

Design And Implementation Of A Wireless Gesture Controlled Robotic Arm With Vision

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Abstract— *The fundamental aim of the project is to develop a robotic arm that can be handled by a normal layman to complete the specific task according to the needs of the customers. In this proposed method, the system was designed and implemented, a prototype was developed to demonstrate the proposed system. The performance of the developed proposed system is evaluated by testing the accuracy of the gesture response, testing the range of the radio communication device, accuracy test in multiple ranges, resistance of the flex sensor in different angles, Recognition Rate and Recognition Time. It is observed that the implemented system has more movement freedom with the navigation platform and a day and night vision compared with the existing products. On the existing systems, most of them lacks on the ability to navigate around the operating space, meanwhile the implemented system contains a gesture-controlled navigation platform. Also, most of the existing systems lack on providing a monitoring feature to monitor the process of the robot from a distance where they only designed the system to be operated within the range of vision while the implemented system offers the feature of operating it remotely.*

Keywords— *robotic arm, gesture-controlled navigation platform, servo motor, flex sensor, Arduino Nano.*

I. INTRODUCTION

In today's reality, in all segments, the majority of the work is finished by robots or automated arm having diverse number of level of opportunities (DOF's) according to the prerequisite [1]. Robots are increasingly being integrated into industries to replace humans especially to perform the hazardous tasks [2]. A robotic hand–arm system in which a robot hand is attached to a multiple-degree-freedom arm are considered useful in performing complicated tasks in various environments [3]. These days, the robotic system has turned into a fundamental component in our everyday life. It works in a wide scope of regions. The pattern of actualizing the robotic system has been embraced by numerous industries and countries. Worldwide, the robotic system is utilized to deal with explicit tasks that are extreme and risky to people. Humans interact in the physical world by the means of the five senses. However, gestures have been an important means of communication in the physical world from ancient times, even before the invention of any language [4].

The researchers [5] presented an overview on hand gesture based wireless robotic arm control for agricultural applications, their technology used a glove as the Human Control Interface (HCI). The sensors are placed in the glove

and interfaced to the Micro Controller Unit (MCU), which will transmit the signal to the robotic harvester that carries the robotic arm and a receiver to get the data of the sensors from the MCU by using a Bluetooth module. The arm contains four servo motors that have a maximum travel of 199.5 degrees, and it's used to move the robotic arm as like the human hand's joints with a total 4 Degrees of Freedom (DoF). The entire system can be improved later on by making an automated system and test it to cut the grape and mango trees. The system was designed and made for the agricultural uses, where it uses a cutter at the end of the robotic arm. [6] made a research on implementation of a wireless gesture controlled robotic Arm. The aim of the research was to make the computer understands the human body language. The Image processing was used as a development for the traditional wired glove or the gesture recognition where those two methods only recognize a specified movement and react based on this movement. The system consists of two parts, transmitter and receiver. The transmitter part contains a PC, RF transmitter and a webcam and all the process is done in this part, and for the receiver it contains a RF receiver, microcontroller and motors to move the arm. The user or the operator has to stay within the detecting range of the camera to get the system going in the right way, and in case of not detecting the hand or if the hand got out of range the robotic arm might perform a wrong command. [7] proposed a research about accelerometer based gesture controlled robot with robotic arm. Accelerometer was used along with Arduino microcontroller, RF transmitter and receiver, motors to achieve the movement of the robot. A fire sensor was added to the system to detect if there is a smoke or a fire in case if a disaster happened in the industry and it will start buzzing if it got triggered. The system can be improved to fit multiple tasks as for what the job needs. The system doesn't have a base to allow it to navigate around the workplace. The system designed in a way where while moving the arm a switch needs to be used to switch to the gripper and move it.

[8] proposed a high level robot programming using body and hand gestures, in the research a visual sensor was used to detect the human motion, where it allows the movement of the robot in a different directions. A microcontroller was used with the robot along with a decoder to translate the movement of the human, and the system used to do that is Robot Operating System (ROS). Microsoft Kinect is the sensor used to implement the hand and body gesture. The robot speed is

20%, while programming, and the response time for the sensors was estimated around 43ms, while the response time from the robot after the communication is measured in 115ms. The system is user friendly and easy to use for untrained individuals. The system can be used in as a in different robot stages, which makes this method a universal way for robot programming.

Nowadays, most robotic systems in the field are controlled by usual inputs ways. This design will seem difficult for those who feel inconvenient to use the robotic system proficiently and expertly with a controller or has a low understanding of the robotic system. Training and essential information are required by the users to control the robotic system. In this way, the structure of controlling the robotic system with hand motions will turn into a way to solve the current issue as it is progressively convenient and easy to use compared with the usual input ways. Users could control the robotic system to move as per their own ideal motion by utilizing hand gesture movements. Other than that, this new strategy of controlling the robotic system by utilizing hand gesture movement additionally ready to enable users to work remotely at those dangerous activities or handle substantial objects. That can deal with the risky activities, for example, handle poisonous substances or bomb transfer, along with dealing with heavy objects or robot controlled tasks in the assembling industry. This new intelligent strategy among human and machine give a more convenient strategy to control the robotic system in many areas, it gives more exact movement of the robotic system rather than utilizing the controller. The fundamental aim of the project is to develop a robotic arm that can be handled by a normal layman to complete the specific task according to the needs of the customers.

II. BLOCK DIAGRAM AND OPERATION OF THE PROPOSED SYSTEM

The overall block diagram shows the schematic diagram of how the entire project is developed. Fig 1. shows that when a movement is sensed by any of the four sensors placed on the hand glove, it will be converted into data and get processed by the microcontroller where each sensor is meant to move a specific part, after that, the microcontroller will transmit the processed data to the second microcontroller to perform the movement via the RF transmitter and receiver.

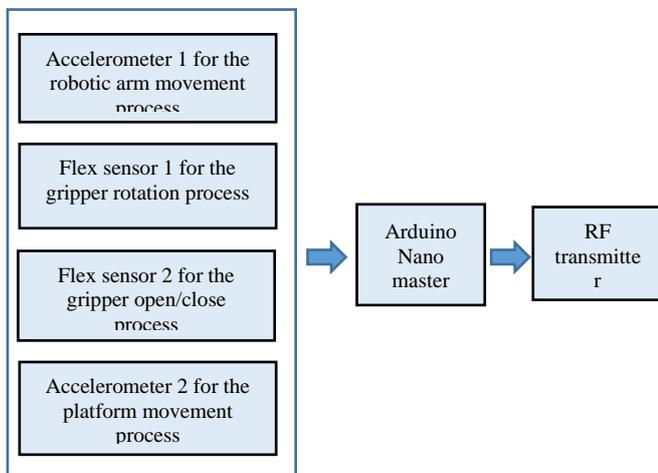


Fig. 1. Hand gloves block diagram

When the data is received by the receiver it will be processed to differentiate which motor it was meant to move, if the data was coming from the first accelerometer then it will be sent to the servo motor drive to move the robotic arm, if the signal was from the flex sensors it will go through the servo motor drive then it will move the gripper at the end of the robotic arm and if the data was coming from the second accelerometer then the data will be given to the DC motor drive to move the navigation platform. Fig 1. and 2. shows the overall block diagram of the two parts of the system.

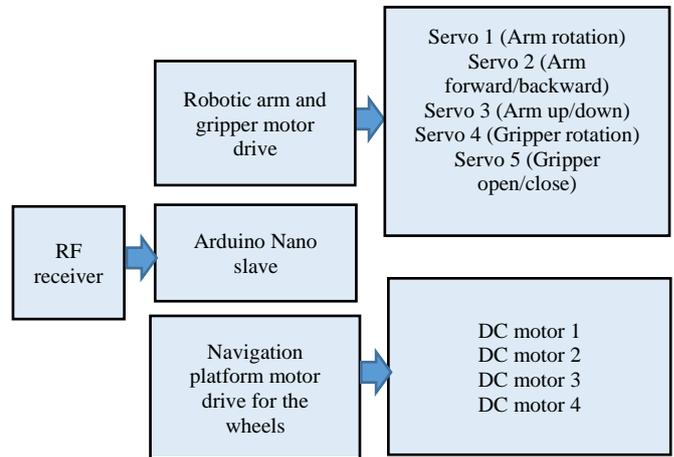


Fig. 2. Robotic Arm, and Navigation Platform Block Diagram

III. CONSTRUCTIONAL DETAILS

The wireless gesture controlled robotic arm has been planned to be constructed in three different phases. Phase one The wireless gesture controlled robotic arm has been planned to be constructed in three different phases. is the hand gloves and the sensors connections and detection testing for the hand movement, phase two is the robotic arm structure and the servo motors connection and testing the reaction to the hand gesture and its movement speed and phase three is the navigation platform structure and the DC motors connection and test its reaction to the left hand gesture and its movement speed.

For the structure of the project starting from phase one there is a wearable gloves where the Arduino nano microcontroller and the two accelerometers and the flex sensors will be placed on, for phase two, the robotic arm is made out of an aluminum 2020 for its durability, roughness and its ability to handle weights, starting from the bottom of the robotic arm there is a circular base with the diameter of 12 CM supported with four screws that connects it with the navigation platform from the bottom and another four screws from the top which is connected to the rotating bracket which is rotating 180 degree using a MG995 servo motor and it's connected to the circular base where the rest of the arm parts is placed, there is a servo motor to perform the front and back movements which is connected with two brackets by screws and a bearing with another servo to perform the up and down movements and it's connected to another servo with a bracket and screws to perform the rotation of the gripper and it's connected to the gripper with a joint and screws then the gripper contains a servo motor to perform the opening and closing of the gripper, and the height of all the arm parts joined together is 37 CM.

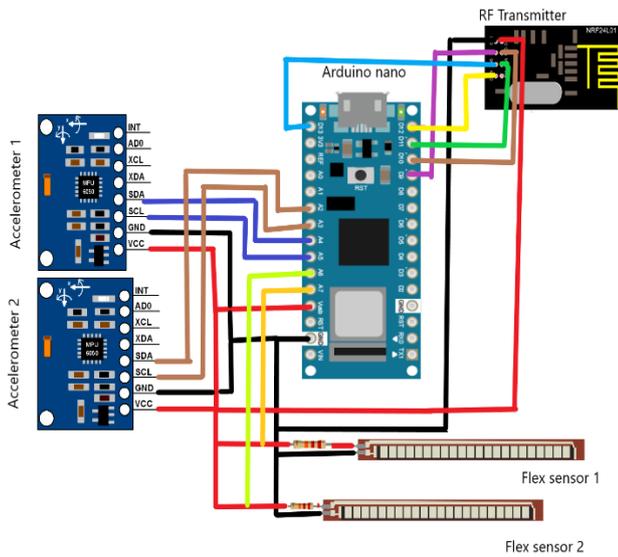


Fig. 3. The Gloves Schematic Diagram

For phase three which is the navigation platform, the base of it is made of acrylic sheet for its durability and the ease of forming, the navigation platform contains two bases, the bottom one contains four DC motors that rotates 360 degrees for the wheels rotation and the motors driver and six screws to join it with the second base on the top of it to carry the robotic arm and the Arduino nano microcontroller, and the dimensions are 5 CM height, 15 CM width and 25 CM length. The height of the whole system joined is 42 CM.

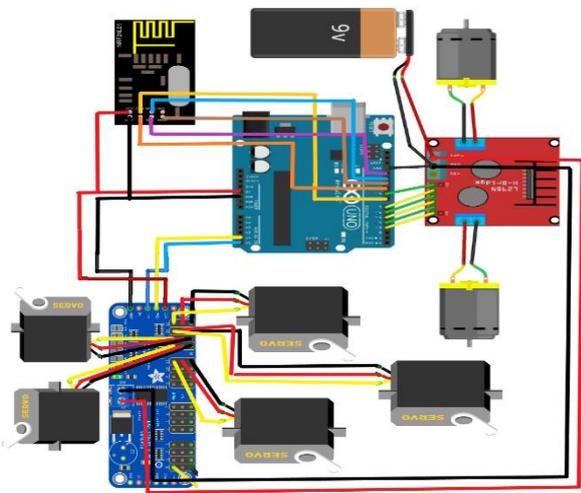


Fig. 4. The Robotic Arm and Navigation Platform Schematic Diagram

IV. IMPLEMENTATION AND FLOWCHART OF THE SYSTEM

The working process of the entire project is segregated into three different parts, the movement detection process and the action taking process. The detection process provides a detailed explanation regarding the hand movement detection data and transmitting it to the second part to perform the action. The action taking process provides a detailed explanation starting from receiving the processed data to taking this data to perform an action on a specific motor. The third part is explaining the monitoring process for the robotic arm.

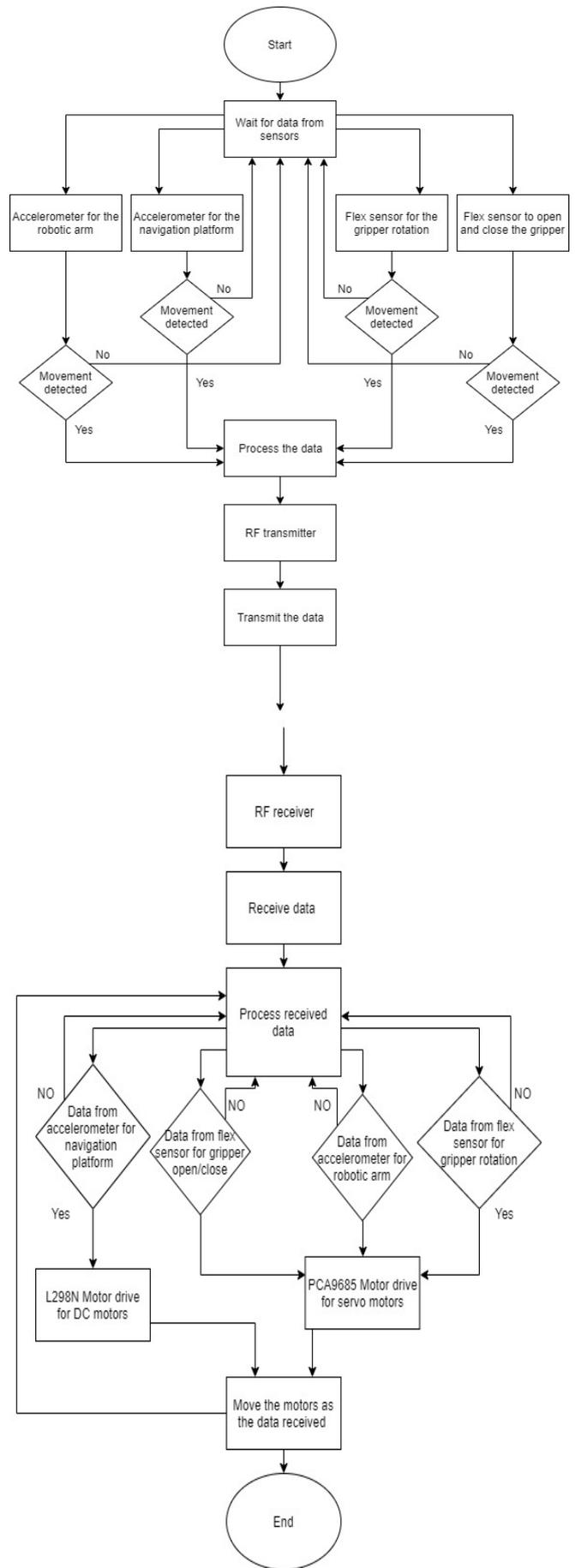


Fig. 5. System flowchart

V. SYSTEM TESTING

A. Accuracy of Gesture Response Test

This test is conducted to determine the accuracy of the accelerometer and the flex sensor on detecting the gesture of the hand and the response from the robotic arm. The setup was to run the system and place the accelerometer and the flex sensor on the hand and make some gesture with the hand in different angles and check the accuracy of the response and if it did what it meant to do. Rotating the hand should result in rotating in the base of the robotic arm, turning it to the right will move it up and to the left will move it down, forward turning should move it forward and turning backwards should move it backwards and it should be turning as the same degree as the hand is turning. Bending the flex sensor 90° should close the gripper and bending it less than 90° should move it halfway to closing.

TABLE I. RESULTS FOR TEST 1

Test number	Sensor	Gesture	Expected response	Accuracy
1	Accelerometer	Rotate 30°	Rotate 30°	65%
2	Accelerometer	Forward 30°	Forward 30°	80%
3	Accelerometer	Backward 30°	Backward 30°	80%
4	Accelerometer	Up 30°	Up 30°	80%
5	Accelerometer	Down 30°	Down 30°	80%
6	Flex sensor	Bend 90°	Bend 90°	90%
7	Flex sensor	Bend 60°	Bend 60°	90%

The analysis shown in Table I. shows the accuracy percentage after testing the gesture of the hand and the response of it in the robotic arm multiple times. The response of the gestures forward, backward, up and down were showing an accuracy of 80% because of the feedback system which keeps calculating the angle of the motor. Moreover, it is considered as a high accuracy level since it came from the accelerometer, and comparing it to the rotation results that came from the gyro meter built inside the accelerometer, the gap can be seen where the results of the rotational gesture came out to be 60% and what caused this drop in the accuracy percentage for the rotation is that the gyro sensor drifts a little bit from its origin point after some time which caused it losing in its accuracy. Furthermore, the flex sensor showed a high accuracy in responding to the gestures, but it can be affected by touching it with hands which might affect its readings.

B. Testing the Range of the Radio Communication

In this test the range of the radio communication between the controlling glove and a beeping device on the other microcontroller and it will be tested indoor and outdoor to check how far it can reach as the maximum range. The NRF radio communication device is placed on the hand glove to transmit the data from the microcontroller to the receiver NRF which is connected to the other microcontroller for the beeping device to keep beeping every one second as long as there is a signal being received from the transmitter and

getting 10 beeps every 10 second then the signal will be a 100% received. The test is done in different ranges to check how far the communication signal can reach, and it was done indoor and outdoor.

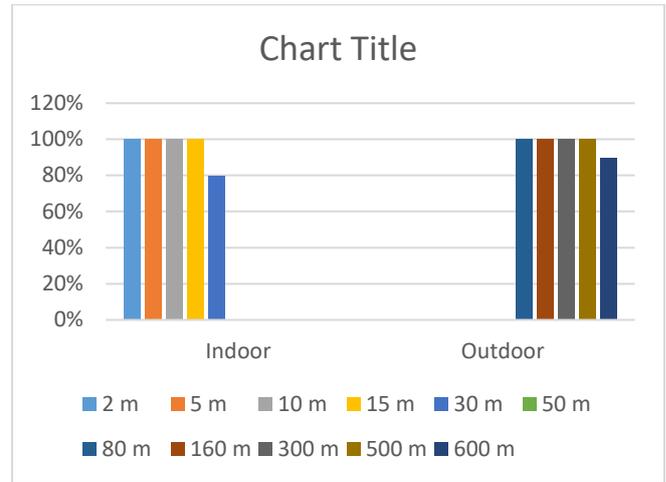


Fig. 6. Testing the Range of the Radio Communication Graph

The range test results of the radio communication module are shown in Fig 6, the test showed a good result in different ranges where the signal was being received in a wide range. The results of the indoor test of 50 m didn't show any readings, and that depends on the walls in between the transmitter and receiver, the more the walls get in between the weaker the signal will get. Moreover, a 50 m test was done indoor but in a less walls condition in between the transmitter and the receiver and it showed a good result where the signal was being received as it should.

Therefore, the indoor test showed that no specific distance can be given as a maximum distance indoors since it depends on what stands in between the transmitter and receiver, and for the outdoor test it gave a good results until the range of 1 km and then it started to lose some data, which makes the maximum distance for the outdoor a 1 km.

C. Resistance of Flex Sensor

In this test the resistance of the 2.2 inches flex sensor will be tested in a different bending angles, since the motion of the finger might be able to yield a continuous range of voltages, and due to that, the test will be performed to insure linearity and adequate sensitivity, and sensitivity is important since it has a direct effect on the accuracy. The flex sensor will be fixed under the knuckle of the index finger of the right hand and it was held in place using a tape. The test involves testing the resistance of the sensor while the finger is held at different angles. The resistance was tested with the finger pointing up, relaxed, straight and in a closed fist. The resistance and the angle will be measured using the Arduino IDE software.

The voltage of the Arduino is fixed at 4.98 V and the sensor is connected to a 47.5 kΩ, and the other pin will be connected to a ground. The resistance of the sensor in a straight position was measured using a multimeter and it came out to be 37.3 kΩ and at a 90 bend to be 90 kΩ. The program is made to get the reading of the sensor and converted to a digital value and then calculate the voltage to find the resistance and the angle after that.

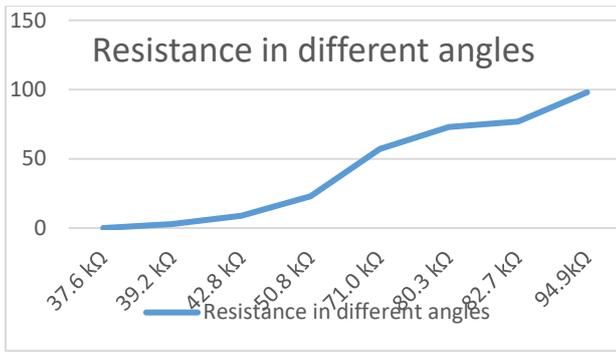


Fig. 7. Resistance in Different Angles Graph

Fig 7. shows the results of the test which calculates the resistance of the flex sensor in a different angles. The Arduino analog to digital conversion can read a voltage from 0 to 5 volts with a 10-bit resolution, which means 1024 different values can be resolved. The main function is to read the value of the analog to digital conversion to use it to get the voltage by getting the digital value and multiply it by the voltage of the power supply which is 5 volts and divide it by 1024. After getting the voltage, the resistance is then found using the following formula:

$$R1 = R2 \left(\frac{V_{in}}{V_{out}} - 1 \right) \quad (1)$$

The voltage divider formula converts the voltage to the resistance of the flex sensor to find the value of R1, after that, the value of R1 can be used to estimate the sensors bending angle by using the map function which will take the linear and bent resistance values and map them to 0° and 90°, then it will take the R1 value and estimate the bend angle based on the two calibration end points values. Furthermore, the test results showed that, the sensitivity of the sensor is high which will help on using it in the project to perform the task of controlling the gripper.

D. Accuracy Test in Multiple Ranges

This test is done to show the accuracy of the gesture and the response of the system wirelessly in multiple ranges as the system should be operated from distance. The setup for this test is to use the hand glove with the sensor, Radio communication device and the microcontroller as the transmitter device and the robotic arm with the motor, radio communication device and the microcontroller as the receiver. The robotic arm will be placed in multiple ranges and the accuracy of responding to the hand gesture will be tested 10 times with respect to the distance at each range. This test will use the flex sensor gesture which should open and close the gripper when it gets bended at 90° and bending it in any degree between 0° and 90° will be closing it halfway.

Table II. shows the results of the response accuracy from a range test. The response were following the gesture from multiple ranges with a high accuracy, but for the distance over 50 m indoor it showed a little bit of delay in holding the same angle which is caused by the angle feedback system and with the range it became a little bit slower in holding the angle. Moreover, the system showed a high accuracy with working in a distance, but this accuracy when tested indoor it showed this delay on the angle feedback, but when tested outdoor with

no walls in between the transmitter and receiver it showed a high accuracy as it can be seen in the result of the 120 m test.

TABLE II. RESULTS TABLE FOR MULTIPLE RANGES TEST

Test number	Sensor	Range	Gesture	Expected response	Accuracy
1	Flex sensor	5 m	Bend 90°	Rotate 90°	100%
2	Flex sensor	15 m	Bend 60°	Rotate 60°	100%
3	Flex sensor	30 m	Bend 90°	Rotate 90°	100%
4	Flex sensor	50 m	Bend 60°	Rotate 60°	80%
5	Flex sensor	100 m	Bend 90°	Rotate 90°	100%
6	Flex sensor	120 m	Bend 60°	Rotate 60°	100%

VI. HARDWARE RESULTS AND SIMULATION

After constructing the wireless gesture controlled robotic arm, the result came out to be as was required to serve the aim and objectives. The prototype contains two main part, the first one is the hand glove which is where the sensors are placed to detect the gesture from the operator and then transmit it to the second part which is the robotic arm with the navigation platform where it receives the data and operates on moving the motors and perform the action required by the operator.



Fig. 8. Hand Glove with NRF24101 and Accelerometer



Fig. 9. Hand glove with Arduino Nano and Flex Sensors

Figs 8. and 9. shows the hand glove which is made from leather and cotton to be comfortable for the operator to wear and will make it easier to stick the sensors to it. Fig 8. shows the MPU6050 accelerometer sensor placed on top of the glove to make it more comfortable and to detect the gesture of the hand better, aside the accelerometer there is the NRF24L01 radio communication device to perform the wireless communication between the two parts of the prototype. Both devices are fixed to a mini breadboard and attached to the hand glove with a double sided tape. Fig 9. shows the bottom side of the hand glove where the Arduino microcontroller is attached to a mini breadboard with the sensors connected to it to perform the process of the detection and convert it from an analog values to digital values which will be processed and then sent to the second part of the prototype by the radio communication device, it also can be seen on Fig 9. at the bottom of the index and the middle fingers are the two flex sensor which were placed there to detect the amount of bending of the fingers which will be used to control the gripper on the second part of the prototype, and both sensors along with the microcontroller are fixed to the hand glove with a double sided tape.



Fig. 10. Robotic Arm and the Navigation Platform

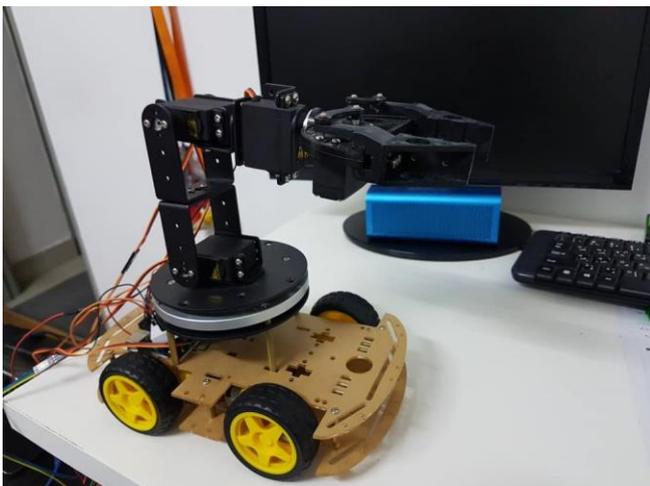


Fig. 11. The Robotic Arm with the Navigation Platform Attached

Figs 10. and 11. shows the second part of the prototype which contains the robotic arm and the navigation platform with the microcontroller, motors drive and the NRF24L01

receiver. After the data is received by the radio communication receiver, it will be processed by the microcontroller to analyze it and Fig the right motor to move. Fig 10. shows the robotic arm and the navigation platform separated and Fig 11. shows them while attached together. The robotic arm parts are made out of aluminum 2020 and contains a base where it connects it with the navigation platform from the bottom, and from the top it contains a rotating base attached to a MG995 servo motor to perform the rotation movement of the robotic arm, and the rotation base is attached to another circular base where another servo is placed and attached to the joint of the arm to perform the front and back movements of the arm, and in the middle of the arm there is a joint with a servo attached to it to perform the up and down movements, at the end of the joint there is another servo attached to the gripper to perform the rotation of the gripper when the middle finger flex sensor is bent, and the gripper is attached to a servo which is used to open and close the gripper if the flex sensor in the index finger is bent. The navigation platform is made of acrylic sheet and it contains four DC motors connected to four wheels to perform the movement of it in four directions forward, backward, right and left and it's attached to the body of the platform by screws and at the first body of the platform there is the DC and servo motor drives aside to the radio receiver then it is connected to the top base by a long screws. At the top base there is the microcontroller placed under the robotic arm and attached to the base with screws.

VII. CONCLUSION

The theory behind the project was to implement a way to ease controlling a robotic arm to replace the traditional way and to design a wireless gesture controlled robotic arm to prevent workers from involving into dangerous tasks. The design was made by utilizing a low-cost sensor which made the project save much more than invested on. With the procedure or the working principle which helped to understand the process of how the system worked which was implemented after analyzing what the researchers were lacking to provide to the system to make it more sustainable for its purpose of preventing workers from involving into dangerous tasks and to ease controlling the robotic arm. The system uses a recyclable material, and it provides the ease of controlling the robotic arm even with a lack of the technical knowledge to use it which makes it user friendly. Along with that, the system being cost efficient considering the features it provides and the low cost of it.

VIII. LIMITATIONS

The major limitation of the project is the coverage range of the radio device used to communicate between the hand glove with the sensor and the master microcontroller and the robotic arm and the navigation platform and the slave microcontroller. Based on the range testing of the device and its response, it turned out that the operator might face some difficulties operating the system indoor in case if there walls in between the robotic arm and the operator, but in outdoor it can't reach farther than 1 km. Another part of the system which also considered is a limitation is that, the system has to be restarted once in a while regarding a limitation in the accelerometer module where the gyro sensor drifts a little bit after a while from operating the system which will make it give less response to the operator or response in a different way than desired. Another limitation in the system is that, the monitoring camera always has to have a WIFI connection in

term of it to stream the process made by the operator through a live streaming video. Beside always having a WIFI connection, also a poor connection might cause some delay in the video streaming which might cause to perform a wrong movement in the robotic arm.

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