Design and Implementation of Upper Prosthetic Controlled remotely by Flexible Sensor Glove

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Abstract: The structuring and the employment for a wireless prosthetic hand adjusted by a flex sensor has been suggested. The prosthetic hand has been constructed for emulating the individual arm motion utilizing a hand mitt. The hand mitt subsists of 5 flexible sensors concerning overseeing the finger motions. The animator's design utilized to prosthetic arm has servo-motors. The fingers motions are adjusted utilizing wires which operate similarly to the tissue for an individual hand. The prosthetic hand dominates from a faraway position utilizing using remotely unit. Prosthetic hand-design equipped with many sensors; these sensors make the prosthetic hand more intelligent. The first sensor is the force sensor resistance. The second sensor is an infrared temperature sensor. This hand contains many medical applications that can be modified to become wearable for people with missing upper limbs, and the possibility of being used by doctors to perform surgeries remotely within the specified range or much further by connecting it to the internet system in addition to industrial and military applications, which is practical and low-cost. Practically tested to imitate human hand freedom movements and holding with high accuracy.

Keywords: Flex sensors, HC-12 wireless module, robotic hand, servo motor.

1. Introduction
The International Federation of Robotics (IFR) indicates a cooperation robot that operates like-rather entirely automatic-ruling for finishing authority useful for the expansion of public as well material, excluding assembling overloads. Such robots are almost implemented within diverse territories of applications along with service, army propositions, necessity infirmary exercises, uncertain circumstances as well as agriculture [1]. It is better to design different parts of the humanoid robot with enhanced features for an appropriate task [2]. Actually, along 70 arm layouts could be formed with the scholarly novel, as well an identical sum of scheme exists within the tolerant novel [3]. The availability of small-expense structure equipment like the 3D typing as well artificial monitor, handout program apparatus like an Arduino kit which is simple to be coded for assimilating envisions into their assimilated construction scampers [4]. The ultimate mutual forms of automation, robot machinery which receive expanded...
concerning various aims defined as Robotic Arms [5]. The motive of human gesture recognition and modeling is transforming gesture into a message to be conveyed. This inspired the researcher to make an animatronic automated arm that may play the condition for the person's arm in antagonistic conditions without the actual presence of the human hand in that environment [6]. This is the reason for the invention which needs combining more than two fields such as mechanical, electrical, and computer engineering to perform different tasks by the single machine [7] because the robot is an electro-mechanical structure that can be made intelligent with the help of the computer and electronic programming [8]. A remotely vitalizing arm is essentially an automated arm that has been employed throughout utilizing a current cellular methodology. Here task plans to realize an economic computerized crop recognized as robotic arm depends on cellular machinery. Robotic arm consisting of two essential portions of the arm, the early one formed from a computerized peripheral, also the other structured from the automated scheme which permits movement [9] during the time that here task considering with the architecture as well improvement of an automotive arm along with actual life management [10]. The computerized hand function may be tight in turn adaptable to mechanical or home applications [11]. The motivation for such an amount has to make elaborating with several of the production where the individual arm is should through finish the recommended mission, yet it could damage a person's surface either cartilage. So that, rather of utilizing a definite individual arm, it is restored via the cellular mechanized arm. One could permit that robotic arm to finish the exact mission to avoid the risk as well the needed mission may be obtained. As a lesson, here Robotic arm could have seated on an acting floor as well as a camcorder for scattering the explosive against a secure area beyond either damage for human life [11,12]. In addition to that, the device can be employed in remote medical assistance wherein doctors can perform surgeries from a distant location, obviating the need for physical presence [12,13]. The data were obtained from the wireless system was evaluated, converted, as well next utilized to integrate a minimized structuring field for an animatronic humanlike arm [14]. Afzal et al. the robotic arm is controlled from a distant location using (ZigBee). Servomotors with a torque of 11 kg are used. The main objective of the project is to design and develop the robot that is used to move using a wireless system by recognizing hand motion that is controlled by haptic technology for the virtual environment & human-machine systems. However, the robotic arm can be controlled over the internet by using Ethernet connectivity and a camera for visual feedback [15]. Khan et al. In this paper propose and design a robotic arm that will be using a new controller which is known as Leap Motion Controller. it is comprising of three light-emitting diodes (LEDs) and two cameras. however, the design is that Leap Motion is not able to "see through the fingers" - for example, when one finger covers the other. Fingers right next to each other also pose a problem for the cameras and might not be recognized individually [16]. Sharma et al. This paper deals with the Design and Implementation of a “Wireless Gesture Controlled Robotic Hand with Vision”. The system design is having 4 parts, namely: Accelerometer Part, Robotic Hand, NRF, and Platform. The objective of this paper has been achieved, which was developing the hardware and software for a gesture-based robotic hand. however, Video is limited with Wi-Fi cameras because of the cost to upload a video to the cloud [17]. Rejab et al. In this paper a control system of the mobile robotic arm was built by using a PS2 joystick and the microcontroller (Arduino UNO) and sent the command by the master Bluetooth (HC-05) that represents the transmitter part. It was possible to develop the prosthetic hand with sensors in order to be more intelligent and able to do multiple tasks. and increase the range of wireless by use another sensor[18]. Angel-López et al. This paper shows the development of a robotic prosthetic hand controlled by voice commands, according to several grasps and movements the robotic hand is controlled with a Graphical User’s Interface (GUI) made upon the MATLAB environment. By increasing the training parameters of the ANN like the number of times a command is trained, the number of LPC for each recorded command, and the error calculation iterations, the voice command detections become more accurate [19]. Beyrouthy et al. In this paper, the work introduces the initial design of an EEG mind obtained from headset controlled smart prosthetic arm .and equipped with a network of smart sensors and actuators that give the patient intelligent feedback about the surrounding environment and the object in contact. Besides, connecting the arm to the internet, and making it part of an Internet of Things network (IoT) will increase the performance and productivity of many industrial applications. One of the determinants of this technique that it was expensive and needed large industrial machines for the
purpose of accomplishing the tasks [20]. Ando et al. This paper developed a human body communication-based wireless transmitter and receiver for transmitting the myoelectric signals from the arm to the motor controller of the myoelectric hand. This result should be the first realization example of wireless control of an artificial robotic hand based on human body communication technology. It may become possible to detect the brain signals and send them wirelessly to the artificial hand, arm, or leg to control its movement [21]. Ku Kim et al. in this paper present an optimal set of materials, design layouts, and fabrication schemes to construct an easy-to-wear seamless electronic glove (e-glove) suitable for arbitrary hand shapes that provides all of the desired human hand-like features. Finally, the application of the established e-glove platform can also be extended to smart gloves for assistive robotic hands, automotive factory workers, and home-based rehabilitation [22]. GÜcüyener et al. In this study, it is aimed to decrease the workload of the physical therapist and develop a hand rehabilitation system with easier and more flexible usage. Also, those units which communicate wirelessly with each other provide a flexible usage System that is made for only the right hand. A Data Glove (Data Glove Unit consists of a glove, six pieces of flex sensors) for left hand shall be made, and this new glove shall be used in a rehabilitation centre [23]. Man et al. Nowadays, the gesture is one of the most natural interaction methods of the human being. This paper discusses the design and implementation of deaf sign language using an automatic hand gesture robot using Bluetooth and the Arduino board. we can replace Bluetooth with Wi-Fi technology that to increase the range of the device [24].

This research contribution can be summarized as follows:

1. This prosthetic hand is practical and low in cost, as it has been practically tested to imitate the movements of the human hand.
2. It can do all the work that the human hand does in the event of its loss or if its presence is somewhere. It represents a risk as well as the ability to measure the strength of the things that hold it with measuring the temperature of the room and things, and in the medical field measuring the temperature of humans and animals remotely if measuring it is dangerous
3. The system achieved high accuracy of 90.9% and with minimal error or delay of the body that does not exceed 9.1%.

2. Materials and Procedures
The schematic illustration for the suggested scheme has demonstrated in Figure 1.

**Figure 1.** schematic illustration for the wireless Prosthetic Hand scheme.

Arduino mitt has been suggested throughout here enquire for observing that release improvement for the arm as well handle that may be applied like a supplement of various structures [1]. The sensors detect the movement of the user’s hand. The information received from the sensors is transmitted to the robotic unit which performs tasks upon such supports for the received information. The animator's arm includes that
complete Figure movement with the movement of joints similar to a human arm. Such arm forms by 5 handles (4 handles as well 1 tumble), both containing 14th degrees of freedom (DOF), that could execute tighten, construction, kidnapping, rounding as well further turning. For that motivation aspiration, the structuring of that animator arm depends upon that necklace resulted at every handle elbow for that animated arm [35]. The robotic hand motion which mimics the hand movement of the user can be very useful to perform different unpleasant jobs easily [8]. The bend sensors which could be formed in single-style either twice styles soften have locators with resistor may be altered using the tension enforced. Because that person's handles could be bent along a single path depending on the essence, a unique-style bend sensor has been elected to be the taster along with such research. Besides assistance from such tasters, servo motors could be composed starting at 0° up to 180° [36]. Each servo has an individual signal port [37]. Hence, animator step high, low, south either north coordinates motions as well gather bodies against single point so maintains along with different wanted points according to positioning applied by a motion for handles with arm [28]. The glove in the transmitter side of the animatronic hand in which the flex sensors were used for capturing the moment of the fingers which work on the principle of Resistance. Moreover, the Arduino Nano is utilized which is capable of reading the inputs like capturing flex movements and produces output like rotating a motor. Then in this research, the hc12 module series were used for transferring wireless messages through the air [29]. The 3D arm is a scheme utilizing the Solid Works Computer-Aided Design (CAD) program. Solid Works has been applied due to the simplicity in utilization also processing. Actually, a strong scheme for robotic arm structuring could be transported towards the Sim Mechanics scheme during three-dimensional motivation as well as kinematics investigation desiring. For obtaining the desired liposuction arm with the exact volume as well density besides that ordinary person arm, totally mechanical and electronic parts had formulated for qualify towards that arm. Behind the 3D scheme has advanced within program design, such scheme demands to be stamped utilizing a three-dimensional printer [30]. Practically, an arm has formed against (Polylactic Acid) PLA substantial. The substantial has elected because of the less weight estate. Such a three-dimensional structure specified for a prosthetic arm has started via the manoeuvre arm. In this hand, 5 servo motors were used to drive the hand movement using a fishing line which runs from the servo till the fingers [31]. In this study HC-12 module was used and Arduino UNO which receives the wireless messages transmitted from the glove to move prosthetic hand fingers individually.

2.1. The Arduino
The Arduino nano in Fig. 2 was used in the transmitter unit considered as a limited, entire, as well bread-board-friendly established upon an ATmega328 (Arduino Nano 3.x) this kit has much either minor like similar operation for an Arduino Due (milanove), rather with a various kit. This package looks just Direct Current energy mate, also operates along the Mini-B USB wire rather than for the specification kit. Arduino computing software has a stated copy from C/C++ [32].

![Figure 2](image_url)  
Figure 2 the Arduino. (a)Arduino Nano and (b) Arduino Uno.

Arduino board is defined as an accessible authority clone appliance as well program association also
customer society which built so as constructs package in order microprocessors of designing arithmetic apparatuses as well bilateral commodity which may detect also adjust substances within a materialistic universe. Arduino panel structures utilizing a diversity of microcontrollers as well as monitors. Arduino UNO that is of ATmega328P microcontroller was used in the receiver unit because the circuit is complex and a lot of data is processed including readings of power, temperature sensors, and servo motor operation of the prosthesis. The board is equipped with fourteen binaries as well as six analogue entry/outcome (Input/Output) nodes which could have an alliance with different extension panels as well as alternative routes [33]. The panel aspect sequential media attachments, counting (USB) upon several schemes, are further utilized in storing software codes concerning special clone (PC). Were Microprocessors classically coded utilizing an idiom of aspects against such software coding C++ as well C. Furthermore, for applying standard authority equipment groups, an Arduino task contributes an integrated development environment (IDE) established upon the refining language task [30].

2.2. Flex Sensors
Flexible sensing devices have been considered essentially as changing resistances along area begin with 1 inch to 3 inches, as shown in Figure 3. Such apparatuses have been utilised to compute the twisting within the handle at the sender part via the altering of the resistors. When the arching slant raises, the resistor value raises as well the altered resistor has transformed in terms of potential via a potential actuator system also provided to analogue to digital converter (ADC) to get binary transformation [12]. Altering such an amount for the resistance will produce variant outcomes. The bend resistance range is 10k in flat 25k in minimum to 125k maximum (depending on bend radius) versus to 300-900 in ADC reading in decimal of range 0-1024 [12]. As the flexible sensing parts resulting in honest readings just when the bent in certain coordination commonly towards that theme front for the sensing tools [34]. Considering analogue outcomes for flexible sensing ports, those had obtained via a factor from that frame containing sensing equipment should require for transform within binary for more continue. This situation has almost so often low-cost from either else sensing part as well as providing better results. Furthermore, the cyphering considered easier from alternative animators. Drawbacks were lower precise, obstruction, also have an unpredictable value of the sensor.

![Figure 3. flex sensor.](image)

2.3. HC-12 wireless Figure
HC-12 cellular sequential gate transmission Figure which has been considered as a modern-formation several medium enclosed cellular information communication Figures illustrated in Figure 4. The cellular functioning range of frequencies from 433.4-473.0MHz, where several mediums could be fit, along with spacing with 400 kHz, as well overall of 100 bands. Actually, ultimate sending Figure energy about 100mW (20dBm), with detecting subtlety about -117dBm on baud rate about 5,000bps for an audio signal, also the transmission length of 1,000m with a wide field. This Figure has packed up using mark gap, that could
accept repair solder, therefore here was so acceptable in the application system. Another circuit of MCU available within such Figure circuitry, so that customer has not required to encode the Figure independently, as well every translucent communication phase has logical reasons to detect as well transmit sequential gate information [29].

![Image](image1.png)

**Figure 4.** HC-12 Wireless Module.

2.4. Servo Motor

Servo motor, as shown in Figure 5, shows a turbine relevant to utilised with a sealed cycle monitoring scheme. This satisfactory combine turbine connected with sensing tips for adjusting situation retaliation in order to sustain a handle motion with revolution [31]. The assembly appears finalised using 30cm cable as well as 3 S type pins with a womanly venture joint which is compatible with most receiving units. Here large-velocity ideal servo may revolve relatively 180 degrees (60 in each orientation) with processing velocity: 0.2 s/60° (4.8 V), 0.16 s/60° (6 V). Servo motors in this system with a torque of 9.4-11 kg are used depend on voltage value.

![Image](image2.png)

**Figure 5.** servo motor.

3. Workflow

The algorithm of this study was utilised for sensing a motion for an individual arm; this arm passion scheme together with the transmission strategy implemented was presented. Device sensors are operating via that assistance of flexible sensing units included in the hand glove as demonstrated via Figure 6.
Flexible sensing units are defined as apparatuses that have varying resistors if such sensors are directed with twisted impact. These resistances ascend if a twisted corner ascends also staying at a formal amount in the absence of any force [34]. The resistances of the flex sensors were read by the Arduino hardware as shown in Figure 7 which shows the flexible sensors were mounted onto the glove to enclosing a full handled distance. The microcontroller in the Arduino converts the analogue resistance value into a digital count by the Analog to Digital Converter. The digital count value is a direct indication for that resistances concerning such flexible sensors and hence represents the bend angle. The digital count that is obtained is used as an intermediate value and is transmitted by the HC-12 module to another microcontroller which rotates the servo motors. Servo motors are a special kind of motors that have a 180-degree sweep angle and run on pulse width modulated signals [31]. In fact, Arduino results in a signal span modulation waves needed via servo generators as well motors so that for result with suitable revolution order. The servo motors are mechanically coupled to the fingers of the robot hand, which leads to the movement of the fingers in response to the positional change of the servo motors.

Figure 6. Block scheme of The Prosthetic Animatronic Hand.

Figure 7. The flexible sensor hardware connections.

Figure 8 illustrates the flexible sensing units with Arduino podium contact. Sensing units have been linked to an analogue entry for a microcontroller associating with the voltage division principle.
The analogue information received from the flex sensors through the movement of the fingers of the gloved person's hand, who wants to control the movement of the prosthetic hand at the other end. Also, the error happens due to higher sensitivity of the flex sensor, the digital count value of the Analog to Digital Converter turned out to be inconsistent and varying rapidly. The readings are converted to digital information and then sent to remotely robot hand through the hc12 wireless communication module. On the other side, the hc12 received information, and the Arduino will process that signal and control the servo motors that move to control fingers in the robotic hand. Several sensors can be added to the robotic hand, as shown in Figure 9. Each sensor has a function to do as a force sensor (FSR400) that is used to measure the force of objects in contact with the sensor as well as can be tested by a grip with a grip of the objects (ball, glass, cup) [35]. And the prosthetic hand designed and equipped with a temperature sensor (MLX906) to measure the temperature of humans, animals, and the environment as a medical application as well as objects in contact with the sensor as an industrial application [36], this sensor gives a prosthetic hand a perceptual sense of the environment and allows the person capable of knowing a hot or cold object.

4. Mathematical Model and Software Requirements
Considering the 2-dimensional mathematical model of the bend sensor variation which equivalent to move the finger in 3 freedoms of movement represented by Figure 10 and hence that for settle relative definition amid $\theta_1$, $\theta_2$ and $\theta_3$ those are revolved corners concerning 3 channels respectively according to the 3 freedoms movement of the finger. The $x$ and $y$ were that latter locations for such several-connection scheme. $\Phi$ considered as an addition of angles $\theta_1$, $\theta_2$ as well $\theta_3$ which are represented the displacement, angular displacement and obtained position respectively.
The following relation of matrix series in (1) & (2) can be considered [37].

\[
R_{1x} = \begin{bmatrix}
1 & 0 & 0 \\
0 & \cos \theta_1 & -\sin \theta_1 \\
0 & \sin \theta_1 & \cos \theta_1
\end{bmatrix}
\]

\[
R_{1y} = \begin{bmatrix}
\cos \theta_1 & 0 & \sin \theta_1 \\
0 & 1 & 0 \\
-\sin \theta_1 & 0 & \cos \theta_1
\end{bmatrix}
\]

\[
L_i = \begin{bmatrix}
0 \\
0 \\
\theta_i
\end{bmatrix}
\]

\[
P_1 = R_{1x} L_1 \\
P_2 = R_{1x} L_1 + R_{1x} R_{2x} L_2 \\
P_3 = R_{1x} L_1 + R_{1x} R_{2x} L_2 + R_{1x} R_{2x} R_{3x} L_3
\]

where \( P_1, P_2, \) and \( P_3 \) are positions of the links, \( R_{1x} \), \( R_{1y} \) is the rotation matrix of finger movement, and \( L_1, L_2, \) and \( L_3 \) are the lengths of three links.

Software requirements participate Arduino software as well as the coding within planted C. Using support for Arduino board kit smart features could be invented via catching the participating supplied by sensing units with switching devices, to monitoring collection of practical results. An Arduino circuit is considered as the ultimate section preferred with real spot which is sensible, essential software coding setting, short phase as well this is free origin software programming also the devices may be extended. Figure 11 (a) and (b) show the flow chart of the Arduino programming of the transmitter and the receiver for the control system of the glove and the robotic arm [1]. The void option is only used in job definitions. Indicates that the job is expected to not return any information to the job it was called from. A clear keyword has been utilised just for the service profession. This points out that the service has normal for recovering non-data towards that service where it had labelled.
5. Results

Each of the flex sensors was initially checked for their nominal resistance values, when not subjected to any stress. Accordingly, resistors were chosen to be connected along with the flex sensors as a part of the voltage divider circuit. The digital count values obtained from the ADC for each of the sensors, under both straight and bent conditions, were noted using the serial monitor. The flex sensors for each finger with its resistance and filter value range were indicated in table 1, flex sensor working principle is that when bent, the resistance increases due to the conductive particles being further apart. The filters libraries supply Arduino software engineers with information channelling procedures with a formable tote for the latter symbol amount. Especially, such an issue is effective when sleeking such information entering by the sensing units, either determining if the brink that navigated without noisy signal at the entered waveform. Arduino library for basic signal filtering identified these used filters to clean up loud signals by blocking small (fast) signal changes while passing through larger (slow) signal changes. This is typically done by suppressing the larger fluctuations frequency. Therefore, the result is more stable (fixed) value with less noise. Table 2 shows the ADC digital count values obtained for each flex sensor used in the module related to the robotic finger movement. A servo motor in the robotic hand was used to sense the variation of the flex sensors represented by digital count values. However, the motion of the robotic fingers due to interferences resulting from the minuscule movement of the flex sensors was avoided. This result has been filtered by program code for two both sides, the glove and the robotic arm and the value of the filter was change according to the value of the flex sensor and servo motor.
Table 1. Flex resistance values range with respect to the filter value range.

| Flex sensor   | resistance value (KΩ) | Filter value range |
|---------------|------------------------|--------------------|
| Sensing 1 (thumb) | 12.8-19.8               | 1-10               |
| Sensing 2 (index) | 15.3-25.9               | 1-10               |
| Sensing 3 (middle) | 14.2-24.1               | 3-10               |
| Sensing 4 (ring) | 14.5-23.1               | 2-10               |
| Sensing 5 (little) | 14.9-24.9               | 1-10               |

Table 2. ADC digital count values for each flex sensor with respect to each finger.

| Flexible sensors | Min ADC Count | Max ADC Count | Nominal ADC Count |
|------------------|---------------|---------------|-------------------|
| Sensing 1 (thumb)| 754           | 840           | 780               |
| Sensing 2 (index)| 769           | 840           | 785               |
| Sensing 3 (middle)| 786        | 840           | 800               |
| Sensing 4 (ring) | 776           | 840           | 790               |
| Sensing 5 (little)| 779          | 840           | 790               |

The relation between the flex sensor value (ADC reading) and the filter's maximum and minimum values are shown in Figure 12.

![Figure 12. Flex sensor value (ADC reading) and filter value range.](image)

Table 3 stated the maximum and minimum degrees of each servo motor with respect to the change in flex sensor values (ADC reading).
Table 3. Minimum and maximum degrees of each servo motor with the change of ADC reading.

| Fingers | Min ADC Count | Max ADC Count | Minimum Servo degrees | Maximum Servo degrees |
|---------|---------------|---------------|-----------------------|-----------------------|
| (thumb) | 754           | 840           | 45                    | 180                   |
| (index) | 769           | 840           | 45                    | 170                   |
| (middle)| 786           | 840           | 60                    | 180                   |
| (ring)  | 776           | 840           | 45                    | 180                   |
| (little)| 779           | 840           | 50                    | 180                   |

The relation between the flex sensor's values and the servo motor minimum and maximum degree were shown in Figure 13 and Figure 14 respectively.

Figure 13. Flex sensor values and minimum servo degrees.

Figure 14. Flex sensor values and maximum servo degrees.
A different photo of the experimental tasks of the prosthesis hand was shown in Figure 15.

![Figure 15. Prosthesis Hand performing different experimental tasks.](image)

6. Conclusions

This enquires introduced a prosthetic arm using a flexible sensor utilising fourteen order freedom degree each finger has three movements except the thumb, two movements with a remotely animated arm that has been employed via utilising a current wireless strategy. The problems faced were corrected, and the module was hence found to be operating without any error approximately. This animator hand could be a supervisor via an internet network through utilising Wi-Fi cloud to Remote surgery as well can connect with the internet of things (IoT) to monitoring. As well as manufacturing them to be wearable for the handicapped, for people suffering from lack of the upper limbs. This prosthetic hand can hold things and carry them from one place to another and fully imitate the human hand for all required applications, whether medical, industrial or military, high maritime and high accuracy of up to 90.9%, as well as being intelligent by measuring the strength of objects held through the force (FSR 400) sensor and measuring the temperature of people and animals And the place through the temperature sensor (infrared) in emergency situations, which is difficult to measure, due to the presence of danger. Future works will be made to produce this wireless hand move from one location to another and change the material that uses for made the prosthetic hand by using polycarbonate or resin material to give a prosthetic hand more hardness and toughness. Furthermore, it is possible to use the mind wave EEG sensor or EMG to control the hand.

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