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يد روبوتية طبية يتم التحكم فيها لاسلكيًا محليًا

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الملخص:

ركزنا على أحد الاستخدامات العديدة للأنظمة الروبوتية في دراستنا. وعلى وجه الخصوص، أردنا الدخول في المجال الطبي لتنفيذ يد يتم التحكم فيها لاسلكيًا من خلال قفاز يتم ارتداؤه. وتتمثل المهمة الرئيسية لهذه اليد في تكرار حركات يد المستخدم الذي يرتدي قفاز التحكم. ولكي تتفاعل اليد الروبوتية مع الإشارات الواردة بفعالية وكفاءة، فإنها تسجل حركات اليد الطبيعية هذه كأساس للمعلومات. يتكون قفاز التحكم من أجزاء متعددة: يتم استخدام متحكم Arduino لمعالجة بيانات الحساسات الموجودة على القفاز. خمسة حساسات قابلة للتكيف والانحناء تلتقط هذه الحساسات الحركة من الأصابع والإبهام. تستخدم وحدة خاصة لقياس التسارع و الحركة لتحديد دوران المعصم. أصبح الاتصال اللاسلكي بين القفاز واليد الآلية ممكنًا بفضل جهاز الإرسال nRF24L01. يتم تضمين ستة محركات سيرفو – واحد لكل إصبع والمعصم – في اليد الروبوتية، والتي تم إنشاؤها باستخدام طابعة ثلاثية الأبعاد تم الحصول على التصميم من مكتبة 3D CAD مفتوحة المصدر وتحوي اليد الروبوتية على متحكم أردوينو وحدة الاستقبال الدقيقة nRF24L01. عند اكتمال التصميم، سيكون قادرًا على تكرار حركات قفاز التحكم دون أي تأخير ملحوظ وإظهار قدرته على الإمساك بالأشياء المختلفة. قمنا بتجميع مستلزمات بناء اليد والدوائر الالكترونية من السوق المحلي. تشير النتائج إلى إمكانية تحسين قدرة اليد الروبوتية على الإمساك بالأسطح الصلبة من خلال توفير درجات إضافية من الحرية للأصابع، وتم اختبار الحساسية ووجدنا أن كل حساس من حساسات القفازات كان خطيًا تقريبًا وبدقة مختلفة. يمكن أن يكون هذا الذراع حلاً مبتكرًا للأشخاص الذين يعانون من إعاقات حركية، مثل أولئك الذين يعانون من شلل في الأطراف العلوية أو الأفراد الذين يعانون من رفع الأشياء بشكل فعال. قد يجد أولئك الذين يعملون عن بعد لأسباب تتعلق بالسلامة أو الذين يعملون في بيئات خطرة أن هذه التقنية مفيدة للغاية.

الكلمات المفتاحية: يد روبوتية، حساس مرونة، طابعة ثلاثية الأبعاد.

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A wirelessly controlled medical robotic hand locally

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Abstract:

We focused on one of the many uses of robotic systems in our study. In particular, we wanted to enter the medical field to implement a hand-controlled wirelessly through a glove. The main function of this hand is to replicate the movements of the hand of the user wearing the control glove. In order for the robotic hand to react to incoming signals effectively and efficiently, it records these natural hand movements as a basis for information. The control glove consists of multiple parts: An Arduino microcontroller is used to process data from the sensors on the glove. Five adaptable and bendable sensors detect movement from the fingers and thumb. A special unit is used to measure acceleration and motion to determine wrist rotation. Wireless communication between the glove and the robotic hand is made possible thanks to the nRF24L01 transmitter. Six servo motors – one for each finger and wrist – are embedded in the robotic hand, which was created using a 3D printer. The design was obtained from the open source 3D CAD library. The robotic hand contains an Arduino microcontroller and nRF24L01 receiver module. When the design is complete, he will be able to replicate the movements of the control glove without any noticeable delay and demonstrate his ability to grasp different objects. We collected hand-building supplies and electronic circuits from the local market. The results indicate that the ability of the robotic hand to grip hard surfaces can be improved by providing additional degrees of freedom to the fingers. Sensitivity was tested and we found that each of the glove's sensors was approximately linear and with varying accuracy. This arm could be an innovative solution for people with mobility impairments, such as those with upper limb paralysis or individuals who struggle to lift objects effectively. Those who work remotely for safety reasons or who work in hazardous environments may find this technology very useful.

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1. Introduction:

According to (Payne & Yang, 2014), medical robots are more than just machines. They stand for the nexus of state-of-the-art medical knowledge and technology. Aim to streamline healthcare procedures and enhance patient outcomes as well, have also grown more human-like as a result of mechatronic advancements, which have led to the creation of precise and intricately designed sensors and actuators. This is feasible to accomplish. using wires or wireless technology to control robots in addition to gesture control. Natural hand motions from people are a valuable interactive tool for robotic hands to use as a data source. The robotic hand is defined as a hand capable of performing a simulation of the movements of the human hand, which requires precision and dexterity. Steady grasping and precise movement using the multi-fingered robotic hand are crucial (Beasley, 2012). On the other hand, creating a human-like multi-fingered robot capable of grasping objects accurately and stability is an important challenge. In addition to the cost of the robotic hand, the challenge is to reduce the cost while maintaining the accuracy of the results. The human hand is considered the most developed part of the upper limb, which represents an advanced engineering achievement, as the hand consists of specific bones connected to a number of muscles, nervous structures, and blood vessels, and anatomically it consists of:

1. Bones(Schwarz & Taylor, 1955):

• Carpus: A group of eight small bones between the wrist and the beginning of the fingers.

• Radiocarpal joint (RC): connects the hand to the wrist.

2. Fingers(Schwarz & Taylor, 1955):

• Each finger, except for the thumb, consists of:

- Metacarpal bone (M).
- Three phalanges: the first phalangeal bone (FP), the second (SP), and the third (TP).
- Four joints: the distal interphalangeal joint (DIP), the proximal interphalangeal joint (PIP), the metacarpal joint (MP), the carpometacarpal joint (CM) and the Intercarpal joint (IC).
- The thumb only has the third and first phalangeal bones, and therefore only two joints between the bones, namely the interphalangeal joint (MP) and the distal interphalangeal joint (DIP) (Clarke, 2008).

These structures work together to enable the hand to move and have the complex skills that characterize it. The primary aim is to implement a simplified and preliminary design of a medical robotic hand controlled by a glove equipped with a set of sensors, and based on locally available materials and electronic components, and to expand our understanding of the functions of the robotic hand and its applications.

A prototype of a robotic hand operated by a glove with a collection of sensors was presented in this article. It can be utilized in research and medical settings to help people with motor disabilities reach objects far away from them.

2. Literature Review:

Many researches about wirelessly controlled medical robotic hand were conducted one of them this paper (Mishra et al., 2017) studied the design and construction of a robotic hand with five fingers that can be moved at a 15-degree angle, and is capable of applying independent forces when grasping objects. The wireless communication capabilities of the robot hand were tested to control its movements and simulate the movements of a user-controlled glove. The results showed the effectiveness of the robotic hand in simulating the movement of the operator's hand and its grasping ability. Another research, (Salman et al., 2020) published a study in 2020 entitled "A Wireless-controlled 3D printed Robotic Hand Motion System with Flex Force Sensors." In this study, a system which could help people to work and operate without directly using hands or contacting by hands, is proposed and demonstrated. This system composed of a glove with flexible force sensors and a 3D printed robotic forearm. The 3D printed forearm simultaneously acted following the motion of the glove. The 3D printed forearm was composed of 46 individual parts that were printed with white biodegradable poly lactic acid (PLA). The fingers' action in the robotics arm was executed with the actuators. After carefully testing the system, the robotic arm followed the action correctly with a maximum 0.133 ms time delay all the time. This system could be really useful for the users who work in dangerous conditions, hazardous environment or require remote operation for safety reasons.

Another research (Hiader et al., 2021) presents the design and development of a 3D prosthetic hand model equipped with the flex sensors in order to generate the human hand replica for a person with no hand. In addition to that, this work also presents the wireless control (select and place) of the prosthetic hand through Radio Frequency. The use of low cost flex sensors for the positioning of fingers and to add handgrip control in the prosthetic hand, makes the whole design cost efficient. The research concluded that the inclusion of flex sensors is very beneficial from the economical point of view because it provides low cost solution as compared to existing costly technologies of prosthetics.

Later research (Benamer et al., 2022), about the use of human hand gestures to control a robotic hand through a glove, where speed and acceleration sensors and curvature sensors were used and controlled through AtMega32 microcontrollers. It explains the operation of the hand gesture sensing technology using three sensors, namely the accelerometer and the sensors. Bending and finger contact sensors, it is used to drive a two-wheeled robot in a wireless mode using radio frequency. It can be used for bomb detection and dismantling and rescue operations if a robot arm is mounted on it, which can be controlled using a glove.

This research was compared with another research (Malathy et al., 2022) conducted by researchers in 2022, and the similarities and differences were shown in Table (1).

Table 1 compare with another research

	My research	Other
Sensors	Flex – MPU6050	Flex – Accelerator sensor- Ultrasonic
Wireless connection	Radio waves (nRF24L01)	ZigBEE
Controllers	Arduino UNO - nano	Arduino UNO
Type of motors	SERVO	SERVO
Results	The angles of each finger were tested and the Sensitivity	The angles and output voltage of the Flex sensor were tested

3. Material and Methods:

3. 1 Transceiver and Adapter Module nRF24L01:

The nRF24L01 wireless module is a wireless transmission module operating in the 2.4 GHz band using the SPI protocol that is typically used to send and receive data on the ISM operating frequency from 2.4 to 2.5 GHz (*GitHub - Maniacbug/RF24: Arduino Driver for nRF24L01*, n.d.). The nRF24L01 module is commonly used for wireless communication with Arduino boards and is a popular choice due to its flexibility and low cost. It is widely used in a variety of applications, including remote control systems, sensor networks, etc.

Figure (1) nRF24L01 wireless module

The transmitter works through the Time Sequence Peripheral Interface (SPI). The SCK, MOSI and MISO electrodes must be connected to the corresponding electrodes on the Arduino (Mahbub, 2019). In order to communicate with the transmitter, the SPI interface and the RF24 library are included in the Arduino software.

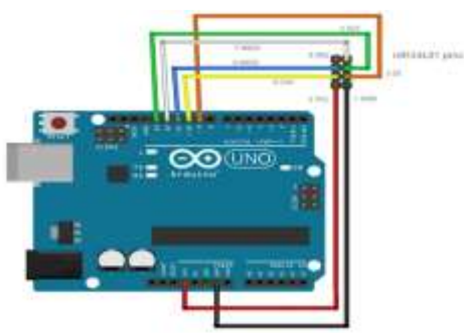

Figure 2 Connect the Arduino chip to the chip's pins

3. 2 Flex Sensor:

Flex Sensor is a variable resistance (Saggio et al., 2015). The amount of tilt in the sensor is determined based on the resistance. Changes in resistance are recorded digitally, and the data in this case is converted into degrees of rotation for the servo motors (Nag et al., 2017). For a 56 mm long inclination sensor, the bending resistance ranges from 40 kΩ to 130 kΩ, depending on the radius of curvature, and the planar resistance is 30 kΩ. The inclinometer sensors are used to record the degree of curvature of each finger of the control glove. To read data from the Flex Sensor, a Voltage Divider is implemented so that analog to digital conversion is possible on the Arduino Nano. The voltage divider delivers a variable voltage to the Arduino that changes proportionally to the variable resistance in the tilt sensor, according to equation (1).

$$v_{out} = v_{in}\frac{R_2}{R_1 + R_2} \quad (1)$$

3. 3 MPU6050 Accelerometer and Gyroscope:

The MPU6050 is a six-degree-of-freedom motion measurement unit (IMU) that includes a three-axis accelerometer and three-axis gyroscope. The MPU6050 is relatively accurate, as it has a 16-bit analog conversion, allowing simultaneous data capture from the x, y and z axes (*MPU6050 6-DoF Accelerometer and Gyro*, n.d.). The gyroscope and accelerometer module allow the range to be adjusted by the user. The gyroscope field can be set as follows: (±250 °/s & ±500 °/s & ±1000 °/s & ±2000 °/s). As for the accelerometer field, it can be set as follows: (±2g & ±4g & ±8g & ±16g). Where the field represents the minimum and maximum of the input data that the gyroscope and accelerometer can detect, which in turn affects the sensitivity when measuring the data (Fedorov et al., 2015). The MPU6050 motion measurement unit (IMU), mounted on the glove, is used to measure wrist orientation from which the wrist rotation angle, φ, can be calculated according to equation (2).

$$\varphi = \text{Arctang}\left(\frac{A_Y}{A_X^2 + A_Y^2}\right) \quad (2)$$

Where the variables AY, AX, and AZ represent acceleration in the y, x, and Z axes.

3. 4 Practical application:

3. 4. 1 Mechanical design & electronic design:

In this article, we relied on the design of a robotic LED from the open source 3D CAD Model Library _ GrabCAD, where the design files were downloaded in STL format and 3D printing of the parts was performed. Figure 3 shows a robotic hand printed by a 3D printer.

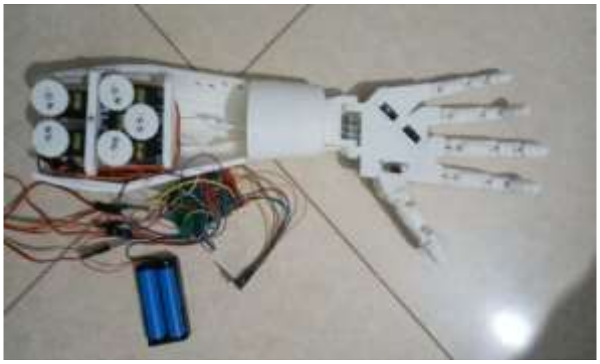

Figure 3 Designed robotic hand.

Consider this suggestion for the correct finger angle:

- When assembling the fingers, make sure the parts are oriented correctly before gluing, and set all servo motors at 10 or 170 degrees before connecting the gears to the servo motors, as when installing the gears we must keep the fingers in the closed or open position (according to the servo angles of the robotic hand). Figure (4) shows the electronic circuit that we designed, whose function is to control the robotic hand

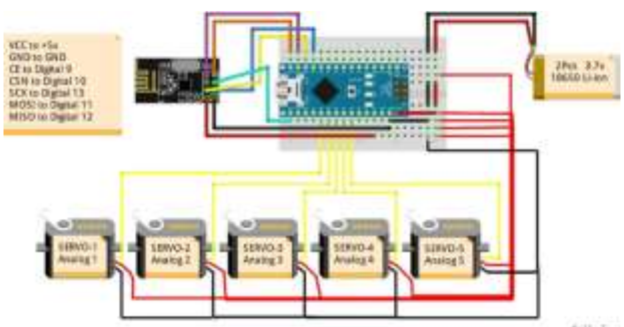

Figure 4 Electronic circuit for the robotic hand.

- The hand-connected servos were programmed by importing the Servo library. As for the transceiver modules, the RF24 library was also imported, which allowed the address of both the transceiver modules to be set. After setting the address and opening communication between the two RF units, the received data was used write() to move the servo. The servo motors were also calibrated using a software code where the position of each servo motor was set within initial conditions. The servo motors were set to 90 degrees using the write function. () to pass the connecting threads and then the servo motors were rotated to 0°, the fully extended state of the fingers.
- One of the contact threads was tensioned to maintain tension throughout the arm and then the servo motors were rotated to 180 degrees, the fully bent state, and the second thread was tensioned to the pulley. Figure 5 shows the algorithm for the robotic hand mechanism.

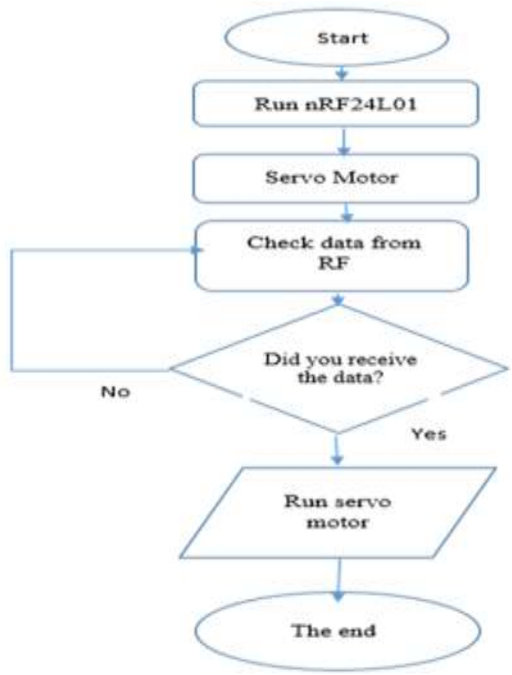

Figure 5 Flow chart of the robotic hand mechanism.

3. 4. 2 Control glove design:

The glove is used to control the robotic hand as it contains five flex sensors. Each finger of the robotic hand was controlled by a single bend sensor. We mounted the bend sensors on the glove and then connected them to the Arduino Nano board. By connecting the variable resistance of the bend sensors to the angle of rotation of the servo motors, extension and bending of the hand were achieved. Figure (6) shows the glove on which the sensors will be installed.

Figure 6 Control glove design.

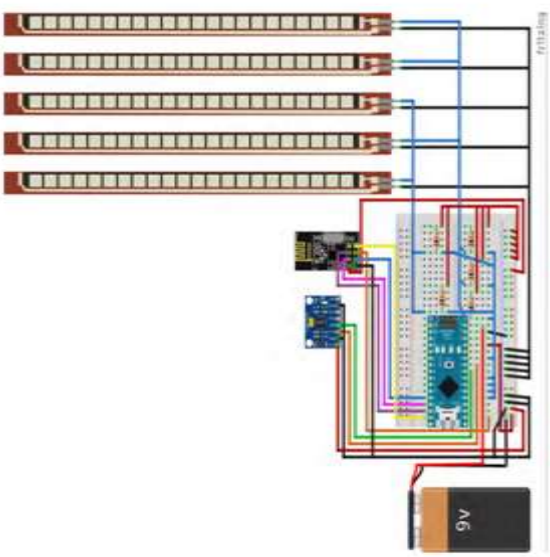

Figure 7 The electronic circuit for the control glove.

First, the flex sensors were calibrated using the analogRead() instruction. The values were observed when it was at rest and when it was fully bent. The values were used and tuned using the map() instruction to be between a range of 0 to 180 degrees, and the IMU was initialized and adjusted. To calculate the orientation of the wrist, ±2 g was chosen as the unit of measurement, and the angle of rotation of the wrist was calculated and collected with the bend sensor data into a message packet, and then the packet was transmitted through the address assigned to the transmitting and receiving units. Figure 8 shows the working algorithm of the glove.

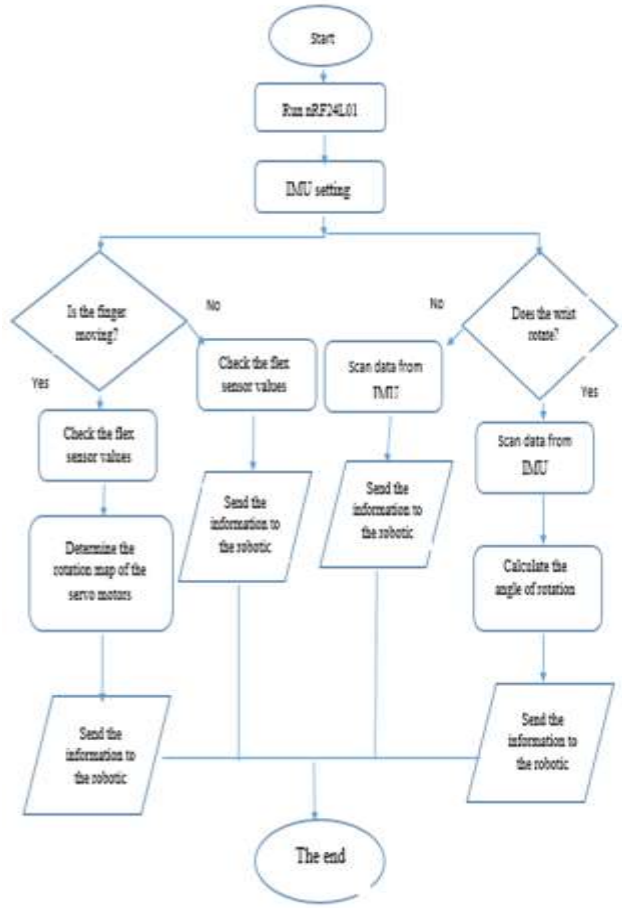

Figure 8 Flow chart for making a control glove.

4. Results and Discussion:

4. 1 Finger initialization tests:

Since the glove material was stiff as shown in Figure 6, the output of each finger was not 0°. When using the glove, the initial value for each sensor was different. A test was performed by gently placing the gloved hand on the desktop shown in Figure 9. The data were from the thumb, which is the first finger. The blue bar was from the index finger to the second finger, 15° degrees and 14° degrees. The green bar was from Middle finger, third finger, 23 degrees. The black bar was from the ring finger, fourth finger, 39 degrees and the red bar was from the child, fifth finger, 34 degrees. There was data for fourth groups in about one minute in this graph and there was angle difference in the second finger, the blue bar, and the finger angle was 14 degrees and not 15 degrees in the fourth group.

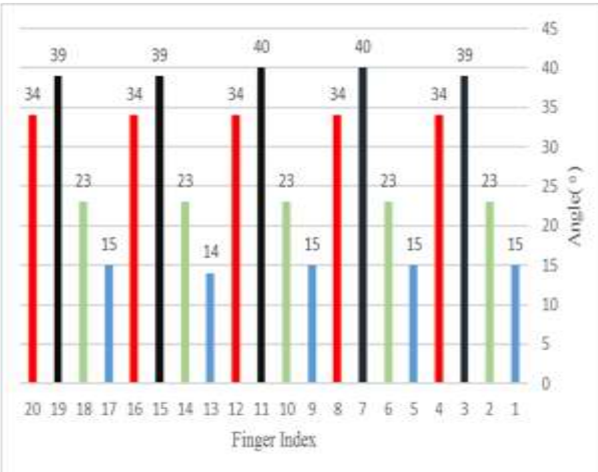

Fig. 9. The flex force sensors' signals response banding on the glove

4. 2 Sensitivity tests:

The sensitivity was tested using a practical method: the minimum angle at each finger would bend was determined. The minimum angle of each finger was measured by keeping the finger moving as slowly as possible, testing the range from holding the hand in its natural position to closing it into a fist; the maximum values for each finger were 125, 127°, 140°, 118°, and 120 in that order. Third, tests were designed to determine how quickly the values could react to the flex sensor when the finger was moved as quickly as possible. The data, totaling 13 values, were obtained in Fig. 10. This figure showed that each sensor of the glove sensors was almost linear with a different resolution.

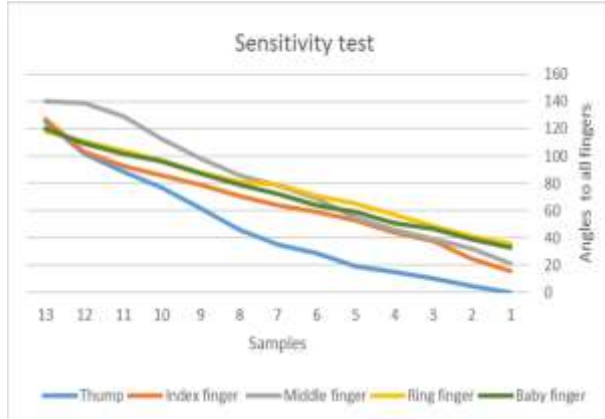

Fig. 10 Sensitivity tests

4. 3 Discussion:

- Each sensor of the glove sensors was almost linear with a different resolution.
- Wireless connectivity allowed the robotic hand to grab things and mimic the hand's actions inside the control glove.
- Up to 150 grams of things could be held in the robotic hand's grasp.
- Good reaction was obtained by mimicking the movements of the control glove, and satisfactory gripping ability was noted.
- Adjusting the flex sensors in the control glove several times until the glove fit tightly, which allowed the full specified angle range of the servo motors to be achieved.
- The glove is not ideal due to the fixed size and the effect of the fit of the glove when worn on the curvature of the flex sensors.
- Because the mechanical construction of the robotic hand is a simplified model of the human hand, its range of motion was constrained by the human hand's structure.

5. References:

Beasley, R. A. (2012). Medical robots: Current systems and research directions. *Journal of Robotics*, *2012*. https://www.hindawi.com/journals/jr/2012/401613/abs/

Benamer, K., Elmabrouk, M., & Hwas, A. (2022). *Animatronic Robotic Hand Controlled by Glove Using Bluetooth*. http://icmie2022.ly/docs/proceedings/ICMIE-2022-35.pdf

Clarke, B. (2008). Normal bone anatomy and physiology. *Clinical Journal of the American Society of Nephrology*, *3*(Supplement_3), S131–S139.

Fedorov, D. S., Ivoilov, A. Y., Zhmud, V. A., & Trubin, V. G. (2015). Using of measuring system MPU6050 for the determination of the angular velocities and linear accelerations. *Automatics & Software Enginery*, *11*(1), 75–80.

GitHub—Maniacbug/RF24: Arduino driver for nRF24L01. (n.d.). Retrieved March 7, 2024, from https://github.com/maniacbug/RF24

Hiader, S. A. A., Nasir, A., Ameen, M., Raza, A., Waleed, A., & Ali, Z. (2021). Design and Development of Low Cost, Wireless Controlled, 3D Prosthetic Hand using Flex Sensors. *2021 International Conference on Innovative Computing (ICIC)*, 1–6. https://doi.org/10.1109/ICIC53490.2021.9692998

Mahbub, M. (2019). Design and Implementation of Multipurpose Radio Controller Unit Using nRF24L01 Wireless Transceiver Module and Arduino as MCU. *International Journal of Digital Information and Wireless Communications*, *9*(2), 61–72.

Malathy, S., Jaipriya, M., Thenmozhi, M., & Priyanka, M. (2022). WIRELESS CONTROLLED HAND GESTURE BASED BORE WELL VICTIMS RESCUE ROBOT WITH VIDEO STREAMING. *NeuroQuantology*, *20*(8), 5990.

Mishra, A., Malhotra, S., & Pradesh, U. (2017). Design of hand glove for wireless gesture control of robot. *Int. J. Pure Appl. Math*, *114*(8), 69–79.

MPU6050 6-DoF Accelerometer and Gyro. (n.d.). Adafruit Learning System. Retrieved March 7, 2024, from https://learn.adafruit.com/mpu6050-6-dof-accelerometer-and-gyro/overview

Nag, A., Mukhopadhyay, S. C., & Kosel, J. (2017). Wearable flexible sensors: A review. *IEEE Sensors Journal*, *17*(13), 3949–3960.

Payne, C. J., & Yang, G.-Z. (2014). Hand-Held Medical Robots. *Annals of Biomedical Engineering*, *42*(8), 1594–1605. https://doi.org/10.1007/s10439-014-1042-4

Saggio, G., Riillo, F., Sbernini, L., & Quitadamo, L. R. (2015). Resistive flex sensors: A survey. *Smart Materials and Structures*, *25*(1), 013001.

Salman, F., Cui, Y., Imran, Z., Liu, F., Wang, L., & Wu, W. (2020). A Wireless-controlled 3D printed Robotic Hand Motion System with Flex Force Sensors. *Sensors and Actuators A: Physical*, *309*, 112004.

Schwarz, R. J., & Taylor, C. (1955). The anatomy and mechanics of the human hand. *Artificial Limbs*, *2*(2), 22–35.