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RESEARCH OF ROBOT - HUMANOID CONTROL METHODS USING HUMAN BODY MOTION RECOGNITION TOOLS

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Abstract. *The aim of the research is to investigate and evaluate the repetition indices of the displacements of the robot's kinematic nodes, using the means of identification human body movements, using a real robotic system. The article presents an analysis of human body motion recognition tools, identifies typical application criteria that meet the requirements of robotic systems control, describes the developed physical research stand "Robot - humanoid": the robotic system is identified with the human body with two of nine-kinematic degrees of freedom hands and a two degree of freedom robotic mechanism replacing the head on which the environmental video surveillance equipment is mounted. The publication presents systematized experimental data and suggestions for the integration of research results into the process of students' practical - applied teaching in a contact or distance way.*
Keywords: *identification of human body movements, robot – humanoid, robot's kinematic nodes, robotic system, students practical – applied teaching.*

Introduction

There are many areas of activity where a sequence of interactions between a human and a robot could be implemented - a collaborative effort that requires training the robot or robotic system to observe, record, and accurately reproduce the movements of the human body.

The aim of this study is to investigate the accuracy of the robotic system control method based on skeletal methods and machine learning algorithms to determine the repeatability indices of the robotic system manipulator using digital optical means of human body motion recognition, linking guidelines for the integration of an actual project directly related to students 'after-school volunteer project activities. The research singles out the directions of self-learning developed by students and the results achieved during this project.

The project described in the article lasted for three years, the whole article is described later as a continuous extracurricular activity of students - project activities: The research methodology, the creation of the problem areas of the

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research, the practical realization of the research, the performance of the experimental activities of the research and the presentation of the results are based on the report structure of the 1st - 3rd year students of Vilnius University of Applied Sciences.

Literature review

Learning is a priority in the educational process today, which is fundamentally changing the roles of all those involved in the educational process. The learner becomes a real and active participant in the educational process, i. y. he not only strives to master the study content and develop the competencies provided in the study program, but also actively participates in the development of the teaching process itself. This is fully in line with the essential provisions of learner-centered teaching: construction of the curriculum in response to the learner's interests, enabling him to learn according to his learning style and individual learning needs, etc., active position as an equal partner in all stages of the learning process training objectives, providing content, training methodology. The increased freedom and activity of the learner in the study process also emphasizes his greater responsibility for the study results, the need for stronger motivation and involvement in the teaching process.

One of the possibilities in this situation is the application of innovative learning methods that would focus on the student's independent lifelong learning, develop his creativity, critical analytical thinking and abilities and skills of independent work, striving to continuously integrate theory and practice in the study process. One such method is the project method. This innovative learning method enables the creation of an attractive and learner-friendly study environment, where theoretical knowledge is applied in practice in order not only to get to know it, but also to reconstruct and improve it.

Experience in the application of projects in educational practice demonstrates the versatility, innovation, openness, flexibility, focus on real and specific problems of this method and emphasizes the following advantages of the project method for the learner:

- each learner gains a different experience that is relevant to him or her;
- promotes the learner's confidence, provides an opportunity to reveal one's personality;
- the learner has the opportunity to influence the implementation of the project, to develop responsibility for their decisions and activities;
- use various sources of information in the learning process;
- it is possible to apply the theory in practice, and conversely - the obtained practical results allow to make theoretical generalizations;
- opportunities are created to generate ideas and implement them in practice;

- learning to be open to ideas, to take initiative, to promote innovation;
- the learner develops the ability to act in a rapidly changing environment;
- developing informal, natural links with the environment through activities;

The most important part of the students' development of the robot - humanoid motion control system was the software, which is less technical: the development of this system requires basic knowledge of electronics, mechanical engineering and programming to solve engine control, robot motion modeling and image recognition algorithms. The purpose of this system is to expand the robot's capabilities by creating an image recognition system for it, as well as to develop algorithms that allow the robot to respond to the respective image with the desired actions. The system is designed to be system-sharing, allowing flexibility to modify or improve other robotic systems without requiring any or minimal changes to the image recognition system (Pocevičienė et al., 2010).

Methodology

Project research covers two main areas: technical implementation and software implementation. After summarizing the problems of the task, the following main tasks were singled out and defined (Davies, 2017):

1. Development and programming of algorithm for visible image recognition and its interpretation.
2. Extract objects from the resulting image.
3. Development of object comparison algorithm.
4. Saving the object from the received image.
5. Identify the object from the saved image.
6. Motor control of robot vision mechanism.
7. Modeling of robot reactions (response).
8. Programming the robot's response to the corresponding image.

1. Technical implementation of the project

The open source “Inmoov” project was chosen as the basic model of the robotic system. The object of the study is a robotic system - a robotic system printed by a 3D printer is identified with the human body, having two robotic arms with nine kinematic degrees of freedom - manipulators, and a head representing a two degrees of freedom robotic mechanism equipped with environmental video surveillance equipment. Servo drives are used for motion motors. The initial repeatability tests presented in the article will be performed with the right-hand movements of the model.

The first stage of technical implementation is the design stage of the robotic system (Fig. 1), which improves the students' competencies to choose the appropriate three-dimensional design environment and its connection with further design stages. In this project, the students chose a professional three-dimensional design tool “Solidworks CAD”. Simulations of the kinematic movements of the robot were also performed with this software package. Students also demonstrated knowledge in the field of mechanics.

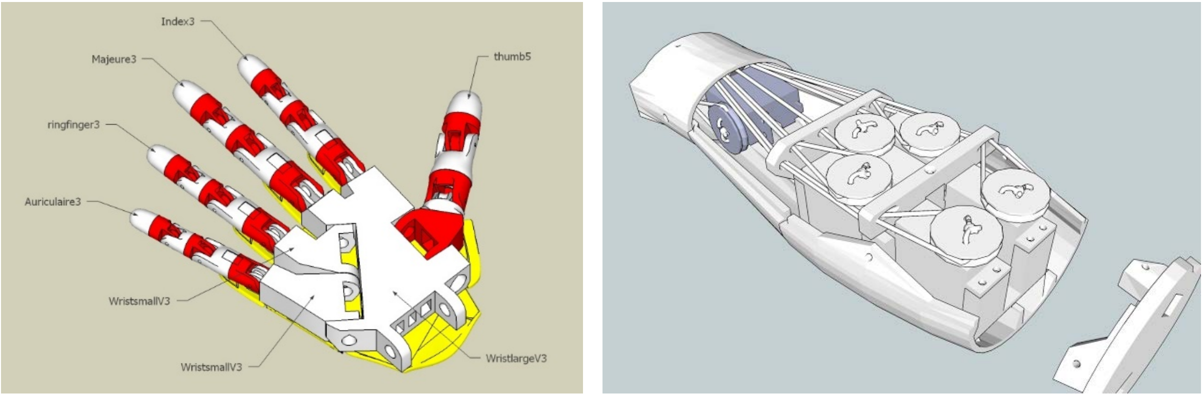

Figure 1 ***Robot – humanoid hand design*** *(Langevin, 2017)*

The second stage of technical implementation is the selection of the production method. At this stage, the competence of students to make appropriate production decisions was revealed, which would allow easy adjustment of the existing robot system design by improving the electromechanical part of the project. The chosen dynamic and modern production method - three-dimensional printing (Fig. 2). Middleware for print preparation for FDM printing was independently mastered: Cura, Simplify 3D, PrusaSlicer.

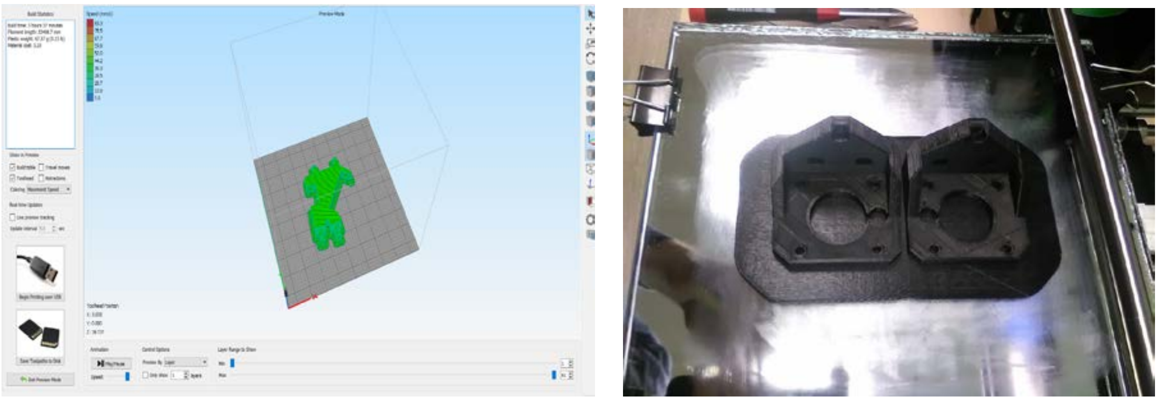

Figure 2 ***Robot – humanoid parts production by 3D FDM printing*** *(created by authors)*

The third stage of technical implementation is related to the selection of suitable electromechanical assemblies, assembly and assembly of individual parts of the robotic system (Fig. 3). At this stage, students demonstrated competencies and independently deepened their knowledge in the fields of electronics, electrical signal processing, electronic control systems, technical design. This allowed the ideas to be put into practice. Servo drives with feedback, programmable logic controller "Arduino Mega", 3 Mpx web-cameras for image recognition are used to ensure the kinematic movements of the robot.

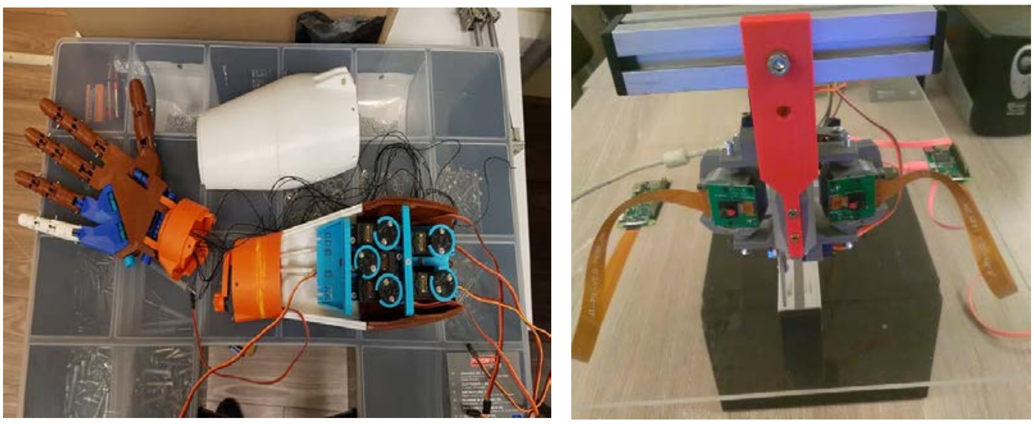

Figure 3 **Robot - humanoid assembling process** *(created by authors)*

2. Software implementation of the project

Because the image recognition algorithm and the control of the robot's visual mechanism can be interpreted and defined very broadly, it is important to know exactly what type of software implementation is required to be developed.

In summary, taking into account the functional requirements of the given task, it becomes necessary to create a graphical user interface that can see the visible image of the robot, control the robot's movements and similar types of actions. Depending on the functional requirements, most of the program for object recognition would be controlled automatically or minimally by the graphical interface (Stitilis, 2014). Examining the functional requirements separately, it is very clear that the program will have to receive the video and be able to broadcast it to the user in real time. This streaming should not interfere with other functionality of the program, but it should be possible to modify it to show the recognized objects to the user. The program should be able to retrieve frames from the video and save the frames as photos, and be able to create frame templates from them for comparison with other frames or photos to identify objects. This type of process could be integrated into the graphical user interface, but is much more important at the stage of modifying and recognizing the image itself. Therefore, this type of process is more likely to be more internal without giving the user much functionality to use it. It is also important for the program to be able to select the recognition accuracy in order to recognize different types of objects faster or easier. This would be done by changing the modes of the recognizable colors, reducing the quality of the photo or frame, or otherwise. As a result, this process is likely to be internal, allowing the user to select the appropriate parameters in the graphical user interface.

Analyzing the non-functional requirements, we can observe the same as in the functional requirements: the system is developed for more automatic use and there are few criteria for user functionality. Non-functional requirements mean that the program is written to allow the use of an external webcam, although this does not prohibit the use of an internal computer camera, but reduces the functionality, which is not very important when creating or testing program code. The programmer is also given the freedom to display the camera image: whether the image is displayed when the user instructs it or at all times, although the modified camera image is required to be displayed only at the user's request. This allows the robot camera to be used as a surveillance tool and allows it to be used as an object recognition tool. It also allows the programmer to choose how object recognition should work: whether using a file system or storing files in dynamic memory as the program runs (Rokicki, 2010).

The control of the robot mechanism is defined by specifying that the Arduino Mega controller is to be used, the mechanism is expected to be servo-driven, and the aim is to obtain different robot responses to the respective objects. This specifies the capabilities of the task, but gives a specific idea of what kind of program code would need to be developed or what environments and libraries might need to be used to accomplish this task. The Arduino application consists of one class of Arduino controller. The purpose of this class is to provide communication and rotate the appropriate engines according to the parameters of the incoming message. This class has horizontal and vertical servo objects (servHor and servVer), vertical and horizontal servo connection contact numbers (servoHor and servoVer), and the current positions of the first and second servos (pos1 and pos2). This class also has the basic setup and loop methods required for the controller, which allow the initial objects to be identified before starting work and perform an ever-repeating cycle of reading messages, evaluating and generating responses, and rotating servo drives accordingly (Chaminade & Cheng, 2009). Additionally, this class has a moveTo function to control the position of the servo as a parameter, specifying the current position, target, and rate of turn.

The following are the main steps in the calculation of motion detection and conversion to servo turn angle (Formulas 1-3):

1. Finding vector differences:

$$\vec{b} = \vec{a}1 - \vec{a}2$$

2. Multiplying the obtained features of the three coordinate vectors to match the coordinate:

$$A * B = x_1 x_2 + y_1 y_2 + z_1 z_2$$

3. To calculate the turning angle of the servo motor, we convert the obtained scalar product to the angle:

$$a = A^{*}B * 180/\pi$$

An optional RaspberryPi 3 microcomputer is available for the video recognition transmitter to generate signals for the Arduino Mega servo controller. A typical motion recognition-shaping diagram is shown in Figure 4.

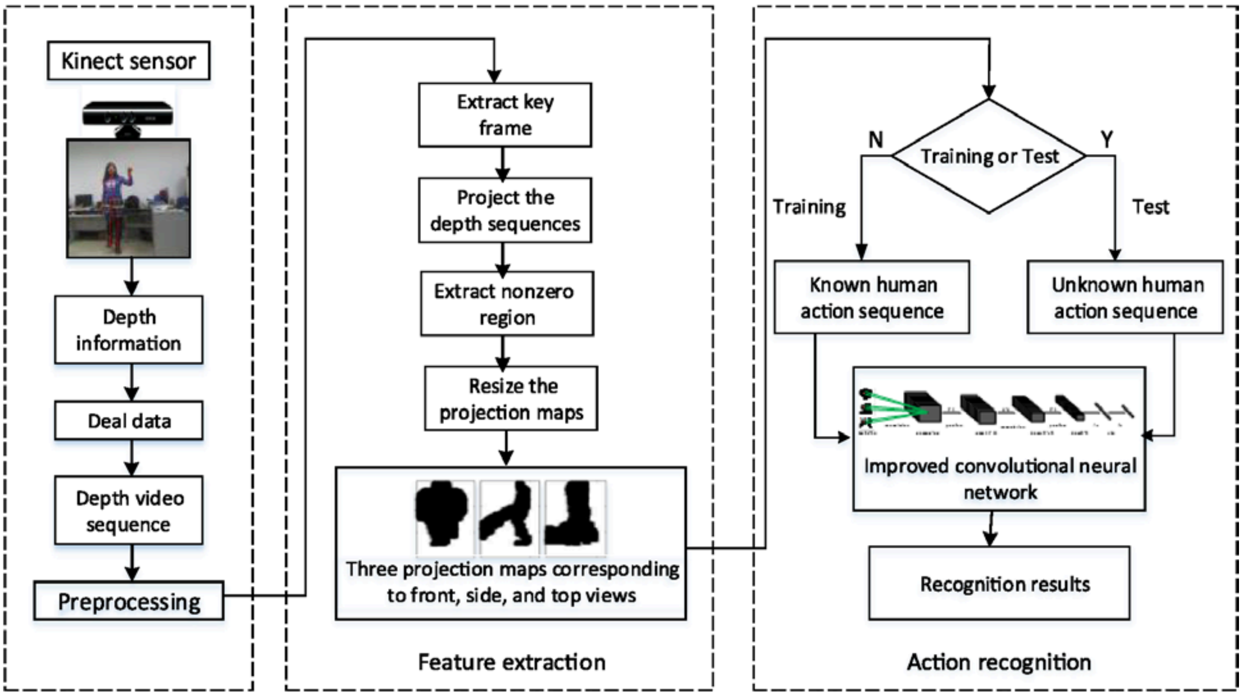

Figure 4 ***Typical motion recognition-shaping diagram*** ***(****Lingin & Xiaolin, 2018****)***

After completing the software implementation, students improved their competencies in software management and software development. Improving interpersonal skills through consultation with project colleagues who were responsible for the implementation of the technical part.

Research results

After the technical and software implementation of the project, a diagram of the research process was created (Fig. 5), on the basis of which the ability of the system to recognize human finger movements and repeat them with the help of a real robotic system was investigated. The generation of the results is performed by calculating the coordinate determined by the video camera, sending the signal corresponding to the required turning angle, comparing it with the real maximum calculated turning angle signal received from the feedback circuit of the servo drive. The test is repeated 20 times with each bending of the robot finger.

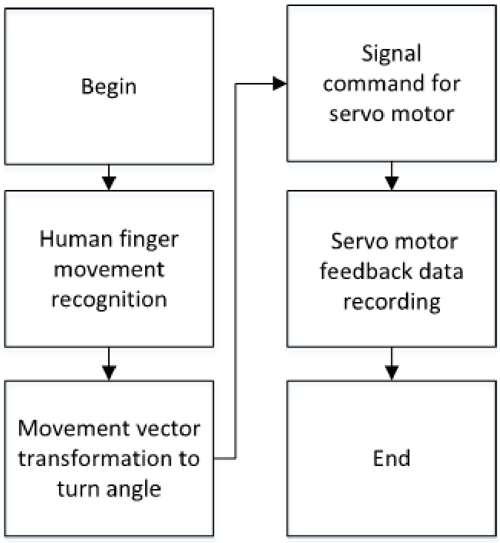

Figure 5 ***Experimental part flow chart*** *(created by authors)*

The diagram (Fig. 6) shows the averaged values of the rotation angle of each finger servo drive obtained from the feedback circuit.

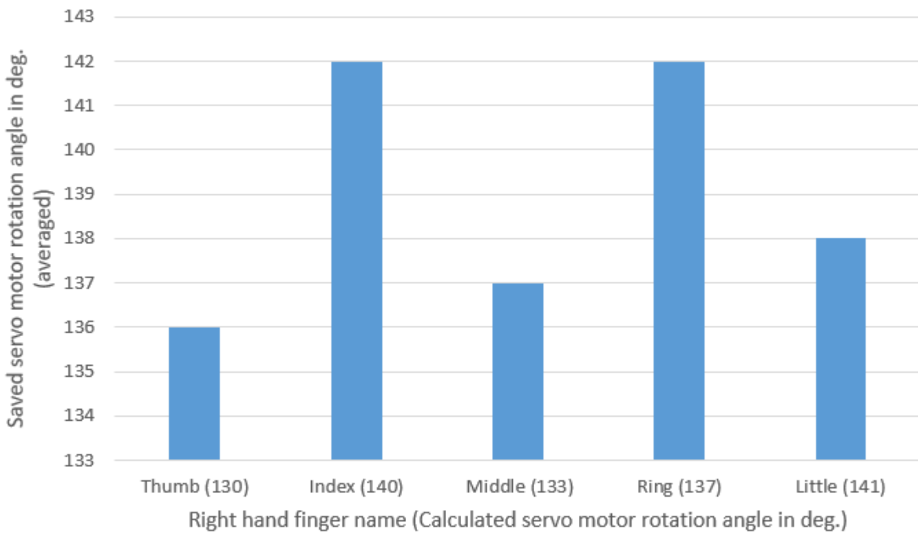

Figure 6 ***Experimental results*** *(created by authors)*

Conclusions

The completed project is complex and integral. Therefore, the activities performed in the project description are smoothly related to both the technical and programmatic implementation of the project and the integrity of the results obtained during and at the end of the project in the teaching and learning processes of students:

- A project was carried out, during which a robot-humanoid model with software control of right-hand finger movements by recognizing the movements of the corresponding human hand fingers was implemented;

- 1-3 year students participated in the extracurricular activities project, divided into two parts according to the study programs studied, who realized the technical and software parts of the project, respectively;
- During the experimental study, the deviations between the program-calculated and real-measured servo gear rotation angles were investigated. The minimum deviation was 2 degrees, the maximum 6 degrees;
- Students independently improved their competencies and deepened their knowledge in the fields of programming, electronics, three-dimensional design, modeling and 3D printing, as a result of which the knowledge was reflected in the subjects studied directly with their study program, students' motivation knowledge with other subjects studied. Emphasis should also be placed on the increased ability of students to work in a team by performing practical classes in a group of students.

In the future, it is planned to expand the project by conducting experimental research with other robot-humanoid kinematic nodes, while defining the same experimental task, but repeating them individually with students of individual courses.

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