Design and Implementation of an Automated Hand Gesture based Powerchair using a Robotic ARM and IoT Integration

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Abstract - *Here I report the synthesis of hand gesture-based powerchair using a robotic arm and IoT keeping in mind communities which mainly includes physically challenged people especially who are dependent on the wheelchair. The methodology mentioned in the paper is the amalgamation of Robotics and the Internet of Things. Unlike the previous design, this design is more automated and enhanced with hand gesture module integration with the addition of efficient functionalities. When a disabled person is using a wheelchair, they can use their left hand to control their powerchair movement using the left-hand gesture module instead of using wheelchair manually and there is an integrated robotic arm which the user can control it using the right-hand gesture module based on finger and hand movements instead of using bare hand to pick up any materials. This whole semi-automated design can be easily operated using the user's wrist movement which is more enhanced with its range of operation, accuracy, and efficiency. The user's data can also be monitored on the web using an integrated IoT module and the nature of the data is customizable; currently, an infrared ray temperature sensor with an ultrasonic sensor is embedded in the system. The IoT module is placed near the arm holder which is capable to record the person's temperature who is residing in the chair and it's a contactless monitoring system. The whole module only works if the person hand placed in front of it and if it's not placed in the desired way, then it alarms its user until it's placed accordingly.*

***Key Words*: Arduino nano, ESP- 8266, Hand-gesture recognition, Robotic arm, Internet of Things, Contactless monitoring**

1. INTRODUCTION

Robotics has always shown a great impact on our community in this technologically evolved era especially in the field of Engineering, Medical, Space science, etc. On the other hand, gesture recognition has always been a great cause in shrinking the distance between the physical and the digital world. Robotics proved its essential role in many important sectors like military, construction, and medical by saving time, increasing productivity, efficiency, reliability, and preventing accidental casualties. In the world of robotics, there are mainly five categories: Pre-Programmed Robots (Operates in a controlled environment to perform the simple monotonous task), Humanoid Robots (Mimic human behavior), Autonomous Robots (Edge sensing robots, Line sensing robots), Remote-Controlled Robots (Teleoperated robots, Gesture controlled robots) and Augmenting Robots (Exoskeleton, Robotic arm, eLegs). Since this paper deals the amalgamation of gesture-controlled powerchair and robotic arm, the primary focus will be on the Remote-Controlled Robots and Augmenting Robots both [1][2].

In today's technological evolving era, the advancement of modern technology has ensured multiple healthcare services with its efficiency and reliability, which led leading-edge technologies to be applied extensively for treatment, diagnosis, monitoring, and testing. The sensors and its network have optimized the healthcare monitoring system from a remote location; with the IoT integration, another new advancement made possible towards additional security, reliability, and efficiency. In recent years, IoT has shown a great success ratio in fulfilling the healthcare needs of people. Internet of Things represents a network that connects multiple physical devices through the internet which led that specific device gets enhanced into a smarter, effective, and efficient device. In the current decade, the incorporation of robotic technology with the integration of IoT has been already taken steps in solving various healthcare problems from assisting the doctors remotely during surgery to make an easy life for physically challenged people.

In this paper, an implementation of an idea has been demonstrated keeping in mind for the community like physically challenged people who are dependent on a wheelchair. This design is mostly built suitable and easily usable for a person whose palm and wrist joint are working fine but still dependent on the wheelchair. A person is no need to move the wheelchair using his bare head or any extra person to control its movement and even a joystick integrated powerchair requires certain pressure from fingers to control. This design helps to eliminate all the above dependent causes which make the person more independent. If a person's arm is broken or due to any reason user can't pick up or grab any substance based on desires, for that purpose robotic arm is placed into action. The user can control not only his powerchair with its wrist movement but also user got an integrated arm with the chair which also works on its wrist movement [3][4]. This design is not only more technologically advanced compared to the previous design but its user-friendly with a greater range of efficiency. Now the design is mostly based on an amalgamation of different techniques so it should have something to monitor the patient, after all the idea is for healthcare services. In the time of the pandemic, contactless sensors are getting more available day by day. This design is embedded with an IoT module that continuously monitors its user's temperature using a contactless infrared ray sensor and for that user will have to place its arm in front of the sensor keeping a distance of 2-10 centimeters from the sensors. If the user's unable to place properly hand in front of the sensor, there is a buzzer that will get a trigger and there is a separate switch to turn ON/OFF the monitoring device manually and a display screen is embedded into this design to display the distance to ensure the user about getting the correct readings and all this real time readings can be monitored in the webpage [5][6].

2. PROPOSED SYSTEM

In the following diagram, my idea of this project has been demonstrated thoroughly. The diagram shows the all the components integration along with its place for implementation.

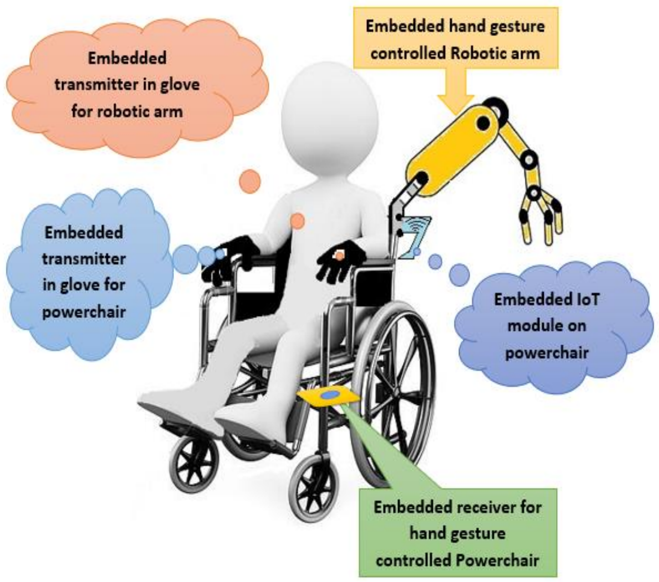

Fig -1: The design of the proposed system

The whole design can be dissected into three components and medium of communication takes place using radio frequency and Internet of Things. The components are as follows: -

2.1 Hand gesture-controlled powerchair

This component represents the powerchair which the user can control with its simple wrist movement. The design is light-weighted and smaller in size. The module comprises two segments the transmitter and the receiver. The little transmitter must be attached to the user's wrist which mainly includes an Arduino Nano, MPU6050, and NRF24L01. The receiver is embedded with the powerchair which mainly consists of Arduino Nano, NRF24L01, four DC motors, and an L238N motor driver. In the transmitter, Arduino Nano fetches data from the gyroscope present in MPU6050. The NRF24L01+ transceiver module is the most inexpensive reliable 2-way RF solution and idea is to fit it beneath the powerchair. In the transmitter, the NRF24L01 module is connected to Arduino Nano that transmits data to the NRF24L01 module connected to Arduino Nano on the receiver. Based on the received data, Arduino Nano moves the DC motors. The NRF24L01 transceiver module is capable to operate in the 2.4 GHz worldwide ISM frequency band and the data transfer rate can vary from 250 kbps to 2 Mbps. The NRF24L01 transceiver module transmits and receives data on a specific frequency called Channel and to communicate to each other in an encompassed environment with multiple transceiver modules present, the pair needs to be on the same channel. Each channel operates in a bandwidth of less than 1MHz and as the channel could be in any frequency between 2400 MHz to 2525 MHz, this gives us 125 possible channels with 1MHz spacing. So, the module can have 125 networks independently in one place. RF channel frequency of your selected channel is set according to the following formula:

Freq (Selected) = 2400 + Channel (Selected)

For example, if you select 108 as your channel for data transmission, the RF channel frequency of your channel would be 2508MHz (2400 + 108).

The module responds on basis of wrist movement so the inclination of the wrist gives the direction to the powerchair and that's is calculated using 6-axis motion tracking device MPU6050. MPU6050 has an embedded chip 3-axis gyroscope and accelerometer sensor, has low power consumption requirements, highly accurate, has high repeatability and high shock tolerance. This module is majorly responsible for gesture detection as well as recognition. So, when the user bends its wrist downwards the gesture-controlled powerchair moves front (acts as an accelerator), and pulling back the wrist towards upwards moves the powerchair in the backward direction (acts as reverse/brake). Similarly, bending the wrist on the left side turns the powerchair left, and bending on the right side turns the powerchair right. So, controlling the powerchair is very much user-friendly.

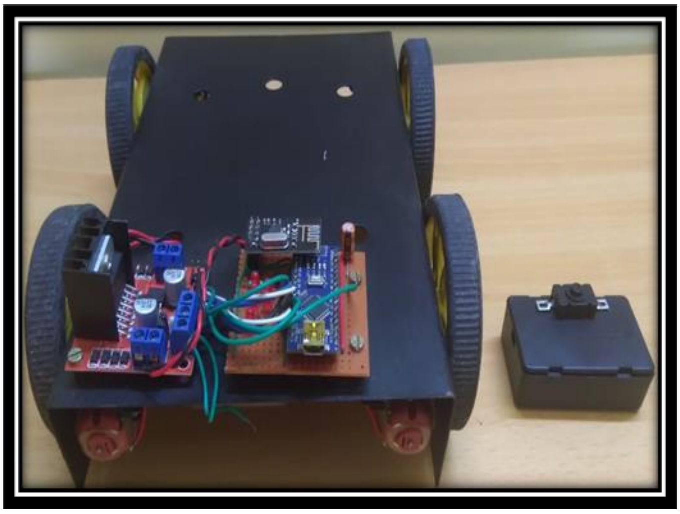

Fig -2: The top view of the robotic car

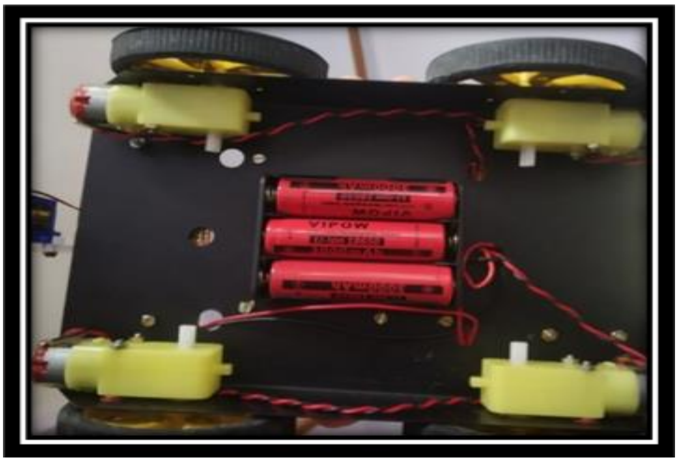

Fig -3: The bottom view of the robotic car

For demonstration purpose, I have designed a hand gestured controlled robotic car instead of using real wheelchair and the list of components required to design this module are as follows: Arduino Nano (2), NRF24L01 (2), MPU6050 (1), L298 Motor Driver (1), 100RPM Motor (4), 3.7Volt LiPo Battery (1), Metal Chassis (1), Wheel (4), 3.7 Volt, 3000mAh Battery (3) and System On-Off Switch (1).

2.2 Hand gesture-controlled robotic arm

This component represents the robotic arm that can control its wrist movement. The working principle is quite similar to the hand gesture-controlled powerchair and the design is also light-weighted, smaller in size. The module comprises two segments the transmitter and the receiver. The little transmitter is attached to the hand gloves which mainly includes an Arduino Nano, MPU6050, and NRF24L01. The robotic arm is embedded with a receiver which mainly includes Arduino Nano, NRF24L01, servo motors and a metal gripper in the robotic arm. In the transmitter, Arduino Nano fetches data from the gyroscope present in MPU6050. The NRF24L01+ transceiver module is the most inexpensive reliable 2-way RF solution. In the transmitter, the NRF24L01 module is connected to Arduino Nano that transmits data to the NRF24L01 module connected to Arduino Nano on the receiver. Based on the received data, Arduino Nano moves the servo motors in the robotic arm. So, the user needs to bend down its wrist to move the robotic arm downwards, and to move upwards user needs to bend up its wrist. Similarly, tilt the hand left or right to turn the robotic arm left or right. Servo motors in the robotic arm work like a ball and socket joint in the human arm. There is a small push button placed on the palm glove, so when the user curls its finger over the palm triggers the robotic arm to fold its finger and tries to grab something. The idea is robotic arm shall be integrated behind the chair with a folding mechanism. After its powered ON, it can be directed in the desired direction as per the user requirements and after the job is done, it should return to its initial folded state behind the chair.

For demonstration purpose I have designed the robotic arm module using following list of components: Arduino Nano (2), NRF24L01 (2), Servo Motor MG90 (2), IC-7805 (1), Heat sink (1), 3.7Volt LiPo Battery (1), and Vero Board (1).

2.3 IoT-based surveillance system

This component represents the IoT monitoring system which is embedded near to arm resting place. The module comprises an infrared ray's temperature sensor integrated with an ultrasonic sensor and an LCD are placed on the powerchair which is capable of measuring the user's body temperature from a certain distance to maintain contactless monitoring. The distance can vary from 2 to 10 centimeters and a buzzer is also placed to ensure the user of placing its body in front of it correctly. Too much distance or closeness between sensors and body triggers the alarm which eventually can be controlled by turning ON/OFF manually. Another usage of the buzzer is if the user ever falls from the chair accidentally then it will alarm its encompassed area. The whole monitoring can be done through the webpage whose IP address is shown on the display screen in the first 10 seconds after the module is powered on and gets connected in its preset network. Later on, in the display, the distance between sensors and the body is shown. In the local webpage, the monitoring correspondent can see the real-time data of the user but they need to be connected in the same network as the module is sharing. The local webpage shows the data of the human body's current temperature in Celsius and Fahrenheit, the distance between hand and sensors, or any other customizable data as per user requirement.

For demonstration purpose I have designed the IoT module using following list of components: NODEMCU (1), HCSR04 (1), MLX906 (1), IC-7805 (1), Heat sink (1), Buzzer (1), 16X2 LCD (1) and Vero Board (1).

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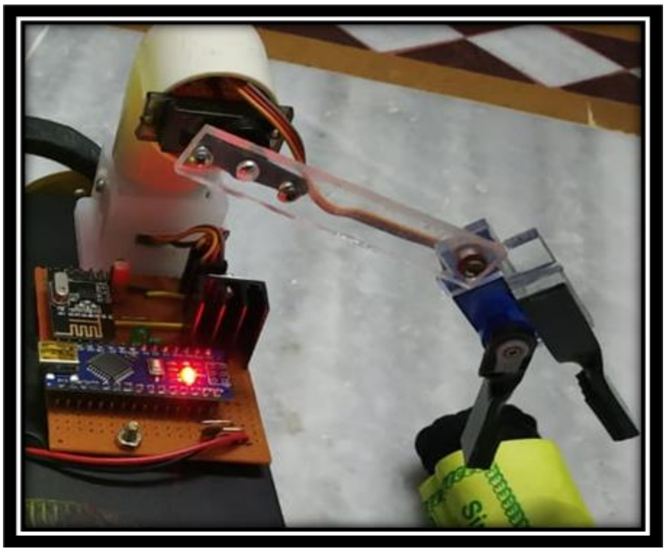

Fig -4: The robotic arm

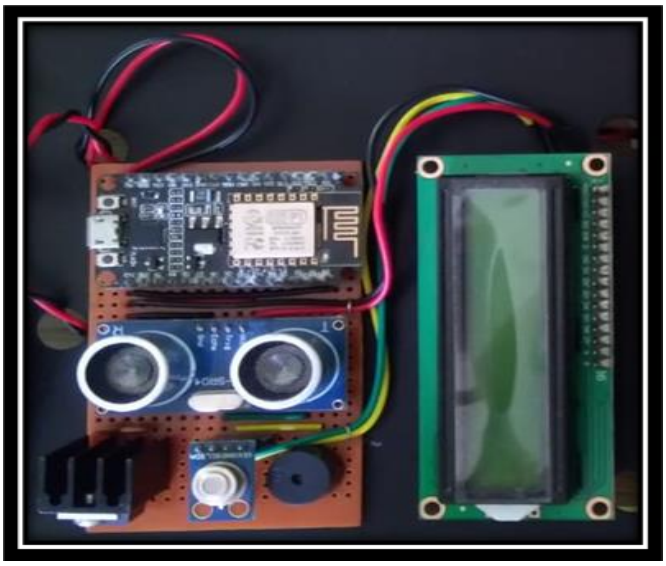

Fig -5: The IoT module

3. CIRCUIT DIAGRAM

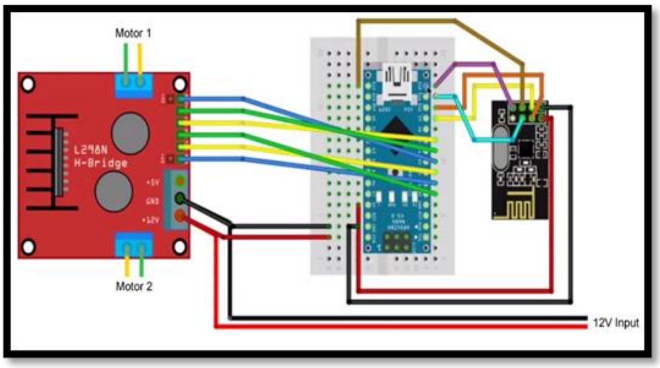

Fig -6: Circuit Diagram of Robotic car Tx

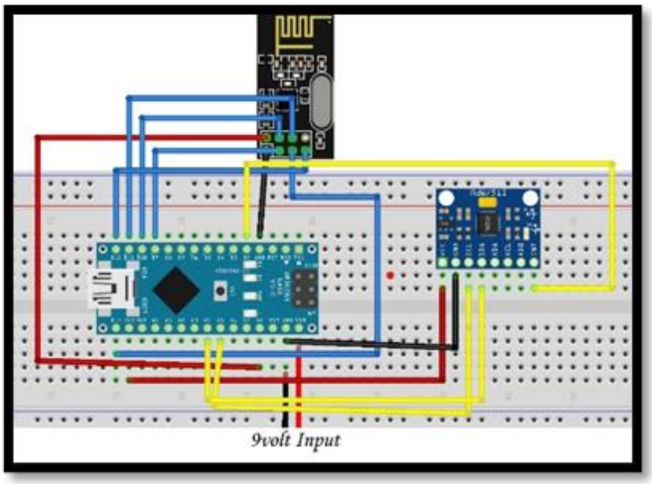

Fig -7: Circuit Diagram of Robotic car Rx

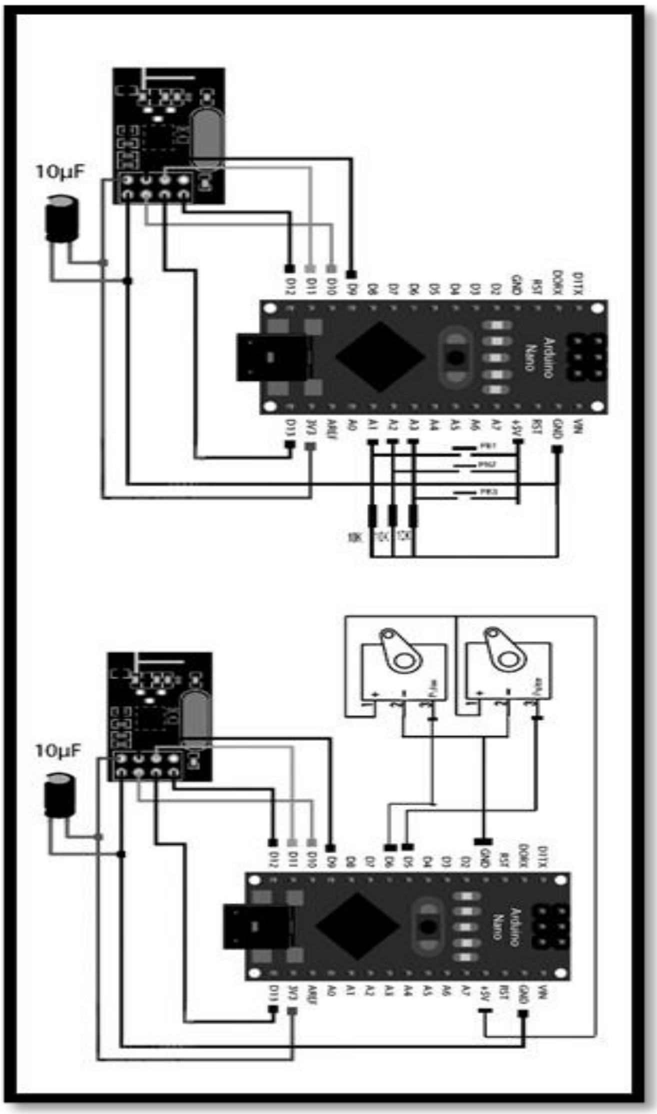

Fig -8: Circuit Diagram of Robotic arm

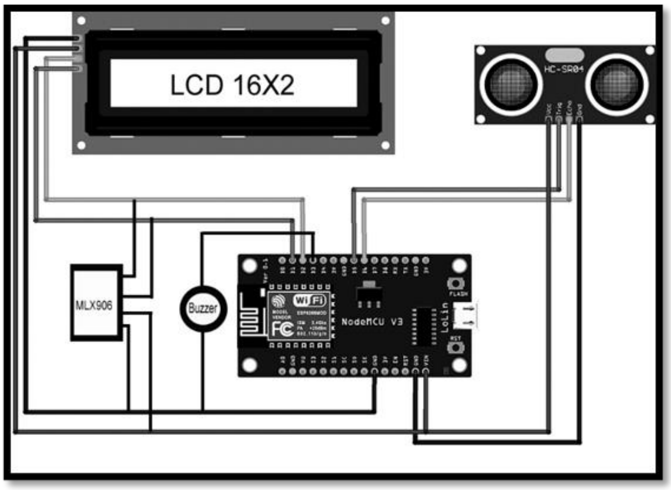

Fig -9: Circuit of IoT module

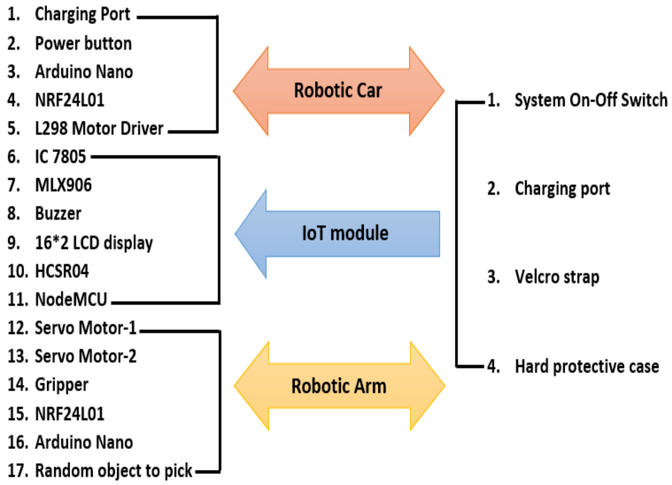

Fig -12: List of integrated components used in robotic car, robotic arm and IoT module

4. RESULTS AND DISCUSSIONS

In the following picture, the full model of the proposed system has been displayed. All the pointers denote each component which is stated after Fig (10) & Fig (11).

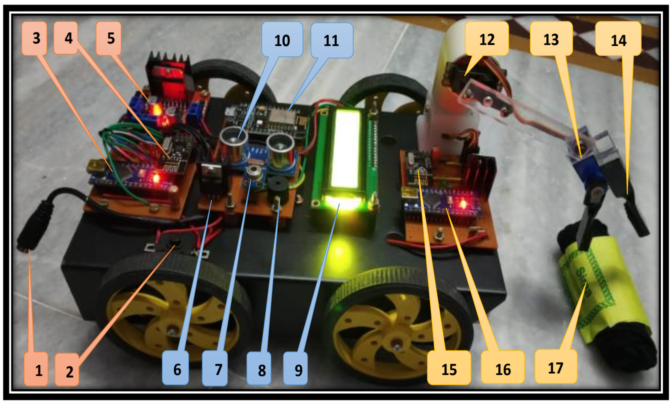

Fig -10: Full model revealing its components implementation

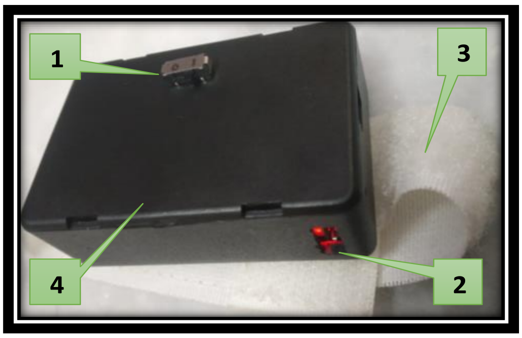

Fig -11: Hand gesture module placed over a Velcro strap

In the above list, only the power sources (3.7Volt LiPo Battery (3), 3.7 Volt/3000mAh Battery (2)) are missing as it wasn't pointed in the figure but you can find it in the earlier images.

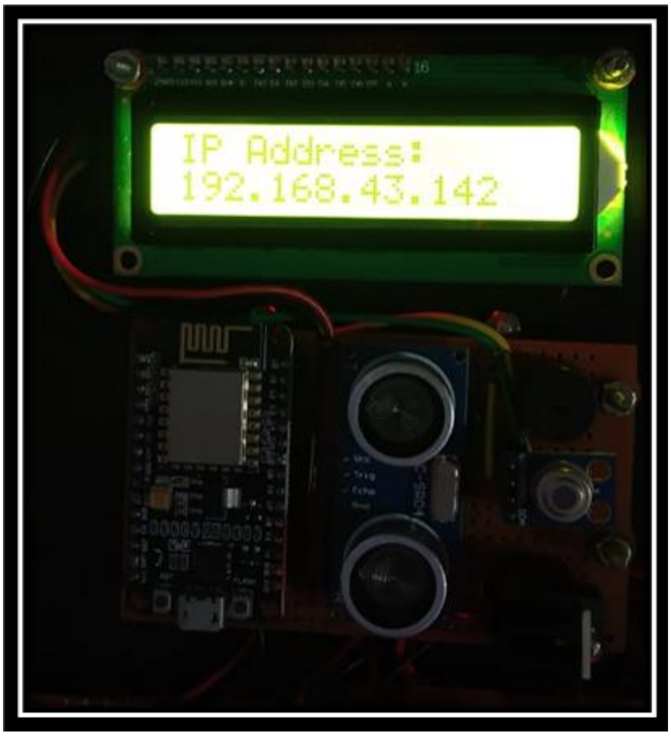

Fig -13: Local IP address in 16*2 LCD displaying for 10s.

Fig -14: Temperature measurement in 16*2 LCD after displaying IP address

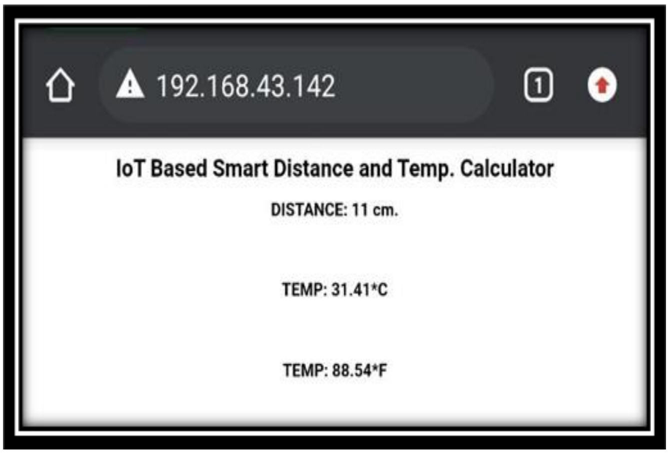

Fig -15: IoT data display on local webpage

5. CONCLUSIONS

The design and implementation of an automated hand gesture-based powerchair using a robotic arm and IoT integration is not only cost-effective but also user-friendly. Its operations are majorly perform using radiofrequency which also gives a wider range of operations. Normally, these types of design are majorly used for military purposes, space science, and even in medical science; but this time I have enhanced and integrated the idea with more advanced technology to be used for physically challenged people as I find there is a small scale of lack of development in this area. In the hand gesture idea, no dependency-based communication has been established like Wi-Fi. The design is also capable of contact-less monitoring which is very much crucial especially in this global pandemic situation. The limitation of the idea has been reduced to a great extent.

The gesture-controlled robot designed in this work has many future scopes like integration with GPS module which helps to know its patient's whereabouts. Also, embedding a few more sensors or cameras will help to monitor the wheelchair user more proficiently by collecting different forms of data. In the conclusion, this design and implementation will reduce the gap between the physically challenged community and the world of robotics.

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BIOGRAPHIES

Soumyadip Chatterjee completed the B.Tech in Electronics and Communication Engineering from the B.P. Poddar Institute of Management and Technology, India, in 2019. He currently works as an associate software engineer at the Edifixio India Private Limited. During his academics, he won multiple accolades for designing innovative prototypes and also has few national and international conference papers.