RoboCup@Work 2018
Team Description Paper
RED

K. Artemov, A. Bobtsov, N. Dema, A. Kapitonov,
S. Kolyubin, E. Matsuev, A. Ovcharov, K. Pachkouski, and S. Kazak

ITMO University
49, Kronverkski prospekt, Saint-Petersburg, 197101, Russia
red-itmo.github.io, github.com/red-itmo, csi.ifmo.ru/en

Abstract. This paper is devoted to the main results of the RED team towards 2018 RoboCup@Work competition. The underlying software and hardware is described. The customized KUKA YouBot equipped with depth camera and scanning range finder is used as the main platform . The main used middleware is ROS.

1 Introduction

Work on the project was started in June 2016. Team members visited RoboCup@work 2016 followed by participation in RoboCup@work competition in 2017. The RED team, advised by one professor and two PhDs, consists of undergraduate and graduate students, who study robotics at the ITMO University. Our research interests are wide-ranging and include system identification, motion control, navigation in unconstrained dynamic environments, computer vision and collaborative robotics.

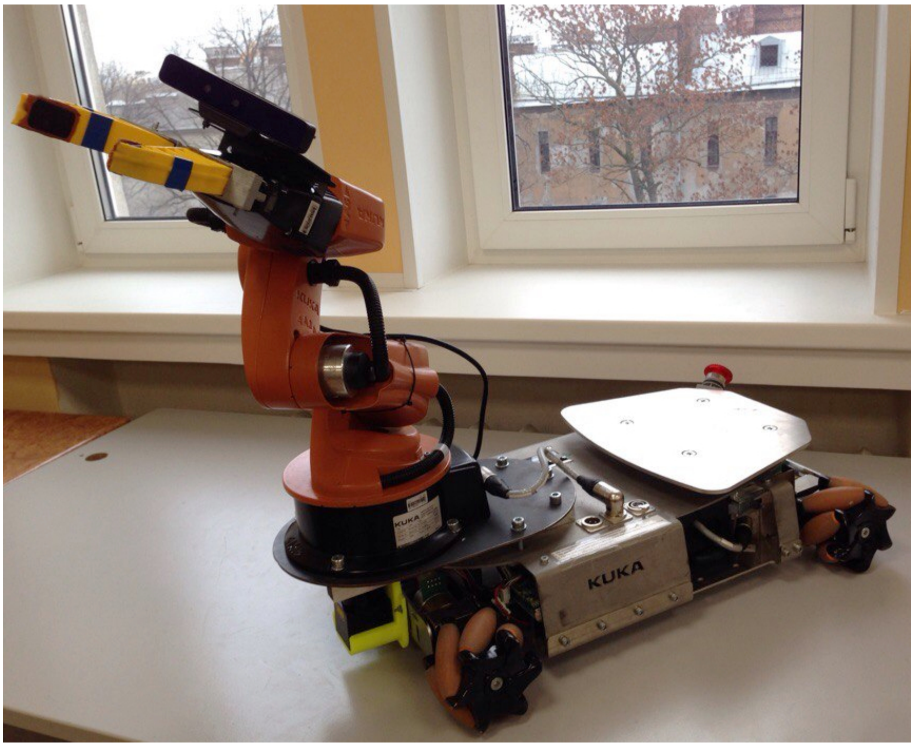

Fig. 1. RED robot configuration based on the KUKA youBot

2 Hardware configuration

In order to meet the goals of competition we equipped KUKA youBot (fig. 1) with the following devices:

– Intel NUC core i7 on-board computer instead of an old one based on Intel Atom
– Customized Festo gripper and holder for LIDAR printed with flex and PLA material respectively on 3D printer. Flex allows gripper to adapt to the shape of objects passively and grab large nuts and screws as well as the small one
– IntelRealsense SR300 RGBD camera. It allows to ignore shadows while detecting objects and operate in low light conditions
– Hokuyo URG-04LX-UG01 lidar mounted on the front of the robot
– Manipulator is moved forward by 3mm thick steel plate mounted on the robot's platform, aluminum profiles is mounted between platform and plate to strengthen the construction and make manipulator base level a little bit higher

3 Software configuration

A structure of the all system is depicted in fig. 2. A unit *Global task planner* ensures interaction with the Referee Box. In *Task's parser* subunit receives data from a RefBox, decomposes it and forms a sequence of elementary actions. *Test execution planner* subunit solves time optimization problem. A unit *Local task planner* is mostly needed for organize an interaction between *CV* and *Manipulation* parts. The system runs on on-board computer with Ubuntu 16.04. ROS kinetic [1] is a main tool for the software development and integration.

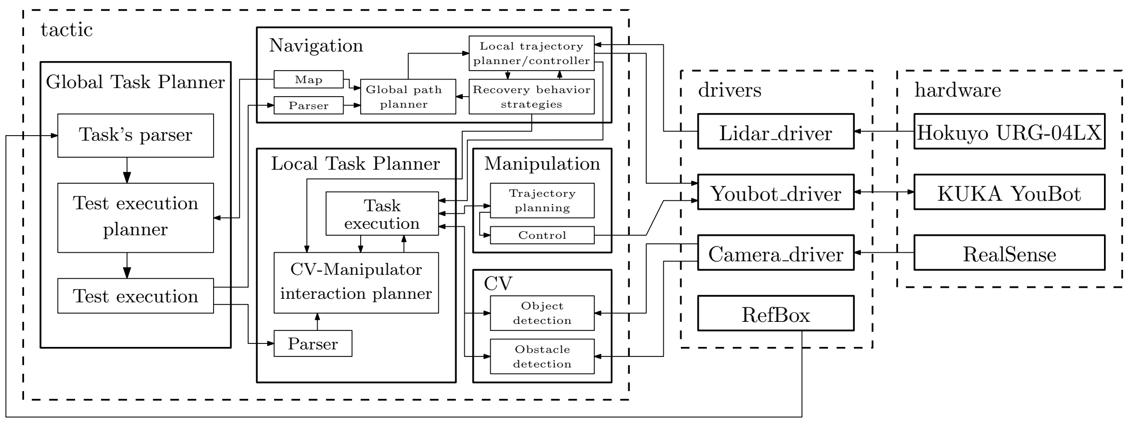

Fig. 2. Functional scheme of all system

3.1 Navigaion

The navigation unit (fig. 2) is based on the ROS Navigation stack. Hokuyo URG-04LX-UG01 sensor is used as the main information source about work environment. The gmapping [2] package is used for an initial map creating. The global path is computed by an A* algorithm. For motion control and obstacle avoidance the teb local planner [3, 4] in its holonomic case is used. To reduce its computational cost we use the costmap conversion which allow to convert occupied costmap2d cells within the local map to the geometric primitives. For the localization while robot is being steering AMCL [5] is used. Current developments focus on new approaches to the implementations of the recovery behavior strategies based on the data fusion from the lidar and the RealSense while controlling the manipulator pose.

3.2 Modeling

One of the main aspect in robotic system development is preliminary modeling, and we chose V-REP as it is widely used for this purpose. V-REP simulator (fig. 3) starts to become the main instrument for navigation and manipulation software development. Simulator V-REP allows to integrate development environment and is based on a distributed control architecture, where each object can be individually controlled via a ROS node.

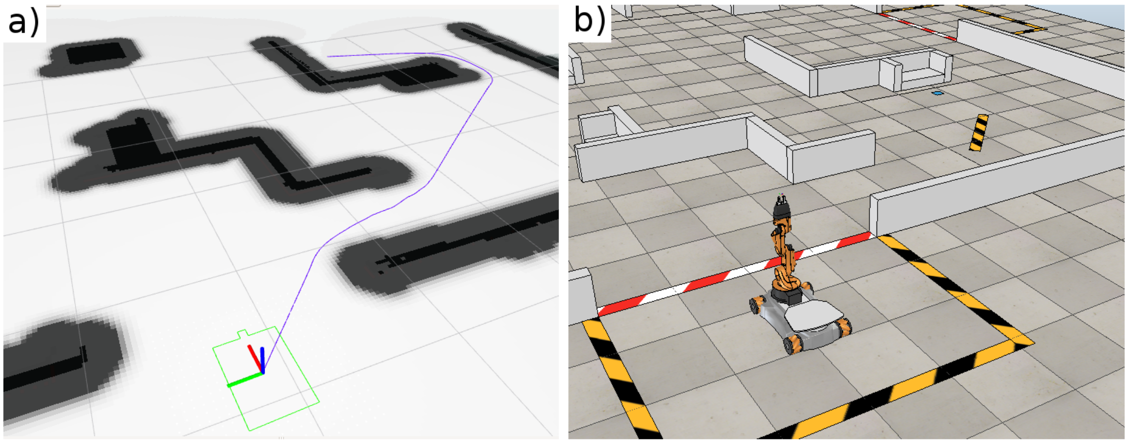

Fig. 3. Simulation of the work environment for RoboCup@Work competition: a) r-viz visualization with the planned global path; b) v-rep environment

3.3 Image processing

Intel RealSense SR300 is used for capturing images. We use RGB camera to segment the image and to identify each object. Depth camera module is used for calculating the distance to the table and for recognition of shadows. Our approach is to conclude each separate object with parallel line segments and to find circles in it. Since objects have angular shape it is possible to recognize them. Firstly, we make preprocessing to minimize influence of noises. After that we consistently apply canny edge detection operator, probabilistic Hough transform algorithm [6] for line segments detection and Hough circle transform [7] for circle detection. The next step is to find the most distant lines in each object and to calculate metrics of them. Then both metrics and presence of the circles in it are used for classifying the object. Final step is calculating object's position and orientation. The main advantage of this approach is high performance speed.

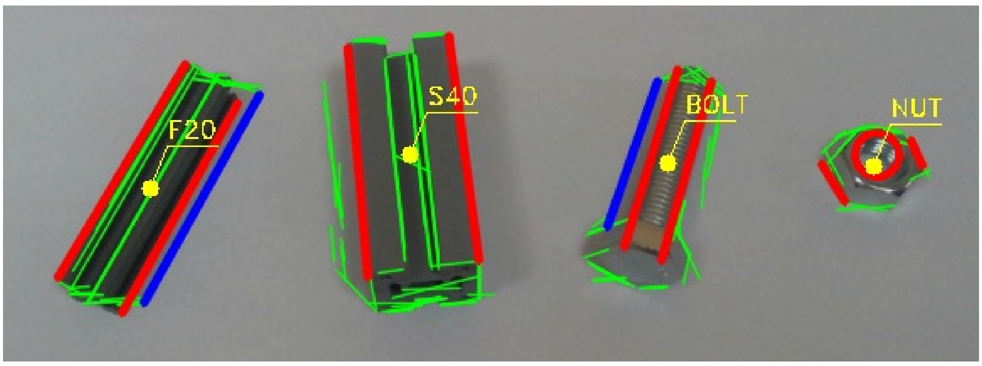

Fig. 4. Camera view

3.4 Manipulation

For manipulation we implement velocity motion controller (Fig. 5) and trajectory generator. The controller is implemented in youbot_driver_ros_interface package. The main contribution to control $\dot{q}_{control}$ is made by desired angular velocity $\dot{q}^*$. Control is corrected by error e between the desired q^* and real angles q_{real}.

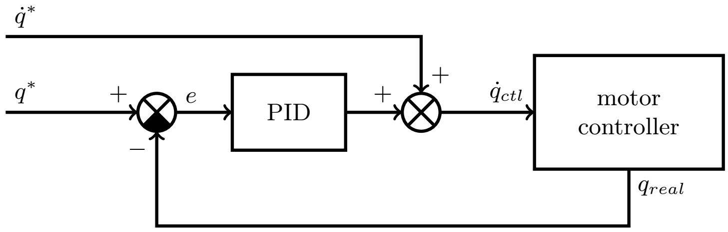

Fig. 5. Motion controller

Trajectory generates depend on the situation. The first approach is based on the integration of angular acceleration with the predefined parameters of maximal angular velocity, acceleration and discreteness of the calculated trajectory. The whole path is divided to acceleration part where robot's joint speed increases to maximum value, uniform speed part and deceleration part. It is also called trapezoidal move profile. The second approach is based on pseudoinverse Jacobian.

4 Competence of Team Members

- **Alexey Bobtsov** Alexey Bobtsov is professor, director of the school of "Computer Technologies and Control" (CTC), head of the "Control Systems and Computer Science" (CSCS) department, ITMO University. He carries on active international activity, like participant of a research project held in cooperation between General Motors Corporation and ITMO University. Since 2008 Alexey Bobtsov is the vice-departmentman of the North- western section of the IEEE Control Systems Society, Computational Intelligence Society and Robotics & Automation Society. Alexey Bobtsov is the leader of several scientific projects, which are being successfully held under the supervision of the Russian Foundation for Basic Research. His research interests include the areas of theory of control processes and automation, adaptive, robust and nonlinear control, identification and estimation, mechatronics and robotics.

- **Sergey Kolyubin** Sergey is an Associate Professor, vice- director for Science & Technology Foresight at CTC, ITMO Univerity. He received Ph.D. degree from ITMO University in 2012. His research interests include mechatronics and robotics, trajectory planning and motion control, system identification, underactuated systems, adaptive and hybrid control, sensor fusion and computer vision.

- **Aleksandr Kapitonov** Ph.D., Assistant professor at CSC, ITMO University (St. Petersburg, Russia). He received a Ph.D. degree in December 2015 from ITMO University. He works at the International Research Lab of Adaptive and nonlinear control systems and Erasmus+ Innovative Open Education on IoT http://iot-open.eu/. Aleksandr is mainly focused on robust control for nonlinear systems, control theory education and heterogeneous network solution.

- **Nikolay Dema** Nikolay is first-year graduate student in Mechatronics and Robotics at ITMO University. He is currently working as a laboratory assistant of the Department of CSCS. His area of interest includes bio-inspired robotics, mobile platform navigation, redundant and underactuated system motion control, computer graphics and virtual reality.

- **Kirill Artemov** Kirill is second-year graduate student in Mechatronics and Robotics at ITMO University. He is interested in computer vision systems, object recognition, control of mobile robots.

- **Aleksey Ovcharov** Aleksey is a fourth-year Bachelor's degree student in Control in technical systems at ITMO University. He is mainly focused on computer science, motion planning for mobile robots, automation control for robotic manipulator.
- **Egor Matsuev** Egor is the fourth-year undergraduate student at the Department of Control Systems and Informatics at the ITMO University. His main goal is to improve robot's hardware and motion and implementing grabbing objects from the conveyor belt.
- **Kanstantsin Pachkouski** Kanstantsin is a third-year Bachelor student at the study program Mechatronics and Robotics. His technical interests include Python programming, computer vison and machine learning.
- **Sviatoslav Kazak** Sviatoslav is a undergraduate student in Mechatronics and Robotics at ITMO University. He focused on computer vision.

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