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Feedback Based Three Finger Robotic Gripper

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Abstract

This research presents the development and validation of a novel three-finger robotic gripper system enhanced with force feedback capabilities. Leveraging Force-Sensing Resistor (FSR) sensors and servo actuators, the gripper is engineered to dynamically adjust its grasp based on real-time force feedback. Through a series of iterative design iterations and experimental validation, the gripper demonstrates robustness and adaptability in various gripping scenarios. The integration of force feedback allows the gripper to autonomously modulate grip strength, ensuring both secure object manipulation and protection against excessive force exertion. Performance evaluations conducted showcase the gripper's ability to achieve precise and stable grasping of objects with diverse shapes, sizes, and materials. The incorporation of force feedback enables the gripper to independently adjust its grip strength, guaranteeing safe object handling and defense against overuse of force. Tests of performance demonstrate how well the gripper grasps objects of various sizes, shapes, and materials with accuracy and stability. the development of robotic manipulation systems through the addition of a tactile feedback mechanism that improves industrial and collaborative robotics applications' operational efficiency and safety. The gripper can adapt to changing environmental conditions and object properties thanks to its dynamic grasp adjustment in response to real-time force feedback. This feature enhances overall performance and reliability in a variety of operational settings. This research contributes to the advancement of robotic manipulation systems by introducing a tactile feedback mechanism that enhances both operational efficiency and safety in industrial and collaborative robotics applications.

Keywords: FSR, PWM, servo actuator, robotic gripper, SLAM

INTRODUCTION

Robotic manipulation systems are critical in various industries, necessitating precise and adaptable object handling. Traditional grippers often lack the ability to adjust grasp dynamically, limiting their effectiveness. Integrating haptic feedback, particularly via Force-Sensing Resistor (FSR) sensors, offers a promising solution to this challenge [2].

This research focuses on developing and validating a three-finger robotic gripper enhanced with haptic feedback [3], using FSR sensors and servo actuators. By continuously monitoring finger forces and adjusting grip strength, the gripper aims to achieve stable and secure object manipulation [4]. This study investigates the gripper's effectiveness across diverse object types and explores its potential applications in industrial automation and collaborative robotics. This study's experimental validation phase entails extensive testing of the gripper enhanced by haptic feedback on a variety of object geometries, sizes, and materials. The quantitative assessment and analysis of the gripper's performance metrics, such as precision, adaptability, and stability during grasping, is done through a systematic evaluation. The study also

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looks at the haptic feedback-enhanced gripper's possible uses in industrial automation settings, where accurate and dependable object manipulation is crucial for streamlining production lines and raising output. Its applicability for collaborative robotics applications is also examined, taking into account its capacity to guarantee safe human-robot interaction by adjusting grip strength in response to changing task requirements and environmental conditions [7]. Overall, this research contributes to advancing robotic manipulation technology by introducing a tactile feedback mechanism [5] that enhances gripper versatility, safety, and efficiency.

ROBOT CONFIGURATIONS

1. Block Diagram (Figure 1)
2. DOIT DEVKIT V1 ESP32 Development Board (Table 1).
3. Servo motors-(Table 2).
4. FSR sensors-(Table 3)

METHODOLOGY

System Design and Hardware Implementation

Defining the size, materials, and actuation mechanisms of the three-finger robotic gripper's design. Choosing the right parts, including microcontrollers, communication modules, Force-Sensing Resistor (FSR) sensors, and servo actuators. Creating simulations and CAD models [6] in order to verify the gripper design and make sure it works with the planned application scenarios. Using 3D printing or machining to fabricate the gripper prototype and integrating servo actuators and FSR sensors into the finger constructions.

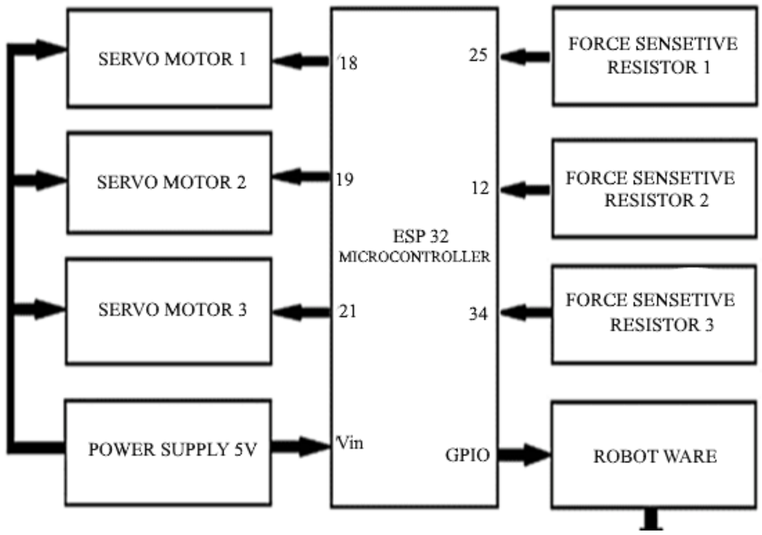

Figure 1. Robotic gripper block diagram.

Table 1. Specifications of DOIT DEVKIT V1 ESP32 development board.

Parameter	Value
Operating Voltage	3.3V
Input Voltage	5-12V
Digital I/O Pins (DIO)	25
Analog Input Pins (ADC)	6
Analog Output Pins(DAC)	2
Flash Memory	4 MB
SRAM	520 KB
Clock Speed	240 MHz

Table 2. Specifications of servo motors.

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Parameter	Value
Dimension	40mm x 20mm x38mm
Torque	4kg-cm at 6V
Stall current	900m A
Operating voltage	4.8V to 6V
Motor weight	50gms
Operating speed	0.33sec/60 degree
Temperature range	20°C to 55°C

Table 3. Specifications of FSR sensors.

Parameter	Value
Size	18.29mm diameter
Active Area	12.7mm
Force Sensitivity Range	0.1 - 10.02 Newtons
Stand-Off Resistance	>10M Ohms
Resistance Range	10 M Ohms to 1K Ohms

Sensor Calibration and Calibration Validation

A variety of calibration techniques are covered, ranging from more sophisticated approaches like bundle adjustment and simultaneous localization and mapping (SLAM) to more conventional methods like geometric calibration and parameter estimation. The study also examines new developments in sensor calibration, including self-calibration algorithms and automated calibration processes made possible by AI and machine learning. To determine the correlation between applied force and sensor output, calibrate the FSR sensors. Validation experiments are being carried out to confirm the precision and dependability of the sensor calibration throughout the anticipated force range. Putting in place error-handling procedures to take into consideration any variations or irregularities in sensor readings when the system is in use [8-11].

Control Algorithm Development

Creating control algorithms that, in response to input from FSR sensors, adjust each finger's grip strength. Use closed-loop control systems to dynamically modify grip strength in reaction to modifications in the characteristics of the item or outside disturbances. Reduce response time and energy usage while maximizing gripper operation stability and smoothness by optimizing control parameters.

Algorithm

Initialization

- Define servo objects for each finger.
- Assign FSR sensor and potentiometer pins.
- Set force limits for each finger.
- Start serial communication.

Setup

- Attach servos to respective pins and set initial positions.
- Configure FSR sensor pins as inputs.
- Configure potentiometer pins as inputs.

Main Loop

- Read user input from the serial monitor.
- If input is 1:

- Print "Starting operation in 2 seconds..." to the serial monitor.
- Wait for 2 seconds.

Force Feedback and Gripper Movement

- Read force sensor values for each finger.
- While force limits are not reached for any finger:
- Move each finger incrementally.
- Limit the maximum position to 160 for each finger.
- Update force sensor values continuously.
- Print force sensor values to the serial monitor.

If user Input is 2

- Set servo positions to 0 for all fingers, stopping the operation[13].

Experimental Setup and Performance Evaluation

Established test conditions to evaluate the gripper's effectiveness in handling a range of objects, such as grabbing, lifting, and releasing objects of varying dimensions and compositions.

Creating test procedures to measure important performance indicators such response time, repeatability, precision, and grasping force. use both real-world items and standardized test objects that are indicative of the intended application domain when conducting experiments. Utilized suitable sensing and measurement methods to record experimental data, guaranteeing precision and repeatability of findings [14].

RESULTS

Sensor Calibration and Validation

Across the designated force range, the calibration of the Force-Sensing Resistor (FSR) [1] [12] sensors revealed a strong linear relationship between applied force and sensor output voltage. The sensor calibration's accuracy was validated by validation studies, which showed minimal differences (<5%) between the force values seen and those predicted across a range of force levels.

Gripper Performance in Object Manipulation Tasks

Cylindrical, cuboid, and irregularly shaped objects were among the many shapes, sizes, and materials that the gripper system was able to successfully grasp and control. For every kind of object, performance measures including grasping force, accuracy, and repeatability were measured. When handling objects [9] with different surface textures, the gripper showed resilience and adaptation, producing stable grasps free from damage or slippage (Figures 2 and 3).

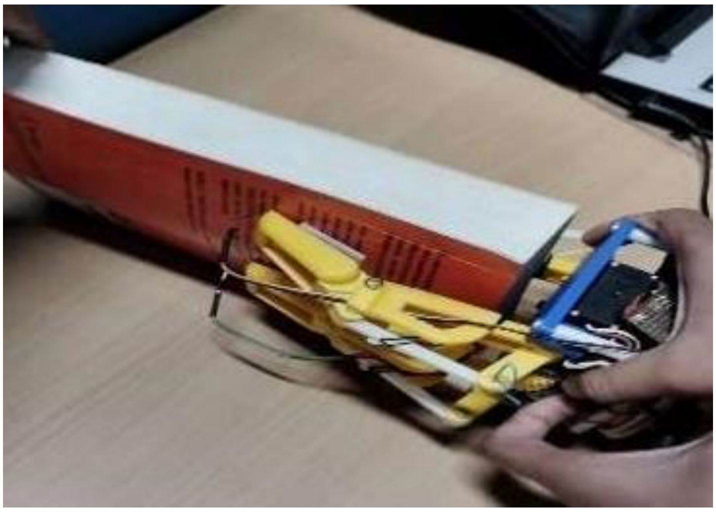

Figure 2. Successfully lifting textbook with gripper picture courtesy. DIAT, Pune.

Figure 3. Successfully lifting bottle with gripper.

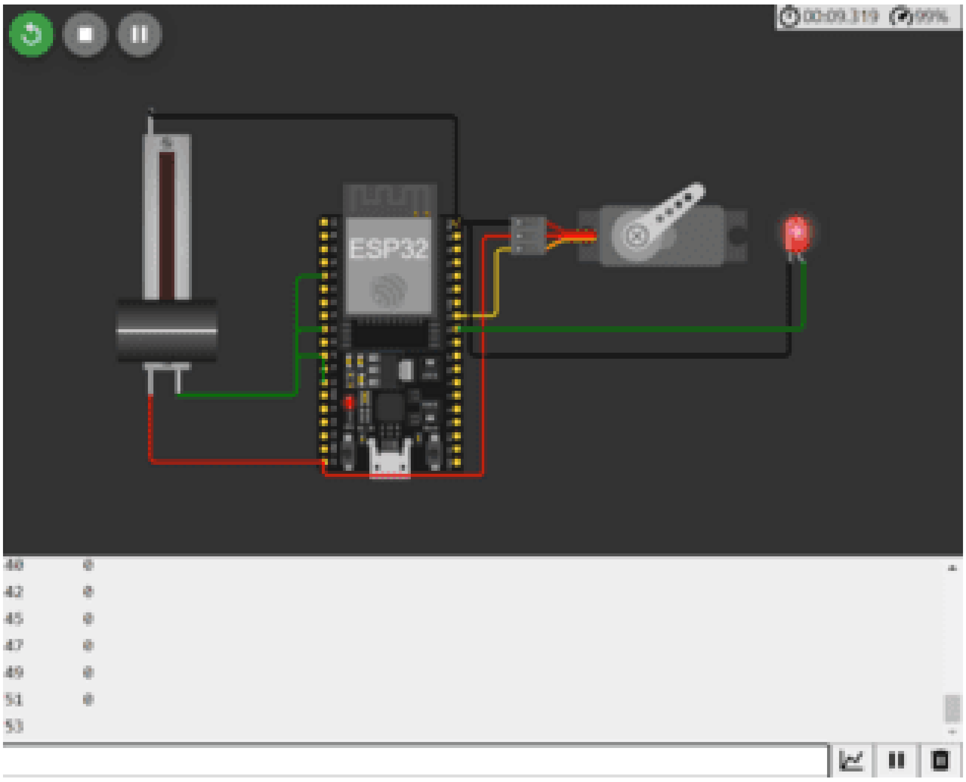

Figure 4. Servo position incrementing by 4 units before contact is made.

Dynamic Grip Adjustment and Response Time

Closed-loop control algorithms enabled the gripper to adjust grip strength dynamically in response to changes in object properties or external disturbances. Response time measurements indicated rapid adaptation of grip strength, ensuring timely and precise object manipulation.

Simulation

Below are the simulation results for the above algorithim on wokwi online simulation platform (Figures 4 and 5).

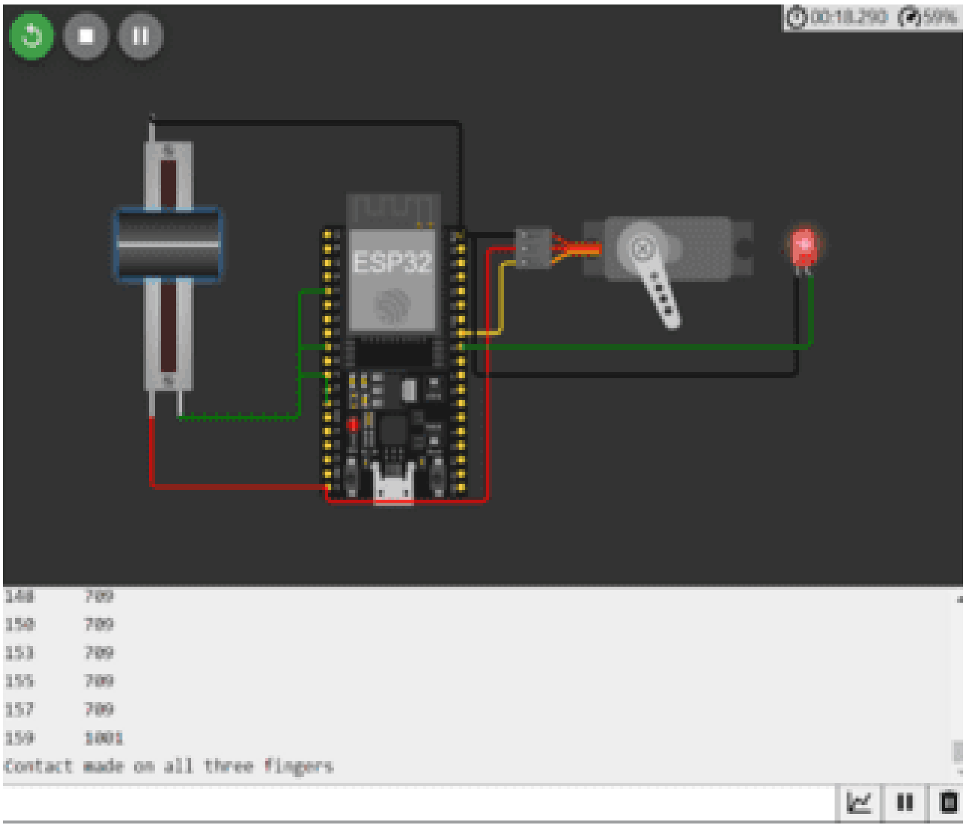

Figure 5. Servo stopped moving after force limit is reached.

CONCLUSION

This project's responsibilities included creating a force-feedback, three-finger robotic gripper that uses servo actuators and FSR sensors for effective object manipulation. The gripper was created to hold things until they made contact and force feedback was detected. This design demonstrates a methodical approach to improving the capabilities of robotic manipulation.

By using FSR sensors, the gripper showed enhanced environmental sensitivity, allowing for flexible and adaptable interactions with different objects. The servo actuators were essential in enabling accurate and regulated finger movements, which enhanced the gripper's overall dexterity and efficiency when grabbing objects.

Including heptic feedback, in particular the force feedback in real-time upon contact with objects, gave important insights into the forces that interplay between the grabbed object and the gripper. This enhanced the grasp's stability and created new opportunities for applications needing deft and subtle manipulation.

In conclusion, the work completed resulted in the development of a robotic gripper that is feedback-based and has improved sensitivity, precision, and flexibility. The inferences made from these assignments demonstrate the gripper's potential for use in a variety of industries, such as manufacturing, logistics, and healthcare.

In the future, our research will focus on improving control algorithms to maximize the gripper's performance, integrating machine learning methods for adaptive learning, and investigating new sensory modalities to increase its range of applications. The project establishes the groundwork for future developments in robotic manipulation technology, which might be used to more specialized and sophisticated activities in the field of robotics as it develops.

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