INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

From Industrial to Cloud Robots

Učební texty k semináři

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1. ABSTRACT

Robotics is a very fast growing field especially in the last years. In the late seventies the first industrial applications of stationary unintelligent industrial robots were realized. Begin of the 90`s a new generation of mobile, intelligent, cooperative robots grows up. This new generation opens new applications areas like in construction, in agriculture, in the food industry, in the household, for medical and rehabilitation applications, in the entertainment industry as well as for leisure and hobby. Current developing trends are humanoid robots and robots supporting the human in everyday life. Other intensive research areas are cooperative robots, bio inspired robots, ubiquitous robots and cloud robots.

In this seminar a practical, industrial oriented overview on these categories of robots, will be given and illustrated by realized examples.

2. ROBOTS

Industrial robots have been widely applied in many fields to increase productivity and flexibility and to help workers from physically heavy and dangerous tasks.

Definition according to ISO 8373*: A manipulating industrial robot is 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.*

From similar aspects the need on robots in service sectors - like robots in hospitals, in households, in amusement parks - is rapidly increasing.

Definition*: A service robot is a robot which operates semi- or fully autonomously to perform services useful to well- being of the humans and equipment, excluding manufacturing operations.*

Cheap and accurate sensors with a high reliability are the basis for „intelligent“ robots. These intelligent robots can be used for conventional as well as complex applications. Furthermore new applications not only in industry are possible.

There are three "starting" points for the development of intelligent robots: Conventional, stationary industrial robots; Mobile, unintelligent platforms (robots) and Walking mechanisms (Coiffet, 1998).

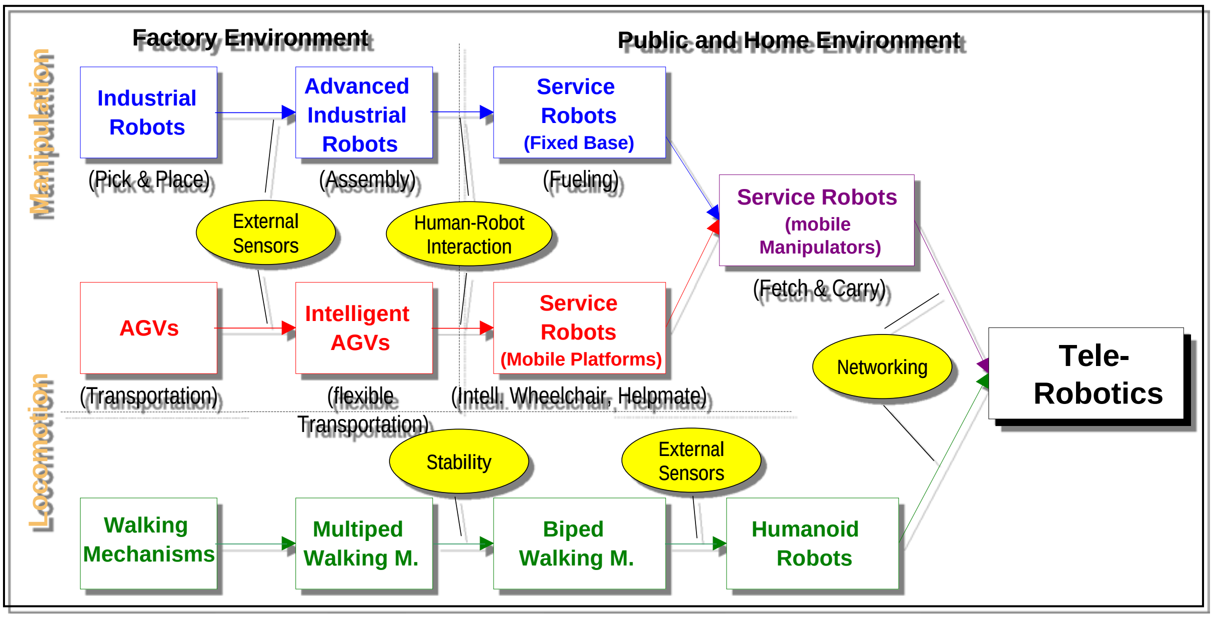


Fig. 1. From Industrial to Service Robots (Kopacek 2005)

Stationary industrial robots consist of the main parts shown in Fig. 2 and Fig. 3 Nowadays they are equipped with external sensors for "intelligent" operations e.g assembly and disassembly, fuelling cars… and are "intelligent" robots.

Partially intelligent mobile platforms "Autonomous Guided Vehicles – AGV`s" are available since some years and are introduced in industry. Equipped with additional external sensors (Intelligent Autonomous Guided Vehicles – Intelligent AGV`s) are currently slowly introduced in industry and cover a broad application field.

Walking machines or mechanisms are well known since some decades. Usually they have 4 to 6 legs (multiped) and only in some cases 2 legs (biped). Walking on two legs is from the view point of control engineering a very complex (nonlinear) stability problem. Biped walking machines equipped with external sensors are the basis for "humanoid" robots. Some prototypes of such robots are available today.

In addition these intelligent robots – especially mobile platforms and humanoid robots - are able to work together on a common task in a cooperative way. The goal is so called “Multi Agent Systems – MAS”. A MAS consists of a distinct number of robots (agents), equipped with different devices e.g. arms, lifts, tools, gripping devices ... and a host computer. A MAS has to carry out a whole task e.g. assemble a car. The host computer divides the whole task in a number of subtasks (e.g. assembling of wheels, windows, brakes ...) as long as all this subtasks can be carried out by at least one agent. The agents will fulfil their subtasks in cooperative way until the whole task is solved.

One of the newest application areas of service robots is the field of entertainment, leisure and hobby because people have more and more free time. In addition modern information technologies lead to loneliness of the humans (tele-working, tele-banking, tele-shopping, and others). Therefore service robots will become a real “partner” of humans in the nearest future. One dream of the scientists is the “personal” robot. In 5, 10 or 15 years everybody should have at least one of such a robot because the term personal robot is derived from personal computer and the price should be equal.

3. INDUSTRIAL ROBOTS

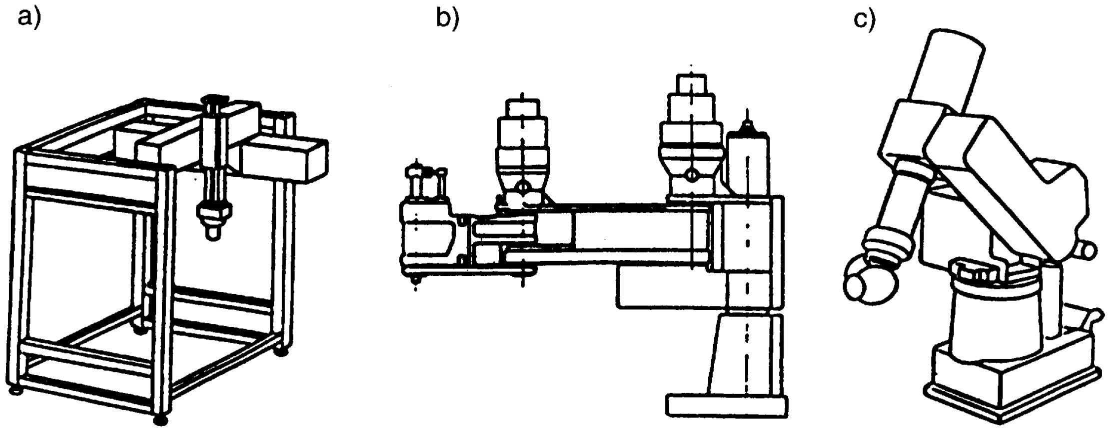


Fig. 2 Different types industrial robots. a) Cartesian (TTT); b) Scara (TRR); c) Spheric (RRR).

To fulfil the tasks of a human arm, an industrial robot should be able to realise its movements. The human arm has six movement possibilities – two in the shoulder, one in the elbow and three in the wrist. These six rotational movement possibilities – degrees of freedom (DOF`s) – are realised in the robot by translational (T) and rotational (R) movements (DOF`s). Three DOF`s (shoulder and elbow) are in the gripper control unit and three in the gripper. Grippers of industrial robots, currently available on the market, are equipped with three rotational DOF`s while the gripper control unit has usually combinations of translational and rotational DOF`s. Three examples are shown in Fig. 2.

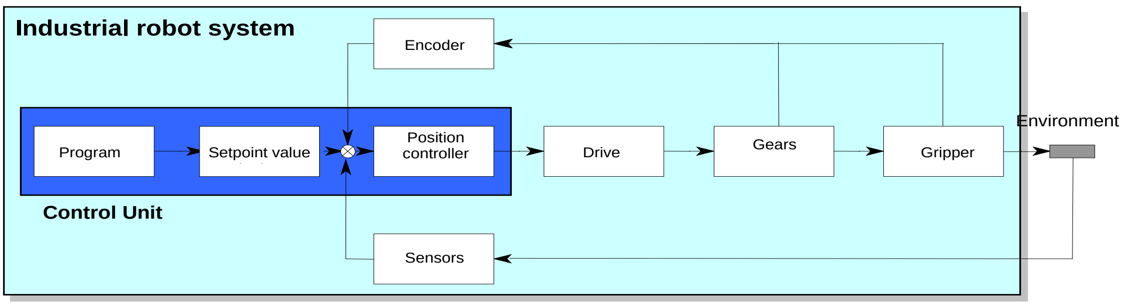


Fig. 3. Main parts of an industrial robot

As shown in the block diagram, Fig. 3., a conventional, stationary, industrial robot consists of the mechanical construction including gears, grippers and gripping devices; the – usually - electrical drives; the control unit; the internal sensors (encoders for translational and rotational positions). External sensors (force torque, visual, auditory…) give the control unit additional information about the working environment of the robot. Such external sensors make the industrial robot "intelligent".

Furthermore the robots will be frequently used as examples for "Mechatronic Systems".

The worldwide industrial robot population was growing up dramatically in the last years. Approximately 15 years ago the number of robots in industry was nearly doubled every three years. Therefore, according to the forecasts five years ago, the number of robots working in industry worldwide should be increased by 30% every year. Work places requiring industrial robots were usually equipped with non-intelligent robots.

At that time the industry was waiting for intelligent robots equipped with external sensors – intelligent robots. As already known the development of such external sensors like visual, auditory, force torque is going on very well in research institutes and laboratories. Now some of these sensor concepts are available for industrial applications at a reasonable price.

Between 1992 and 1994, the producers of industrial robots were confronted with a decreasing demand of industrial robots. The number of installed robots in the industry worldwide was approximately 30 % less than the estimations five years ago. One of the reasons was that in classical application fields like spot welding, spray painting, coating, materials and parts handling a saturation effect were obtained especially in the years 1992 - 1994. As a logical consequence the prices for industrial robots decreased dramatically. At present in some cases industrial robots are available for reasonable prices.

Latest developments deal with a modularization of the robots as well as the control system. Probably in the nearest future it might be possible to buy an industrial robot and separately, from another company, an advanced control computer as well as external sensors at low prices.

Such "unintelligent" industrial robots were used mostly in production systems equipped with NC, CNC or DNC machines as well as in CIM- or ims - systems.

Some of the features are collected in Tab. 1. These robots are not mobile (stationary), not equipped with sensors, have the classical kinematical structures (e.g. TTT, RTT, TRT, RRT, RRR) and are conventional controlled (time discrete, digitalized PI algorithms). Programming is done usually off-line by "teach-in" or in some cases by a programming language (textual programming).

Robot Features	Industrial Robots "unintelligent"	Industrial Robots "intelligent"	Mobile Robots "intelligent" (Service Robots)	"Agents" Multi-Agent-Systems
Kinematics	Classic	Classic	Advanced	Advanced
Control	Conventional	"Advanced"	Advanced	Advanced
Programming (HMI)	Manual	Manual	Semi-Automatic	Automatic
Intelligence (Sensors)	∅	Partially	yes	yes
Mobility	∅	∅	yes	yes
Navigation	-	-	Classical	Advanced
Portability	∅	∅	yes	yes
Adaptability	∅	Partially	Partially	yes

Table 1 Comparison of required robot features.

4. Mobile robots

During the last years, mobile robot systems were gaining more and more importance in both, service sectors (with one special emphasis on applications in health care) and in manufacturing areas (Dillmann, 1995), (De Almeida, Khatib, 1998).

Mobile platforms with external sensors (Fig. 4.) are available since some years and cover a broad field of new applications. The core of each mobile robot is an intelligent mobile platform with an on-board PC. On this platform, various devices, like arms, grippers, transportation equipment, etc., can be attached. Communication between the „onboard PC“ and the „supervisory PC“ is carried out by radio-based networks - communication with the environment can be accomplished by voice,…… (Cox, Wilfong, 1995)

Compared with industrial robots, service robots would be characterized by the following features to permit the operating effectively and unobtrusively in the human living environment:

Mobility:

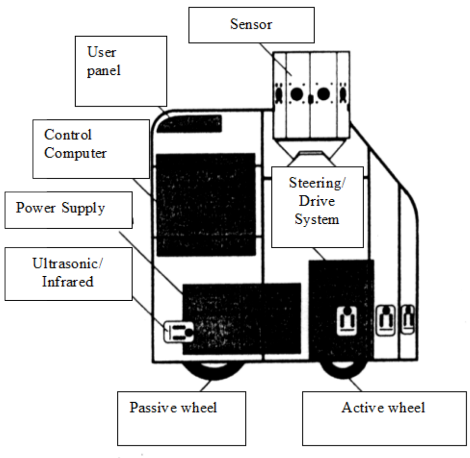
To possess the means of displacing itself in the manner most suited to the envisaged activities (wheels, legs, suction cups, adhesive pads, friction flying, swimming).

Autonomy:

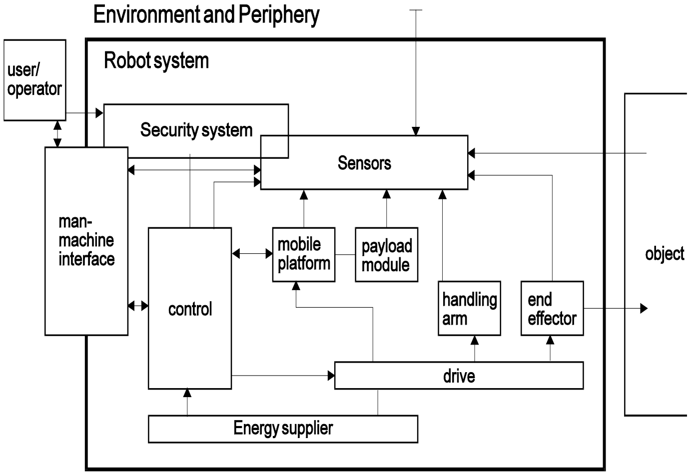
To be compact and lightweight, and preferably equipped with self containing energy source.

Human-Machine-Interface (HMI):

To be provided with an interface with the human operator/client, that will present the least difficulty to him (e.g. ultimately to function in oral conversation between man and machine).



4a. Design



4b. Block Diagram

Fig. 4. Parts of a mobile platform

Sensing/learning/judging function (artificial intelligence- AI):

To be equipped for operations in unfamiliar environment - with scanty information on external conditions, varying with time, subjects and measurement errors. An intelligent robot should be able to compensate all these effects.

Adaptability to widely varying operations and environmental conditions:

The ideal multipurpose robot which cannot be expected in the nearest future, might possibly able by the adoption of multiple single robot functions to fulfill these requirements.

Possible applications including the tele-operation or semi-autonomous operation of robot platforms in various scenarios could be:

- Factory automation: Mobile robots transport components between distinct machining and (dis-) assembly sites;
- Operation in hazardous environments, including the deployment of mobile robots in mine excavation, and the use of autonomously navigation robots inside nuclear facilities for inspection purposes;
- Planetary and space exploration, using autonomous rovers and probes, and the employment of tele-robotic systems in space construction;

- The use of robots for deep-sea surveying and prospecting;
- Assistance for the handicapped, application of „service robots“ in healthcare;
- „Service robots“ for personal use - e.g. cleaning robots.

Today the number of service robots in operation in industry is very small - approximately 80000 worldwide. However, the evolution of people working in the service field shows a constant growth rate and consequently enormous potential. Great hopes are attached to the expansion of this sector, however the possibility of the automated implementation of services through robot systems is barely apparent, neither to the supplier and manufacturer, nor to the user/customer. The use of robot systems in the field of services offers, in principle, advantages to all those involved.

5. Walking machines – Humanoid robots

Walking machines or mechanisms are well known since some decades. Usually they have 4 to 6 legs (multiped) and only in some cases 2 legs (biped) – walking on two legs is from the view of control engineering a very complex (nonlinear) stability problem. Biped walking machines equipped with external sensors are the basis for “humanoid” robots.

It was always an old dream to have a personal robot looking like a human. Main features of a humanoid robot are

- biped walking
- voice communication – speech recognition
- facial communication

A humanoid robot is a robot with its overall appearance based on that of the human body. Perception, processing and action are embodied in a recognizably anthropomorphic form in order to emulate some subset of the physical, cognitive and social dimensions of the human body and experience.

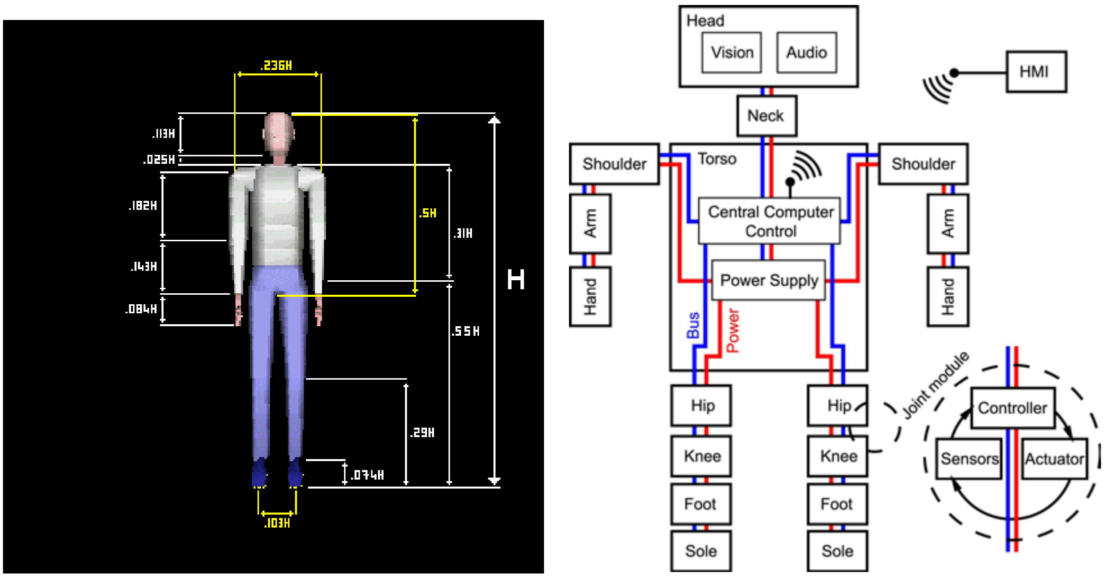


Fig. 5. Parts of a humanoid robot (Kopacek 2009)

Humanoid Robotics is not an attempt to recreate humans. In general humanoid robots have a torso with a head, two arms and two legs, although some forms of humanoid robots may model only part of the body, for example, from the waist up. Some humanoid robots may also have a ‘face’, with ‘eyes’ and ‘mouth’.

The definition of a humanoid is as simple as “having human characteristics.” That is exactly what humanoid robotics is about. There are studies going on trying to advance our knowledge with technology. And according to these studies, the humanoids will be able to show emotion, think for themselves, and learn by watching their surroundings.

The main feature of a real human is the two legged movement and the two legged way of walking. Much research has been conducted on biped walking robots because of their greater potential mobility. On the other side they are relatively unstable and difficult to control in terms of posture and motion.

The stability during the walking process decreases with the number of the legs. Therefore there were 8, 6 and 4 legged robots copied from the nature (insects, swarms, …) developed in the past. With new technologies and new theoretical methods two legged robots can be realised responsible for human tasks like service applications, dangerous tasks, tasks on the production level, support of humans in everyday life….

Furthermore biped walking robots are much more flexible than robots with other movement possibilities. The main advantage of legged robots is the ability to move in a rough terrain without restrictions like wheeled and chained robots. Legged robots could work in environments which were until now reserved only for humans. Especially fixed and moved obstacles can be surmounted by legged robots. In addition to walking such robot could realize other movements like climbing, jumping…

In robotics there are two methods of walking: Static and dynamic. "Static walking" means the robot keeps its centre of gravity within the zone of stability - when the robot is standing on one foot, its centre of gravity falls within the sole of that foot, and when it is standing on two feet it falls within a multi-sided shape created by those two feet - causing it to walk relatively slowly. In "dynamic walking", on the other hand, the centre of gravity is not limited to the zone of stability - in fact it often moves outside of it as the robot walks. Basis is mostly the “Zero Moment point – ZMP” method introduced in 1972. People moves usually by "dynamic walking".

Currently there are worldwide four categories of two legged humanoid robots available:

“***Professional” humanoid robots*** developed by large companies with a huge amount of research capacities. Examples are: the Honda robots (P1, P2, P3, ASIMO) – with the idea to assist humans in everyday working, the SONY robots (SDRX – 3,4,5,6 and QRIO) – with the background to serve mostly for entertainment, leisure and hobby or in the future as personal robots.

Since 1986 the Japanese Company Honda has developed humanoid robots, P2, P3 and ASIMO (Advanced Step in Innovation mobility). The basic idea is to integrate the intelligence and moving capability to robot for trivial works. Over the years the robot is smaller (P3-160cm, ASIMO-120cm) and lighter (from 130kg of P3 to 43 kg of ASIMO). The last development is ASIMO. It can move up to 6 km/h. This robot has 26 DOF. This kind of robot can easily be used in home as wheel driven robots, because their capability move in an uneven surface, like stairs.

QRIO (Fig.6) is SONY's next step after the Robodog “AIBO”. Qrio is a biped humanoid robot that is able to:

- walk on uneven and sloppy surfaces
- run
- jump
- perceive depth through its two CCD cameras
- be able to create a 3D map of its surroundings
- recognize people from their faces and voices
- learn
- connect to the internet via a wireless home network
- download and read information it thinks you're interested about

- sing
- dance
- and survive a fall unscathed and get back up by itself again.

Fig. 6. QRIO

In order for QRIO to walk and dance so skilfully, an actuator was needed with the ability to produce varying levels of torque at varying speeds and respond with quickness and agility. The robot moves with "dynamic walking".

If pushed by someone, QRIO will take a step in the direction it was pushed to keep from falling over. When it determines that its actions will not prevent a fall, it instinctively sticks out its arms and assumes an impact position. After a fall, it turns itself face up, and recovers from a variety of positions. It is equipped with a camera and the ability to analyze the images it sees. It detects faces and identifies who they are. Moreover QRIO can determine who is speaking by analyzing the sounds it hears with its built-in microphones.

"Research" humanoid robots: There a lot of such robots currently available or in the development stage e.g. approximately worldwide more than 1000 University institutes and research centres are active in this field. The robots of this category a usually prototypes developed by computer scientists to implement methods of AI, image processing, theoretical scientists from mechanics implementing and testing walking mechanisms, control scientists to implement new control strategies, social scientists to implement human machine interfaces (HMI) for an efficient communication between humans and humanoid robots.

An example for a reasonable cheap research robot is the humanoid robot of Robonova (Fig. 7.). This robot offers educators, students and robotic hobbyists a complete robot package. It is a fully customizable and programmable aluminium robot.

16 digital servos and joints give complete control of torque, speed and position. The programming software is simple, so advanced knowledge of programming is not needed. It can walk, run, do flips, cartwheels and dance. The robot is available as a kit – assembly time approximately 8 hours - or as pre-assembled, ready to walk robot. In addition to the typical robot talent for walking until it senses a wall using ultrasound, Robonova can be instructed to do cartwheels, take a bow and even do one-handed push-ups.

Fig. 7. Robonova

The simplest way for programming is with the "catch and play" function. With RoboScript or RoboBasic the robot is moved to any position and by mouse click that position is "captured". The software then links these "captured" positions and once activated, smoothly transitions the robot's movements through these programmed positions.

For beginners in robot programming two software packages are available. With these the users can create operational subroutines without knowing any programming language at all. The computer screen displays sliders for every individual servo (joint). Moving the sliders changes the position of the servos. Simple movements can then be assembled to produce complex movements simply by clicking the mouse. On a graphical user interface these movements can called up.

For more advanced users a programming tool based on the BASIC programming language is available. It enables the users to create complex applications designed to accomplish their own individual tasks. The independent development environment includes editor and compiler. Commands for synchronous servo movements, servo point-to-point movements and servo motion feedback are also available. The robot can be extended with several accessory modules and items: additional servos and brackets, gyros, acceleration sensors, speech functions, R/C control accessories and more can also be added as they become available.

The other two categories "Edutainment (Toy) Robots" and " Cost Oriented Humanoid Robots – COHR" are described below.

6. Robots of the future

Fig.8. shows possible development trends in robotics. We are now on the way from unintelligent industrial robots via intelligent industrial robots to intelligent mobile – including humanoid – robots to the third generation "advanced" robots able to interact and work symbiotically with us.

21th century robots will be used in all areas of modern life. The major challenges are:

- To develop robotic systems that can sense and interact useful with the humans.
- To design robotic systems able to perform complex tasks with a high degree of autonomy.

In the same way as mobile phones and laptops have changed our daily lives, robots are poised to become a part of our everyday life. The robot systems of the next decades will thus be human assistants, helping people do what they want to do in a natural ad intuitive manner. These assistants will include: Robot co-workers in the workplace; robot assistants for service professionals; robot companions in the home; robot servants and playmates; robot agents for security and space.

The role of these robots of the future could be improved by embedding them into emerging IT environments characterized by a growing spread of ubiquitous computing and communications and of ad-hoc networks of sensors forming what has been termed "ambient intelligence".

Current available robots are fare away from this vision of the 3rd generation being able to understand their environments, their goals and their own capabilities or to learn from own experiences.

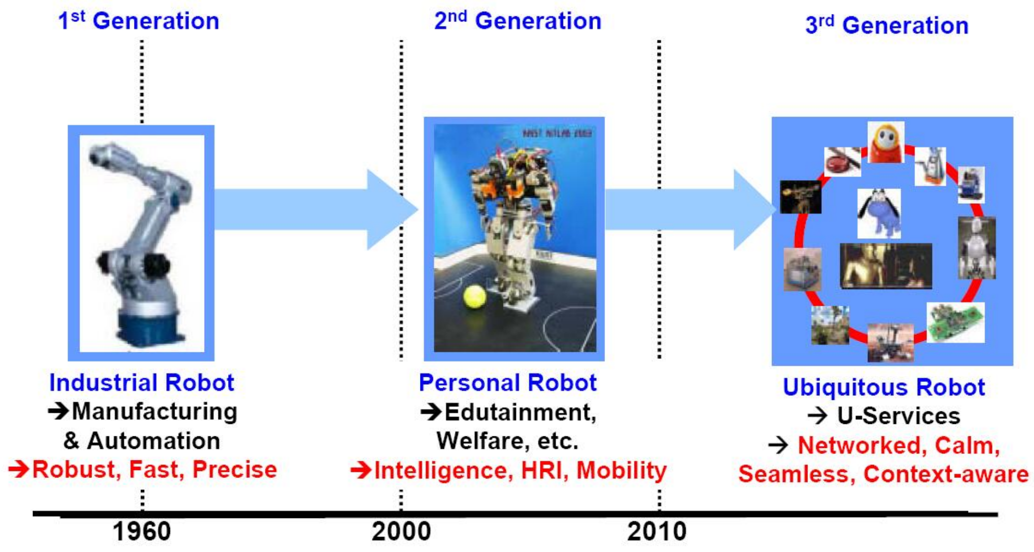


Fig. 8. Development trends in robotics (Kim 2006)

6.1. Industrial robots

One of the development trends are robots for SME`s. SME`s need simple, flexible and cheap automation solutions with robots. Therefore standardized robot production cells for SME`s are in development. These cells should be available to a reasonable price according to the current international research headline "Cost Oriented Automation – COA". One of the most important advantages of European SME`s, in contrast to Asian companies, is flexibility. Flexibility is closely related to the production of very small lot sizes – the theoretical goal is one part – in an economic way.

This new family of SME suitable robots (robot work-cells) should have the following features (Haegele, Nilsson 2006).

- Reducing the average costs of a robot production cell from approximately €150.000.-- to approximately € 75.000.— or less.
- Reduction of the re-programming time of such cells to 20%.
- Reduction of the installation time of a cell to 20% or three days.

- Reduction of the meantime between operational failures of the system to 10%.
- Reduction of the process-tuning time to 10%.
- Reduction of the time for service and maintenance at least to 50%.
- Increase the sensor supported operations from 5% to 100%.
- Guarantee a 100% safe operation

These goals should be reached by pursuing focussed RTD in the three innovation fields:

- The robot capable of understanding human-like instructions
- The safe and productive human-aware space-sharing robot
- The three-day-deployable integrated robot system

Therefore following features of the robot (the robot work cell) are necessary:

- Motion teaching: Task operations including complex motions should be taught in a human-like manner.
- Installation time: The installation time today is one of the major barriers to install robots in SME`s. The installation should be carried out by non-experts
- Simplicity of use: Automation is still hard to use by regular operators. Special training and customization is needed and not always work. Human-Machine Interfaces play a special role here but are very difficult to set-up and is currently done on an individual basis. Novel solutions enhancing usability and friendliness can decrease the meantime between operational failures.
- Process knowledge: Since RTD today is less familiar with SME shop-floor needs, software for process control too often provides complex settings and parameters that are expressed in technical

system-oriented terms (rather than in the terms of the SME users) and are difficult to tune

- Safe operation (also contributing to installation time reduction): Should permit simple integration with existing production and manual work.
- Service and maintenance: Although robot reliability is very high today. The addition of other automation components makes a system more complex and more likely to fail. Nevertheless, SME personnel should be supported in such a way that service and maintenance can be done independently of manufacturer support.

These robot cells should be available in 2012 at latest.

Another development trend is safety and security of industrial robot systems.

6.2. Mobile robots

According to the rapid development of new, relevant technologies (e.g. embedded sensors, nanotechnology, communication (GPS), artificial muscles, ...) mobile robots will be cheaper, more accurate and faster in the future. As a logical consequence a lot of new applications will arise.

One application of mobile robots is using these as “agents” in production automation. This is closely related to “holons” or MAS. Following the results of the historical TC5 of the worldwide ims initiative a holon is an identifiable part of a system that has a unique identity, yet is made of subordinate parts and in turn is part of a larger whole. This is similar to the usual „fuzzy“ definition of an agent. The features of „technical“ agents are:

- Ability to optimize one or more processes simultaneously
- Autonomy – an agent can made own decisions to stabilize to current state and to improve this state to reach to optimum of the whole system.
- Communication and interaction – for reaching this optimum each agent must interact with the other agents in the MAS.

Another example is MAS for landmine detection, removal and destroying (Kopacek 2004; Silberbauer, 2008). According to current estimates, more than 100.000.000 anti-personnel and other landmines have been laid in different parts of the world. A similar number exists in stockpiles and it is estimated that about two million new ones are being laid each year. According to recent estimates, mines and other unexploded ordnance are killing between 500 and 800 people, and maiming 2.000 others per month.

Landmines are usually very simple devices which are readily manufactured anywhere. There are two basic types of mines:

- anti-vehicle or anti-tank (AT) mines and
- anti-personnel (AP) mines.

AT mines are comparatively large (0.8 – 4 kg explosive), usually laid in unsealed roads or potholes, and detonate which a vehicle drives over one. They are typically activated by force (>100 kg), magnetic influence or remote control. AP mines are much smaller (80-250g explosive, 7-15cm diameter) and are usually activated by force (3-20kg) or tripwires. There are over 700 known types with different designs and actuation mechanisms.

A commercially available mobile robot is used as a platform for a metal detection sensor. This robot is equipped with an internal micro controller as well as internal sonar sensors, position speed encoders and a battery pack for network-independent and autonomous operation. An addressable I/O bus allows the installation of 16 additional sensors or devices like grippers. Furthermore, two RS-232 serial ports, five A/D ports and PSU controllers are accessible via server software. With appropriate software a tele-operation could also be achieved.

The robots base-weight is about 9kg with an ability to carry 30kg. Overall-dimensions of the basic robot setup are about (length/width/height) 55x50x50cm. With the mounted mine detector search head and telescopic pole the length increases up to 120cm.

A commercially available mine detecting set – produced in Austria - is attached on the robot basic-platform. This device is intended to detect land mines with a very small metal content (1.5g) 10cm below the surface of the ground and in fresh or salt water. The overall weight of the mounted sensor components is about 2.5kg.

When an object is detected a tone is released with its intensity and pitch depending on size, shape, depth under ground level and metal content of the object. For very tiny metal objects the tone is higher near the inner ring of the search head than in the middle. When searching for large metal objects, the continuous tone automatically changes to a pulsed tone whereas the pulse rate of the tone will be highest when the search head is immediately above the object. Outdoor tests with this robot were carried out. All functions could be validated only high grass could influence the sonar-sensors of the robot.

Furthermore a prototype of a six-wheeled robot (HUMI – Robot for Humanitarian Demining) based on the Ackermann Geometry for movement in rough terrain was developed.

The ultimate target to be reached would be a robot that possesses faculties approaching that of human beings - autonomous robot agents. Leaving such an ideal robot as a goal for the future, intermediate robots that only satisfy a limited selection of the most requisite functions should still find good use in human society. Among the faculties cited above, mobility is the most indispensable feature for a service robot.

6.3. Humanoid robots

Service-robots will become a real "partner" of humans in the nearest future. One dream of the scientists is the "personal" robot. In 5, 10 or 15 years everybody should have at least one of such a robot. Because the term personal robot is derived from personal computer the prices should be equal. Some new ideas in automation especially in robotics are realized very fast while others disappears.

Honda is trying to build Asimo robot to be a partner for people. So far it is merely a study about how to imitate human movements and make it able to help people somehow. It is 120cm high which is enough to reach most of the gadgets designed for humans. Latest model can even run 6km/h like a human.

As the number of humanoids increases, the collective population of humanoids will learn, develop and perhaps eventually reproduce themselves more effectively. Unlike cars or televisions that improve along a linear, highly controlled trajectory, humanoids will be the ultimate in self-accelerating technology. Likewise, robotics is a self-enabling technology. Robotic tools will make the humanoids we ourselves could never make. Once we have a large population of self-motivated agents attending to separate tasks, these agents will negotiate, exchanging tasks and resources in mutually beneficial ways. Humanoids will comprise a new distributed infrastructure comprised not only of information, but real-world action. As a given task arises, humanoids will place bids, often partnering with other humanoids to get the job done. Humanoids will not only share workload and resources, but will also evolve by passing host-independent, modular code.

As robots become more pervasive, they will, like automobiles, become increasingly complex. Already, some robots are comprised of millions of parts. Those skeptical of humanoid research often point to the high price tags of today's humanoids. If fast, cheap, rapid manufacture of robots is to occur, it will be necessary to remove humans from the design and manufacturing process. Through mutation and recombination, the genetic algorithm might modify bar length, split bars, or connect neurons to various components as it propels generations of increasingly fit robots. Finally, the robots are fabricated automatically by a machine that prints the robots, layer by layer, out of plastic.

In an ubiquitous era we (Kim 2006) will be living in a world where all objects such as electronic appliances are networked to each other and a robot will provide us with various services by any device through any network, at any place anytime. This robot is defined as a ubiquitous robot, Ubibot, which incorporates three forms of robots: software robot (Sobot), embedded robot (Embot) and mobile robot (Mobot). The Ubibot is following the paradigm shift of computer technology. The paradigm shift of robotics is motivated by ubiquitous computing and the evolution of computer technology in terms of the relationship between the technology and humans.

The basic concepts of ubiquitous computing include the characteristics, such as every device should be networked; user interfaces should operate calmly and seamlessly; computers should be accessible at any time and at any place; and ubiquitous devices should provide services suitable to the specific situation. Computer technology has been evolving from the mainframe era, where a large elaborate computer system was shared by many terminals, through the personal computer era, where a human uses a computer as a stand-alone or networked system, in a work or home environment, to the ubiquitous computing era, where a human uses various networked computers simultaneously, which pervade their environment unobtrusively.

Because of the limited market and the high price of professional humanoid robots, the availability of research humanoid robots, and the limited capabilities of humanoid toy robots, in this contribution a new fourth category – Cost Oriented Humanoid Robots (COHR), was introduced (Kopacek, 2011). These robots will be able to support humans in everyday life e.g on the working place, in the household, in leisure and entertainment, and should be available on the market for a reasonable price. These goals could be reached by standardisation of the hard- and software platform, using the latest technologies, applying modern control concepts, ...

To support humans in everyday life e.g working place, household, ... , these cost oriented robots (COHR) must have an appropriate size (minimum 1.2m) as well as much more functionality then the currently available toy robots. The software has to be "open" for easy adapting according to the special demands of the user. The price should be not more than the price of a currently available, expensive toy robot. Probably COHR are a first step to one of the oldest dreams of the humans – the Personal Robot.

As a compromise between "amateur" and "professional" humanoid robots a "cost oriented" two legged robot called ARCHIE is currently in development in Austria. The goal is to create a humanoid robot, which can act like a human. This robot should be able to support humans in everyday life; at the working place, in household and for leisure and hobby.

Therefore Archie has a head, a torso, two arms, two hands and two legs and will have the following features:

1. Height: 120 cm

2. Weight: less than 40kg

3. Operation time: minimum 2hrs

4. Walking speed: minimum 1m/s

5. Degrees of freedom: minimum 24

6. “On board” intelligence

7. Hands with three fingers (one fixed, two with three DOFs)

8. Capable to cooperate with other robots to form a humanoid Multi Agent System (MAS) or a “Robot Swarm”.

9. Reasonable low selling price – using commercially available standard components.

Archie will be equipped with sensors for measuring distances and to create primitive maps, for temperature, acceleration, pressure and force for feeling and social behaviour, two CMOS-camera-modules for stereoscopic looking, two small microphones for stereoscopic hearing and one loud speaker to communicate with humans in natural language.

The control system is realised by a network of processing nodes (distributed system), each consisting of relative simple and cheap microcontrollers with the necessary interface elements. According to the currently available technologies the main CPU is for example a PGA module, one processor for image processing and audio control and one microcontroller for each structural component.

7. ROBOTS FOR EDUTAINMENT

There is a new term "edutainment". It is composed with two terms – education and entertainment. The aim of edutainment is to make easier and more transparent "High Tech" for a broader public (Kopacek, 2008).

Edutainment is one of the newest application areas of service robots and especially MAS, because people have more free time, modern information technologies yield to loneliness of the humans (teleworking, telebanking, teleshopping,....). Entertainment robots are expected to be one of the real frontiers of the next decade. These robots are currently used as sport assistants, for promotion, marketing and PR, personal robots, ... (Kopacek 2008).

A special group are robots for competitions. Classical examples are:

- ⇨ Robot outdoor tournaments,
- ⇨ Robot soccer,
- ⇨ Ping Pong playing robots
- ⇨ Robot wrestling,
- ⇨ Sumo wrestling robots
- ⇨ Billiard robots.

This list will be much longer in the nearest future (Kopacek 2008).

Table 2. gives two examples of the largest currently existing robot games.

7.1. Robo Games

RoboGames (previously ROBOlympics) is an annual robot contest held in San Francisco, California. RoboGames is the world's largest open robot competition. They invite the best minds from around the world to compete in over 70 different events. About 2/3's of the robot events are autonomous, while the remaining 1/3 are remotely operated (ROV's.).

In Japan a similar event – Robofesta - takes place every year with the games listed in Tab.2.

Beam Robot Games/Olympics		Robofesta Official Games
Solarroller ***Photovore*** ***Aquavore*** ***Rope climbing*** Robot Sumo Nanomouse	High/Long jump Legged Race Innovation machine Robot - Art Micromouse Aerobot Competition	Robocup ***Robot Grand Prix*** ***All Japan Sumo Tournament*** ***All Japan Micromouse Contest***

Table 2. Two examples of robot games

The first goal is to bring builders from combat robotics (mechanical engineering), together with soccer robotics (computer programming), sumo robotics (sensors), androids (motion control), and art robots (aesthetics) together for exchange experiences. The second goal is to offer recognition to engineers from around the world in varying disciplines with consistent rule-sets and low-cost or free contestant fees. There are no prerequisites for contests, the event is open to anyone regardless of age or affiliation. 28 countries competed with more than 800 robots in 2007.

Competition categories

- Combat:
    - Categories from 1 to 340 lbs (454g-154.5kg)
    - RC/ and autonomous
- Robot Soccer:
    - MiroSot 5:5/11:11
    - Biped Soccer 3:3 (R/C)
    - Aibo Soccer 4:4 (autonomous)

- Autonomous Humanoid Challenges
    - Basketball
    - Weight lifting
    - Obstacle run
- Autonomous Autos
- Sumo
- Bot Hockey
- R/C Humanoid Competition
- Tetsujin (Exoskeletons)
- Art Bots
- Junior League (<18 yr old)
- Open
- BEAM

Another very popular, industry driven competition is the DARPA Grand challenge.

7.2. DARPA Grand Challenge

The DARPA Grand Challenge is a prize competition for driverless cars, sponsored by the Defense Advanced Research Projects Agency (DARPA), the central research organization of the United States Department of Defense. Congress has authorized DARPA to award cash prizes to further DARPA missions to sponsor revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their use for national security.

Fully autonomous vehicles have been an international pursuit for many years and the Grand Challenge was the first long distance competition for robot cars in the world and the main goal is to make 1/3 of the cars autonomous by 2015.

The first competition of the DARPA Grand Challenge was held in 2004 the Mojave Desert region of the United States, along a 150-mile to just past the California-Nevada border in Primm. None of the robot vehicles finished the route. Carnegie Mellon University's Red Team travelled the farthest distance, completing 11.78 km (7.36 miles) of the course.

All but one of the 23 finalists in the 2005 race surpassed the 11.78 km (7.36 mile) distance completed by the best vehicle in the 2004 race. Five vehicles successfully completed the race:

Vehicles in the 2005 race passed through three narrow tunnels and negotiated more than 100 sharp left and right turns. The race concluded through Beer Bottle Pass, a winding mountain pass with sheer drop-offs on both sides. Although the 2004 course required more elevation gain and some very sharp switchbacks (Daggett Ridge) were required near the beginning of the route, the course had far fewer curves and generally wider roads than the 2005 course.

The third competition of the DARPA Grand Challenge (2007) was named the "Urban Challenge". The course involved a 96 km (60-mile) urban area course, to be completed in less than 6 hours. Rules included obeying all traffic regulations while negotiating with other traffic and obstacles and merging into traffic. While the 2004 and 2005 events were more physically challenging for the vehicles, the robots operated in isolation and did not encounter other vehicles on the course. The Urban Challenge required designers to build vehicles able to obey all traffic laws while they detect and avoid other robots on the course. This is a particular challenge for vehicle software, as vehicles must make "intelligent" decisions in real time based on the actions of other vehicles. Other than previous autonomous vehicle efforts that focused on structured situations such as highway driving with little interaction between the vehicles, this competition operated in a more cluttered urban environment and required the cars to perform sophisticated interactions with each other, such as maintaining precedence at a 4-way stop intersection. 4 teams completed successfully the course.

The cars are usually equipped with laser measurement systems, laser sensors, global positioning systems (GPS) and cameras. The teams employed a variety of different software and hardware combinations for interpreting sensor data, planning, and execution. Some examples:

- C++ and C# and runs on Windows hosts, planning by Bayesian mathematics.
- Mac Minis running Linux because they can run on DC power at relatively low wattage and produce less heat. Mac Minis running Windows.
- Embedded version of Windows XP.

A very popular worldwide sport is soccer. Therefore one of the most exciting robot competitions for a broader public is robot soccer. It will be described in more detail.

7.3. Robot soccer

The fascinating idea of using small robot cubicles to play soccer was born just a decade ago in Korea and Japan and has since spread all over the world. Even yearly championships are organized in different countries. From the scientific point of view, robot soccer is one of the first applications of MAS. The players – robots or agents – have to solve the common task: “Win the game with the highest score”.

Robot soccer was introduced to develop intelligent cooperative multi-robot (agents)-systems (MAS) and to bring young generation the difficult scientific and engineering subjects easy in the way of playing. From the scientific viewpoint a soccer robot is a partially or fully intelligent autonomous agent, which carries out tasks with other agents in a cooperative, coordinated and communicative way. Generally robot soccer is a good test bed for the development of MAS. Furthermore it is also a good tool for spending leisure time and for education.

In future production systems will become more complex. Several independently working autonomous mobile robots are working together and therefore conflict situations in certain areas could appear, (e.g. several robots are gathering in an intersection). In order to avoid conflict situations and delays and guarantee a smooth movement, robots should have the capability to communicate and to cooperate in order to coordinate their actions.

Soccer is one of world wide well-known sport. It is exciting to watch how robots play the game. It is also possible not only to watch the game but also to play the game - human against computer, human against human - using Joystick as well as keyboard. The big question for common use is the price of whole system. With the development of electronic devices and peripheries the cost is going down. For the realization of interdisciplinary research works should be done including following areas, like robotics, image processing, sensors, mechatronics, communication etc.

At the moment there are worldwide two robot soccer organizations, FIRA (Federation of International Robot-soccer Associations – www.fira.net) and RoboCup (www.robocup.org). The objects and scope of both organizations are similar. The size, speed, acceleration of the robots, the sizes of the playgrounds and the numbers of playing robots are different.

7.3.1. *Robocup*

RoboCup is an international research and education initiative. Its goal is to foster artificial intelligence and robotics research by providing a standard problem where a wide range of technologies can be examined and integrated.

The main focus of the RoboCup activities is competitive football. The games are important opportunities for researchers to exchange technical information. They also serve as a great opportunity to educate and entertain the public. RoboCup Soccer is divided into the following leagues:

Simulation league

Independently moving software players (agents) play soccer on a virtual field inside a computer.

Small-size robot league (f-180)

Small robots of no more than 18 cm in diameter play soccer with an orange golf ball in teams of up to 5 robots on a field with the size of bigger than a ping-pong table.

Middle-size robot league (f-2000)

Middle-sized robots of no more than 50 cm diameter play soccer in teams of up to 4 robots with an orange soccer ball on a field the size of 12x8 metres.

Four-legged robot league

Teams of 4 four-legged entertainment robots (SONY's AIBO) play soccer on a 3 x 5 metre field. The robots use wireless networking to communicate with each other and with the game referee. Challenges include vision, self-localization, planning, and multi-agent coordination.

Humanoid league

Biped autonomous humanoid robots play in "penalty kick" and " 2 vs. 2" matches and "Technical Challenges". This league has two subcategories: Kid-size and Teen-size.

<u>RoboCupRescue</u>

The intention of the RoboCupRescue project is to promote research and development in this significant domain by involving multi-agent team work coordination, physical robotic agents for search and rescue, information infrastructures, personal digital assistants, standard simulator and decision support systems, evaluation benchmarks for rescue strategies and robotic systems that are all integrated into a comprehensive system in future.

7.3.2. *Federation of International Robot-soccer Associations - FIRA*

In 1995 robot soccer was introduced in FIRA with the purpose to develop intelligent cooperative multi-robot (agents) systems. Not only the study on the behavior of single player but also the study on group behavior of players is required.

Similar to RoboCup there are also different categories in this “Robotsoccer World”.

Micro Robot World Cup Soccer Tournament (MiroSot)

A match is played by two teams, each consisting of three, five, seven or eleven robots on a dark playground with different dimensions (Tab. 6.2.) with an orange golf ball. Three human team members, a "manager", a "coach" and a "trainer" are only be allowed on the stage. One host computer per team, mainly dedicated to vision processing and other location identifying is used. The size of each robot is limited to 7.5 cm x 7.5 cm x 7.5 cm. The height of the antenna shall not be considered in deciding a robot's size (Fig. 9).

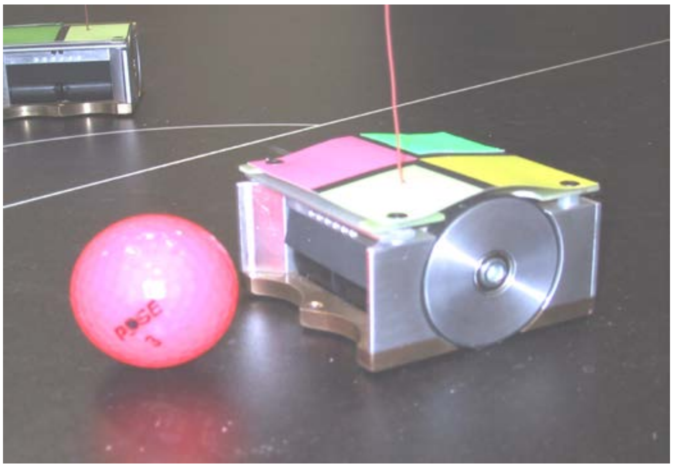


Fig.9 MiroSot robot

Nano Robot World Cup Soccer Tournament (NaroSot)

It is similar to MiroSot. The size of the five robots is limited to 4cm x 4cm x 5cm (Fig.10). They are playing with an orange ping-pong ball on a playground 130cm x 90cm.

Fig. 10 NaroSot robot

Category	No. of players	Size of the playground (cm)
Small	3	150 x 130
Middle	5	220 x 180
Large	7	280 x 220
X- Large	11	420 x 330

Table 3. MIROSOT categories

Kheperasot

The Kheperasot game shall be played by two teams, each consisting of an robot player and up two human team members. The robot will be fully autonomous with on board vision system. The human team members will only be allowed to place their robot on the field, start their robot at the beginning of each round at the position indicated by the referee before each round, start their robot when indicated by the referee and remove the robot from the field at conclusion of the match. They are playing with a yellow tennis ball on a playground 130cm x 90cm.

Humanoid Robot World Cup Soccer Tournament (HuroCup)

A humaniod robot shall have two legs (Biped Robot). The game is played using humanoid robots on a playground 340~430 cm ×250~350cm. The maximum size of the robots is 150 cm and the maximum weight is 30 kg. The robots have remote or auto control.

RoboSot

A match shall be played by two teams, each consisting of one to three robots with the maximum size 20cm x 20cm x (no limit in height) on a playground 260cm x 220cm with a yellow or light green tennis ball. Three human team members, a "manager", a "coach" and a "trainer" shall only be allowed on stage. The robots can be fully or semi-autonomous. In the semi-autonomous case, a host computer can be used to process the vision information from the cameras on-board the robots.

Simulation Robot World Cup Soccer Tournament (SimuroSot)

SimuroSot consists of a server which has the soccer game environments (playground, robots, score board, etc.) and two client programs with the game strategies. A 3D colour graphic screen displays the match. Teams can make their own strategies and compete with each other without hardware. The 3D simulation platform for 5 vs. 5 and 11 vs. 11 games are available at FIRA web site – www.fira.net.

MiroSot and NaroSot

As an example for robot soccer games the FIRA categories Mirosot and NaroSot will be described in more detail.

The system works as follow (Fig.11): A camera approximately 2m over the playground delivers 60pictures/second to the host computer. With information from colour patches on top of the robots, the vision software calculates the position and the orientation of the robots and the ball. Using this, the host computer generates motion commands according to the implemented game strategy and sends motion commands wireless to the robots. The duration of a game is two halves at 5min. net each.

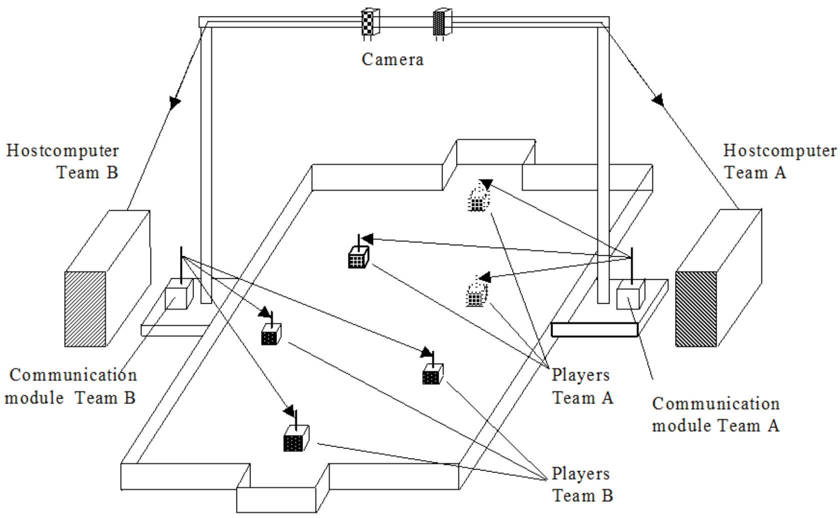


Fig. 11. Overall system of robot soccer

A soccer robot is an excellent example of mechatronics. Its main parts are wheels, drives, a power source, a microprocessor and a communication module – all these parts have to be included in a very small volume - a cube 7,5 x 7,5 x

7,5 cm or a cuboid 4,0 x 4,0 x 5,0 cm. The soccer robots of a team (between 3 and 11 players) are controlled by the team computer.

The robot itself has a drive mechanism, power supply, electronic part for control the robot behaviour as well as the communication. Most of the teams using time discrete, digital PID-controllers. For the determination of the optimal controller parameters fuzzy and neural methods are applied.

One major problem is the speed of the robots. They reach more than 25km/h with an acceleration of 9m/s². The time from taking a picture until the robot get the movement command is 12ms. That means the robot is approximately 4cm away from the actual point until getting the movement command. Therefore most of the teams are using prediction algorithms well known from control engineering.

Another problem is the power sources of the robots. Usually batteries are approximately 50% of the weight of the robot and have only a "life" time of 2 hours.

Worldwide there are already more than 150 teams competing in regional and World Championships.

As pointed out earlier a soccer robot is an excellent example for interdisciplinarity. For construction and manufacturing of the body knowledge of mechanical and because of the small dimensions precision engineering is required. Electrical as well as control engineering is necessary for the drives and the power source. The control and communication board of the robot is more or less applied electronics. The controller is realised by a microprocessor. It is also responsible for the wireless communication with the host computer. For this task and for the software of the host computer fundamental knowledge in computer science is necessary. The software of the host computer include on line image processing, game strategies, control of the own players, communication with these and together, user interface.

Development of a robot soccer team is therefore teamwork of specialists from various disciplines – having different thinking and a different language. The project leader has to harmonize such a team and must have at least basic knowledge of all these necessary subjects.

One possibility to go into a broader market is to replace conventional games in amusement parks and restaurants.

Therefore, as a first step into this direction, the software had to be adopted to also use a joystick to control each robot. This offers the following possibilities for playing:

- Humans against humans (both teams controlled by joysticks)
- Humans against computer (only one team controlled by joysticks)
- Computer against computer (state of the art)

In contrast to the soccer video games this new technology offers a “real life” feeling similar as in the soccer stadium.

Until now the robots are completely unintelligent they have no sensors and are controlled by the host computer. In the future robots will be more and more intelligent and will be equipped with different sensors (ultrasonic, infrared, laser.....). This offers the possibility for the robots to adapt the commands of the host computer.

Next developments will be towards humanoid soccer players – humanoid leagues. A humanoid soccer playing robot has to

- be able to accelerate and slow down as fast as possible
- keep its balance all the time, even after a crash with another robot
- localize itself on the field
- localize the ball
- localize the opponents
- make autonomous decisions which actions to take.

As a first step some producers are offering robots with 4 or 6 legs to a high price. Probably in some years we will have players with two legs available – then we can start with the first soccer games humans against robots.

8. UBIQUITOUS ROBOTS

The term is, as usual in robotics, derived from ubiquitous computing. Basic concepts of ubiquitous computing and robots include the characteristics, such as every robot should be networked; user interfaces should operate calmly and seamlessly; robots should be accessible at anytime and at any place; and ubiquitous devices should provide services suitable to the specific situation. Computer technology has been evolving from the mainframe era, where a large elaborate computer system was shared by many terminals, through the personal computer era, where a human uses a computer as a stand-alone or networked system, in a work or home environment, to the ubiquitous computing era, where a human uses various networked computers simultaneously, which pervade their environment unobtrusively.

9. Cloud Robots

Several research groups are exploring the idea of robots that rely on cloud-computing infrastructure to access vast amounts of processing power and data. This approach, which some are calling "cloud robotics," would allow robots to offload compute-intensive tasks like image processing and voice recognition and even download new skills instantly.

Imagine a robot that finds an object that it's never seen or used before—say, a plastic cup. The robot could simply send an image of the cup to the cloud and receive back the object's name, a 3-D model, and instructions on how to use it.

For conventional robots, every task—moving a foot, grasping an object, recognizing a face—requires a significant amount of processing and preprogrammed information. As a result, sophisticated systems like humanoid robots need to carry powerful computers and large batteries to power them.

Cloud robots could offload CPU-heavy tasks to remote servers, relying on smaller and less power intensive onboard computers. Even more promising, the robots could turn to cloud-based services to expand their capabilities. Using the cloud, a robot could improve capabilities such as speech recognition, language translation, path planning, and 3D mapping. Now cloud robotics seeks to push that idea to the next level, exploiting the cheap computing power and ubiquitous Net connectivity available today.

But cloud robotics is not limited to smart phone robots. It could apply to any kind of robot, large or small, humanoid or not. Eventually, some of these robots could become more standardized, or de facto standards, and sharing applications would be easier.

But there are also disadvantages. As any Net user knows, cloud-based applications can get slow, or simply become unavailable. If a robot relies too much on the cloud, a problem could make it "brainless."

In this field some research projects are currently ongoing.

The main goal of the European project "RoboEarth" is the development of a huge database where robots can store and retrieve information about objects, environments and different tasks.

Researchers in Singapore have built in the framework of the ASORO project a cloud computing infrastructure for generating 3D maps of the robot environment. This method is much faster than the generation with an on-board computer.

Based on the humanoid robot NAO from France a children hospital in Italy will relay on a cloud infrastructure for performing speech recognition, face detection and other tasks. This should improve the interaction between the robot and the patients.

Other research projects deal with a software platform for the control of robots by smart phones or repositories for frequently manipulated objects by robots to simplify gripping tasks.

10. FUTURE VISIONS

The robotics industry, while in development for half a century, is still relatively in its infancy and faces a number of challenges in the years ahead. Besides the technological and cultural hurdles to overcome, questions remain unanswered regarding their economic and environmental impacts as well as the ethical issues of human and robot interaction. What is obvious is that robots, whatever form they take, will increasingly play a role in societies around the world and that the ecosystem of services and capabilities will offer increasing opportunities for designers in the years to come (Dezfouli, 2011).

Today's market is not fully mature, as information technology advances, robots and other forms of automation will ultimately result in significant unemployment as machines and software begin to match and exceed the capability of workers to perform most routine jobs. As robotics and artificial intelligence develop further, even many skilled jobs may be threatened. Technologies such as machine learning may ultimately allow computers to do many knowledge-based jobs that require significant education. This may result in substantial unemployment at all skill levels, stagnant or falling wages for most workers, and increased concentration of income and wealth as the owners of capital capture an ever larger fraction of the economy. This in turn could lead to depressed consumer spending and economic growth as the bulk of the population lacks sufficient discretionary income to purchase the products and services produced by the economy.

There are main 10 top reasons for investments in robotic market as presented in Fig. 12. But what are the benefits from using intelligent robots? Robots can do many tasks now. However, the tasks that cannot be easily done today are often characterized by a variable knowledge of the environment. Location, size, orientation, shape of the work piece as well as of the robot must be known accurately to perform a task. Obstacles in the motion path, unusual events, breakage of tools, also create environmental uncertainty. Greater use of sensors and more intelligence should lead to a reduction of this uncertainty and because the machines can work 24 hours a day, should also lead to higher productivity. More intelligence could also lead to faster,

Fig. 12 Reasons for Investment

easier setups and reduced cycle times. More intelligence should also lead to faster diagnosis of problems and better maintenance for the systems. Finally, there is the fact that to remain internationally competitive, the best technology usage is required. Waste of human or material resources is too expensive for industry and for society. It is said that as manufacturing goes so does the quality of life.

The future for robots is bright. But, how will robots affect future generations? Sometimes you can get ideas for the future by looking into the past and thinking about the changes we've seen as a result of other great inventions, like the cotton gin, airplane or Internet. Perhaps one day we will have true robotic ''helpers'' that guide the blind, assist the elderly. Maybe they'll be modular devices that can switch from lawn mower to vacuum cleaner, to dish washer and window washer.

The trends in cost oriented autonomous robot market and challenges and demands of the robot industry in Japan (has more robots in use than the rest of the world), Korea, Germany and in the world is compared and evaluated. As it can be seen from existing projection of future market trend and the technological challenges, there will be a mature personal robot product series in line with the infrastructure of robotics industry for coming next 10 to 20 years. By a scenario methodology a future robotic society is plotted to examine what will be needed necessarily in constructing market and how to layout a convincible business strategy for those who wants to play in robotics industry.

The financial crisis restricts lending and financing of new initiatives in private as well as public organizations. Especially SMEs are unable to gain sufficient funding for their development and this reduces, and in some cases even terminates, innovation and growth in the private sector. Thus, investments in growth and innovation are under pressure and the current crisis even appears to be deeper and longer lasting than expected, but the robotic market and it's global trends can be affected due to following items:

- Robot performance will be improved. Robots will be applied to the fields where no robots have been used, and the market of the industrial robots will expand.
- As the robot technologies progress, work that can only be carried out by human beings will be reduced and automatic work done by robots and man-robot
- Cooperative work will increase. As a result, the Japanese manufacturing industries will maintain their international competitive forces even in the age with a low birth rate and many elderly people.
- Robot teaching operations will become simpler, and cost performance will improve further. As a result, robots are used more widely in not only large-scale enterprises but also middle- and small-scale enterprises, contributing to solution of manpower shortage in middle- and small scale enterprises.
- Structuralization of environments where robots may work easily may be easier in factories than in homes and general society environments. In cooperation with development of intelligent robots, such environment structuralization will expand the areas to which industrial robots may be applied.

- As the industrial robot capability is improved, the technical results will have influences upon nonmanufacturing fields and contribute to development of robots for various non-industrial uses.
- In the age with a low birth rate, people liberated from the manufacturing industry may be engaged in work in various fields, manpower will be re-distributed, and the active power of the society will be maintained.

While the last 25 years saw tremendous progress due to the Internet, the next revolution is considered to be robotics. Robotics has the potential to be a real-game changer for job growth and quality of life. Today the big commercial robotics programs are in Europe, Japan and South Korea. Global trends in autonomous robotic market is summarized and categorized from 1980 till forecasting up to 2020 in Fig. 13. The overall conclusions indicate that in almost all the surveyed countries, not only the potential for robot installations in the non-automotive industries is still tremendous, but it is also considerably high in the automotive industry among the emerging markets and in some traditional markets as well. This is mostly due to the necessary modernization and retooling that is needed in these markets.

The trends in manufacturing industries can be summarized in Green Automation, Energy-efficiency, reduction of CO^2 output and quality management are the main factors of future production processes in all industries. The successful robot suppliers will be the ones that can provide the right solutions for the industry in order to face the challenges ahead. After the substantial fall of robot sales in 2009, an increase will resume in the period between 2010 and 2012 about 15% per year on average attaining a level of more than 100,000 units. The strong decrease in 2009 and the slow recovery will result in a more or less stagnating operational stock in the forecasted period.

In most of the traditional robotic markets the stock will stagnate or even decrease, while in the emerging markets it will further increase. Meanwhile future products and systems in robotic market are becoming:

- Smarter, Faster
- Greener
- Smaller
- Nicer

- Cheaper

Robotics enables existing industry and will create a new industry. The trend towards automation will go on. Industrial robots are a key component in the automation of processes, and automation is the key to a more eco-friendly production, to rising productivity, to more quality and safety of the work place and to solve the problem of demographic shifts in our societies.

11. ESTIMATION FOR THE FUTURE

❖ 2011-2015

• Robot dance tutors

• Nanowalkers, nanoworms, nanofish

• Mechanical intelligence using MEMS and NEMS (early stage)

• Android robots used for factory jobs (prototype HRP-3 Promet MK II)

• Fleet of garden robots for plant and lawn care and tidying Robots for cleaning, washing fetch and carry, in office (prototypes)

• Robot pest killers (some prototypes)

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.

Tab. 4. Global Trends in Robotic Market

- 2013-2017
  - Housework robots - fetch, carry, clean & tidy, organise etc.
  - Robots for guiding blind people (First car drive of blind person 2011)
  - Cybernetic use in sports (Ossue Flex-foot, Otto Bock C-Leg)
  - Robots for cleaning, washing, fetch and carry, in home (Roomba, Scooba, prototypes)
- 2016-2020
  - Self diagnostic self repairing robots (?)
  - Actuators resembling human muscles (Polymer Actuators research)
- 2020s
  - Insect sized robots banned in gardens due to effects on wildlife (UAV restrictions already discussed)
  - Robotic delivery for internal mail (AGVs)
  - Robotic exercise companion (TOPIO robot play ping-pong with humans)
  - More robots than people in developed countries (very optimistic)
  - Android gladiators (EU FET Flagship project Companion Robot for Citizens)
  - GM and robotics converge, GM used to make organic robots (artificial meat projects)
- 2030s
  - Micro-Mechano fractal construction kit
- 2040s
  - i-Robot style robots with polymer muscles and strong AI a vision of near future of robots are estimated as follows:
- Robots will be everywhere,

- In the factories
- In hospitals, public buildings, schools, services firms…
- In cities‘ streets
- In every home

❖ To assist, educate, help, and entertain people,

- Less chores
- Less risks
- More productivity
- More time
- Smart jobs and smart life

❖ As distributed intelligent systems or multifunctional companions

Let’s have a look!!!!!!!!

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