Joystick Control of a 3D Printed Robotic Manipulator for Student Learning

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Abstract—In the present work, the control mode of a robotic manipulator with a joystick when moving an object to a desired position is considered. In automated systems, it is always necessary, in addition to the main automatic mode, to have an additional mode allowing additional adjustment. In addition, it can serve to determine the most suitable trajectory for the robot's motion, both for its recording and for motion training. 3D printing technology was chosen to create the individual details of the robot, which significantly reduces its cost. The details can be restored at any time if necessary. Arduino IDE and Nano board are used as the control development platform. The project is the basis of a student's thesis on automatic control of a robotic manipulator. The finished project will serve to train students and make it easier to adopt and adapt to these modern technologies. This step-by-step project implementation approach was chosen, as it will lead to consolidation and acquisition of new knowledge at each stage of implementation.

Keywords— Arduino, robot, joystick, 3D printing.

I. INTRODUCTION

The entry of robotic systems into people's lives is happening without much fanfare, and in recent years it has increasingly manifested itself in one form or another. Industrial enterprises have long used various types of industrial robots or manipulators for specific purposes in production. Training people to work with robots could start at a very early age, as it is taught in elementary, middle, and high school. The user working with a robot must not only be able to program, but have knowledge of electronics, electrical engineering, mechanics, mechanical engineering. Universities offer training on different types of robots, some of which are like industrial robots, using the same programming language and control controllers. This is nice on the one hand as it offers access to this cutting-edge technology, but on the other hand such robots are only found in universities and factories. After passing the relevant course, the student does not have access to this technique, unless he works with it and can't realize his ideas or projects. On the other hand, 3D printing technology offers opportunities for creating prototypes, thus everyone can create their own projects, choose management and implementation options themselves, can gain experience working with this technology. A systematic review specific to robotics research is done in a report [1]. The greatest interest is in applications of robots in medicine, industry, space, military affairs, agriculture. The research shows that there are very few studies on communication between robots. Of great importance is the design of the robot's joints and their mobility. In a report [2], various control strategies for robots applied to flexible joints were investigated with MATLAB to improve their interaction with disabled people. A robot operating system (ROS)-based joystick remote control method for KUKA industrial robots is developed in a report [3]. An independent application programming interface (API) has also been developed for data transfer. MATLAB's Robotic Toolbox package for designing the motion trajectory of a 6- degrees of freedom

(DOF) mechanical arm by the triple and five-fold polynomial interpolation techniques has been used in a report [4]. In report [5], an optimal parameter finding algorithm based on soft-actor-critic (SAC) instead of a conventional PID controller is proposed to stabilize the robot operation affected by changing environmental conditions. In a report [6], a modification of a commercial haptic device was made to convert it into a 2D haptic joystick. A simplified haptic interface (API) has been created for the joystick feedback. A gamepad as a control device for KUKA industrial robots in order to improve existing solutions is proposed in a report [7]. The control of the gamepad has been improved by adding a smartphone, for visualization of information to the user. The gamepad robot control method was tested with two different tasks for data validation. A comparative analysis of basic controllers from the ROS control package and advanced controllers in a 3D Gazebo simulator of a 7 DOF robotic arm has been conducted in a report [8]. A disturbance resistance test was also conducted. A new design of ergonomic gesture control with visual feedback for collaborative work with a UR3 robot is presented in a report [9]. The system enables users with little or no knowledge of robots to perform basic tasks and programming. The principle of operation mirrors that of a 3D joystick, but a Leapmotion device is used to track the user's hands and prevents the need for a physical joystick or buttons. A report [10] proposed an LSTM neural network to achieve safe trajectory planning and navigation for a mobile robot from start point to end point while avoiding dynamic obstacle. The mobile robot and its dynamic environment are simulated in the Gazebo 3D simulator. Controlling the movement of a robotic arm through a Raspberry pi remotely using an internet connection is proposed in a report [11]. A report [12] described the mechanical system, design and prototype of a 6 DOF robotic arm. A Raspberry Pi and a graphical user interface (GUI) written in Python were used for control. The values of the PID controller are obtained in MATLAB Simulink. There are areas of life where the environment is dangerous or harmful to humans and the efforts of developers are directed in this direction. Deep-sea robots are widely used in studying the seas and oceans [13]. If necessary, robotic arms controlled by a person on the surface are used to perform certain operations underwater [14]. In the present report, a model of the MK2 manipulator [15] produced by 3D technology is used. All the necessary files for its production are open source. The project will serve as the basis of an undergraduate student's thesis.

II. Materials and methods

The manipulator has four degrees of freedom. Manipulator manufacturing can be divided into three distinct parts: mechanical, hardware, and software.

A. The mechanical part

It includes printing the parts of the robot, assembling and fitting the individual parts. 3D printing technology is very convenient for this project. On the one hand, the student can be trained by creating the physical model of the robot, and on the other hand, directly reproduce it. Another important point is the duplication of a damaged part or correction on the very details of the robot if necessary. The time is not far when this type of printer will become a part of people's daily life, like personal computers. Having a home 3D printer, the user will be able to independently create a more complex manipulator without the need to work with an expensive industrial robot. For the movement of the base, 6 mm diameter 3D-printed spheres were initially used, but later they were replaced by metal ones. They act as a bearing around which the base of the manipulator rotates. Added a 4mm axle running through the base and arms that are connected to the motors. In this way, the structure and movements are stabilized. The robot has four servo motors: M1 for base rotation (x-axis), M2 for up-down movement (y-axis), M3 for forward-backward movement (z-axis), M4 for grasping objects (x-axis). The manipulator file was inserted into the Oneshape software to check the 3D model as well as the movement of the individual motors along the axes (Fig. 1). After selecting a motor, its direction of movement is set and the robot is driven to the desired position.
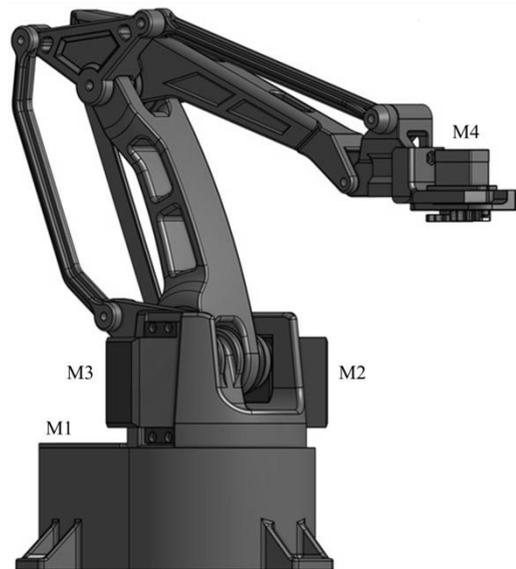

Fig. 1. View of the 3D model in Oneshape.

B. Hardware part

When the mechanical part of the manipulator was assembled, the servo motors were run separately. Initially, a board (CCPM Servo Consistency Master/Servo tester) was used to test the motors. It can be used to control three engines simultaneously in manual or automatic mode, but is suitable for starting only one engine. If all three motors are connected at the same time, unpredictable behaviour of the robot may result. Each motor was tested individually with this board, which showed the performance of the manipulator, but also showed its shortcomings. The board is useful to visualize the operation of a particular servo motor from the manipulator. For manual mode involving rotation, lifting, lowering and gripping, four such boards are required, making free control pins redundant. Due to these

shortcomings, a variant with two joysticks was chosen to control the four servo motors. Each joystick outputs two analogue signals indicating the presence of movement along the x, y axes. The analogue signals from it are converted by the controller's ADC, and then it produces a control signal to the motors. The first joystick is for controlling M1, M2 along the x, y axes, and the second for controlling M3, M4 along the y, x axes. Actually, the second joystick is for controlling the M3 motor along the z axis, but it is marked y on the joystick. When the joystick is in the centre position, it outputs an analogue signal proportional to the value in bits (512, 512) for x, y. This report uses a 4$ Nano board, but in the thesis, project will use the UNO R3. The control unit and joystick are powered by the computer. Servomotors M1, M2, M3 are MG996R type, and M4 is SG90 type. Since the consumption of the three motors is high, a separate power source is provided. All motors move in the range of 0 to 180 degrees. The controller in turn outputs a control signal to each servo motor. An additional driver is not used at the moment, but one is planned at a later stage in order to obtain a higher resolution output signal for smoother movement. In fig. 2 shows a block diagram of the hardware part.
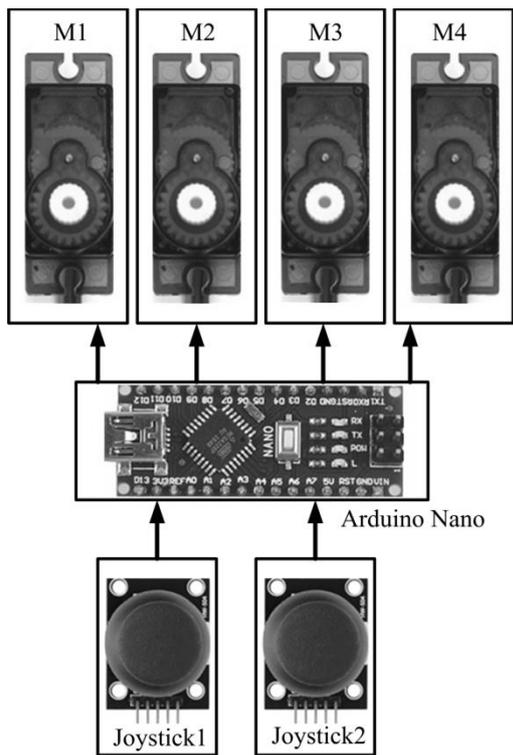

Fig. 2.   Block diagram of the hardware part.

C. *Software part*

The open source development platform Arduino IDE was chosen. The software part includes initialization of variables, analogue inputs, servo motors. The position of the servo relative to the joystick is determined. A dead zone is set in the central part of the joystick in the range from 400 to 600, which are marked in Fig. 3 with the

abbreviation dBL and dBH. The status of the analogue inputs is read. Then their value (xval, yval) is checked. If it is within the dead zone range, the motors do not operate. When the value of the signal goes out of the dead zone, a check is made to see if the value is below 400 or above 600, then the servo motor is started in the desired direction. Finally, the position is updated. A block diagram of the program is shown in Fig. 3.
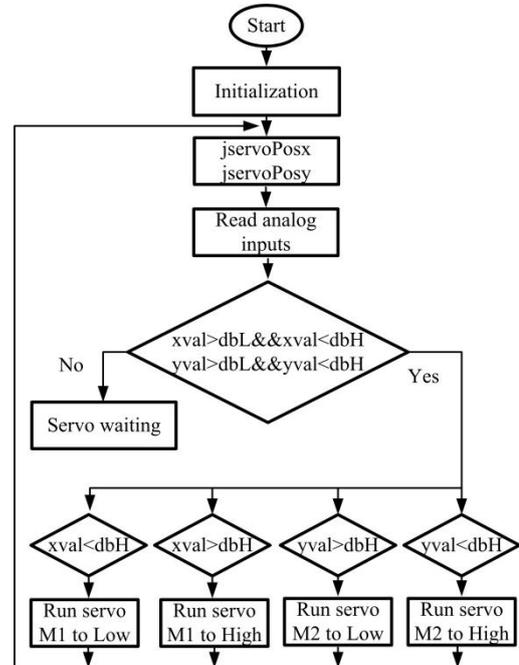

Fig. 3.   Block diagram of the program.

III. RESULTS AND DISCUSSION

A photo of the manipulator is presented in fig. 4. The MK2 manipulator is manufactured using 3D technology with PLA material with 15% infill. Part of the received data from the serial channel can be seen in fig. 5. When serial communication starts, the positions of both joysticks are in the centre of the range. Changing the position of the joystick along the x-axis brings the servo motor to a minimum value. The mode of simultaneous movement of two or more servomotors is not foreseen. Currently the motors do not have current protection, this will be added at a later stage. Visualization and recording of the readings is provided for the purpose of designing the movement trajectory.
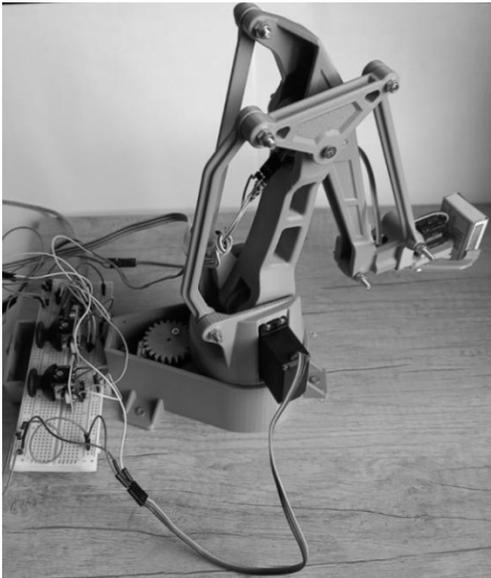
Fig. 4.   Picture of the manipulator.

Fig. 5.   Data from analog inputs.

IV. CONCLUSIONS

The introduction of the MK2 manipulator in the training of students will significantly improve the level of their professional skills. They will be able to program and control the robot not only in the exercises, but also outside of them, with whatever control modules they want. The 3D printing technology allows the students to print, assemble and put the manipulator into operation themselves. The student has the opportunity to see the construction of an article from start to finish. The materials used free software significantly reduce the cost of the robot. The most valuable thing about the case is the experience they will get in developing it. Adding a display, driver, protection scheme at a later stage to the project will improve the operation of the manipulator. Another aspect of the project is connecting the robot to the Internet or controlling it via a smart phone, as well as adding a surveillance camera.

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