TuijinJishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 6 (2023)

The Bionic Robot Thumb's MATLAB/Simulink-Based Design Features an Electromyography Smart Sensor

M. Nalini[1*], V. Sakthi Visagan[2], S. Sanjay[3], A. Sripathy[4], B. Sriranjan[5]

[1] *Department of Electronics and Instrumentation, Sri Sai Ram Engineering College, West Tambaram, Chennai, Tamil Nadu, India.*

[2, 3, 4, 5] *Student, Department of Electronics and Instrumentation, Sri Sai Ram EngineeringCollege, West Tambaram, Chennai, Tamil Nadu, India*

Abstract:-This project uses servo motors to create a low-cost bionic robot thumb. A control using fuzzy logic incorporates human heuristic expertise manages the servo motor actuator. The thumb can retrieve, hold, and lift desired objects using this expertise. The robot thumb is outfitted with ELECTROMYOGRAPHY, which recognizes the electrical potential brought on by the conflict between the muscles of the arm and hand. The amount of movement of the thumb and other hand muscles as detected by the muscle sensor, which looks for electrical activity in the muscle, determines the output voltage's magnitude.

Keywords: *Bionic Robot, smart sensor, ELECTROMYOGRAPHY.*

1. Introduction

The immobility of all movement or a portion of is referred to as paralysis. Finger paralysis can result from a disease, accident, or hereditary susceptibility. Researchers in robotics have developed exoskeleton robots that provide support systems outside the body to get around the body's inability to move or operate. An aid that aids in regaining finger function is an exoskeleton robot that resembles a finger. Using simulations, the best kinematics for biped robots with low power consumption have been created using an electric motor. An exoskeleton robot is supported by, liver, pneumatics, hydraulic system, or a combination of technologies that improve the strength and endurance of the limbs. A human-like outer-mechanical framework, the exoskeleton arm transmits mechanical force from itself to the human finger. In order to prevent joint spasticity in stroke victims, such devices enable physiotherapy rehabilitation and passive therapy. In clinical studies, passive robotic therapy outperformed standard physiotherapy in helping patients with spastic hemi-paresis regain use of their elbow and shoulder movements.

A fuzzy logic control program is used in the current study to operate the DC motor that takes the place of the servo motors. A formal framework is provided by fuzzy controllers for representing, manipulating, and using human heuristic knowledge. The DC motor is controlled by an auto-regressive neural network with a proportional integral-derivative (PID) controller to simulate organic muscle.

Electromyography (EMG), a method for recording muscle activity, was used to create the bionic robot finger with motion input. When a nerve stimulates a muscle, electromyography (EMG) detects the muscle's reaction or electrical activity. This is used to identify problems in neuromuscular function. One or more tiny needles, commonly known as electrodes, are introduced through the skin and into the muscle during the test. Anoscilloscope, a monitor that shows electrical activity as waves, then displays the electrical activity that the electrodes have detected. In order to hear the action, an audio amplifier is employed. The electrical activity of the muscle during rest, a modest contraction, and a strong contraction is measured by EMG. At rest, muscle tissue doesn't typically create any electrical impulses. There is a brief period of activity when an electrode is introduced, but there is no signal beyond that. Weak and disadvantaged people can reclaim their freedom and go about their daily lives when given a bionic robot hand. The Dynamize MX-28T servo motors in the Evison elbow arm robot output 2.5 Nm of torque and take a heavy sensor (a load cell sensor) as input. Due to the DC motor's increased torque requirements as the load it is driving develops, the servo motor becomes more expensive. These costs inevitably result in a rise in the cost of the exoskeleton robot. A robot needs to have a cheap exoskeleton arm in order to lower the cost for consumers.

This study replaces the servo motors with a DC motor, simulating the reaction of an arm muscle to build a low-cost exoskeleton arm robot. While the DC motor actuates the robot, the signal for action is transmitted a microcontroller. The output voltage is a function of the amount of movement in the muscle fiber that is being detected through the muscle sensor, which records the muscle's electrical activity. The fuzzy logic algorithm that controls the DC motor is described above. The application is written using the program MATLAB/SIMULATION with an Arduino mega 2560 board serving as the interface. It is anticipated that the DC motor motion will be regulated by the elbow-mounted control system on the robot with an exoskeleton arm. The bionic robot finger moves in response to the finger's muscles.

2. Research Methods

2.1. Research Description

We must first understand the exoskeleton robot's structure before we can build it. The exoskeleton arm's robotic structure is supported by the forearm and upper Arm., same as the bionic robot finger's design was developed using the human finger as a model. Demonstrates how the robot simulation was built in three dimensions using an application called 3d Inventor Automatic desk. The dimensions of the robotic constructs are determined by anthropometric information gathered from various samples.

2.2. Research Methodology

In MATLAB/SIMULINK, the robot's control system was developed. The control system receives inputs from angle-position sensors and EMG sensors, and it outputs a voltage that controls the motor's rotational direction. Lifting the arm upwards and downwards allowed the EMG sensor data to be collected. A series of the angles that the arm makes during the up-and-down movements are identified by work systems provided by the authors for the building of such a control system with a muscle sensor on a bionic robotic finger using angle-position sensors.

2.3. Process for Testing

MyoWare EMG sensors measure muscular power (Advancer Technologies) an analogue signal indicating the strength of the muscular contraction is produced by the EMG sensor after it analyses the electrical activity. From 0 (complete relaxation) to 1024, the indicators of muscular relaxation or contraction are transformed into a set of numbers (maximum contraction). The MATLAB Workspace has the data that the EMG sensor produced. The first stage in the suggested process is to create a prototype robot exoskeleton. The actual bionic robot thumb prototype utilizes the DC motors with high torque used in car-wiper systems. The MATLAB toolbox includes fuzzy logic is used for simulation. In addition to specifying the angular tolerance for the arm motion, Researchers can track the DC motor's voltage input under the voltage setting, the fuzzy logic software controls the rotation of a motor the fuzzy logic algorithm's input is the difference between the muscle signals. Robert Arm angle as it actually moves. Between 0° and 5° were the input angles that the fuzzy logic mapped Extremely Small (SK), Small (K), Moderate (SD), and Large are the four sizes to make up thecategories for both the input and output membership functions (B). From 0 to 12 volts were available as fuzzy logic output. Figure 1 shows the basic block diagram of the entire system.

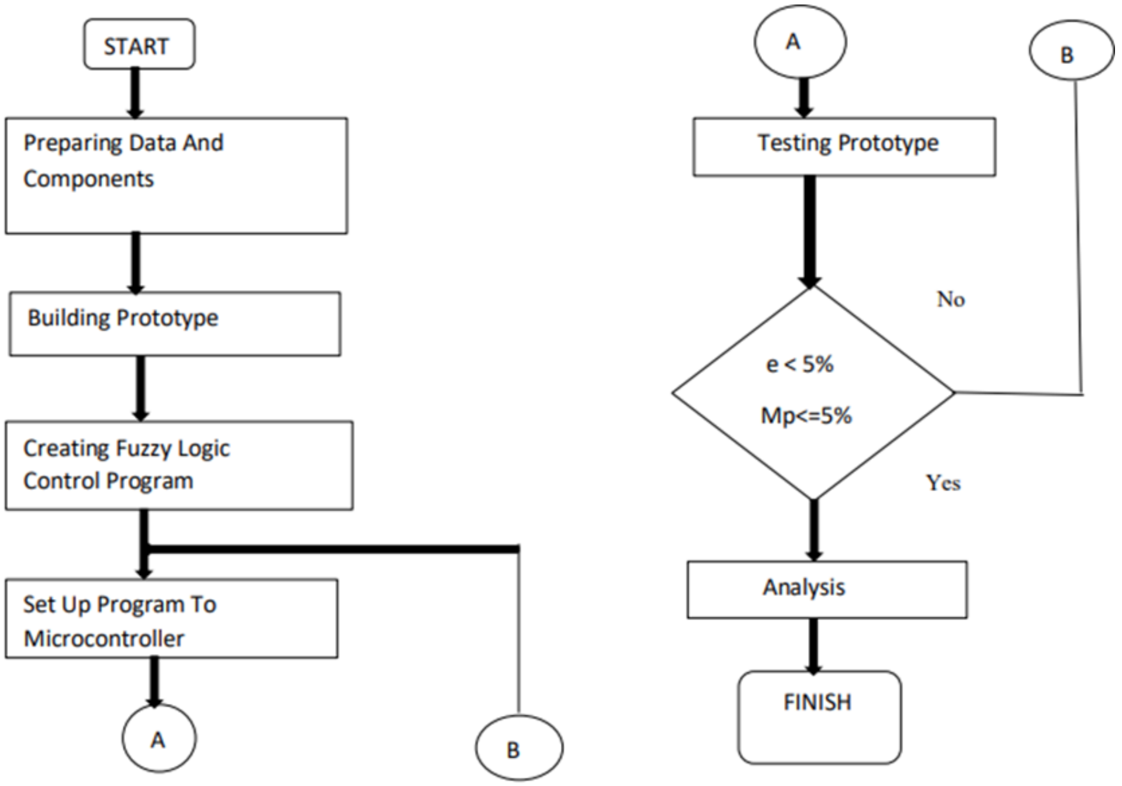

Fig 1. Block Diagram of Bionic Robot finger

3. Manufacturing of Prosthetic Hand Using 3d Printing

The prosthetic hand prototype was produced with the help of the EDISON 3D printer manufactured by 3D Design Company. The necessary adjustments for the production (e.g., resolution, amount of fullness, amount of support) were made using the Simplify 3D program, which was offered by the same company as the software program. 3D printing model diagram is shown in figure 2.

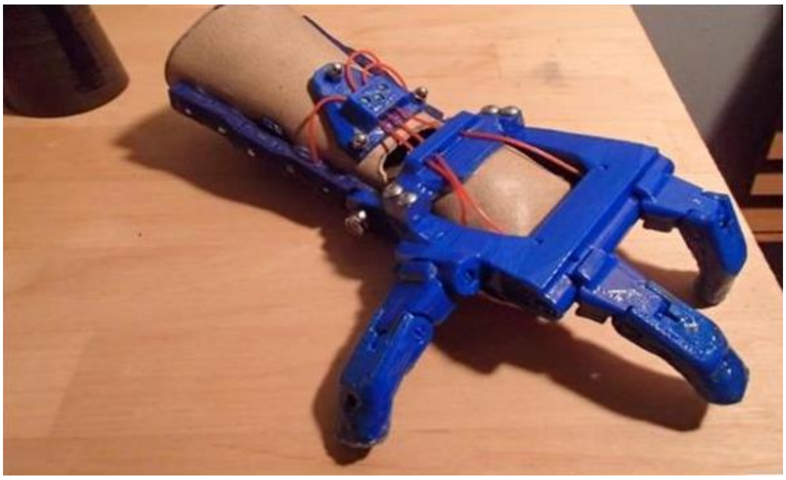

Fig 2. 3D Printing Model

4. Results and Discussion

The prototype was connected to a computer during testing, which allowed a screen to show the robot's reactions. After that, the researcher used a transient response analysis to examine the robot's replies. A 90° reference angle was used in the initial test. Without a load mass, the test ran for ten seconds contrasting robot behaviours with and without a fuzzy control scheme.

TuijinJishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 6 (2023)

In the absence of the DC motor, the control system oscillatory instability was visible. The motor is only able to be controlled by movement direction in the absence of rotational speed control. 2.38 seconds passed before reaching the reference angle of 90°, and 2.52 seconds before reaching the top of the first time. 99.4° was the greatest angle. The fuzzy control system-controlled DC motor, on the other hand, was steady and oscillated-free, and the angle stayed within the acceptable range. The reference angle 90° was reached faster thanks to the fuzzy control (from 2.38 to 1.96 s). In 2.1 seconds, the first peak was attained, with a maximum angle of 91.71°.

The DC's voltage and angular velocity motor are controlled by the fuzzy logic control system. The mechanism gives the DC motor a big angular speed an extremely little (near-zero) tangential velocity when the inaccuracy or degree difference is too large. Conventionally, the DC motor's spins in the positive and negative directions are referred to as the motor's positive and negative angles, respectively. Raw EMG signal and Bionic thumb control signal is shown in figure 3 and Raw EMG signal with finger in Motion state is shown in figure 4.

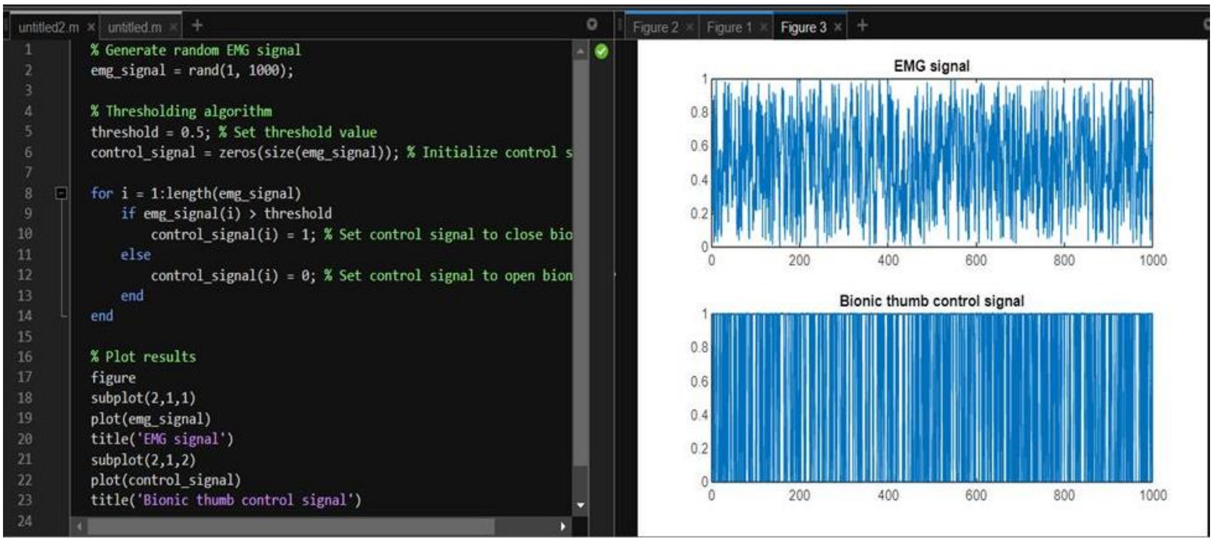

Fig 3. Raw EMG signal and Bionic thumb control signal

The DC motors in this study were controlled using a combination of pulse width modulation (PWM) and direction control. PWM enabled the application. The voltage was continuously varied, which controlled the motor's speed and torque. The motor's spin direction was determined using direction control.

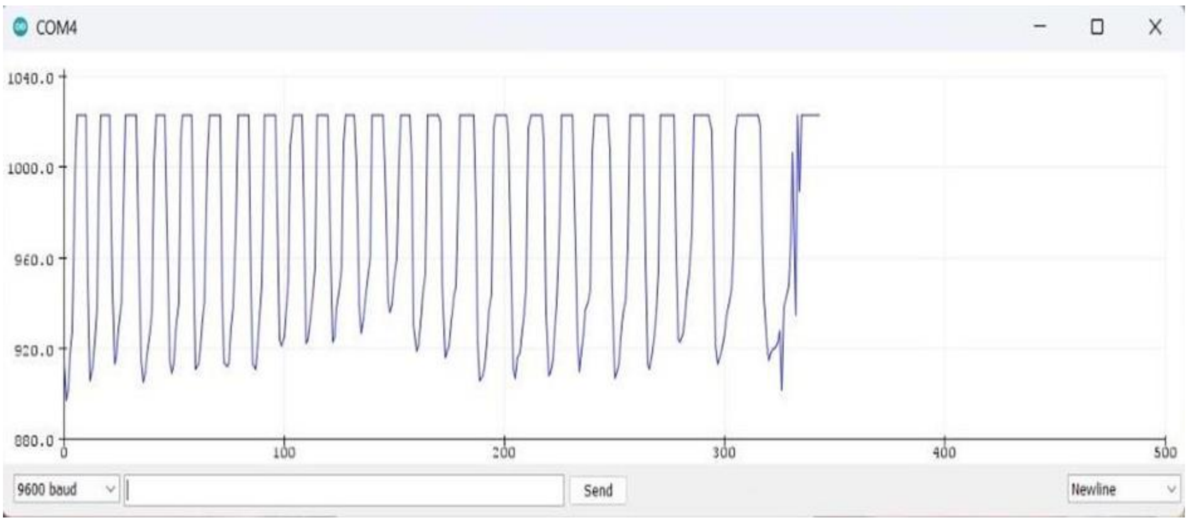

Fig 4. Raw EMG signal with finger in Motion state

5. Conclusion and Future Work

In this work, a DC motor was used in place of the customary servo motor to create an exoskeleton robot. MATLAB/SIMULINK makes it simple to create and implement fuzzy logic program which were used to regulate the motor movement. A DC motor that was an appropriate replacement for the servo motor, which costs more and thanks to the fuzzy logic architecture. The robot reached the reference angle (90°) while being controlled using fuzzy logic in less than 1.96 seconds, plateauing at2.1 s. With a 1.9% inaccuracy and a maximum angle of 91.71°, it was within the 2% tolerance that was required. The authors plan to create an entire bionic robot Thumb gripper in a subsequent study.

The gripper fingers will move in a manner that resembles how human fingers move. A clever control system will direct the motion of the robot.

3D printing has now been completed. The project has completed all necessary connections and is now focusing on the finalization of necessary movement components to ensure full functionality and operational readiness. MATLAB code was used to simulate both basic and advanced movement of the robot thumb. Basic movement is a pre-programmed process that only moves up and down, whereas advanced movement senses through the muscle sensor and moves as needed, which is still under development. Both have had their coding sessions completed.

References

[1] Weichlein, T., Zhang, S., Li, P., & Zhang, X. Data Flow Control for Network Load Balancing in IEEE Time Sensitive Networks for Automation. IEEE Access, 11, 14044- 14060, **2023**.

[2] Glover, J. R. A theoretical design model using the shape memory alloy, nitinol, in a robotic finger (Doctoral dissertation, California State University, Sacramento), **2022**.

[3] Craelius, W. Prosthetic Designs for Restoring Human Limb Function. Springer, **2022**.

[4] Wankhade, K., Yadav, P., Dhamdhere, U., Ghatake, V., & Kulkarni, V. Exoskeleton Arm for Rehabilitation and Activity Assistance, **2022**.

[5] Weichlein, T., Zhang, S., Li, P., & Zhang, X. Data Flow Control for Network Load Balancing in IEEE Time Sensitive Networks for Automation. IEEE Access, 11, 14044- 14060, **2023**.

[6] Sierotowicz, M., Lotti, N., Nell, L., Missiroli, F., Alicea, R., Zhang, X., ...&Masia, L. EMG-driven machine learning control of a soft glove for grasping assistance and rehabilitation. IEEE Robotics and Automation Letters, 7(2), 1566-1573, **2022**.

[7] Chiaradia, D., Tiseni, L., Xiloyannis, M., Solazzi, M., Masia, L., &Frisoli, A. An assistive soft wrist exosuit for flexion movements with an ergonomic reinforced glove. Frontiers in Robotics and AI, 7, 595862, **2021**.

[8] Godfrey, S. B., Ajoudani, A., Catalano, M., Grioli, G., &Bicchi, A. A synergy-driven approach to a myoelectric hand. In 2013 IEEE 13th International Conference on Rehabilitation Robotics (ICORR) (pp. 1-6). IEEE, **2013**.