Wireless Animatronic Hand Using Control Glove

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Abstract- **This paper discusses the design and implementation of a wireless animatronic hand using Radio frequency (433 MHz) module and Arduino-UNO board. The main aim of this paper is to highlight mainly the use of wireless communication and it's applications by using wireless animatronic hand. The system/ electronic product were implemented using control glove, micro servo motors, RF module and Arduino-UNO board having on-board Atmega-328. It was observed that after bending the single flex sensor at the transmitter side, the corresponding robotic finger moved in the same manner and same angle. Servo motor causes the movement of a robotic finger. With reference to this, all five servo motors moved (or controlled) by five flex sensors on a single control glove. In this way, a wireless communication has been achieved successfully. So, now it is possible that a man can control a robotic hand from a distance wirelessly.**

Index terms- **Arduino, Servo motors, Flex sensors, Robotic Hand, RF**

I.INTRODUCTION

The human hand is one of the universal tools in nature. There is no wonder that researchers are eager to apply the advantages of the newest evolutionary designs to develop the generation of the robotic hand applications. Over the last decades, the research interests in the upper limb robots have increased significantly. The available commercial robotic hands are described by the low in the number of degrees of freedom and the complicity of the control system. Thus, it has become essential to introduce a new design strategy to help exceeding those limits. Also, the technology development has introduced simplified methods to improve such devices. Syed et al. presented in 2012 a flex sensor to determine the state of robotic motion in the applications with high repeatability, precision, and reliability [1]. Afterwards, the type2 fuzzy was used to control the servomotor position in the rehabilitation robot application to increase accuracy in the nonlinear robot motion [2]. Khor et al. developed a rehabilitation robot with simplicity and low cost for stroke patients [3]. In 2014, Ali et al. proposed a system for controlling the gripper of multi-fingers via the emphasis on finger joints and tips [4]. Hassan and Karam designed a 4-DOF rehabilitation robot for the upper limbs to rehabilitate persons affected by strokes [5]. Hande et al. developed a hand that performs various tasks and can be used as prosthetic hand controlled via a microcontroller [6]. The force position controller with type-1 fuzzy was designed to control the 4-DOF rehabilitation robots for the disordered persons [7]. In 2017, Afzal et al. presented a robotic arm that workslike gesture using control flex sensorsto simulate the human hand motion for the disordered persons [8]. Olewi and Abdulmajeed built a human hand robot using a 3D printer and flex sensors placed on a smart glove to sense motions [9].

This work proposes a robotic hand design that is manufactured using the 3D printing technique including the forearm. It aims to provide hand functionalities similar to those of the real human hand such as gesture movements and objects grasping. The actuation system mechanism that is used is the Tendon-Driven mechanism in which tendons are connecting the servomotors to the fingers of the hand. Also, the control framework utilizes the Arduino micro-controller that controls the output servo angles depending on the input from the muscle sensor (flex sensor). Furthermore, five servomotors are used for controlling the robot fingers motion based on flex motion sensors. The sensing circuit (transmitting master circuit) senses the signals from the human hand motion using flex sensors that are supported on a wearable glove. Both the Bluetooth module and Arduino card are applied to process and transmit the sensed motion signals to the robotic hand from a faraway place. The robotic hand will receive the motion signals using another Bluetooth module

along with an Arduino card (receiving slave circuit) to process the motion signals in a suitable form as actuation signals to the servomotors.
This paper is organized as follows. Section II presents the literature review and then a 3D printer. Section III describes the electrical circuits designs that are proposed to drive and control the robotic hand (Master and Slave circuits). The route of control signals from glove to the robotic hand is showed in section IV. Section V states the kinematics mathematical equations derivation and simulation with applied motion trajectory. Section VI presents the physical test of motion in acceptable phase using the proposed Arduino AT commands as well as the simulation test which prove the derived Kinematic equations. Finally, the conclusion of this paper and future work are presented in section VII.

II. LITERATURE REVIEW

A. Wireless Controlled Robotic Arm by Using RF Modules for Picking and Placing an Object

Typical applications of robotic arms in the industry include welding, painting, assembly pick and place, packaging and palletizing, product inspection, and testing. The purpose of this Wireless Controlled Robotic Arm is to develop wireless controlled robotic arm by using RF (radio frequency) modules that are designated for picking and placing an object. The system is made up of a controller keypad for the input command for the robotic arm system, a microcontroller which will interpret the signals from RF modules, and motors that will actuate the robotic arm. The main objective of this project is to build a wireless controlled robotic arm that is capable of picking and placing an object [8].
The system consists of two working parts which are the input part where the controller keyboard is used to input command and the output part where the DC motors perform the task needed. The input of the system is from the controller keypad where users press keys to command the robotic arm movements. The controller keypad input data is first encoded so that it is compatible to use for the transmitter RF module [9]. Then the transmitter RF module transmits the encoded data to the receiver RF module thru the air (wireless). The data is then decoded after being received by the receiver RF module for the microcontroller to process it.
After that, the microcontroller sends the data to a motor controlling circuit that helps rotates the actuators which are the DC motors. As a result, this system has succeeded in developing a wireless based controlled robotic arm for the purpose of picking and placing an object. However, the controlling method used which is the controller keyboard will not be easy when it comes to a sophisticated need for complex control

B. Inertial Sensor Based Wireless Control of a Robotic Arm

This system uses the technology of an inertial sensor where it consists of motion, rotation, and magnetic sensors to continuously calculate the position, orientation, and velocity of a moving object without the need for external references [10]. Basically, this system focuses on designing a control unit based on motion sensing. The main objective of this project is to build a system that allows the robotic arm to be controlled over a long distance, with an intuitive and simple to use the controller in addition to a sufficiently accurate response.
The system consists of two working parts which are the input part where the inertial sensor which is placed on a real person's arm to read the data from the human's arm movements and the output parts which are servo motor that moves all the robotic arm joints. The system uses an IMU board manufactured by Sparkfun that consists of a digital three-axis accelerometer (the ADXL345, manufactured by Analog Devices) and a digital three-axis gyroscope (the LTG-3200, manufactured by InvenSense) in the control unit [11]. An analog three-axis accelerometer, Analog Devices ADXL335, is strapped to the arm. The analog three-axis accelerometer controls the movement of the main body of the robotic arm, while a potentiometer is used to control the end effector which is the gripper. Wireless transceivers modules used for this system is based on the ZigBee protocol for wireless transmission and reception of data. Processing of the data is carried out using Atmel ATMega16 microcontrollers -one in the control unit, and one at the receiving end to control the robotic arm. As a result, a wireless motion sensing control unit was successfully built and used to control a robotic arm from a distance. The intuitive nature of the system allows it to be handled easily, without much guidance or practice. The system has potential

in fields where teleportation may be required, including medicine, industrial operations, disaster recovery, bomb disposal, and undersea recovery.

III. METHODOLOGY

The proposed robotic hand consists of a forearm, five fingers and a palm, all are manufactured using the 3D printing technique. The work steps start from the design phase that is done by SolidWorks software then printing the parts in 3D to ultimately assemble them and connecting the actuation system. Each finger, except the thumb, is constructed from three phalanges that are considered as the links jointed together by wheels and pins. The wheel is connected to tendon and the pin is fixed to support the hinge. Fig.1 shows the CAD design of the index finger with 3-DOF. The palm is a one part constructed in a very sophisticated design which is the center that connects the fingers and the forearm. It has grooves to allow the tendons passing from the actuators which are located in the forearm. These grooves ensure that the tendons for each finger will not interrupt with others and constrain its movement in a specific area that makes the control of movement easy to some points.

The forearm is constructed from two main sections; each contains three parts connected tightly by screws. Fig.1 shows the forearm shape and the complete palm. Tendon-Driven mechanism (TDM) depends on wire steering over pulleys. It is utilized to build up a lightweight spatial arm, automated hands, a suspended fast framework and a humanoid robot. The driving force is transmitted to a series of joints by the pulleys.

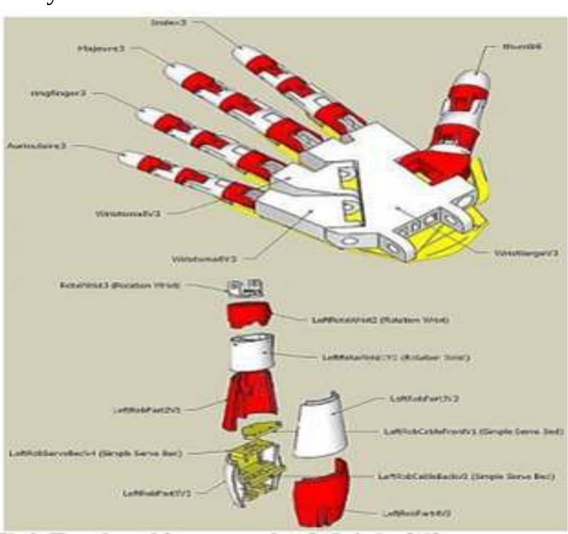


Fig.1.The palm and forearm complete CAD design [10].

IV. TRANSMITTING AND RECEIVING INTERFACING CIRCUITS DESIGN

The interfacing circuits contain the Arduino UNO card as the processer of the transmitting and receiving signals. The communication mechanism between the human and robotic hands is depicted in Fig.2.

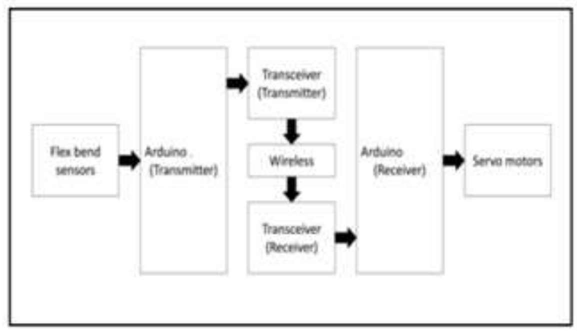


Fig. 2. Block diagram of the System

Fig. 1 shows the block diagram of the wireless hand gesture controlled robotic arm system. Flex bend sensors are set to be input and servo motors are set to be the output. It starts with flex bend sensors as the input as the system that sends readings of resistivity of the flex bend sensors into the Arduino UNO. The 1st Arduino UNO is placed at the transmitter circuit that will transmit the signal to the receiver circuit via a transceiver connected to it. Wirelessly the signal is received by a receiver transceiver connected to the 2nd Arduino UNO that will send the signals to the servo motors to do its task.

V. HARDWARE IMPLEMENTATION

A. Arduino UNO

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by arduino. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and

Leonardo. The hardware reference design is distributed under Common Creative Attribution Share-Alike 2.5 license and is available on the arduino website. Layout and production files for some versions of the hardware are also available. "UNO" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0.The UNO board and version 1.0 of arduino Software (IDE) were the reference versions of arduino, now evolved to newer releases. The UNO board is the first in a series of USB arduino boards, and the reference model for the arduino platform. The ATmega328P on the arduino UNO comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The UNO also differs from all preceding boards in that it does not use the FTDI USB-toserial driver chip. Instead, it uses the Atmega16U (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Fig -3: Arduino Board

B. FLEX SENSOR

A mechanical device which provides a variable resistance values after bending it; is known as a flex sensor. Using a flex sensor, it is possible to measure the amount of resistance which is produced by a flex sensor by passing particular amount of a voltage through a flex sensor and into an analog input on Arduino UNO board. A flex sensor is also known as a potentiometer or a variable resistor. Flex sensors are basically made up of resistive carbon elements. A flex sensor has a great form factor on a flexible thin substrate, as a variable printed resistor. When the substrate is bent, potentiometer or a flex sensor produces the output resistance as per the bent angle. Refer the figure 4.

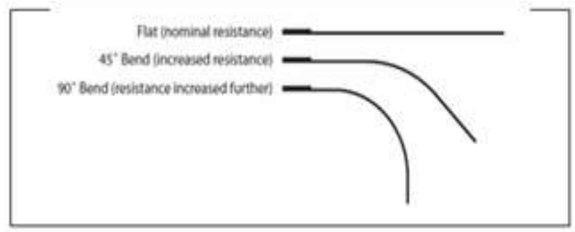


Figure 4. Varying resistance correlated to the bent (image from "google.com")

From the above figure (figure 4), it is clear that as the bend angle of a flex sensor increases, resistance goes on increasing. Nominal resistance is present at a flat position of a flex sensor. Smaller the radius, the resistance will be higher.

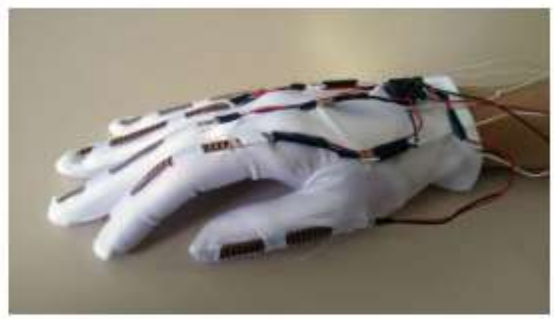


Figure 5. Control glove at the transmitter side

Output voltage is measured by using a mathematical formula. This formula is a voltage divider formula (figure 6) using which, corresponding variable voltage will be measured which will be given as an input to the Arduino-UNO.

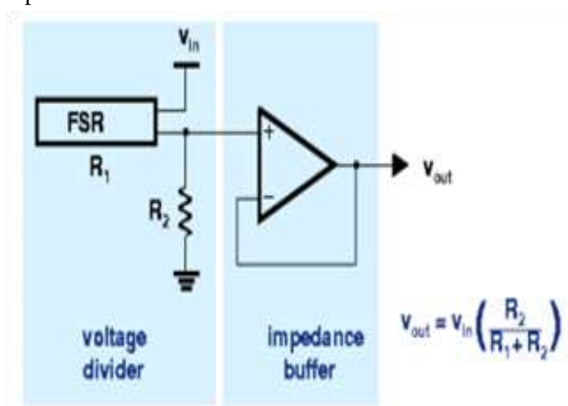


Figure6. Output voltage calculation

C. ANGLE MEASUREMENT OF A SERVO MOTOR:

To handle the finger movements and rotations, micro servo motors are being used in this project. A rotary actuator that allows for a precise control of velocity, acceleration as well as an angular position is known as a servomotor. Servomotor is a motor suitable for use in a closed loop control system. It includes suitable motor coupled to a sensor to get a position feedback. It need a relatively sophisticated controller, often a dedicated module which is designed specifically for use with servomotors.

Figure7. Micro-servo motor (image from "google.com")

Servomotors can be used in various applications such as robotics, CNC machinery or automated manufacturing. As shown in the figure 7, servo motor gives different angles for different duty cycles. In this project, at the receiver side, these five motors are connected so that, we can achieve a smooth movement of a finger of a robotic hand.

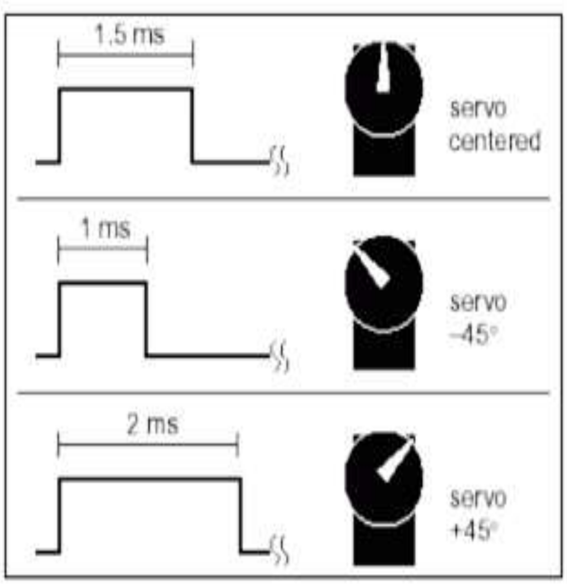


Figure 8. Angle control of a servo motor

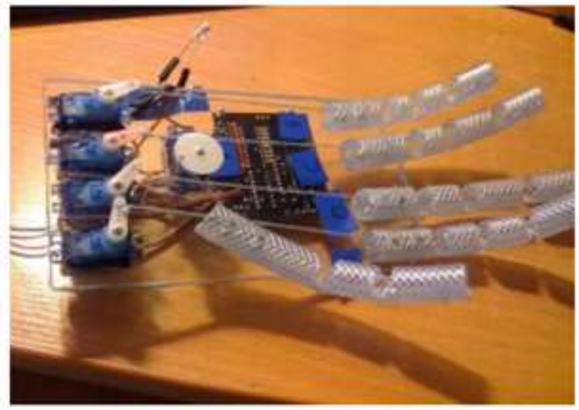


Figure 9. Robotic hand model at the receiver side

D. RF transmitter & RF receiver

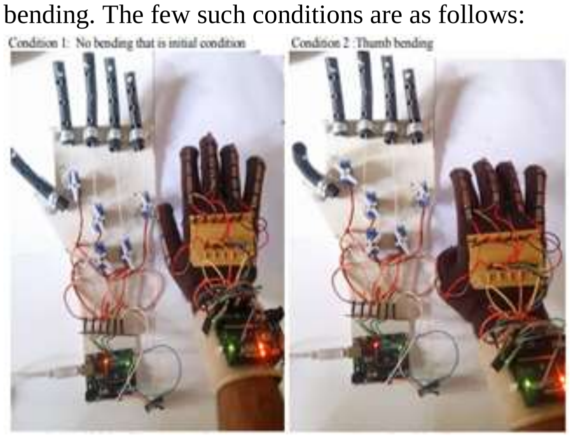
RF it means radio recurrence. We have utilized 433 MHz RF Transmitter/Receiver module. It has been planned in various working frequencies and furthermore in various working reach. To transmit and get the sign by means of RF module is important to have an encoder and decoder module which encodes and unravels the sign to transmit and get the sign. The transmitting extent is up to 500ft with range rate of 1kbps to 10kbps. TX module comprises (GROUND, VCC, DATA, ANTENNA) absolutely 4 pins. Encoder seventeenth stick is associated with the information stick of the module. A 17cm reception apparatus is utilized to transmit and get the sign which are associated with radio wire stick of TX module. TX gets sequential information and RF sign is transmitted remotely to the collector by means of this radio wire

VI. RESULTS AND DISCUSSION

The Animatronic hand using wireless modulation works smoothly without any hindrance. When the fingers are bent, the flex sensors resistance changed accordingly and with the help of voltage divider network, this change in resistance is converted into change in voltage. The inbuilt ADC converted the analog voltage into digital form and finally sent to the serial port which is sent wirelessly through X-Bee. The receiver electronic hand imitated the control glove which is mounted on the receiver's hand. The receiver side RF received the transmitted data from the flex sensors. The Arduino UNO processed the received data and produced the precise PWM signals to control the movement of servomotors. As the user bent the fingers , the servomotors rotated to control the movement of electronic hand fingers and all the movements of hands are imitated. So the objectives mentioned in the previous sections of the project report are completely fulfilled.

Fig:10 Flex sensors mounting

The control glove (Transmitter side) and electronic hand (Receiver side) are connected to power supply. Both are parts are synchronized with each other for wireless serial communication. There can be different conditions of control glove and electronic hand like one finger bending, no finger bending, thumb bending. The few such conditions are as follows:



Left: Initial Condition (No Bending) Right: Thumb bending

VII. CONCLUSION

The Wireless Animatronic Arm is a successful development. Implementation of wireless and motion sensing technology makes using the device easier than previous models. A 3D printed hand model can be used to provide high accuracy. As technology grows, the selection of hand model, sensors, microcontrollers and wireless communication system will need revision to implement various applications. The Prosthetic Animatronic Hand, analyses the actions of a human hand, and synchronously controls a robotic hand. The work was successfully tested and was found to operate in a hassle free manner. The problems faced during the execution were rectified and was made sure to not repeat under any conditions. During testing each module, a certain amount of problems were faced that included erratic behaviour of the servo motor that resulted from intermittent changes in the voltage. Also, 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 high sensitivity of flex sensors also resulted in the unstable functioning of servo motors.

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