Autonomous Mobile Robots

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Abstract. *Robotics is a very fast growing field especially in the last years. 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 humans in every day life. In the future probably ubiquitous robots will support us.*
After an introduction in this paper three examples for autonomous, mobile robots, developed at IHRT will be described and shortly discussed.

Key words: *Mobile Robots, Humanoid Robots, Space Applications, Landmines.*

1 Introduction

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 (AGV`s) and walking mechanisms.
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.

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 (Kopacek, 2005).

2 Development Trends

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 habit, robots are poised to become a part of our everyday life. The robot systems of the next decades will 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 improved by embedding them into emerging IT environments characterised 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 experience. 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 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.

3 Examples of "advanced" robots

In the following some realised examples for this new robot generation are shortly described. Special emphasis is on the new headline: Cost Oriented Automation (COA).

3.1 Robots for Landmine Detection

An example for a MAS is robot swarms for landmine detection, removal and destroying (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 approximately 800 different types with different designs and actuation mechanisms.
Currently demining is carried mostly by human deminers. Because this is very dangerous we developed a prototype of a demining robot (Silberbauer, 2008). It consists of a platform and 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.
This prototype of a six-wheeled robot (HUMI – Robot for Humanitarian Demining) based on the Ackermann Geometry for movement in rough terrain is shown in Fig. 3.1.

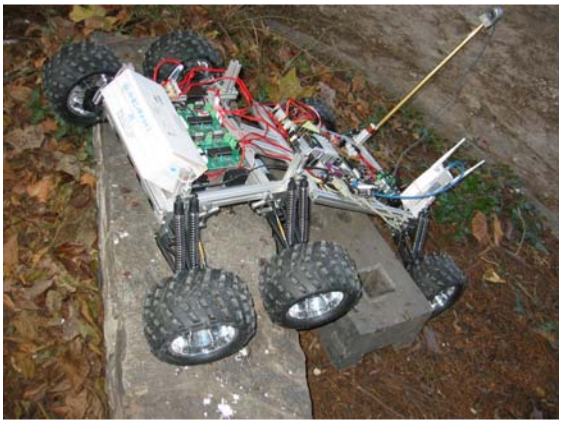

Fig. 3.1 HUMI at Outdoor Tests

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.

3.2 Roby Space

The concept of solar power from the space (SPS) was proposed in 1968. The basic idea of this concept is the generation of emission-free solar energy by means of solar cells from outer space and the transmission of energy to the earth using microwave or laser beam. Because of high launch cost the structure - consisting of solar cells as well as microwave transmitters - should be light weight. Instead of the conventional rigid structures a new concept (Furoshiki Concept) of a large membrane or a mesh structure was proposed. Next step to be realized is the transport of solar panels and microwave transmitters on this mesh structure.

The main purpose of this project was the development of mobile mini robots that place solar cells and transmitters on the net structure to build a solar power plant based on the Furoshiki net concept. A sounding rocket launches four satellites (one mother satellite and three daughter satellites), robots, net, solar panel and the microwave transmitters in the orbit. Approximately 60 seconds after launch the rocket reaches an altitude of 60 km. The mother satellite and three daughter-satellites build the Furoshiki net. Robots transport solar cells and microwave transmitters on the net structure (Fig.2). In the frame work of the project a feasibility study was done to verify the performance of the Furoshiki net as well as the crawling robots.

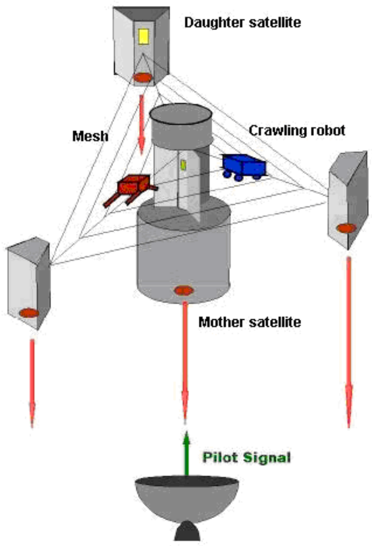

Fig. 3.2 Solar power plant by means of Furoshiki Satellite

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). The weight of the robot plays an important role. Even the launching cost per kilogram is very high. Another point to be considered is that in case the robot is too heavy, the satellite can not produce enough net tension. For a free movement the moving and holding mechanism of the robot should be well designed. Other difficulties are the vibration and shock during launching of the rocket. The robot should pass the vibration and shock tests up to 40 g. Last but not least the working environment of the robot is in outer space – 200 km over the earth. The high/low temperature, the radiation as well as the vacuum and others should be considered in the design phase.

The robot (Fig.3) consists of two parts – the upper part has two active driven belts, the lower one two passive driven belts (Kopacek et.al., 2006). Magnetic forces push them together. The special surface between the parts prevents the lower part from moving away.

The advantage of this construction is the very low friction between mesh and robot during operation. There are no high sliding forces between the passive and the active driven belts of the upper and lower part as well as the mesh.

Fig 3.3 Robot fixed on the mesh ready for action

The robots passed following tests:

- Microgravity tests during parabolic flights in January and March 2005 in Japan
- Vibration and shock tests in May 2005 at the ESA Mechanical Systems Laboratory, The Netherlands
- Mechanical verification tests, June 2005 in Japan

After the tests and technical updates of the systems a sounding rocket S310 with two RobySpace-Junior were launched on January 22, 2006 at the Uchinoura Space Center, Japan. One of two robots worked well. It crawled on the net with small resistance – the robot had a constant high voltage level and moved with constant velocity for more than 30 seconds. For the other robot we have to wait for the results from the telemetry data.
Three cameras in the satellite delivered the video signals. The video which sent the satellite showed one of robots which moved on the net. According to European Space Agency (ESA) and Japan Aerospace Exploration Agency (JAXA) the experiment completed successfully.

3.3 “Archie” – a humanoid robot

A “cost oriented” two legged robot called ARCHIE is currently in development in Austria (Baltes et.al., 2010). 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.
The upper part is currently in the final test phase.

4 Summary

Robotics is currently a very fast growing field not only in science and industrial application. In the last time more and more mass medias (TV, broadcast, journals, newspapers) are interested in this field because a broader public is in favour to get familiar with these new " intelligent machines". It is a first step for the realisation of the old dream of humans to have a robot available looking like a human. In the nearest future such robots or the next generation – ubiquitous robots - will be available for a reasonable price.
In this contribution some examples of currently available robots under the headline COA (Cost Oriented Automation) were presented. It is possible that small research teams are able to develop such robots in a reasonable time.

References

Baltes,J., A. Byagowi, P.Kopacek (2010) : A Teen Sized Humanoid Robot – Archie. IJAA ??????

Kopacek,P., B.Putz. M.W.Han (2006):Development of Mobile Mini Robots for Space Application. In: 37th International Symposium on Robotics ISR 2006 and 4th German Conference on Robotics ROBOTIK 2006, p. 209, VDI Publishing Company (2006).

Kopacek,P (2005).:Advances in Robotics. In: Proceedings of the 10th International Conference on Computer Aided Systems Theory – EUROCAST 2005, pp 549-558, Springer Berlin, Heidelberg, New York (2005).

Kopacek,P (2010).:From Industrial to Ubiquitous Robots. In: Proceedings of the 12th International Conference on Computer Aided Systems Theory – EUROCAST 2010, Springer Berlin, Heidelberg, New York (2010).

Silberbauer,L. (2008): A new 6 wheeled robot for humanitarian demining. In: EURON/IARP International Workshop on Robotics for Risky Interventions and Surveillance of the Environment. Spain.

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