Analysis of Grasping Force of Random Selected Objects for Children Robotic Prosthetic Arm

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Analysis of Grasping Force of Random Selected Objects for Children Robotic Prosthetic Arm

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Abstract: *This study focuses on the development and evaluation of a 1 Degree of Freedom (DOF) 3D-printed prosthetic hand specifically designed for pediatric users. The goals of this study are three: to develop an operating prosthetic hand appropriate for children, to compare its grasping force ability with an assortment of objects. Experiments involved testing the prosthetic hand's grasping performance using distinct objects. Results indicated that object attributes significantly influenced variations in applied force.*

Keywords: 3D-printed prosthetic hand; grasping force evaluation; control, precision grasp.

1. INTRODUCTION

Prosthetic robotic arms have changed the face of assistive technology, providing persons with amputation or limb differences greater autonomy and function in everyday activities. Such advanced devices improve the quality of life by permitting the user to perform a vast range of activities that were difficult or impossible earlier. The technology of 3-D printing has contributed significantly to this progress by enabling prosthetic limb customization as accessible, efficient, and affordable. The technology offers the capacity to customize prosthetics to fit unique anatomical characteristics, bridging the main barriers such as financial constraints and the lack of skills in manufacturing quality prostheses [1,2]. Therefore, 3-D printed prosthetic limbs are an important development for the widespread provision of high-standard prosthetics [3, 4]. One of the most critical characteristics of prosthetic robotic arms is the ability to hold objects of varying shapes and sizes securely. The grasp force of these arms determines their dependability, usability, and convenience to the user. Insufficient grasp force can lead to slippage or objects that fall off, limiting user activity and frustration. Conversely, excessive grasp force can damage fragile objects or cause discomfort to the user. It is therefore important to maximize the range of grasp forces for different objects for successful design. Myoelectric prosthetic systems, which are founded on biological signals to control limb movements, play a key role in making this aspect feasible. Electrodes monitor muscle action potentials, while sensors in the created socket identify electrical signals to operate the prosthesis [2]. This integration of biological and mechanical systems offers enhanced usability and user satisfaction [5,6]. Slippage, or unwanted downward movement of a grasped object along the vertical axis while the arm posture is horizontal, is the most critical issue in prosthetic hand design. Detection and prevention of slippage are crucial to developing more stable prosthetic hands. Technologies such as tactile sensors, adaptive grip control algorithms, and surface texture analysis enable the detection of slippage in real time and its prevention [6,7]. These mechanisms enable steady object manipulation in dynamic conditions, such as consuming water or spilling a cup, even in the case of external disturbances [9-11]. Prevention of slippage is important to allow a good hold and to provide confidence to users about the stability of the prosthetic arm. Several studies emphasized the need for measuring grasp force and designing improved control systems to prevent this. As an example, adaptive sliding mode control techniques have been proposed for prevention of slippage while minimizing object deformation during grasping simultaneously [9,12]. Besides, tactile sensing in force control for grasping has been shown to be more stable and responsive to different objects [13,15]. Utilizing stringent testing with varying volume, weight, and physical properties objects, this study aims to further improve the understanding of grasp force requirements and performance of measures for preventing slippage in prosthetic robotic arms. By analyzing such factors, we aim to improve the ongoing advance of assistive technology, the end result ultimately being the increasing functionality and user-friendliness of prosthetics. This in-depth review will provide valuable information on how prosthetic arm designs can be enhanced, thereby enhancing the quality of life of the users [3,15].

2. DEVELOPMENT OF THE PROTOTYPE

The Arduino Mega acts as the central control unit, processing input signals from the sensors and generating appropriate output commands for the servos and display. The connections are implemented using a breadboard for prototyping, with proper routing of power, ground, and signal lines. Such arrangements are extensively used in advanced prosthetic systems to ensure control and adaptability under practical conditions [2,7].

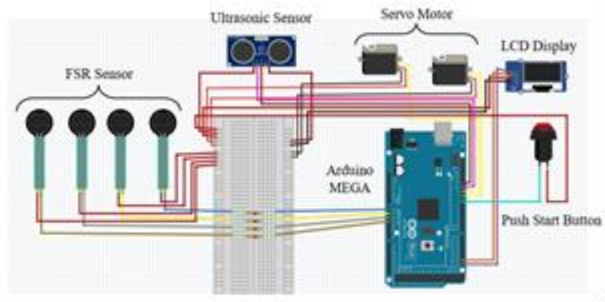

Fig. 1. Circuit diagram.

The Fig 1. is a circuit diagram of a prosthetic hand control system with an Arduino Mega microcontroller and the system has different components: force-sensitive resistor (FSR) sensors, ultrasonic sensor, servo motors, LCD display, and push-button. The FSR sensors are used to detect the variation in force or pressure applied, serving as input signals to the servo motors. The ultrasonic sensor provides obstacle sensing or distance measurement, enhancing the prosthetic hand's functionality. The servo motors are connected to mimic finger action by driving the mechanical parts of the prosthetic hand. The LCD display provides real-time system operation or reading feedback, while the push-start button turns the system's operation on.

3. RESULT AND DISCUSSION

The hand is positioned horizontally to grasp the object by its edge to edge in the experimental setup for experiment comprehension. Three wooden object shapes—cylinder, rectangular, and cube—with pinch grasps that can only be grasped with the thumb, index, and middle fingers have been chosen for these experimental projects. The results of the experiments as below:

3.1 Experiment 1

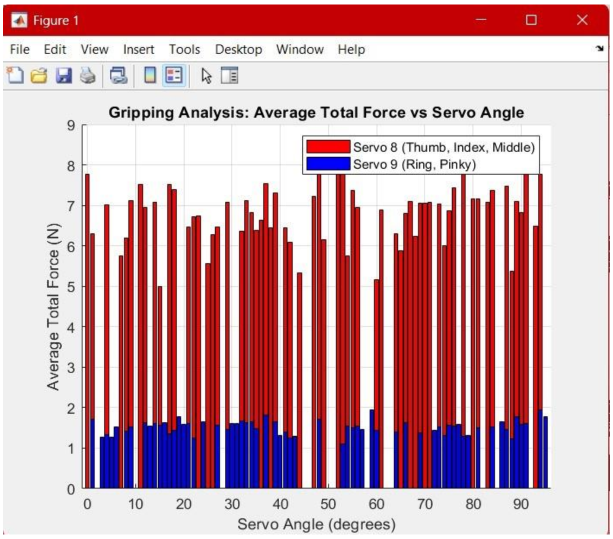

Fig. 2. Gripping analysis (plastic cylinder).

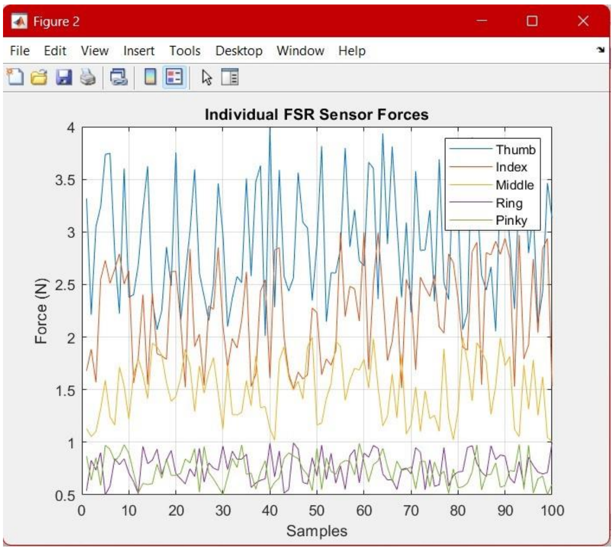

Fig. 3. FSR sensor analysis data (plastic cylinder).

3.2 Experiment 2

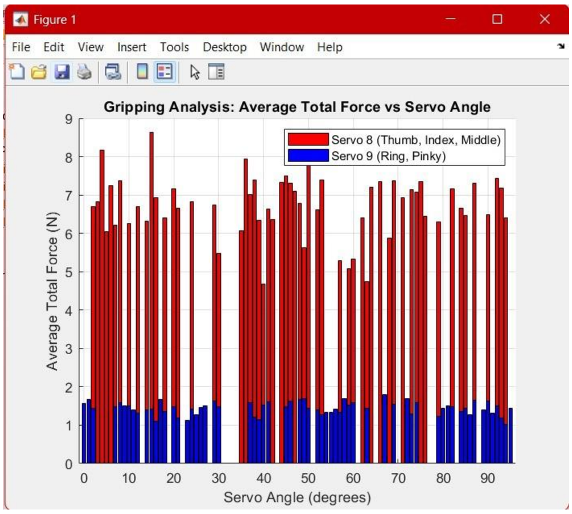

Fig. 4. Gripping analysis (wooden cylinder).

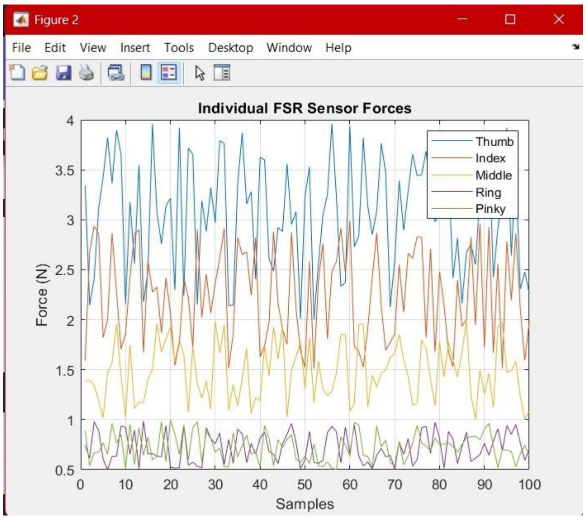

Fig. 5. FSR sensor analysis data (wooden cylinder).

3.3 Experiment 3

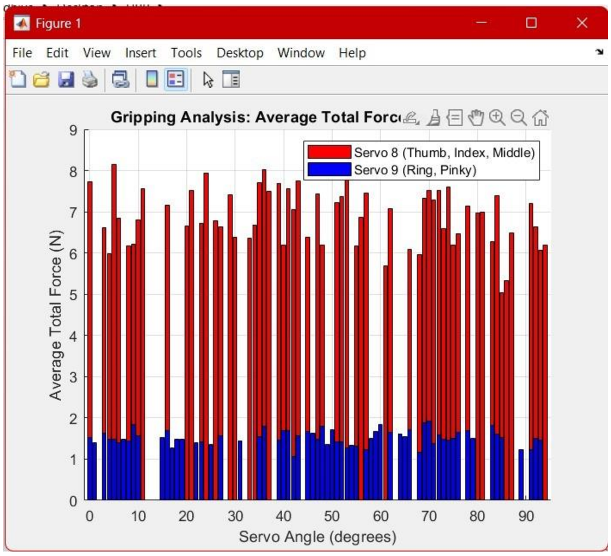

Fig. 6. Gripping analysis (plastic cuboid).

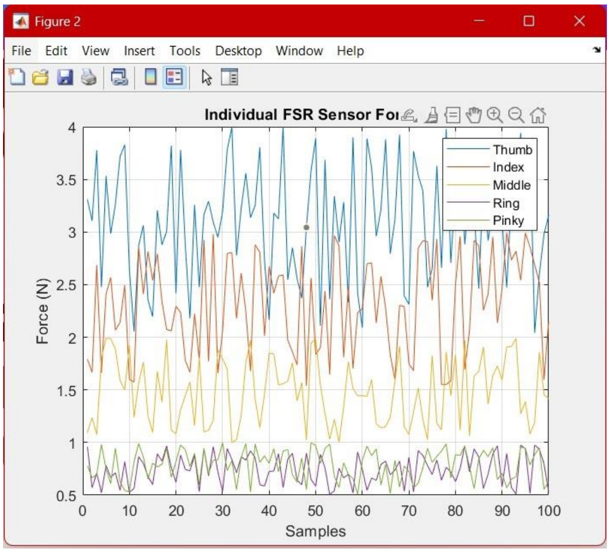

Fig. 7. FSR sensor analysis (plastic cuboid).

3.4 Experiment 4

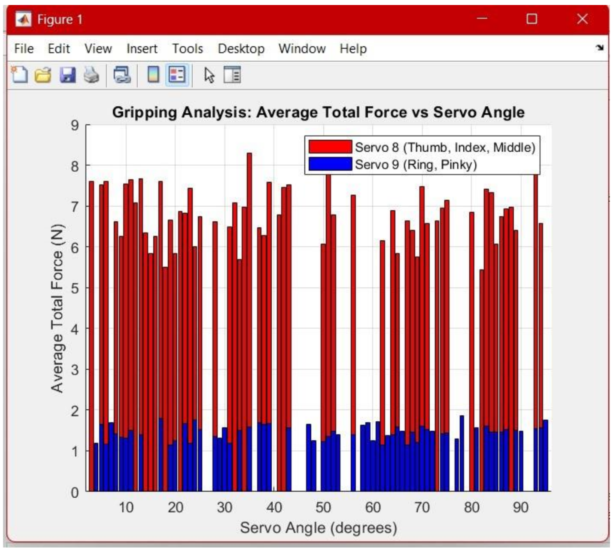

Fig. 8. Gripping analysis (wooden cuboid).

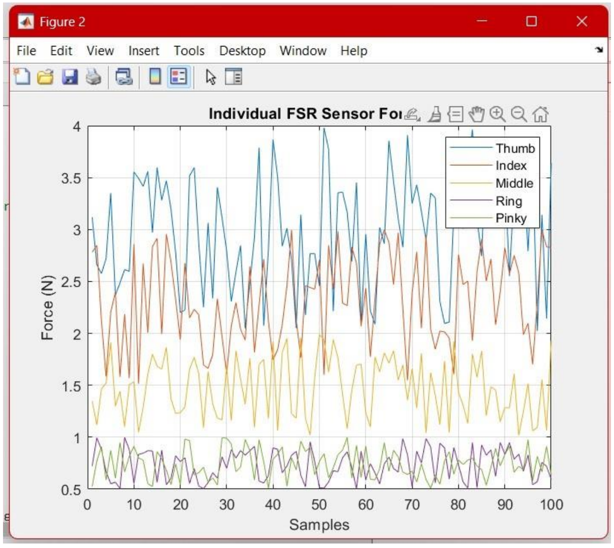

Fig. 9. FSR sensor analysis (wooden cuboid).

3.5 Experiment 5

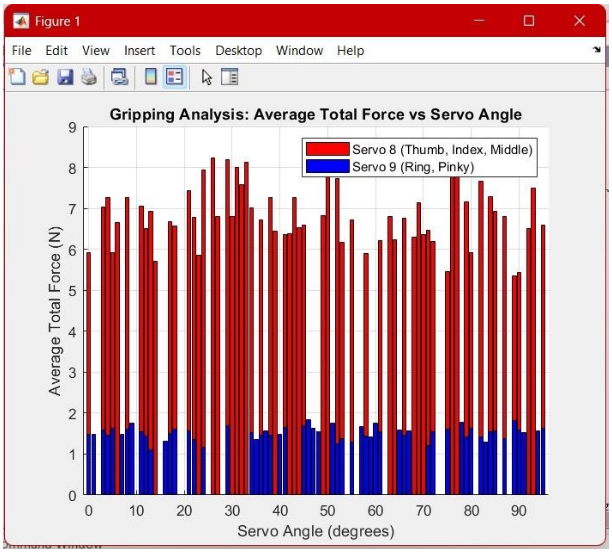

Fig. 10. Gripping analysis (plastic cube).

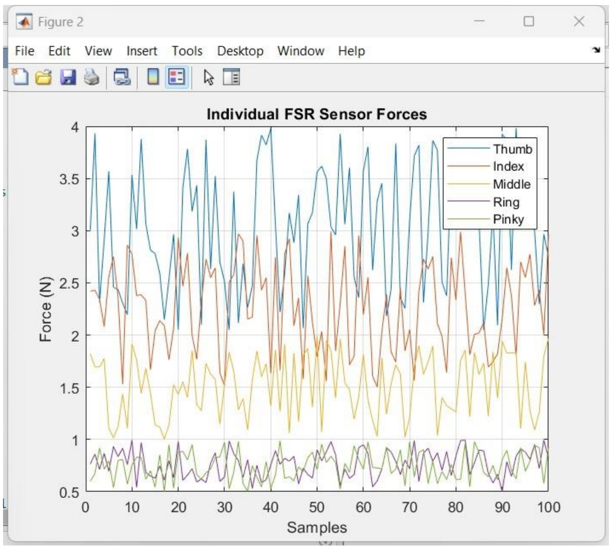

Fig. 11. FSR sensor analysis (plastic cube).

3.6 Experiment 6

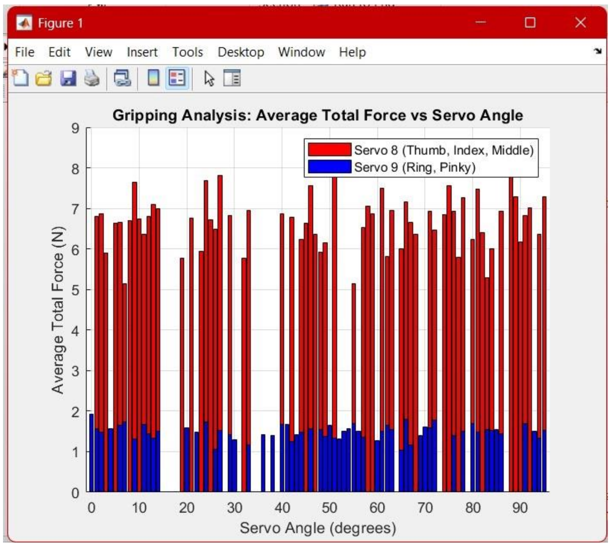

Fig. 12. Gripping analysis (wooden cube).

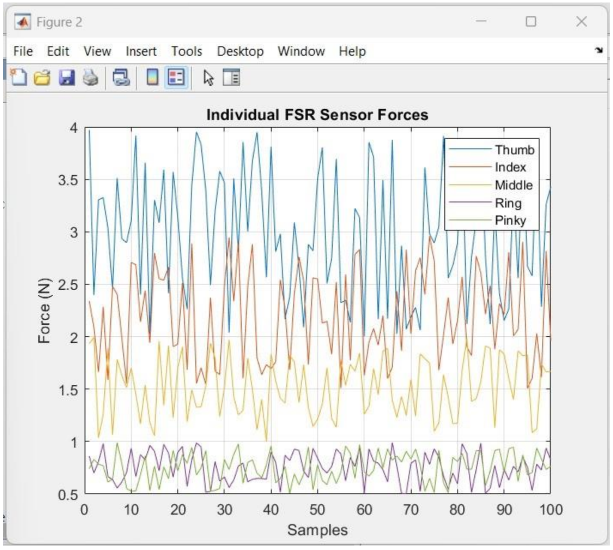

Fig. 13. FSR sensor analysis (wooden cube).

4. CONCLUSION

In summary, this research documents the design and execution of an economical robotic prosthetic arm intended for children with disabilities. The prosthetic robotic arm is designed to enhance mobility, assist with daily tasks, and promote greater independence, particularly for those with financial limitations. Utilizing 3D printing technology, the arm is produced at a lower cost compared to existing market options. A compact microcontroller alongside a force sensor controls the prosthetic arm and detects muscle flex activity, allowing for accurate object grasping. The test results indicate that the prosthetic arm is able to grasp objects of arbitrary shape weighing up to 26 grams, but further improvement is required in grasping different materials as well as both normal and irregularly shaped objects. The proposed prototype demonstrates the possibility of a low-cost prosthetic robotic arm and provides information about the grasping force of some normally shaped objects. These results show favorable improvements in disabled children's quality of life. However, the development and further research are still needed to advance the arm further to grasp and learn in situations such as pick-and-place training and object localization to render the prosthetic robotic arm more feasible.

5. ACKNOWLEDGEMENT

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