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RoboCupRescue - Robot League Team Bremen Rescue Walkers[1] (Germany)

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Abstract. In this paper, we present our application for RoboCup Rescue 2005. We introduce two autonomous walking robot systems: AIMEE and SCORPION. Both are based on a biomimetic approach, which will be described very briefly. 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 founded in October 2003. Its aim is to build walking robot systems for a participation in the RoboCup Rescue 2005. At the two Bremen universities, there are two robotics research groups which are applying for the RoboCup Rescue 2005. Furthermore, Bremen is hosting the RoboCup 2006.
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, which is described in [7].

[1] former "Projekt Laufroboter Bremen"
[2] Please refer to chapter 1 for a complete list of team members and their contribution

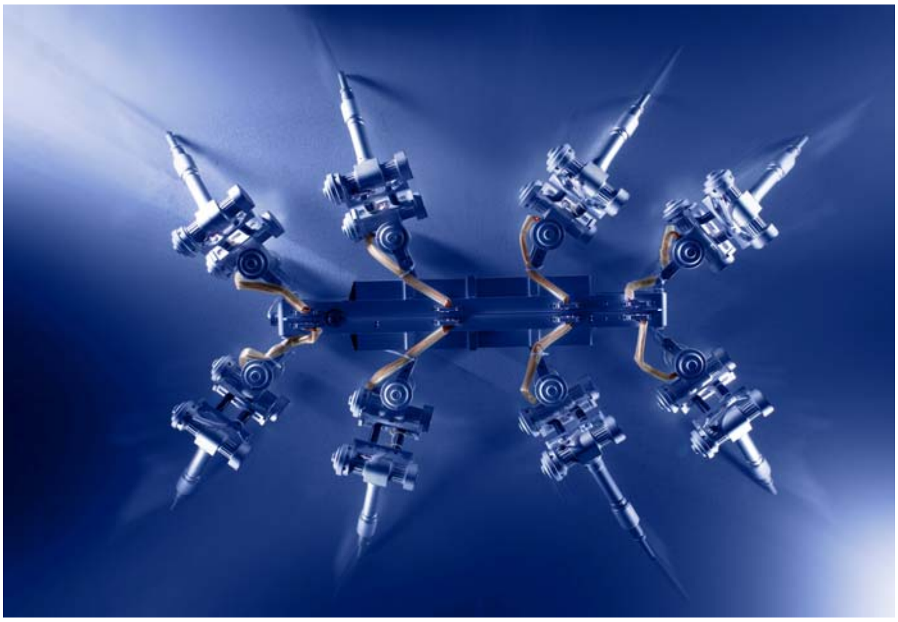

Figure 1: The SCORPION Robot

“Bremen Rescue Walkers” relied on the experience of the Robotics Lab to develop the 4-legged robot AIMEE. The project's website can be found at [4].

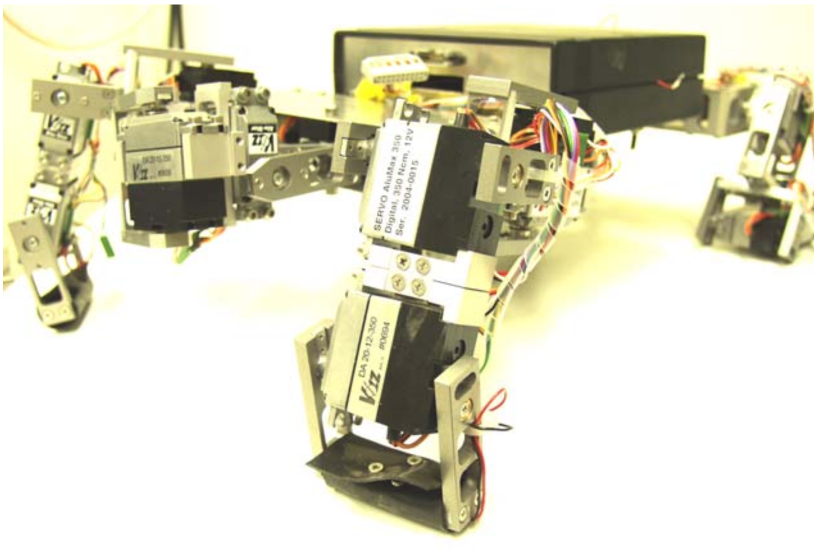

Figure 2: The AIMEE Robot

Both systems are developed for highest stability in hard- and software. The microkernel controlling the robots is custom-developed 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.

1. Team Members and Their Contributions

- *Head of Working Group:* Prof. Frank Kirchner
- *Team Leader:* Dirk Spenneberg
- *Mechanical Design:* Gerrit Alves, Sebastian Bartsch, Uwe Bellmann, Friedrich Boye, Heiko Diesing, Markus Hagen, Daniel Kühn, Tobias Quintern, Henning Stöppler, Gerrit Wolter
- *Sensor Research:* Stefan Haase, Jens Kleinwechter, Steffen Planthaber, Martin Rohlfs
- *Software Architecture Development:* Martin Albrecht, Till Backhaus, Jan Hardel
- *Simulation:* Simeon Djoko Dzoukou, Felix Schlick
- *Interface Design and Development:* Justus Brückel, Arne Garbade, Paul Niechwiedowicz, Alexander Schmidt, Jie Tang
- *Walking Approach:* Larbi Abdenebaoui, Robert Borchers, Jan Evers, Istvan Lovas, Arne Martens, Michael Rohn, Malte Römmermann

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 the 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 (see Table 2) which is part of the camera used in our systems.

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

Technical Data	
Frequency	1.88 GHz to 1.9 GHz
Temperature Range	-10 to +55 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. Technical information of the communication module of the camera

Technical Data	
Frequency	1.3 GHz

Rescue Robot League		
Bremen Rescue Walkers (Germany)		
Frequency	**Channel/Band**	**Power (mW)**
1.9 GHz - DECT		
1.3 GHz		

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 chapter 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 both robots at the same time and offers a intuitive operation of our systems as the walking approach is completely handled by the robots[3].
The task of the operator is to direct the robot to a certain direction, to identify victims,

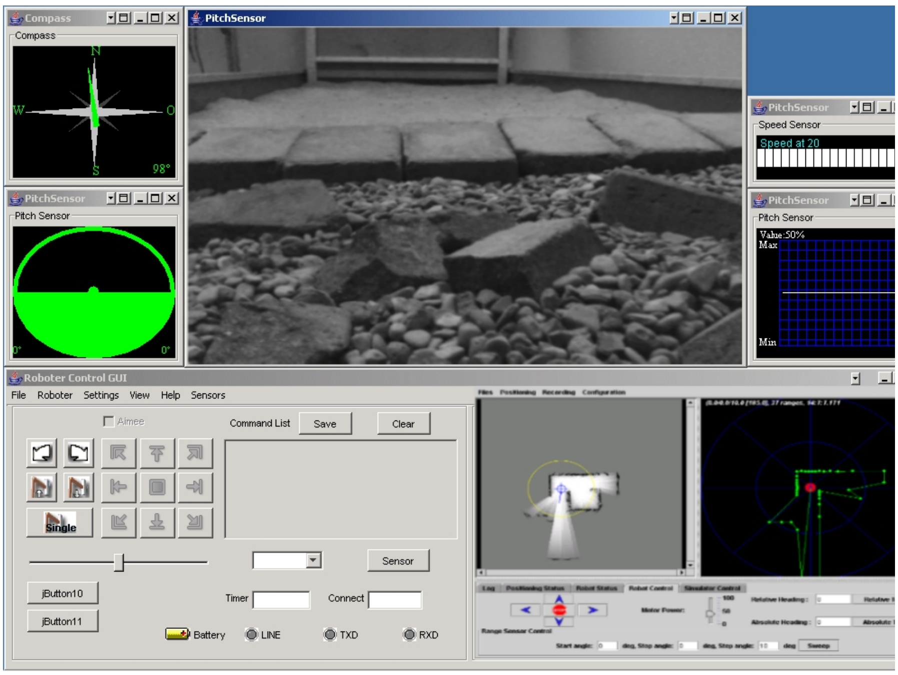

Figure 3: Interface Screenshot

and to intercept whenever the robots cannot solve a situation themselves.

5. Map Generation/Printing

Our research is mainly concentrated on excellent mobility in rough terrain, therefore we did not develop new mapping algorithms. To map the environment, we use a mapping algorithm which uses sonar data as proposed in [1] and [2].

6. Sensors for Navigation and Localization

The robots are equipped with several sensors to navigate and to orientate in their environment. Two pivoting ultrasound distance sensors are used to generate a map of the environment. The ultrasonic distance sensors (SRF 08, Devantech) have a range of 6 meters (20 feet). 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. We also use a camera which is used by the operator to detect victims.

7. Sensors for Victim Identification

For localizing and identifying victims, we use cameras which are integrated into the heads of our robots. Their 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 cameras are equipped with microphones 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. With such sensors, the decision whether a victim is nearby may be made on the basis of temperature distribution around the robots.

8. Robot Locomotion

As our systems are 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

for cockroaches and scorpions [6] walking is controlled through a central pattern generator (CPG) while Cruse's Walk-Net [5] models the reflex-triggered walking strategy of grasshoppers. While central pattern generators work with a fixed system of rhythmic patterns to control leg movements, Walk-Net uses reflexes triggered by local sensor feedback at the leg and couplings between neighbored legs for control.
Our systems are based on central pattern generators combined with reflex components. This combination offers a stable gait while still offering the possibility of quick reactions to observed obstacles. Details on the control approach can be found at [7].
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.
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”.
Thus, our approach offers the robustness and flexibility of walking systems while keeping the complexity of development and operation low.

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. 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 on M.O.N.S.T.E.R. will be available for reference after the RoboCup.

10. Team Training for Operation (Human Factors)

Our operators are trained at two sites. We built our own “behavior lab” with several different terrains for training and automated testing. Furthermore, the International University of Bremen granted us access to their RoboCup Rescue training site.
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 [3]. 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

TOTAL SYSTEM COST (Aimee): about 17000€

KEY PART NAME phyCORE-MPC565
PART NUMBER: PCM-019
MANUFACTURER: Phytec
COST: 452,40 €
WEBSITE: http://www.phytec.com
DESCRIPTION/TIPS: Controller board, including Microcontroller

KEY PART NAME: Connector board
PART NUMBER: Custom-built
COST About 400 €
DESCRIPTION/TIPS: Connector board for the phyCORE-MPC565 microcontroller board

KEY PART NAME: **Alu-Star digital-350**
MANUFACTURER: Volz
COST: Abaut 400 €
WEBSITE: http://www.volz-servos.com/
DESCRIPTION/TIPS: Servo motors for locomotion (19x)

KEY PART NAME: **Construction kit for Servo assembly**
PART NUMBER: Custom-built
COST: 183,00 €
DESCRIPTION/TIPS: one per Servo

SENSORS: altogether about 500 €
CAMERA:

TOTAL SYSTEM COST (Scorpion): about 60000€

KEY PART NAME: phyCORE-MPC565
PART NUMBER: PCM-001-2101
MANUFACTURER: Phytec

COST:	375 €
WEBSITE:	http://www.phytec.com

KEY PART NAME:	**FPGA**
MANUFACTURER:	Xilinx
COST:	Abaut 300 €
WEBSITE:	http://www.xilinx.com

KEY PART NAME:	DC Motors
MANUFACTURER:	Maxon
COST:	About 150 €
WEBSITE:	http://www.maxon.ch/index_a.cfm
DESCRIPTIONS/TIPS	price including transmission (24x)

SENSORS	Altogether about 500 €

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