RoboCup 2012 - homer@UniKoblenz (Germany)

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Abstract. This paper describes the robot hardware and software used by team homer@UniKoblenz of the University of Koblenz and Landau, Germany, for the participation at the RoboCup@Home 2012 in Mexico-City. A special focus is put on novel scientific achievements and newly developed features with respect to last year's competition. For navigation and mapping we use well-established SLAM techniques based on particle filter and grid maps. Object recognition is achieved by clustering of local invariant features. Three-dimensional scans of the environment are acquired using a RGB-D sensor mounted on a pan-tilt unit. In order to manipulate objects at different heights, a 2 DOF gripper and a 6 DOF industrial-grade robotic arm are employed. A new abstraction layer in our software architecture allows for task planning and general purpose task execution. We integrated the open-source operating system ROS to provide reusability for a broad community. For the improvement of human-robot interaction we developed a generic face model that is synchronized to speech and can show seven different face expressions. This robot face is available as a ROS-node for other teams.

1 Introduction

Our team homer@UniKoblenz has already participated successfully as finalist in Suzhou, China (2008), Graz, Austria (2009) and in Singapur (2010), where it was honored with the RoboCup@Home Innovation Award. Further, we participated in stage 2 at the RoboCup@Home World Championship in Instanbul, Turkey(2011). Besides RoboCup@Home we competed in the RoboCup Rescue league with our robot *Robbie*, where our team won the Interleague Mapping Challenge award (2010) and became German Champion in Rescue Autonomy for the 5th time (2011). In 2012 we will attend the RoboCup@Home World Championship in Mexico-City with our robots *Lisa* and *GiGo*. Our team will be presented in the next section. Section 3 describes the hardware used for our master robot Lisa and slave GiGo. In Section 4 our software architecture, autonomous navigation and human-robot interaction will be discussed. Finally, Section 5 will summarize this paper.

2 About our Team

The members of team *homer@UniKoblenz* are students from the University of Koblenz-Landau, Germany. They develop and improve our robots in practical courses.

2.1 Team Members and their Contributions

Team *homer@UniKoblenz* consists of the following members and their contributions.

Fig. 1. Our robots GiGo (left) and Lisa (right)

Viktor Seib:	team leader *homer@UniKoblenz*, scientific supervisor
Veronica Luing:	team leader assistant, programming
Lubosz Sarnecki:	technical chief designer, programming
Thomas Grün:	quality assurance, programming
Malte Knauf:	hardware, programming
Andreas Barthen:	hardware, programming
Liane Syré:	human ressources, programming
Alruna Veith:	public relations, programming
Olaf Poneta:	website and blog, programming
Sonja Polster:	media, programming
Michael Kusenbach:	media, programming
Marco Maas:	infrastructure, programming
David Nagel:	flexible manpower, programming
Julian Giesen:	development and release of the robot face as ROS node
Susanne Thierfelder:	technical support

2.2 Focus of Research

Our interests in research are grid-based 2D mapping, localization and navigation, system architecture for autonomous systems, real-time visualization of sensor data and system states, sensor fusion for person tracking, object, face and gesture recognition as well as object manipulation using a manipulator.

3 Hardware

3.1 Robot Platforms

Master Robot We use a MobileRobots Pioneer3-AT as a platform. It provides sonar and odometry sensors and is equipped with four air-filled tires having a diameter of 21.5 cm. They can be controlled individually, allowing the robot to turn on the spot while maintaining a high degree of stability. Attached to the platform is a 2 DOF gripper, which is used to pick up objects from the floor. On top of the P3-AT, we have installed a prototype framework, which was designed and built by the Center of Excellence of the Chamber of Crafts in Koblenz and is able to carry additional sensors and a notebook running the control software.

Cleaning and Disposal Robot The slave robot uses the commercial vacuum robot Roomba 531 from iRobot[1] as platform [SGVP10]. It is equipped with a notebook and a Hokuyo URG-04-LX laser range finder for self localization. The master robot controls the slave via a wireless LAN connection with the same control software running on both systems. A bin is mounted on top of the platform that allows the robot not only to clean the floor, but also to carry items that are inserted by the master robot. Our robot face is projected on the inside of the bin to allow for user friendly interaction.

3.2 Sensors and additional Hardware

Notebooks The software of the master robot runs on a Lenovo W520 notebook equipped with an Intel Core i7-2670QM processor and 4 GB of RAM using Ubuntu Linux 11.10 as operating system. The slave robot is controlled by a HP Mini 210-1019EG netbook with a 1,6 GHz Intel Atom and 1 GB RAM running Ubuntu Linux 11.10 as well.

SICK LMS100 laser range finder The SICK LMS100 is mounted at the bottom and generates 270° scans. It has an adjustable angular resolution, while its maximal measured distance is 20 m. It is used for mapping, localization and people tracking.

Hokuyo URG-04-LX laser range finder The Hokuyo laser range finder generates 240° scans that measure the distance of the closest objects. It has an angular resolution of 0.36° and a range of 5.6 m. One Hokuyo URG-04-LX is mounted on the slave robot in order to localize itself and forward this information to the master robot.
(New in 2012) Another Hokuyo URG-04-LX is mounted on the Neuronics Katana 400HD on master robot to allow for precise gripping.

Microfon Samson C03 The Microfon Samson C03 is mounted on the master robot and is used for speech input.

DirectedPerception PTU-D46 pan-tilt unit The DirectedPerception PTU-D46 is mounted on top of the robot's neck. It is able to rotate 159° in each direction and to tilt from +31° to −47° out of a horizontal position. The angular resolution is 0.012857°. Further sensores are attached on top of this unit.

Philips 1300NC color camera A color camera with 1.3 megapixels is mounted on the robot platform for object recognition. Is is used to capture images of objects reachable by the 2 DOF gripper.

Neuronics Katana 400HD The Katana 400HD is a 6 DOF industrial-grade robot arm. It is attached to our robot's body plate and used to manipulate objects on tables and other furniture of similar height. With an accuracy of 1 mm and a length of 90 cm, it enables us to perform delicate manipulation tasks on light-weight objects. The end effector is a standard pincher gripper and is safe for interaction with humans. Furthermore, it allows within its workspace to hand over items from the 2 DOF gripper or the slave robot's bin.

Microsoft Kinect The Microsoft Kinect ist attached to the pan-tilt unit and provides depth and color images of size 640x480 pixels at 30Hz. The depth sensor operation range lies between 0.8 m and 3.5 m at a horizontal field of view of 58° and a vertical field of view of 45°. It also has two microphones and a tilt motor for sensor adjustment. However, the main robot is equipped with another microphone for speech recognition. Its tilt motor is not used because of the pan-tilt unit that the Kinect is mounted on.

[1] iRobot Corporation `http://www.irobot.com/`

4 Technology and Scientific Contribution

4.1 System Core Architecture

Our R18 software is based on a generic core that handles the forwarding of messages in the system. Messages are sent and received by modules and exchanged via a dispatcher. Modules use workers as a small set of program code which mainly provide computing functionalities. Devices provide access to hardware components. The system can be configured dynamically by a central registry that contains various profiles that store the required modules and configuration settings for a certain task.

The R18 software architecture has an interface for using the open-source meta-operating system ROS[2]. It allows to use all services provided by ROS and meanwhile keep the current system core architecture of R18. The main idea is to use both systems in order to keep on the one hand the robust and extensive implementations of R18 and on the other hand to develop new skills in ROS. However, in the long-term a complete changeover to ROS is intended to provide easier compatibility by using a widely spread platform and to offer open-source implementations to the community (please refer to section 4.7).
(New in 2012) This year most of our hardware and the robot face is integrated using ROS nodes.

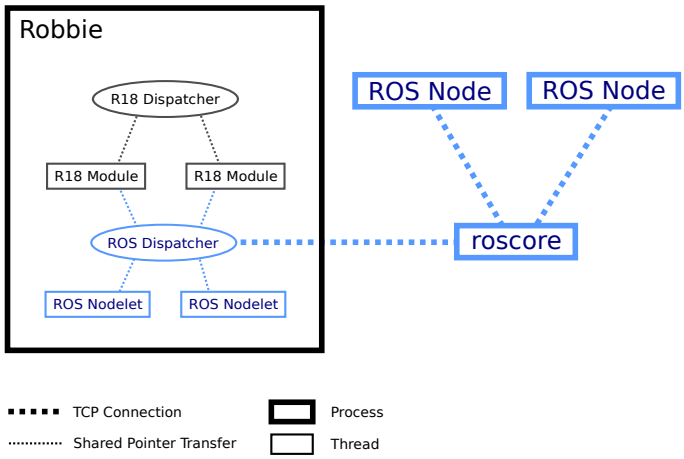

Fig. 2. Schematic description of the communication between R18 and ROS.

Figure 2 gives a schematic overview of the communication between the R18 software architecture and ROS. The changes in R18 include an additional ROS dispatcher besides the R18 dispatcher that manages the messages transfered by ROS nodelets within R18. Nodelets in R18 can subscribe and publish topics via shared pointer transfer within R18 and in the meantime also receive and publish the common R18 messages. They act as a linkage between the two systems. Beyond R18 the common ROS functionalities can be used which is depicted here as ROS Nodes communicating with roscore.

4.2 Graphical Interface

The R18 framework offers a GUI that can be run directly on the robot or on a different computer via WLAN. The user interface is realized using Qt4 and OpenGL. This feature has shaped up as a very important tool for understanding and improving the complex algorithms needed for a fully autonomous robot.

[2] Documentation of ROS `http://www.ros.org/`

4.3 General Purpose Task Planning

(New in 2012) A new abstraction layer in our software architecture allows for task planning aiming at general purpose task execution. For this purpose we encapsulated most common tasks (e.g. navigation to a given location or grabbing a specific object) in so called *task modules*. Every task module is designed for a single task and has the same interface, thus hiding the rather complex, task specific interfaces of each single task. Using this abstraction principle, complex behavior can be triggered by a speech command. The input string is processed and the required task modules are activated to perform the given actions.

To support this task planner a new layer was added to our map. It not only allows to define points of interest for navigation, but also whole areas that can be assigned a name. Hence, rooms can be defined by areas rather than points as before.

4.4 Simultaneous Localization and Mapping

To enable users without technical knowledge to use the robot and to ease the setup procedure, it has to be able to create a map without the help of a human. For this purpose, our robot continuously generates and updates a 2D map of its environment based on laser scans. Figure 3 shows an example of such a map.

Fig. 3. Real-time maps of the RoboCup 2008 (left) and 2009 (right) @Home arena.

4.5 Navigation in Dynamic Environments

In real-life situations, the approach described above is not sufficient for navigating through an everyday environment, as due to the movement of persons and other dynamic obstacles, an occupancy map that only changes slowly in time does not provide sufficient information.

Thus, our navigation system, which is based on Zelinsky's path transform (see [Zel88,Zel91]), always merges the current laser range scan as a frontier into the occupancy map. A once calculated path is then checked against obstacles in small intervals during navigation, which can be done at very little computational expense. If an object blocks the path for a given interval, the path is re-calculated. This approach allows the robot to efficently navigate in highly dynamic enviroments.

4.6 Autonomous Exploration

Several tasks in the @Home league, like "Go Get It!", require the robot to autonomously explore its environment. For this purpose, we are using an exploration algorithm combining Yamauchi's frontier based exploration [Yam97] with Zelinsky's path transform. The path transform is extended in a way that instead of calculating the cost of a path to a certain target cell, the cost of a path that leads to a close frontier is calculated (see Figure 4). More details can be found in [WP07].

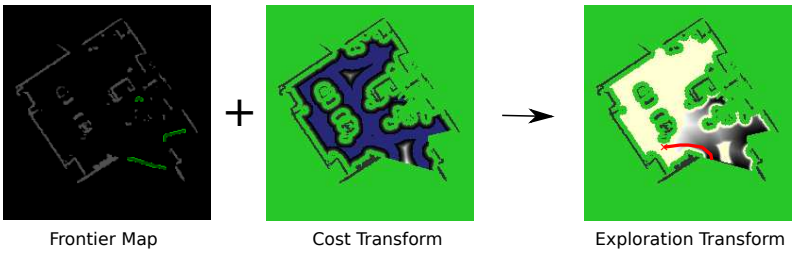

Fig. 4. Illustration of the exploration transform algorithm described in [WP07]. The left image shows the extracted frontiers. The blue area in the middle image contains accessible areas. The red line in the right image represents the path of the robot. The dark values indicate a short distance to the next safe frontier, white cells indicate a long way.

4.7 Human-Robot Interface

The robot is equipped with speakers and a microphone, which enables communication via speech interface. In addition, it has a small screen that is used to display facial expressions and state information. On the software side, we decided to use two open source libraries: pocketsphinx[3] for speech recognition and festival[4] for speech synthesis.

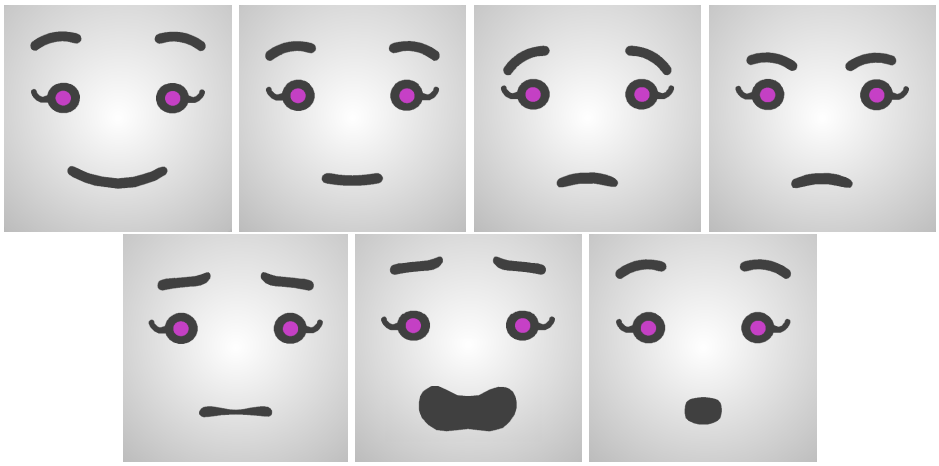

Fig. 5. Animated face of our home robot

We have designed a concept of a talking robot face that is synchronized to speech via mouth movements. For this new feature we are using the open source libraries festival for speech synthesis

[3] Speech recognition system pocketsphinx `http://www.speech.cs.cmu.edu/pocketsphinx/`
[4] Speech synthesis system festival `http://www.cstr.ed.ac.uk/projects/festival/`

and speech output and Ogre3D[5] for visualisation. Furthermore, the face is modelled with Blender[6] and exported via the Ogre Mesh Exporter[7] for the use with Ogre.

(New in 2012) To include the robot face into the R18 software, we have created a ROS node for this application. We extended the robot face to show seven different face expressions (Figure 5). Further, we provide two similar face meshes, a female and a male one. The colors and the voice (female or male) can be configured via a configuration file without recompiling the application. The robot face will be released as an open source package for ROS[8] in a few weeks, so it will be possible to apply it for any robot. More details regarding the concept and implementation of our robot face can be found in [SGGP].

4.8 Gesture Recognition

Gestures are recognized from the depth data of our RGB-D camera. During a gesture, the user has to stand in front of the robot, facing it. First, hands are detected by creating a histogrammimage from the depth data. Their motions are tracked and low-frequency fourier features extracted from their geometrical paths. These are then matched against the training set by an approximate nearest-neighbour search.

4.9 Object and Face Recognition

The object recognition algorithm we use is based on Speeded Up Robust Features (SURF) [BTVG06], which are local scale-invariant features of gray images.

First, features are matched between the trained image and the current camera image based on their euclidean distance. A threshold on the ratio of the two nearest neighbours is used to filter unlikely matches. Then, matches are clustered in hough space using a four dimensional histogram using their position, scale and rotation. This way, sets of consistent matches are obtained. The result is further optimized by calculating a homography between the matched images and discarding outliers. Our system was evaluated in [DTPG10] and shown as suitable for fast training and robust object recognition.

4.10 People Detection

(New in 2012) People are detected by the combination of three sensors. The laser range finder is used to detect legs. The RGB image of the Kinect camera provides data for face detection. We use the face detection algorithm implemented in the OpenCV library. Finally, the Kinect depth camera allows to detect silhouettes of persons. For a person to be detected, not every sensor has to see the person. However, the more sensors see a person the higher the probability to really encounter a person at the position in question.

4.11 Object manipulation

Our system detects planes in the acquired 3D point cloud using RANSAC. This information is used to find euclidean point clusters on top of planes which fit into the gripper and are thus regarded as candidates for grasping.

If a specific object has to be grasped, one of the color cameras is adjusted to face the object cluster. The object detection algorithm is executed on the region of interest defined by the object cluster's bounding box. Depending on the position of the object, camera and manipulation device are selected. These are either the bottom camera with the 2 DOF gripper or the Kinect RGB-camera combined with the 6 DOF robotic arm. Additionally, a laser range finder on top of the 6 DOF arm help for precise gripping.

[5] Open-source graphics rendering engine Ogre3D `http://www.ogre3d.org/`
[6] Free open source 3D content creation suite Blender `http://www.blender.org/`
[7] Ogre Mesh Exporter `http://www.ogre3d.org/tikiwiki/Blender+Exporter`
[8] Expected URL: `http://www.ros.org/wiki/agas-ros-pkg`

The movement planning for our robotic arm is performed using an approach operating directly in working space. Chaining motion primitives, our path planner builds a graph from the starting position to the goal. The planning can be optimized towards specific objectives. These are performing a smooth path or keeping a maximum distance from obstacles using heuristic and cost functions [CCL10].

5 Conclusion

In this paper, we have given an overview of the approach used by team homer@UniKoblenz for the RoboCup@Home competition. We presented a combination of out-of-the box hardware and sensors and a custom-built robot framework. We explained the fundamentals of our message-based robot architecture and its further enhancements, the use of well-established techniques like SLAM based on a particle filter and a grid map. Furthermore, we explained our approach for object recognition using matching and clustering of local invariant features and the ability to detect and manipulate objects with a 2 DOF gripper and 6 DOF robotic arm. Based on the existing system from last years competition, effort was put into enhancing the detection of people and the human-robot interaction abilities of our robot. 3D scans of the environment are aquired using a RGB-D sensor. A slave robot was developed which is controlled by our main robot. A new task planner facilitates the execution of tasks that are typical for service robots.

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