Implementation of Industrial Robots in Instruction at Tallinn University of Technology

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Abstract—Currently, over 1.4 million industrial robots are expected to be operational around the world. Each year more than 100,000 new industrial robots are implemented in industry for product manufacturing. Therefore, a need of skilled workers and engineers able to use industrial robots and develop new production lines exists.

To promote this purpose the Department of Electrical Drives and Power Electronics in Tallinn University of Technology has developed several laboratory tasks where future young engineers obtain first experience with industrial robots. The laboratory tasks have been developed in collaboration with ABB AS and Tech Group AS.

This paper reviews the laboratory equipment and tasks used to introduce industrial robots to the students.

I. INTRODUCTION

Since the 1960s when the first industrial robot was introduced, over 2.31 million industrial robots have been installed worldwide. At the moment more than 1.4 million industrial robots are expected to be operational. That number is based on an assumption that the average service life of an industrial robot is about 15 years [1].

Figure 1 shows that around 100,000 new industrial robots are implemented in product manufacturing each year. The highest number of new installed industrial robots was achieved in 2011, when the number of new installed industrial robots was around 166,000 [1]. The most important purchasers of industrial robots have been automotive (everything what has to do with vehicles) and electrical/electronics industry (Fig. 2). The latter industry also includes computer, radio, TV, communication devices, medical, precision and optical instrument manufacturers.

The reasons why each year so many new industrial robots are implemented in the industry are:

- industrial robots can work 24/7 (produce massive products);
- industrial robots are fast and punctual (repeatability precision of a point can be up to 0.01 mm [2]);
- industrial robots can work in an unfavorable working environment (dark and cold places);
- industrial robots can do monotonous work, which may be unsafe, boring and/or wearisome for humans (putting products into boxes);
- industrial robots can replace skilled workers in simple tasks, allowing the worker to do more complex tasks (welding).

Around 3 - 6 new industrial robots are annually installed in Estonia. But more second-hand industrial robots are sold and used in Estonia, because they are cheaper than the new ones. In some cases mother companies are sending their old production lines with industrial robots to their Estonian subsidiaries, which use these lines in their manufacturing process.

Therefore, there is a need of skilled workers and engineers who are able to use industrial robots and develop new production lines with industrial robots. They are needed not only in Estonia but around the world. For this purpose, the Department of Electrical Drives and Power Electronics in Tallinn University of Technology (TUT) has developed several laboratory tasks in the courses of Introduction to Robotics and Advanced Course of Robotics, where young engineers obtain first experience with industrial robots.

This paper reviews these laboratory tasks and equipment used in the laboratory work.

Fig. 1. Estimated worldwide annual number of installed new industrial robots [1].
II. LABORATORY EQUIPMENT

Department of Electrical Drives and Power Electronics uses three different manufacturing robots in the courses of Introduction to Robotics and Advanced Course of Robotics. The robots are manufactured by Mitsubishi Electric, ABB and KUKA.

Mitsubishi Electric industrial robots MELFA RV-2AJ (Fig. 3) and RV-1A (Fig. 4) are used in laboratory works. These robots are part of Multi FMS (Flexible Manufacturing System) production line described in [3]. The robot RV-2AJ is a 5-axis robot arm used to assemble pneumatic cylinders. The robot RV-1A is a 6-axis robot arm with additional linear axis used for transporting workpieces to and from the CNC machine. Both have a pneumatically driven gripper, a controller CR1 and a Teach Box. These robots are used in industry for low payload pick and place or assembly jobs.

ABB Industrial robot IRB1600-5/1.45 (Fig. 5) is also used in laboratory works. The robot IRB1600-5/145 is a 6-axis robot arm designed for welding jobs. It consists of a controller IRC5, FlexPendant (almost the same as Teach Box by the Mitsubishi Electric robot) and workpiece positioner IRBP 250L (a table). Two markers are used as the robot work tool which replaces the welding tool. Markers can be used to simulate welding on a real object.

KUKA industrial robot KR 90 R2700 pro is the newest laboratory equipment. The robot has a 6-axis robot arm designed for pick and place, laser cutting and welding jobs. It consists of a controller KR C4, KUKA smartPAD (almost the same as the teach box by the Mitsubishi Electric robot) and a conveyor. A marker is used as the robot work tool.
TUT Department of Electrical Drives and Power Electronics laboratories are equipped with industrial robots from Mitsubishi Electric and ABB. Only KUKA industrial robot is installed in the company Tech Group AS and the industrial robot laboratory tasks are carried out in collaboration with the company.

III. LABORATORY TASKS

As already mentioned, two courses are offered in which students acquire knowledge and experience of industrial robots. These are Introduction to Robotics and Advanced Course of Robotics. There are over 60 students from three different faculties who have taken the first course and around 20 students from two faculties who have taken the second course. The courses are offered to students of the following faculties:

- Faculty of Power Engineering,
- Faculty of Mechanical Engineering,
- Faculty of Information Technology (only the first course).

A. Introduction to Robotics

In this course there are three laboratory tasks based on each manufacturer industrial robot. The laboratory tasks are designed so that students can find similarities and differences between Mitsubishi Electric, ABB and KUKA industrial robots, and conclude what can be expected from other manufacturers’ industrial robots. Two first tasks are the same for all industrial robots. Only the last task is different for Mitsubishi Electric industrial robots.

In laboratory task 1 students control the industrial robot with the control panel (Teach Box, FlexPendant or smartPAD) and make a small program to control the industrial robot. For Mitsubishi Electric industrial robots students make a pick and place program and for ABB and KUKA robots they compose a drawing program. In this laboratory task students learn how to:

- move the robot arm with the control panel in different coordinate systems and moving methods;
- teach the coordinates of the work tool and work object (can be done only with ABB and KUKA robots);
- create a program with the control panel where three main moving commands are used (point to point, linear and circler movement);
- teach the robot positions with the control panel;
- test a written program with the control panel.

Below the command lines from each manufacturer’s industrial robot controlling program are presented:

- 20 MOV P1 (MelfaBasic IV for programming Mitsubishi Electric industrial robots) [4];
- MoveJ P100, V100, Z30, tool0 (RAPID for programming ABB industrial robots) [5];
- PTP P1 Vel= 50 % PDAT1 Tool[0] Base[0] (KRL for programming KUKA industrial robots) [6].

As seen, all command lines have a movement command and the position to which the robot arm has to move. In ABB and KUKA industrial robot command lines, the maximum speed for moving the robot arm, position accuracy (if the robot is moving through the point or the robot starts to move to another position before reaching the position), and the work tool and work object coordinates (if these coordinates should be taken into consideration or not for moving the robot arm) are also defined. With the drawing program students can see how the parameter changes in the command line change the behavior of the robot arm movement.

In task 2 students make a control program for an industrial robot on the computer by using the robot programming software. For Mitsubishi Electric industrial robot students make a pick and place program for three boxes. For ABB and KUKA industrial robots they make a welding program (Fig. 6). With this laboratory task students familiarize themselves with the robot programming software. They will learn how to:

- move the robot in a 3D environment;
- teach the robot position in the 3D environment;
- write the robot program in the robot programming software;
- test the written program offline in the 3D environment.

In laboratory task 3 students make a new program or change in the laboratory task 1 written program and get it working with the real industrial robot by using the robot programming software. For the Mitsubishi Electric industrial robot, students make a palletizing program (Fig. 7), where they have to place six workpieces into the product holder. For ABB and KUKA industrial robots, students make a 3D model from the actual industrial robot system, copy the written drawing program from laboratory task 1 into the 3D model and change it so that the robot draws the picture on two different papers. In this laboratory task students learn how to:

- create a 3D model from an actual industrial robot system;
download (also upload) the program written in robot programming software into the real industrial robot;
• move the real industrial robot arm with the robot programming software;
• test the written robot program on the real industrial robot with the robot programming software;
• they will learn that not all the positions taught in the 3D model are the same as in the actual industrial robot system.

At the end of each manufacturer’s industrial robot laboratory task, students have to write a report where they present their written programs and taught positions from all three laboratory tasks, describe the written program (what a command line does) and the positions (that the position is used for), and write down what they accomplished in the corresponding laboratory task.

B. Advanced Course of Robotics

This course has only one team-based laboratory task. In this laboratory task students have to design an industrial robot station, which is part of a production system, document it and get it work on the PC (personal computer) by using a robot programming software. Students can propose by themselves an industrial robot station or choose from the list provided by the teacher. Their proposed station cannot coincide with previous tasks (the industrial robot has to be from another manufacturer).

Ciros Studio, ABB RobotStudio and KUKA.WorkVisual allow them to create a 3D model of the industrial robot station and simulate its work on the PC. The 3D model can be made up from the components existing in the robot programming software library (Fig. 8) and/or components made by the students. It is possible to import drawings made with 3D mechanical CAD (computer-aided design) software like SolidWorks into the robot programming software.

Fig. 8. Pick and Place application made by students in RobotStudio.

Every two weeks, students have to give a short presentation about their achievements in the laboratory task to avoid work accumulation at the end of the semester. At the end of the course students have to submit industrial robot station documentation and give a presentation about the industrial robot station by demonstrating its work on PC or on a real industrial robot. The documentation must contain:
• a list of main parts used in the industrial robot station;
• mechanic, electric, hydraulic and/or pneumatic schemes;
• 3D model of the industrial robot station;
• industrial robot positions and the program that controls the industrial robot station.

This laboratory task provides students experience on the design of an industrial robot station that is used or can be used in industry.

IV. CONCLUSION

Several laboratory tasks have been developed in the TUT Department of Electrical Drives and Power Electronics covering the courses of Introduction to Robotics and Advanced Course of Robotics where students obtain experience with industrial robots.

In first course three different manufacturer’s industrial robots are used for the laboratory task: Mitsubishi Electric MELFA RV-2AJ and RV-1A, ABB IRB1600-5/145 and KUKA KR 90 R2700 pro industrial robots. Three laboratory tasks for each manufacturer’s industrial robots are required. These laboratory tasks enable students to compare the robots and find out similarities and differences between the industrial robots, and what can be expected from the third manufacturer’s industrial robots. In addition, students learn how:
• to control an industrial robot with a control panel and robot programming software;
• to teach the coordinates of the work tool and work object;
• to write a robot program with the control panel and robot programming software;
• to test the written robot program on the PC and on the real industrial robot;
• the parameter changes in the robot program command line change the behavior of the robot movement;
• to create a 3D model from an actual industrial robot system.

In the second course students have to design an industrial robot station and get it working on the PC. The industrial robot has to be chosen from Mitsubishi Electric, ABB or KUKA, because the robot programming software (Ciros Studio, ABB RobotStudio or KUKA.WorkVisual) supports only this manufacturer’s industrial robots.

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REFERENCES