RoboCupRescue 2006 - Robot League Team Bremen Rescue Walkers (Germany)

Direction and support:
Prof. Dr. Frank Kirchner[2], Dipl.-Inf. Dirk Spenneberg[2],
Dipl.-Inf. Markus Eich[2], Dr.-Ing. Dipl.-Inf. Udo Frese[1]

Students[1]:
Natallia Alkhovik, Jan Ole Berndt, Veit Briken, Leif Christensen,
Immo Colonius, Matthias Gernand, Simon Görler, Rabea Gransberger,
Wilken Haase, Jonas Heer, Christoph Hertzberg, Marco Horn, Jan Kahlbohm,
Nikola Stefanov Kalchev, Christian Limberg, Kevin Löhmann,
Janosch Machowinski, Claas Meyer-Barlag, Jan Osmers, Marc Sievert,
Jakob Suchan, René Wagner, Tobias Weihmann, Dirk Wenig, Norman Wessel,
and Pierre Willenbrock

[1] Universität Bremen, FB3 Mathematik und Informatik
Bibliothekstr. 1
28334 Bremen, Germany
`rr-orga@informatik.uni-bremen.de`
`http://rescuerobotics.informatik.uni-bremen.de`

[2] Deutsches Forschungsinstitut Künstliche Intelligenz
Forschungsgruppe Robotik und Intelligente Technische Systeme (RITS)
Robert-Hooke-Str. 5
28359 Bremen, Germany
`bremen@dfki.de`
`http://www.dfki.de`

Abstract. In this paper, we present our application for RoboCup Rescue 2006. We introduce two autonomous walking robot systems: AIMEE and SCORPION. Both are based on a biomimetic approach, which will be described very briefly. There is also a description about our newly developed flying system which will take part in the next years competition. A grid-based SLAM Algorithm with data from a Laser Range Scanner is used for Mapping. Furthermore, all necessary technical data for our participation is listed.

Introduction

“Bremen Rescue Walkers” is a student’s project at the University of Bremen which was originally founded in October 2003. The current group named *“Rescue Robotics”* took over the project in October 2005 from the former group

"Laufroboter"[3]. The project's aim is to build walking robot systems for the participation in RoboCup Rescue Competitions. We are working hard to achieve a good result in this years RoboCup in our hometown.

Coordinated by Dirk Spenneberg, the "Bremen Rescue Walkers" was initiated by the Robotics Lab of the University of Bremen under the supervision of Professor Frank Kirchner. Research at the Robotics Lab is focused on biomimetic walking robots. Especially in scabrous rescue scenarios, these offer a great advantage over wheeled systems as they feature more degrees of freedom, e. g. allowing to walk across stones or to climb stairs. The Robotics Lab developed the 8-legged robot SCORPION (see Figure 1), which is described in [8].

Fig. 1. Scorpion

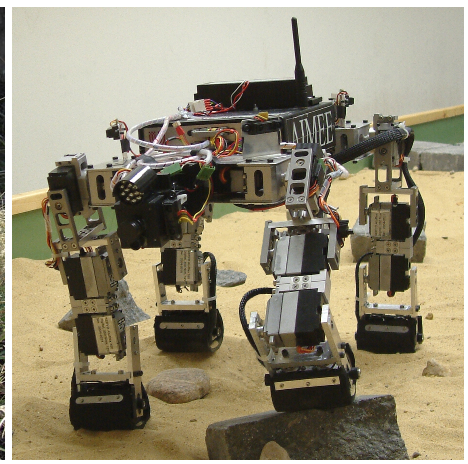

Fig. 2. AIMEE

"Bremen Rescue Walkers" relied on the experience of the Robotics Lab to develop the 4-legged robot AIMEE [2] (see Figure 2). The website[3] contains additional information about the project's aims and the robots themselves.

Both systems are developed for highest stability in hard- and software. The microkernel based operating system controlling the robots is an in-house development and runs on a Motorola MPC555/MPC565 microcontroller with very low power consumption. The robots do not require any active cooling systems which allows us to create completely closed systems. This makes our systems very robust regarding typical environmental influences of rescue scenarios, e. g. dust. We use low bandwidth communication (115200 Baud) via the DECT standard.

Additionally, we are developing a semi-autonomous unmanned aerial vehicle (UAV) for indoor use, which is going to assist the walking robot AIMEE during

[3] http://rescuerobotics.informatik.uni-bremen.de

exploration missions (such as rescue scenarios). As a mid-term goal we plan to extend the capabilities of AeroBot (see Figure 3 and Figure 4), so it can be carried on top of the walking robot and take off and land on it, giving the operator a better view of the surroundings via live pictures from the onboard video camera. The robot will be controlled through the operator interface via high level commands (e. g. “lift off”, “land”). Since this sub-project is still in its early stages, AeroBot will not take part in the actual competition. There will, however, be a demonstration of the state of this robotic system as of RoboCup 2006.

Fig. 3. AeroBot

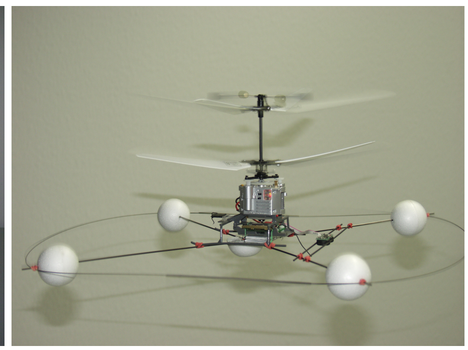

Fig. 4. AeroBot flying

1 Team Members and Their Contributions

Head of Working Group: Prof. Frank Kirchner

Team Leader: Dirk Spenneberg

Integration/Sensor Research: Wilken Haase, Marco Horn, Marc Sievert, Jakob Suchan, Norman Wessel

Software Architecture Development: Jan-Ole Berndt, Immo Colonius, Simon Görler, Janosch Machowinski

Interface Design and Development: Veit Briken, Matthias Gernand, Rabea Gransberger, Christian Limberg

Mapping: Natallia Alkhovik, Christoph Hertzberg, Nikola Kalchev, Tobias Weihmann

Flying System: Leif Christensen, Jonas Heer, Jan Kahlbohm, Kevin Löhmann, Jan Osmers, René Wagner, Pierre Willenbrock

Operator: Claas Meyer-Barlag

2 Operator Station Set-up and Break-Down (10 minutes)

Besides booting the operator's notebook and connecting it to the DECT communication module and starting the robots, no further steps need to be performed. Our robots are designed to be very lightweight. Fully operable weights are: AIMEE 4 kg, SCORPION 12kg, including power supply.

3 Communications

For the communication between the operator's user interface and the robots, we use wireless communication to avoid that the robots are handicapped with long cables.

Sensor information from both robots and instructions to the robots will be sent via a wireless bidirectional connection based on a DECT module (see Table 1).

Video and audio information from the robots to the user interface are sent over a second communication channel (2.4 GHz) which is part of the camera used in our systems.

There will also be a third communication channel, which will be used to transfer information of AIMEE's laser scanner. This channel will be realized by a Bluetooth-chip (2,402 GHz to 2,480GHz).

Table 1. Technical information of the HW86010 DECT Module by Höft & Wessel

Technical Data	
Frequency	1.88 GHz to 1.9 GHz
Transmit Power	250 mW (max)
Temperature Range	$-10°C$ to $+55°C$ operating
Data interface	Up to 115.2 KBaud (RS-232)
Range	Up to 300m (outdoor), up to 60m (indoor)
Reliability	Error protection and flow control

Table 2. Communication Overview

Robot League			
Bremen Rescue Walkers (Germany)			
Robot	**Frequency**	**Channel/Band**	**Power**
AIMEE	2.4 GHz - Camera Module	n/a	n/a
AIMEE	2.4 GHz - Bluetooth	n/a	n/a
AIMEE	1.9 GHz - DECT	n/a	250 mW (max)
Scorpion	2.4 GHz - Camera Module	n/a	n/a
Scorpion	1.9 GHz - DECT	n/a	250 mW (max)

4 Control Method and Human-Robot Interface

Our control concept is best described as supervised autonomy meaning that influence by the operator is kept on a quite abstract level and that the systems handle most tasks automatically. Please refer to section 8 for details of the robot side of this approach.

The operator's interface is entirely written in Java for easy portability and requires no dedicated hardware besides a DECT communication module and a frame-grabber card to process the incoming analog video data.

Our interface is designed to handle multiple robots at the same time and offers an intuitive operation of our systems as the walking approach is completely handled by the robots[4]. The task of the operator is to direct the robot to a certain direction, to identify victims, and to intercept whenever the robots cannot solve a situation themselves.

The control interface has undergone a complete redesign (see Figure 5) since its first version. The primary goal has been to improve usability, extensibility and the overall speed and responsiveness of the application. Due to the fact that the interface is completely written in Java, speed improvements have been accomplished by using the Standard Widget Toolkit[5] of the Eclipse Project instead of Sun's Swing. Improved extensibility has been achieved by engineering the redesigned application plug-in-based. Usability has been improved by redesigning the interface. The driving force behind the entire redesign process has been the feedback by our operators describing their experiences with earlier versions of the software.

Due to the fact that the redesigned interface is now extremely extensible our future plans are to include new, innovative control concepts like head-mounted-displays with datagloves or speech-controlled-robots.

---

[4] Please note that it is also possible to control every motor explicitly

[5] http://www.eclipse.org/swt

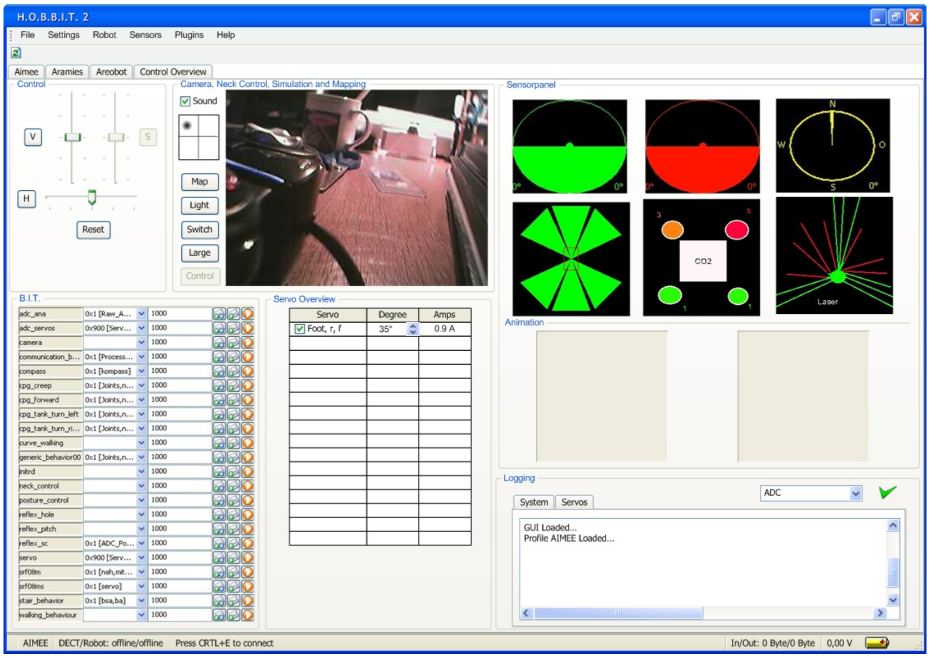

Fig. 5. Screenshot of the GUI (design example)

5 Map Generation/Printing

Our research is mainly concentrated on excellent mobility in rough terrain, therefore we have not developed any entirely new mapping algorithms.

Instead, our work on map generation is based on the Grid-based SLAM algorithm with Rao-Blackwellized Particle Filters by Adaptive Proposals and Selective Resampling as described in [4].

As the robot can access different levels (e. g. tables or desks), the map is separated in different levels as well. A 2D map is generated for each level. As far as the mapping algorithm is concerned, the transfer from one level to another occurs without operator intervention. If the scanned data is inconsistent to the already generated map, it will not be used for the current map. As soon as the program receives stable data input, the map creation will continue at the next level. If the robot reenters an already visited level the algorithm joins the data to the corresponding map.

6 Sensors for Navigation and Localization

The robots are equipped with several sensors to navigate and to orientate themselfes in their environment. A laser scanner is used to generate a map of the environment. The URG-04LX laser scanner by Hokuyo [5] can detect objects in a range from 20 mm to 4000 mm and has an angular range of 240 degrees (see Figure 6).

Fig. 6. Laser Scanner

Furthermore, an infrared-sensor (GP2D12, Sharp) is used as distance-sensor as well, which has a range of 40 cm (16 inch). The infrared-sensor is used to locate obstacles. The robots are also equipped with a compass and a pitch sensor, which take care that the robot is balanced (ADXL202, Analog Devices). The feet of our robots are equipped with pressure-sensors which make sure that the robots stay stable.

7 Sensors for Victim Identification

For localizing and identifying victims, we use a CMOS color camera which is integrated into the head of our robot. The video feeds are streamed to the operator's interface. As the robots have no image recognition on board, it is the operator's duty to identify an object as a victim.

Furthermore, our camera is equipped with a microphone whose audio stream is forwarded to the operator's interface as well, so we can identify victims through their noise as screams.

To gain more possibilities for automatic victim identification, we are planning to integrate a sensor for distance temperature measurement[6]. With such sensors, the decision whether a victim is nearby may be made on the basis of temperature distribution around the robots.

We are also planning to integrate a CO_2-Sensor to identify victims by their breathing.

8 Robot Locomotion

As our system is walking, the locomotion is far more complex than for wheeled ones. On the other hand, walking systems offer superior performance on rough terrain as they can navigate more freely.

To control this added complexity, several strategies are known, of which most are adapting strategies found in nature, mainly in insects. Biologic research assumes that walking is controlled through a central pattern generator (CPG). We use central pattern generators with a fixed system of rhythmic patterns to control leg movements. Also we programmed reflexes for acting after collisions with non-moving objects and a special behaviour named the 'creeping behaviour'. We use this to climp steep surfaces. Above the level of direct leg coordination exists the behavior level which handles more abstract tasks like the direction of walking and the posture while doing so. Each of such tasks is handled by one behavior process. These processes do not exclude each other from hardware (leg) access but compete for influence on the resources. E.g., a forward walking behavior competing with a step right behavior would make the system move forward in a 45° angle if both behavior process take equal influence. Therefore combinations of these behaviors allow a wide range of system behavior while keeping the code-base small and simple. Thus, our approach offers the robustness and flexibility of walking systems while keeping the complexity of development and operation low. On top of this behavior level exists either an automatic mission planer, a command interface from the operator, or both. This level handles even more abstract tasks such as "room scan", "wall follow", "victim search".

9 Other Mechanisms

To implement this control approach, we had to develop a custom microkernel which provides real-time capabilities and a behavior programming framework. Behavior-based programming has the shortcoming that its theoretically powerful scaling-up capabilities and elegance of programming are limited by the parallelism simulation which is required here, and non-periodic interrupts as reflexes are not foreseen. Real-time operating systems on the other hand feature high reactivity and robustness but lack the biologically inspired architecture we require.

[6] This might be a Pyroelectric Infrared Motion Detector

Furthermore, they offer way too many features for our task. Our own microkernel M.O.N.S.T.E.R. combines the features required by us from both worlds. A Paper which describes M.O.N.S.T.E.R. is available here [7].

In the current state we are using the second version of this implementation, M.O.N.S.T.E.R. II. The main benefits are the improved time-management and a better interprocess-communication.

10 Team Training for Operation (Human Factors)

For Operator-Training we built our own "behavior lab" with several different terrains for training and automated testing. As a first training under competitive conditions, we will participate at the RoboLudens[1] in Eindhoven from 7^{th} till 9^{th} of April.

We believe, however, that very little training is required for getting started in manoeuvring our systems as the added complexity of walking over driving is handled by our biomimetic control approach.

11 Possibility for Practical Application to Real Disaster Site

The SCORPION robot has already accomplished some outdoor tests, videos are available at [6]. As the AIMEE system was built on top of the same architecture, we are quite confident that it will also accomplish its tasks in rough terrain. Both robots have limited means for victim identification. At the current state of the project, the video data from the cameras of the robots are the only information source the operator receives to recognize victims and identify their state.

12 System Cost

This section gives a brief overview over the costs for AIMEE and SCORPION and their key-parts.

TOTAL SYSTEM COST (AIMEE): about 17000 €	
Key part name:	phyCORE-MPC565
Manufacturer:	Phytec
Part number:	PCM-019
Cost:	452,40 €
Website:	http://www.phytec.com
Description/Tips:	Controller board, including Microcontroller
Key part name:	Connector board
Manufacturer:	Custom-built
Cost:	About 400 €
Description/Tips:	Connector board for the phyCORE-MPC565 micro-controller board
Key part name:	Alu-Star digital-350
Manufacturer:	Volz
Cost:	About 400 €
Website:	http://www.volz-servos.com/
Description/Tips:	Servo motors for locomotion (19x)
Key part name:	Construction kit for Servo assembly
Manufacturer:	Custom-built
Cost:	183,00 €
Description/Tips:	one per Servo
Key part name:	CMOS COLOR Camera w. IR & MICRO
Manufacturer:	Conrad
Part number:	190840 - 62
Cost:	45,95 €
Website:	www.conrad.de
Description/Tips:	Camera for Victim Indentification
Key part name:	Scanning Laser Range Finder for Robotics
Manufacturer:	URG-04LX
Cost:	2800 €
Website:	http://www.hokuyo-aut.jp/products/urg/urg.htm
Description/Tips:	Used for Mapping
other Sensors:	Altogether about 500 €

TOTAL SYSTEM COST (SCORPION): about 60000 €	
Key part name:	phyCORE-MPC565
Manufacturer:	Phytec
Part number:	PCM-001-2101
Cost:	375 €
Website:	http://www.phytec.com
Description/Tips:	Controller board
Key part name:	FPGA
Manufacturer:	Xilinx
Cost:	About 300 €
Website:	http://www.xilinx.com
Description/Tips:	
Key part name:	DC Motors
Manufacturer:	Maxon
Cost:	About 150 €
Website:	http://www.maxon.ch/index_a.cfm
Description/Tips:	price including transmission (24x)
Sensors	Altogether about 500 €

References

1. RoboLudens: Dutch Open RoboCup (7-9 April 2006). http://www.roboludens.nl.
2. M. Albrecht, T. Backhaus, S. Planthaber, H. Stoeppeler, D. Spenneberg, and F. Kirchner. AIMEE: A Four Legged Robot for RoboCup Rescue. http://ag47.informatik.uni-bremen.de/downloads/papers/aimee.pdf, Sep. 2005.
3. Bremen Rescue Walkers. Project Website: http://aimee.informatik.uni-bremen.de.
4. Giorgio Grisetti, Cyrill Stachniss, and Wolfram Burgard. Improving Grid-based SLAM with Rao-Blackwellized Particle Filters by Adaptive Proposals and Selective Resampling. http://www.informatik.uni-freiburg.de/ stachnis/research/rbpfmapper/, Sep. 2004.
5. Hokuyo Automatic Co. Ltd. URG-04LX Scanning Laser Range Finder for Robotics. http://www.hokuyo-aut.jp/products/urg/urg.htm.
6. AG Robotik. Outdoor Tests with SCORPION. http://ag47.informatik.uni-bremen.de/eng/videos.php.
7. Dirk Spenneberg, Martin Albrecht, and Till Backhaus. M.O.N.S.T.E.R.: A New Behavior-Based Microkernel For Mobile Robots. http://ag47.informatik.uni-bremen.de/downloads/papers/ecmr-spenneberg-et-all.pdf, Sep. 2005.
8. Dirk Spenneberg and Frank Kirchner. SCORPION: A Biomimetic Walking Robot. *Robotik 2002*, Vol. 1679:pp. 677–682, 2002.