Smart Wheelchair Management System for Disabled People

Ishan Patel, Krish Sethi, Simrit Kaul, Soumya, and Sumit Kumar Jindal

Abstract Over the recent years, the field of integrating human machine interface to power wheelchairs for autonomous driving control has gained great attention by the scientific and engineering communities. The fundamental objective of the human—wheelchair interface is to permit the individual to control the versatility of the seat in least exertion and with more vigour and security. A large variety of electric powered wheelchairs do not meet the needs of a substantial proportion of users because of requirement of muscle force and accuracy. An assistive component for executing well-heeled wheelchair motion for seriously incapacitated individuals is introduced. For making the lives of disabled people easier and less dependent, the wheelchair has been incorporated with eye control interface for the movement and direction control. For the safety of the patient, obstacle avoidance and fall alert mechanisms have been included. Also, body temperature and heart rate are two parameters that are considered for health monitoring of the patient.

Keywords Smart wheelchair · Eye control · Spinal cord injury · Human machine interface · Internet of Things · MEMS sensor

1 Introduction

From the insights of the on-going years, the quantity of paralytic residents is on the ascent. As per the National Census 2011, in India out of 1.2 billion populace, 26.8 million individuals are 'handicapped' which is 2.21% of the absolute populace. These people have either temporary or permanent disabilities due to illness or accidents. It is realized that handicap power is higher in evolving countries. An enormous segment of populace that falls into this category cannot resume normal life in light of detachment to assistive gadgets. This ailment can frame an endless loop and a tiny bit at a time can spoil the life of the person. Inability ought to be not any more an impediment to individual and social improvement in this time. These disabled people must

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be offered with gadget which may equip them portability alongside some progressive control attributes so they may have at least an average existence. Independent mobility decreases reliance on guardians and relatives, increases vocational and educational opportunities, and advances sentiments of confidence. For infants, self-reliant portability fills in as the establishment for early stage of learning. Youngsters without protected and self-ambulation are denied basic learning opportunity which places them at a formative disservice. For elders, unconstrained movement is a significant device of confidence and takes on a vital job in settling with the age. For instance, if more elder individuals think that its much hard to trundle themselves to the objections, they may dodge or do so less regularly. Versatility challenges are likewise, the core contenders of activities of daily living (ADL) and instrumental ADL handicaps due to the requirement to move to achieve huge numbers of such pursuits. Despite the fact that the requirements of several people with inabilities could be mollified with conventional manual or steerable wheelchairs, a portion of the debilitated network thinks that it is troublesome or strenuous to make use of wheelchairs freely. It is critical to build up an intelligence driven wheelchair whose movement is interceded by an electronic framework which knows about environment and can link with the client to accomplish versatility objectives and maintain a strategic distance from risky circumstances [1–3]. This decreases the client's human exertion to propel the wheels of the wheelchair. Autarchic perception wheelchairs are regulated by the Human UI where the human settles on choices at the most significant intensity of activity and the shrewd control innovation makes the rest of the movement programmed [4, 5]. The insight is added to a wheelchair stage around client control regardless of their incapacities, which makes the investigation of the human–machine interface (HMI) between the client and the wheelchair a significant assistive automated branch of knowledge [6].

2 Literature Review

A huge assortment of electric instigated wheelchairs that utilize distinctive human machine interfaces (HMI), for example, sip and puff control, head movement, speech identification, jaw control and EEG signals have been incorporated since years. Rabhi et al. [7] used fuzzy logic with Vector Field Histogram (VHF) algorithm to develop joystick controlled wheelchair. The signal coming from the VFH refining algorithm and the change in the action of the hands of the debilitated which is identified from the information received from the joystick is acknowledged by the fuzzy logic controller. The fuzzy logic generates output in the form of signals that decide the speed and angle of motor's rotation. LIDAR sensor has been utilized to distinguish the deterrents before the wheelchair. The VFH algorithm processes these signals from LIDAR and gives the input to the fuzzy algorithm which decides the direction to avoid collision from the object coming in path of the wheelchair. Abedan Kondori et al. [8] have instigated an unmediated process for 3-D head pose estimation. The head developments are assessed from a grouping of profundity pictures obtained by Kinect. A

succession of pictures are apprehended by Kinect which is put before the client. Head restriction, head pose assessment and direct 3-D movement assessment are finished. To distinguish and confine the client head, image sequence is then sent to the system. Finally, the steer of the wheelchair is controlled by mapping the recovered motion parameters onto the control commands of the wheelchair. Sivakumar et al. [9] have presented voice controlled wheelchair. Speech customisation is used to prepare the system to interpret signals from the sound commands. Voice capture module records speech commands using the microphone found in the speech package. It then transforms the received commands into binary codes, depending on the speaking command frequency. Comparing the ported binary codes with the one stored in the microcontroller is the responsibility of the Voice Recognition sub module. Then if both are remarkably similar, it compares these commands. Achkar et al. [10] have introduced Mobile controlled wheelchair, which allows the clients to locate the position of their wheelchairs and move them to the intended location through the use of special android application. The router was used as a source of direct link between the Mobile App, Arduino, and the relays in this project. An IP camera over the front end of the wheelchair was incorporated to visualize the desired trajectory. The IP camera analyses the data via its unique IP address provided by the router, in order to trace and connect. The router will then send the information packets via Wi-Fi or Internet to the user-installed android device. Thakur and Kulshrestha [11] have presented eye controlled wheelchair. The system consists of a camera, a software for image recognition and a motor controller to control a wheelchair. Shape-adjusted mean shift algorithm is used as mapping algorithm in NI Vision assistant along with NI Vision Acquisition and NI Laboratory View. The outcomes of eyeball monitoring are then used to generate sufficient wheelchair movement. The Chin control interface [12] uses a force-sensing joystick shaft that does not require any precise movement of the face. The person needs to exert force using the neck muscle to provide the input. The necessary force is usually between 0.09 and 0.3 kg. Only people who possess significant strength in their neck muscles will embrace this technology. The Sip-n-puff interface [13, 14] is regulated by the sipping (ingestion) and puffing (exhalation) commands on a pneumatic tube. Sharp sips and puffs are expected to change the trajectory of the wheelchair whilst lower/softer tiers of sips and puffs can achieve the steering. These instruments are mostly designed for speed control and each time require tremendous precision in the sips and puffs. They are still constrained by the fact that they need an external starting point. The tongue touch keypad (TTK) control interface is the only language controller device currently available. It comprises of switches that are installed into the dental mouthpiece and that fit into the mouth roof. The big drawback of such a device is that they must be replaced regularly before feeding and even drinking water.

3   System Overview

The control structure as represented in Fig. 1 for the smart wheelchair comprises the

Fig. 1 System overview
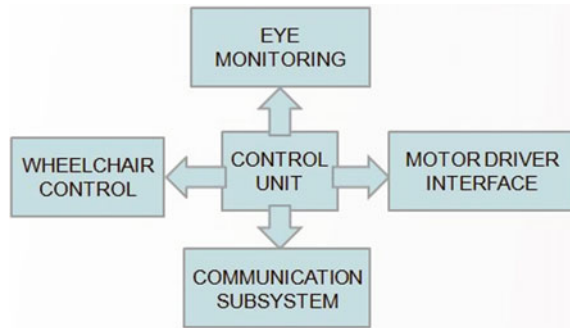
following sub-blocks:

- Control Unit—Control unit consists of Arduino UNO. The control unit is responsible for all the decisions and data processing.
- Wheelchair Power Motors—The movement of the wheelchair is controlled via motor driver and DC motors.
- Wheelchair Control Interface—The eyeball control unit, the accelerometer MEMS sensor, Ultrasonic sensor.
- Communication Subsystem—This consists of the GSM module, Wi-Fi module, IoT platform.

A. *Wheelchair Direction control*

The wheelchair model is attached with wheels at both the ends and at the centre. The DC motors are connected to the wheels that convert the electrical energy to mechanical energy and help to rotate the wheels. DC motor driver drives the motors by providing the necessary current to provide the torque. It uses L293D H-bridge motor driver IC with Voltage regulator 7805. This IC provides a +5 V regulated power supply with provisions to add a heat sink. They for the most part go about as current amplifiers that acknowledge the low current signal from the controller and convert it into a high current signal which assists with driving the motor.

Eye sensor (QTR-1RC) with an operating voltage of 5 V is mounted in front of the patient's eyes. The sensor consists of infrared transmitter and infrared receiver. There is an angle of ±45° between the transmitter and receiver which acts as the directivity of the sensor. The optimum sensing distance for this particular sensor is 3 mm and the maximum is 9.5 mm. The infrared transmitter continuously transmits the infrared rays in the surrounding. When an object appears in front of the infrared rays, it is mirrored backwards and processed by the infrared receiver. In this scenario, when the eye sensor is kept in front of the eyes of the patient, the opening and closing of eyes produce electrical signal of different intensity due to difference in amount of reflected infrared rays. When the eye is open, the black ball in the eye absorbs some amount of infrared rays and rest of the rays are reflected back to the receiver. Whereas, when the eye is closed almost all of the emitted infrared rays are reflected back to the transmitter. This change in the amount of intensity of infrared rays received by the

Fig. 2 Wheelchair
movement control
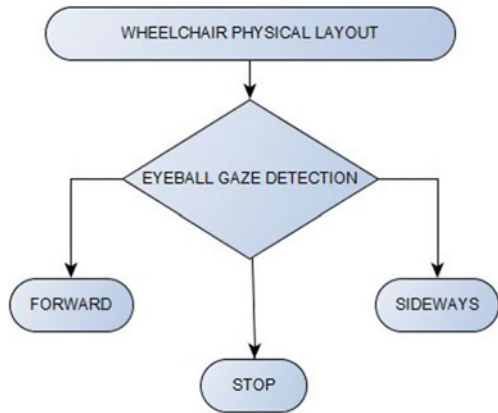
receiver of the eye sensor [15, 16], produces a HIGH as well as LOW signal. Two such sensors are used for each eye which produces for combinations of HIGH and LOW signals which instructs the wheelchair for movements in four eye controlled ways: FORWARD, LEFT, RIGHT and STOP. Inputs from both the eye sensors are fed to the Arduino board. When both the eye sensors produce a LOW voltage signal, the wheelchair motor is given command to STOP. When the right eye sensor produces a HIGH voltage signal whereas the left eye sensor produces a LOW voltage signal, a command to turn towards RIGHT direction is given to the wheelchair motor. When the left eye sensor produces a HIGH voltage signal whereas the right eye sensor produces a LOW voltage signal, it turns LEFT.

The following flowchart in Fig. 2 shows the steps to determine the movement of the wheelchair.

B. *Obstacle Detection and Collision Avoidance*

HC-SR04 ultrasonic sensors are used to detect obstacle and measure the distance from the obstacle. The operating voltage of this sensor is 5 V and its range is between 2 and 400 cm with a resolution of 0.3 cm. The sensor is attached in front of the wheelchair which helps to identify any obstacle in the path. The transmitter (trig pin) sends a 340 m/s output signal of high frequency in the local field. If the signal hits an entity, it is mirrored, and it is received by the receiver (echo pin). The echo pin provides the cumulative time of sound wave propagation. Since, the ECHO pin give the total propagation time which includes the time taken by the sound wave to hit the target and the time taken to reach the receiver. The distance considered is double the actual distance between the ultrasonic sensor and the object. Therefore, the distance of obstacle is:

$$d = \frac{\text{speed of the sound wave} \times \text{total propagation time}}{2}$$

Buzzer alarms the patient if the distance of the object is less than 20 cm. The patient is alarmed immediately so that he can stop or change the direction of the

Fig. 3 Collision avoidance
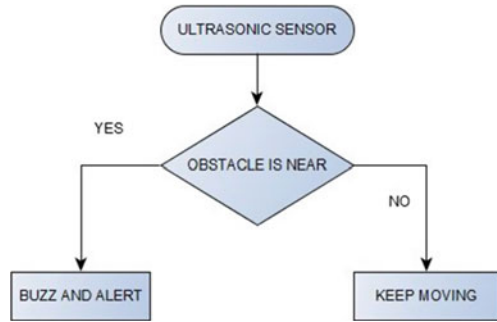
wheelchair as soon as possible. This helps to avoid any collision between the patient and the object. The following flowchart in Fig. 3 shows the steps to determine any obstacle in the path of the wheelchair.

C. *Health Monitoring*

Body temperature and heartbeat of the patient is continuously monitored. LM35 temperature sensor and heart beat sensor measures the values and relay that in the form of a signal to the Arduino UNO. The LM35 sensor has a wide range of −55 °C to 150 °C with an operating range of 4 V to 30 V. The heart beat sensor operates at 100 mA and the heart beat detection is indicated by LED and Output High Pulse. Wi-Fi module containing the ESP8266 module helps the controller connect to the Internet [17]. It operates at 3.3 V and a baud rate of 9600. A serial connexion is established between the Wi-Fi module and Arduino, as well as the Wi-Fi module and the data storage platform for Internet. This data is sent to the cloud by the Arduino which is assisted by the Wi-Fi Module. These data can be retrieved even in the form of graph for statistical analysis. The following flowchart in Fig. 4 shows the steps to monitor the health of the patient.
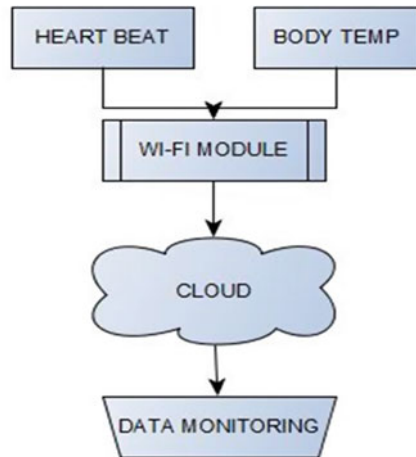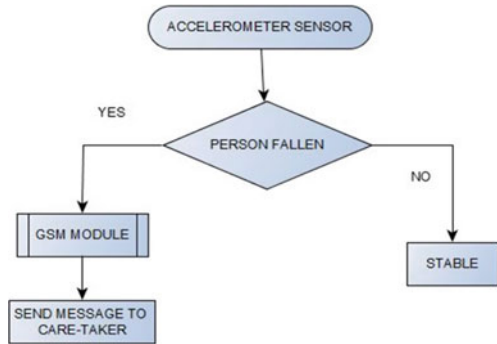
Fig. 4 Health monitoring

Fig. 5 Fall detection

D. *Fall Detection*

The accelerometer sensor measures the orientation [18] of the wheelchair. It operates within the range of 3–6 V (DC) and provides an analogue output. It has a measuring range of ±3 g. For a negative value of X-axis, the wheelchair is considered to be fallen. In this case, the GSM module decides to send an alert message on mobile to the caretaker. The mobile number of the caretaker is provided in the Arduino code. This helps to provide the patient immediate help. If all the three axes values are positive, the wheelchair is considered to be stable and thus, no action is taken. The following flowchart in Fig. 5 shows the steps to detect the fall of the patient.

E.   *Technical Specifications*

The section below discusses all the technical aspects of the sensors and actuators used in the wheelchair model.

4 Results and Discussion

Figure 6a and b present the hardware setup for the proposed design.

(a)   The wheelchair direction control is controlled by the eyes. The wheelchair moves forward, left, right and stops according to the input from the eye sensor. When a HIGH signal is received from both the eyes then the wheelchair moves forward. When a HIGH signal is received from only left eye, the wheelchair

Fig. 6 a Control unit **b** Complete device arrangement
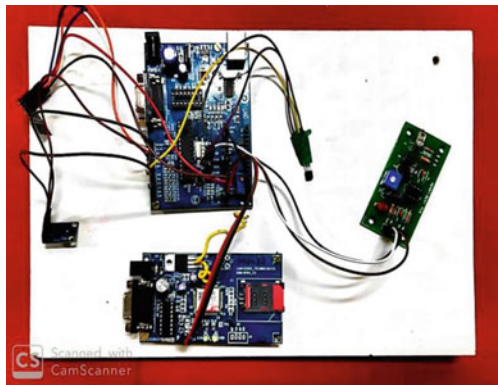
(a)
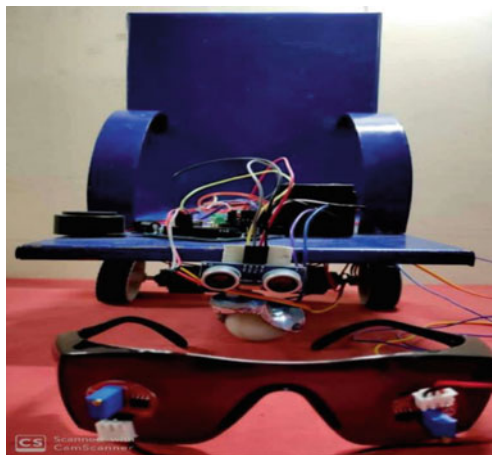
(b)

turns left. When a HIGH signal is received from the right eye, the wheelchair turns right. Finally, if LOW signal is received from both the eyes, the wheelchair STOPS.

(b) When an obstacle comes in the way of wheelchair, the patient is alarmed by the buzzer. The ultrasonic sensor successfully detects the presence of any small object in front of it in the range of 2–400 cm with a resolution of 0.3 cm. Thus, obstacle avoidance subsystem works efficiently.

(c) The temperature and heart beat of the patient is continuously measured. The values are displayed on the serial monitor of the Arduino IDE as shown in Fig. 7. This data is successfully uploaded on the Internet and displayed in the form of a graph for data visualization. This can be seen in Fig. 8. Also, the data is updated time to time to keep a hold of the real time data.

(d) The caretaker is informed if the wheelchair is detected to be fallen. The accelerometer sensor measures the x-orientation of the wheelchair. The GSM module is connected to a 4G mobile network. It sends SMS message, as represented in Fig. 9 immediately to the registered phone number so that the patient can get aid from the caretaker.

Fig. 7 Fall detection on serial monitor

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TEMPRATURE = 28.81*C
TEMPRATURE = 83.86*f
3.69
/iotmakers/upload.php?id=sssdbkgf&data1=28.81&data2=0TCP connection ready
Sending..
Packet sent

 +IPD,221:HTTP/1.1 200 OK
Content-Txpe: text/html; charset<UTF-8
Soy
-Pa0 n
TEMPRATURE = 27.34*C
TEMPRATURE = 81.22*f
10.03
/iotmakers/upload.php?id=sssdbkgf&data1=27.34&data2=0TCP connection ready
Sending..
TEMPRATURE = 28.32*C
TEMPRATURE = 82.98*f
-41.54
AT
AT+CMGF=1
AT+CMGS="9431437479"
WARNING::wheel chair has fall down
 /iotmakers/upload.php?id=sssdbkgf&data1=28.32&data2=0TCP connection ready
Sending..
Packet sent
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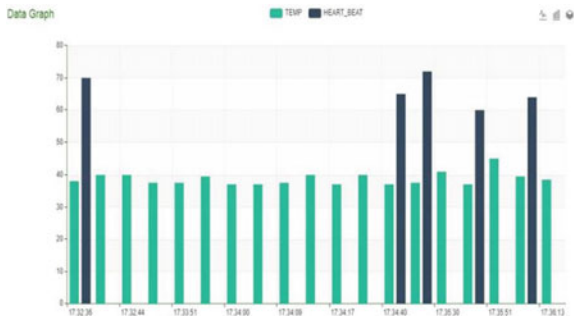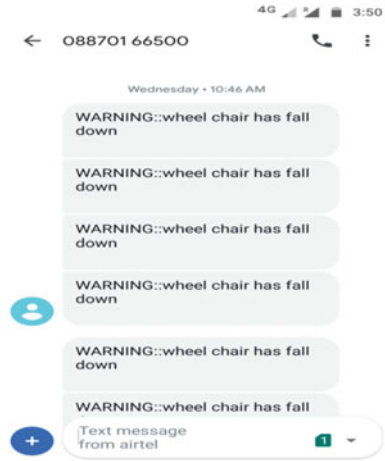**Fig. 8** Bar Graph showing temperature and heart beat

Fig. 9 Alert SMS to
caretaker

5   Comparative Study

The proposed work is compared with the existing literature in the tabular format
given below (Table 1).

The proposed work focuses on distraction free movement of the wheelchair
ensuring more safety than the works suggested in the literature survey. The constant
monitoring of the temperature and pulse rate and simultaneous uploading of data
to the internet proves to be an additional feature. Automatic communication of a
distress signal when a fall is detected evinces an auxiliary functionality.

Table 1 Functional comparison for different features of the electric powered wheelchair (EPW)

Wheelchair type	Features
Multimodular Wheelchair (Ben et al. [1])	HMI to control the movement of EPW by gaze tracking technique using a webcam
Electric Wheelchair for Paralyzed Users (Arai et al. [19])	EPW movement is strictly controlled by motion of the eye using a camera attached on the patient's glasses
Electric Wheelchair control using head gesture (Ohtsuka et al. [2])	The motion of the wheelchair is based on the gestures of the head which is detected by the depth sensor
Touchscreen-based multifunctional wheelchair (Makwana et al. [3])	The portability of the wheelchair can be directed by one finger touch along with obstacle detection
Smart Wheelchair Management System [Proposed Work]	EPW movement is guided using the eye sensor in company with obstacle detection and health monitoring system

6 Conclusion

This mechanism provides an assistive method for the introduction of secure wheelchair motility for chronically disabled individuals. Eye controls four motion of the wheelchair, i.e. FORWARD, LEFT, RIGHT and STOP. Accelerometer sensor detects the orientation of the wheelchair and informs the caretaker immediately using GSM module in case the person falls from the wheelchair. Ultrasonic sensor measures the distance of the obstacle and alarms the person when its distance is less than 20 cm. It continuously monitors health of the patient. The temperature and heart beat sensor upload continuously the data on the Internet through Wi-Fi module for statistical analysis.

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