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Design and fabrication of a moving robotic glove system

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ABSTRACT

This paper presents the research, design, and manufacture of a robotic hand to control movement with a glove. The moving glove-controlled robotic hand is based on two main parts: the hand mechanism and the control circuit. The control glove unit includes an Arduino nRF24l01 microcontroller module and five flex sensors for five fingers. These sensors are used to collect data about the curvature of each finger. Then those data will be received by the Arduino microcontroller and sent by the nRF24l01 module. The hand's microcontroller will process that information and control five servo motors so that the five fingers of the robotic hand are moved. The result of this research is to produce a robotic hand that accurately simulates the curvature of a user's finger and mimics the motion of a glove well. Moreover, the robot hand can grip objects of different sizes (from 0.1 to 1 kg) and shapes, from which this robot helps users easily manipulate objects.

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1. INTRODUCTION

Science is now making more significant strides in the development of hardware and software, particularly in the study, creation, and construction of robots [1]–[3]. As a result, more robots will replace people in hazardous environments, putting employees' lives in peril [4]. The glove control robot hand is another invention that mimics the actions of a human hand [5]–[7]. The glove-operated robotic hand also has the potential to develop and evolve as a result of intelligence control. The glove-operated robotic hand is utilized for impaired consumers and tasks that do not need human interaction. As a result, it is easy to see how closely related robots and humans are becoming. Because there is a growing need for robots to take the place of people eventually. Simultaneously, technological advancement has led to a rise in the number of robot occupations that potentially displace people [8]–[10]. In the beginning, robots worked together in production to promote health, do easy tasks, and eventually replace people at risky phases. Because of this, leading robots will alter how humans operate in the future for the better and safer while increasing productivity and corporate efficiency [11]–[13].

The use of a robotic hand to manage straightforward hand tasks with hazardous substances for scientific study is discussed in this study. Ensure the sensor and Bluetooth module on this robot are stable and long-range and that the oil on the knuckles is sufficient. Since this is a simplistic system, maintenance will be quick and simple, and replacement components are readily available on the market in the event of a failure. Additionally, the flex sensors will play a significant role in this project, so make sure it functions well and is reliable [14]–[16]. The operator will have a sensor on each finger, and when the curvature of the finger changes, the sensor will be immediately impacted. The data is sent via the nRF24l01 module by the Arduino microcontroller, which will collect it and convert it to the specified suitable motor rotations [17]–[20]. Because the nRF24l01 supports advanced shock burst (ASB), a straightforward protocol that permits two-way data transfer, the Arduino of this circuit will receive and send data using five servos motors that correspond to each of the robot's fingers [20]–[25].

This paper is separated into five distinct and logical parts. Part 1 begins by introducing the function and benefits of hand robots. Second, parts 2 and 3 outlines the robot hand design process, including the mechanics, control circuitry, and technique for mechanically positioning the robot hand. Part 4, the software used to operate the robot and assess the experimental outcomes of this research, and lastly conclusion.

2. ROBOTIC HAND CONTROL DESIGN

2.1. The Arduino Uno

As illustrated in Figures 1 and 2, this project employed Arduino Uno R3 for the robotic arm circuit and Arduino nano V3.0 ATMEGA328P for the glove circuit. The Arduino Uno R3 has 14 digital I/O ports, a universal serial bus (USB) interface, and six analog input pins for connecting to electrical circuits and external devices. Six pulse-width modulation (PWM) outputs also provide designers straightforward control over auxiliary circuits. Additionally, to interact with the IDE programming software, which is appropriate for Windows, MAC, or Linux Systems, the Arduino Uno R3 is directly linked to the computer through USB. Windows is more practical to use, however. The IDE uses programming languages like C and C++. Users have the option of using an additional power source in addition to a USB to power the board.

The tiny, adaptable architecture of the Arduino Nano V3.0 ATmega328P circuit is ideal for small breadboards. Two more analog pins, A6 and A7, are needed since the Arduino Nano V3 board has an ATMEGA328-AU V3.0 processor. Additionally, the board uses an OPAMP that turns power on automatically when the board's voltage increases. Using the CH340 chip for communication is another noteworthy aspect of Arduino Nano, which saves money and lowers manufacturing costs.

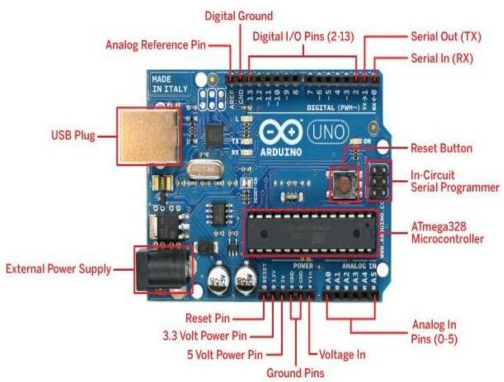

Figure 1. The Arduino Uno R3 pin

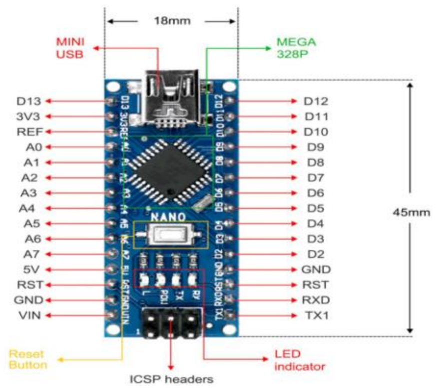

Figure 2. Arduino nano V3.0 ATmega328P pin

2.2. The flex sensors

The Flex Sensor achieves great form-factor as a variable printed resistor on a thin, flexible substrate. When the substrate is bent, this sensor produces a resistance output correlated to the bend radius-the smaller the radius, the higher the resistance value. Figure 3 depicts the flex sensor.

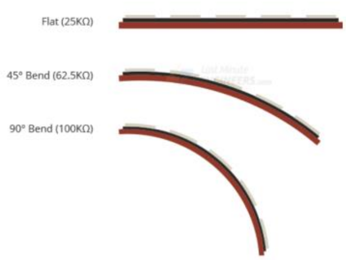

Figure 3. Some angles of the flex sensor

Because the resistance will vary when twisted, thus this sensor functions similarly to a rheometer. The surface's linearity may have an impact on how resistance varies. For instance, this sensor generates a resistive output matching the bend radius when the base is bent. The resistance value increases as the radius decreases [4].

2.3. The module Bluetooth nRF24l01

The 2.4 GHz global industrial, scientific and medical (ISM) band is the intended operating range of the nRF24l01 transceiver module, which transmits data using Gaussian frequency shift keying (GFSK) modulation, can be seen Figure 4. Data transmission speeds range from 250 kbps to 1 Mbps and 2 Mbps. This module delivers a network of 125 independently running modems in one location and supports 125 distinct channels. Each channel may communicate with up to six addresses at once, and each department can talk to up to six other departments. This module uses just approximately 12 mA of electricity when transmitting. The other pins can tolerate 5V logic levels, while the module's operating voltage ranges from 1.9 to 3.6 V. This module may thus be connected to Arduino without needing a logic-level converter.

2.4. The servo motor

Servo motors Figure 5 can run between 4.8 and 6.5 volts. However, 4.8 volts is the most typical range. The greater the voltage, the more torque it can produce. Due to their gear design, almost all hobby servo motors can rotate only from 0° to 180°. Therefore, be sure the project can tolerate the half-circle. If not, the user may change the motor to produce a full circle or choose a 0° to 360° motor. The gears in the engines are prone to deterioration. Therefore, if your application calls for more substantial and longer-lasting motors.

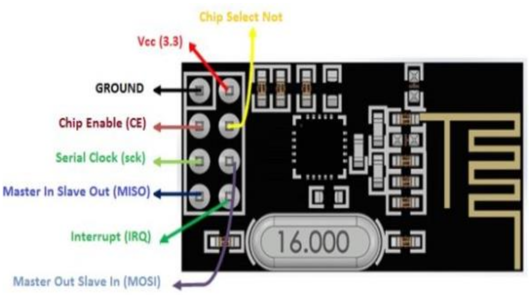

Figure 4. The nRF24l01

Figure 5. The servo motor

3. CONTROL DESIGN AND ASSEMBLY DIAGRAMS

3.1. Block diagram control of the robotic hand and glove

The schematic diagram control of the robotic hand and glove is shown in Figures 6 and 7. The robot hand in Figure 6 will get direct 12 V electricity from the inverter. The robot hand's nrfF24l01 module will take the transferred data and deliver it to the Arduino Uno r3. In this work, the system operates the mechanical component with the proper range of motion on the finger, and the data will be encoded and controlled by a servo motor.

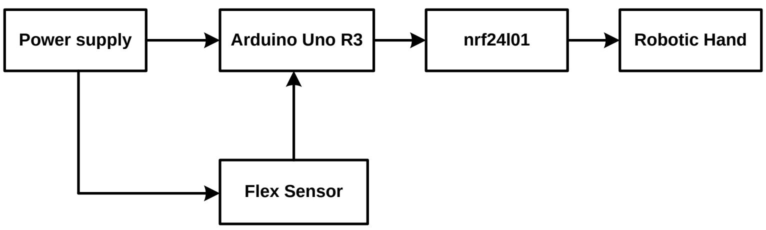

Figure 6. Block diagram control of the robotic hand

A 9-volt battery powers the robotic gloves in Figure 7. The Flex sensor relies on the amplitude of the finger movement to collect data and feed it to the Arduino nano v3. At the time, this information will be sent through the nRF24l01 module. The control software in Figure 8 is written in code.

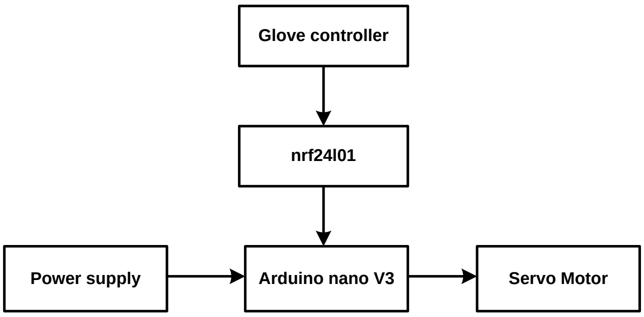

Figure 7. Block diagram control of gloves controller

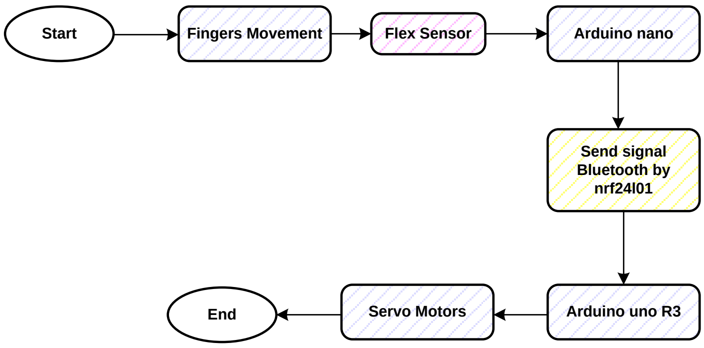

Figure 8. Robot hand control program

3.2. Wiring diagram and connecting

The circuit diagram of the glove is shown in Figures 9 and 10. This circuit diagram consists of a 9 V battery, a sensor connected to a resistor, and an Arduino to ensure current. The printed circuit is drawn on the computer. It is then printed on a single-sided glossy paper. The item will then be heated up using a heat transfer iron to transfer all of the ink to the copper board. The copper board should be immersed in a corrosive drug solution after it has all the circuit wires. The iron will rust in copper parts without ink, but the copper will not corrode (the copper line is preserved again). It was time to wash and melt the ink once it had soaked in the solution. The lines we created on the machine will then be preserved on the copper board. Finally, drilling and soldering the components together will create a complete printed circuit. Robotic glove and hand-printed circuit goods, as seen in Figure 11.

3.3. 3D printing and product assembly

A mechanical assembly process put together the glove control and the robotic hand. The completed result is shown in Figure 12. The stainless-steel robotic hand positioned on the standee's surface allows the needle to stand upright for simple operation and viewing.

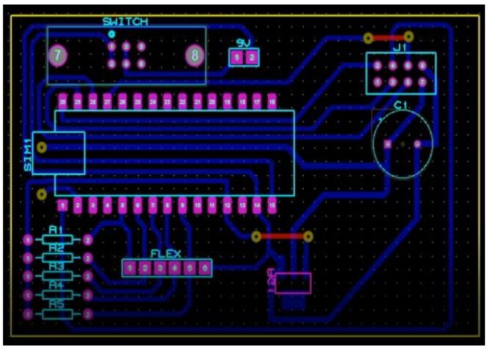

Figure 9. The printed circuit of the robotic glove

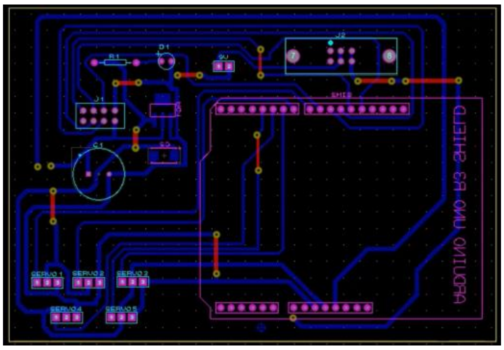

Figure 10. The printed circuit of the robotic hand

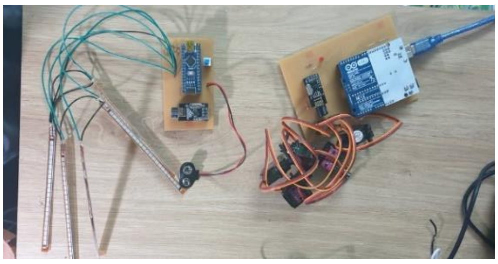

Figure 11. Printed circuit products of the robotic glove and hand

Figure 12. Finished product of robotic hand

4. EXPERIMENT RESULTS AND DISCUSSION

The test is performed empirically in the manner described: Move each finger in the first step, and the robot hand will get a signal based on the distance between the control gloves. Next step is assessing the muscle's functionality to see if it is tangled up in the moving points. You can tweak the product after this test to make it function more effectively. Figures 13(a) to 13(h) show the outcomes in determining if the mechanical component received the signal, examining how each finger responds 1, examining how each finger responds 2, examining how each finger responds 3, examining how each finger responds 4, examining how each finger responds 5, examine the functionality of fingers with a little curvature and examine how fingers with a lot of curve operate.

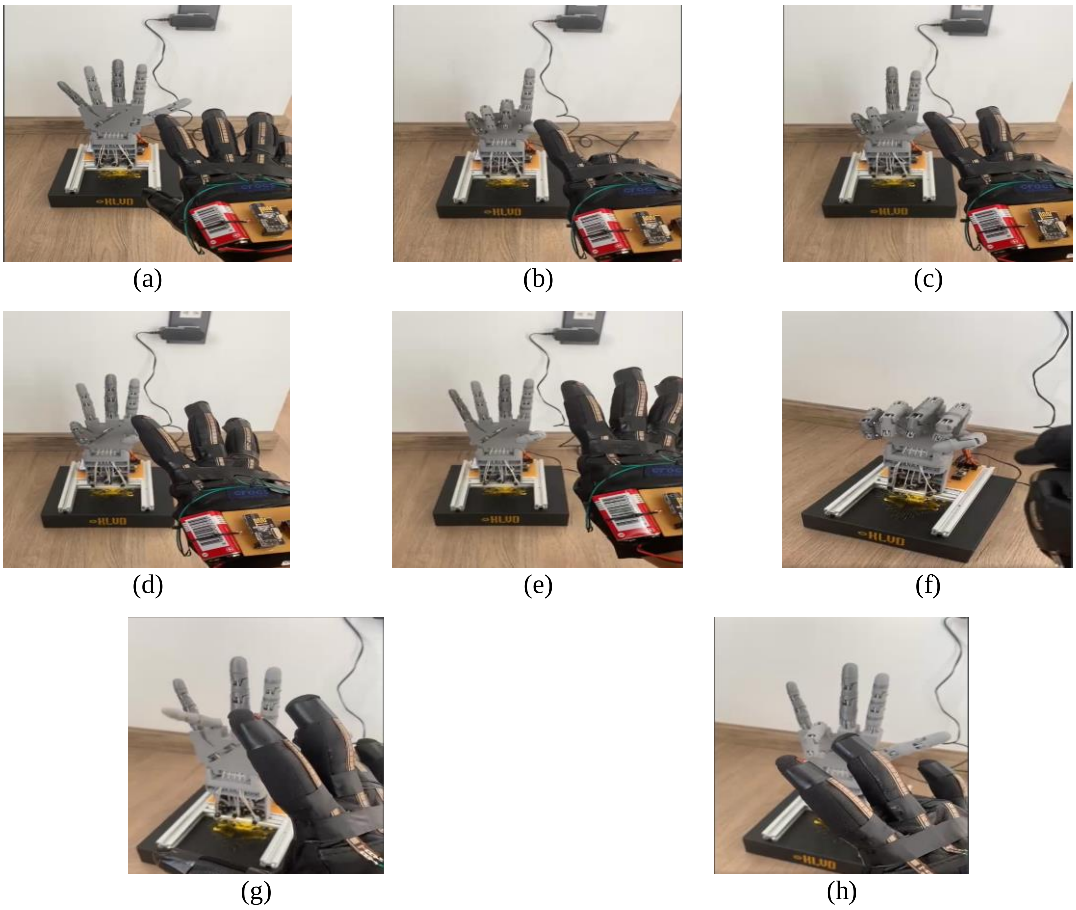

Figure 13. Actual test results in (a) determining if the mechanical component received the signal, (b) examining how each finger responds 1, (c) examining how each finger responds 2, (d) examining how each finger responds 3, (e) examining how each finger responds 4, (f) examining how each finger responds 5, (g) examine the functionality of fingers with a little curvature, and (h) examine how fingers with a lot of curve operate

The testing findings show that:

a. Latency: There will be a delay in data transmission since the servo motor takes roughly 0.5 seconds to start moving the finger.
b. Distance: The operational range is relatively large; it may be up to 10m if there are no obstacles or just a few. If there are numerous obstacles. However, the robot's operating range can still be reached, but the delay time will rise to 1s or less.
c. Joint movement: Since the mechanical part's orientation of the joint was carefully considered. At the same time, it was being drawn, and 3D printed, there will be suitable cuts to aid the movement from becoming tangled. Also, extra plastic will obstruct printing movement when tested because it is printed on regular plastic.
d. To fix the issues mentioned above: Two solutions are provided for the one case—excess plastic—that prevents finger mobility that was previously discussed.
e. Option 1: To remove the extra and sharpen the curved tips to function more efficiently, use a knife or pair of scissors. The benefit of obtaining raw materials cheaply and quickly. This work is offset by the drawback of the product's poor appearance due to human handling.
f. Alternative 2: Water-washable plastic with superior print quality and durability will be used instead of the inferior wire resin. The benefit is that it is attractive and robust; the drawback is that it requires starting from scratch, which adds cost and time to the process.

5. CONCLUSION

The glove-controlled robot hand is made to function freely and broadly and is based on the natural hand. This project is tiny in scope, yet it is processed quickly. Even if the production model is a 3D-printed piece of plastic, it can hold small items. Following the project's implementation, it is clear that it will serve various purposes beyond conducting research and assisting personnel in hazardous tasks. It may also benefit those with disabilities. Almost every component may be upgraded for multiple uses, replacing it with an alternative with greater usefulness and longevity. Users will not need much time to learn how to use and repair the system of this product since its components are utilized with common characteristics that are simple to buy and replace.

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