ADVANCES IN ROBOTICS

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Abstract
The field of robotics is one of the most innovative in the last decade. We are moving now from conventional, unintelligent industrial robots to mobile, intelligent, cooperative robots. This new generation of robots offers a lot of new application fields. Some of them will be growing dramatically in the nearest future.

Therefore in this paper the present state will be discussed, selected applications described and an outlook on future developments will be given.

Keywords: Mechatronics, industrial robots, intelligent robots, cooperative robots.

1. Introduction

Conventional industrial robots from the late 70´s are now only a tool on the production level. One of the oldest dreams of the robotic community – intelligent, mobile, cooperative as well as humanoid robots – starts to become reality not only because of the rapid development of "external" sensors and micro- and nanotechnology.

External sensors (e.g. visual, auditive, force-torque…) combined with micro drives, embedded systems,… offer intelligent robots the possibility to see, hear, speak, feel, smell like humans. Compared with conventional, unintelligent, industrial robots, intelligent robots fulfill new, innovative tasks in new application areas.

There are three "starting" points for the development of intelligent robots: Conventional, stationary industrial robots; mobile, unintelligent platforms (robots) and walking machines.
Stationary industrial robots equipped with external sensors are used today for assembly and disassembly operations, fluelling cars, cleaning of buildings and airplanes, humanitarian demining ... and have been the first "intelligent" robots.

Mobile platforms with external sensors are available since some years and cover a broad application field. The core of each 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, beep or bell.

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 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

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.

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 goals are so called “Multi Agent Systems – MAS”. MAS consist of a distinct number of robots (agents), equipped with different arms, lifts, tools, gripping devices, ... and a host computer. MAS have to carry out a whole task e.g. assemble a car. The host computer divides the whole task in a number of different 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 fulfill their subtasks in a cooperative way until the whole task is solved.

In industry intelligent robots will work together with humans in a cooperative way on a common working place.

2. Application examples

In the following some examples for introducing AI methods on a very low and cheap level in SME´s will be shortly described and discussed. These solutions were developed with and are realised in companies.

2.1. Disassembly cell for printed circuit boards

The layout of the cell is shown in Fig. 1. The basis of a disassembly cell is a very stiff frame construction developed from commercially available profiles. In a manual feeding station the PCBs with a maximum size of 300 x 220 mm are attached on special work holding device. The disassembly cell consists of 4 stations:

- Vision system
- Laser desoldering system
- Removal station
- Heating removal station

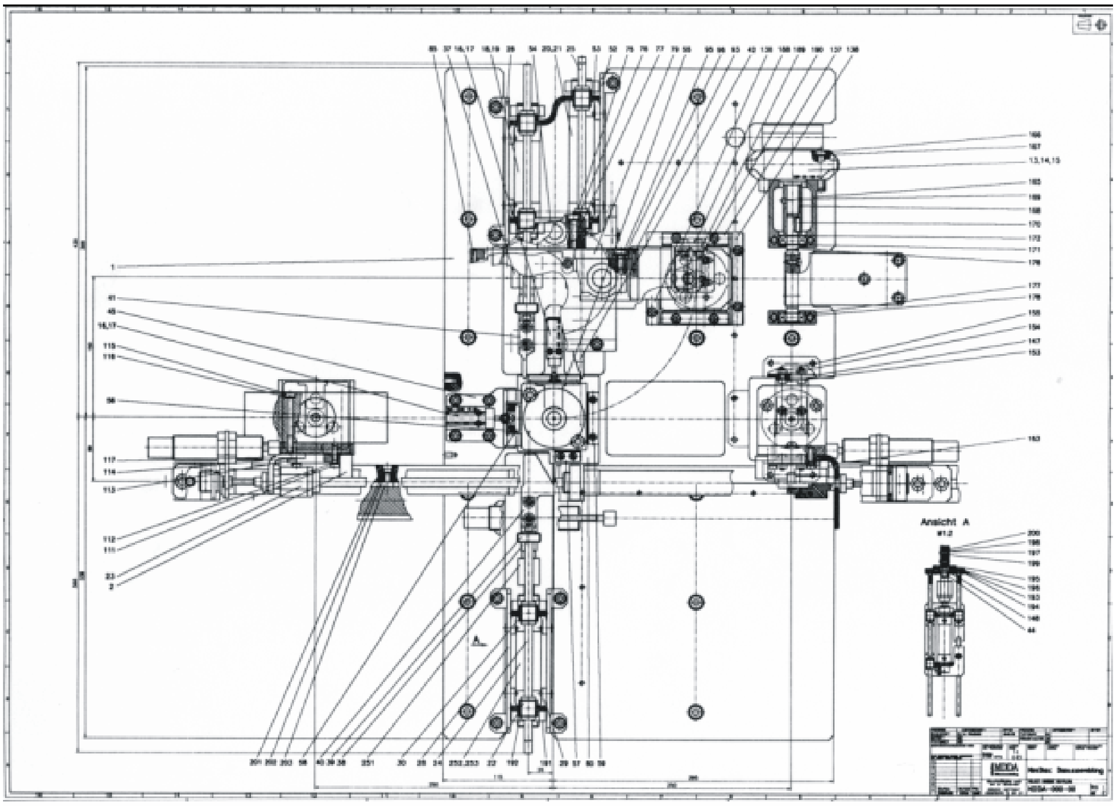

Fig. 1 Layout of the disassembly cell for PCB’s (Kopacek, Noe, 2001)

The vision system has several tasks. It has to recognize the re-useable parts by means of a data base containing the data (kind, production company, assigned, dimensions). The vision system has to detect the re-useable part and to determine the position, the size and the centre of inertia. Furthermore it has to classify the useable parts to be desoldered or removed from sockets.

The desoldering station consists of a cross table – two linear axes – controlled to reach every point (centre of inertia) on the PCB. The desoldering process is carried out by laser technology. The desoldered parts are put on a distinct area outside the laser from which they are removed by the industrial robot and to put into the appropriate magazines.

The third station is the removal station for socket parts. An industrial robot equipped with special grippers as well as external sensors carries out process. The robot removes these parts and puts them also in the right magazines. A prototype of this disassembly cell is now in use since 3 years.

2.2. A semiautomatized Disassembly Cell for Mobile Phones (Kopacek, Kopacek, 2003)

After a detailed analysis of used mobile phones concerning the parts as well as the assembly technology and tests for disassembly with the most frequent mobile phones the following concept for the disassembly cell was created (Fig. 2). It consists of five automated stations plus a manual feeding and removal station:

- Feeding and removal station
- Drilling and milling station

- Removal station for the covers
- Drilling station
- Circuit board removal station
- Drilling station

For disassembly of the mobile phones they were fixed on a pallet in a distinct position. These pallets are moving around on a transportation system. According to the necessary disassembly operations the pallets with the mobile phones to be disassembled are stopped, lifted and fitted in a distinct station.

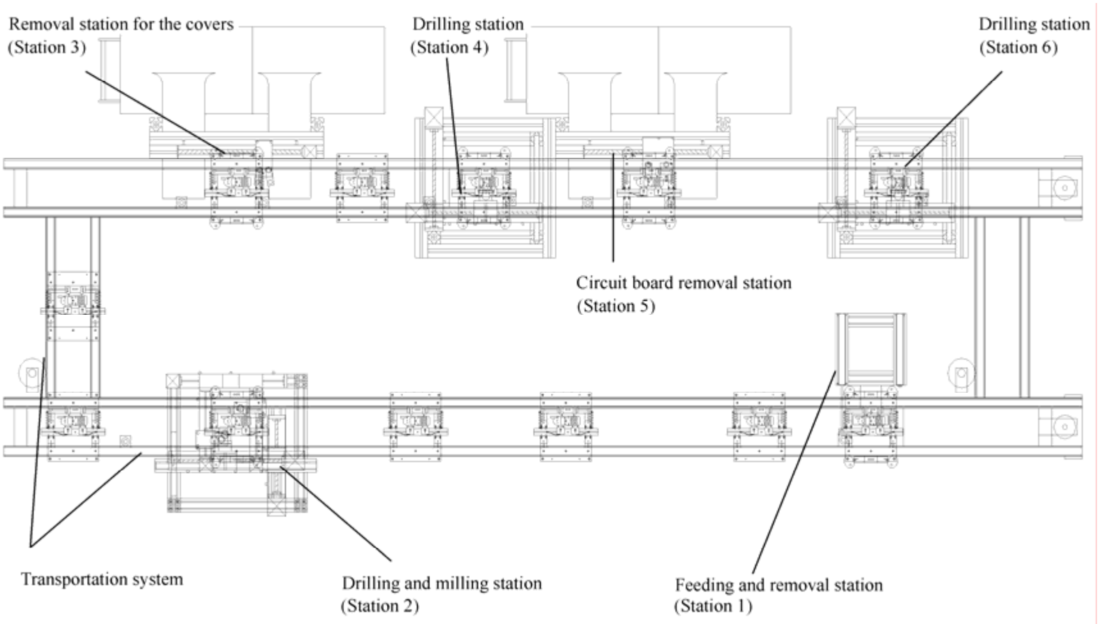

Fig. 2 Layout of the disassembly cell (Kopacek, Kopacek, 2003)

Before the mobile phone is fixed on a pallet the power supply will be removed and the type of the handy will be recognized by a barcode reader manually. Now the control computer knows exactly the type of the handy. The main dimensions of the handy are stored in a database of the host computer.

In the drilling and milling station (no. 2) the upper part of the handy will be cut off from the lower part and the screws – usually between 4 and 17 – are removed by a simple drilling mechanism. The dust content is removed by air from the pallet.

In the third station – the cover removal station – the cover as well as the keyboard of the handy will be removed by pneumatic sucks. These two parts are separated in a storage device. In the next station – drilling station; no. 4 – the screws which connect the printed circuit board on the lower part of the housing are removed. In the printed circuit removal station various other parts will be removed from the handy and separated in special storage devices. Because some mobile phones have additional parts connected with the power part of the housing of the handy the remaining screws will be removed in the last drilling station – station 6. Finally the lower part of the handy will be removed in the fixing and removal station.

As a development of this semi-automated disassembly cell for used mobile phones some previous tests were necessary. For the milling in the drilling and milling station (no. 2) it was necessary to make tests with grinding wheels, with different saws and with milling devices. Finally a milling device was chosen as the right tool for this task.
Further extensive tests were carried out for the removal of the screws. From the literature there are very high sophisticated, complicated and therefore very expensive and heavy devices known. We found a very simple and very cheap method for the removal of the screws.

2.3.A 'Tool Kit' for mobile robots

The basis of a modular concept for mobile robots is the Mobile Robot Platform (MRP) which can be described as a multi-use mobile robot, developed in its basic configuration.
These platforms can be divided in some basic systems:

- Locomotion system
- Driving system
- Main control system
- Communication system

The mobile robot platform can be upgraded and modified by adding a number of peripheral systems and tools for the performance of different tasks or functions. There is a large variety of tools, which can be used.
Basically these tools can be divided into two major categories:

- Conventional tools
- Special tools

Conventional tools (screw drivers, drilling tools, polishing tools, etc) are similar in regard to their function to conventional hand-held tools for manual operations. The difference is in their design, since they have to be fixed on the mobile robot platform, and actuation.
Special tools installed onboard of a mobile robot platform changes the same to a specialized mobile robot system. When special tools are lightweight constructed the manipulation system can be more flexible and with wider reach. Heavier tools cannot be very flexible. They need more rigid and strong manipulation systems. So there is often only one degree of freedom applied, and the other DOFs are realized by the mobility of the platform.
Installing a tool changing system enables the robot to achieve a wide variety of performable operations. Tool changing systems are normally placed at the end of a robot arm. They have to be light, simple and very reliable.

The basic configuration of each mobile robot platform has its integrated sensors. The navigation system makes excessive use of sensor for position determination and collision avoidance. But there are numerous possibilities to upgrade the system with additional sensors for some special applications or to extend its abilities.

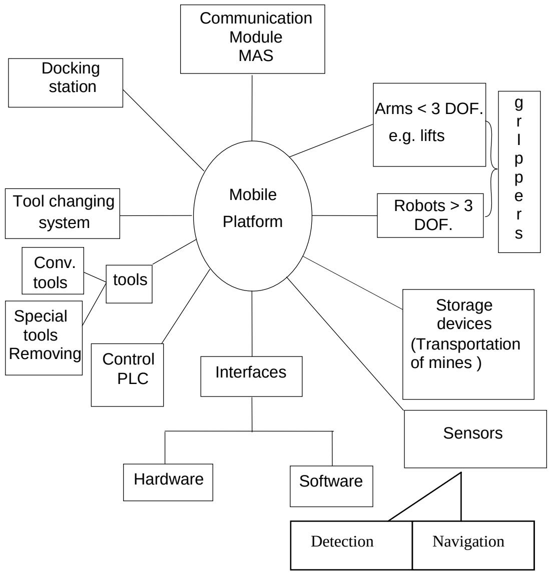

Fig. 3 Modular Robot System (Shivarov, 2001)

In many mobile robot applications transportation is an important part of the overall task. To transport different items mobile robot platforms have to be upgraded with another type of peripheral devices: special storage systems or devices.
Although mobile robot platforms are normally equipped with a communication system it could be necessary to use some special communication systems. Especially in multi agent systems (MAS) where a team of robots acts together is communication between the team members of importance.

2.4. A Tool Kit for Humanitarian Demining (Kopacek, 2004)

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 may different designs and actuation mechanisms.

Hand-prodding is today the most reliable method of mine clearing, but it is very slow, and extremely dangerous. A person performing this type of clearing can normally perform only this task for twenty minutes before requiring a rest. This method clears one square meter of land in approximately 4 minutes. A better solution for the future is the usage of demining robots.

Today used methods for destroying and removal are brutal force mechanical methods including ploughs, rakes, heavy rolls, flails mounted on tanks. The main problem with this method is the contamination of the ground for 10 – 20 years.

The advantages of robots for demining are:

- Minefields are dangerous to humans; a robotic solution allows human operators to be physically removed from the hazardous area.
- Robots can be designed not to detonate mines.
- The use of multiple, inexpensive robotized search elements minimises damage due to unexpected exploding mines, and allows the rest of the mission to be carried on by the remaining elements.

But there are also disadvantages of using robots:

- it is very difficult for robots to operate in different frequently rough terrain
- they are still expensive
- you need special qualified operators

Teams of robots can be connected so that one team is for searching and one for destroying or displacement. This means that many robots are searching and a few or only one robot is destroying or displacing the mines.

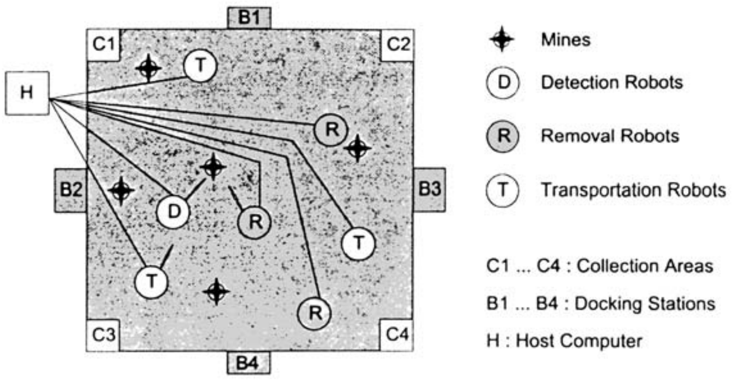

Fig. 4 Robot swarms for demining (Kopacek, 2004)

Robot swarms improve the capacity of robotic applications in different areas where robots are already used today. Robot swarms are similar to – or a synonym for - 'Multi Agent Systems – MAS'. These systems are very well known in software engineering – "software agents" - since more than twenty years. In the last years there are more and more works related to "hardware agents" like robots.

As mentioned before the use of modular robots is perfect for the design of task specific demining robots because of the similarities between the tasks. All three different types of robots can be constructed by the toolkit mentioned before.

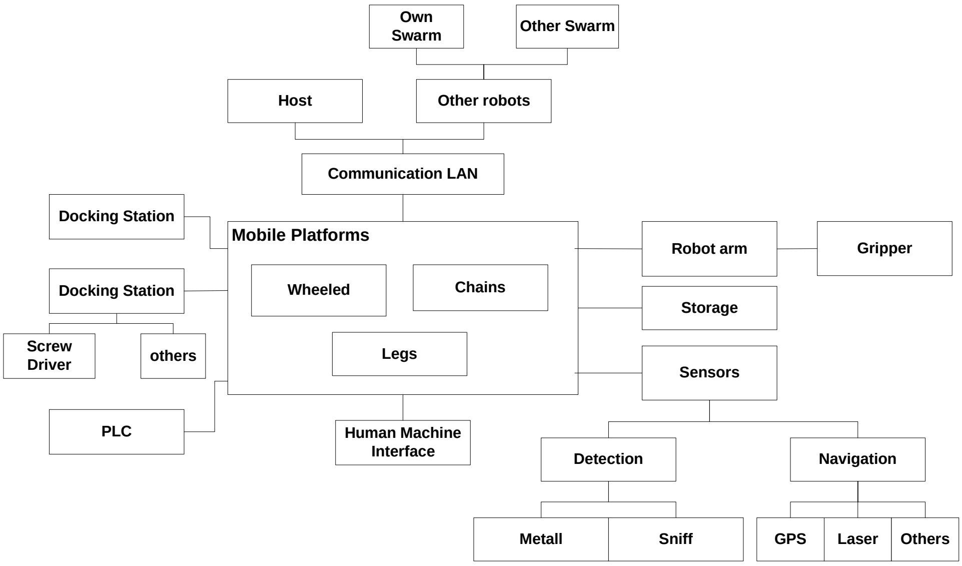

Fig. 5 “Tool Kit” for demining robots (Kopacek, 2004)

2.5.Roby-Run : a mobile mini robot

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.

Robot soccer was introduced with the purpose to develop intelligent cooperative multi-robot (agents) systems (MAS). From the scientific point of view a soccer robot is an intelligent, autonomous agent, carrying out tasks together with other agents in a cooperative, coordinated and communicative way. Robot soccer provides a good opportunity to implement and test MAS algorithms. One of the newest approaches in robotics is the application of robots in entertainment, leisure, hobby and education. A new term “edutainment” – composed of two words, education and entertainment, is widely spread. The Robot soccer is a good tool to teach people the complicated technical knowledge in the way of playing. At our institute two robot soccer teams in category MiroSot (Micro-Robot Soccer tournament) are used as a test bed for MAS and edutainment.

The size of playground (Fig. 6) bounded on all sides in category "MiroSot" is 150 x 130cm, 220 x 180cm, 280 x 220 cm or 440 x 280 cm depending on the number of the players.

A camera at a height of approximately 2m delivers pictures to the host computer. With color information placed on the top of the robot, the vision software calculates the position and the orientation of robots and the ball. The host computer generates motion commands using implemented game strategy and position information and sends to the robots by wireless communication.

The human operators are not allowed to directly control the motion of their robots either with a joystick or by keyboard commands under any circumstances. While a game is in progress the host computer can send any information autonomously. The duration of a game shall be two equal periods of 5 minutes each, with a half time interval for 10 minutes.

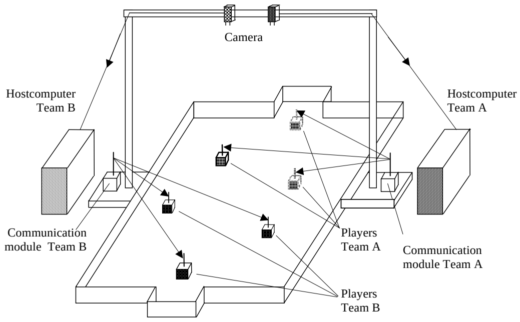

Fig. 6 Overall system of robot soccer (Kopacek et. al, 2003)

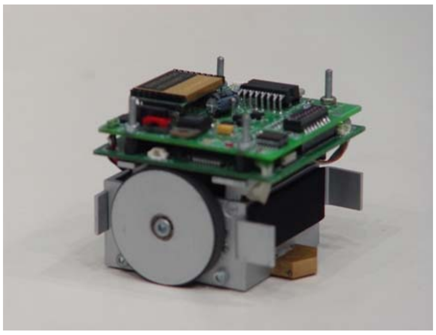

Fig. 7 The mobile mini robot

3. The new concept of a Humanoid Robot

Currently there are worldwide two 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) – with the background to serve mostly for entertainment, leisure and hobby or in the future as personal robots.

"Research" humanoid robots: There a lot of such robots currently available or in the development stage e.g. approximately worldwide more than 500 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.

We are currently working on a humanoid, two legged robot called **ARCHIE.** The goal is to build up a humanoid robot, which can simulate in some situations a human being. Therefore Archie needs a head, a torso, two arms, two hands and two legs and will have the following features:

1. Height: 80 - 100 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.

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 PDA module, one processor for image processing and audio control and one microcontroller for each structural component, e.g.: a Basic Stamp from Parallax.

4. A mobile mini robot for space applications: Roby Space

To get energy from the sun an approach is to set up nets with solar cells in the space and transmit the obtained energy to earth by microwave. A net (approximately 40 x 40 m) equipped with solar cells should be built in outer space (~ 200 km above the earth). The main problem is the positioning of the solar cells on the net structure. To fulfil this task autonomous mobile robots are necessary which are able to move (crawl) on this large quadratic structure – mesh (20 – 40m side length). The distance of the mesh lines is between 3 and 5cm; the thickness of the wires between 1 and 3mm.

The features of an autonomous mini robot for this purpose are:

- the maximum dimension 10x10x5cm
- light weight (less than 1 kg)
- on board power supply for approximately 10min
- equipped with a camera sending pictures to the earth
- wireless communication with the mother satellite by Bluetooth or similar
- free movement on the mesh
- mechanical and electronic robustness against vibration and shock.

The paper deals with the development of a low cost mini robot able to move on a mesh in outer space. Main difficulty is the design of the moving and holding mechanism of the robot on the mesh. Other difficulties are that the working environment is outer space (about 200 km over the earth) – low/high temperature, radiation, micro-gravity etc. - and the robot should be brought by means of rocket - vibration and shock. The requirements on the robot are the limited maximum size (10 x 10 x 5 cm), a simple mechanical construction, miniaturized electronics, robustness, “low cost”, and independence of the mesh’s dimension (from 3 x 3cm to 5 x 5cm).

Already two prototypes (Fig. 8) - Roby-Sandwich and Roby-Insect - were built and tested. Two tests – low temperature test at the 40 degree below zero and micro gravity tests- were already successfully done. At the 40 degree below zero Roby-Sandwich crawled on the net without any problem. In January 2005 two robots were tested in the micro-gravity environment by means of the parabolic flights in Japan.

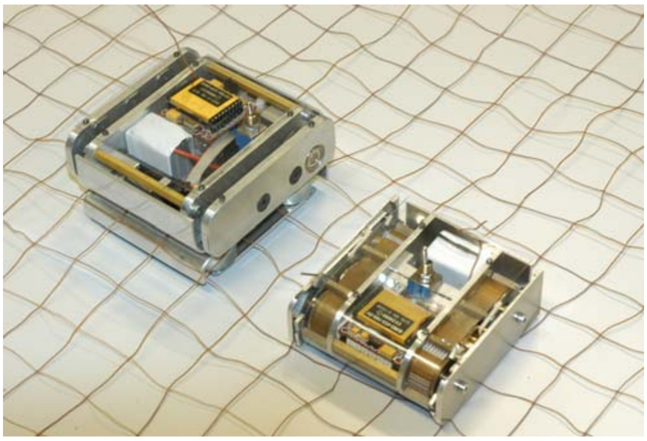

Fig. 8 Roby-Sandwich (Left) and Roby-Insect (Right) (Kopacek et. al (2004))

5. SUMMARY AND OUTLOOK

In this paper some new applications of a new robot generation are described. In addition modern information technologies lead to loneliness of the humans (teleworking, telebanking, teleshopping,....). 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 the prices should be equal.

6. LITERATURE

Kopacek,P. and D.Noe (2001): Intelligent, flexible assembly and disassembly. In: *Proceedings of the IFAC Workshop „Intelligent Assembly and Disassembly – IAD’01”*, p.1–10.

Kopacek,P. and B. Kopacek (2003): Robotized disassembly of mobile phones. In: *Preprints of the IFAC Workshop „Intelligent assembly and disassembly – IAD’03”*, Bucharest, p.142-144.

Kopacek, P., M.-W. Han, B. Putz, E. Schierer, M. Würzl (2003). Robot soccer a first step to “edutainment” *In Proceedings of RAAD’03, 12th International Workshop on Robotics in Alpe-Adria-Danube Region Cassino, Italy*

Kopacek, P. (2004). Robots for humanitarian demining. *In: Advances in Automatic Control (Ed. M Voicu)*, Kluwer, p.159- 172.

Kopacek, P. M. Han, B. Putz, E. Schierer, M. Würzl (2004): "A concept of a high-tech mobile minirobot for outer space"; in: "ESA SP-567 Abstracts of the International Conference on Solar Power from Space SPS'04 together with the International Conference on Wireless Power Transmission WPT5", Granada, Spain, 132 - 133.

Shivarov, N. (2001): A ‘Tool Kit’ for modular, intelligent, mobile robots, *PhD. Thesis*, Vienna University of Technology.

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