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# Manipulation Tasks in Robotics Education *

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**Abstract:** In this paper a series of practical tasks on control for manipulators is presented. This series represents a laboratory part of the course "Control Methods for Robotic Applications" included in the curriculum of the master's degree program at the Department of Control Systems and Informatics of ITMO University. The exercises are aimed to attract and motivate students, improve their practical competency and simplify their understanding of theoretical background. The tasks are focused on such problems as path and trajectory planning, automatic code generation and design of a tracking system for moving target.



*Keywords:* Control education, Control applications, Robotics, Manipulation tasks, Robotic manipulators.

## 1. INTRODUCTION

During the course of any applied science it is extremely important to develop both theoretical and practical experience of students. Understanding of lecture material will be much easier for them if they have to conduct practical exercises testing various just learned results. Thus, the experimental equipment is highly useful for educational and research control purposes. Recently mobile robots and quadcopters (Pyrkin et al. (2014a,b); Bazylev et al. (2014)) have become popular in conducting various experimental studies. They can be constructed by students or purchased ready-made. For example, Lego Mindstorm NXT can be used to construct simple mobile robots equipped with actuators, sensors and encoders (see Bobtsov et al. (2011); Kolyubin et al. (2012); Pyrkin et al. (2013a)). In Bazylev and Pyrkin (2013) the Bioloid kit is used to construct an experimental setup for testing of control approaches for biped robots. In Bazylev et al. (2014) models of a quadcopter and 2-DOF robotic arm are investigated and combined together.

Use of various applications to motivate students, promote control science and improve practical experience is quite common between scientists and professors across the world. In Astrom et al. (2005) the problem of bicycle dynamics modeling is addressed. The presented results are used in education to attract students. At the department of Mechanical Engineering of Eindhoven University of Technology the liquid-based emulator of manufacturing processes was designed (see details in Starkov et al. (2012)) to teach students principles and practical concepts dynamics and control of manufacturing network. The Mechatronic Control Kit in Spong et al. (2001); Bobtsov et al. (2009) is considered as configurable application for testing various modeling, identification, nonlinear control approaches. The remote control framework for a robotic arm situated at the laboratory of Technische Universität for education and research purposes is presented in Ruderman et al. (2012). In this work a number of projects carried out by students using the framework are described.

In this paper a practical part devoted to control of manipulators of the course "Control Methods for Robotic Applications", which is being taught at the Department of Control Systems and Informatics of ITMO University, is presented. It consists of three exercises assumed to be carried out by students at the laboratory. They concern such robotic problems as path and trajectory planning, forward and inverse kinematics, identification of sinusoidal signal parameters, tracking system design, etc.

The paper is organized as follows. The brief overview of the course and used equipment is presented in Section 2. Sections 3–5 are devoted to description of the practical exercises on control of manipulators. The reactive response of the students passed the robotic course is given in Section 6. The conclusion of the paper and further work direction are presented in Section 7.

## 2. COURSE OVERVIEW

The education course "Control Methods for Robotic Applications" is included in the curriculum of the master's degree program at the Department of Control Systems and

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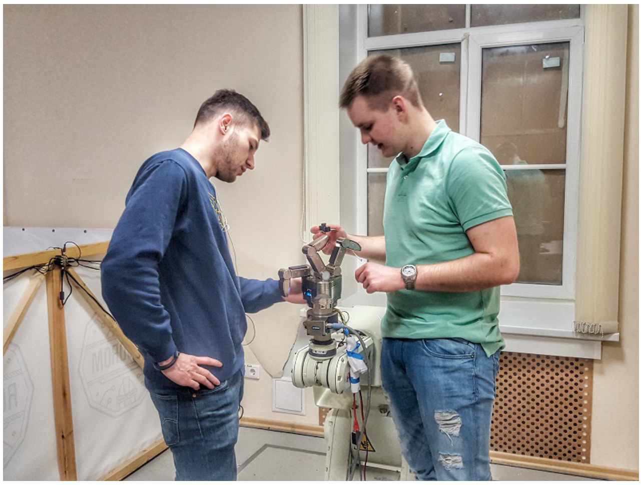

Fig. 1. Students at work

Informatics of ITMO University. Students learn this course for one semester. This academic discipline requires skills and knowledge relevant to automation control, design of digital systems, programming and computer networks. Students are supposed to study all these areas during the passed bachelor program.

This course is comprised of theoretical and practical parts. The first one is traditionally represented by a series of lectures on advanced control for robots. The second part provides involvement of students in work with the robotic equipment at the laboratory of the department. Carrying out tasks they use various mobile and manipulating robots. There are even a series of the exercises devoted to controller design for a robotic boat described in Wang et al. (2015b,a). In this paper three scenarios of laboratory tasks on control design for manipulators are demonstrated. There are various robots used in these exercises:

- Kawasaki FS06N;
- Mitsubishi MELFA RV-3SDB;
- KUKA youBot.

The exercises presented in the paper are focused on path and trajectory planning problems, automatic code generation for a manipulator and design of tracking system for moving target.

Kawasaki FS06N is a standard 6-DOF industrial robot equipped with the SCHUNK 3-finger gripping hand (see Fig. 1). Mitsubishi MELFA RV-3SDB is an also 6-DOF manipulator, which is a part of the Festo Robot Vision Cell (see Fig 2). The latter represents the educational setup for simulation of such industrial operations as welding, assembly, sorting, etc. KUKA YouBot is a mobile platform with four omni-directional wheels, 5-DOF robotic arm and 2-finger gripper (see Fig. 5). These robots allow to practically verify theoretical approaches learned at the course "Control Methods for Robotic Applications". Feedback used in these robots can be complexed with various external sensors. So, a regular USB camera is used below to design tracking system using the KUKA youBot. The latter also allows to use ROS (Robot Operating System; see its overview in Quigley et al. (2009)) to provide, for example, a such important for mobile robots function as SLAM (Simultaneous Localization and Mapping).

## 3. TRAJECTORY PLANNING USING SPLINE FUNCTIONS

The first exercise is devoted to a common trajectory planning problem (see Fu et al. (1988); Spong et al. (2006)). The robot used in this task is Kawasaki FS06N (see Fig. 1). The input data for students is the following

- Denavit-Hartenberg parameters of the robot;
- Cartesian coordinates of the four reference points (they are assumed to be starting, departing, arriving and final ones);
- time moments assigned to the given reference points.

The entire trajectory from starting point to the final one is separated by the given reference points into three parts. Students are supposed to solve the inverse kinematic task for the each reference point specified by Cartesian coordinates. Time should be parametrized and converted to the relative time $\tau_i$ assigned to the each part of the trajectory ($i$ is a number of the trajectory part, for this case it looks as $i = \{1, 2, 3\}$) such that $0 \le \tau_i \le 1$. Then it needs to take into account the constraints related with exact values of all the generalized coordinates (obtained from the solution of inverse kinematics), velocities and accelerations of the each joint corresponding to the reference points with respect to the relative time $\tau_i$. Then the such well-known approach as the spline interpolation is used to calculate all intermediate values of the generalized coordinates between the given reference points. So, changing of all the joint relative positions are described by low degree polynomials (spline functions) with unknown coefficients. Taking their first

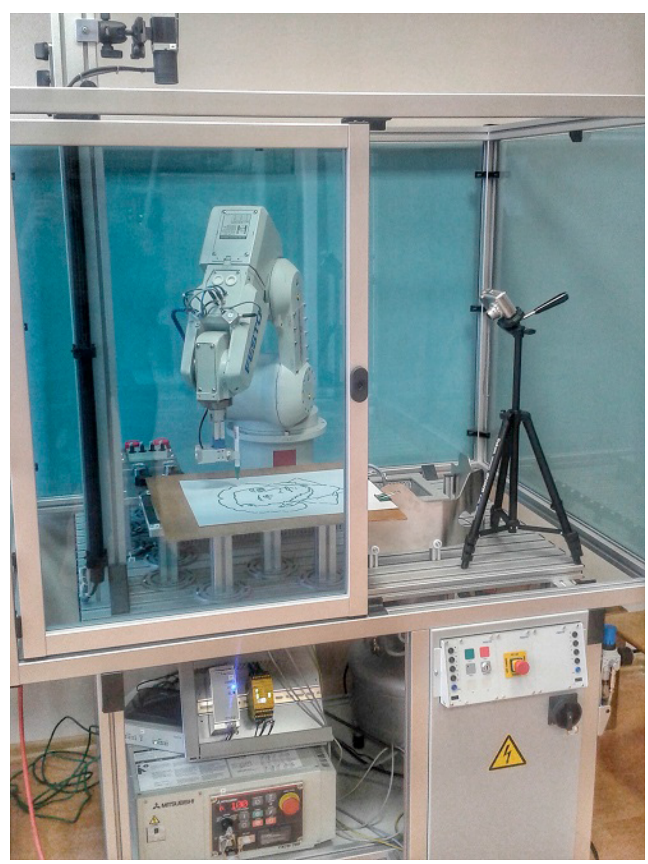

Fig. 2. The Festo Robot Vision Cell equipped with the robot Mitsubishi MELFA RV-3SDB