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Wireless Motion Control of an Intelligent Wheelchair Using Hand Gesture Recognition Technology

Ajit M. Choudhari
M.E (Production)
Department of Mechanical Engineering,
Shri Guru Gobind Singhji Institute of Engineering and Technology,
Vishnupuri, Nanded.

Dr. J.V.L. Venkatesh, Ph.D
HoD,
Department of Mechanical Engineering,
Shri Guru Gobind Singhji Institute of Engineering and Technology,
Vishnupuri, Nanded.

Abstract

A 'hand gesture' based easy to operate navigation mechanism using the wireless technology in the form of wheelchair control system is presented in this work. This work proposes an integrated approach for detection, tracking and recognition of hand gestures in real time. The approach uses acceleration technology to establish a reliable medium of human-machine interaction for the movement control of an intelligent wheelchair. The remote control facility up to 60 meters and obstacle avoidance technology provided for additional comfort during navigation task for elderly or disabled people. The wheelchair motion is controlled by employing Arduino microcontroller interfaces with MEMS accelerometer sensor, motor driver unit, proximity and edge detection sensors. The designed system was tested with five experiments by two subjects independently. An average accuracy of 98 to 99% was found for all modules. Overall system performed well and result shows encouraging outcomes.

Keywords – ***Wirelessrobot control, Hand gesture controlled wheelchair, Obstacle avoidance,Assistive Technology, MMI interface***

Introduction:

Elderly people or persons with physical disabilities & partial paralysis always find it difficult to navigate through their habitat without the assistance. Wheelchair is the most common mean of locomotion after paralysis or physical disability.Driving a wheelchair in domestic environments is a difficult task even for a normal person and becomes even more difficult for people with impairment.

The use of powered wheelchairs with high navigational intelligence is one of the important step towards theservice of these people. Tetra pelagic people are completely unable to operate a joystick unless they use the tongue, which is obviously a very tedious task.

Someone's need for navigationoften causes feeling of dependency and demoralization.With the present development in the robotics, assistive technology, embedded system and rehabilitation engineering, it is possible to address this problem. For that, a working model demonstrating the successful use of hand gesture for controlling a wheelchair has been developed and that too at a very low cost. The wheelchair in context can be controlled wirelessly without muscular forces and also without help of attendee. The chair can be controlled by simple hand gestures in required directions. Previous developments on this topic include the presence of a laptop or CPU on the wheelchairfor the purpose of processing [1]. Some other studies employed voice recognition system for robot control [2].

These systems are suffering from drawbacks of their bulkynature as it required processing computer system. This limits the navigation flexibility and autonomy of system. Further speech impaired users cannot operate this system. The ability to understand hand gestures will improve the naturalness and efficiency of human interaction with robot, and allow the user to communicate in complex tasks without using tedious sets of detailed instructions.

Literature review reveals that the gestures control robots are employed to achieve human non-verbal communication. In a study conducted by Lu et al the accelerations of a hand in motion in three perpendicular directions are detected by a MEMS accelerometer and transmitted to a PC via Bluetooth wireless protocol [3]. In an another study, hand gesture recognition using convexity hull defects to control 6 axis industrial robot is demonstrated, the image is acquired by means of a web cam system, and undergoes several processing stages before a meaningful recognition can be achieved [4-5]. Finger gesture and pattern recognition based device security system presented. In this study an image database for matching of image pairs to trigger unlocking of mobile devices [5].

Though remarkable progress has been made, still systems suffers from limitations of need of processing computer [6], heavy architecture, necessity of lot of training [7],signal processing , image processing [8],and many more. Here, in the presented interface, we used Micro Electro Mechanical Sensor(MEMS) sensor to recognize hand gesture which is a highly sensitive device capable of detecting even the small tilt of hand. MEMS is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology. MEMS based devices can be easily reachable to the common man due to its low cost and easy availability. MEMS accelerometer is a single chip with small size and low cost. Because of their small size and weight, accelerometers can be attached on hand, figures or gloves directly. User can wear it to his wrist like a watch and can operate it by tilting the accelerometer sensor and can control the desired motion of linked devices.

The proposed model makes the wheelchair a lot easier to assemble and simple in the use, in addition the cost of manufacturing also reduced to large extent. Also, with the use of ZigBee wireless technology the wheelchair can be controlled remotely from near about 60 to 70 meters of a distance. So a person laying on a bed can move the wheelchair near or away from him just by simple hand movements. It can also help people during the night without the need for a third person, for the person to get on the wheelchair and move inside or outside the habitat. Wheelchair will autonomously detect the obstacles in its path and will avoid by changing the path. Thus people can control the chair in narrow spaces without collision.

Methodology

System architecture-

Architecture for wireless motion control of an intelligent wheelchair using hand gesture recognition technology is shown in Fig. 1. MEMS accelerometer sensor is used to control the wheelchair as per the movement of the hand. The accelerometer sensor senses the accelerating force and convert the hand position into 3-Dimensional Output in the form of a particular voltage for the x, y and z coordinate orientation. Crystal oscillator is used here to generate the clock pulse & to support the RF module with its frequency. It is provided in both the transmitter and the receiver section. RF transmitter transmits the data signals with its carrier wave which can be accepted only by the receiver of the same frequency. The signals from accelerometer sensors that are received in analog form has to be converted in to digital form. This is done by employing AD converter and the digital values are fed to Arduino microcontroller. On receipt of these digital values, programmed controller controls the direction of motors through motor control unit.

Depending on the direction of the MEMS, wheelchair directions like front, right, left and back are controlled. Arduino also receives input from proximity sensor and edge detection sensor. A working model is implemented with a wheelchair and DC motors operating on 12V rechargeable battery. In this system we are implementing it with Arduino AT mega 328 microcontroller at transmitter and receiver sections. This system uses regulated 5V, 500mA power supply. 7805 three terminal voltage regulator is used for voltage regulation. Bridge

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type full wave rectifier is used to rectify the ac output of secondary of 230/12V step down transformer.

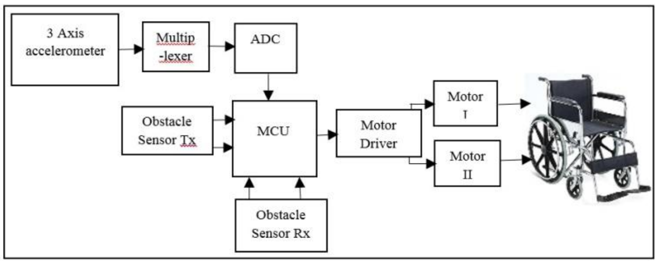


Fig. 1. General Architecture of hand gesture based wheelchair control system.

Components

Hand gesture module:

The hand gesture module has been designed by using a triple axis ADXL 335 accelerometer sensor. An accelerometer measures acceleration (change in speed) of anything that it's mounted on. The relatively low cost sensor provides the data for the orientation of the hand and therefore helps in recognizing the gestures.This is a very handy device for measuring the orientation of an object relative to the earth. Sensor senses the accelerating force and thus gives a particular voltage for the x, y and z coordinate orientation.

The data obtained from the accelerometer for the various orientations of the hand gave us the readings to decide the threshold value for each x, y and z coordinate reading.The data can be observed in integer format through the serial port of MCU on the computer's serial monitor as shown in Fig. 7. Accordingly the orientations of the hand can be sorted out.The basic working block diagram of the accelerometer sensor is as shown below in Fig.2

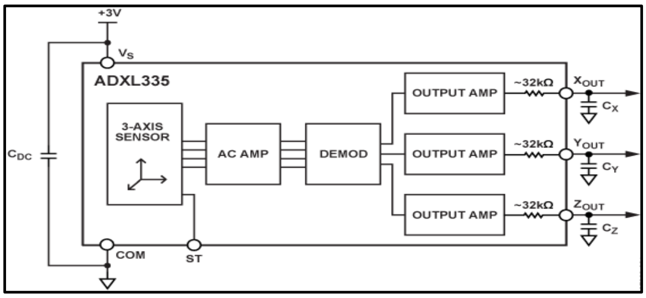


Fig.2.The basic working block diagram of the accelerometer sensor.

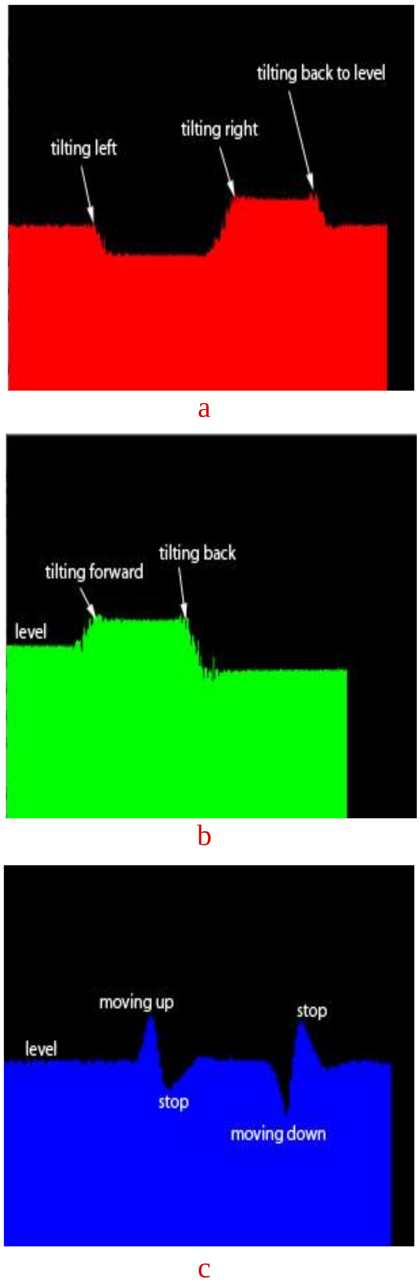


Fig. 3. Accelometer levels in X,Y and Z directions.

The actual happening within the sensor part during movement of MEMS is shown in Fig. 3. a) in X axis movement, It starts at level, and then is tilted to the left, then to the right, then level again. Fig. 3 b) shows the Y axis orientation, starts at level, and then is tilted forward, then back, then level again. Fig. 3 c) shows the Z axis. The accelerometer is at kept level, but raised up in a quick motion, then lowered quickly. Moving up produces a sudden increase in force (and voltage) followed by a sudden decrease when the movement's stopped, then finally the voltage levels out again. Moving down has the opposite effect.

Transmitter & receiver module

In transmitter part, hand gesture recognized by the MEMS sensor in digital output is transmitted to the controller by RF transmitterafter encoding. Fig. 3 a) & b) shows the block diagram of the transmitter and receiver unit. The transmitted data signals are received by RF receiver which operates in the same frequency as the receiver. The encoded data signals are separated by the decoder

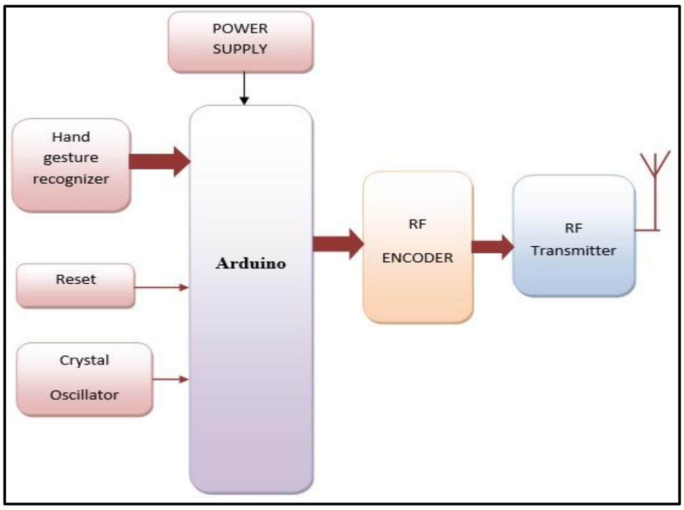


Fig. 4 a. Block diagram of transmission section.

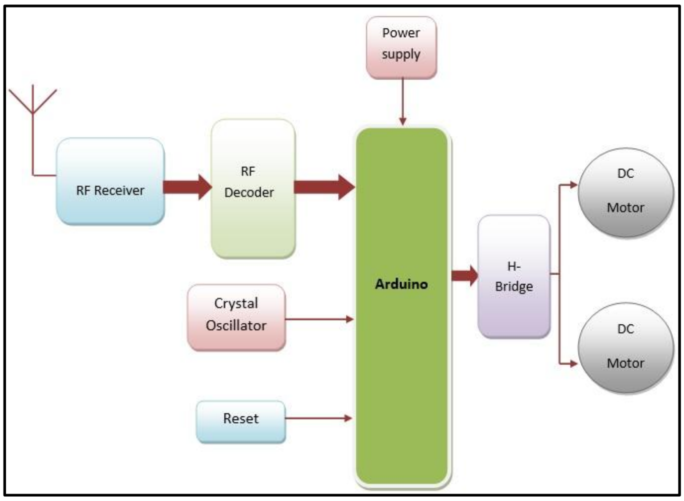


Fig. 4b. Block diagram of receiver section.

Control module

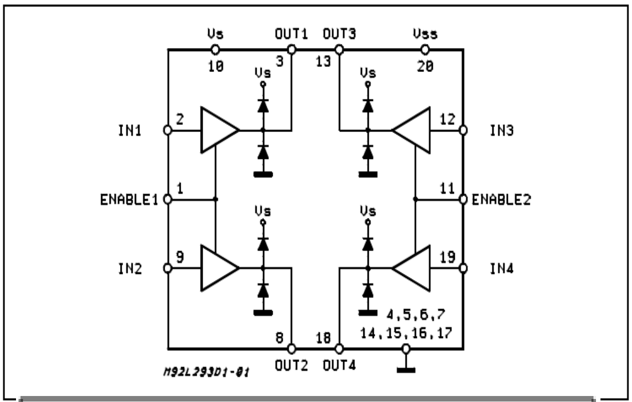
Microcontroller

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The microcontroller, the motor driver unit, proximity and edge detection module together forms the control module for designed system. Each sensor is interfaced in ADC module of the controller. Accelerometer sensor has specific values which are read as analog inputs by controller. The data obtained from the accelerometer for the various orientations of the hand gave us the readings to decide the threshold value for each x, y and z coordinate readingthe values obtained from the accelerometer are analog values which should be further converted into digital values so they can be used by the Arduino controller.

Motor driver unit

For the desired motion of the wheelchair we have used high torque geared DC motors. The motors are controlled by the bi-directional motor driver IC – L293D. The motor driver is connected through the microcontroller on the wheelchair which sends the signal to the driver for the various conditions. For smooth turning during the motion of the wheelchair we have used the method of Pulse Width Modulation (PWM). The PWM allows the microcontroller to send the power to the motor driver in small packets over high frequency. The constant ON and OFF states actually helps to conduct smooth turning motion.

H – Bridge - The H-bridge is so named because it has four switching elements at the "corners" of the H and the motor forms the cross bar. The basic bridge is shown in the Fig. 5 .The switches are turned on in pairs, either high left and lower right, or lower left and high right, but never both switches on the same "side" of the bridge. If both switches on one side of a bridge are turned on it creates a short circuit between the battery plus and battery minus terminals. If the bridge is sufficiently powerful it will absorb that load and your batteries will simply drain quickly



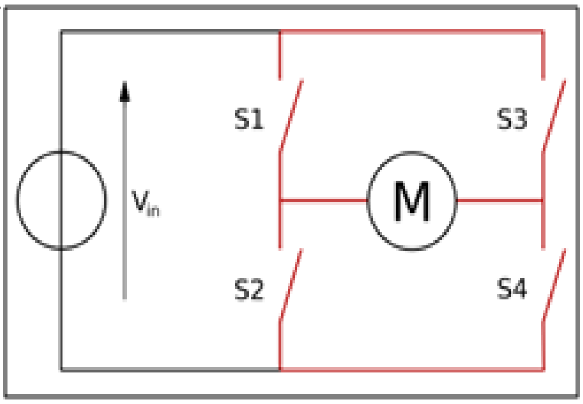


Fig. 5. H-bridge working model.

Proximity detection module

As part of the proximity detection module HC-SR04, an ultrasonic sensor is used for measuring closeness to the objects or the walls when the wheelchair is in motion we have used. The ultrasonic module sends the analog voltage data to the microcontroller which effectively converts it into centimeters and hence the distances are measured. Thus the microcontroller can command the motor driver to successfully avert the obstacles or walls during motion.

Edge detection module

The edge detection sensors have been used on the backside of the wheelchair. The sensors are at a constant digital low state on the straight surface. But if there is a sharp increase of height during any backward motion of the wheelchair then it automatically sends a digital high signal to the microcontroller on board

Control Mechanism

MEMS sensor has piezo resistive material at the center of the chip, which is suspended by 4 beams doped with piezo resistive material. When the sensor is subjected to acceleration in any direction, the movement of the mass causes the 4 beams to deform and so changes the resistance of the piezo material. This enables the sensor to detect the acceleration motion. MEMS sensor contain Tilt register. When there is a change in the direction, the tilt register values are changed and that values are given to ADC, which converts analog to digital values. These values are given as an input to the microcontroller. Then the Arduino produces the output which instructs the driver circuit to close or open the switches in it. Depending on the switches closed it produces either positive or negative output and motor rotates accordingly. Microcontroller is programmed in such a way that, whenever MEMS sensor detects the extension of hand it will rotate both motors in anticlockwise directions and wheelchair will move in forward direction. Similarly for flexion of hand backward movement is assigned. Right side tilt of hand and left side tilt are assigned to right and left turn respectively. The different hand gestures and their corresponding control commands are depicted in Fig .7.

On the basis of tilt of the MEMS, microcontroller controls the wheelchair in front, right, left, back directions. Additional safety feature called “panic button” is provided. On pressing, it wheelchair stops immediately. Further the proximity sensor and edge detection sensors are used to detect the obstacles near wheelchair and accordingly microcontroller will control the movement of wheelchair for avoiding these obstacles.

Experimentations

Experiments were conducted to test the validity of proposed model. Two subjects have controlled the wheelchair with our designed interface. The experiments were repeated for five times with 50 trials of commands in each experiment to test conformity of operability of designed system. The gestures employed for different

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motions and their threshold values in x, y and z coordinates are outlined in Fig. 6.

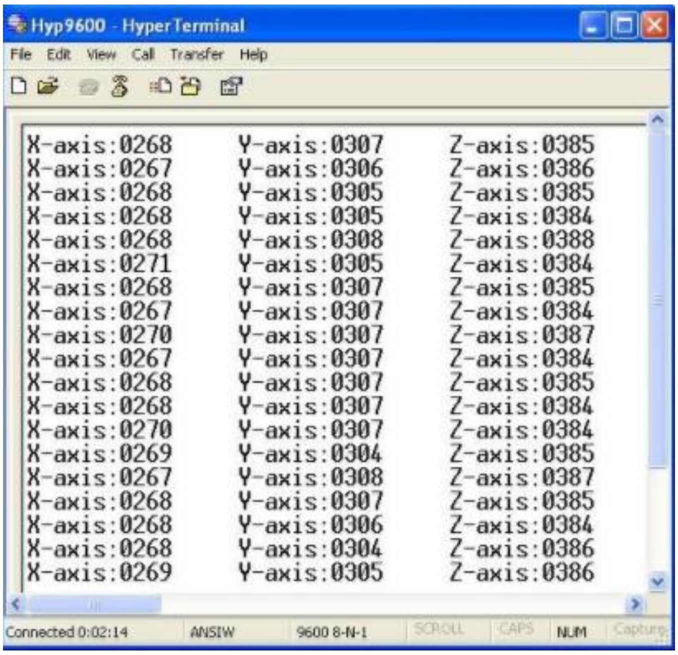


Fig 6. X, Y, Z coordinate values of accelerometer sensor.

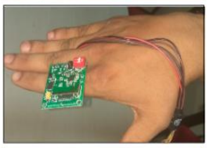
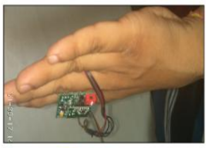
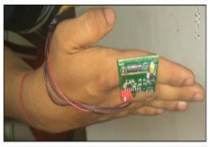
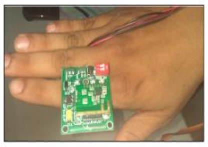
	Forward	X >= 250 Y <= 250 Z <= 210 & Z>=275
	Backward	X <= 250 Y <= 250 Z <= 210 & Z>=275
	Left	X <= 250 Y >= 250 Z <= 210 & Z>=275
	Right	X <= 250 Y <= 250 Z <= 210
	Stop	X <= 250 Y <= 250 Z>=275

Fig. 7. Hand gestures and corresponding control commands.

Results and discussions

All the components after integration gave us the working skeleton model for the wheelchair. The wheelchair model works perfectly according to the hand gestures. The number of successful recognition of detection of gesture, obstacle and edge are noted against total number of trials in each experiment. The readings are calculated based on the following formula: Success Rate = (No. of successful trials*100)/ (Total no. of trials). The experiment results for both the participants are shown in Table No. 1 and their corresponding graphs are depicted in Fig. 8 a) and b)

Table. 1 Experimental results.

Experiment No.	Gesture Recognition % Success		Obstacle Avoidance % Success		Edge detection % Success	
Participant	**P-1**	**P-2**	**P-1**	**P-2**	**P-1**	**P-2**
1	98	96	98	98	100	98
2	100	100	100	98	100	100
3	100	98	96	100	98	98
4	98	96	100	98	96	100
5	100	100	100	100	100	100
Average %	**99.2**	**98**	**98.8**	**98.8**	**98.8**	**99.2**

It is evident from the above results that, in all five experiments first participant shown an average accuracy of 99.2%, 98.8% and 98.8& in gesture, obstacle detection and edge detection respectively. Fig. 7 a) shows the graphs of performance quantifiers for first subject. First participant shown quite good performance in all three control modules. His performance in all experiments were in between 98% to 99%, which is quite promising.

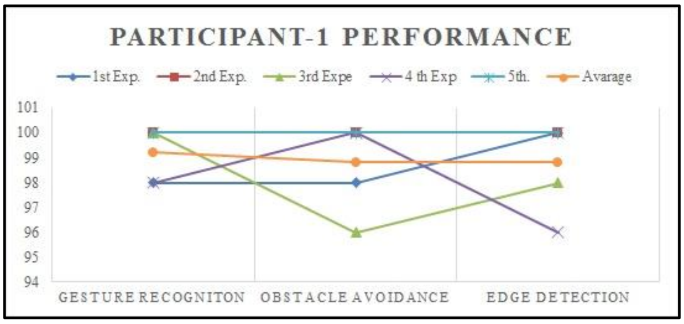


Fig 8a) Experimental performance- Participant 1

On the other hand second subject shown an accuracy of 98%, 98.8% and 99.2% in all three modules in the same order. This participant also shown consistent performance in all five experiments. Thus from these ten experiments and their consistent performance, it can be inferred that the designed system is performing quite well irrespective of the user. Both participant shown more than 98% accuracy with our designed system which is quite encouraging.

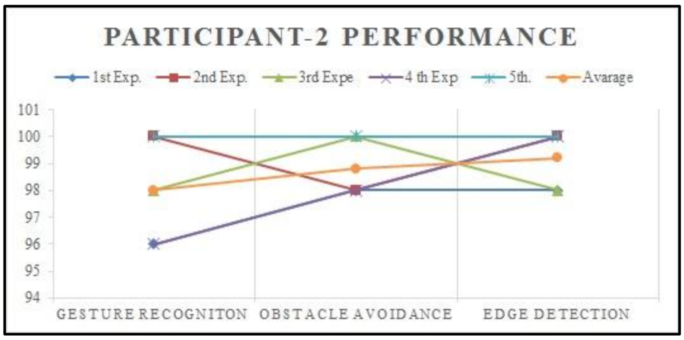


Fig. 8 b) Experimental performance- Participant 2

Range of communication for the employed wireless ZigBee module found to be well operable up to 60 meters in the indoor conditions. This facilitated the remote control of wheel chair rather than the constricted need of the person to be on the wheelchair the entire time to control it.The ability to avoid the obstacles is kept to a limit of 15 cm from the wheelchair. If obstacle is detected, the wheelchair turns in the other direction from the obstacle still it is completely avoided. It has been seen that the proximity sensors hold good for an angle maximum of 200-250.

Conclusion & Future scope

This study successfully demonstrated wireless motion control of an intelligent wheelchair using hand gesture recognition technology.The various gestures as outlined in Fig. 5 were tested and the outputs were studied to check if the right control codes were transmitted. The designed system was found to be very quick and responsive for gesture recognition and obstacle detection. Overall accuracy of the system is more than 98% for all three modules viz, gesture recognition, obstacle avoidance and age detection. Age detection and obstacle avoidance made it intelligent still a low cost affordable device. This wireless gesture based navigation technology provided an effective medium of locomotion for disabled. The system got positive feedback form the users.

As a part of further development, this assistive technology could be integrated with EEG or EOG interface mechanism, so that the wheelchair can be operated by brain signals of users, which will further improve its usability of ALS or tetraplegia patients. An autonomous navigation technology in indoor environment with fixed path can be implemented for ease of movement in familiar environment.An additional feature of mobile alert messaging system may be implemented in case of emergency with user.

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