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 opens 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.

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 driven by 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 fulfil 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 [1], fuelling cars, cleaning of buildings and airplanes, ... 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 (multi-ped) and only in some cases 2 legs (biped) – walking on

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two legs is from the viewpoint of control engineering a very complex (nonlinear) stability problem. Biped walking machines equipped with external sensors are the basis for “humanoid” robots.

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 System – MAS”. A MAS consists of a distinct number of robots (agents), equipped with different arms, lifts, tools, gripping devices, ... and a host computer. The MAS has 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. assembly 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 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 partially developed with and realized in small and medium-sized enterprises -SME´s will be shortly described and discussed.

2.1 Disassembly Cell for Printed Circuit Boards

The layout of the cell is shown in Fig. 1. In a manual feeding station the Printed Circuits Boards (PCBs) with a maximum size of 300 x 220 mm are attached on special work holding device.

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),
– to detect the re-useable parts,
– to determine their position, size and the centre of inertia, and
– to classify the useable parts to be desoldered or removed from sockets.

The laser 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.

In the heating and removal station the PCB`s were heated by 3 infrared elements until the desoldering temperature for each of the parts is reached. The parts are removed by a simple pneumatic or a controllable two finger gripper and putted in the storage devices.

A prototype of this disassembly cell is now in use since 3 years.

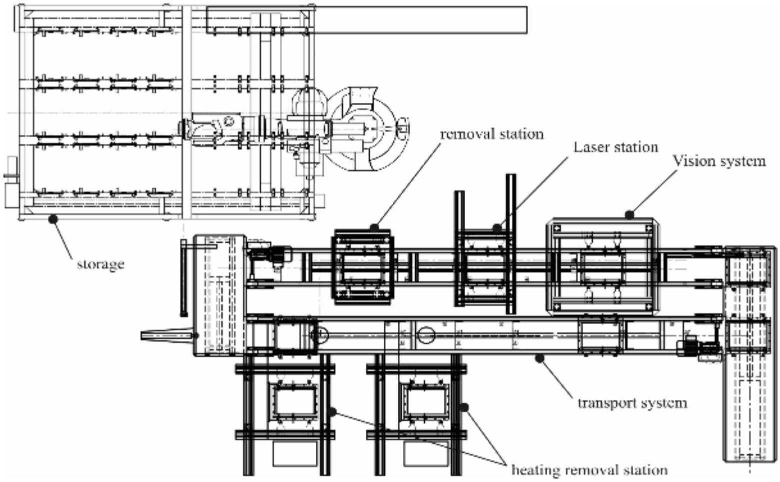

Fig. 1. Layout of the disassembly cell for PCB`s [2]

2.2 A Semiautomatized Disassembly Cell for Mobile Phones [3]

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.

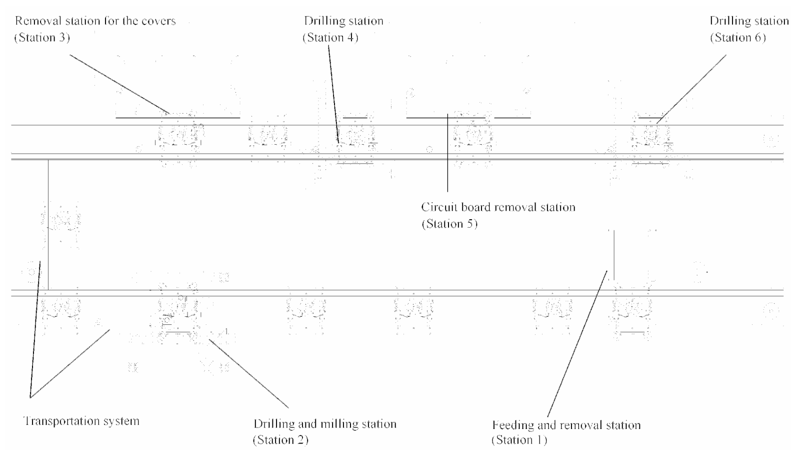

Fig. 2. Layout of the disassembly cell

For disassembly, the mobile phones were fixed on a pallet in a defined 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 the corresponding stations.

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.

In the next station – drilling station; no. 4 – the screws which connect the printed circuit board to the lower part of the housing are removed.

In the printed circuit removal station various other parts will be removed from the handy.

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
- Drive 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 (Fig.3). There is a large variety of tools, which can be used.

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.

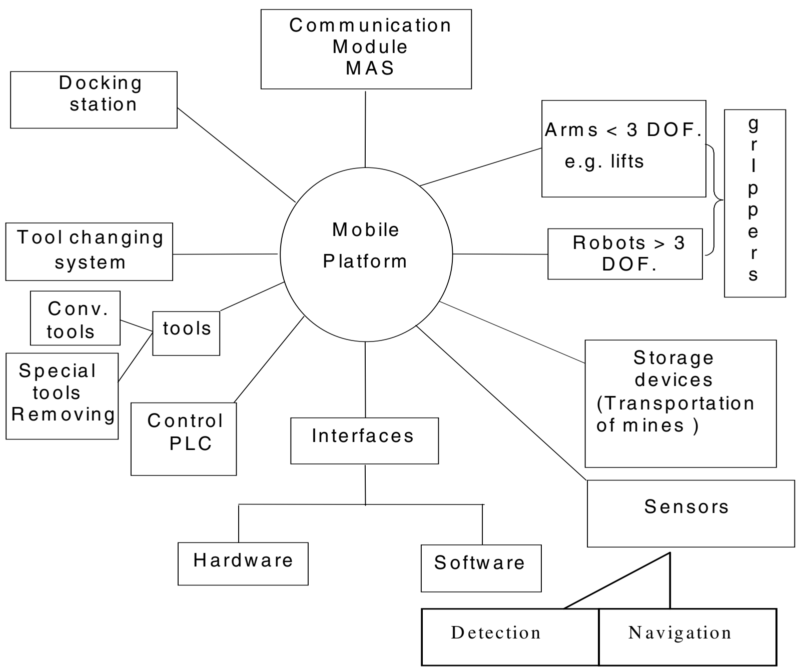

Fig. 3. Modular Robot System [7]

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.

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 more robots act, cooperatively together communication is important.

2.4 A Tool Kit for Humanitarian Demining [5]

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.

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.

Todays methods for destroying and removal are brutal force mechanical methods including ploughs, rakes, heavy rolls, flails mounted usually on tanks. The main problem with these methods is the contamination of the ground for 10 – 20 years. A better solution for the future is the use of demining robots.

A new approach is the use of robots in "Swarms". Swarms of robots can be connected; one is for searching, one for destroying and one for displacement. These three swarms consist of different types and numbers of robots. Many robots are searching and few or only one is necessary for destroying or displacing the mines.

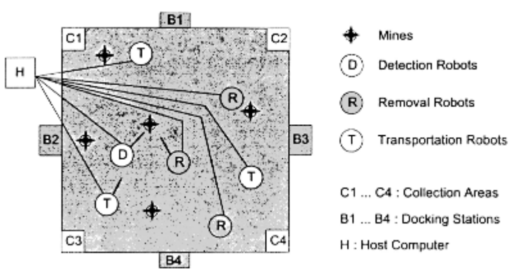

Fig. 4. Robot swarms for demining [5]

Robot swarms increase the number of robot applications in various 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.

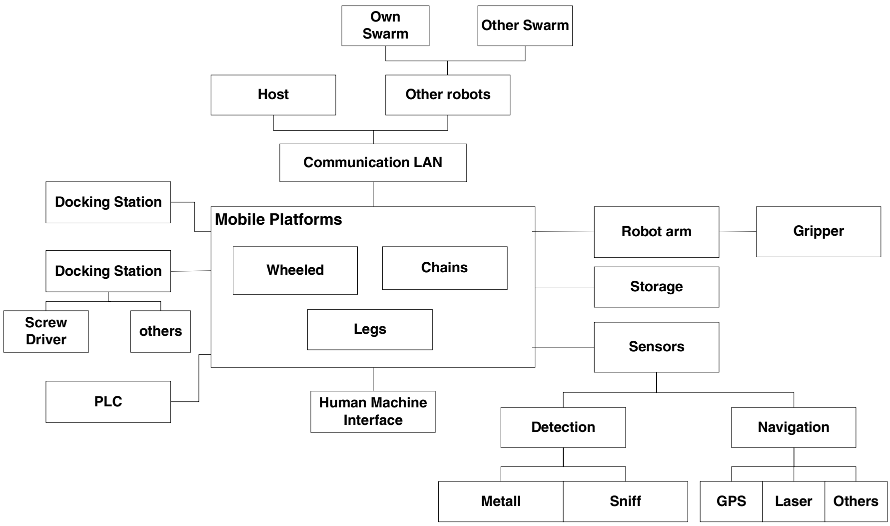

Fig. 5. "Tool Kit" for demining robots [5]

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 realised by the toolkit of Fig. 5.

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. A new term "edutainment" – composed of two words, education and entertainment was created.

One example is robot soccer 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. Furthermore it is an excellent tool to make "High Tech" transparent to broader public by playing.

At our institute four robot soccer teams, three in the category MiroSot (Micro-Robot Soccer tournament) and one in the category NaroSot (Nano-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 approximately 2m over the playground delivers pictures 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.

It is strictly forbidden that the three human team members directly control the motion of their robots either with a joystick or by keyboard commands during the game. Only the host computer is responsible. The duration of a game is two times 5 (7.5) minutes with a half time break of 10 minutes.

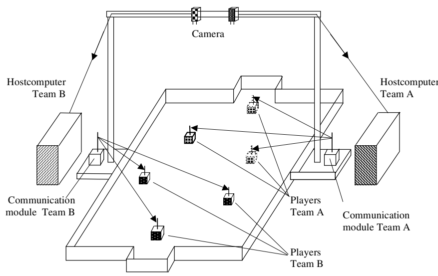

Fig. 6. Overall system of robot soccer [6]

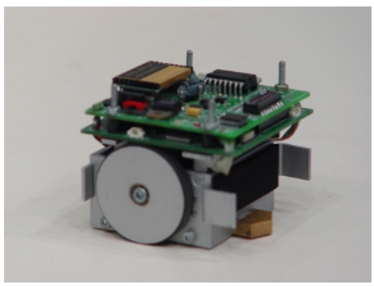

Fig. 7. The mobile mini robot "Roby Run"

2.6 Mobile Mini Robots 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 energy wireless to the earth by microwaves. For first tests a net (approximately 40 x 40 m) equipped with solar cells should be installed in outer space (~ 200 km above the earth). The main problem is the positioning of the solar cells on the net structure. For this task autonomous mobile robots could be used able to move (crawl) on this large quadratic mesh. The distance of the mesh wires is between 3 and 5cm; their thickness 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)
- simple mechanical construction,
- miniaturized electronics
- "low cost"
- independent of the mesh's dimension (from 3 x 3cm to 5 x 5cm).
- 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 low/high temperature, radiation, microgravity, vibration and shock during the flight in the rocket.

The main problem is the design of the moving and holding mechanism of the robot on the mesh. As a direct spin off from robot soccer two prototypes (Fig. 8) - Roby-Sandwich and Roby-Insect, based on “Roby Run” - 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 these two robots were tested in the micro-gravity environment by means of parabolic flights in Japan.

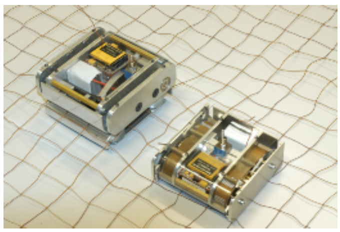

Fig. 8. Roby-Sandwich (Left) and Roby-Insect (Right)

3 The New Concept of a Humanoid Robot

The two legged, humanoid robots currently available can be divided in two categories:

“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) and “Qrio” – with the background to serve mostly for entertainment, leisure and hobby or in the future as personal robots. These robots are currently not available on the market not only because of the very high price.

“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.

1. We are currently working on a humanoid, two legged robot called ARCHIE. The goal is to build up a humanoid robot situated just between these two worlds. Therefore Archie needs a head, a torso, two arms, two hands and two legs.

New is the control system 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 Summary and Outlook

In this paper some new, partially realized, 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.

Acknowledgements

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