Hand Gesture Controlled Mobile Robot and Robotic Arm

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Abstract

Currently, mobile robots are involved in many applications. Those works are done by robots or robotic arm having different number of degree of freedoms (DOF) as per the requirement. A gesture controlled robot is operated by hand gestures without using the old fashioned way of pressing buttons. This paper presents a novel approach for hand gesture recognition. The objective is to develop a hand gesture-control based mobile robot with 2DOF robotic arm. The gesture is based on only fingers movements and resistive flex sensors are used to detecting the bending of fingers and mounted on a hand glove. The robot has two control systems, robot chassis and robotic arm, and both can be activated by a switch on the hand glove. Xbee modules have been used for long range wireless control. The speed measurement of the robot's chassis, experimental results, kinematic analysis and calculation of tolerance between hand glove and robot are discussed in this paper.

Keywords: Hand Gesture, Flex Sensor, Xbee Module, Differential Steering, Robotic Arm, Two Wheels Drive.

1. INTRODUCTION

Robot is a system that contains sensors, control systems, manipulators, power supplies and software working together to perform a task. A gesture controlled robot is a kind of robot which is controlled by hand gestures without using the old fashioned way of pressing buttons. Robots are mounted with the robot arms to perform tasks like humans. Depending on having different number of DOF, the requirements of robotic arm in most of applications are varied [1]. Development of mobile manipulators has been done by many researchers [2].Mobile manipulator is a type of robotic systems.It is capable of two advantages, which are mobility of a mobile platform and handiness of the manipulator. The mobility can provide limitless workspace to the manipulator. The main system compositions of a mobile manipulator are: Mobile platform, Robot manipulator, vision and tooling [3].Designing a robot chassis for the area applications has some difficulties. For such conditions, sensing and controlling systems become complicated. The robot can avoid slippage and it can obtain a pure rolling movement using differential steering method [4]. Several tasks are performed by a robotic arm. It needs an end effector moving in a space. End effectors are designed to cooperate with the environment and to grip any physical thing. To get this goal, difference designs of the claw and mechanism are used [5]. Gesture is one kind of non-verbal communication in which body actions connect particular messages and they can be contributed all the gestures such as sound, light variation or other body movements [6]. For such types of robots, path of their movements are generated by each wheel, controlling speed (angular rotation) of each wheel. Different speed will give different direction of the robot including steep turning. When both wheels have same speed, the robot can move straight forward or backward [7].A mobile robot developed by author in [8] can be used in security systems as it contains a wireless camera and speed and direction controlling process using different hand gestures.

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A freely movable accelerometer is used to detect the 3D space (coordinated spaces) of hand movements. Many types of robotic arms are being used in robotic research as they have unique features, design criteria and several research efforts have been focused on recognizing human gestures [9]. There are many ways to control a robot and one of the widely used ways is wireless control. Among the wireless control systems, hand gesture control is becoming a prevalent one in robotic field. Based on the movements of human hand, gesture based controlling process has several types using fingers, arm, wrist or detecting tilt of hands. Gesture recognition can be considered as a way for computer to understand human body language. This has minimized the need for text interfaces and GUIs (Graphical User Interface).

The main objective is to build a remotely controlled mobile robotand two DOF robot arm which is controlled by the gesture of a hand glove. The mobile robot should be able to move forward, move backward, and turn right and left also turn left and right while moving forward and backward. Additional switch panels or joysticks are not required to control the vehicle remotely. Then its robotic arm can be able to grip and lift objects. A proposed methodology is presented in Section 2. Section 3 shows the results and discussions and finally conclusion in Section 4.

2. Proposed Methodology

2.1 System Overview

The main focus is to develop the gesture controlled wireless mobile robot usingresistive flex sensor, controlling speed of the dc motors, motion of arm and end effector contribute according to the bending of the sensors. Figure 1 shows the overall process of controlling the robot system. The robot in this study has two main processes: chassis controlling process and arm controlling process.

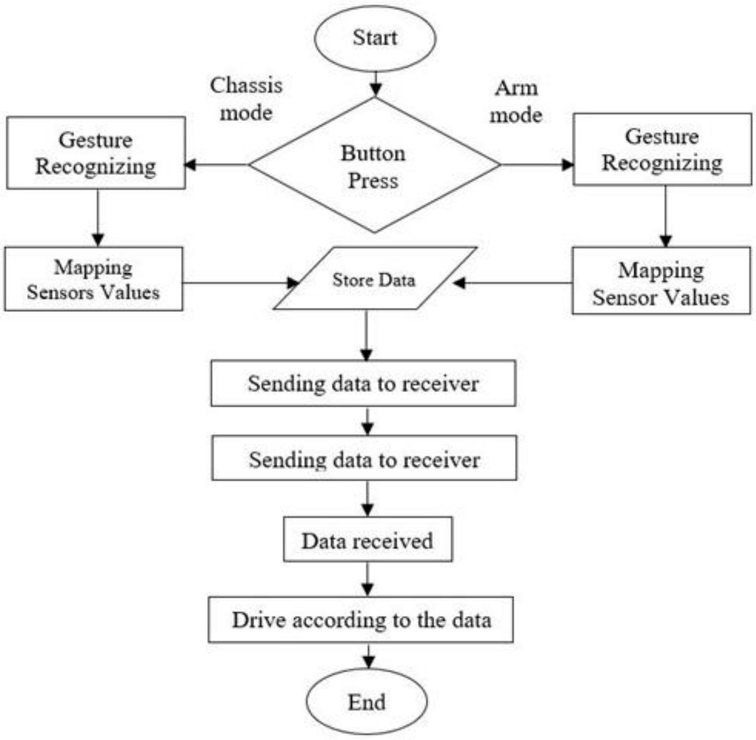

Fig 1. Overall process of controlling the robot system

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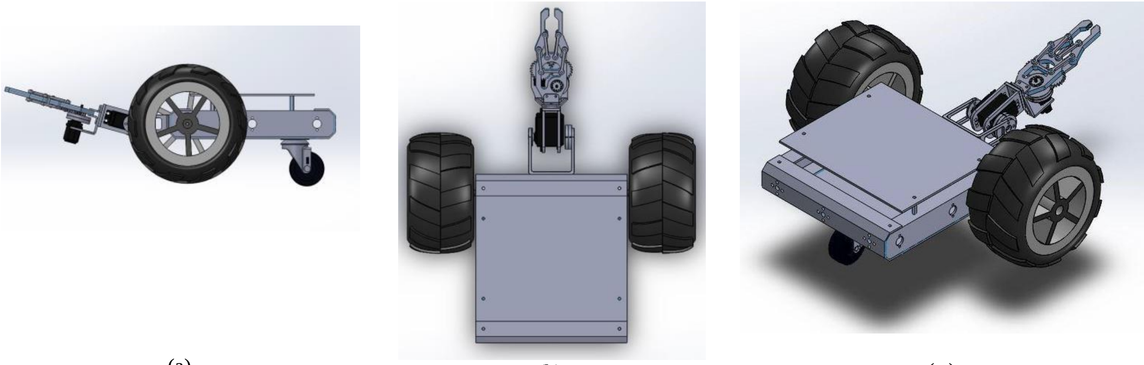
2.2 Mechanical Design of Robot

In order to achieve light weight and high strength, the chassis part of the robot (See Figure2) is completely aluminum plate and, in this case, AS-4WDA mobile robot platform which has the very light aluminum casing is used. Figure 3 represents the final robot after the assembly.



(a) (b) (c)

Fig. 2. CAD design of the robot: (a) Side view, (b) Top view, (c) Isometric view

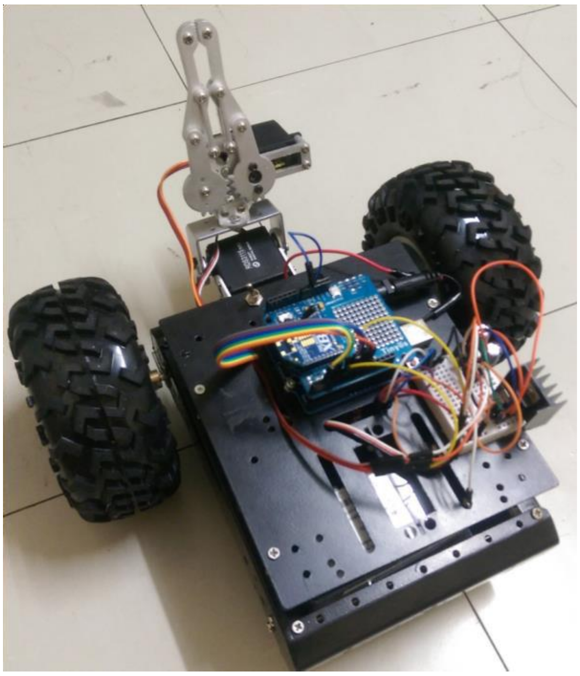


Fig. 3.Final robot after assembly

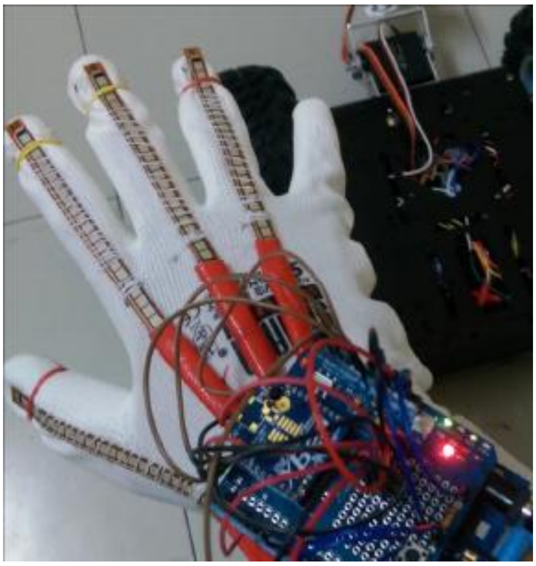


Fig. 4. The actual design of hand glove

The design of this platform is especially for differential steering. The thickness of the aluminum plate is about 2mm. Two robotic wheels of 130mm in diameter and a caster wheel are used. Couple of 100RPM DC geared motors are used to drive differential steering. For the robotic arm, MKII gripper and 1DOF aluminum bracket are used in which the total length of the arm is about 170 mm.

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The specifications of entire mechanical part are:

- Chassis length of 200mm
- Chassis width of 140mm
- Wheel radius of 65mm
- Robotic arm length of 170mm
- Maximum claw width of 40mm
- Robot total weight of 3.6kg

An elastic and safety hand glove is used and four resistive flex sensors are attached to four fingers as shown in figure 4. The Arduino Uno is mounted on the wrist. 9V battery is used as a power source. The main purpose of the hand glove is to detect fingers movements and XBee mounted on the Arduino Shield transmits data to the robot. Each of flex sensor is responsible for forward, backward, left and right movements and thumb and fore finger movements are relevant to arm control. The more bending fingers, the more speed the robot gets. The controls of the glove are: thumb for backward and gripper moving, index finger for forward and arm moving, middle finger for turning right and ring finger for turning left.

2.3 Sensor Calibration

Figure 5 represents the sensor calibration process. As the resistance of the flex sensor can be increased when it is bending, there are three positions to obtain the sensors results consistent with the bending fingers. Sensors can be measured in flat position (normal resistance), 45 degree bending position (increasing resistance) and 90 degree bending position (further increasing resistance).

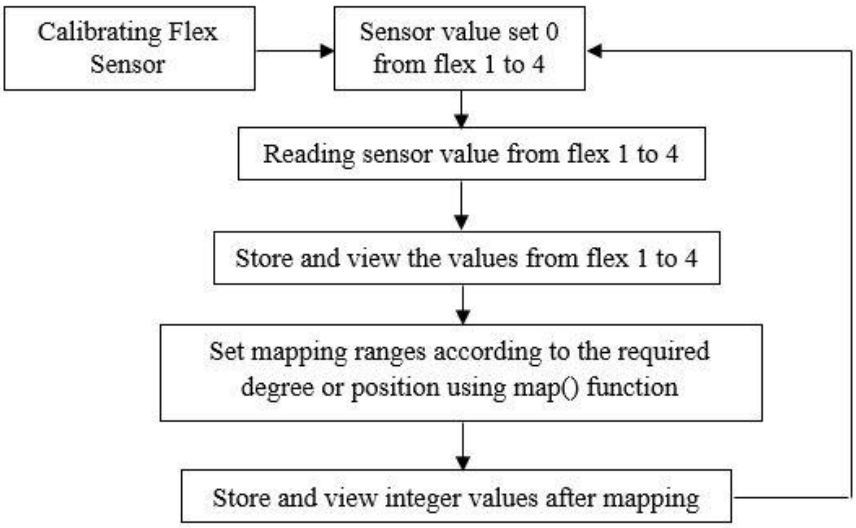

Fig. 5. Sensor Calibrating Process

The flat position of sensor has about 25K Ohms and, at the peak point of bending position, it gains about 125K Ohms. Although it depends on the radius of bending, the maximum values can be reached by 90 degree of bend. Using the parallel circuit connection of 5V input and 22K Ohms resistor to the ground, all the sensors are prepared to connect with the Arduino Analog Ports, A0 to A3. Reading the sensor values in different positions of bending is the first calibration process. The Microcontroller first reads the actual values of each of all sensor, stores then, and shows in serial monitor. After taking the sensors values in straight position and bending position, they have to be set the range of degree or analog values depending on the position of sensor. To get the initial values of the sensors, all fingers must be nearly in the flat position which means all the sensors remain nearly at the

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same level. And the results are taken in 0-degree position, 45- degree position and 90-degree position of bending. The sensor values have resistance tolerance which can affect the speed control and angles of servo motor. If the range of the tolerance is low, error occurrence can be acceptable and if the range is very large, there might be data traffic in transmission and fluctuating angles of servo. This problem is occurred due to the temperature of surroundings and humidity-tolerance. Mapping values can be adjusted to avoid such errors.

2.4 Calculations

The consideration in trajectory of the robot is not very important when both wheels travels with constant speed. If the wheels are moving with identical velocities, the robot will move in the straight position and the trajectory of the robot cannot be changed. In the case of using different speeds, the robot will turn relating with the pivoted point. Differential steering is a type of trailing a steady circular arc. In the robot, one of the wheels is taken as a pivot point or a reference point to get steep turning which means that wheel must be at RPM of 0. The following differential steering equations are applied to fine the turning velocity of robot with a relative degree of an angle. Figure 6 shows the robot trajectory diagram.

$$x_0 = r/2(v(left) + v(right)) \cos\beta$$
$$y_0 = r/2(v\ (left) + v\ (right)) \sin\beta$$
$$\beta_0 = r/l\ (v\ (left) - v\ (right))$$

Where, r = radius of wheel, l = length between two wheel, v = velocity of wheel, and Beta = angle of robot heading.

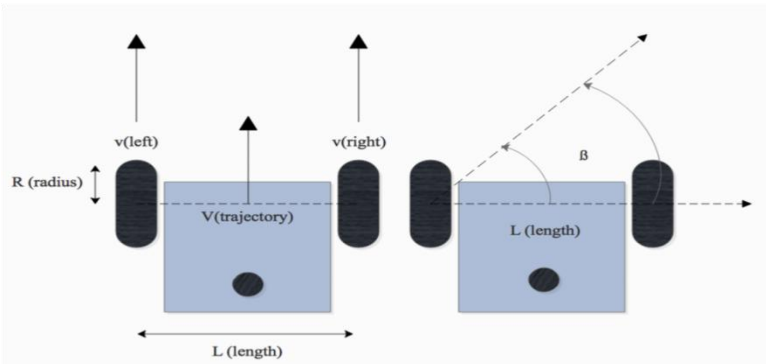

Fig. 6. Robot trajectory diagram

Applying the general equation where the wheel of robot is moving with constant speed, the equation can be written as

$$x_0 = v\ (constant) \cos\beta$$
$$y_0 = v\ (constant) \sin\beta$$

Therefore, the finalized equation should be

$$V = r/2\ (v\ (left) + v\ (right))$$

Where, V is the center point moving velocity of the robot.

In this case, the velocity of one motor of 0.48 meters per second is set, and thus the trajectory velocity of the robot is obtained as 0.0156 meters per second by applying the above equation.

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In the process of torque analysis of the arm, the torque law, Torque = mass of a body * perpendicular distance from the point of rotating to the point of force acting to the body, is used.

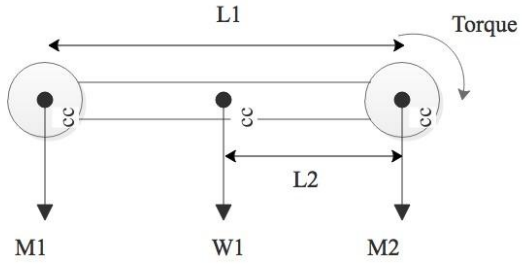

Fig. 7. Torque analysis in free body diagram

The motion with vibrations is neglected but, in critical case, the body weight makes the larger torque and it is equal to the torque of motor. The torque acquired by motor will be T = L * A, where A is the weight of the motor. The torque of the link will be T = 0.5 * L * W, where W is the weight of the linkage. Therefore,

$$Torque = Torque\ (motor) + Torque\ (linkage)$$

In figure 7, torque at M2 = L1 * M1 + 0.5 * L1 * W1. L1 is the length of robotic arm, M1 is servo motor weight, and W1 is weight of the linkage. From calculation using above equation, torque of arm is 0.0066 kg.m.

3. Experimental Results and Discussion

In the distance vs time experiment as shown in Table 1, the robot goes to the destination point and picks up an object, then returns back to its initial position, drops down the object and time taken to complete the whole process is recorded. In this case, the distance of 10m and the motor's average velocity is 0.162 meters per second are set. According to the results, it takes average 1 minute and 43 seconds to complete the task.

Table 1. Distance and time taken table

Round	Distance In Meter (m)	Time Taken to go and come back (Sec)	Time taken to pick up and drop down (Sec)	Total time taken (Min & Sec)
1	10m	85s	16s	1min 41 s
2	10m	92s	17s	1min 50 s
3	10m	83s	16s	1min 38 s
4	10m	87s	16s	1min 43 s

As the bending angle of flex sensor changes, the mapped reading values increase or decrease, and the speeds of DC geared motors vary. The more the sensors can bend, the more speed robot gets. The maximum speed of the DC motor is gained at the maximum revolution per minute and, it this case, it is 100RPM and it can be obtained by 90-degree bending. See figure 8.

Linear velocity of Motor = radius of wheel * RPM *0.10472
Maximum RPM = 100, Radius of wheels = 0.065m
Therefore, speed of motor at maximum RPM = 0.065 * 100 * 0.10472 = 0.681 meters per second
Minimum RPM = 50,
Speed of motor at minimum RPM = 0.34 meters per second

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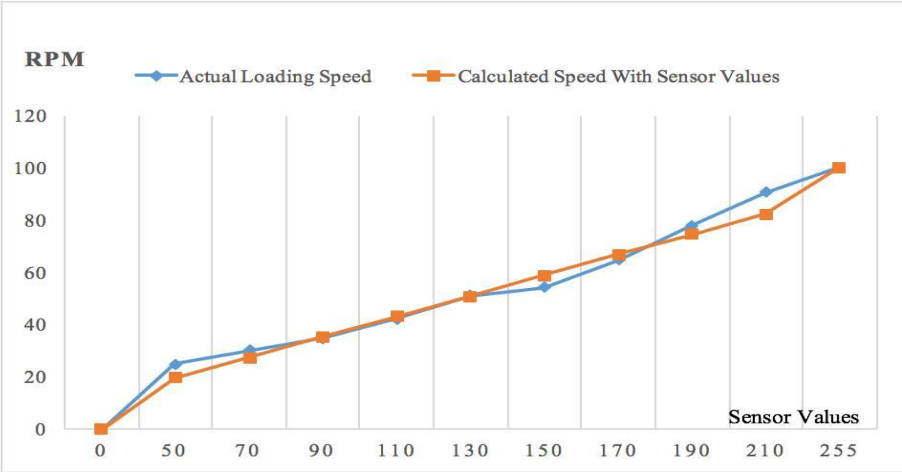

Fig. 8. Graph of speed control with sensor value

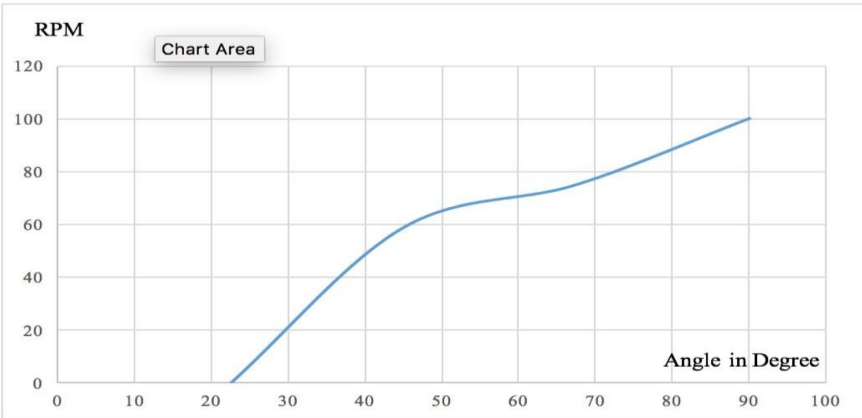

Fig. 9. RPM of DC motor vs angle of flex sensor

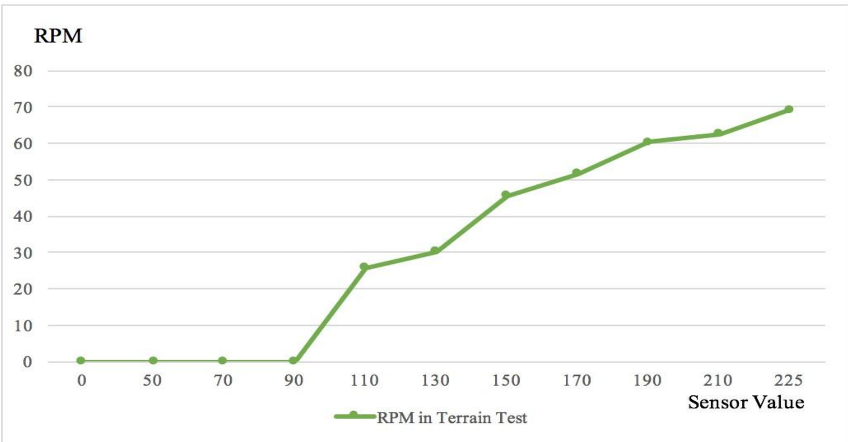

Fig. 10. RPM of DC motor during terrain test

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For the terrain test (See Figure 9 & Figure 10), the RPM of DC motor decreases significantly and, according to the decreased RPM compared to the test in smooth surface, the speed also decreased and maximum speed occurred in terrain is about 0.48 meters per second and minimum speed is about 0.18 meters per second.

In the test of robotic arm control process(See Table 2), three positions of finger movement which are flat, 45- degree bend and 90-degree bend, are used. I tried to get the servo angles relation with the bending of two fingers: thumb and index finger. The mapped values of claw angle are from 150 to 90 and that of arm are from 0 to 90 and the values are received from the transmitter. In table 2, claw angle means the angle of servo for robotic claw in which the data are shown in analog reading values from Arduino serial monitor, and arm angle is the angle of servo for robotic arm in which the data are the angle of arm link.

Table 2. Reading servo angle analog values

	Flat Position	45-deg Bending	90-deg Bending
Claw Angle	150	124	90
Arm Angle	0	56	90

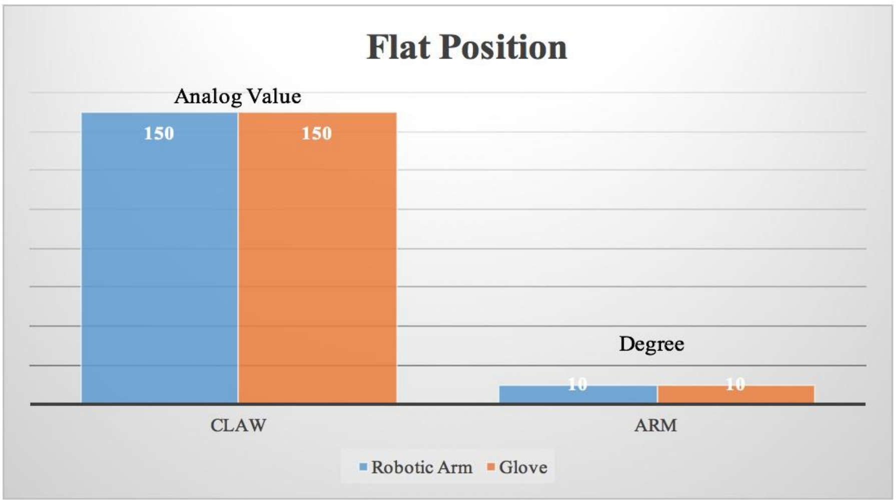

Fig. 11. Comparison between robotic arm and hand glove at flat position

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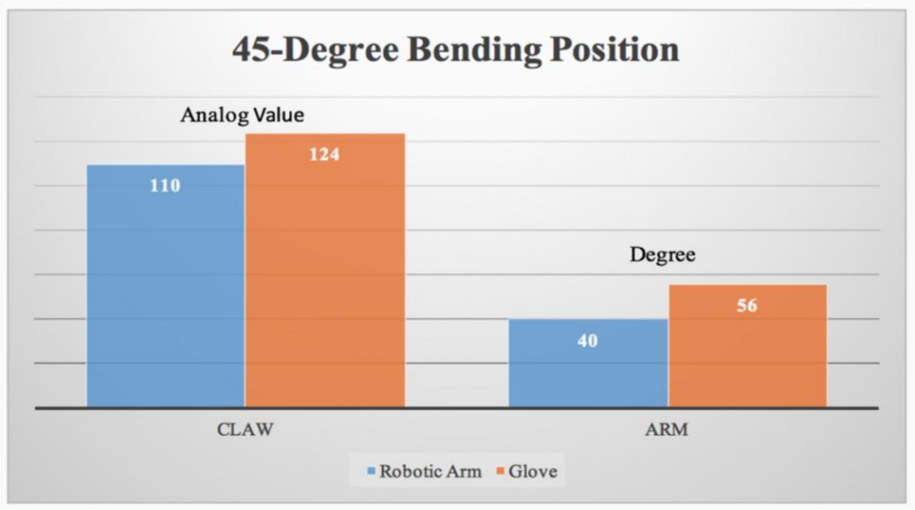

Fig. 12. Comparison between robotic arm and hand glove at 45-degree bending position

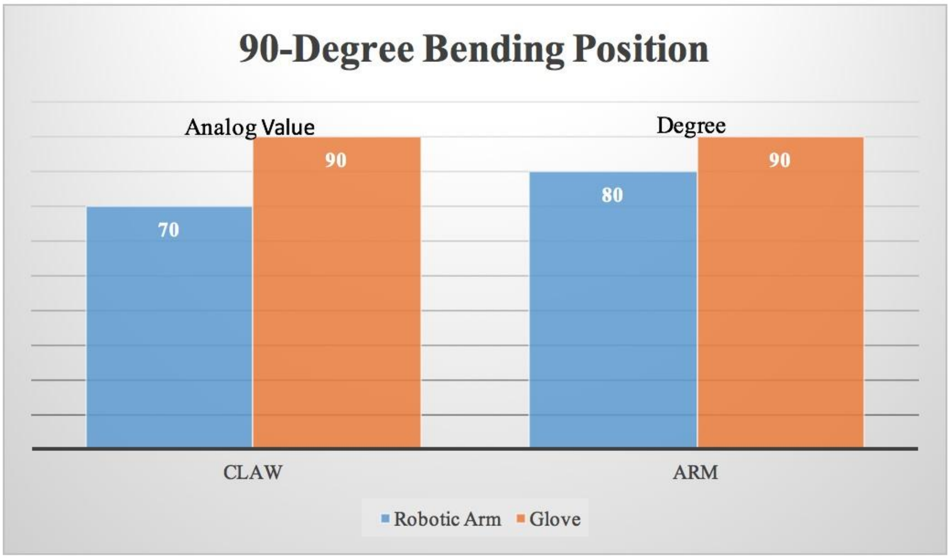

Fig. 13. Comparison between robotic arm and hand glove at 90-degree bending position

From the results, there is a tolerance between hand glove reading values and robotic arms servo angles (See Figure 11, Figure 12 and Figure 13). The relationship between finger positions and arm positions has a little difference. According to overall comparison of arm controlling process, the glove positions have grater values than that of arms positions. Depending on the tolerance and grip type of the robotic arm, the end effecter also has failure in some gripping process. Most of failures are happened in gripping un-circular shaded objects. As the maximum claw width is about 40mm, the end effecter cannot grip those objects which are larger than 40mm in diameter or length. Figure 14 presents the test fails percentage of gripping process.

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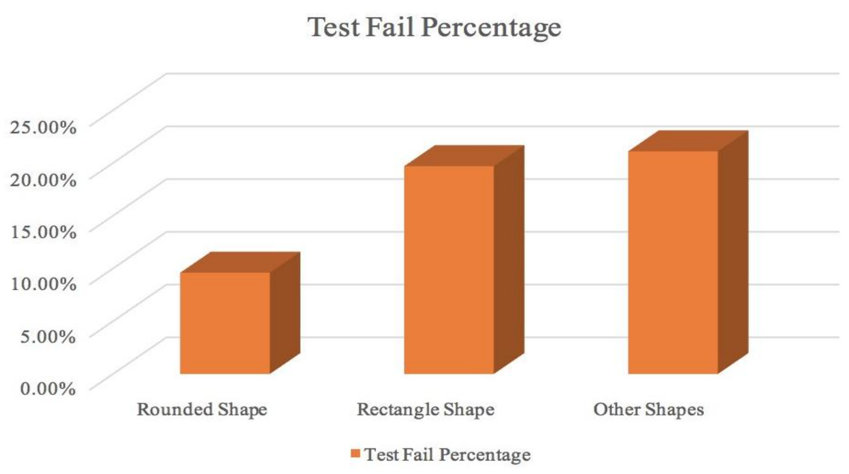

Fig. 14. Test fails percentage of gripping process

The small amount of data gap between robot and hand glove mainly depends on the humidity tolerance. By the way of attaching flex sensors on hand glove, there should be a difference between robot and glove due to the finger movements which sometimes cannot bend actually from 0-degree to 45-degree or 0-degree to 90-degree, and fingers cannot stay stable for long time; there is sometimes shivering of fingers. From the results taken after experiment, the glove control and motor has 16.67 % tolerance and 24% of tolerance is found in arm and hand glove control. See figure 15.

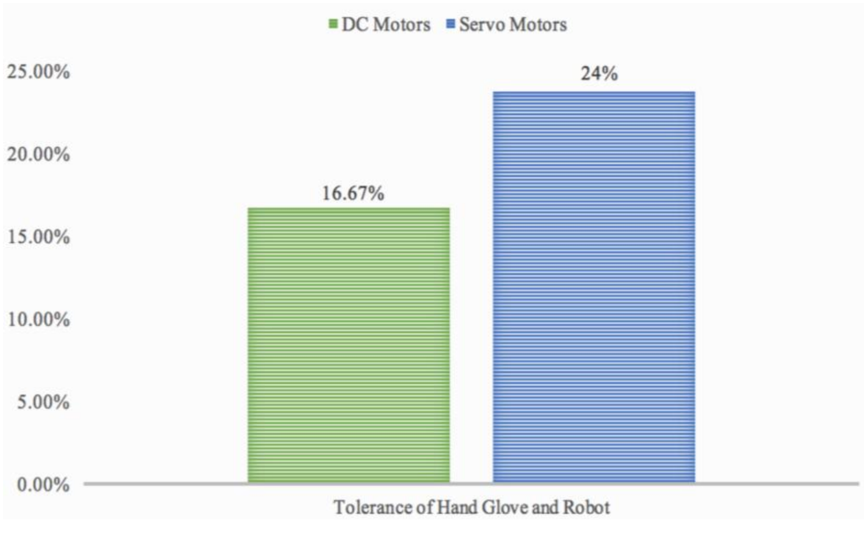

Fig. 15. Percentage of tolerance between hand glove and robot

4. CONCLUSION

The developed mobile robot and arm with gesture control have been implemented and discussed. The developed system was able to successfully control the robot and its arm when the set of hand gesture is given to the system. It has been developed to control the robot using motion of four fingers and controlling the arm using two fingers. The results can be applied and useful for further developments. The control system was very easy for users. It is simple and convenient for any user. Speed control in dc motors contributes in robot systems and PWM (pulse width modulation) in motor driver module is used to drive two wheels. The glove has initial position

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which commands the robot to stay at rest and bending finger positions which can drive the robot and control the arm. The stability in turning the robot's trajectory is controlled using differential steering with constant speed. The robot can be controlled within 30.48meter range with consistent network signal. The accuracy of 85.7% is provided in the system and the average tolerance of the resistive flex sensors is about 20.335%.

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