UDC 621.3:681.527.6

Knysh V.O., student of the Electric Drive Department
Plahunov O.M., student of the Electric Drive Department
Shykhov S.K., postgraduate student of the Electric Drive Department
Dnipro University of Technology, Dnipro, Ukraine

DEVELOPMENT OF EDUCATIONAL CYBER-PHYSICAL STAND ON BASIS OF ROBOT MANIPULATOR WITH SIX DEGREES OF FREEDOM

Nowadays, the rapid development of automation and robotization of production forces engineering personnel, regardless of age and specialty, to constantly seek new knowledge and develop, according with the modern concept of Live Long Learning. Industrial robots are improving, becoming more complex, and mastering an ever-increasing range of tasks. As a result, industrial robot manipulators with six degrees of freedom have become almost an integral part of modern production process, and the skills to work with them are absolutely necessary.

However, modern challenges in the world and in Ukraine have clearly demonstrated that face-to-face attendance at educational courses can be difficult, or even impossible. This has led to the rapid spread of online education in all fields, which in turn has created new challenges. One of them is the performance of laboratory experiments on equipment that can be present only at the university. For this reason, the international DAAD project "Lab4All" was established with the further development of specific domains of digital education as its primary objective. The following provided a framework for the creation of an educational cyber-physical stand involving a manipulator robot.

Manipulator [1] is a controlled device (machine) equipped with a working organ to perform movements similar to the ones of a human hand, during the transition of objects in space. The ability of such robots to perform programmed tasks of varying complexity with high accuracy and speed makes them an extremely useful and highly effective industrial tool.

The stand is based on the 6DOF DoIt Mobile Robot Arm (Fig. 1, a), which is a reduced version of industrial robots with 6 degrees of freedom [2]. The weight of the manipulator is 1 kg, the maximum load is 0.5 kg. The robot consists of six kinematic pairs (Fig. 1, b) with seven servo motors (Fig. 2, 7), powered by 5V 30 A power supply (Fig. 2, 8).

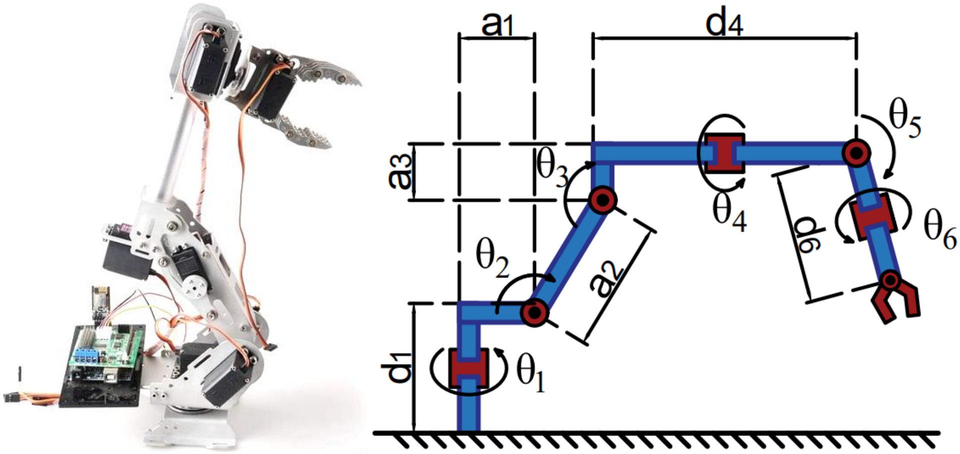

Fig. 1. a – appearance; b - kinematic scheme

To perform laboratory experiments, the following equipment is used:

1. 3 position sensors based on MPU6050 gyroscopes-accelerometers;
2. 3 current sensors INA3221 were connected to servomotors;
3. Multiplexer TCA9548A for communication with sensors via the I2C interface;

4. Arduino Uno for processing measurements;
5. Servo Shield Board for controlling servo motors;
6. Raspberry Pi 4 for gathering and transferring data to the network.
7. 7 DS3218mg servo motors for movement of each link
8. 5V 30A power supply for energy provision to the robot`s systems

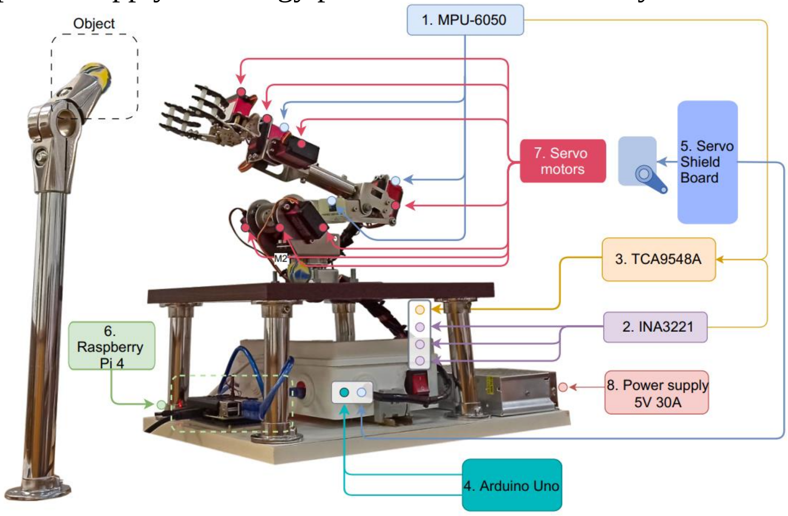

Fig. 2 Robot Arm cyber-physical stand

Cyber-physical laboratory experiments operate using Denavit-Hartenberg (DH) method [3]. This method uses following matrices and equations emanating from them:

$$ {}^{i-1}_{i}T = \begin{vmatrix} \cos(\theta_i) & -\sin(\theta_i)\times\cos(\alpha_i) & \sin(\theta_i)\times\sin(\alpha_i) & a_i\times\cos(\theta_i) \\ \sin(\theta_i) & \cos(\theta_i)\times\cos(\alpha_i) & -\cos(\theta_i)\times\sin(\alpha_i) & a_i\times\sin(\theta_i) \\ 0 & \sin(\alpha_i) & \cos(\alpha_i) & d_i \\ 0 & 0 & 0 & 1 \end{vmatrix}, $$

$$ \begin{matrix} x_{Oi-1} \\ y_{Oi-1} \\ z_{Oi-1} \\ 1 \end{matrix} = {}^{i-1}_{i}T \times \begin{matrix} x_{Oi} \\ y_{Oi} \\ z_{Oi} \\ 1 \end{matrix}, $$

Through a web interface, students connect to the stand, engage with it, acquire data from the sensor system, control the robot, and carry out lab objectives. The lecturer can then evaluate the work that has been completed. This approach not only helps students develop professionally but also gives them the chance to learn real-world skills without requiring to be physically present next to the lab stand. It establishes new approaches for teaching and learning, advancing the usage of remote learning, which has shown to be a successful and forward-thinking way to acquire information.

Перелік посилань

1. ДСТУ 2879-94 Маніпулятори, автооператори, роботи промислові та системи виробничі гнучкі. Терміни та визначення

2. Shenzhen Doctors of intelligence & Technology, User Manual For Do Arm, Chapter 1 Robot Arm (2016). P.:3-4 URL http://bbs.smartarduino.com/

3. Beshta A. S., 6_M&R_UA_DHC_homogenous_matrix (2021). P.:1-23 URL https://do.nmu.org.ua/pluginfile.php/455011/mod_resource/content/1/6_MR_UA_DHC_homogenous_matrix.pdf

4. John J. Craig, Introduction to Robotics: Mechanics and Control. 3rd Edition. Pearson/Prentice Hall, 2005. 400 p. ISBN 978-0201543612