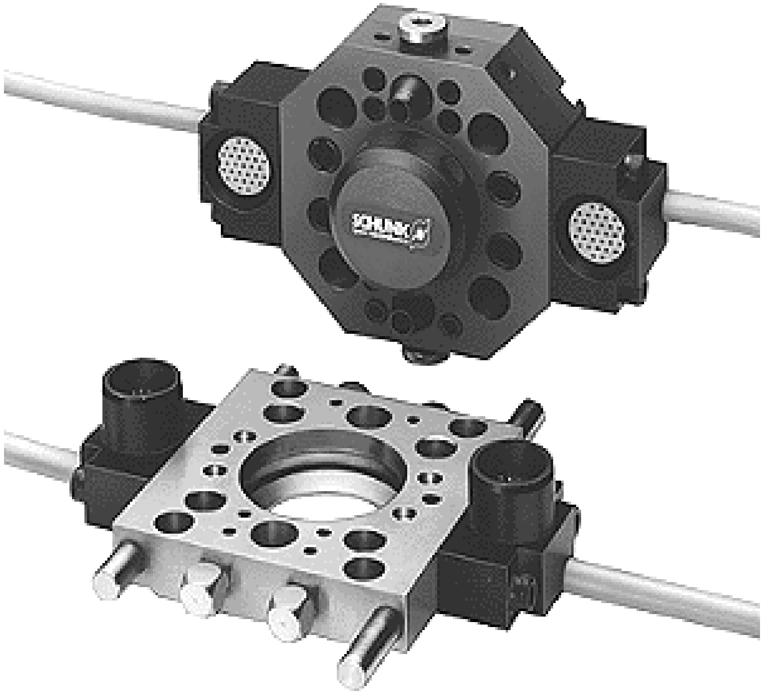
Gripper changing systems I



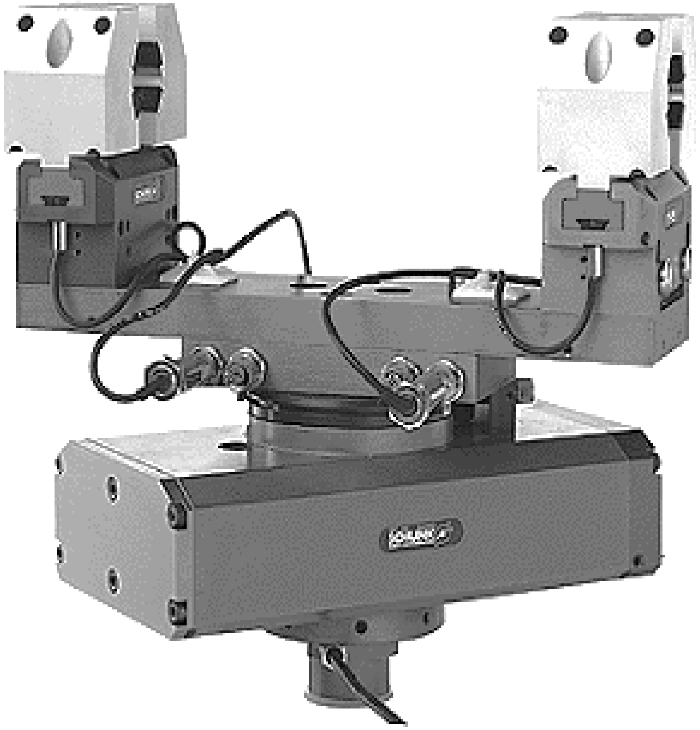
Pivoting head



Gripper changing systems II



Gripper changing system



Pivoting arrangement

Type of control

- Point-to-Point (PTP)
  - Starting and end point are given by the controller. After starting movement each joint moves independently. In general joints are moving synchronously.
- Multi point (MP)
  - The position values are provided in predefined tact as the setpoint value to joint. (programming of setpoint value: sequential programming)
  - Disadvantage : memory intensive, The path can be hardly corrected.
- Continuous path
  - The path from starting point and end point is calculated with linear, circular, spline interpolation spatially. The calculation of setpoint value is carried out on-line (in millisecond interval)

Tasks of the control computer

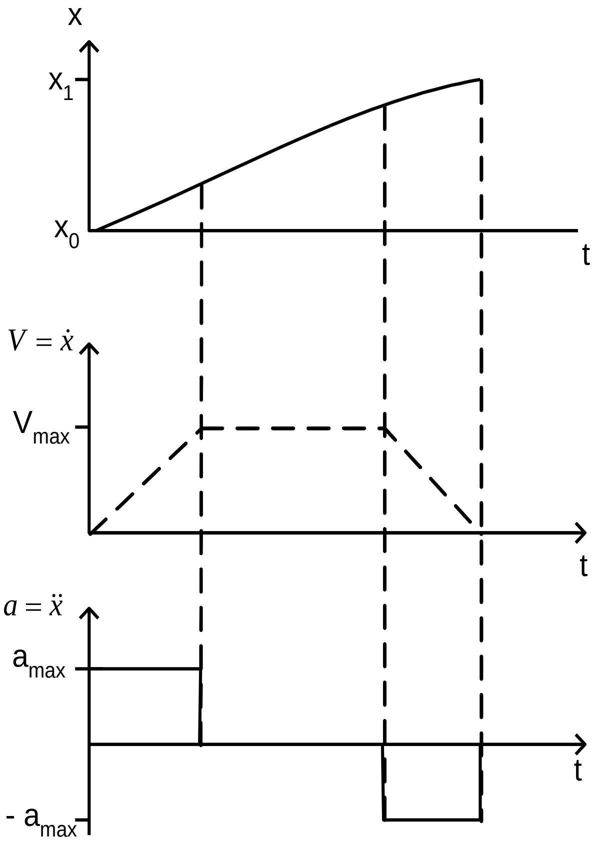
- Coordinate transformation
- Path calculation
- Speed and acceleration calculation
- Position control

↳ Hierarchical structure

Position control (1)

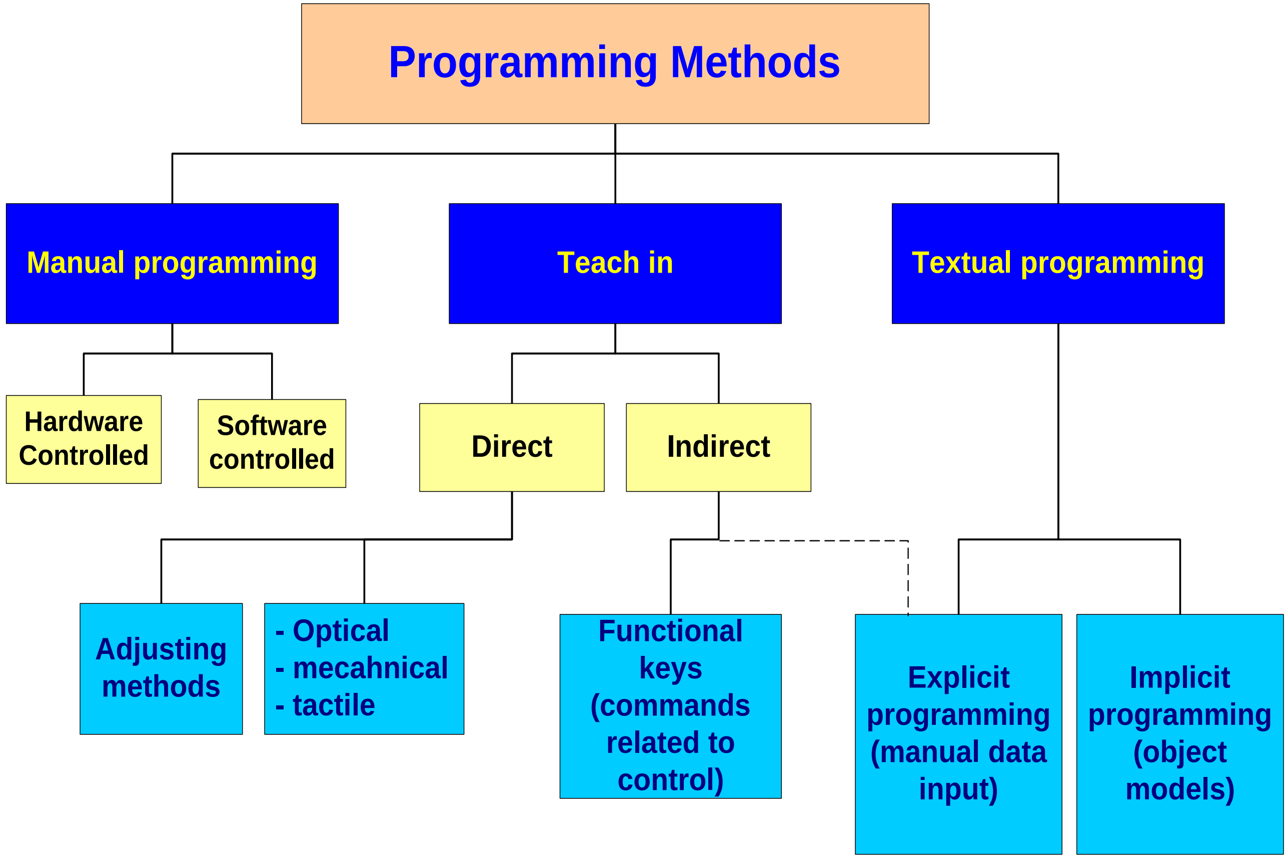
- Exact and reproducible (0,01 to 2 mm)
- High positioning speed
- High accuracy
- Large speed range

Position control (2)



Time-optimal positioning from x_0 to x_1

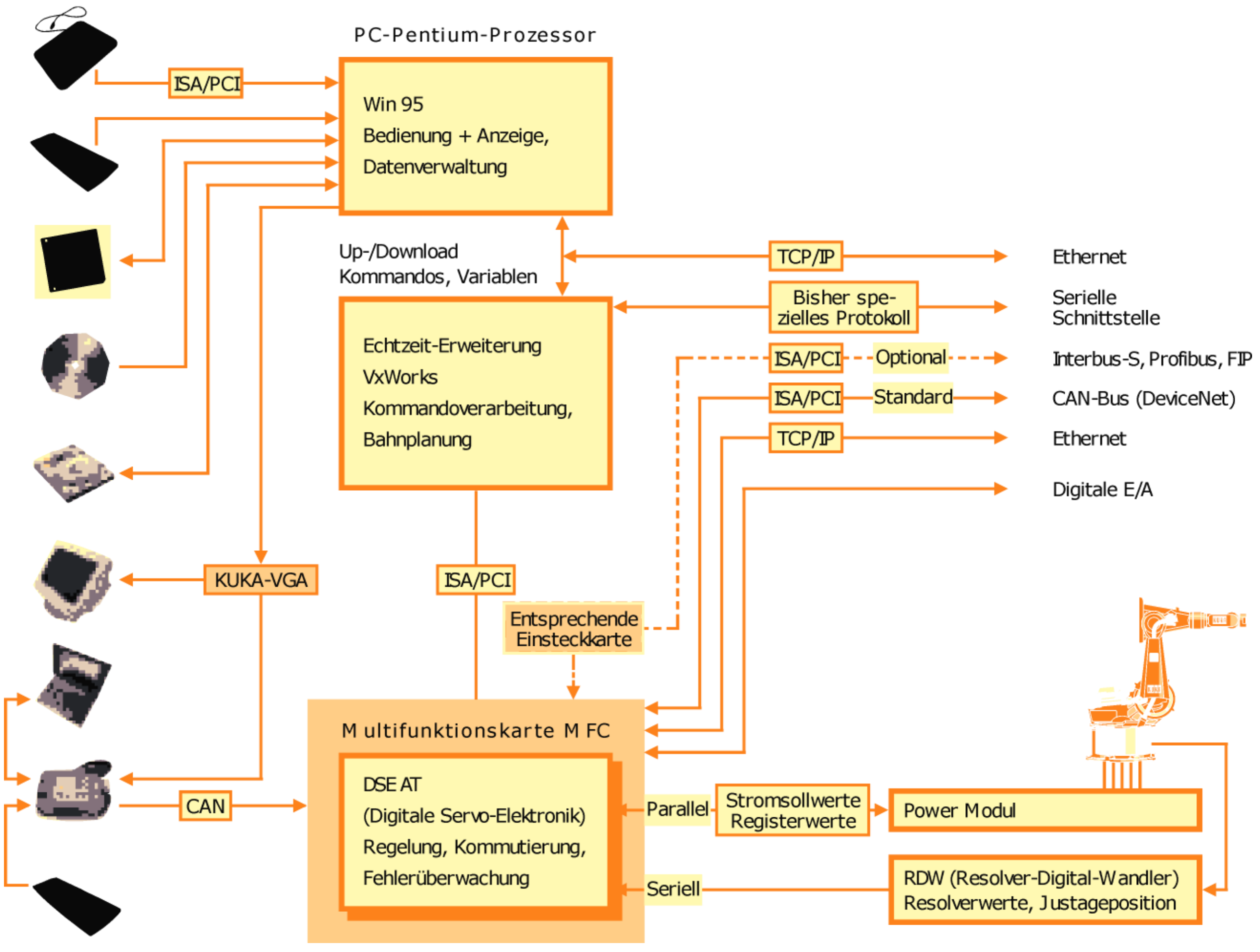
Programming Methods



Modes of operation of a robot control

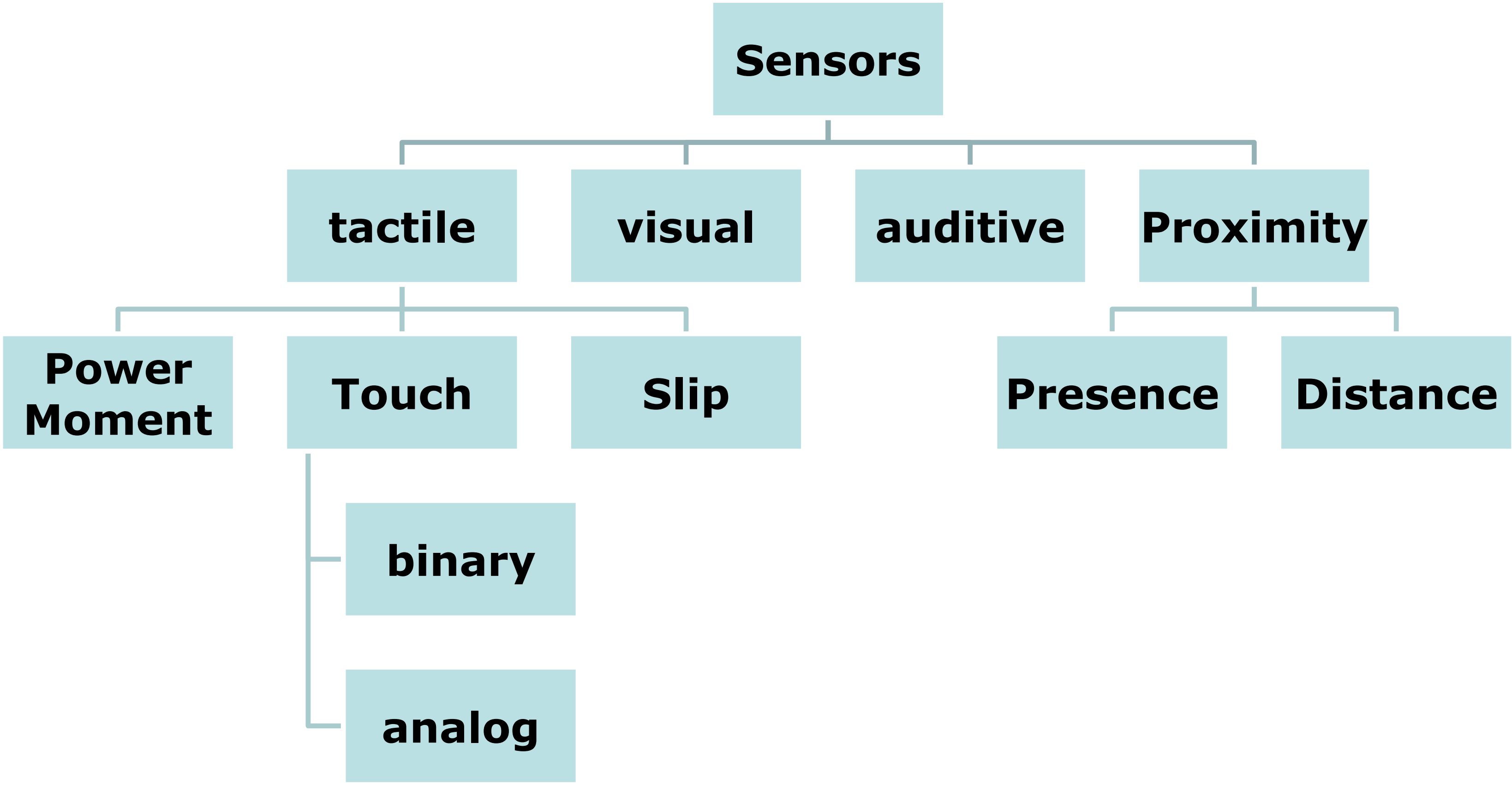
- Programming
  - Movement of robots through driving commands
  - Single step
  - Cycle
- Testing operation
  - Exiting from program (sections) in individual steps
  - Speed <25 cm / sec (Safety gate open)
- Automatically operations
  - In production facility
  - Programs are in full speed with all functions
  - Safety gate must be closed

Example for a Robot Controller



Teach Panel

External Sensors



Sensor

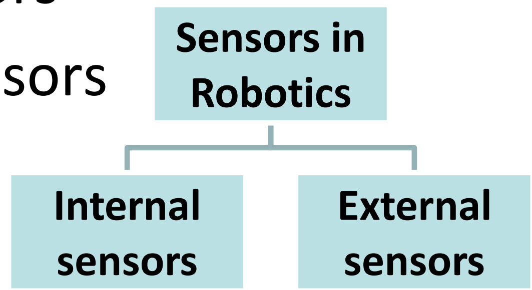
Definition: A system that physical quantities and their
changes transform in electronic signals in suitable formats.

Sensors

- Elementar sensors
    - Inclusion of a size measuring and mapping signal
- Integrated sensors
    - additional signal processing: amplification, filtering, linearization, standardization
- Intelligent sensors
    - integrated sensor with additional signal processing: amplification, filtering, linearization, standardization sensor with computer analysis. Output: processed size. Example: Model recognition

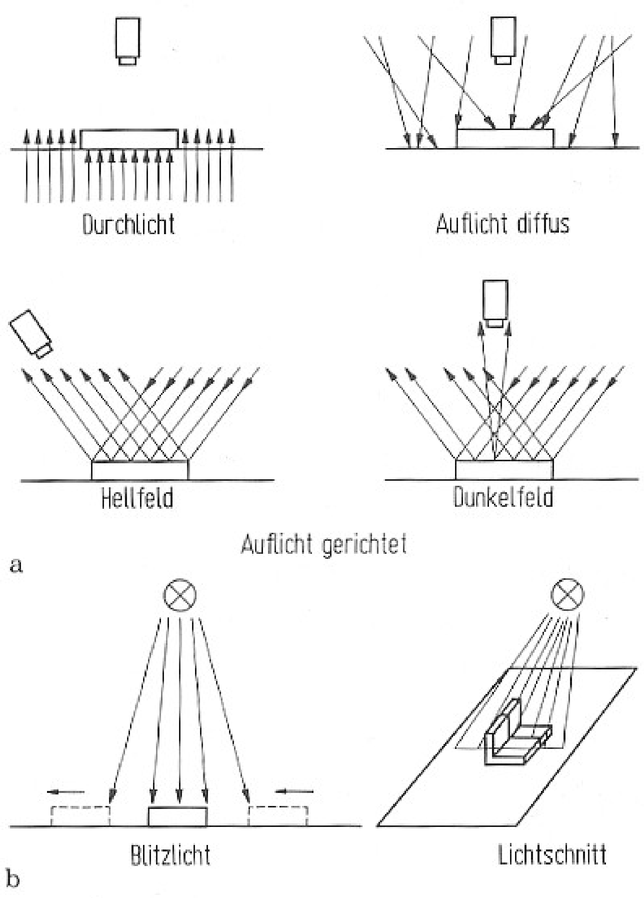
Classification by functionality

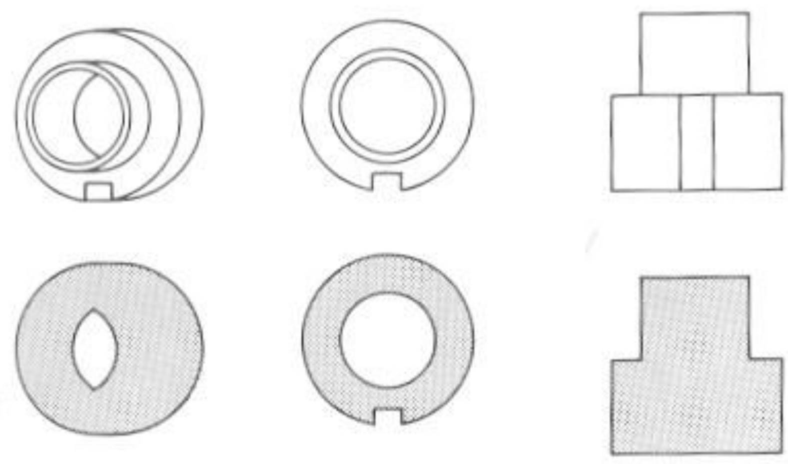
- Capturing the internal states
  - Speed sensors
  - Position sensors



- Information of the states environment
  - Visual sensors
  - Distance sensors

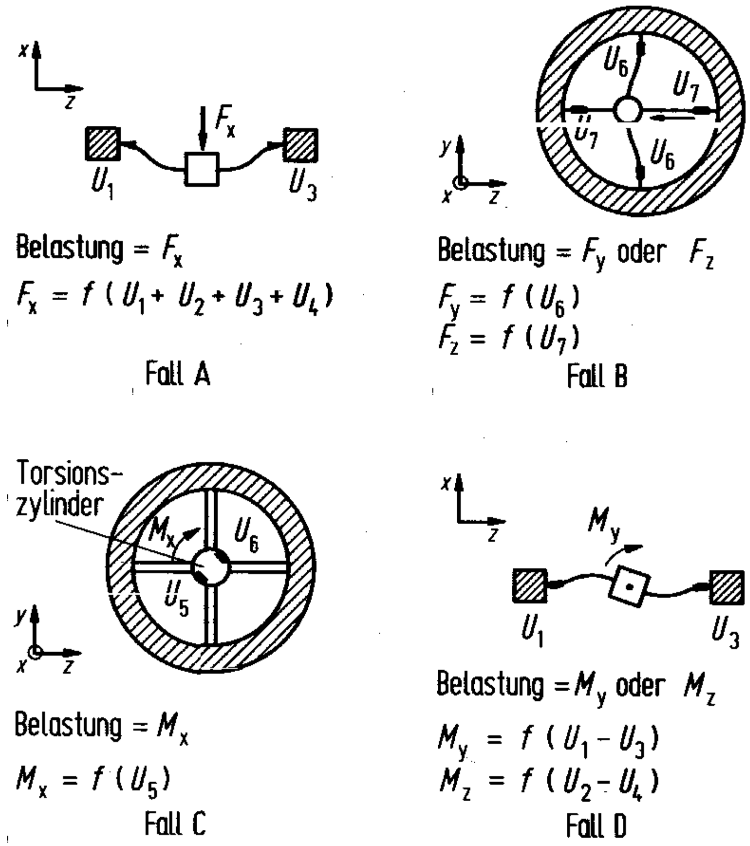
Video-Optical Sensors





Binary images from different views of the part

Force-/Torque-Sensor



Force-/Torque-Sensor in form of a spoke wheel with strain gauges

Application Areas of Robots

Robots / Applications	Conventional	Advanced
Classical	Industrial robots	Assembly robots
Advanced	Disassembly robots	Service robots Microrobots

Applications of IR with tool guidance

- Gas shield welding
- Coating
- Torch cutting
- Plasma cutting
- Deburring
- Laser cutting,
  -welding
- Water jet cutting
- Glueing
- Spot welding
- Grinding
- Polishing
- Milling

Application Examples

Disassembly Cells

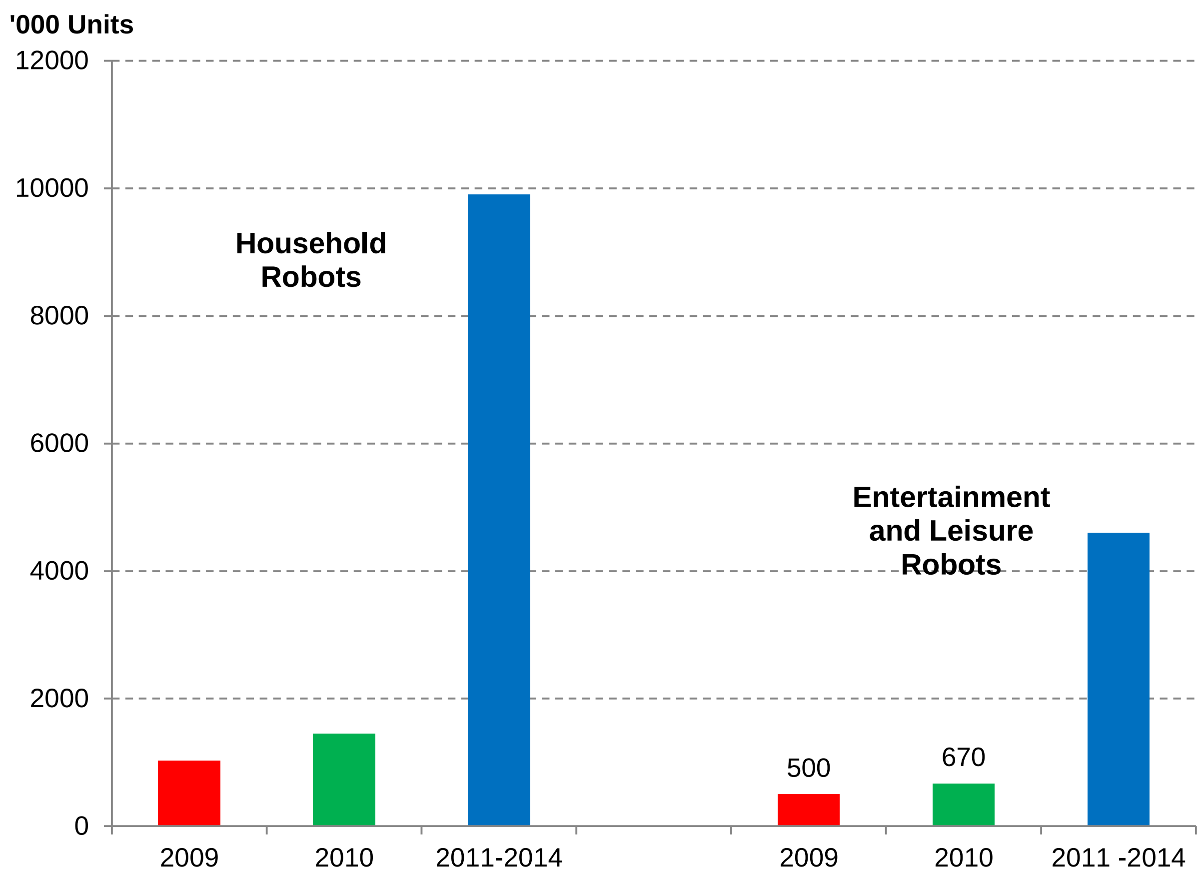
for

Printed circuit Boards

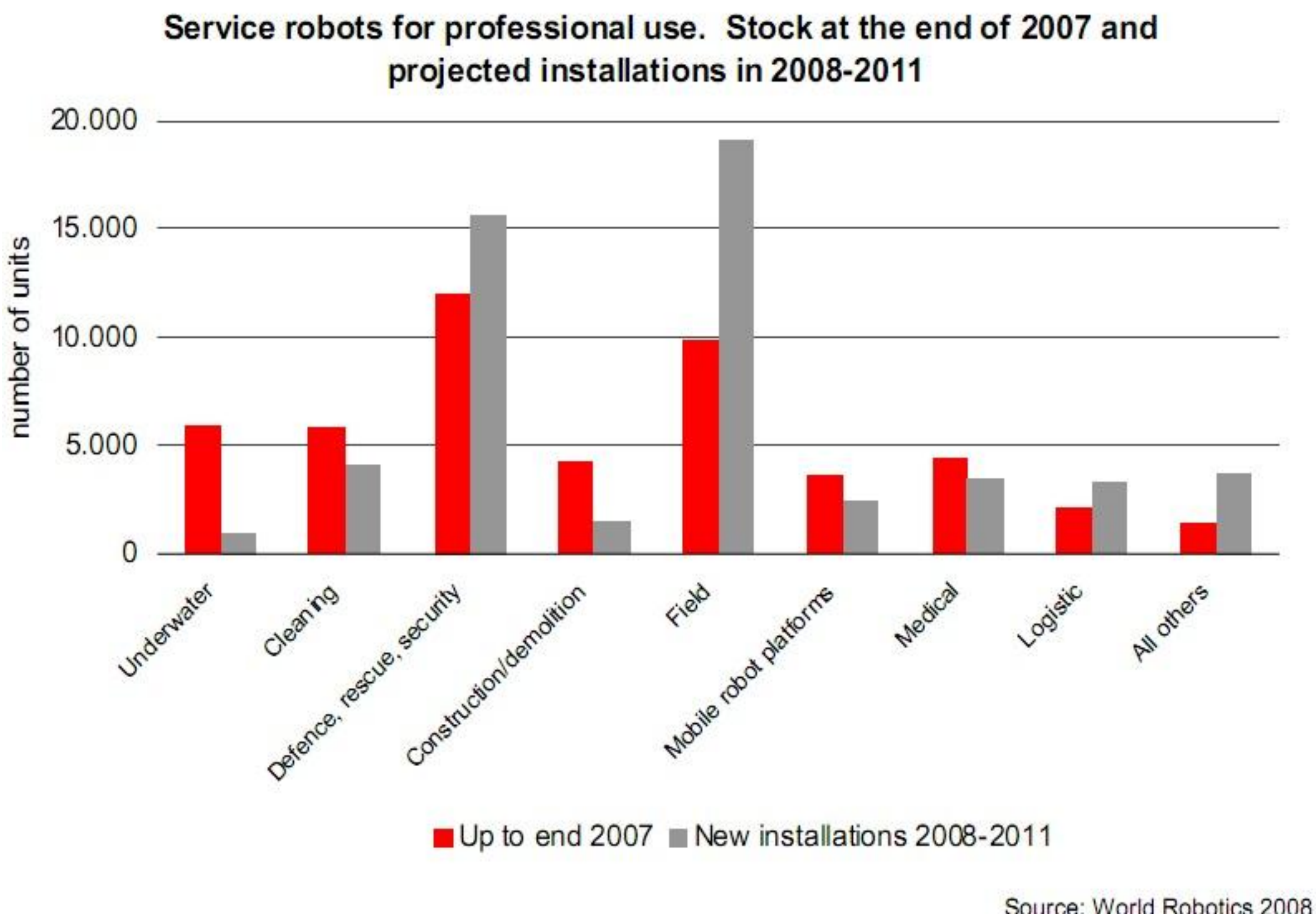
Mobile Phones

AUTONOMOUS MOBILE ROBOTS

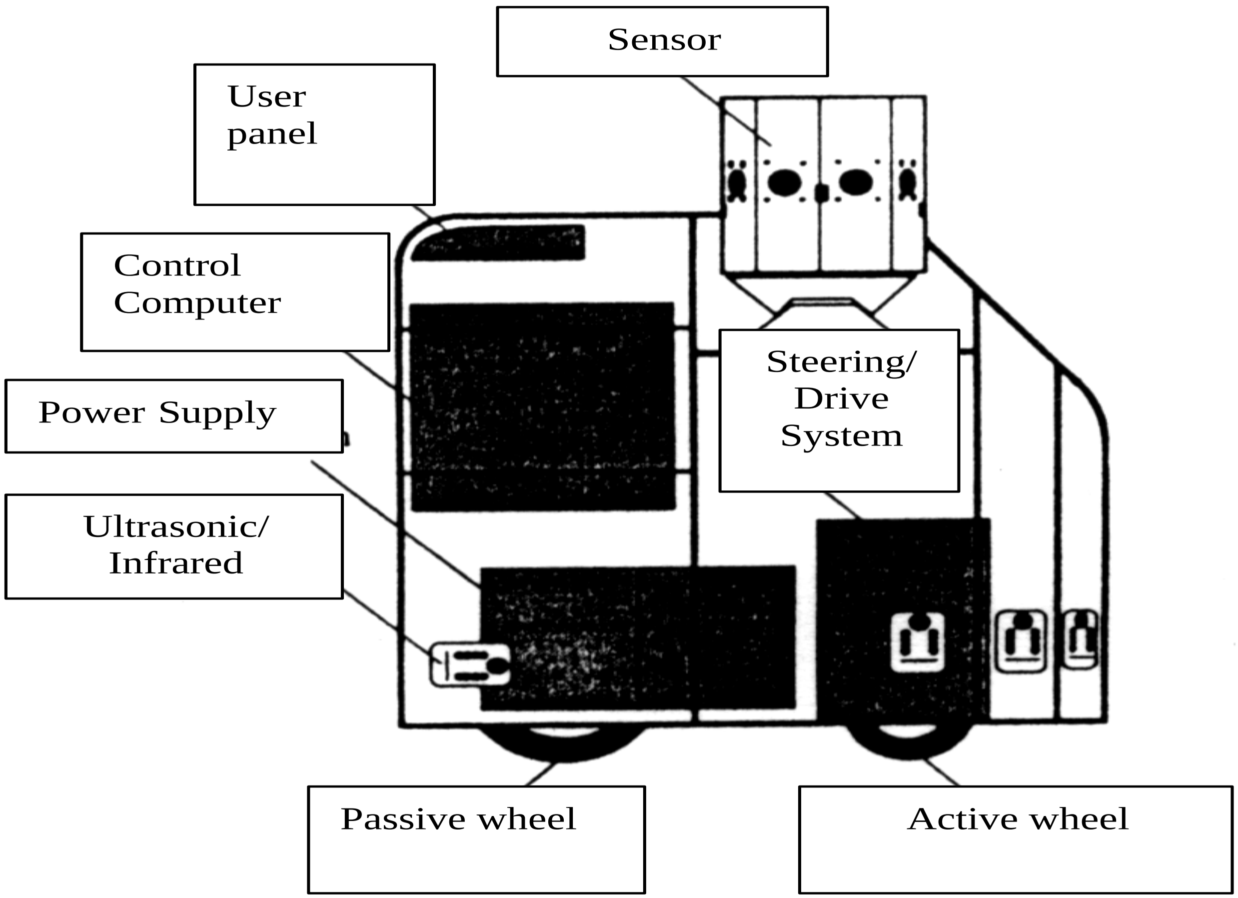
Service Robots for Personnel/Domestic use, Units sales 2009 and 2010 - Forecast 2011-2014



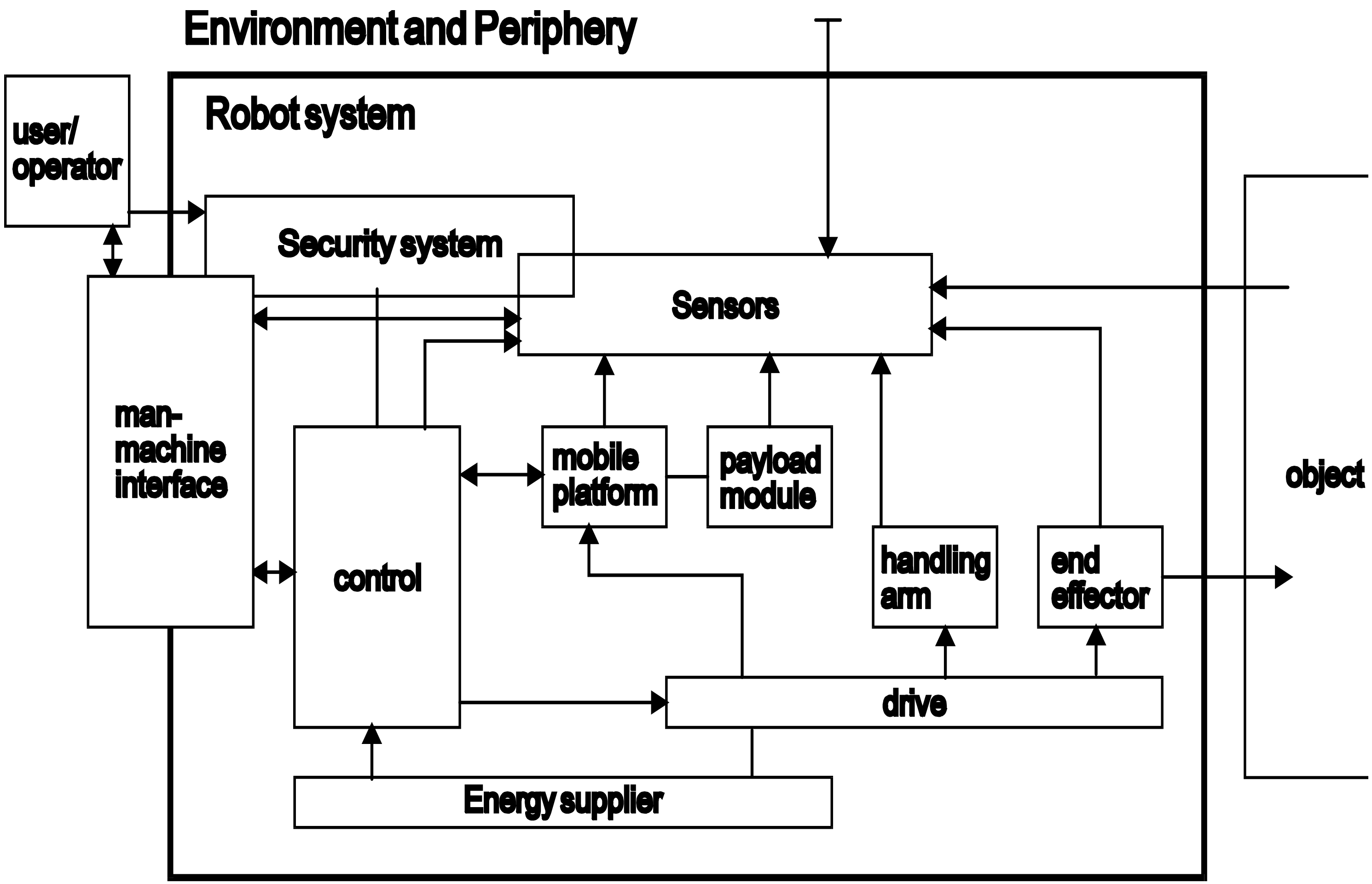
Service robots



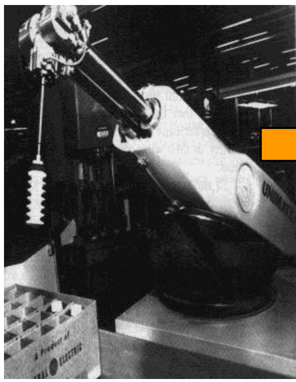
Main Parts of a mobile Robot



Block Diagram



Historical development of mobile Robots



First industrial stationary robot in 1961

Space & Military mobile applications since 1970ies

Present commercial deployment of mobile intelligent robots (underwater, leisure, medicare, household and agriculture)

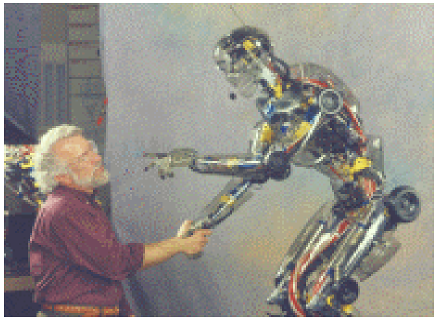
Mobile Robots - Locomotion

- Wheels (3;4;6 – wheels)
- Legs (2, 4, 6,……..legs)
- Tracks - Chains
- Aircraft – Helicopter
- Underwater

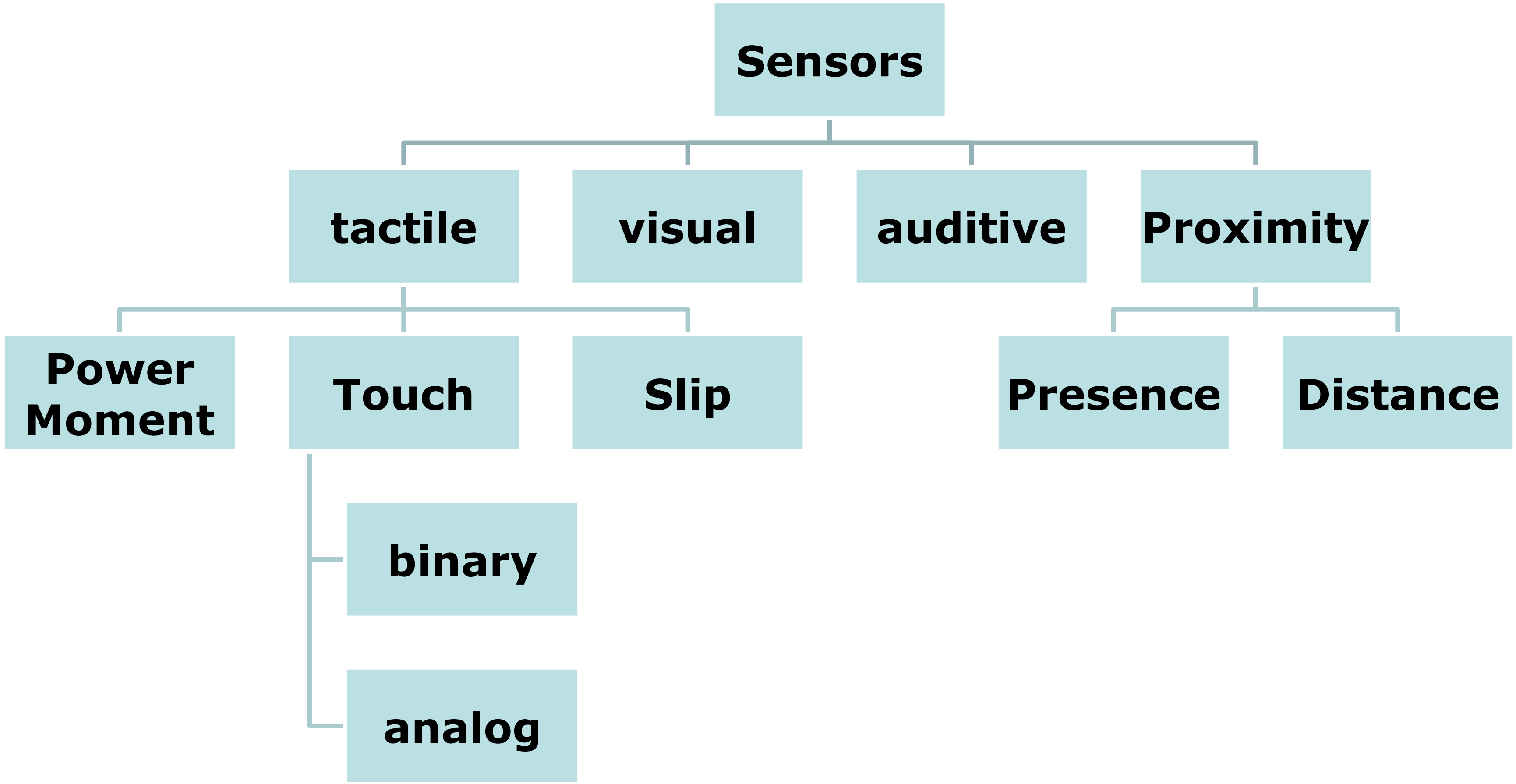
Automatic guided vehicles

Containerterminal Altenwerder Hamburger Hafen- und Lagerhaus-AG

Examples for mobile Robots



External Sensors



Sensors for mobile robots

- Features
  - Field of view and range
  - Accuracy, repeatability and resolution
  - Responsiveness in the target domain
  - Power consumption
  - Hardware reliability
  - Size

Ultrasonic sensors

- Proximity sensors
- Distance sensors

Tactile Sensors

- *Main idea: Copy of the human sense*
- **Measurement values:**
- Presence
- Form, Position and orientation of a part
- Pressure and Pressure distribution (on contact area)
- Force: Value, Position and Orientation

  Torque moment: Value, area and Orientation

Sensors for IR-movement control

- With contact
  - Force-Torque
    - Measurement - Gripping Force
    - Measurement –Force/Torque
    - Active Assembly Gripper,
    - RCC, IRCC
  - Tactile
    - Switch,
    - Distance measurement
    - Sample line or matrix
    - Area switch
    - Slip measurement
- Without contact
  - Video optical
    - 2D-image processing
    - Binary, Grey scale
    - 3D-Stereo-image processing
    - Active lightening
  - Optical distance measurement
    - Light barriers and –switch
    - 1D-Abstand, 2D-, 3D-Scanner
    - Lightcut
  - Ultrasonic
    - Proximity switches and barriers
    - Distance, Scanner

  Inductive, capazitive, magnetic
    - Distance measurement
    - Welding path recognition
  - Various
    - Microwave
    - Pneumatic
    - Nuclear
    - Chemical

Autonomy Definition

Features

- Communication with the environment
- Autonomous generation of action plans for a distinct task
- Automatic execution and monitoring of the action plans
- Own understanding of the environment by means of sensor information and internal models
- Reaction on unpredictible situations.

Application of Image Processing in Industry

- Position recognition
- Robot control
- Surface inspection
- Measurment and testing
- Completeness detection
- Packaging inspection
- Label inspection and reading
- Accesscontrol
- Vehicle control
- ....

Tasks of Navigation

- **Bringing a moving** object
- **from a start** position
- **based on partially** incomplete information
- **considering** several, partially known limit conditions
- **to a** distinct goal

Features of Navigation

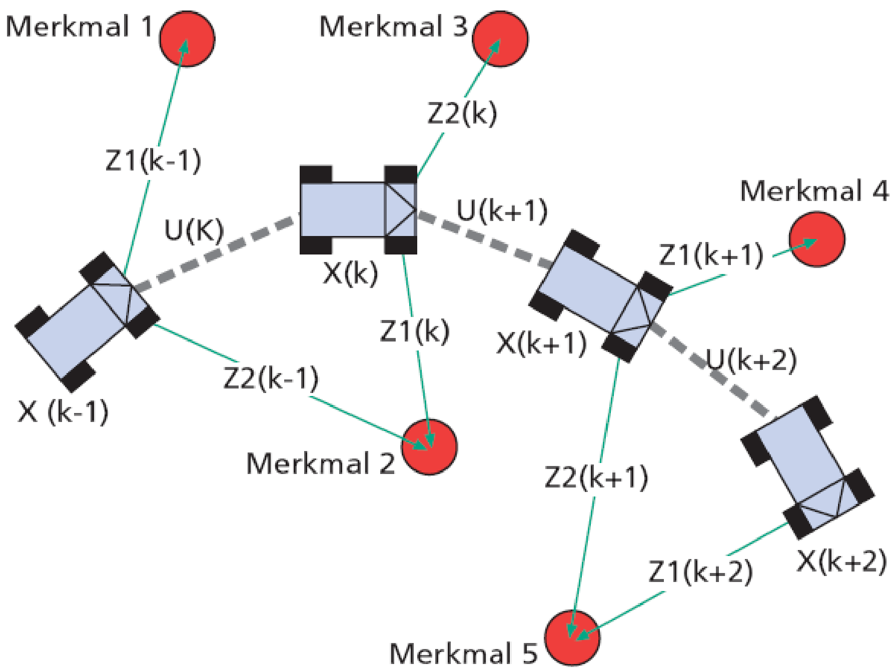
- Collision free path
- minimum path lenght
- minimum travel time
- minimum computing time for the calculation of the path
- Safety aspects
- Efficient work in unkwon environment.

Mapping and Localisation

Consists of two main components:

- Calculation of the actual position based on the distance covered
- Adjustment wit the actual sensor data (Laserscanner, camera)

From these information a local map is generated.



Control architecture 1/3

- Deliberative architecture
  - Sense – plan –act
  - World model is necessary
  - Task planning
    - Task specification
    - Task planning
  - Program synthesis
    - Motion planning
    - Trajectory planning

Control architecture 2/3

- Reactive architecture
  - No planning only reaction on sensor data
- Advantages
  - Always up to date
  - Simple hardware
- Disadvantages
  - Complete tasks difficult to implement

Control architecture 3/3

- Hybrid architecture
  - Combines deliberative and reactive architecture
  - Scheme based architecture
    - Motor scheme
    - Perceptual scheme

Applications of mobile Robot Systems

- Factory - Automation
  Transport e.g. components between the machining and assembling
- Dangerous environment
  Landmine detection, roboter in a nuclear - reactor
- Space
  e.g. Pathfinder at the Mars
- Underwater
  exploitation, surveying

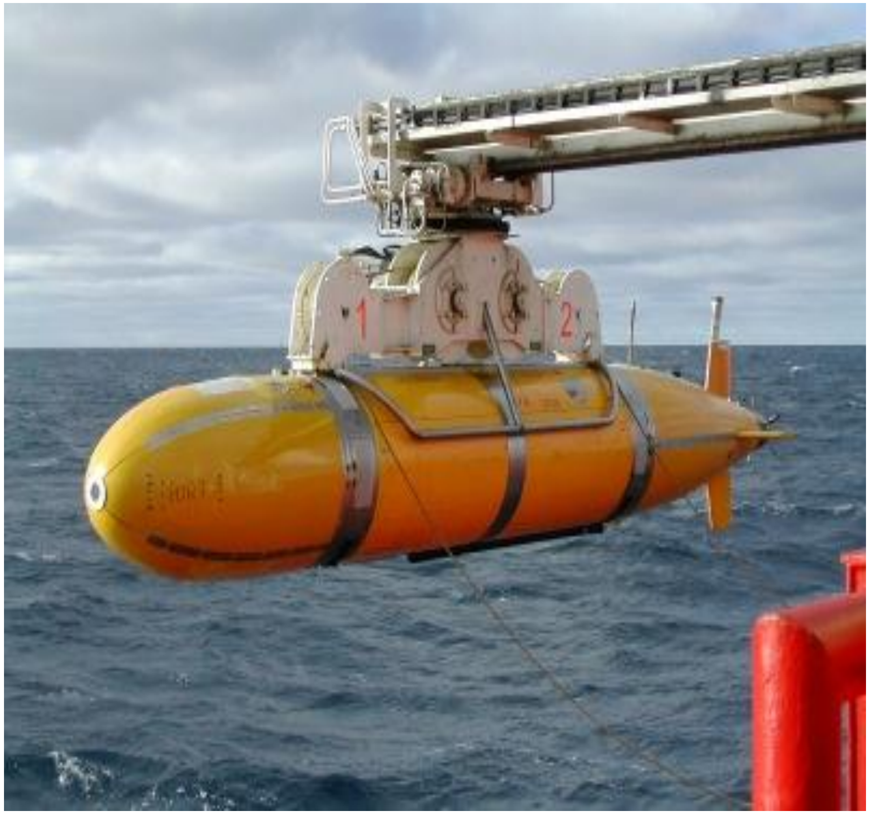
  Medical applications
- „Service Robotes“ for personal use
  e.g. Cleaning robots

Selected Applications

Underwater (UAV`s)
Aerial
Space
Agriculture
Construction
Hazardous Environment
Search and Rescue
Domestic
Education

Example: „Autosub“

- purpose: oceanography, mapping, for example beneath sea ice
- length: 7 m, diameter 0,9 m
- batteries provide energy for 500 km range or 6 days endurance
- max. depth: 1600 meters
- sensor or data driven path determination and terrain following



Flying Robots

Example: TU Berlin´s „Marvin“

designed for participation in the
IARC 1998-2000 (International
Aerial Robotics Competition)

autonomous flying robot, based on a helicopter-model

permanent data link to basestation on ground

GPS-navigatio

sends a high-resolution digital image every 9 sec

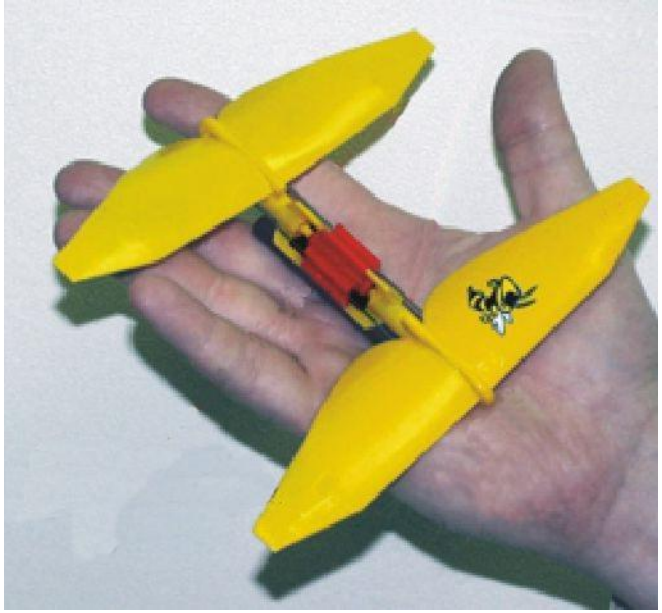
fire detection

Inspirations

- Just as most of robots, flying robots are inspired in the nature, specially in the insects.

Applications for Rescue

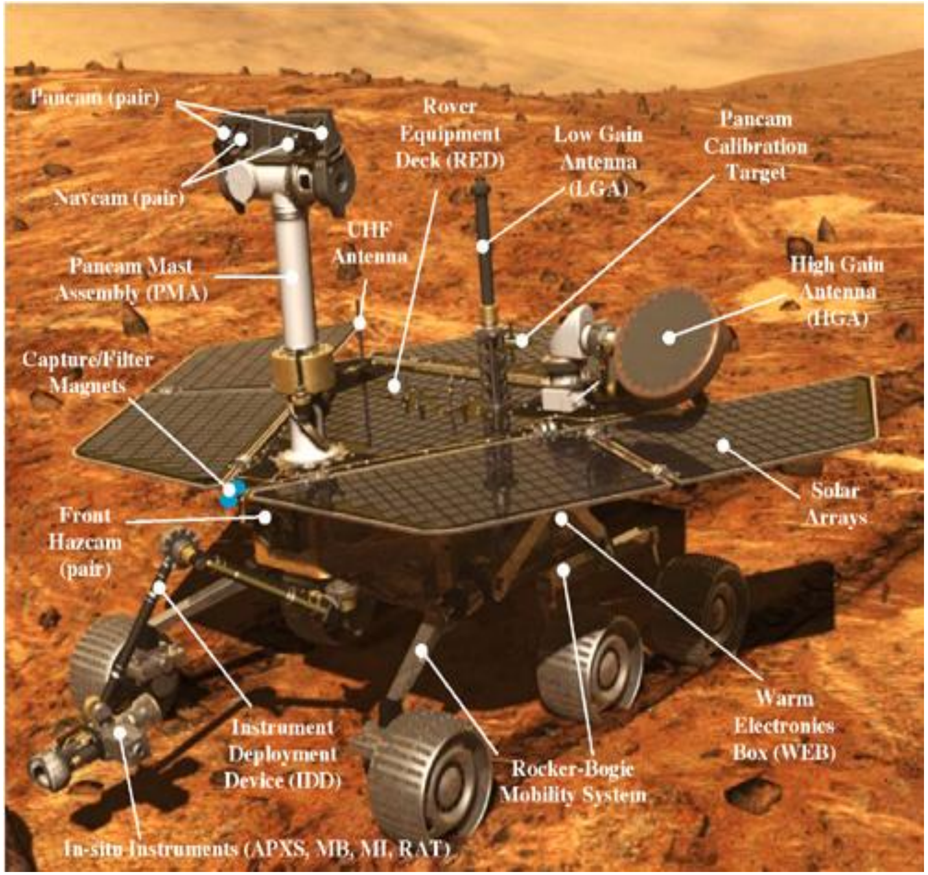
- Flying robots have also importance in **rescue missions**, accessing to dangerous places or small holes in rubble.



Robots for Space Exploration

Example:
„The Marsrovers“

- NASA's twin robot geologists, the „Mars Exploration Rovers“, launched toward Mars on June 10 and July 7, 2003, in search of answers about the history of water on Mars
- Moving from place to place, the rovers perform on-site geological investigations



Rescue Robots

- Mini robots

- Bomb-squad robots

- Construction robots

Bomb-squad Robots

- Most commonly used robot
- Used by militaries and bomb squads
- Used for bomb and mine defusing

Toy Robots: AIBO

- Wireless connectivity
- AIBO´s senses
  - *to see*
  - *to hear*
  - *to feel*
- AIBO´s mind
- AIBO´s expression
- Self-charge
- learning, ability to mature

Personal Robot PaPeRo 2003

Personal Robot PaPeRo 2003

Development

R100: NEC developes first prototype that should communicate with human beings as one of the family members in 1997

descendant PaPeRo named after „Partnertyped Personal Robot“ in year 2001

latest improvement 2003 focused on sophisticated human-robot interaction

RoboX

- **System Overview**

Hardware Platform

Navigation Computer :PowerPc 750 at 380 MHz

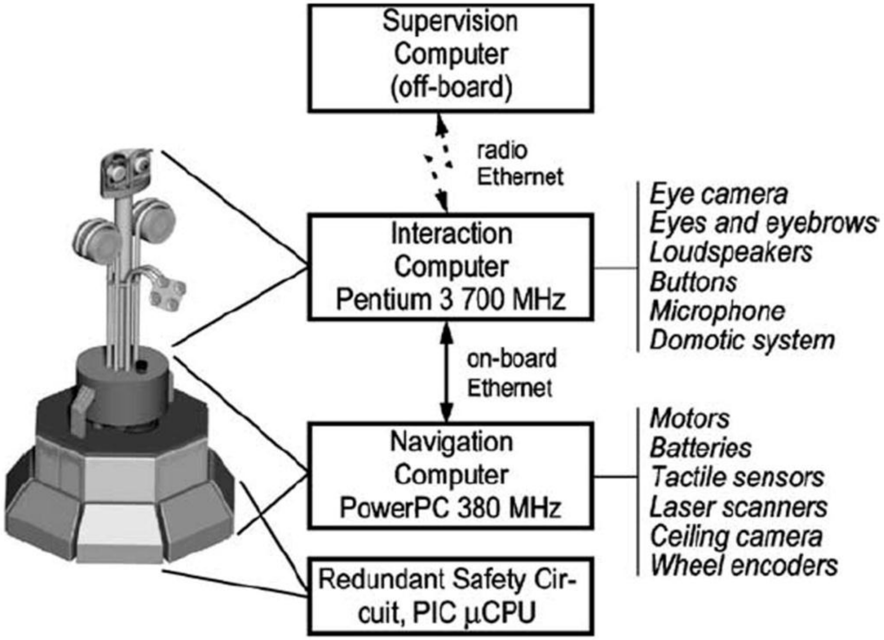
Interaction Computer :Pentium 3 at 700 MHz
under Windows 2000

Software Architecture

- An Intel Pentium and a Motorola PowerPC board

Hardware relation: Sick LMS 200 to the PowerPC **Safety**: the XO/2 operating system

Availability: Windows-based machine



RoboX

- ## Navigation System

  - graph-based global planning with feature-
  based localization
  - an algorithm for obstacle avoidance combining
  the dynamic window approach (DWA) with an
  elastic band method.

***Localization**: conventional Extended Kalman Filter (EKF) localization approach*

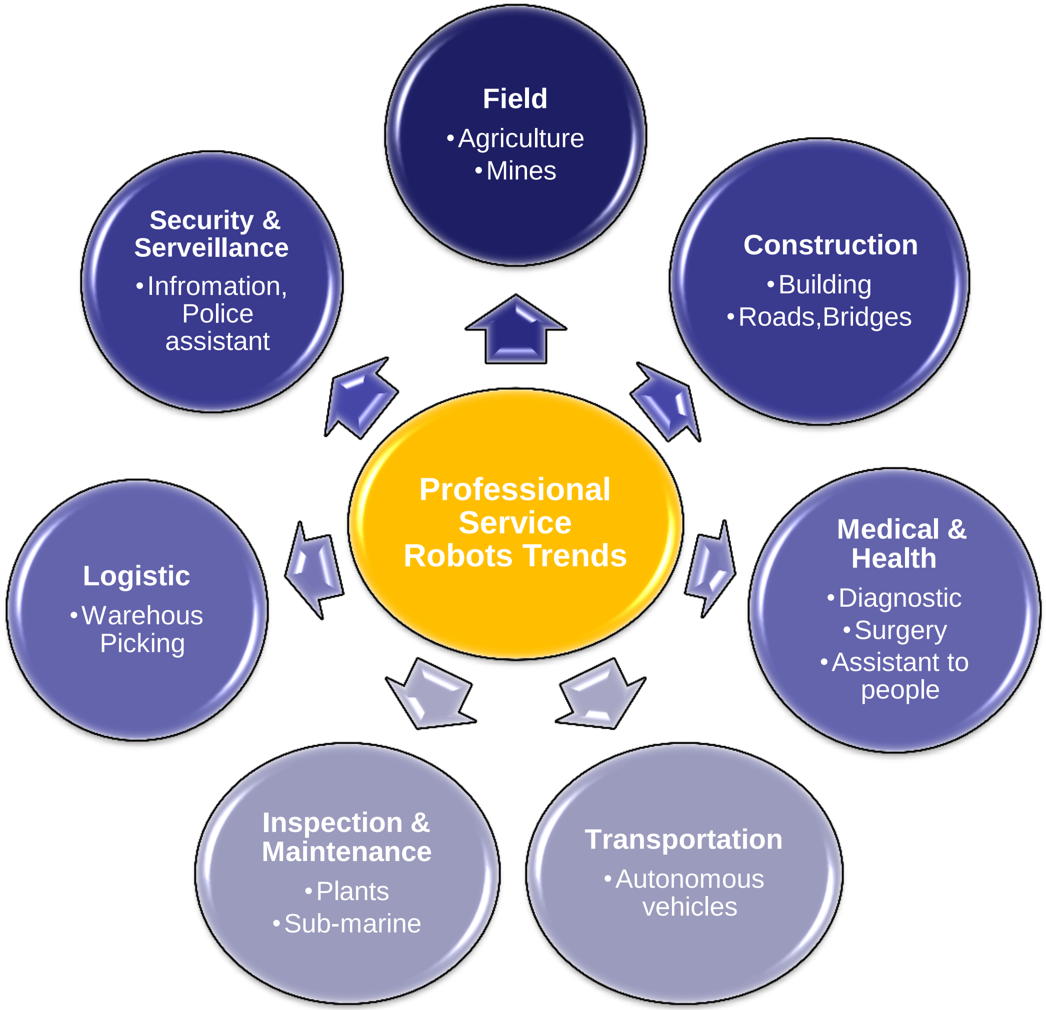
- ## Human Robot Interaction

  - *Scenario Object Utility Language* (SOUL)   - *People Tracking*

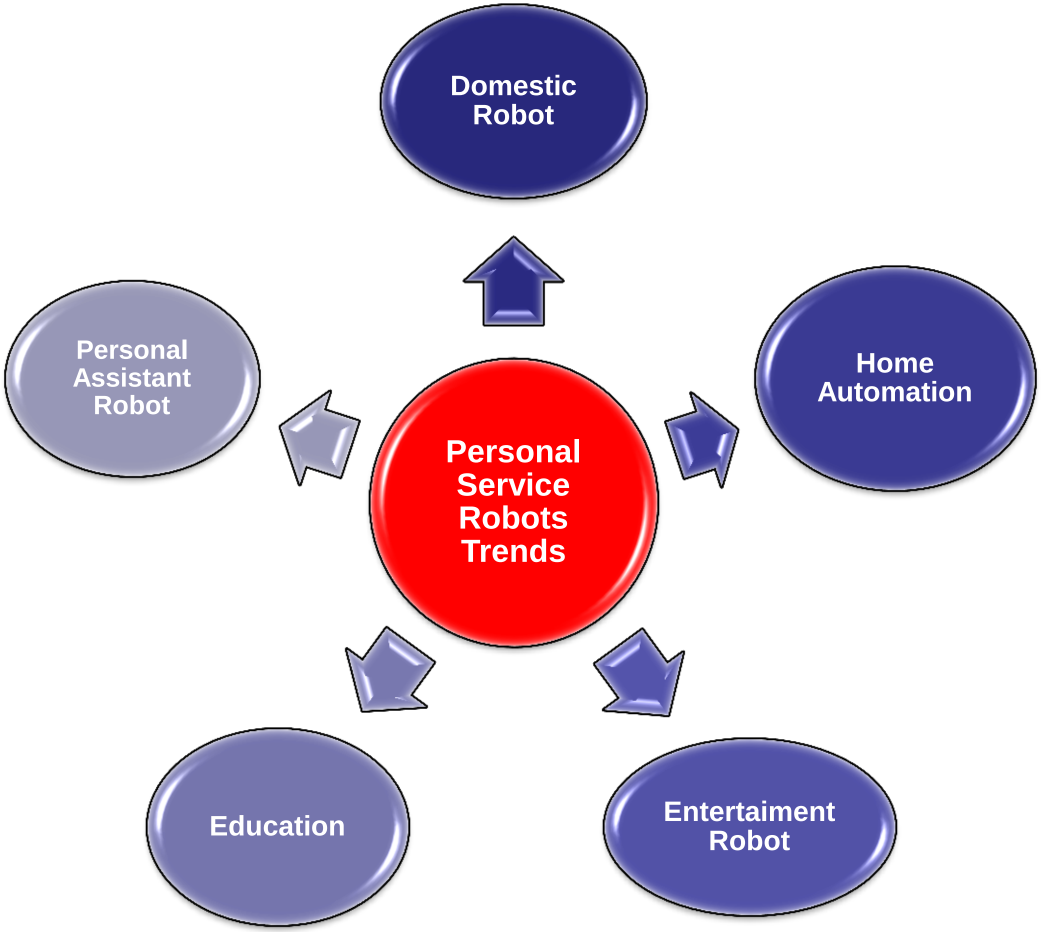
- Visitors seen from the robot

happy, surprised and angry.

Trends in Professional Service Robots



Non professional Service Robotic Trends



Application Examples

- HUMI
  - a Robot for Humanitarian Demining
- Robi Speed
  - a Mini Soccerrobot
- Roby Space
  - a Mini Robot for Space Applications

HUMANOID ROBOTS

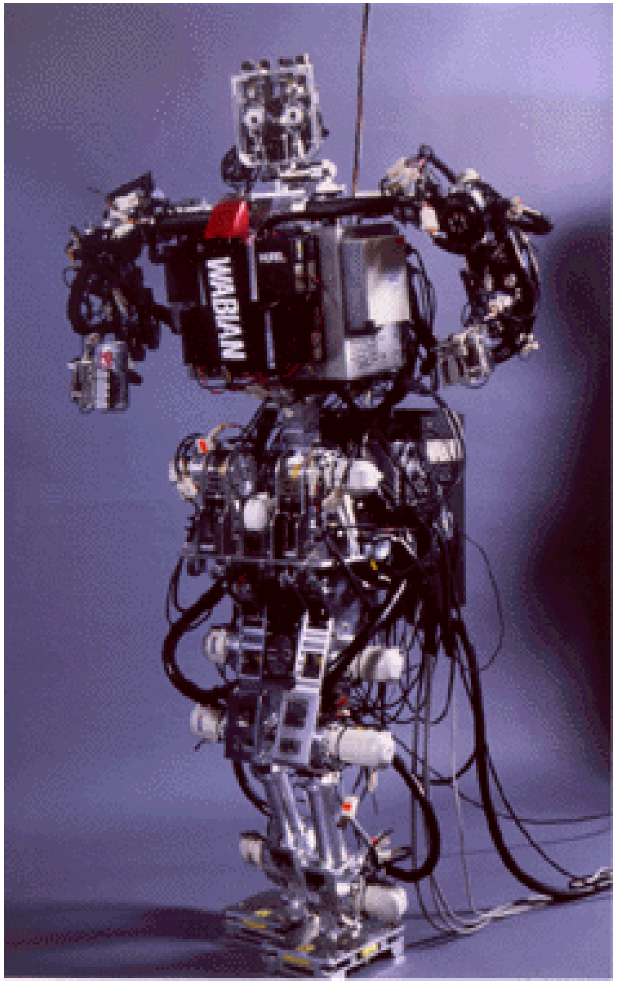
Humanoid Robots

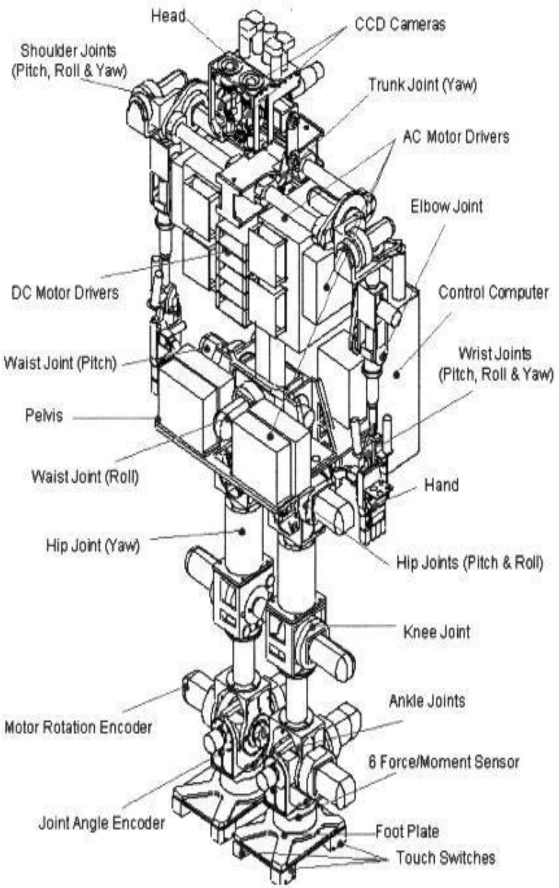
Introduction

- From engineering view point, human- being
  - Locomotion,
  - Navigation
  - Handling
  - Recognition
  - Sensing (5 senses)
  - Intelligent and autonomous system
  - Etc.
- Example, walking
  - Human-being, with muscles with our inner sensors
  - Robot, motors and gears and also sensors

Research robot „COG“ - MIT

Research Humanoid Robot WABIAN – Waseda University, Japan





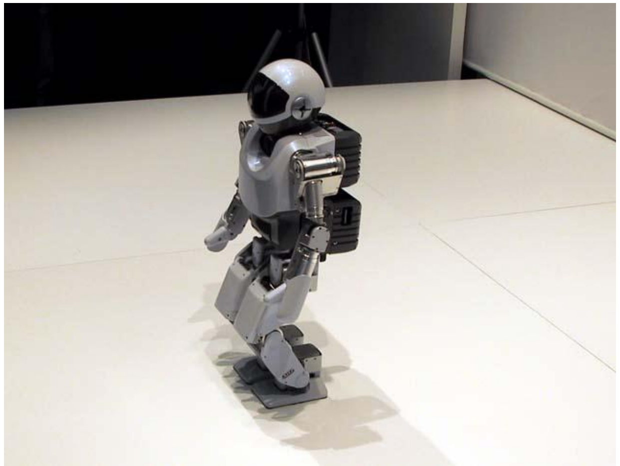
HRP-2 (AIST, Japan)

- Development (1998 – 2002)
- 1539 mm x 621 mm x 355 mm
- 58 Kg
- 30 DOF
  - 6 DOF / each leg
  - 6 DOF / each arm
  - 2 DOF / each hand
  - 2 DOF Waist
  - 2 DOF Head
- Sensor
  - Acceleration sensor
  - 6 axis force sensor for ankle and wrist
  - Three cameras (head)
  - DC servo motor with harmonic drive
  - NIMH Battery (48 V, 18AH)
- Capability to stand up by itself

„Professional“ humanoid Robots

- ASIMO (Honda)
- SDR-4X (SONY)
- QRIO(SONY)
- TOYOTA
- …

- Relatively expensive
- For own PR purpose
- „Closed“ Software



HONDA & TOYOTA

- Why car companies build the humanoid robot?
- Why did TOYOTA build humanoid robot?

Robot Band, Toyota

EXPO 2005 TOYOTA GROUP

Performance Details

< Seating Capacity Per Show : Approx. 800 people >

Welcome Show (Approx. 10 minutes)

Music Playing Robot (2-Legged Walking Model)	3 units
Music Playing Robot (Wheeled Rolling Model)	4 units
DJ Robot (Wheeled Rolling Model)	1 unit
MC	1 person

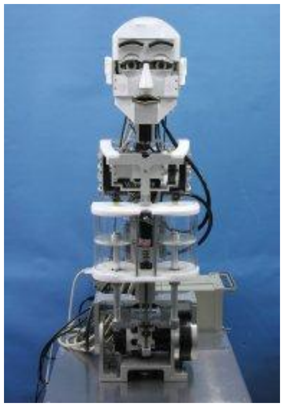
Main Show (Approx. 20 minutes
Producer / Show Director : Yves Pépin)

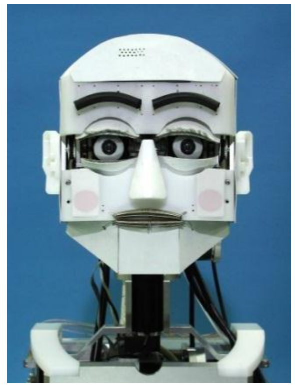
i-unit (Single passenger vehicle)	12 units
i-foot (Mountable, walking robot)	1 unit
Performers (Dancers)	Approx. 10 persons

EXPO 2005 AICHI, Japan

www.expo2005.or.jp

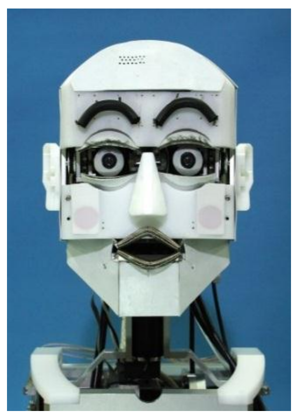
Face





Neutral

Angry

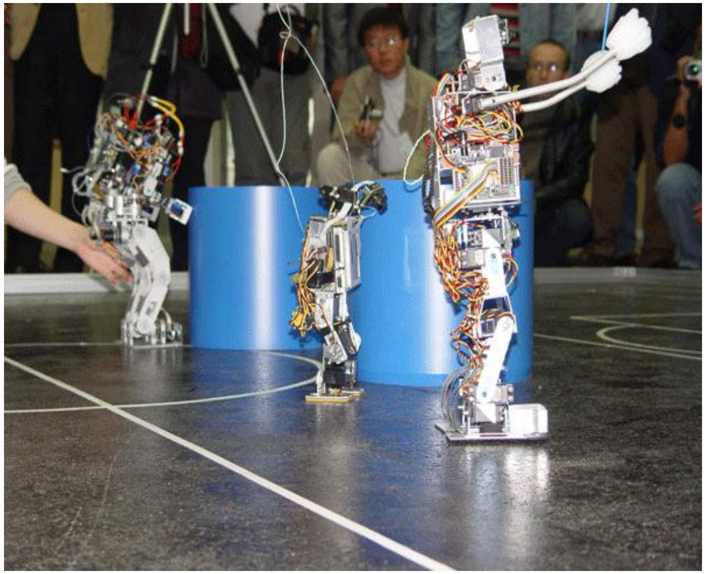


Astonished

Sad

Humanoid robot events

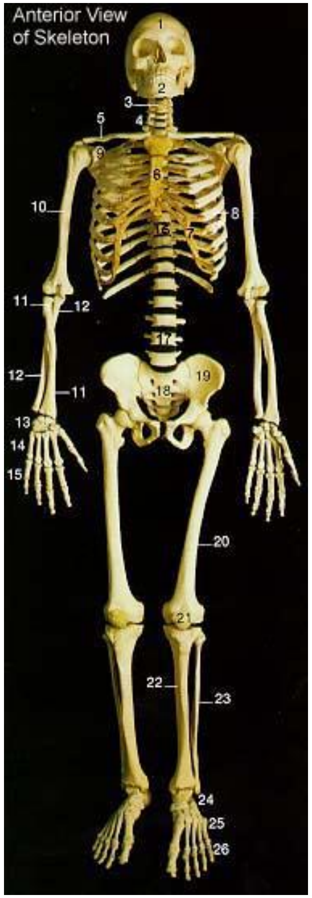
- Robot soccer
  - FIRA HuroSot
    - Robot Dash
    - Obstacle run
    - Penalty Kick
  - RoboCup Humanoid League
    - Penalty Kick
    - Game
    - Obstacle run
- Battle
  - Robo-One

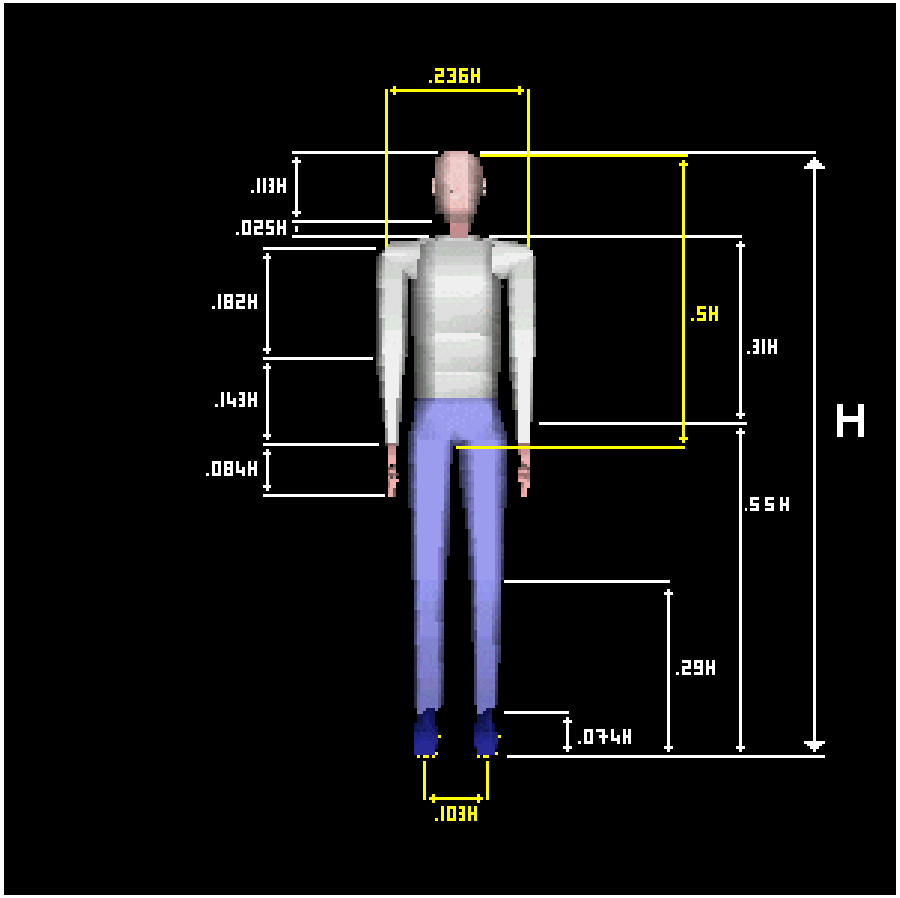


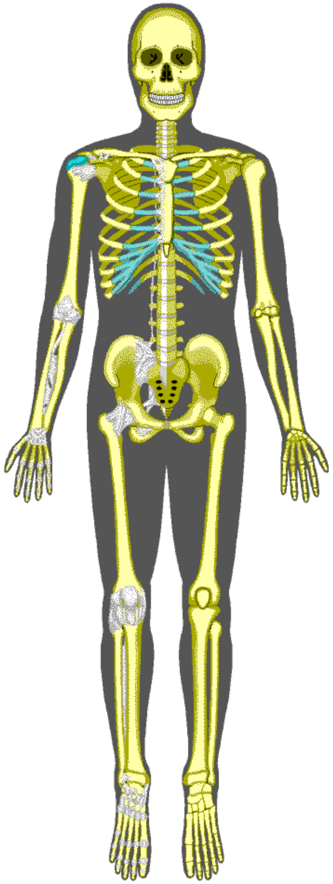
Introduction

- From scientific - engineering view point, human- being posesses
  - Locomotion
  - Navigation
  - Handling
  - Recognition
  - Sensing (5 senses)
  - Intelligent and autonomous system
  - Etc.
- Example, Locomotion (walking)
  - Human-being
    - muscles with inner sensors
  - Robot
    - motors, gears and sensors
    - Artificial muscles

(European) Humanoid Dimensions

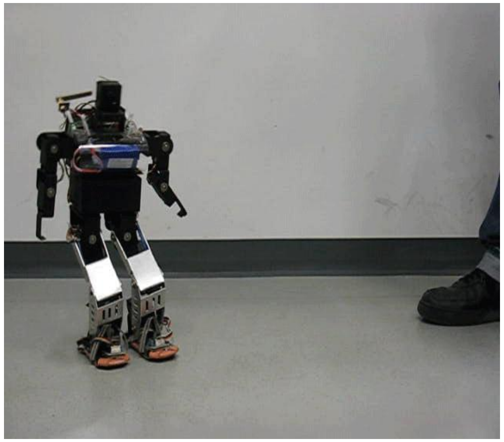






Humanoid robots

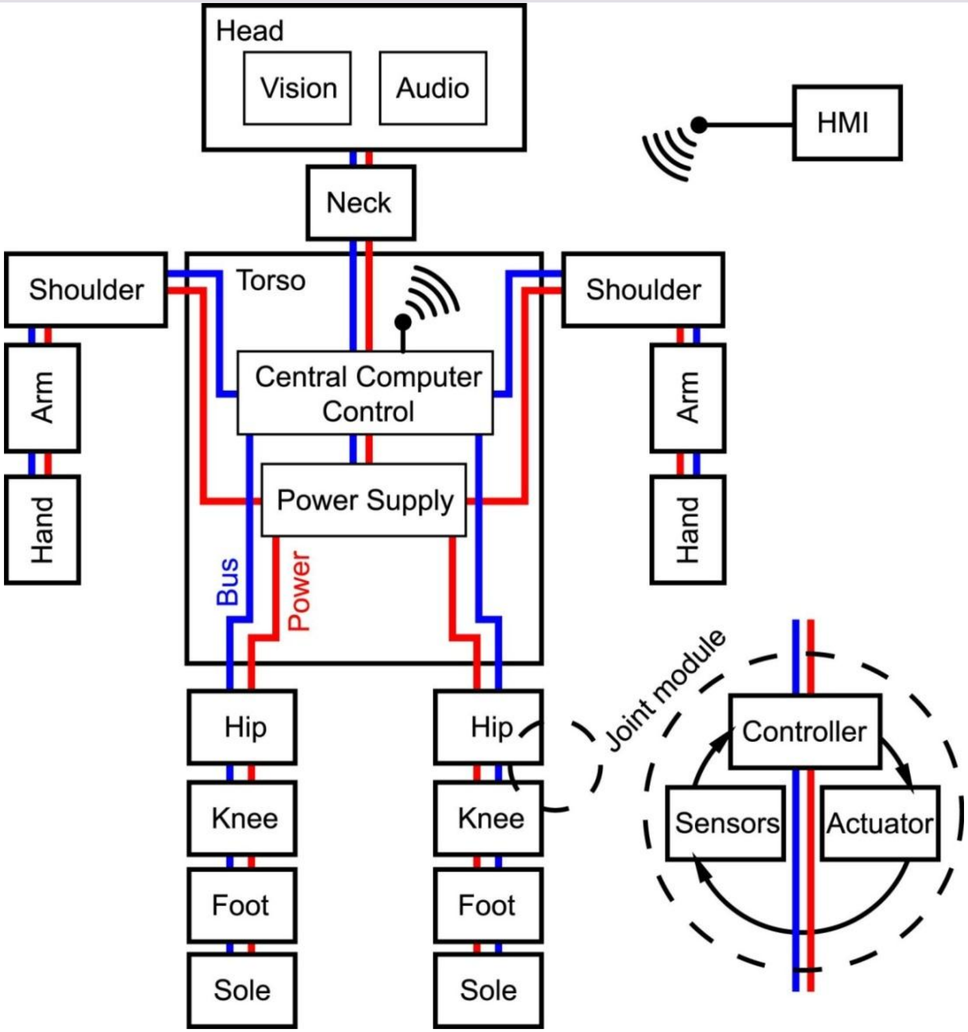
- Research humanoid robots
  - Developed by more than 500 research institutes as well as universities
  - With less budget as well as man power
  - Small, short step, no hands
- Professional humanoid robots
  - For own PR (Public Relation) purpose to promote the product, like Honda, Toyota
  - More budget and man power
  - Good walking, even running, stand up
  - Good hands
- Currently no real industrial applications



Humanoid robot - ARCHIE

- Goals
  - Humanoid, two legged robot
  - Development of a reasonably cheap “personal” robots
  - supporting humans in every day life (working place, home, etc.)
- Application areas
  - Humanitarian Demining
    - Outdoor – rough terrain
  - Support for elderly and disabled people
- ARCHIE
  - a head,
  - a torso,
  - two arms,
  - two hands and
  - two legs.

Structure of Archie



Future perspectives

- Implementation of the Control algorithms
- Improvement of simulator
- Walking mechanism
- Sensor based artificial intelligence
  - Vision system
  - Speech recognition
  - Man-Machine Interaction
- Other components
  - Arm, Finger, etc

Development Trends

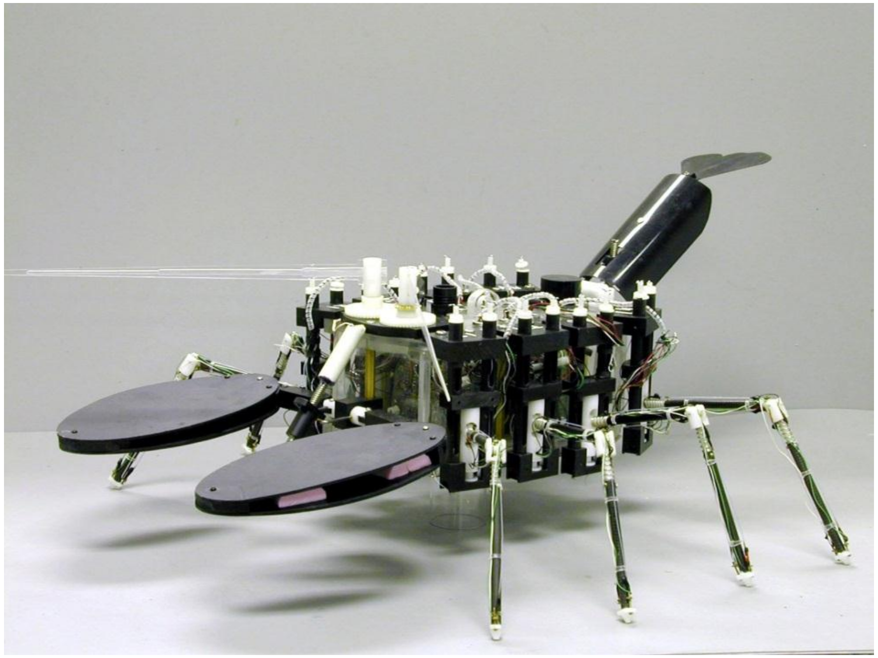
- Ubiquitous Robots
- Nano (Femto) Robots
- Bioinspired Robots
- Cloud robots
- Robots beyond 2020

Bionic Underwater Robots

The **lamprey-based** robot imitates the natural locomotion of eel-type creatures. Undulatory propulsion is wakeless and of high efficiency

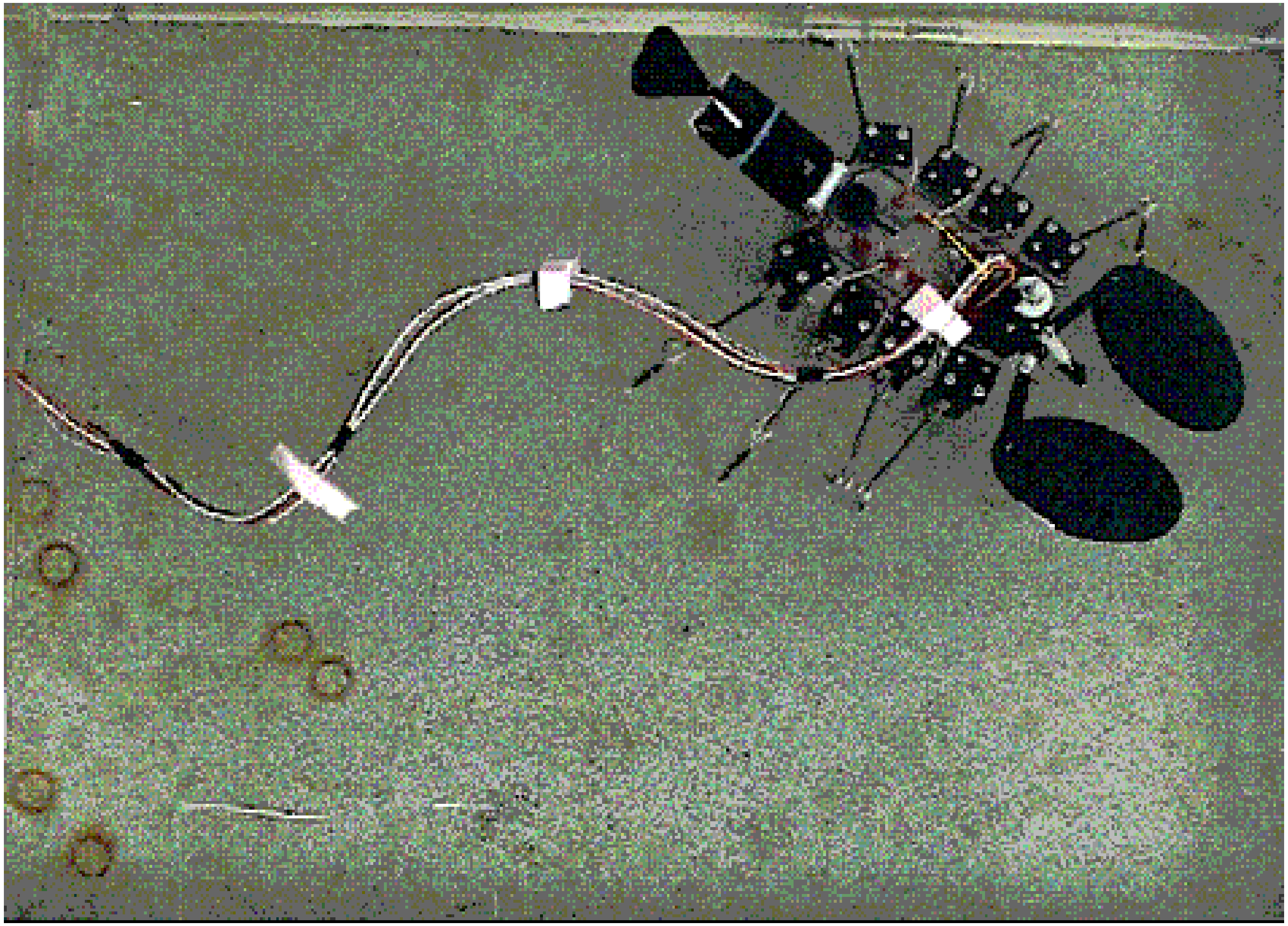
Lamprey-Based Undulatory Robot

The **lobster-robot** moves in the fashion of a real lobster and is intended for autonomous remote-sensing operations in rivers and ocean. Its bendable and pivoted antennae recognize obtacles and analyse the water current



Lobster-Robot

Autonomous movement of the Lobster Robot



Robot Swarms

Characteristics and Advantages:

~ Many equal swarm members (up to millions of units)

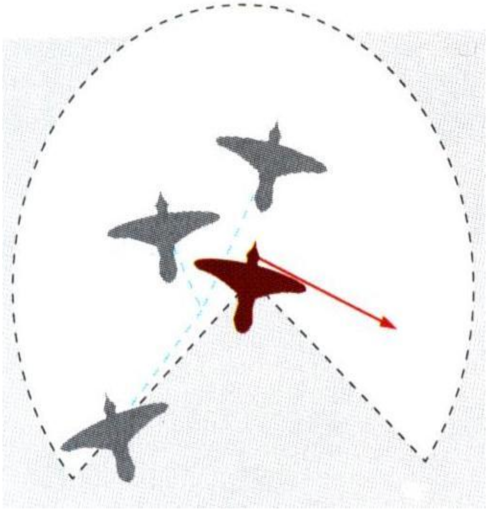
~ Setup of individuals simple

~ Intelligence results from interactions

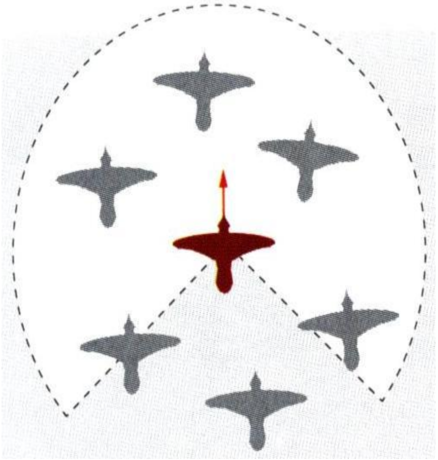
~ Stability against disturbance

~ No leader, simple rules

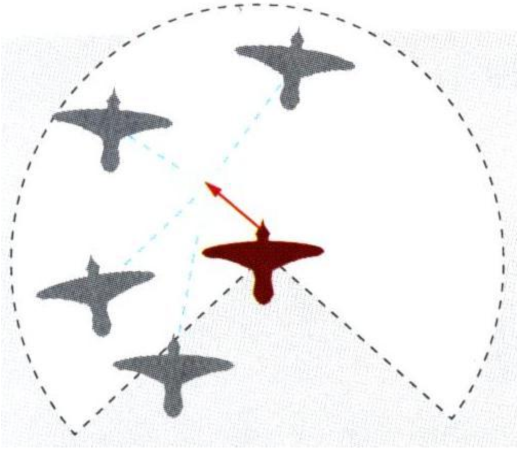
Example: Three Rules of Bird Swarms



1. Avoid Collisions!

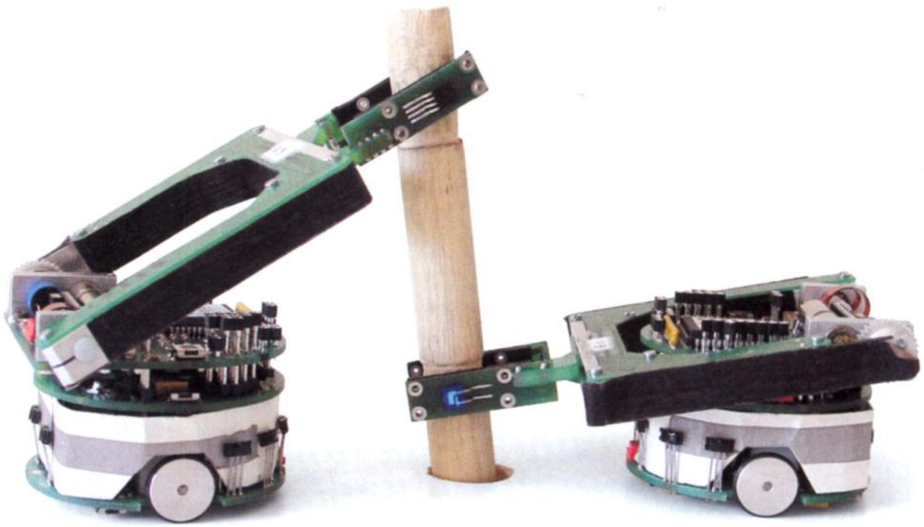


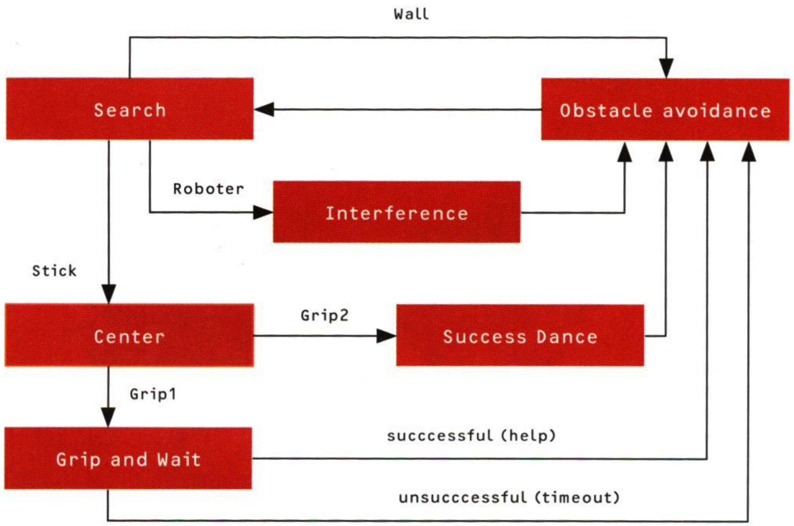
2. Catch up with others!



3. Fly to center!

COROs "Stick-Pulling-Experiment"





Fields of Application

~ Humanitory help in large crisis regions

~ Search for victims of avalanches

~ Restrain oilslicks after tanker disasters

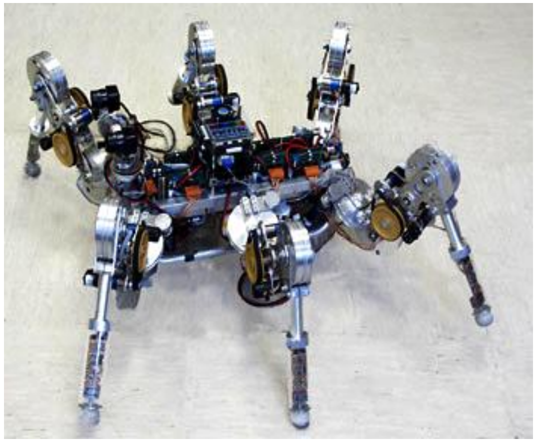
~ Remove landmines

~ Repairs in Space

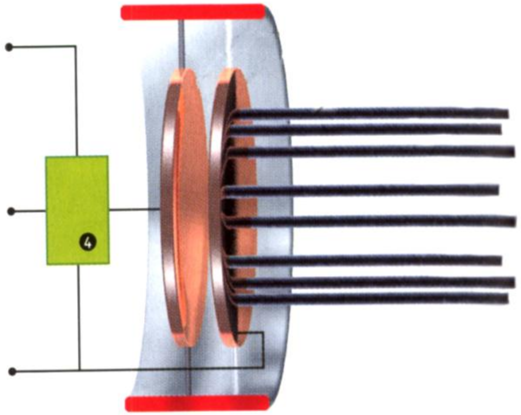
~ Intelligent granulate as long-term perspective

Bionics

“Bionics is the application of biological analogies for the study and design of engineering systems.”



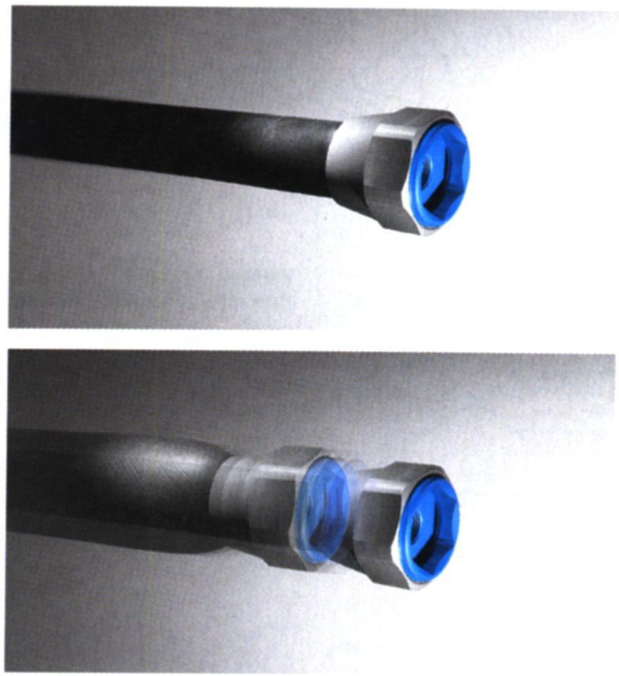
Robots similar to insects or spiders



Bionic haptic sensors

„Gecko-like“ adhesion effects

McKibben-Muscle



Advantages to pneumatic cylinder:

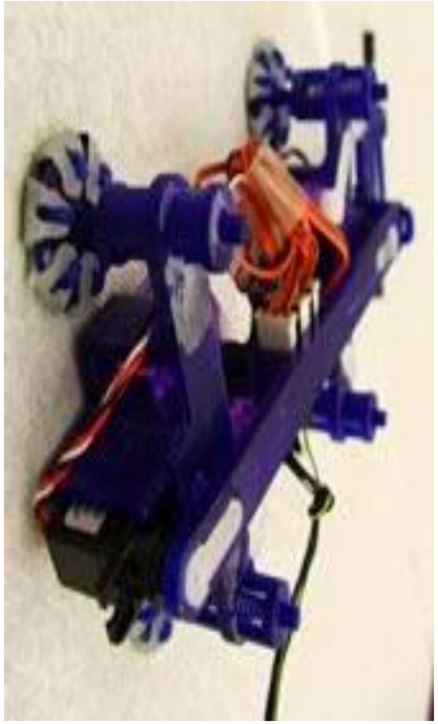
~ Weight loss 90 %

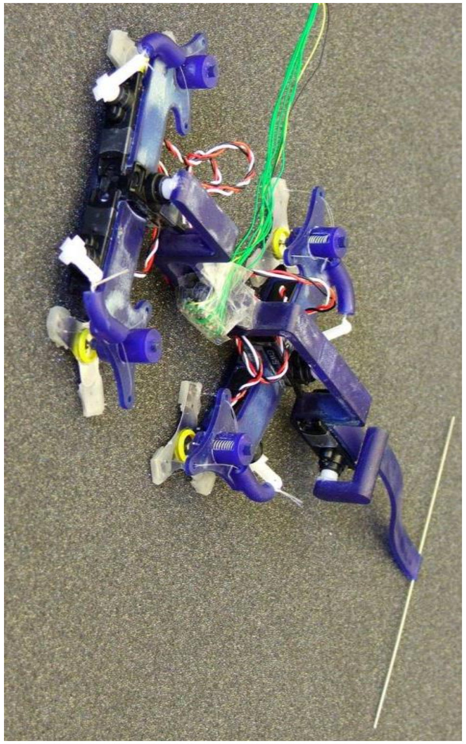
~ Higher achievable forces

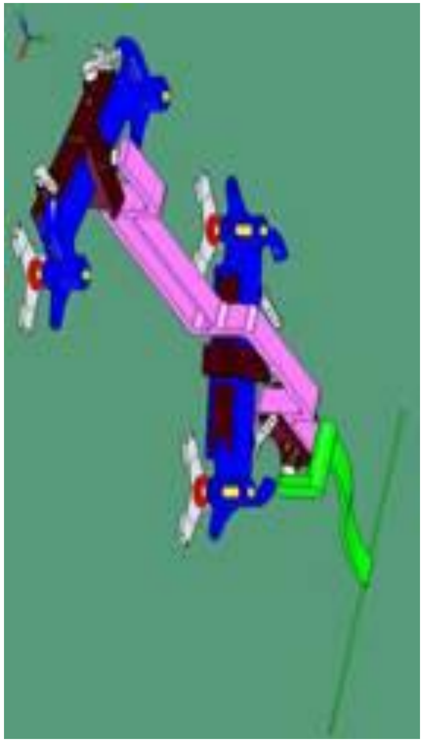
~ Energy savings of 40 %

~ Hermetic impermeable
(can be used in high-purity areas)

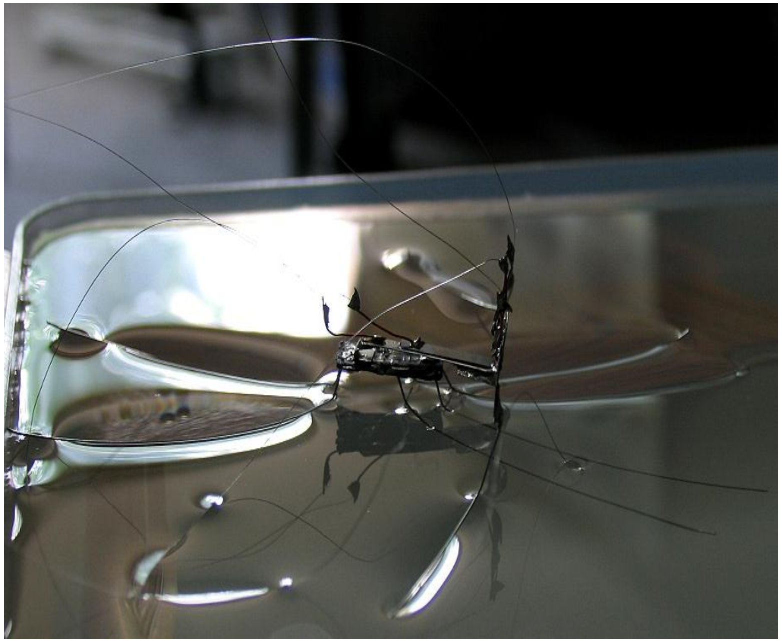
Geckobot: A motor actuated robot inspired by the gecko lizard







Water Strider: A miniature water strider robot



Nanorobots's Tomorrow

In the future, nanorobots could revolutionize medicine. Doctors could treat everything from heart disease to cancer using tiny robots the size of bacteria, a scale much smaller than today's robots.

Robots might work alone or in teams to eradicate disease and treat other conditions. Some believe that semiautonomous nanorobots are right around the corner -- doctors would implant robots able to patrol a human's body, reacting to any problems that pop up. Unlike acute treatment, these robots would stay in the patient's body forever.

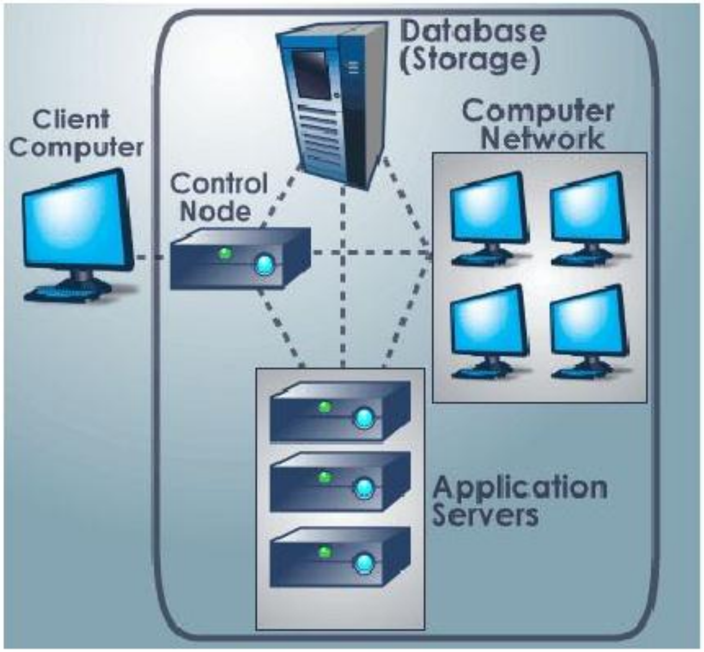
Although this 2-centimeter-long robot
is an impressive achievement,
future robots will be hundreds
of times smaller.

Cloud Computing

❖**Documents "live"**
In the cloud
(backed up and accessible anywhere

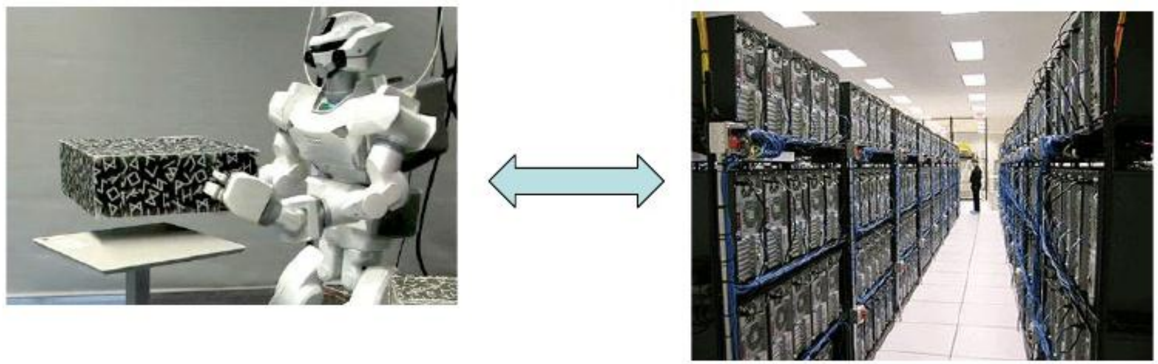
❖**Netbook**

❖**Supercomputing:**
(Heavy CPU or data-intensive processing handled by distributed network)



Cloud Enabled Robotics

Cloud-Enabled Robotics



❖ **Recent Proposal:**

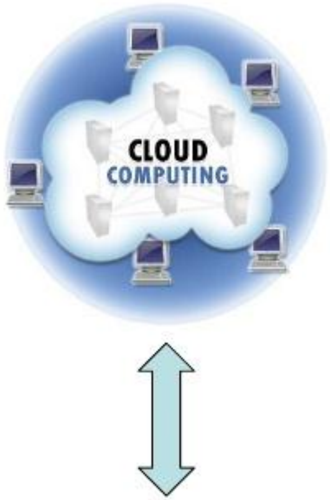
"DavinCi: a cloud computing framework for service robots" [Arumugam, et. Al. , ICRA 2010]

- Hadoop cluster with ROS communication infrastructure
- FastSLAM map/reduce

Benefits of “Cloud Robotics”

❖ **Provides a shared knowledge data base**

-Organizes are unifies information about the world in a format usable by robots



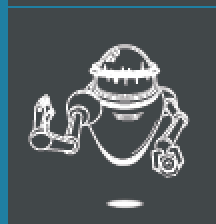
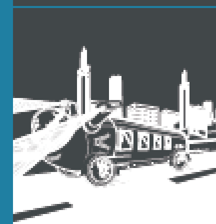
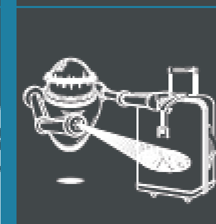
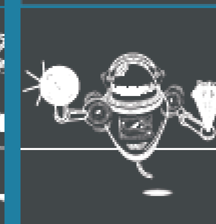
❖ **Offloads heavy computing tasks to the cloud**

- Cheaper, lighter, easier-to maintain hardware (akin to desktop PC vs. a thin-client “notebook”)
- Longer battery life
- Less need for software pushes/updates
- CPU hardware upgrades are invisible & hassle-free

❖ **Skill / Behavior Data base**

- Reusable library of “skills” or behaviors that map to perceived task requirements / complex situations.
- Data mining the history of all cloud-enabled robots

SRA – Robots beyond 2020

APPLICATION SCENARIOS / SECTORS	ROBOTIC WORKERS	ROBOTIC CO-WORKERS	LOGISTICS ROBOTS	ROBOTS FOR SURVEILLANCE & INTERVENTION	ROBOTS FOR EXPLORATION & INSPECTION	EDUTAINMENT ROBOTS
						
INDUSTRIAL	■	■	■			
PROFESSIONAL SERVICE	■	■	■	■	■	■
DOMESTIC SERVICE		■	■	■		■
SECURITY		■	■	■	■	
SPACE	■	■	■		■	

Further Topics

- Roboethics
- End of Life (EoL) Management of Robots
- ………….

- **INTRODUCTION**

- We can forecast that in the XXI century humanity will coexist with the first alien intelligence we have ever come into contact with - robots. It will be an event rich in ethical, social and economic problems.

- **The public is already asking questions such as:**

- “Could a robot do "good" and "evil”?
- “Could robots be dangerous for humankind?”

- **ABOUT ROBOETHICS**

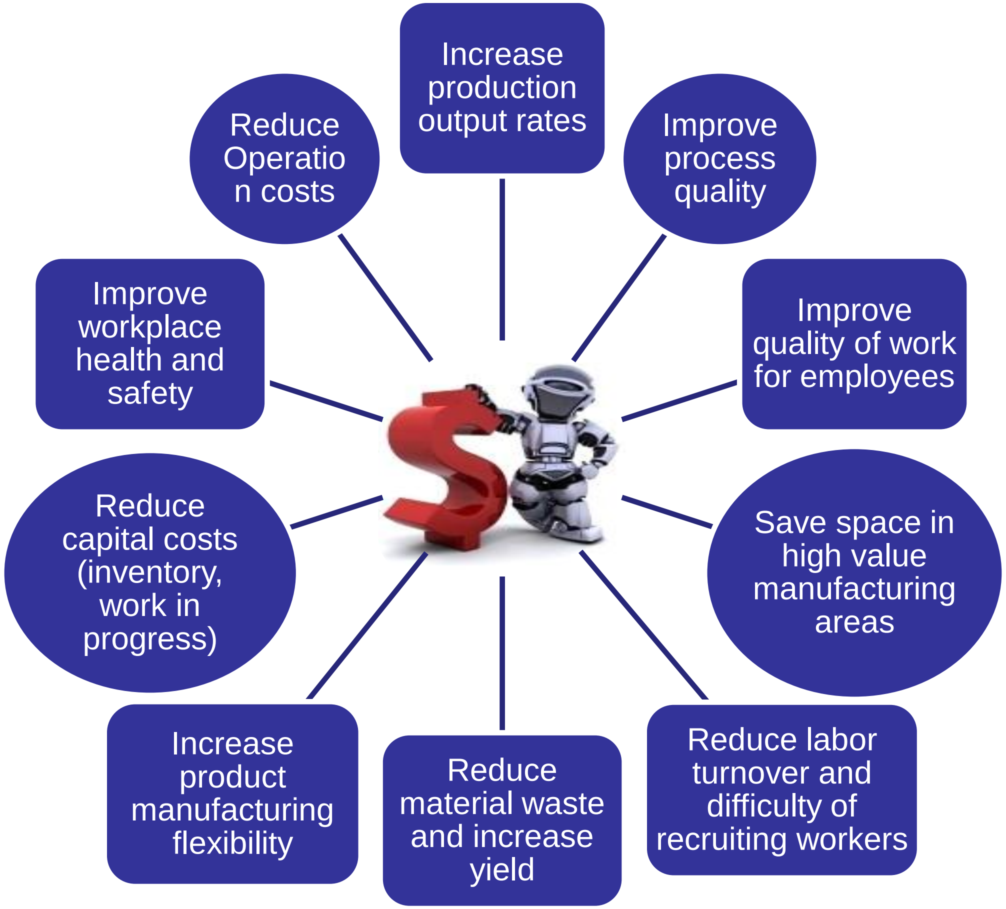
- **Three Laws of Robotics** from Isaac Asimov:

  1. A robot may not injure a human being, or through inaction, allow a human being to come to harm.
  2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
  3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

- Asimov added the **Fourth Law** (Law Zero):

  4. No robot may harm humanity or, through inaction, allow humanity to come to harm.

Top Reason of Investment in Robotic Market



Global Trends in Robotic Market

1980 ~ 1990	• society was ready to accept robots • industrial robots were popularized in car industry and hand wide applications.
1990 ~ 2000	• Improvement of production efficiency (welding, handling, inspection, painting, assembl, mounting, etc.). • Attaching much importance to product quality • Communication (between robots and other equipment)
2000 ~ 2012	• Safety standard was revised. (coorperative work with menhuman beings were enabled.) • Cell manufacturing enabled production of many kinds of products.. • Accuracy improvement due to progress of robot-workpiece relative position control.
2012 ~ 2020	• Market of highly intelligent robot expanded sharply worldwide. • Estimated sales of robots in Japanese market increased sharply. • Expanding of interactive robot with simplified operation. • Increase of sensor utilization, higher speed mommunication and more accurate sensors will be enbaled. • Weight reduction (high rigidity) due to progress of material technology and improvement of mean power rate due to further progress of motor and drivers. • estimated sales of robots in Japanese market moe than 6 trillion yen. • Improved intelligence due to progress of offline teaching and interface technology for efficient information exchange between robots and human.