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Abstract*— Design and implementation of a low-cost hand gesture controlled automated wheelchair-using Arduino based microcontroller and Node MCU is presented in this paper. The main focus of this study is to control the wheelchair with the movement of the hand-wrist movement. Besides hand gestures, the wheelchair can also be controlled via Bluetooth technology. If any problem occurs during the hand gesture control, Bluetooth technology can help to control the wheelchair through assisting person. The design also has some additional features such as tracking the location of the wheelchair through GPS from anywhere of the world and emergency switching system to send messages to the assisting person through sensor-based network. Arduino Mega, Arduino Nano, NODE MCU, MPU 6050 Gyro sensor, Sonar Sensor, GPS Module, GSM Module, HC-05 Bluetooth Module, nRF Transceiver, and relay-based H-Bridge Motor Driver Circuits are used to design the wheelchair prototype. The designed wheelchair is comparatively simpler in a sense that if any person can able to move their wrist only, then he/she can operate the wheelchair. Some other types of wheelchair designs were proposed in literature which contains complex computing system along with processing biological signals such as EEG, EMG, and EOG etc. The good recording of these bio-signals is quite challenging for very elderly/movement disabled subjects and complex signal processing along with bulky computing systems are required to operate such types of wheelchair. In the proposed design, the hand gesture control system is designed such that it overcomes the necessity of extra sensors and complicated biological signal processing systems. The proposed technique will have a great impact on society because of its easier use and cheaper price compared to other automated wheelchair designs.

Keywords*— movement disabled people, hand gesture, Arduino Mega, NODE MCU, GSM Module, MPU 6050 accelerometer, nRF Transceiver, Sonar Sensor, HC-05 Bluetooth Module.

I. Introduction

The number of handicapped/movement disabled people in Bangladesh is increasing due to the incremental rate of accidents. About 650 million people are suffering from several types of physical disabilities [1]. A wheelchair is such a type of mechanical device, which is used by the elderly patients and the people who are physically unable to move properly due to some kind of accident or neural disease. Most of the electric wheelchairs used in Bangladesh are imported. Moreover, these wheelchairs are above the level of affordability of most common class people here in Bangladesh due to higher cost. Several works have been done in the wheelchair design project with various techniques to design low cost version. But those techniques are not efficient enough and not much affordable in terms of cost and complexity.

Previously a wheelchair concept that presents a control-method to maneuver a motorized technology wheelchair merely by the movement of fingers as described in [2]. In 1953, George Klein first invented the electric-powered wheelchair. He worked for the National Research Council of Canada, to assist injured veterans of World War II [3]. But this chair had no extra safety intelligent systems that could make the life of the operator easier. Many research works have been presented since then and there are different versions with different technologies of wheelchairs what we see today in the market such as eye movement control, voice control, electromyogram signals (EMG), electroencephalogram (EEG), Tongue controlled and joystick-controlled technologies [4]. But not all of them are available in Bangladesh except for a joystick-controlled wheelchair. Along with the higher buying and maintenance costs, there are some other drawbacks to those types of wheelchairs. For controlling the wheelchair through eye movement, there would be a screen always in front of the operator/patient. The wheelchair won't move without the perfect detection of the movement of the eye/eyelid [5]. In a voice-controlled wheelchair, the wheelchair is being operated by the voice command through a speech processing system. However, in a real-life environment, noise around the user may mix with the user's speech. This may make the operation of this device difficult in noisy environments. It

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might even cause undesirable accidents due to misinterpretation of voice commands. Moreover, different people have different accents which could create difficulties for the processor while processing a user's speech who is a native speaker [6]. To control the wheelchair with the tongue the user has to wear a headset. A magnetic pallet is placed within the headset of the user to touch the pallet with his tongue to use tongue-controlled wheelchair. Patients with the oral disease should not be using such devices. Sensors that are being used to detect command of the user through tongue may have short longevity due to being continuously touched by saliva [7].

Practical solutions of these problematic issues have been tried to solve by proposing this hand gesture-controlled wheelchair. It's an Arduino based standalone platform. Hence the power consumption by this device is less. The reasonable cost of production is useful for the handicapped persons and can easily be controlled by the hand gesture of his own. Moreover, if any difficulty occurs in the patient control system or any authorized person wants to control the wheelchair it can be done by the Bluetooth and the location of the wheelchair can be determined through IOT based network. The following sections of this paper describe the design principle, the sensors used and the overall functionality of the proposed system.

II. WORKING FUNCTION OF THE PROPOSED SYSTEM

The main function of the hand gesture controlled automated wheelchair is shown in figure 1 indicating the basic functionality.

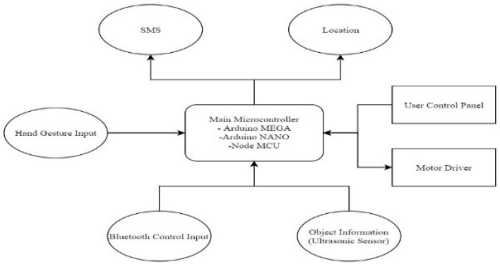

Figure 1: Basic block diagram of the proposed system

In this study, three microcontrollers have been used (Arduino Mega, Arduino Nano, and Node MCU). At first, data input goes from hand gesture recording module, Bluetooth control, sonar sensor, and user control panel to the microcontroller. After receiving the input, the microcontroller executes the function as per the given instruction and as an output the receiver gets SMS, buzzer beeps and the location of the wheelchair can be traced. The block diagram is divided into two parts which are the transmitter system and another one is a receiver system.

1. Transmitter section:

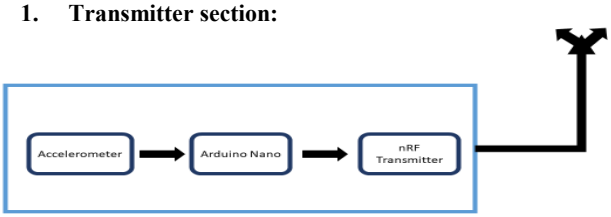

Figure 2: Transmitter Block diagram of Arduino Nano.

Figure 2 represents the working procedure of this transmitter part. Arduino nano is the main microcontroller of the transmitter section. First, the information data is received from different movement of the wrist recorded by accelerometer which is sent to the microcontroller. Then the required data is sent by the nRF transmitter.

2. Receiver section:

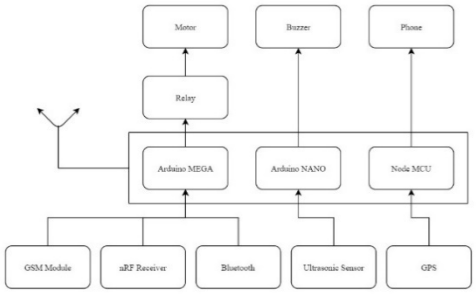

Figure 3: Receiver Block diagram

The controlling strategy of the wheelchair is shown in this above diagram. There are three microcontrollers in the receiver part. nRF receiver receives the data which is sent by the transmitter section. Then the received signal is sent to the microcontroller. GSM module and Bluetooth are connected with Arduino mega and an Arduino Nano is used for obstacle detection through sonar sensors. Node MCU is used for the GPS to trace the location of the wheelchair.

Figure 4 and 5 represents the process and additional features of the proposed system .These flowcharts show the all-controlling system of the hand gesture controlled wheelchair. The main function of the microprocessor is followed by the command which is given by the person. Command automatically goes to the microprocessor when any sensor receives desired data. After receiving the data, the microprocessor gives the desired output.

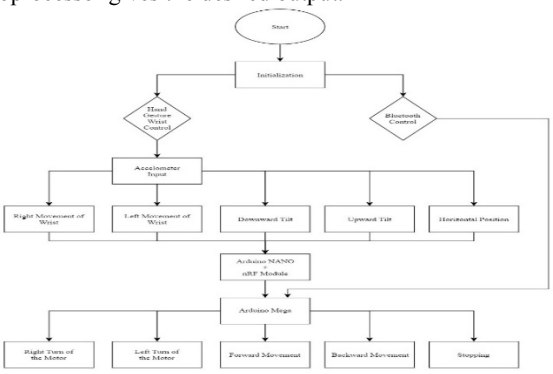

Figure 4: Flow diagram of the working principle of the proposed system.

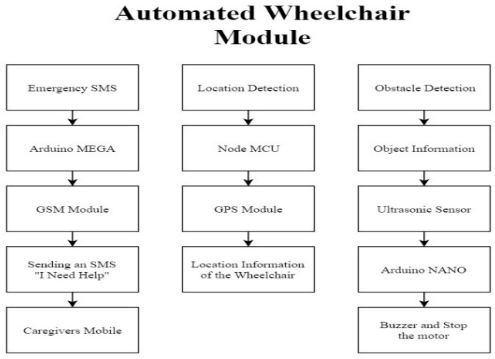

Figure 5: working principle of additional features of the proposed system.

III. Sensors and modules used in the project

This section describes the characteristics of the hardware components used for the design of the prototype.

Motor Driver:

A custom based motor driver has been designed by using relay and power MOSFET based on the H-bridge principle for the 12V DC motor.

Microcontroller and Processing unit:

The microcontroller job is to collect data from the sensors and give the desired output signal by which the wheelchair will operate. This project uses an Arduino Mega 2560 microcontroller board which is based on the Atmega2560. It consists of 54 digital input/output pins among which 14 can be used as PWM outputs, 4 UARTs (hardware serial ports), 16 analog inputs, a 16 MHz oscillator, a power jack, a USB connection, an ICSP header and reset button. It simply has to be connected to a computer or a laptop with a USB cable or battery to power the system [8].

DC Motor:

For the prototype wheelchair in this project, 12V DC geared high torque motors are used. Geared DC motors are suitable for various applications such as golf carts, quad bikes, buggies, kiddie carts, electric bikes and so on.

GPS:

GPS has been implemented to track down the location of the wheelchair by the responsible person of the user.

GSM system:

GSM system has been implemented to notify a pre-specified person that the user is in trouble; he/she only needs to press an emergency button and an emergency message will be sent to the desired mobile phone using the GSM module implemented in the wheelchair.

nRF Transceivers:

Wirelessly controlled nRF Transceiver (Transmitter and Receiver) module is designed to operate in 2.4 GHz worldwide ISM frequency band for the transmission of data. This module has an operating voltage between 1.9 to 3.6 V. This module will establish a wireless connection between the designed hand glove and the microcontroller to execute the user's command.

Ultrasonic sonar sensor:

Ultrasonic sonar sensors called "HC-05" are used in this design to provide the safety. The transmitter part of the sensor transmits an ultrasonic sound in the air. The receiver end captures the reflected sound of the obstacle and generate an echo. When an object is detected, and the wheelchair is about to hit the object; the buzzer makes beeps to aware the operator.

Node MCU:

Node MCU is a SOC (System on Chip). It is a Firmware based on the ESP8266 WIFI module chip. Wi-Fi is mandatory to control ESP8266 that is why it is called the ESP8266 Wi-Fi module chip. But Wi-Fi is not necessary to operate the system. The ESP8266 module has its built-in setup to connect to the internet on its own [9].

Gyro-accelerometer:

To keep track of the command of the user of the wheelchair, the MPU6050 Gyro-accelerometer is used. It detects the position of the user's hand and the wheelchair executes the commands accordingly by its built in 3-axis gyro and 3-axis accelerometer to provide horizontal and vertical position simultaneously.

Power Source:

To provide the power of the entire system we have used two rechargeable Li-Po (Lithium Polymer) battery each of 12 volts. The main reason behind using two 12volt batteries is to control 12volt DC geared motor by one battery, as it consumes more power. Another battery is used to give supply to all others system. Those Batteries were connected in series to supply the power to the motor.

IV. Implementation and result of the prototype

The software and hardware part of the prototype wheelchair along with the structural design is described here. Tested GSM data output result is also showed at the last part of the section.

1) Software part:

The proposed system is quite complicated to simulate in total due to its various components, as they are not all available in every simulation software. Arduino programming is done in standard way to process and transfer information. The transmitter and receiver circuits PCB layout have been done by the software called "Eagle" as shown in figure 6 for example to validate their performance.

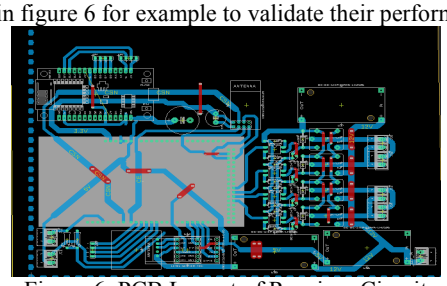

Figure 6: PCB Layout of Receiver Circuit

2) Hardware Part:

To avoid a short circuit, the implementation of Arduino and other modules were done using relays. To release the heat absorbed from the ICs and motor driver system, the heat sink has been used.

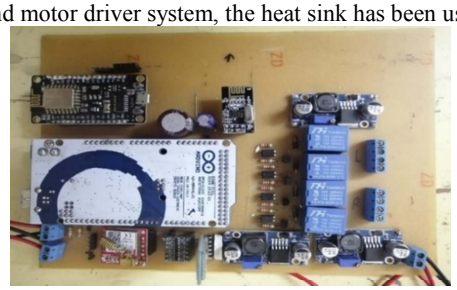

Figure 7: Designed Receiver Circuit Board.

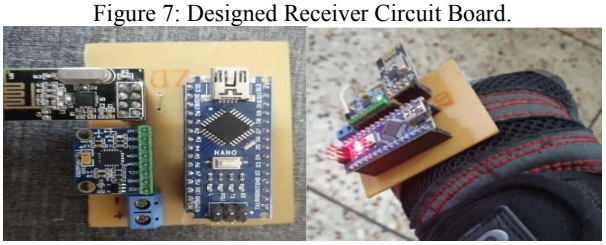

Figure 8: Transmitter Circuit Board and the designed glove for recording wrist movement.

PVC pipes have been used to design this prototype wheelchair model to make it lightweight and low in cost. PVC pipes are also known to be structurally strong.

Figure 9: Front and side view of the implemeted prototype of the proposed system.

3) Result:

By the movement of hand, the accelerometetr sensors will take the inputs, and with respect to this input, movement operation will be

done. Figure 10 represents the implemented form of the hand gesture control gloves.

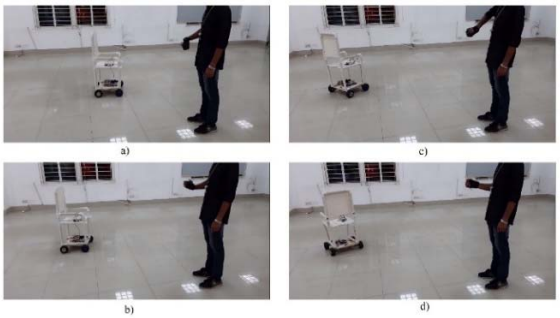

Figure 10: Implemented prototype hand gesture controll gloves

Figure 10 represents the implemented prototype of the hand gesture control gloves. Figure 10(a) and 10(b) shows the forward and backward movement by the upward and downward tilt of the hand. While,Figure 10(c) and 10(d) represents the right and left turn of the motor by moving the wrist right and left respectively.

The location of our project has been tested by GPS module which is connected through Node MCU. The output of the GPS module is shown below.

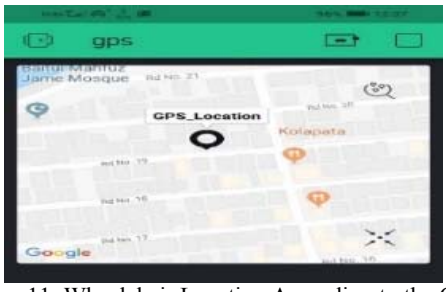

Figure 11: Wheelchair Location According to the GPS.

V. COMPONENTS AND COSTS ANALYSIS

The following table represents the hardware implementation cost of the proposed system for comparative benefit of this system. The proposed system prototype can be successfully implemented under $200 whereas for the practical wheelchair it can be designed under $300 according to the available wheelchair in Bangladesh.

Table 1: Mechanical and Electrical components cost for prototype wheelchair

Mechanical Components Cost			**Electrical Components Cost**		
Components	**Quantity (piece)**	**Cost (in $)**	**Components**	**Quantity (piece)**	**Cost (In$)**
DC Gear Motor	4	40.11	Arduino Mega	1	8.85
Motor Mount	4	7.08	Arduino Nano	2	7.08
Motor Hex	4	5.66			
Wheel	4	14.17	Node MCU	1	5.90
PVC Pipe	20 feet	4.72	nRF	1	4.72
PVC Connector	14	8.26	MPU 6050	1	2.83
			Li-Po Battery	2	29.49
			GPS	1	13.57
			GSM	1	5.31
			Bluetooth HC-05	1	3.42
			Buck Connector	3	2.48
			Relay	4	1.42
			Sonar (SR-04	2	2.60
			Logic Level Counter	1	1.53
			Connecting Wire	N/A	2.36
Total		**80**	**Total**		**91.56**
Net Cost: $ 171.56					

VI. DISCUSSION

The proposed prototype wheelchair is an automated wheelchair which uses hand gesture-controlled technology that can be controlled only by the movement of the hand of the patient. This is also controlled through the Bluetooth module if needed. The location of the wheelchair can also be traced from anywhere in the world by using IOT based technique. This is an Arduino based system where obstacles can be detected through ultrasonic range detector sensors (i.e. sonar sensors) and the buzzer makes a sound to alert the operator for avoiding accidents. A GPS tracking system is used in this project to know the position of the operator. GSM system is also embedded in the project to send an emergency message to the responsible person. Node MCU has given this project a lift up in case of IoT technology. With this technology, the location of the operator can be known by the responsible person of the operator. Therefore, it is believed that the proposed system can reduce the complexities of other automated wheelchairs and improve the lifestyle of movement disabled people through easier techniques.

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