

# LUHbots RoboCup@Work 2016 Team Description Paper

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**Abstract.** In this paper we provide a description of the LUHbots team. We describe the current state of the team as well as current plans and research goals towards the 2016 RoboCup@Work tournament in Leipzig. The software is based upon a ROS-architecture and the hardware uses a KUKA youBot as a basis. The focus of the team lies with failure tolerant approaches to mobile manipulation.

## 1 Introduction

The LUHbots team was founded in 2012 at the Institute of Mechatronic Systems Leibniz Universität Hannover, consists of bachelor and master students. Most of the founding team members have participated in the research inspired practical lecture RobotChallenge [10]. Nowadays the team is a part of the Hannover Centre for Mechatronics. The team consists of students from mechanical engineering, computer science and navigation and environmental robotics. In 2012 the LUHbots team first competed in the RoboCup@Work challenge and was able to win the competition [9], in 2013 a second place was achieved [1]. In 2015 the LUHbots won both events, the German Open and the RoboCup in Hefei.

## 2 Hardware

Our robot is based on the mobile robot KUKA youBot (see Fig. 1) [2]. The robot consists of a platform with four meccanum wheels [8] and a five degrees of freedom (DoF) manipulator. Additional a gripper is attached at the end of the manipulator (see Fig. 1). The internal computer of the youBot has been replaced by an Intel Core i7 based system. In addition, the robot is equipped with an emergency stop system, allowing for keeping the platform and the manipulator in

the actual pose when activated. The manipulator has been remounted to increase the manipulation area. The hardware itself does not offer failure tolerance, this is only achieved in combination with software.

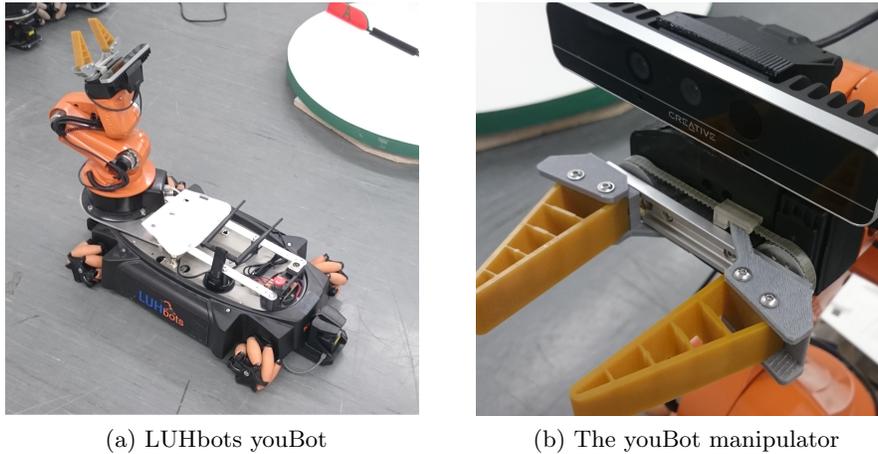


Fig. 1: LUHbot 2016 - equipped with a new Gripper and the Intel RealSense F 200 camera.

## 2.1 Sensors

The youBot is equipped with two commercial laser range finders (Hokuyo URG-04LX-UG01) at the platform's front and back. A RGB-D camera (Intel RealSense F200) mounted on the wrist of the manipulator (see Fig. 1a).

## 2.2 Gripper

One of the major hardware advances performed by the team is the development of a custom gripper. The original gripper has a low speed and stroke. As a result, it is not possible, to grasp all objects defined by the RoboCup@Work rule book, without manually changing the gripper-fingers. Besides the limited stroke, the low speed limit does not allow for an appropriate grasping of moving objects. An advancement was to include force feedback into the gripper. Thanks to the integrated feedback within our custom made gripper, we are able to verify performed grasps. If a failure occurs during grasping, we are able to recover.

## 3 Approach

We take advantage of an open source software framework called Robot Operating System (ROS) [12]. We are using the Indigo release for 2016. In our opinion

dependability is one of the most important aspects of mobile robots, therefore we are constantly improving our testing procedures.

### 3.1 Overview

Since our software architecture is based on ROS, different nodes are used (see Fig. 2). The yellow nodes are drivers they give access to the sensors. The youBot driver in red, can be accessed via the youBot OODL node. The camera data is first processed by the vision node and then filtered and clustered by the observer node, which is triggered by the state machine. The laser scanners are publishing to the navigation stack and the navigation watchdog. The watchdog filters the navigation commands. The task planner and the referee box connection communicate with the state machine. The laser scanner nodes are used unmodified. The ROS navigation stack is used but the global and local planners have been replaced. The youBot OODL driver is heavily modified. All other Nodes are developed entirely by the team.

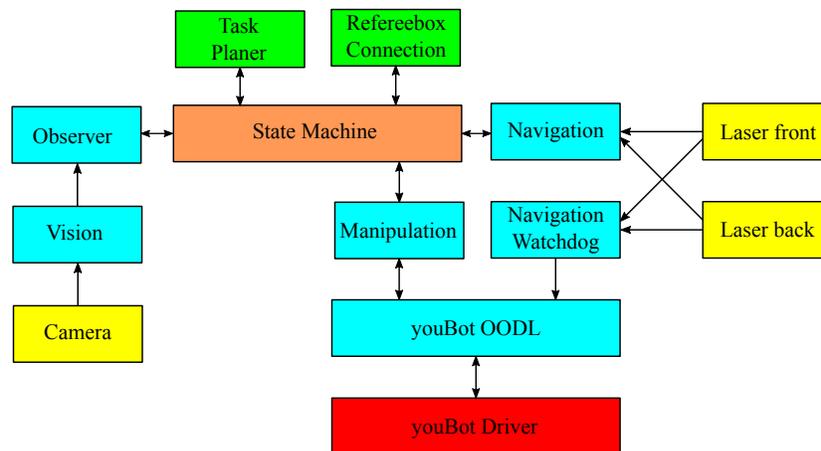


Fig. 2: Overview of the software architecture

### 3.2 Manipulation

During the last years we developed a new software system that can be seen as a software development kit (SDK) for manipulation tasks with the youBot. The aim was to facilitate the development of applications for the youBot by providing advanced functionality for the manipulator and the mobile platform combined with user friendly interfaces. Some of the features for the manipulator are: inverse kinematics, path planning, interpolated movement in joint- and task-space, gravity compensation and force fitting. Features for the mobile platform

include incremental movement, collision avoidance and movement relative to the environment based on laser scans. The provided interfaces contain a documented API and a graphical interface for the manipulator. In the RoboCup we use this software e.g. to grab objects using inverse kinematics, to optimize trajectories and to create fast and smooth movements with the manipulator. Besides the usability the main improvements are the graph based planning approach (see Fig. 3) and the higher control frequency of the base and the manipulator. Planning on a graph which is based on known and, therefore, valid positions leads to a higher robustness. Using an A\*-approach the best path is generated [6]. The higher frequency leads to better executed motion plans and an overall smooth and more accurate motion.

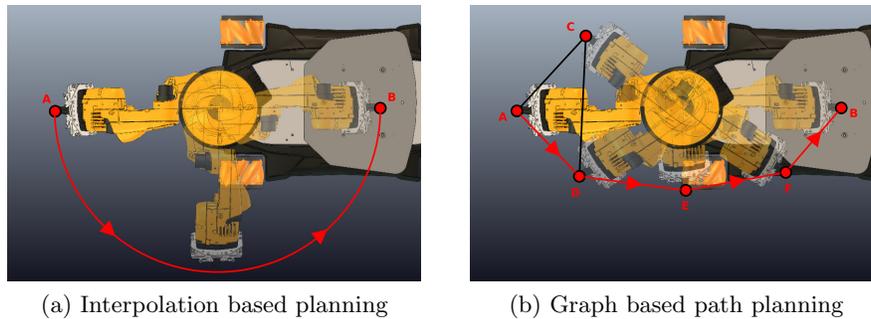


Fig. 3: Graph based approach for the path planning, thanks to the proposed approach (b) a shorter motion is executed

### 3.3 Navigation

The navigation is based on the ROS navigation stack. The main improvement has been done in the local and global planners. The global planner has been extended to calculate the orientation for each pose of the global plan. This helps to reach the bottlenecks in the best position for a collision free and fast passing. Besides improving parts of the navigation stack we implemented a watchdog which operates based on the laser scanner data and is therefore much faster than a costmap-based local planner. The watchdog reduces velocities if an obstacle is too close, or permits the execution of a movement command if a collision would be eminent.

### 3.4 Vision

We use the Intel RealSense F200 for object recognition, which has one basic advantage in comparison to similar devices. Firstly it works at close range. We use the 2D-images of the infra-red and RGB camera to segment the image, to

extract features and to classify the objects. From the infra-red image first the objects are separated using the canny algorithm [4]. Then, the objects are then classified using Hu-moments and a random forest classifier [13] [7]. Finally, the 3D-points are used to determine the object’s position and orientation. Besides using the 2D-image we are developing a new Vision based on RGBD-point-clouds. The goal is that objects can be specified by standard CAD Files and a example texture. This would greatly increase the industrial usage, since it will be easy to include objects which the robot never had seen before. In order to get a robust vision system that can handle miss detections and which can memorize detected objects, all detections are clustered using a modified version of DBSCAN [5]. Each cluster is weighed, filtered and the positions are averaged. Then, the clusters are classified as objects or as failures.

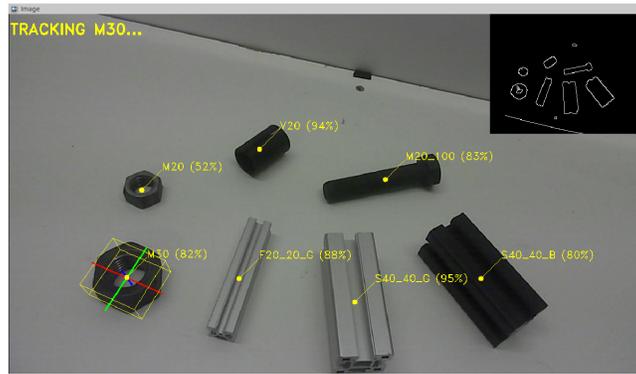


Fig. 4: Detected objects, classified and scored

### 3.5 Task planning

Our task planning is based on a graph based search. In each step all known service areas are used as possible navigation tasks. All objects on the back of the robot (there are up to three allowed) are used as possible placing tasks and the objects on the service area are used as grasping tasks. A greedy-based planning [11] is used up to a max depth and repeated until a complete plan is produced. The greedy algorithm is based on the cost function (see Eq. 1) taking the time to perform the task, the probability to fail and the expected output. For the navigation tasks the distances are precomputed based on the known map. The manipulation time costs are averaged based the last respective manipulation action. When the state machine is not able to successfully recover a failure, the task is rescheduled and increasing the probability to fail.

$$Score_{n+1} = \frac{Value_n + Value_{Action} \cdot \prod Chance_i}{\sum Cost_i} \quad (1)$$

### 3.6 State machine

The state machine is based on SMACH [3]. Which is a python library for building hierarchical state machines in ROS. Due to the capabilities of SMACH our state machine is modular and consists of the main components task planning, task execution, navigation and manipulation (see Fig. 5). The state machine acts as an action client, which sets the goals in navigation and manipulation to accomplish the tasks and receives feedback in case of issues. The state machine is designed for recovery. If a failure is detected a direct recovery is applied, the current task will be retried or postponed and tried again later, respectively.

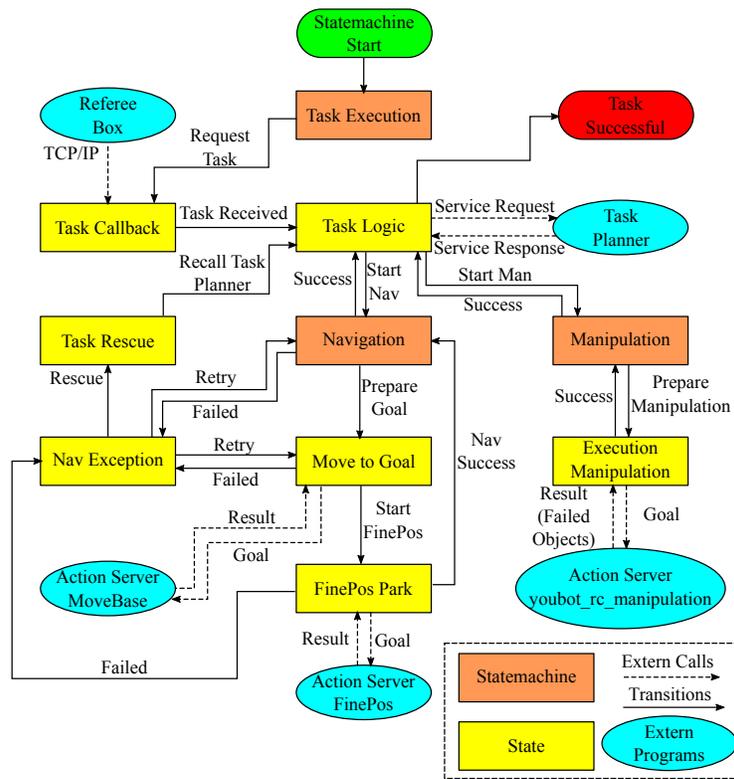


Fig. 5: State machine

### 3.7 Manipulation of dynamic objects

Our previous approach for gripping moving objects limited us. We could only grip two objects in one orientation. Since the approach was based on calculating a point where to grasp the object and then performing a standard grasp. Resulting in problems with orientations since the speed was not used to alter the

grasp motion. The new approach differs after the object recognition (see Fig. 6 - at time 1 ). The robot measures the speed and position of the object. It calculates the point and time where the object reaches the task place(see Fig. 6 - at time 2 ). The arm moves above the calculated point. Waits for the object and accelerates until the arm is directly above the moving-object with the same speed. Overlapping the down movement with the current speed until gripping the object (see Fig. 6 - at time 3 ). The advantage of this approach is that while the calculated position and speed are correct every orientation and much higher objects can be gripped.

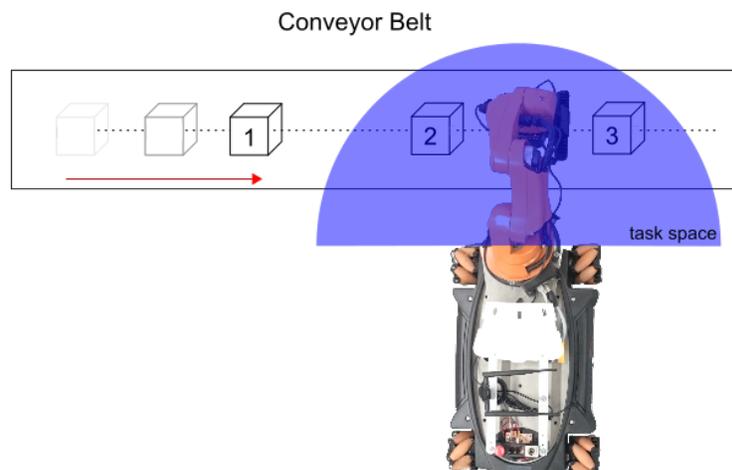


Fig. 6: Manipulation from the conveyor belt.

## 4 Acknowledgements

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