RoboCupRescue - Robot League Team IUB Rescue, Germany

Andreas Birk, Stefano Carpin, Winai Chonnaparamutt, Viktoras Jucikas, Hamid Bastani, Ivan Delchev, Ivan Krivulev, Seongchu Lee, Stefan Markov, Andreas Pfeil

International University Bremen
Campus Ring 1
28759 Bremen, Germany
a.birk@iu-bremen.de
http://robotics.iu-bremen.de/

Abstract. This paper describes the IUB rescue robot team 2005. The team is active since 2001 and it has competed in four RoboCup real rescue competitions. The team takes an integrated approach to rescue robots, i.e., developing the systems from the mechatronics to the high-level functionalities for intelligent autonomous behavior.

1 Introduction

IUB robotics is working in the domain of rescue robots since 2001. The team has already participated in the real robot rescue league at RoboCup 2002 in Fukuoka (4th place), RoboCup 2003 in Padua (4th place), American Open 2004 in New Orleans (2nd place) and RoboCup 2004 in Lisbon [Bir05,BCK04,BKR$^+$02].

The goal of the team is to develop field-able systems within the next years. An integrated approach is taken for this purpose, i.e., the systems are developed at IUB from the mechatronics to the high-level software. The two main types of rescue robots are the so-called papa- and mother-goose robot types (figure 1). Currently, two robots of the papa type with its 6-wheel drive are still in use for research purposes. But a new set of robots based on a caterpillar drive (figure 2) is under development in cooperation with the IUB oceanography group. These robots come already much closer to application scenarios as their drive components are water- and dust-proof. All robots are based on the so-called CubeSystem designed for fast prototyping of robotic systems [Bir04a,BKW00]. The center of the CubeSystem is the so-called RoboCube controller hardware [BKW98]. On the software side, the CubeSystem features a special operating system, the CubeOS [Ken00], and libraries for common robotics tasks [KB05,BKS02], supporting teleoperation as well as autonomy [BK03]. In addition to the systems engineering side of the robots, the team engages in basic research related to rescue robotics and autonomous systems in general. This includes work on multi-robot mapping [CB05,CJB04] and exploration under the constraints of wireless networking [RB05,RB04].

2 Team Members and Their Contributions

– Andreas Birk: Team Leader

Fig. 1. Mother and papa goose entering the orange arena at the RoboCup 2003 competition.

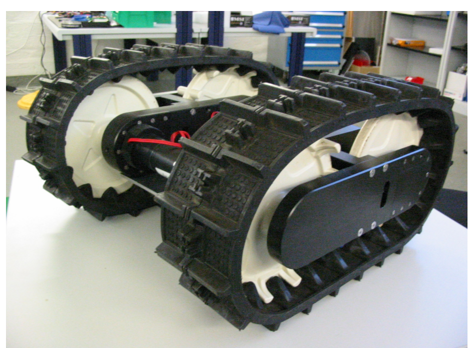

Fig. 2. The new locomotion system based on tracks that replacing the 6-wheel drive of the papa-goose type robots.

– Stefano Carpin: System Design
– Viktoras Jucikas: Map Building and Localization
– Stefan Markov: Autonomy and Perception
– Ivan Delchev: Autonomy and Perception
– Ivan Krivulev: Systems Programming and Communication
– Andreas Pfeil: Systems Programming and Communication
– Winai Chonnaparamutt: Mechatronics and Systems Programming
– Hamid Bastani: Mechatronics and Systems Programming
– Seongchu Lee: Mechatronics and Systems Programming

3 Operator Station Set-up and Break-Down

The IUB operators station is based on a barebone-PC integrated in an operator's box, which also includes all communication equipment like media converters and switches. The operator's box is optimized for fast set-up and break-down. The robots are designed to be easily handable by one human when being set-up.

4 Communications

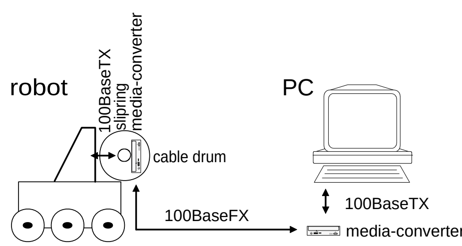

Fig. 3. The components of the deployable glassfibre communication system. The overall system behaves much like a standard 100BaseTX FastEthernet connection between the robot and an endpoint like a PC (cross-cable connection) or a network bridge (straight-cable connection).

Communications between the robots and to the operator's station is based on glassfiber cables deployed by the robots. The system provides 100MBit ethernet connections over up to 100m in its default configuration. The glassfibres provide high bandwidth, they are very lightweight and thin, and they can take a lot of stress, much more than normal copper cable. The glassfiber links are deployed from the mobile robot via a cable drum. The system is based on media converters at both ends. One of them is integrated on the drum, thus allowing the usage of inexpensive wired sliprings. The glassfibre system turned out to be very performant and reliable, both in operation in the challenging environment of rescue robotics as well as in concrete experiments. Furthermore, RF-LAN based on 802.11A is used as fallback in situations where the tethered solution has to be discarded.

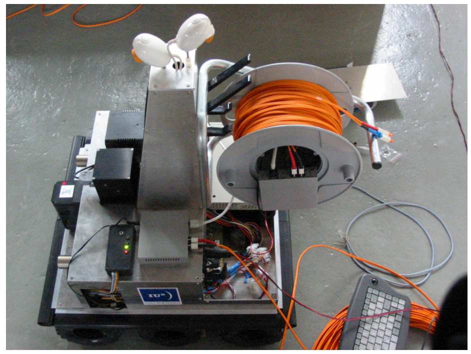

Fig. 4. A rescue robot with the cable deployment system

5 Control Method and Human-Robot Interface

A single operator controls all robots working in parallel. The robots are semi-autonomous in the default mode, i.e., the operator specifies small, short-term tasks like move to a target location, which are autonomously carry out. The operator is in addition assisted by autonomous functionality like map-building, identification of victims via passive infrared and in the future via machine vision. There is also the option the run the robots in full autonomous mode, which will be tried in the yellow arena.

6 Map generation/printing

In current work, simultaneous localization and the fusion of several maps from different robots is implemented. The map is computer drawn and printed. The map is based on a probabilistic occupancy grid, i.e., it shows the free space and obstacles as gray values. A hall-way for example is shown as white floor and red walls, black depicts unknown territory (figure 5).

7 Sensors for Navigation and Localization

The sensors for the 2005 team have not changed compared to the previous year. The robots are equipped with a low-cost laserscanner from Hokuyo Automatic, the PB9-11. It covers 162 degrees in 91 steps up to a depth of 4m. This sensor is the main tool for gathering obstacle data.

The bases are in addition equipped with several one-dimensional obstacle sensors, namely

- coarse range Ultrasound Sensors
  - from Polaroid
  - with a long range, i.e., up to 10 m, wide scan angle of 60 deg
- high precision Ultrasound Sensors

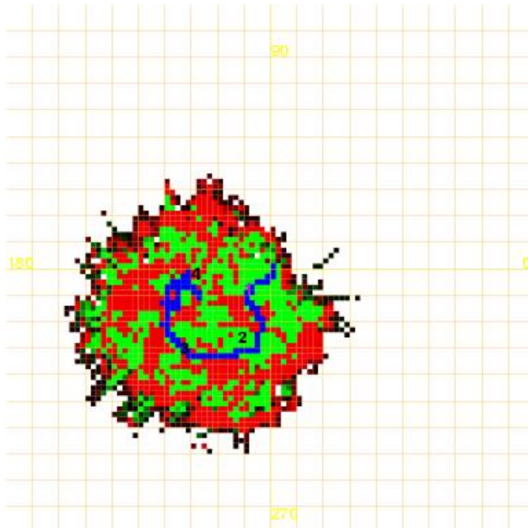

Fig. 5. A map of the arena based on data from the localization sensors and the laser scanner.

  - from Baumer Electric
  - with a medium range, i.e., up to 7 m, narrow scan angle of 10 deg
- active InfraRed Sensors
  - from Sharp
  - with a short range, up to 0.7 m, narrow scan angle of 10 deg

These sensors are ideal for simple control behaviors like wall-following to autonomously negotiate long corridors.

To estimate the absolute orientation of robot, two digital compasses are used. The first one is based on the Philips KMZ51 IC. It has an I2C interface and it is directly connected to the CubeSystem. The second compass is from Honeywell. Its RS232 interface is serviced by the onboard PC.

The motors of both robots are equipped with high resolution quadrature encoders from HP. The software modules of the CubeSystem not only use this data for control, but also for odometry and dead-reckoning to estimate the robot's pose. In doing so, the data from the compass is used for a leaky update of the orientation estimation via odometry. By this, the performance of dead-reckoning gets significantly improved. This can be explained by the fact that the odometry based estimation of orientation severely suffers from cumulative error and hence significantly drifts. The absolute orientation measurements of the compass compensate this drift.

8 Sensors for Victim Identification

The main sensors for victim detection via video are USB cameras from Philips. The cameras are high resolution with 1280x960 pixels. The main advantage of these sensors is that they are low-cost. In the standard configuration, papa goose is equipped with 4 and mother goose with 2 of these cameras.

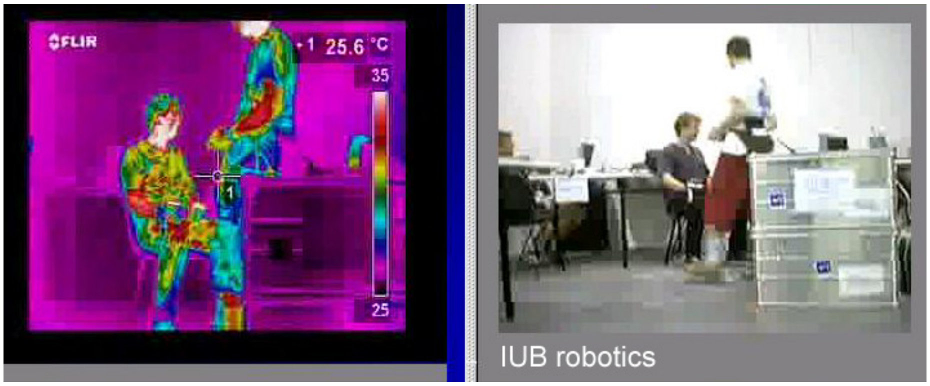

Fig. 6. A typical image from the thermal camera (left) and a normal camera (right).

Furthermore, a thermal camera is used that not only provides data to the human operator but also to an autonomous vision module for victim detection. The Flir A20 thermacam has a uncooled, high resolution Focal Plane Array (FPA). Its 160x120 elements provide temperature information in a range of -40^{o}C to 120^{o}C with 0.08^{o}C resolution. The color to temperature map can be changed such that the related image highlights only spots with human body temperature. For the autonomous victim detection a template match algorithm is used.

Vaisala CO_2 probes are mounted on the robots to detect breathing victims. But the strong delay (up to 30 sec) in the sensitivity of the sensor makes it difficult to use. Last but not least, microphones are used on the robots to identify and to locate victims via sound.

9 Robot Locomotion

Papa goose is the main type of robot used in the IUB rescue robots team. It has a 6-wheeled base that is equipped with substantial onboard computation power and various sensors. Its locomotion system was originally already developed in 2001 and has been improved over the years. The 3 wheels of each side are driven via belts and a motor-unit connected to the axis of the rear, respectively front wheel on the left, respectively right side of the robot. The motors have 90 W power each and they are equipped with HP quadrature encoder with 500 pulses per channel. Two of these robots are currently used.

Meanwhile there is a successor of this robot design under way. The main difference is the locomotion component, which is based on tracks, and an improved housing. The payload especially in terms of sensors is identical to the papa goose designs.

10 Team Training for Operation (Human Factors)

Fig. 7. An robot in the IUB rescue arena.

For testing and training purposes, a rescue arena has been set up at IUB [Bir04b]. The arena is based on a high bay racking system (figure 7). This allows to have a large floor-space and many different levels. The arena has a footprint of 5.60m by 4.70m and it is approximately 6m high. It has 3 main floors and several intermediate floors, which are interconnected.

11 Possibility for Practical Application to Real Disaster Site

As mentioned before, the goal of the IUB team is to get within the next years to a level where the overall system is field-able. Crucial issues are the hardening of the robots in respect to water, dust, etc., the provision of a turn-key start-up of the robots, and an intuitive user-interface of the operator's console. For this purpose, all software components are integrated in a general framework that supports adjustable autonomy.

12 System Cost

The costs for each bare robot with control and locomotion system plus on-board PC is in the order of 8,000 Euro. The most expensive single sensor is the Flir A20 therma cam with 16,000 Euro. The standard sensor load of each robot costs in the order of 4,000 Euro. Some detailed information on components and suppliers is located at

- `http://robotics.iu-bremen.de/CubeSystem/`
- `http://robotics.iu-bremen.de/RoboWiki/`

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