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Design of 2 dof arm robot control system using ultrasonic sensor

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Abstract. This paper explains about design of 2 DOF hand-shaped manipulator robot prototype with articulated manipulator joints configuration. The manipulator robot joint driven by a servo motor in a closed loop that was controlled using an Arduino uno microcontroller. Movements of joints and end-effector robots were well-designed and allowed real-time observation interfaced by Arduino uno-based computer software. The manipulator robot that is developed can move objects to the right and left. The robotic gripper can grab objects that are less than 5 cm in size and have the ability to move objects with a maximum weight of 1 kg.

1. Introduction

Microchip and microcontroller technologies have produced many new innovations, such as in the case of smart devices and robot technology. The robot technology widely used in industry to help human performance for a routine and sophisticated work. Similarly, in the automotive manufacturing industry and transportation equipment many use this robot technology to lift large enough objects, move them, and also install them. This technology is very helpful for human performance in accelerating the production process in the industry due to its strength and very long working time lead to maximum quality of products. One of the recent important robot technology is the arm robot or usually called a robot manipulator. Arm robots are produced and used in industry for certain functions such as to move, lift, and install objects that have relatively large weights [1][2].

This paper reported the design of a 2 DOF manipulator robot which was applied to the motion control system used to lift and move objects according to the capabilities of the robot. A servo motor was placed in each of the rotation joint and was controlled and reconfigured by the computer through Arduino Uno microcontroller based software. The prototype of DOF 2 manipulator robot was intended as a medium of learning for students, especially in robotics course.

2. Manipulator Robot

Illustration of an industrial robot as a manipulator robot usually has a complete arm shape including: hands, wrists, to the ends of the hands. The entire robot is usually designed with various equipment so that it has the ability to perform the desired task [3]. A manipulator robot designed in the form of a mechanical arm (manipulator) is one of the components of a robotics system which includes: the mechanical arm itself, an external power source, the function of the manipulator robot end arm, such as: gripper, internal and external sensors, computer interface, and the controller computer. Programming



software on robots must be considered as a whole of the whole system, because the design of control and programming on the robot will have a major impact on performance, accuracy and repeatability.[1]

The robot manipulator configuration, arms (links) on robotic manipulators connected by joints form kinematic chains. This joint will usually revolute or linear (prismatic). A rotary joint is identified as a hinge that forms a rotary motion between two links. Whereas prismatic joints, will form a linear motion between two links.[3][4] Images of rotary and prismatic joints are represented in figure 1.

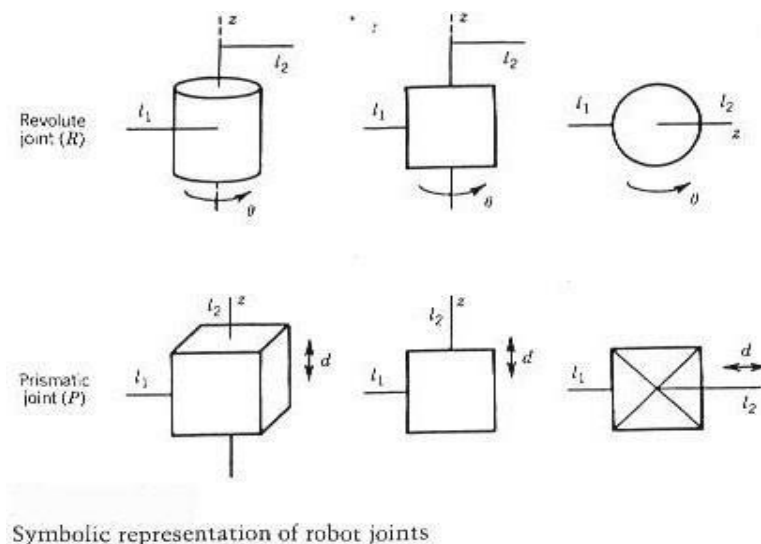


Figure 1. Symbol of revolute (rotary) and prismatic joints [3].

In the motion of robotic manipulators, the design right kinematic control will be able to solve the desired position problem rather than prioritizing dynamics control. Because dynamic modeling is very complicated and if the results are not correct then the kinematic modeling function becomes inaccurate and even not useful in improving the overall quality of control [5][6].

This manipulator robot consists of reverse kinematics and forward kinematics. Forward Kinematics is a method for determining the orientation and position of the end-effector from the magnitude of the joint angle and the link length of the robot arm. Advanced kinematics equations are obtained based on the DOF number and kinematic chain type of the robot manipulator. Meanwhile, kinematic inverse is the opposite of forward kinematics. This method is needed to determine the angular value of the joint needed so that the end-effector can reach the desired position [4].

Kinematic equation of the manipulator robot is explained as follows; figure 2 describes that if two arms are connected with a rotary joint, the end-effector is located at position x_r , y_r can be calculated by knowing the values of θ_1 and θ_2 and arm length-1 (l_1) and arm-2 (l_2) with the following equation [5][7]:

$$x_r = l_1 \cos \theta_1 + l_2 \cos(\theta_1 + \theta_2) \quad (1)$$

$$y_r = l_1 \sin \theta_1 + l_2 \sin(\theta_1 + \theta_2) \quad (2)$$

The above equation can be obtained using advanced kinematic analysis. By law trigonometric identity [5][7] :

$$\cos a + b = \cos a \cos b - \sin a \sin b \quad (3)$$

$$\sin a + b = \sin a \cos b + \sin b \cos a \quad (4)$$

then obtained,

$$x_r = l_1 \cos \theta_1 + l_2 \cos \theta_1 \cos \theta_2 - l_2 \sin \theta_1 \sin \theta_2 \quad (5)$$

$$y_r = l_1 \sin \theta_1 + l_2 \sin \theta_1 \cos \theta_2 + l_2 \cos \theta_1 \sin \theta_2 \quad (6)$$

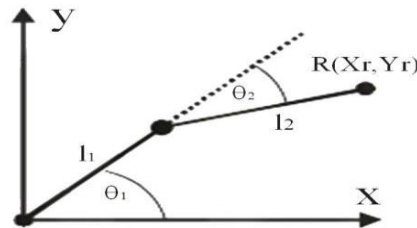


Figure 2. Manipulator 2 joint [5][7].

In inverse kinematics will be obtained [5][7] :

$$\theta_2 = \arccos \frac{(x_r^2 + y_r^2 - l_1^2 - l_2^2)}{(2 l_1 l_2)}$$

$$\theta_1 = \arctan \frac{y_r(l_1 + l_2 \cos \theta_2) - x_r l_2 \sin \theta_2}{x_r(l_1 + l_2 \cos \theta_2) + y_r l_2 \sin \theta_2}$$

3. Stages of making robotic arms

The stages of designing the arm robot are shown in figure 3 . Preparation of tools and materials as well as the mechanical design of the system were the first steps in developing a robot arm. The second step is the installation of a servo motor. The design of the servo motor 1 is different from the other servo because it has a gripper attached to the servo. This gripper is useful for grabbing the desired object. The scale for this design measure is used in units of millimeters (mm). The width of the opening that the gripper can do is 5.6 cm. This makes the Robot only able to grab objects with a size below 5.6 mm. Wrist servo motors (servo 2) have a servo design that is almost the same as servo 1, but it doesn't have additional devices like a gripper. The motor on the wrist plays a role in attaching the gripper. The servo base (servo 3) design is designed to be more robust and large than the other servo to be able to withstand greater loads. The shape of the servo 3 is like a box with the bottom cut off which serves as a place to place the robot . Especially for servo 3, 4 bearings are mounted on the round shaft to reduce the amount of friction when rotating. The next stage, the robot arm that is made requires a sensor to detect objects or objects that will be taken. The sensor used is the SRF04 Ultrasonic sensor so that it can be easily read by the Arduino microcontroller. The Arduino microcontroller has a support circuit that helps work from program operations. Sensor and servo circuits are connected to the microcontroller on certain pins. Testing of microcontroller program on the robot arm movement is the final stage of making a robotic manipulator arm [2].

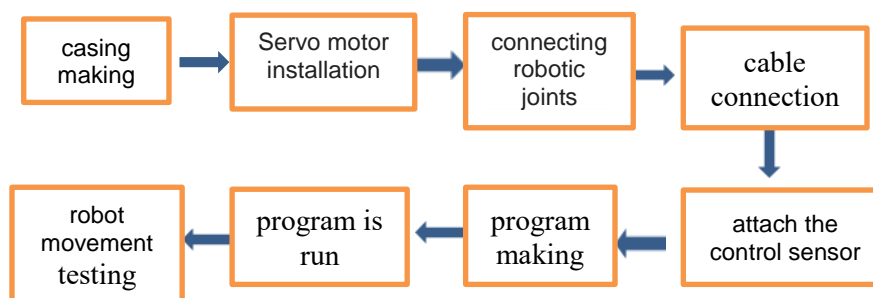


Figure 3. Stages of developing a robot arm.

3.1. Mechanical design

The manipulator robot that is made has a resemblance to the human arm. This robot has three rotation joints including a gripper. Where the rotation joint on the base becomes the base for the robot's shoulder. This robotic arm has the advantages of being able to take objects of certain size and weight and can perform spontaneous movements [8][9]. Detection of objects to be taken and moved by the robot using the SRF04 ultrasonic sensor.

The placement of the gripper on the end effector in figure 4 is useful for the robot arm to grab the object to be moved. The shape of the gripper is chosen to resemble claws, because this form is easy to design and has synchronous movements between the two parts of the claws. A pair of claws will give a balanced grip on the object being taken. The gripper cap makes it easier for the arm robot to grip the object well in vertical conditions [1][2].

In Figure 4 it is shown that the robotic arm is equipped with an Ultrasonic sensor which functions as a controller of robot movements. The placement of sensors in front of objects in a certain way makes the sensor can detect objects well.

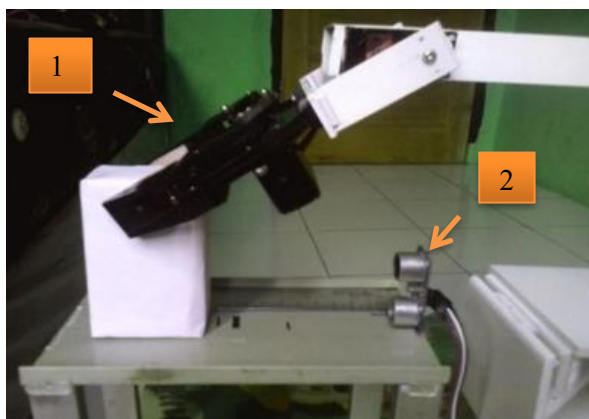


Figure 4. Mechanical of robotic arms show (1). Gripper; (2) SRF04 ultrasonic sensors

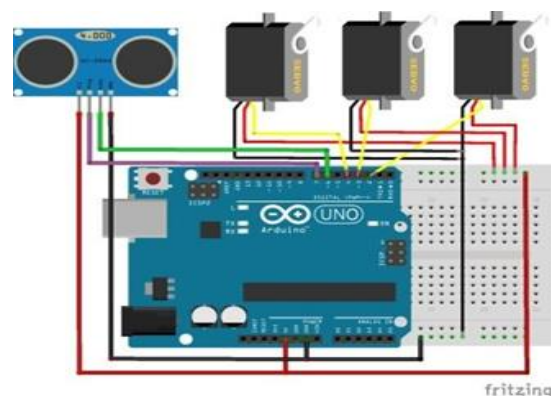


Figure 5. Servo series and robot sensors on Arduino

The Arduino microcontroller has a support circuit that helps work from program operations. The sensor circuit will be connected to the microcontroller at Pin 6 for the trigger and pin 7 to echo. while for servo motors there are pins 2,3, and 4. This sequence can be seen in figure 5.

3.2. System flow diagram

The program flow diagram for robot arms is shown in figure 6. The program is made with input in the form of values $d1, \theta_1, \theta_2$ and output in the form of end-effector position on the robot. Input values $d1, \theta_1, \theta_2$, are limited according to the configuration space of each joint [5]. If the sensor input value exceeds or is smaller than the specified distance, the program generates an error message. This system serves to determine the actual movements that occur in the manipulator and see the accuracy of the motion control system reaching the desired reference point.

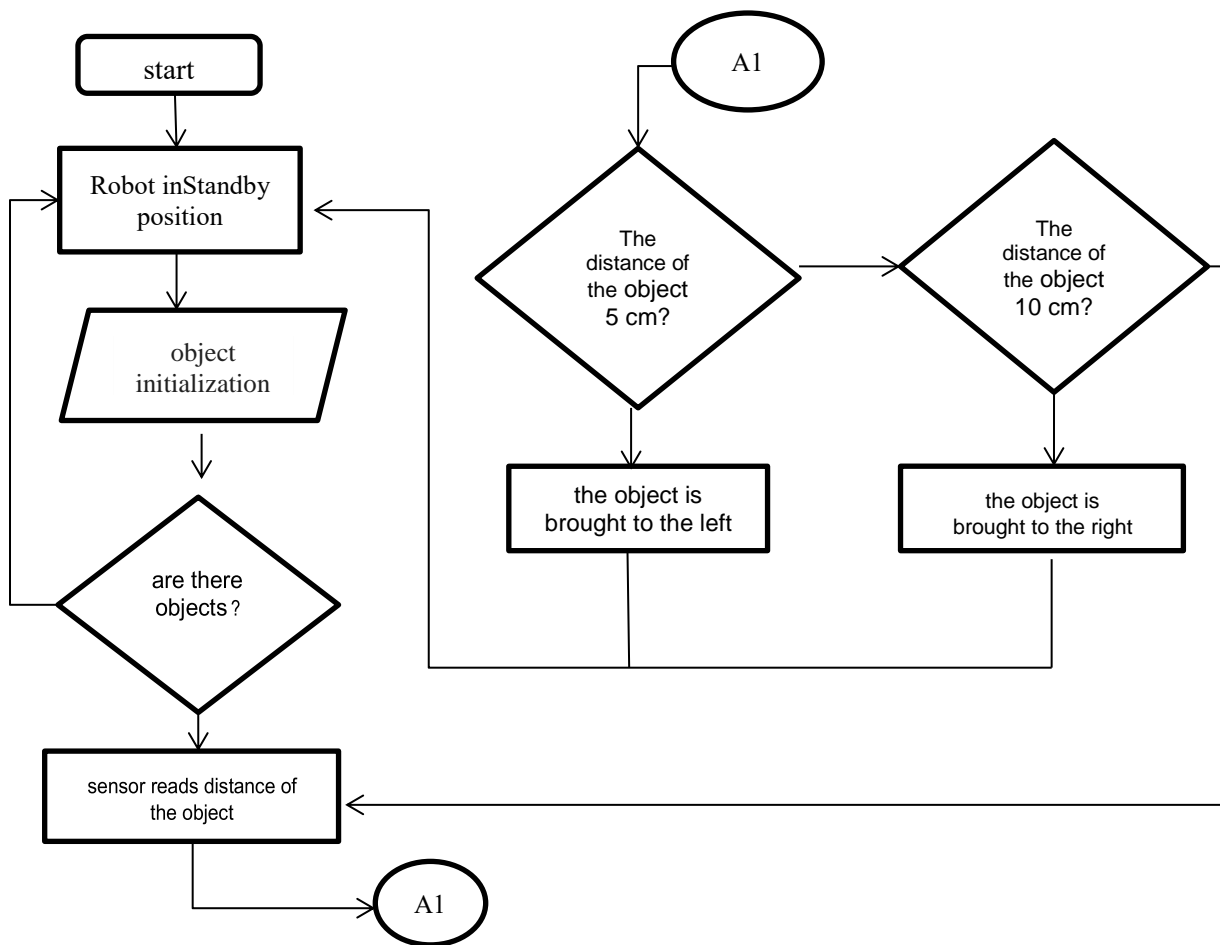


Figure 6. System flow diagram.

4. Results and discussion

Each servo has a pulse width limit to do circular motion with a certain angle. Maximum and minimum pulse widths are obtained from measurements when servo motors are installed. The results of measuring the maximum pulse width and the angle formed are shown in table 1. Table 2 shows the test results data entered in the program to provide the appropriate angle for each servo, so that the robot can perform movements to reach objects that have been specified without errors. The gripper grip is carried out nine times with different object objects. The results of this test are shown in table 3.

Table 1. Results of measurement of pulse width and servo angle

| No | Servo type | Max and Min pulse width values (uS) | Angle of rotation on servo (°) |
|----|---------------|-------------------------------------|----------------------------------|
| 1 | Servo gripper | 600 | 0° |
| | | 2400 | 180° |
| 2 | Servo wrist | 650 | 0° |
| | | 2500 | 180° |
| 3 | Servo base | 550 | 0° |
| | | 2600 | 180° |

Table 2 . Angle values for robot movements.

| No | Servo type | Angle of rotation on servo (°) | Information |
|----|---------------|----------------------------------|-----------------|
| 1 | Servo gripper | 20° | Pinch |
| | | 80° | Open |
| 2 | Servo wrist | 45° | Down |
| | | 90° | Up |
| 3 | Servo base | 83.° | Middle position |
| | | 130° | Right position |

Table 3. Test results of gripper grip on objects

| No | The form of the object being grasped | Object dimension (cm) | Object weight (kg) | Surface conditions of objects | Observation result |
|----|--------------------------------------|-----------------------|--------------------|-------------------------------|--------------------|
| 1 | Acrylic | 8.5 x 5 | 0,0617 | Slippery | Good |
| 2 | Plastic | 10 x 5 | 0,1263 | Rude | Good |
| 3 | Battery box | 4,5 x 2.5 | 0,0845 | Slippery | Good |
| 4 | Marker | 14 x 1 | 0,006 | Slippery | Good |
| 5 | Aluminium rod | 13 x 2 | 0,007 | Slippery | Good |
| 6 | Iron cylinder | 13 x 2.5 | 0,1332 | Slippery | Good |
| 7 | Big screwdriver | 4.5 x 3 | 0,0609 | uneven | Good |
| 8 | Medium screwdriver | 8,5 x 2 | 0,0293 | uneven | Good |
| 9 | Pilers | 16.5 x 5 | 0,0937 | uneven | Good |
| 10 | Wood | 10 x 5 | 1 | Rude | Good |

In this test the acquisition of ultrasonic sensor distance measurements with actual distance is used ruler per 10 cm to a distance of 300 cm. Testing based on the object color of the object being transferred, namely: black objects, white objects, glass, and objects that have uneven surfaces.

Table 4. Test results on robot movements.

| Distance of objects (cm) | Robot movement |
|--------------------------|----------------|
| 3 | Not moving |
| 4 | Not moving |
| 5 | Not moving |
| 6 | Not moving |
| 7 | Not moving |
| 8 | Move right |
| 9 | Not moving |
| 10 | Move left |
| 11 | Not moving |
| 12 | Not moving |
| 13 | Not moving |
| 14 | Not moving |
| 15 | Not moving |

The test results in table 4 , show the movement of the robot in accordance with the program made. The robot will move and move the object to the right if the object is at a distance of 8 cm against the sensor. And the Robot will move and move the object to the left if the object is at a distance of 10 cm against the sensor.

5. Conclusion

This paper presents the design of a 2 DOF manipulator robot prototype for the application of lifting and moving light material objects less than 5 cm with the help of a Gripper. The ultrasonic sensor as a detector for the presence of objects will give a signal to the Arduino microcontroller. Furthermore, the Arduino Uno controller is used to control the servo motor in combined motion and robot end-effector. The manipulator robot designed has the ability to move objects with a maximum weight of 1 kg.

References

- [1] Microchip.Sept/Okt 2018. The Power Of Two. Micro Solutions. A Microchip Technology Inc. Publication. www.microchip.com
- [2] Mohamed Fezari and Ali Al-Dahoud 2014 Easy Way to Learn Robotic Using Microcontrollers. Proceedings of the 2014 International Conference on Circuits, *Systems and Control* 100-105.
- [3] Qi A N W, Voon K L, Ismail M A, Mustaffa N and Ismail M H 2015 Design and Development of a Mechanism of Robotic Arm for Lifting Part1. *2nd Integrated Design Project Conference (IDPC)* (Pahang: Faculty of Mechanical Engineering, Universiti Malaysia)
- [4] Ismail M H, Qi A N W, Voon K L, Ismail M A and Mustaffa N 2015 Design and Development of a Mechanism of Robotic Arm for Lifting Part 5. *2nd Integrated Design Project Conference (IDPC)* (Pahang: Faculty of Mechanical Engineering, Universiti Malaysia)
- [5] Nurhakim H R 2010 The Motion Control System of Continuous Path Tracking Using Cubic Trajectory Planning On 4 DOF Robot Manipulator *Final Project of Electrical Engineering* (Depok: University of Indonesia)
- [6] Solichin A 2009 Design Of Robot Arm (Robotic Arm) with Manual Control Final Project (Bogor: Faculty of Fisheries and Marine Science, Bogor Agricultural Institute)
- [7] Budiharto W 2014 *Modern Robotics, Theory and implementation (revised edition)* (Yogyakarta: ANDI) 42-44
- [8] Pitowarno E 2006 *Robotics, Design, Control, and Artificial Inteligence* (Yogyakarta: ANDI)
- [9] Iqbal J, Islam R, Khan H 2012 Modeling and Analysis of a 6 DOF Robotic Arm Manipulator, *Canadian Journal on Electrical and Electronics Engineering* **3**(6) 300-306