Development of Two-Fingered Underactuated Robot Gripper using 3D Printer

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Abstract. This research present the development of a two-fingered underactuated robot gripper by using 3D printed machine with a material of Polylactic acid or PLA. The gripper design consist of two individual servo motors that drives the finger movement to perform a certain amount of grasping force. The new design of the finger using Solidworks was inspired by several existing robot gripper however with a low cost approach to obtain a good finger tracking and angular control. The fully fabricated and assembled gripper was then tested to determine the operation results during basic grasping and ungrasping by connected to Arduino Mega and MATLAB software. The angular data during the operation shows that the gripper successfully perform a stable operations despite some minor disturbance due to the mechanical defect on the servo plate. Further analysis will be conducted in the future in order to identify the full capability of the gripper in real world application such as force control operations.

Keywords: Robot Hand, Gripper, 3D printing, Grasping, Functional Needs Design

1.0 Introduction

Robotic application has been widely used in various industries to reduce labor cost by replacing human with robots in the production line since robot offer superior performance in terms of accuracy, precision, rigidity, and most importantly speeds. Robot arm are often used to pick and transport an object from one place to another. Since robot movement could cause fatigue, it may cause damage to the robot structure. Gripper is the main mechanism used to pick up an object. It is one of the incomplete parts from the robotic arm where it consists of shoulder, elbow and wrist. Grasping mechanism design has been the focus of several researchers in the field of robotics [1] [2] [3]. In addition to other existing limitation (such as backlash and frictions), a robot gripper grasp of an object are restricted within regular geometries [1]. Especially for 2 finger robot gripper where it has limited force that can be applied with limited shape to grasp. Designing gripper fingers properly can increase the work cell throughput, overcome robot inaccuracy and enhance overall system performance.
2.0 Background Review

In this section, useful components for this project such as the robotic gripper mechanism, sensors and actuators involved are explained in detail.

2.1 Underactuated Gripper Mechanism

In general, there are two types of robot gripper design which are fully actuated and underactuated as shown in figure 1 [4] [5]. The fully actuated designs tend to shapes like human hand (humanoid) where the underactuated design tend to look more industrial application [1].

![Figure 1. Robot Gripper Design](image)

For underactuated designs, a two finger grippers could perform optimally for a single specific task with small rectangular or cylindrical objects. However, it worth noting that this type of gripper has a geometrical limitations for grasping an object with a complex shapes [2]. Due to these limitations, researchers make an effort dedicated to the development of multiple finger underactuated robot hands/grippers. These devices tries to mimic one or more characteristics of the human hand [6]. The three-finger gripper has existed for some time, but only been widely used recently. In the future, robots are more flexible and will be able to handle wider range of tasks without changing its parts. The most common used gripper would be two finger gripper as it is easy to handle and operate and has a better grasping for parallel gripper.

2.2 Servo Motors

This is the most commonly used in actuators for the robot hand/gripper prototype. The motor is light weight and equipped with DC motor and gear system which allows it to produce a decent amount of torque (depending on the motor pricing). The servo motors are shown in figure 2.

![Figure 2. The DC Servo Motors](image)
3.0 Design and Fabrication

This section describes the overall method of the project including the robot design, setup testing and analysis. The design and development stage for the Robot gripper is shown in figure 3.

![Figure 3. The Design Process](image)

The 3D design and components of the gripper are illustrated in figure 4. The drawing consist of main component such as finger links and servo motor placement. The universal attachment lock was also considered in the design as this robot can be attached to any other design parts such as robot arm in the future [7].

![Figure 4. The Robot gripper 3D Design](image)

These main components that are important and directly affect the physical operation and properties of the grippers. The design also considered the potential force sensor placement on the gripper for the next stage analysis, however the results of the testing are not discussed in this paper. The fabrication process is shown in figure 5 where the completion of all parts took approximately 16 hours (using the Cura Ultimaker software). The material used was the Polylactic acid or PLA which is common material for prototyping.

![Figure 5. The Fabrication Stage](image)
4.0 Prototype Testing and Analysis

The hardware setup for the testing and analysis are shown in figure 6. Similar setup can be seen in [8].

![Hardware Setup](image)

**Figure 6.** The Hardware Setup for Testing and Analysis

Based on the test results, it was found that the gripper capable of moving within the $\theta_1$ and $\theta_2$ range of 25 degrees until 180 degrees as shown in figure 7. The $\theta_1$ and $\theta_2$ also represents the maximum and minimum opening respectively.

![Closing and Opening Angle](image)

**Figure 7.** The Actual Closing and Opening Angle ($\theta_1$ and $\theta_2$)

Moreover, the operation results for repeatable task between $\theta_1$ and $\theta_2$ (25º to 180º) for 30 seconds are shown in figure 8 below.

![Individual Finger Movement](image)

**Figure 8.** Individual Finger Movement Finger 1 (f1) and Finger 2 (f2)

Based on the results, there is not much difference for the angle range between desired position and the actual gripper position. However, the results at 4s and 8s shows the finger does not return to 25º due to the mechanical defect on the servo plate that hold the servo motor from returning to the original state. There are also minor fluctuation detected on Finger 2 (f2) due to frictions on the links.
5.0 Conclusion and Recommendation

The overall process which involve the product design, fabrication, testing and analysis has been successfully conducted in the development stage of the prototype gripper. The proposed new design has shown a promising results whereby it capable of performing grasping and ungrasping operation smoothly. The gripper maximum opening has been verified to the extent of $\theta_1 = 25^\circ$ while the minimum opening is $\theta_2 = 180^\circ$. The simple underactuated mechanism of the prototype were able to provide a decent grasping force for grasping operation. However, the topic of grasping force will not be discuss further in this paper. The design of universal attachment lock has also been developed to be used as attachment mechanism for further integration with robot arm. Nevertheless, further test will be conducted for this gripper such as the installment of force sensor, the measurement of grasping force and implementing force control during grasping operation.

6.0 References

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