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Robot Arm Kinematics Learning using Point Plotter

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Abstract. Learning kinematics of the robot arm can be very challenging for engineering students, especially when delivered in equations only. Students are expected to understand the basic theory while knowing where the theory should be applied. The aim of this research is to develop visual media for learning kinematic using simple tools and material. This visual media is called point plotter and consists of only cardboard and two protractors. The test conducted on two different treatment groups shows significant differences on learning outcomes. Moreover, student response for the subject, interface, and benefits aspect show positive results with the summary of all aspect is 82.93%, indicating this media is very acceptable.

Keywords: robot arm, kinematics, learning media, point plotter

I. INTRODUCTION

A robot is a unit which forms mechanical, physical, or virtual that having its own intelligence [1]. In the era of technology and science, the application of robots are almost covering in every field. The example of robot application is the welding robot, the welding robot is required to weld something human cannot handle and also make it much faster than human [2]. This is one of the results of the fourth industrial revolution [3]. This development forcing the human to switch their job from doing to operating.

Therefore the issue about studying robot especially for engineering student is very important. On the contrary, 93% of papers that exist now are about robot competition, 3% are about robot teaching, and only 4% are about robot education [4]. The aim of the robot competition implementation is to popularize and develop the robot education, but what is the usability of the students' future. Robot competition cannot directly provide the student about how the robot works in the industry.

The robot arm is one of the robots used in the industry and it requires kinematics analysis in the application of this robot. There are two types of kinematics, forward kinematics, and inverse kinematics. Forward kinematics is the process of calculating the orientation and position of the end effector based on the corners of the joint [5]. While inverse kinematics is the opposite, given the position of end-effector, then what to look for is how many angles should be changed for each joint to be able to reach the end-effector position. The formulas of the forward kinematic and inverse kinematic are very complicated. It is used a lot of equations for only aiming the position of end-effector or determine the angle of the arm. Therefore we need a solution to overcome difficulties in learning forward and inverse kinematics.

Learning media is one way to overcome that problem. Therefore in this study learning media will be used to solve the problem. The learning media that used is "Point Plotter". Point Plotter is used to determine the end-effector and angle required by the arm robot. In addition, students can also know the working area of a robot arm. Thus the students will be easier to understand the function and how to use forward kinematics and inverse kinematics.

Industrial Robot

The industrial robot consists of a manipulator, sensors, actuators, and controllers. A manipulator in robotics is a device used to manipulate materials without direct contact and commonly referred to a robot arm. Manipulator consists of rigid links connected by joint actuators that create relative motion of neighboring links. Sensors are attached to joints for position and speed sensing. Monitoring positions and orientations of a manipulator is very important in robotics in order to ensure the precise function of a robot.

The robot function and working area are determined by the degree of freedom (DoF) of a manipulator. The industrial robot usually has six degrees of freedom since its manipulator has six revolute joints. Therefore, it can perform a complex task such as welding and assembling auto parts. The more DoF on a robot the more function it can perform.

However, the working area on human perception usually marked by points in a Cartesian coordinate system. Whereas, many robot manipulators utilize motor as actuators which only work in a planar coordinate system. Taking an example of 2-DoF manipulator depicted with a kinematic trigonometric diagram in figure 1. The equations for the forward kinematics are shown in equation 1 and equation 2.

$$x_2 = L_1 \cos\theta_1 + L_2 \cos\left(\theta_1 + \theta_2\right) \qquad (1)$$

$$y_2 = L_1 \sin\theta_1 + L_2 \sin(\theta_1 + \theta_2) \qquad (2)$$

While the equations for the inverse kinematics are shown in equation 3 and equation 4.

$$\theta_1 = \tan^{-1}\frac{y_2}{x_2} + \cos^{-1}\left(\frac{L_1^2 + L_3^2 - L_2^2}{2L_1L_3}\right) \qquad (3)$$

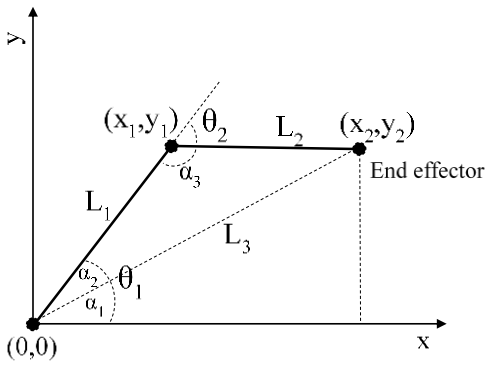

Figure 1. Kinematic Trigonometric Diagram for 2-DoF Manipulator

$$\theta_2 = \cos^{-1}\left(\frac{L_1^2 + L_2^2 - L_3^2}{2L_1L_2}\right) - \pi \qquad (4)$$

where $L_3 = \sqrt{x_2^2 + y_2^2}$.

Transferring points in a Cartesian to a planar coordinate system can be a very difficult task, especially in higher DoF. Therefore, we develop point plotter robot arm in order to simplify the learning complexity of robot kinematics.

Media Design

The point plotter media is designed using two protractors, the pad, and two arms. The protractors are displaying degrees (-90 to 90). The pad is showing y-axis (-16 to 16) and x-axis (0 to 16). The length of each arm in this media is 8 cm. The design of Point Plotter can be seen in figure 3.

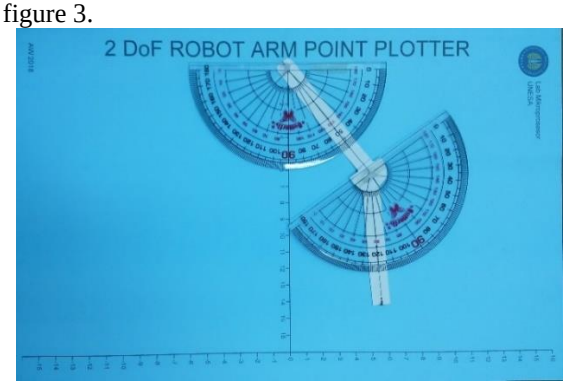

Figure 3. Point Plotter Media

The x-axis and y-axis in the pad will be used to determine the coordinate of end-effector. And the protractor will be used to determine the degrees for every arm.

II. METHOD

This research uses a true experimental method with pretest-posttest control group design. Pretest-posttest control group design is a research design using two sample groups that separated into experimental and control groups [8]. The experimental group and control group will be taken from the Electrical Engineering student at Surabaya State University. The number of sample in this experiment is 22 students. They were chosen randomly from any study program in Electrical Engineering Major Surabaya State University. They will be separated into 11 for the experimental group and 11 for the control group. This separation is based on their pretest.

The goal of this research is to compare the experiment group with control group competence, and to know the students' response about Point Plotter Media. The test question is consisting of 5 test about trigonometry and 15 about kinematic. Every student has 20 minutes for answering the question, and the result is how many right answers they have. And for the questionnaire, there are three aspects that will be asked to the students. The three aspects are the subject, the interface, and the benefits of the media.

III. ANALYSIS AND RESULT

Student Competence

The test results in this study were analyzed using SPSS software. Analysis begins by conducting the requirement tests. The requirement tests are the normality test and homogeneity test. The standard error used in this study was 0.05.

The normality test result obtained are 0,055 for experimental group and 0.58 for control group (p value>0.05). That means the data was distributed normally. The homogeneity test result obtained are 0,282 (p value>0.05). And also that means the data was homogeneous.

According to the requirement tests, the analysis that used in this study is parametric analysis. By using 2 Sample Independent T-test the mean of every group was obtained. The experiment group gets 7.4 and control group get 2.3. Thereafter the result was compared to know the difference between experimental and control groups. So, the result is 0.00 (p value<0.05). That means there is the difference between the experimental group and control group.

Students Response

The questionnaire that used consist of 11 questions. The question one number until four are asking about the subject, question number five until eight are asking about interface and question nine until eleven are asking about benefits. The result of that questionnaire was presented in table 1.

Table 1. The Questionnaire Result.

No	Question	Answer				
		1	2	3	4	5
1	Media "Point Plotter" is in accordance with the subject			3	7	12
2	Media "Point Plotter" can simplify the subject			3	9	10
3	The subject is easier to be understood using the media "Point Plotter"			6	7	9
4	Media "Point Plotter" can shorten learning time		1	6	7	8
5	Media "Point Plotter" simulation is easy to use			6	8	8
6	Media "Point Plotter" is interesting			3	10	9
7	Media "Point Plotter" appearance is easy to follow			7	7	8
8	The functions and the ways of working are clear and easy to understand			7	8	7
9	Media "Point Plotter" improves students' motivation and interest			4	11	7
10	Media "Point Plotter" makes the student more active			5	10	7
11	Media "Point Plotter" is useful for practical application		1	3	10	8

The summary of that result presented by figure 4.

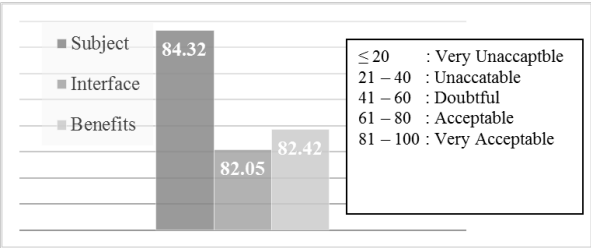

Figure 4. The questionnaire result summary

The histogram showing that all of the aspects was very acceptable. And the summary of all aspect is 82.93% which means this media is very acceptable.

IV. CONCLUSION

The issue in this study is how to teach the forward kinematics and the inverse kinematics analysis more efficiently and easy to be understood. Both have many equations that hard to memorize. The point plotter can help and improve learning process quality. It can help students to understand the ways of working robot arm by providing students a visualization of the end-effector or the angel of robot arm's joint.

The evidence can be seen in the students' competence result. The result reveals that the experiment group students' means (7.4) bigger than the control group students' (2.3). Moreover, the SPSS analysis shows that there is a difference between experimental group students and control group students.

The questionnaire also reveals that the point plotter has 84.32% for the subject, 82.05% for the interface and 82.42% for benefits. That means the point plotter is in accordance with the subject, interesting, easy to use and beneficial for students.

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