Design and Analysis Robot Puzzle for Capacity 0.5 Kg

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Abstract. The industrial revolution 4.0 brought many changes to the manufacturing process. The use of robots in manufacturing is used to increase efficiency. One type of robot used is a robotic manipulator. Robot manipulators are robots that make up arms, and arms. The purpose of this study was to study puzzle assembling robots with a capacity of 500g. The robot is divided into five parts, namely the gripper, swing arm, standing beam, slide base, base X and base Y. Robots using Arduino UNO microcontroller as controller. The material used to approve the robot is the PLA which has the ultimate strength of 17,772 MPa. Robots are made with 3D printing methods. From the results of the design obtained several parts must have a cross section in order to be able to load the puzzle.

Keywords: Robot manipulator, Arduino uno, Assembling robot.

1. Introduction
The industrial revolution 4.0 brought many changes to the manufacturing process. The development of automatic machines or robots into the manufacturing process makes many companies competing to invest in industrial systems 4.0 where later to move a factory does not require a lot of human labour. In Indonesia, the development of robots has started a long time ago. The government has supported the development of this robot since the 80s with the establishment of a development laboratory. When compared with developed countries, Indonesia is still lagging behind. One contributing factor is the cost of implementing a robotic system is very expensive. The high cost required causes people are reluctant to learn it. There are several reasons that make the application of this robotic system expensive to implement, namely robots purchased from foreign companies or imported from abroad, the components used are also quite excessive if used to perform simple tasks. Therefore, we need prototype robot assemblers intended to move objects, robots are made in the country with components that are adapted to simple tasks. Where later this prototype can be applied in small and large factories and also this robot can also be used as a medium for vocational high school learning and this robot will later be applied to industrial systems 4.0.

2. Research Methodology
2.1 Preliminary Design
The design of static mechanics in the structure is carried out to determine the load sharing in the
robot structure. Understanding the robotics system and the workings of sensors, controllers and actuators. Before entering the layout, design stage and building tools. Puzzle beams are used as a parable of material to be assembled into products. As shown in Figure 1 below is a specification of the puzzle beam to be assembled.

![Figure 1. Block puzzle.](image)

The layout design is to place the blocks to be taken and the placement of the blocks. From this layout design can be obtained how to design the right robot manipulator to perform the task. In Figure 2 it is explained that part number one is where the beam is placed, while part two is where the assembling robot is in charge of moving the beam at number one to number three where the collection point is located.

![Figure 2. Layout Design](image)

2.2 Assembling Robot Design

In Figure 3 and table 1 the parts of robot assemblers and related components are explained. To simplify the explanation and calculation of robot component parts, it is divided into three components, namely gripper, swing arm, standing beam, sliding base, base X and base Y.

![Figure 3. Robot assemblers](image)
| Part Name       | Design                                                                 |
|-----------------|------------------------------------------------------------------------|
| Gripper         | ![Gripper](image1)                                                     |
| Swing arm       | ![Swing arm](image2)                                                   |
| Standing beam   | ![Standing beam](image3)                                               |
| Sliding base    | ![Sliding base](image4)                                                |
| Sliding base    | ![Sliding base](image5)                                                |
| Base Y          | ![Base Y](image6)                                                      |
| Base X          | ![Base X](image7)                                                      |

Table 1. Robot component
The manufacturing process begins with the supply of tools and materials needed. Then proceed with the process of making self-made components. Structural components that are self-made using the 3D printing engine. Then the following steps are carried out:

a. **Trial of Motion**
Motion testing is the stage of the experiment after making a robot. The robot is tried to be moved without using an actuator, it aims to determine the absence of errors in the assembly, manufacturing and calculation processes.

b. **Electronic Circuit Assembly**
The electronic circuit is assembled after completing mechanical robot manufacturing. Actuators are connected by jumper cables to Arduino Uno and sensors. Assembling robots use two servo motors, one nema 17 stepper motor, and three byj-25 stepper motors.

c. **Electric Test**
Electrical testing is carried out after all electronic components are connected. The purpose of this electrical trial is to determine the absence of errors in connecting cables.

d. **Programming**
At this stage the robot system is created by entering the program. Programming is done by Arduino IDE software. Figure 4 below is a system flowchart for the device to be made.

![Flowchart robotic system](image)

**Figure 4.** Flowchart robotic system.

Blog diagrams of the system created as described in Figure 5, where the sensors used in Arduino UNO have an important role, where the computer is used to design and programming to move the actuator.

![System diagram](image)

**Figure 5.** System diagram.
e. **Overall System Testing**

A trial of the whole system is carried out to show that the program created can be used to reach the target or not. This trial is done by moving the whole robot to carry out their duties.

### 3. Data Analysis and Discussion

Before making parts and assembling robots, it is necessary to have a design analysis of the carrying capacity of the robot mechanics design. Analysis is done on the manipulator.

#### 3.1 Mechanics Design

By considering the layout and process of taking material, a robot design is made as shown in Figure 6. To simplify the process of making a robot, it is made into several components and parts. Robot is broken down into several components.

![Figure 6. Assembling robot design.](image)

#### 3.2 Design of Part Gripper 3

Part gripper 3 function as a stepper R anchor which is connected to part gripper 1 and 2. Required calculation as a basis for design on part gripper 3 so that the robot is able to carry loads with a mass of 0.5 Kg. To simplify the calculation of parts connected to part gripper 3 made into one center of gravity. The emphasis of each part is sought with CAD software. Table 2 shows the results of the search for the emphasis on each part.

| Name | Part             | Result                                    |
|------|------------------|-------------------------------------------|
| M1   | Gripper 1        | $\begin{align*}
X &= -23.31 \\
Y &= -71.65 \\
Z &= 95.33
\end{align*}$ |
| M2   | Gripper 2 (1)    | $\begin{align*}
X &= 2.06 \\
Y &= -54.99 \\
Z &= 84.62
\end{align*}$ |
| M3   | Gripper 2 (2)    | $\begin{align*}
X &= -6.86 \\
Y &= -25.20 \\
Z &= 82.71
\end{align*}$ |
| M4   | Stepper G        | $\begin{align*}
X &= -7.72 \\
Y &= -52.61 \\
Z &= 86.50
\end{align*}$ |
Center of gravity calculation uses the center of gravity formula, shown in Figure 7 the size of part gripper 3 is used as the basis for calculation. Table 3 below is the result of the calculation.

Table 3. List of weight gripper 3.

| Name | Weight (gram) |
|------|---------------|
| M1   | 2             |
| M2   | 7             |
| M3   | 1             |
| M4   | 34            |
| M5   | 34            |
| M6   | 500           |
| Total| 578           |

Figure 7. Part gripper 3 to be counted

Figure 8. The center of gravity of the load connected to gripper 3
In Figure 8 explained related to determining the weight point of the load connected to the gripper 3. Analysis is carried out to determine the part that will receive the greatest moment, then the analysis is carried out using the equilibrium equation. In figure 9, it is explained the direction of the forces that occur in gripper 3 and also the calculated point A.

![Figure 9. Part gripper 3 and the shape of the crossbar](image)

The force calculation acting on point A uses the force and equilibrium equation. As shown in Figure 10 below. Analysis is done to determine the cross-sectional dimensions at point A because part A is the part that receives the greatest force. To determine the cross-sectional dimensions used the deformation equation and section modulus. Previously determined the allowable voltage using the safety factor equation.

![Figure 10. Moment Diagram and force on part gripper 3.](image)

Based on the material used is 3d print PLA with 25% infill, it is found that it has an Ultimate Strength of 17,772 MPa using a safety factor 5. Below is the result of the calculation of the cross-sectional dimension A where the value of b has been determined is 4, because the cross-sectional shape is square where the section modulus formula square so that the results are obtained. From these results it was determined that the shape of the cross-section A dimensions 4mm x 6.74mm. The results of calculations on the gripper part 6, swing arm and standing beam as shown in table 4.
below.

**Table 4.** The calculation results on part gripper 6

| No | Name                | Result            |
|----|---------------------|-------------------|
| 1  | Part Gripper 6      | 4mm x 16.34mm     |
| 2  | Swing Arm           | 15mm x 11.81mm    |
| 3  | Standing Beam       | 10mm x 15.58mm    |

3.3 Lift Load Calculation Results Servo Z

Based on the specifications, the data obtained from the Z servo motor has a torque of 11kg.cm if given a 6-volt voltage then to calculate the ability of the Z servo can be proven through calculations and as shown in Figure 11 below.

![Figure 11. Center distance with servo Z.](image)

From these results it can be concluded that the motor is able to lift the gripper component. To find out the maximum load on the Z servo motor with a distance of 93.09 mm.

4. Conclusion

Based on the results of the design of robot assemblers obtained the following results:

1. Robot is made into six components, namely gripper, swing arm, standing beam, slide, base Y and base X, each component consists of various parts that have their respective functions. Most parts are made using a 3D printing machine with PLA material which has an ultimate strength of 17,772 MPa.

2. To transport 500 grams of load A cross section dimensions at least part 3 of the square gripper with dimensions of 4mm x 6.74mm, on the gripper 6 with dimensions 4mm x 16.34mm, on the swing arm component dimensions 15mm x 11.81mm, and on the standing beam component dimensions 10mm x 15.58mm, the maximum load that can be lifted by servo Z with a force distance of 93.09 mm is 1.18165 Kg.

3. The assembly process lasts for 6 hours while the printing process lasts for 1 week. To be able to run a robot assembler required a maximum voltage of 6v which comes from the power adapter. The process of making the program lasts for 2 weeks. The program is created using Arduino IDE software.

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