Robotic Gripper With Force Feedback System

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Abstract. The aim of the project is to design an accurate responsive robot gripper that is capable of measuring the grasp force exerted on the object and varying its grasp force depending on the material of the object. A parallel gripper is used which is actuated by a servo motor. The force is measured by mounting the force sensor on one finger of the gripper and the current to the servo motor is measured by a load current sensor. Hence by combining the force measured with the load current consumption of the servo motor, a control system is designed which will help in adjusting the grasp force of the gripper.

1. Introduction

A gripper with force feedback and position sensing is discussed. This uses a closed loop position/force switching control strategy [1]. A parallel gripper has a tactile array sensor on one of its jaw, which provides the robot controller with force feedback signals [2]. A Force Sensitive Resistor (FSR) attached to one of the fingers of the grippers, which provides the force feedback to the controller. It helps the gripper in three different ways: one, senses if an object has been grasped successfully, second determine the co-efficient of friction of the object, and third prevent damage when the object will be grasped [3]. Force control of the gripper is achieved using armature current sensing as a means of detecting motor torque and hence the force applied between the gripper jaws [4-5].

Robotic grippers handle objects of various sizes and materials. The amount of force required to successfully grasp an object varies. Additionally, delicate items may need to be grasped carefully. In order to handle these delicate items a force sensor is mounted on one finger of the parallel gripper. The gripper is actuated by Mg996 high torque servo motor. The current to the servo motor is measured with the help of ACS 712 load current sensor [6-8]. In this paper, our aim is to design a control system for a parallel gripper using the FSR and the ACS 712 load current sensor. By combining the force measured with the load current consumption of the servo motor, a new control system is designed which will adjust the grasp force based on the material.

1.1. CAD Model

The Gripper assembly consists of a dual rack arrangement driven by a pinion connected to the servo motor. The jaws of the gripper are connected to their respective racks on the underside of the assembly and are fastened by screws. The 14 tooth pinion, when engaged with the rack provides a travel of 40.47 mm/rev of the servo shaft.
1.2. Force Sensor
The Force Sensing Resistor or FSR is an electronic component that converts force or pressure over the sensor area to detectable changes in resistance. The FSR consists of a layered sandwich-like arrangement, with the spacer separating electrodes and a sensing film. When force is applied, the layers come in contact with each other and the resistance changes according to the magnitude of stress. Connected to the Arduino microcontroller, the voltage measured by the analog I/O pin is inversely proportional to the force applied and the resistance. A sensor array must be used instead of a singular FSR. A single sensor was used for the purpose of the experiment. The typical Force versus Resistance characteristic for FSR used is linear in nature past the activation threshold or the minimum force required to register on the sensor.

![Figure 1. CAD Model.](image1)

![Figure 2. Resistance Vs Force response.](image2)

1.3. ACS 712 Load Current Sensor
The ACS712 current sensor works on the principle of the Hall Effect. The current to be sensed flows through an internal conductor and a magnetic field is generated. The intensity of this magnetic field is directly proportional to the magnitude of the current and the Hall effect sensor produces an output voltage.

1.4. Servo Motor
The servo used for electromechanical actuation is an MG996R metal gear servo motor. This motor was chosen because of its durability and high stall torque (11 kgf.cm maximum). The high torque will ensure that the gripper will be able to grasp objects with a higher maximum force exerted. A servo is usually comprised of a motor, a position sensor (for feedback) and relevant control electronics.
2. Experimental Work

2.1. Working
The 3D printed rack and pinion parallel configuration gripper is driven by an MG996R servo motor. The pinion gear is fitted onto the servo shaft and the rack is connected to the movable jaw using bolts and nuts. When the program starts, the gripper moves to its original opened position to reset any previous position change. Then, the Servo is made to move in step durations of 15ms per degree, slowly closing on itself and reducing the distance between the jaws. When the object begins to get pressed between the jaws, force will be exerted on the sensor attached to the stationary gripper jaw. Because of the strain exerted on the Servo internals, the current consumption of the servo will also rise. If the value rises above a certain, predefined acceptable threshold, then the servo rotation stops and the gripper holds the object in place.

![Gripper](image)

Figure 3. Gripper.

2.2 Circuit Diagram
The circuit consists primarily of an Arduino microcontroller that reads and processes sensor data from the sensors used and sends appropriate signals to the servo motor. The Force Sensitive Resistor is used to detect when an object is pressed against the side of the jaw. The ACS712 load current sensor detects changes in the current consumption of the servo when the gripper assembly is strained. The microcontroller compares these signals to presets and decides whether to stop the gripper motor or not.
2.3 Servo Modification
A break was made in the connection between one motor terminal and the internal control circuit. Two long wires were soldered to these ends and drawn out through the body of the servo. By connecting these live wire ends to the ACS712 Load current sensor, the current draw of the motor can be measured. A single motor terminal's connection to the control circuit is intercepted and passed through the ACS712 current sensor.

2.4 Code Implementation-Steps
The variables are declared initially. Important parameters here include the Servo gripping parameters, i.e. the open and closed angle of the servo-gripper arrangement. The sensitivity of the load current sensor is also mentioned, and the value must be changed for different models of the sensor. The force sensor threshold should be changed according to the object that needs to be gripped. The setup subroutine assigns the pin numbers and resets the gripper to its open position. The loop subroutine contains the main code. The gripper, after being reset starts to close in on the object slowly. For every degree that the servo rotates, we read the force and load current value and compare it to the threshold. The gripper keeps closing until either the force value
exceeds a certain amount, or the servo reaches its maximum angle.

2.5. Load Current Sensor Code

The VCC terminal input from the Arduino to the ASC712 is 5V. When there is no current flowing through the IP+ and IP- terminals, the output voltage at VIOUT of ACS712 is 2.5V. This means that 2.5V must be subtracted from the voltage measured at the analog pin. Now, in order to calculate the current, the value must be divided by the sensitivity of the sensor given in millivolts/Amps. (185mV/A for 5A Sensor, 100mV/A for 20A Sensor and 66 mV/A for 5A Sensor).

Code snippet:

```c
adcValue = analogRead(currentPin); adcVoltage = (adcValue / 1024.0)*5000;
currentValue = ((adcVoltage - offsetVoltage) / sensitivity);
```

3. Conclusion

The components of the robot gripper were printed and assembled. The force and load currents sensor for measuring the necessary parameters are integrated into the gripper arm and servo motor. The readings were taken on an aluminium cube of side 1cm that was chosen to cover the surface of the force sensor. Force and load current readings are measured as feedback and the results obtained are used to stop the gripper motion based on predefined values and provide parameters for further improvement of the design. When compared to a single force sensor configuration, this method provides better feedback and force regulation.

4. Reference

[1] Chen W, Qu, J, Chen W and Zhang J 2017 A compliant dual-axis gripper with integrated position and force sensing Mechatronics 47 105-115
[2] Fiorillo A S, Dario P and Bergamasco M 1988 A sensorized robot gripper Robotics and Autonomous Systems 4 49-55
[3] Kumar R, Mehta U V and Chand P 2017 A Low Cost Linear Force Feedback Control System for a Two-fingered Parallel Configuration Gripper Procedia computer science 105 264-269
[4] Tedford J D 1991 Design of a robot gripper with force feedback control Mechatronics 1 311-319
[5] Chan K C and Cheung N C 2001 Grasping of delicate objects by a novel two-finger variable reluctance gripper Conference Record of the 2001 IEEE Industry Applications Conference. 36th IAS Annual Meeting 3 1969-74
[6] Chen C H 2013 Force controlled robot gripper with flexible joint for delicate assembly task 13th International Conference on Control, Automation and Systems (ICCAS 2013) IEEE 935-939
[7] Tabassum M and Ray D D 2016 Force Sensitive Robotic Gripper In CAD/CAM, Robotics and Factories of the Future Springer 569-578
[8] Kim G S 2007 Development of a three-axis gripper force sensor and the intelligent gripper using it Sensors and actuators A: Physical 137 213-222