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Simple Hand Gesture Controlled Wheelchair for Physically Impaired Person

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ABSTRACT Smart wheelchairs equipped with Brain-Computer Interfaces (BCIs) represent a significant technological advancement aimed at enhancing the mobility and independence of individuals with disabilities. In the present world, physically impaired people and elderly people who are in need of wheel chair are estimated to be over 100 million. Usually wheelchairs are driven manually by the help of another person or by self-propelling. So, the wheelchair are automated to reduce the complexities for those who don't have strength to move wheelchair by themselves. The automated wheelchairs which are currently available are joystick-controlled wheelchair. This project is to develop an automated wheelchair which can be controlled by hand movement. The proposed hand gesture-controlled wheelchair costs is cheaper methods. It employs IR sensor which controls wheelchair motion by detecting user's hand. By detecting the hand of the user, the system can move in specific directions (forward, backward, left, and right).

Keywords Wheelchair, IR sensors, obstacle detection

I. Introduction

INTRODUCTION:

In the present world for a good quality of life mobility is very important. Loss of mobility causes a severe damage to a person's life which leads to decrease in there self-confidence. Over 650 million people are disabled out of 7.7 billion people in the world according to the statistics about 10% of them require wheelchair. The project aims to significantly improve the mobility and independence of physically impaired individuals by creating a motorized wheelchair controlled through an electronic hand gesture recognition system. This system seeks to address several key challenges with current wheelchair designs, particularly the reliance on physical strength or the assistance of another person. Here's an in-depth look at the critical components, benefits, and potential development considerations for the project: enhanced mobility independence, ease to use, and reliability in various environments. But the present available joystick not afford it. And also people with severe disability like spinal cord injury (SCI), dystonia etc will not be able to operate the joystick wheelchair.

The aim of our project is to build a user friendly wheelchair which does not require much effort to operate .The idea is to design a wheelchair which can be controlled by a simple hand movements . The system does not require any connection with the hand for detecting the hand movement. Switching to an IR (infrared) sensor-based hand gesture recognition system offers several advantages, including cost-effectiveness, simplicity, and robustness in various lighting conditions. IR sensors which controls the motion of the wheelchair by detecting the hand of the user the system can move in specific directions i.e, forward, backward, left, right and stop. Wheelchair moves forward when the users hand moves towards first IR sensor .similarly wheelchair moves backward when the users hand moves towards second IR sensor, moves right when the users hand hand moves towards first IR sensor .similarly wheelchair moves backward when the users hand moves towards second IR sensor, moves right when the users hand moves towards third IR sensor, moves left when the users hand moves towards fourth sensor. And the wheelchair stops when all the sensors does not recognize any obstacle

So, main aim of the project is to reduce the cost powered wheelchair by including lower cost components ,making the design simpler by avoiding very complex programmable circuits which makes an efficient wheelchair for the physically impaired people .The available designs for gesture based wheelchair uses complex programming and raspberry pi, but our design employs an Arduino UNO which reduces the cost and complex programming and also we are employing IR sensor in place of accelerometer sensor to make the system less cost and robust.

2. LITERATURE SURVEY

LITERATURE SURVEY

In [1], a ADXL335 accelerometer has been placed at patient's fingertips due to its temperature stability and quantization error reduction properties. The proposed wheelchair was made efficient by avoiding the error margin and thus the response time has been made more impulsive. In [2], a low cost control device, gpaD which is a small case with an IR Sensor-Detector pair array, a microcontroller, power control circuit, power switch, and speed control knob, connector and battery charge indicator has been proposed. Even a minimum of 7° - 9° ulnar deviation and 7° - 9° radial deviation can be recognized by customizing the gPaD. In [3-7] a presence sensor for detection of obstacles, a light sensor for establishing the intensity of light and a bumper type digital sensor has been used. The Hu invariants were taken as discriminants due to their robustness under transformations like translations, rotations and scale changes. The algorithm developed here makes use of the Lab-View tool to present an optimal way of control machine vision. Wi-Fi dongle has been interfaced to raspberry-pi and remotely viewed through SSH via putty to achieve a semi-autonomous robot model in [8]. Motors have been directly interfaced to Raspberry-pi which reduces both the cost and circuit complexity. Phase-sensitive demodulation techniques have been used to determine the direction and magnitude of the accelerations in [9]. Information about the accelerometer tilt has been sent to ADC module. Corresponding signal for room automation has been transmitted through Zigbee modules and received through Zigbee receiver. In [10], the hand gestures captured by the MEMS 3 axes accelerometer has been recognized by three different models which are:

1) Sign sequence and Hopfield based gesture recognition model;

2) Velocity increment based gesture recognition model; and

3) Sign sequence and template matching based gesture recognition model. In these methods, the acceleration patterns have been segmented and recognized directly in time domain rather than transforming into frequency domain. The experimental results as provided in this paper states that model 3 has the highest accuracy rate of 95.6% while model 1 has the lowest accuracy rate of 50%. In [10], Feedforward Neural Network (FNN) classifier has been used for recognition of accelerometer-based input gestures. The most similar sequences have been identified using similarity matching (SM) algorithm. SM approach enhances the system's extendibility while FNN classifier provides better accuracy. Thus a combinational approach has been used in this paper. The accuracy rates of user independent and user dependent recognition has been found to be 98.88% and 99.88 %. Since the accelerometer sensors are very sensitive, a mean of N samples of sensory data have been used in data pre-processing algorithm in [11]. Gesture coding using probability distribution function has been used for converting the float mean value to integer value. A standard recognition library called the gesture database has been created using CHG technique. A gesture spotting process has been proposed to distinguish gestures from daily hand movements. The sensing system in [12] is a smart ring which consists of 3-axis MEMS accelerometer (MMA9555L, Free scale Semiconductor), a SoC (BCM20732S, Broadcom), a rechargeable battery, a vibrator and three LEDs. Here the complex gestures have been decomposed into a sequence of simple gestures for easy recognition. The computational cost of the proposed system is low since the data values of the hand gestures has been reduced to a gesture code of four binary digits. In [13], the hand gesture has been recognized by the accelerometer sensor and the analogy value is transmitted to the controller. And then the processed signal is transmitted to receiver side by the RF transmitter. The same transmitted data is received at the receiver by RF receiver. In [14], MEMS sensor has been used which has inbuilt I2C protocol. The speed of the system has been improved by the use of I2C protocol. [15], the whole paper has been divided into two parts, 1) Transmitter part – Accelerometer (ADXL 335), Arduino Uno, Encoder and RF transmitter, 2) Receiver part – RF receiver, Decoder, Motor driver IC(L293D), DC motor and wheels of wheelchair. In [16], flex sensor is attached to the gloves which is worn by the patients. A pulse sensor which is attached to the wheelchair is used to measure the heart beat range of the patients. This system especially measures the patient heart beat pulse and it indicates the directions for the patient to move on flat surface. In [17], the system has three functions which are done in parallel, the wheelchair movement based on voice command, the obstacle detection using ultrasonic sensor and the temperature sensing for patient monitoring. In [18], the system uses ZigBee Technology to transmit the given instructions. An accelerometer sensor detects the hand gesture and sends data to the microcontroller which processes the data and transmits the digital output to the ZigBee module at the transmitter section. The ZigBee module at the receiver section receives the transmitted signal which will then be processed by the microcontroller and controls the motors using motor driver circuit which helps in the movement of the wheelchair. [19], developed a wheel chair automated by both head and hand gestures. The head gestures are detected by connecting MEMS sensor and hand gestures are detected by touch pad. The user can change the operation of the wheel chair by switching the modes. In [20], AVR micro controller Atmega 328 circuit and direct current motor are used to control the movement of the wheel chair from the mobile application. The instructions given to the mobile applications are received through the Bluetooth module and processed for the movement of the wheel chair accordingly.

METHODOLOGY:

In our proposed work, each armrest consists of 2 infrared sensor and thus a total of 4 infrared sensors are utilized. When the user places his hand in front of the first sensor, the sensor detects the obstacle within the range and sends the output low. All the other sensors remain high. Similarly, when the user places his hand in front of the second, third and fourth sensors, the corresponding sensor goes low while the other sensors goes high [21-22].

In case of no gesture by the user all the sensors remain high. This output is given to the Arduino Uno board. L298N H-bridge motor driver is used to drive the two DC motors connected to two wheels of the wheelchair. The IN1, IN2, IN3, IN4 pins of the motor driver are connected to the digital pins of Arduino and the enable pins are given to the PWM pins of Arduino. The direction of the motor is controlled by sending a high or low signal to the driver for each motor. According to the output of the IR sensors, a 16*2 I^2C LCD display is interfaced with the Arduino to display the direction of motion. A 12V, 1.3AH battery is used to power the entire system as shown in Figure 1.

IR SENSORS:

The system uses IR sensors for detecting the hand movement. The infrared sensors are usually used as an obstacle detector .The basic concept of infrared sensor is to transmit an infrared signal. This signal reflects back to the infrared receiver, when it hit a surface of any object. A typical infrared detection system uses five basic elements which are infrared sensor, a transmission medium, optical component, infrared detectors or receivers and signal processing .Signal processing is done by amplifiers because the output of infrared sensors is very small.

Fig 2. IR sensor module

There are two types of infrared sensors: passive infrared sensors and active infrared sensors. Passive infrared sensors do not have any infrared source and detects energy emitted by the obstacle. Active infrared sensors consist of two elements infrared source and infrared detector. Infrared source consists of an LCD or infrared laser diode. Infrared detector consists of photodiode or photo transistor. The infrared source emits energy which hits to an object reflects back to the infrared detector The working principle of an IR sensor as an obstacle detector has been explained in the figure.

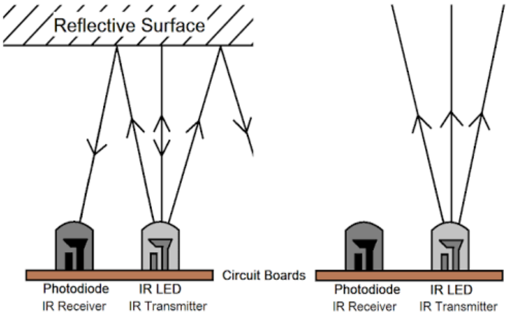


Fig 3. Working flow of IR sensor

CIRCUIT DIAGRAM:

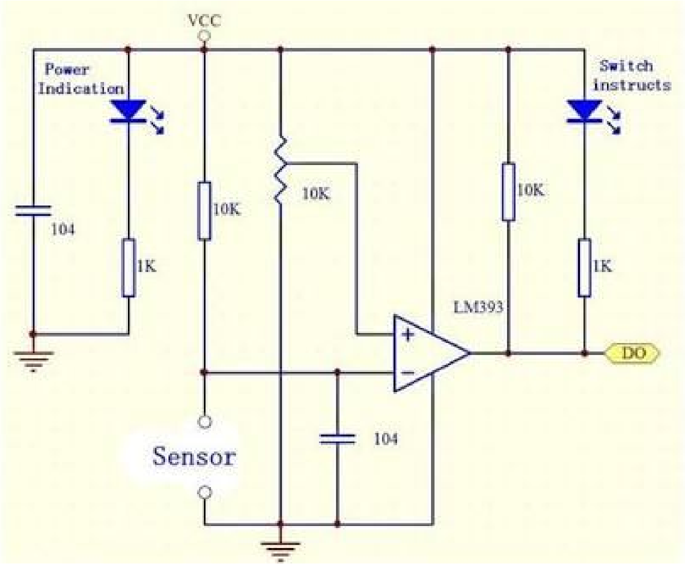


Fig 4. Circuit diagram of IR sensor

The circuit diagram consists of following components:

1. IC LM393 & 1R TX & RX pair
2. Resistor of the range kilo ohms
3. Variable resistor
4. LED

The IR sensor in the transmitter section transmits the IR rays which are received by the receiver in the IR receive module. Depending upon the receiving IR rays the output terminal of the receiver varies. The variations are not analyzed as such, therefore output will be fed to a comparator circuit. An operational amplifier of LM393 is used as comparator.

When the IR sensor does not receive any signal then the inverting input potential goes high and the output is low and LED is off. similarly when the IR sensor receives signal then the non-inverting terminal potential goes high and therefore output goes high and LED glows .The resistors used here make sure that LED receives minimum of 10MA power even when the sensors do not receive any signals. Variable resistors are used to adjust the sensitivity of the circuit.

Here we are using four IR sensors in order to move wheelchair in four directions. The IR sensors are placed at the either sides of the arm rests. Two IR sensors are placed at the right arm rest while the other two are placed at the left armrest. The conditions given to the IR sensors is shown in table 1.

Table 1. Logical conditional of the IR sensors in the system

	FORWARD	BACK WARD	RIGHT	LEFT	STOP
IR 1	LOW	HIGH	HIGH	HIGH	HIGH
IR 2	HIGH	LOW	HIGH	HIGH	HIGH
IR 3	HIGH	HIGH	LOW	HIGH	HIGH
IR 4	HIGH	HIGH	HIGH	LOW	HIGH

It has four screw terminal blocks for connecting the motors A and B – OUT1 and OUT 2 for VCC and GND of motor A and OUT 3 and OUT 4 for VCC and GND of motor B. The +12V and ground pins are used for powering the motor driver. The +5v pin can be used as input or output. Here we are using it to power the Arduino by enabling the on board 5v regulator using the jumper. The IN1, IN2, IN3 and IN4 pins of the motor driver are connected to the digital pins of the Arduino. These input pins control the switches of the H-bridge inside the L298N IC. An H-Bridge circuit consists of four switching elements, transistors or MOSFETS and the motor at the center forming the H-like configuration.

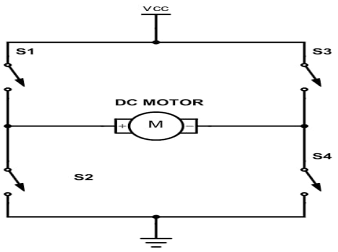


Fig 5. Internal circuit in L298N IC

By activating two particular switches at the same time, the direction of current flow is changed and thus there is a change in direction of motors. IN1 and IN2 control the motor A and IN3 and IN4 control the motor B. If IN1 and IN3 are high and IN2 and IN4 are low, both the motors move forward. If IN1 and IN3 are low and IN2 and IN4 are high both the motors move backward. If IN3 is high and IN1, IN2, IN4 are low motor B alone moves forward while the motor A remains stationary. As a result, the wheelchair turns left. If IN1 is high and IN2, IN3 and IN4 are low motor an alone moves forward while motor B remains stationary. As a result the wheelchair turns right. If IN1, IN2, IN3 and IN4 are low the motor stops rotating.

Table 2. Direction of wheelchair based on the four conditions

IN1	IN2	IN3	IN4	DIRECTION
0	0	0	0	Stop
1	0	1	0	Forward
0	1	0	1	Backward
0	0	1	0	Right
1	0	0	0	Left

The speed of the motor can be altered by changing the voltage given to the motors. This is possible the motor enable pins of the motor driver are fed by the PWM pins. The average voltage value which goes to an electronic device (in our case, the dc motor) by turning on and off the power at a fast rate can be adjusted by a technique called pulse width modulation. The average value depends on the proportion of time the signal is high compared to when it is low over a period of time. This is given by percentage duty cycle which specifically describes the percentage of time a signal is on over an interval of time.

The jumper pins at enable A and enable B pins are removed and the pins are connected to the PWM pins of the Arduino.

It is also important to note that L298nit has voltage drop of about 2% which is made by the IC. When a 12V power supply is given, the voltage at the motor terminals will be around 10V. Thus, a maximum speed cannot be obtained.

Fig 6. 12V 1.3 Ah sealed lead acid battery

In our project we used a 12V 1.3Ah sealed Lead acid battery. This battery has low self-discharging than compared to other common battery systems which goes as 2- 3% per month compared to 20 - 30% for others. The operating temperature range is between -15°C to +50°C when fully charged which is wide when compared to other systems. A special technique called Stealing technique is used to ensure that no electrolyte leakage is there in the terminals. This provides safe and efficient operation of the battery at all orientations. The battery also utilizes a glass fiber separator material which is available in an electrolyte suspension material. The maximum service life can be achieved by using the suspension material which helps to retain the electrolyte and preventing it from escaping from the separating material. Since they are valve regulated, maintenance free, leak proof and there is no loss in power output over the battery life, these lead acid batteries are preferred.

FUZZY LOGIC:

Here, we are using fuzzy programming which gives fuzzy-implementations of conditional statements. Usually, Fuzzy rules are formed in the form of

'IF *fuzzy condition* THEN *result*'

Where fuzziness of the condition gives the result. Generalized standard control statements in programming languages which includes *if-then-else* conditional statements and *while* repetition statements. The Boolean conditions only evaluates either the condition is true or false and the corresponding body is executed respectively. For example, if IR Sensor1 is receiving an input then move forward or else go to the next condition and check if next sensor is receiving and this execution continues according to the program. The overall fuzzy flow is explained in the flowchart given below.

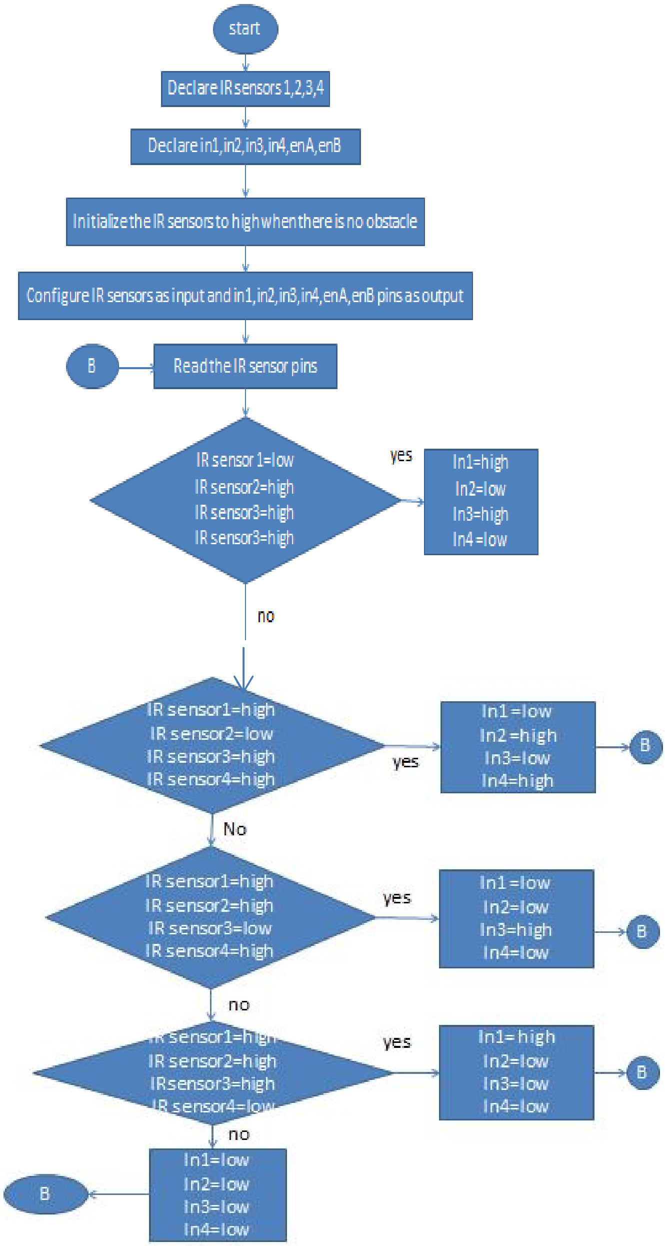
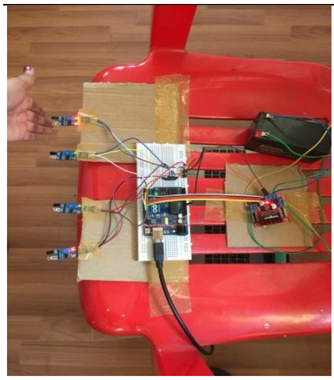


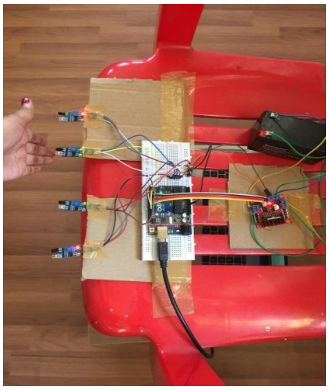
Fig 7. Fuzzy logic work flow in the wheelchair system

RESULT:

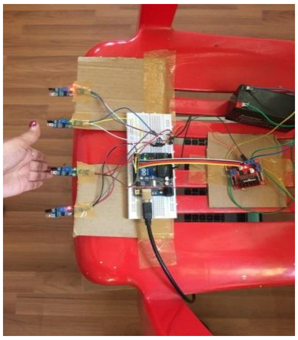
Input hand gestures:



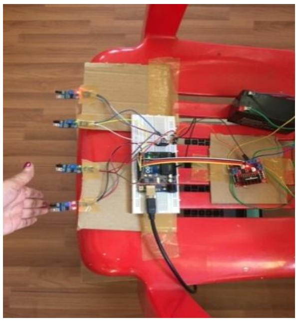
Forward



Backward

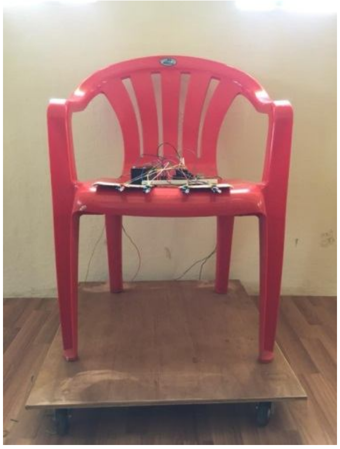


Right



Left

Final output:



Recognition time:

The response time of the system to the user's input have been calculated and tabulated below:

S.No	Forward	Backward	Right	Left
1	21ms	16ms	52ms	21ms
2	20ms	16ms	50ms	21ms
3	27ms	16ms	34ms	22ms
4	18ms	17ms	21ms	37ms
5	20ms	18ms	24ms	30ms
6	17ms	16ms	21ms	44ms
7	19ms	15ms	23ms	19ms
8	20ms	17ms	55ms	33ms
9	18ms	16ms	48ms	28ms
10	21ms	18ms	20ms	24ms
Average	20.1ms	16.5ms	34.8ms	27.9ms

The average time the system takes to recognize and respond to the forward, backward, right and left commands have been found to be 20.1ms, 16.5ms, 34.8ms and 27.9ms respectively.

CONCLUSION:

Building a low cost and easily controlled wheelchair contributes a lot to the increasing demand of wheelchairs every day. The uniqueness of this project is the use of IR sensors which reduced the complexity and cost. The proposed system makes use of just the user's fingers and thus it requires minimal effort than joystick based and gesture-based wheelchairs.

FUTURE SCOPE:

Since we built a prototype of the proposed model, two 12V, 150rpm motors were enough. Higher power motors can be employed in the future in order to implement the same concept in a real wheelchair. An ultrasonic sensor can also be included for detecting obstacle on the way. Speed control can also be made possible by connecting a potentiometer to the circuit. If a GPRS system is included to the wheelchair, the movement and location of the patient using the wheelchair can be tracked by their family members.

REFERENCE:

[1] Yash M. Jain ; Saurabh S. Labde ;Dr. Sunil Karamchandani , "Gesture Controlled Wheelchair for Quadriplegic Children ", The 2016 3rd International Conference on Systems and Informatics (ICSAI 2016), Pages:121-125

[2] Rajesh Kannan Megalingam ; Venkat Rangan ; Sujin Krishnan ; Athul Balan Edichery Alinkeezhil , "IR Sensor-Based Gesture Control Wheelchair for Stroke and SCI Patients ", IEEE Sensors Journal (Volume: 16 , Issue: 17 , Sept.1, 2016), Pages: 6755 – 6765

[3] A. Turnip, D.E. Kusumandari, G.W.G. Arson, D. Setiadikarunia, Electric wheelchair controlled-based EMG with backpropagation neural network classifier, in Cyber Physical, Computer and Automation System. Advances in Intelligent Systems and Computing, vol. 1291, ed. by E. Joelianto, A. Turnip, A. Widyotriatmo (Springer, Singapore, 2021). http://doi.org/10. 1007/978-981-33-4062-6_13

[4] J. Vigliotta, J. Cipleu, A. Mikell, R. Alba-Flores, EMG controlled electric wheelchair, in Intel-ligent Systems and Applications. IntelliSys 2021. Lecture Notes in Networks and Systems, vol. 296, ed. by K. Arai (Springer, Cham, 2021). http://doi.org/10.1007/978-3-030-82199-9_29

[5] R. Posada-Gomez ; L. H. Sanchez-Medel ; G. Alor Hernandez ; A. Martinez-Sibaja ; A. Aguilar-Laserre ; L. Leija-Salas, "A Hands Gesture System Of Control For An Intelligent Wheelchair", 2007 4th International Conference on Electrical and Electronics Engineering, Pages: 68 – 71

[6] K. J. Ritu *et al.*, "SelfBOT: An Automated Wheel-Chair Control Using Facial Gestures Only," *2023 26th International Conference on Computer and Information Technology (ICCIT)*, Cox's Bazar, Bangladesh, 2023, pp. 1-6, doi: 10.1109/ICCIT60459.2023.10441531

[7] S. Chatzidimitriadis, S. M. Bafti and K. Sirlantzis, "Non-Intrusive Head Movement Control for Powered Wheelchairs: A Vision-Based Approach," in *IEEE Access*, vol. 11, pp. 65663-65674, 2023, doi: 10.1109/ACCESS.2023.3275529

[8] Smitha Paulose; M.P.Fathima Anooda; Geethu Mohan; M.S.Sajana4 K.A.Anupama, "Automatic Wheelchair using Gesture Recognition Along with Room Automation", Transactions on Engineering and Sciences , Vol. 2, Issue 5, May 2014

[9] Ruize Xu, Shengli Zhou, and Wen J. Li, "MEMS Accelerometer Based Nonspecific-User Hand Gesture Recognition", IEEE SENSORS JOURNAL, VOL. 12, NO. 5, MAY 2012

[10] Renqiang Xie; Juncheng Cao, "Accelerometer-Based Hand Gesture Recognition by Neural Network and Similarity Matching", IEEE SENSORS JOURNAL, VOL. 16, NO. 11, JUNE 1, 2016

[11] Hari Prabhat Gupta; Haresh S. Chudgar; Siddhartha Mukherjee; Tanima Dutta; Kulwant Sharma, "A Continuous Hand Gestures Recognition Technique for Human-Machine Interaction Using Accelerometer and Gyroscope Sensors", IEEE SENSORS JOURNAL, VOL. 16, NO. 16, AUGUST 15, 2016

[12] Renqiang Xie; Xia Sun; Xiang Xia; Juncheng Cao, "Similarity Matching-Based Extensible Hand Gesture Recognition", IEEE SENSORS JOURNAL, VOL. 15, NO. 6, JUNE 2015

[13]Abhirami B,Anupriya S R,Divyarani R,Nagaraju V, "ACCELEROMETER BASED HAND GESTURE CONTROLLED WHEELCHAIR",International Journal of Technical Research and Applications,Volume 4,Issue 4,(July-Aug 2016),Pages 188-192

[14]Diksha Goyal and Dr.S.P.S.Saini, "ACCELEROMETER BASED HAND GESTURE CONTROLLED WHEELCHAIR".International Journal on Emerging Technologies 4(2):15-20(2013)

[15]Mohite Nita Baburao,Kachare Ashwini Vitthal,Lengare Pankaj Shahaji, "A REVIEW ON AUTOMATIC WHEELCHAIR CONTROL USING HAND GESTURE",International Journal of

Electronics,Electrical and Computational System(IJEECS),Volume 6,Issue 11,November 2017,Pages 1-5

[16]Yuvaraju.M,Priyanka R, "FLEX SENSOR BASED GESTURE CONTROL WHEELCHAIR FOR STROKE AND SCI PATIENTS",International Journal of Engineering Sciences and Research Technology,May 2017,Pages 543-549

[17]Pooja Raj,Neetu Skariya,Anikha Babu,Reshma Jacob,Neetu Jo Vavachan, "IMPLEMENTATION OF A MULTIFUNCTIONAL SMART WHEELCHAIR", International Journal of Engineering Research and Development,Volume 13,Issue 4(April 2017),Pages 103-106

[18]Sushree Swayamsiddha,Arunava Banerjee,Joy Chowdhury, "ADAPTIVE HAND GESTURE CONTROLLED WIRELESS WHEELCHAIR USING ZIGBEE PROTOCOL",International Journal of Science and Research(IJSR), 2013

[19] D.Sharath Babu Rao, T.Anusha, "Gesture Controlled Wheelchair", International Journal Of Science,Engineering and Technology Research(IJSETR), Volume 4,Issue 8,August 2015

[20] Shardul S.Kulkarni, Atul B.Dhembare, Pratik D.Deshmukh, Vishranti M.Marathe, Mayur U.Yelpale, Pragtee B.Tathe, "Home Automation By Smart Wheelchair for the Physically Handicapped Person Using Arduino", International Journal Of Advance Research ,Ideas And Innovations In Technology, Volume 4, Issue 2,2018, Pages 1403-1407

[21] G. S. Amarnadh Satvic Reddy, P. Akki, B. N. Deepak, B. M and A. K. Gujjala, "Breaking Barriers: Hand Gesture Recognition for Paralysis Rehabilitation with Voice Enhanced Support," 2024 2nd International Conference on Networking and Communications *(ICNWC)*, Chennai, India, 2024, pp. 1-6, doi: 10.1109/ICNWC60771.2024.10537492.

[22] Z. Lu *et al.*, "A Wearable Human–Machine Interactive Instrument for Controlling a Wheelchair Robotic Arm System," in *IEEE Transactions on Instrumentation and Measurement*, vol. 73, pp. 1-15, 2024, Art no. 4005315, doi: 10.1109/TIM.2024.3376685.