Gesture Controlled Wheel Chair using IR-LED TSOP Pairs along with Collision Avoidance

Rajesh Kannan Megalingam
Dept. of Electronics and Communication Engineering
Amrita School of Engineering, Amritapuri,
Amrita Vishwa Vidyapeetham, Amrita University,
India
rajeshkannan@ieee.org

Clarion Chacko, Binu P Kumar, Ashwin G Jacob, Gautham P
Dept. of Electronics and Communication Engineering
Amrita School of Engineering, Amritapuri,
Amrita Vishwa Vidyapeetham, Amrita University, India
clarionputhette@gmail.com, binupkumar@gmail.com, aswin_g_jacob@yahoo.com, gauthamp666@gmail.com

Abstract— **In this era of fast growing Medical and Health facilities, there are still a large number of people who are finding it difficult for day to day locomotion. Evidently a Wheel chair is the best option that will help them to a great extent. Our goal is to help physically disabled people who are impaired with diseases which affect their day to day navigation. Driving a wheelchair in domestic environments is a difficult task even for a normal person and becomes even more difficult for people with arms or hands impairments. The use of powered wheelchairs with high navigational intelligence is one of the great steps towards the integration of severely physically disabled and mentally handicapped people. We propose a system that will solve the difficulties faced by these individuals using an innovative navigation system. The powered wheel chair is a great technological achievement which may prove to be a boon in the lives of physically challenged and mentally handicapped people. Although there are existing technologies, people experience significant difficulties for their day to day locomotion. None of them served to be customizable, economical and user friendly all at the same time. So with this problem of concern, we developed an electrically powered wheel chair that is customizable, economical and at the same time user friendly. The proposed system uses IR-LED - TSOP pair of sensors arranged in a specific pattern that are used to sense the gesture. The control signals generated are fed to the microcontroller which will drive the motors of the wheelchair. This systematic arrangement detects the hand gestures made by the user and interprets the direction of movement of the wheelchair and moves accordingly. The whole arrangement provides an effortless, convenient, quick and smooth navigation experiences. The hard ware implementation of this projected wheel chair consists of wheel chair, an ATmega microcontroller ,Ultrasonic Sensor, Hercules power driver system and finally the gesture recognition module made up of IR-LEDTSOP pair technology. We have also calculated the response of the system under various conditions which is detailed in the paper.**

Keywords — Powered Wheelchair, Microcontroller

I. INTRODUCTION

In today's world, with the advancements of science and technology and related medical fields, the number of elders has significantly increased. An estimated 7% of the world's population needs a wheelchair. An increased percentage of elderly and disabled people who want to enhance their personal mobility, for them wheelchair is the best assistive device. We developed a system which can aid these elderly and physically disabled individuals in their indoor locomotion. A motorized wheelchair, powerchair, electric wheelchair or electric powered wheelchair (EPW) is a wheelchair that is propelled by means of an electric motor rather than manual power. Motorized wheelchairs are useful for those unable to propel a manual wheelchair or who may need to use a wheelchair for distances or over terrain which would be fatiguing in a manual wheelchair. They may also be used not just by people with traditional mobility impairments, but also by people with cardiovascular and fatigue based conditions. An important aspect of a successful robotic system is the Human-Machine interaction. In the early years the only way to communicate with a robot was to program which required extensive work. With the development in science and robotics, gesture based recognition came into life. Gestures originate from any bodily motion or state but commonly originate from the face or hand. Gesture recognition can be considered as a way for computer to understand human body language. This has minimized need for text interfaces and GUIs(GRAPHIC USER INTERFACE).Our objective is to develop a cost efficient ,Gesture Controlled Wheel-chair navigation System working on a single PCB board which can be used to help the unfortunate elderly and physically challenged people to move with the help of an easy navigation system.

II. MOTIVATION

The existing technologies are not comfortable enough that they had to put at least a significant amount of force in order to operate the wheelchair. And also they are not customizable for different degree of disabilities and at the same time it is very costly. Present technologies like Joystick-controlled, key board-controlled systems are not sufficiently customizable to deal with different degrees of disability. In order to trigger these systems the user needs to apply a significant amount of force. Aiming to fix these defects, we arrived at a user friendly, fully-customizable gesture-recognition-based wheelchair control system, which is built in the most simple and economical way possible. We aim to develop a system that can benefit the elderly and the physically challenged people for their day to

978-1-5090-5203-5/16/ $31.00 ©2016 IEEE

day navigation. In short-term the seated wheelchair user is to rest his hand on a smooth, frictionless surface, which has the means for catching a gesture of the hand, and control the movements of his/her wheelchair with small, pre-defined motions. The system will be effective in reducing the physical effort the user has to apply for locomotion.

.

III. AVAILABLE SOLUTIONS AND SHORTCOMINGS

The current solutions as far as aids for locomotion are concerned, are custom-fitted motorized wheelchairs that have a variety of control systems based on the degree of disabilities being addressed. The most common among these are mouth stick based control, keypad-based control, and joystick-based control and brain actuated wheelchair controls. Other methods such as direct-neural control, pupil-tracking control, head movement-based control and tongue-based control are sometimes used in severe cases of paralysis. The main shortcomings of the above systems are that they are far too expensive and suitable only for niche use. The latest rehabilitation products available in the market nowadays such as DX-RJM-VIC-CCD finger steering control of Dynamics are solutions available wherein the user can control the motorized wheelchair using finger movements. But such systems also can be used only with one finger movement, whereas our system can be used for customizing by the users hand, fingers or even leg. The inexpensive wheelchairs available in market are not motorized and require the help of an external person for movements. This is a huge hurdle for the large majority of physically challenged and elderly people to overcome. They can exert precious little force, which may only be sufficient to just move their limbs alone. They find such solutions extremely difficult to use - movements such as pressing buttons or controlling a joystick are impossible for these people, who lack fine motor control.

IV. OUR PROPOSED SOLUTION

Define The elderly and the physically challenged often retain some imprecise motion of their fingers, though they may find it difficult to exert any sort of force or leverage. Therefore, one of the best option is a gesture-based interaction with their environment, in particular their wheelchairs.

Fig 1:Wheel Chair

.We developed a gesture pad by using IR-led and TSOP sensor pairs, where it detects certain fixed gestures and the motors for the wheelchair are driven accordingly to the desired location. We have tested this on a real time wheelchair by using Atmega microcontroller as its core.

V. THE SYSTEM AND ITS COMPONENTS

Figure 1 shows the picture of the wheelchair designed with the gesture pad at the right hand side.

A. The Wheelchair

The wheelchair is designed in such a manner that motors which are cylindrical in shape are fixed next to the main wheels. Gesture Pad along with the motor drivers is fixed on one of the hands of wheelchair for easy to use purpose. An Ultrasonic sensor is fixed on the front side of gesture pad for obstacle detection. There are also 24 V, 26 Ah batteries that are kept under the wheelchair for powering up the motor drivers and for successfully running the motors.

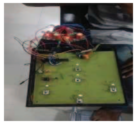


Fig 2: Gesture pad

B. Gesture Pad

Figure 2 shows the gesture pad in the wheelchair. The system consists of IR-Led-TSOP sensor pairs arranged in a particular pattern with microcontroller that has been programmed using Arduino IDE. It also includes a 555 timer circuit to produce 38 Khz frequency signal to modulate IRLED. Atmega 328 microcontroller is interfaced in the board instead of using arduino board as a whole.

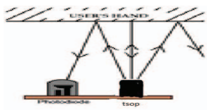


Fig 3: IR-led TSOP Pairs

C. TSOP-IR-LED pairs

IR LED means an Infrared Light Emitting Diode. The IR LED emits IR light up to some range which gets reflected if any hindrance is present in the direction of emitted IR ray; the reflected IR ray will be caught by the TSOP which indicates the detected state. The TSOP 1738 is a member of IR remote control receiver series. The output of TSOP is active low and it gives +5V in off state. When IR waves, from a source, with a centre frequency of 38 kHz incident on it, its output goes low. Figure 3 shows the pictorial representation of the system mentioned above.

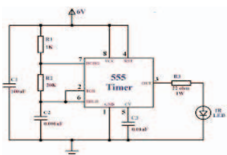


Fig 4:555 Timer Circuit

D. 555 timer circuit

The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. In the above circuit, 555 Timer is wired as an Astable Multivibrator. The 100F capacitor (C1) is used to reduce ripples in the power supply. 1st and 8th pins of 555 are used to give power Vcc and GND respectively. 4th pin is the reset pin which is active low input, hence it is connected to Vcc. 5th pin is the Control Voltage pin which is not used in this application, and hence it is grounded via a capacitor to avoid high frequency noises through that pin. Capacitor C2, Resistors R1, R2 determines the time period of oscillation. Capacitor C2 charges to Vcc via resistors R1 and R2. It discharges through Resistor R2 and 7th pin of 555. The voltage across capacitor C2 is connected to the internal comparators via 2nd and 6th pins of 555. Output is taken from the 3rd pin of the IC. Charging time constant of the capacitor (output HIGH period) is determined by the expression 0.693(R1+R2)C2 and discharging time constant (output LOW period) is determined by 0.693R2C2. They are approximately equal. Figure 4 shows the circuit for the generation of 38Khz using 555 timer. For receiving signals send by the transmitter you need only TSOP1738. Connect 5V to Vs and Ground to GND pin of TSOP1738. The output will be active low. Output of TSOP1738 will be HIGH when no signals fall on it and the output will be LOW when 38KHz infrared rays fall on it.

E. Atmega Microcontroller

The microcontroller is the heart of the system. It is to the microcontroller that all the different components of the system are interfaced. The microcontroller is programmed using Arduino Development platform. It has several I/O pins which receive signals from the Gesture module that are connected to the microcontroller. The microcontroller is encoded with a particular logic so as to work according to the gestures generated by the gesture Module and generate control signals to the motors of the Wheelchair. Along with the gesture capture module ATMEGA328 microcontroller is interfaced. The microcontroller is programmed using Arduino IDE. The ATmega328 has 32 KB memory (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM. There are 14 digital pins and 6 analog pins. Out of the 14 digital pins, 6 can be used as PWM pins for motor control applications. It can transmit and receive TTL serial data. It also has SPI and I2C interfaces. ATMEGA328P microcontroller is having 3 registers namely port B, port C and port D. Each port is controlled by three registers. PORTB maps to digital pins 8 to 13. PORTC maps to analog pins A0 to A5. PORTD maps digital pins 0 to 7. The microcontroller will read the sensor pairs in the Gesture capture Module. Based on the received signals the microcontroller will determine the gesture and it will call for the matching function viz. Forward, reverse, Left, Right and brake. These functions will drive signals to the motor driver unit that moves the motors of the wheelchair.

F. Potentiometer

The value of potentiometer is read through analogRead() command and the value is proportionately converted to a digital value which serves as the limiting speed of the motor, this is achieved by writing this digital value into PWM pin which controls the motors.

Fig 5: Ultrasonic Sensor

G. Ultrasonic Sensor

The ultrasonic sensor in Figure 5 is used for obstacle detection. Ultrasonic sensor transmits the ultrasonic waves from its sensor head and again receives the ultrasonic waves reflected from an object. Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The module includes an ultrasonic transmitter, a receiver and a control circuit.

H. Hercules Motor Driver

Hercules 6V-36V, 16Amp Motor Driver can take up to 30A peak current load and can be operated up to 3 KHz PWM. Motor driver can be interfaced with 3.3V and 5V logic levels. Motor driver has built-in protection from under / over voltage, over temperature and short. The Motor driver has terminal block as power connector and 7 pin 2510 type relimate connector for the logic connection. The motor drivers used in the gesture pad can be seen in the Figure 2.

Fig 6: Motors

I. Motors

The motors being used are Motion Tech DC gearbox motors shown in Figure 6 that operate in 24 V. A PWM frequency of less than 40 KHz should be applied to drive the motors. Each of the motors are connected to OUTA and OUTB pins of the corresponding motor driver.

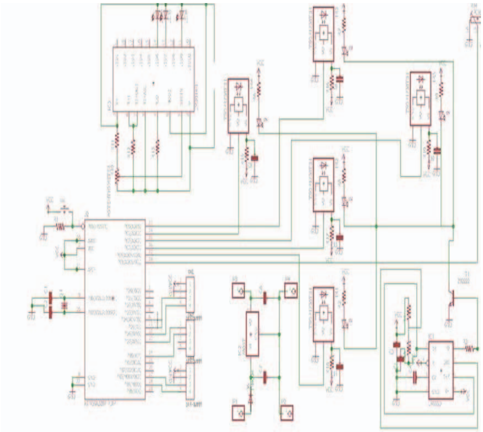


Fig 7: Eagle Cad Schematic Diagram

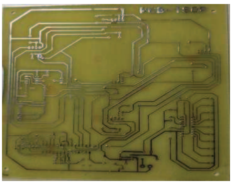


Fig 8: PCB Board

J. Eagle Cad and PCB Fabrication

EAGLE stands for Easily Applicable Graphical Layout Editor is Computer aided software design developed by Cad soft. It is a flexible, expandable and scriptable EDA (electronic design automation) application with schematic capture editor, PCB layout editor, and auto-router. It has a Flexible User Language Programs (ULPs) that enables custom features, such as individual instruction sequences, simulation, data export and import etc. The eagle cad layout of the gesture pad is given in the Figure 7. With the introduction of laser printers it becomes easy making PCBs (Printed Circuit Boards). Regardless of the method that is being used, the idea of making PCBs is to have a copper clad board and turn it into a printed circuit. A Laser printer will transfer the design to the board as a etch resist coating. An etchant will be used to remove where there is no resist, then the left resist coated traces and the that are cleaned will make the board ready for drilling and use. The PCB board designed for the gesture pad is shown in figure 8.

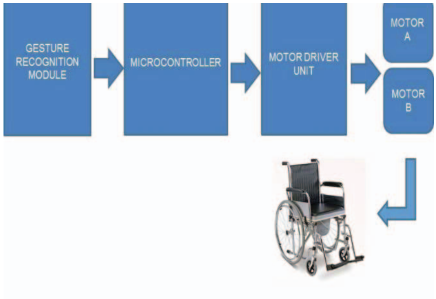
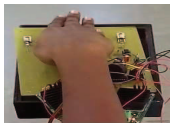


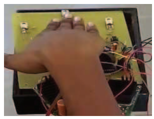
Fig 9: System Overview

VI. SYSTEM DESCRIPTION

Overall functioning of the wheelchair is given in the figure 9.

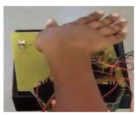


(a) Forward



(b) Reverse

(c) Left

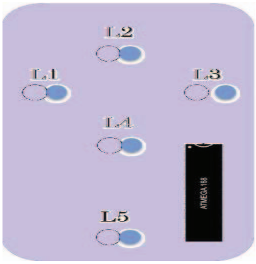


(d) Right

Fig 10: Gestures

A. Gesture Recognition Module

The gesture recognition module consists of 5 pairs of IRLED and TSOP sensors arranged in a specific pattern. When the system is in use, the gestures are being identified based on the variation in the output of each TSOP sensors. The IR-LED transmits a 38 Khz signal which is detected by tsop sensors, will be sent for recognition to the microcontroller. The function for the motion is defined according to certain combination of sensor pairs. For the recognition of the each gesture, the user has to place the hand or even the leg over the platform where the sensor pairs are arranged to make the gesture that is predefined for the motions viz, Left, Right, Forward, Reverse. Figure 11 explains about the gesture pad consisting of the sensor pairs and the microcontroller. The figure 10 depicts the gestures that will affect the motion of the wheelchair.



(a) Gesture pad Blue Print

L1	L2	L3	L4	L5	GESTURE
	✓		✓	✓	Forward
✓			✓	✓	Left
		✓	✓	✓	Right
			✓	✓	Reverse

(b) Gesture identifier Table

Fig 11: Gestures

B. Obstacle Detection Module

The ultrasonic sensor is used for obstacle detection. Ultrasonic sensor transmits the ultrasonic waves from its sensor head and again receives the ultrasonic waves reflected from an object. Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The ultrasonic sensor emits the short and high frequency signal. These propagate in the air at the velocity of sound. If they hit any object, then they reflect back echo signal to the sensor. The ultrasonic sensor actually consists of two parts; the emitter which produces a 40 kHz sound wave and detector detects 40 kHz sound wave and sends electrical signal back to the microcontroller. Its working principle is depicted in the figure 12.The ultrasonic sensor enables the chair to virtually see and recognize object, avoid obstacles, measure distance. The basic principle of work: (1) Using IO trigger for at least 10us high level signal. (2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back. (3) IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning. Test distance = (high level time velocity of sound (340M/S) / 2. In our design if an obstacle is detected within 15cm in front of the wheelchair, it applies a brake to avoid further movement and the chance of possible collision with an object.

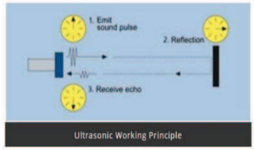


Fig 12: Ultrasonic Working Principle

C. Interfacing Module

The interfacing module refers to the interface between gesture recognition module and the motors of the wheelchair. The Arduino based microcontroller is designed in the gesture pad and is used to drive the wheelchair motors through motor drivers. Microcontroller can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The values from the TSOP receiver is fed into the analog pins of the microcontroller. The microcontroller detects these values and control motors through drivers by using direction pins and PWM pins of motor drivers. We used Atmega328P microcontroller and is integrated into the board by using a 16 MHz crystal oscillator, 2 22pf capacitors and a reset button. The microcontroller is powered from 12v to 5v converter circuit from the 12v battery which powers the wheelchair.

D. Motor Control Module

This module is used to control the motors of the real time wheelchair. Two motors connected to the rear wheels of the wheelchair have to be controlled to define its motion. We have used Motion Tech DC gearbox motors for the movements of the wheelchair. These motors can be controlled using Pulse Width Modulation (PWM) techniques that can be generated using the Arduino microcontroller. The power wheelchair can be directionally controlled using suitable motor driver. We have used a motor driver in between the Arduino board and these motors. We used Hercules 6V - 36 V, 16 A motor drivers to control the motors. These motor drivers can take up to 30A peak current load and can be operated up to 3 KHz PWM. It also gives out false diagnostic outputs and pre settable overload protection limit. The direction of the movement can be controlled using separate pins on the motor driver which is used for this specific purpose. Hence the wheelchair can also be made to move in the reverse direction with the help of these direction pins on the motor driver. The various commands with values that are written to the microcontroller on the Arduino board such as analogWrite(0) for 0% duty cycle, analogWrite(127) for 50% duty cycle etc. to generate the desired PWM outputs. This PWM pin in the motor driver is used to control the speed of the motor. The maximum value that can be written is 255 as the microcontroller used has only 8 bit digital output data.

VII. CHARACTERISTIC BEHAVIOUR AND PARAMETERS

One would expect that as soon as a valid gesture is performed above the gesture pad, the gesture recognition module would immediately recognize it and the wheels of the wheelchair would instantly turn in the expected direction, or not at all for an invalid gesture. However, this is only the ideal case. There are some deviations in the real case. Those are discussed below:

A. Deviation

There are several factors that can cause deviations from the expected behaviour. The accuracy of gesture detection is governed by some external factors, despite our best efforts to make the gesture module insensitive to these. Unnecessary movements above the gesture pad either by users hand or with any external objects may cause the wheelchair to move. So a user has to make sure that, top of the gesture pad is not distracted by any means and has to be switched off if not in use.

Speed Levels	High(s)	Medium(s)	Low(s)
1	6.2	9.1	13.4
2	6.5	9.3	13.5
3	6.6	9.3	13.7
4	6.3	9.2	13.5
5	6.4	9.3	13.5
6	6.4	9.1	13.4
7	6.2	9.4	13.3
8	6.3	9.3	13.4
9	6.2	9.2	13.5
10	6.4	9.2	13.2
Average	6.35	9.24	13.44
Speed	3.40Km/h	2.34Km/h	1.60Km/h

TABLE I: Speed Test

Gesture Change	Response Time(s)
Forward	0.3
Left	0.3
Right	0.4
Reverse	0.4

TABLE II: Response Measurement

B. Jerk Avoidance

The control signals which include PWM and direction signals are given by Arduino board to Hercules motor driver. The Hercules motor driver acts as a switch between the input 5 volt signals and required 24 volt output signals. The wheelchair moves at a considerably good speed when it is given 15 volts. Thus to prevent the jerk or a sudden unwanted vibration when the wheelchair starts or stops, the required 15 volts is reached by incrementing PWM duty cycle in linear steps. Even then, there were jerks when the wheelchair had to move from one direction to another, say from right to left. This was solved by making the wheelchair to have an intermediate state of brake before transition from one direction to another. Thus whenever there is a sudden change in the direction, the wheelchair slows down and gains the required amount of speed in expected direction. Thus the problem of jerk was reduced considerably.

VIII. THE EXPERIMENTS AND ITS RESULTS

We conducted various experiments to determine the response time, speed and to check the success rate of gesture recognition by the user with the gesture pad of the wheelchair. Considering the speed test of the wheelchair, it has 3 different levels of speed termed High, Medium and Low. We can run the wheelchair on either of these 3 modes. We tested the time taken by the wheelchair to complete a certain distance and calculated the speed of the wheelchair in these 3 modes. Its values are depicted in the Table I. Referring to the table we can find that wheelchair can move at 3.40Km/h, 2.34Km/h, 1.60Km/h w.r.t High, Medium and Low level respectively. We restricted the maximum speed to 3.40 Km/h by giving prioritize to the safety of the user. Table II, denotes the response time for various gesture changes. It shows how well the system responds to the gesture made by the user. Its measurement is taken by taking initial point as wheelchair at rest. As we know it's very important to note the success rate of gesture recognition by the gesture pad, we were very successful that it gave 100% success rate in this area, and it can be referred in Table III. Every time the gesture pad successfully recognized the gesture made by the user.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Forward	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reverse	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Right	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Left	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Fig 13: Table III

IX. CONCLUSION

This paper discusses on development of Gesture Based Wheelchair - effortless to use, customizable, economical, highly convenient and non-intrusive gesture-based wheelchair control system for elderly and physically challenged. These individuals can make use of small gestures of their hands or feet in order to control the motion of their wheelchairs. Four modules are serially connected in order to achieve this Gesture Capture Module, Gesture Recognition Module, Interfacing Module and Motor Control Module. Nowadays the electronic wheelchairs are mainly controlled by using joysticks or keypads. But this gesture based system is economical, effortless to use and user friendly when compared with the existing systems. Thus our system will definitely help all the misfortunate physically challenged and elderly people. This wheelchair can be used by a physically challenged or a handicapped person who require external aid for their day to day locomotion. By the use of our wheelchair, they no longer require external aid for their movements inside their house or surroundings.

ACKNOWLEDGMENT

The authors wish to thank Amrita Vishwa Vidyapeetham University, Amritapuri, India for their infrastructure support and lab facilities which was essential to successfully complete our work.

REFERENCES

[1] L. Montesano, J. Minguez, M. Diaz, and S. Bhaskar, "Towards an Intelligent Wheelchair System for Cerebral Palsy Subjects."

[2] L. Montesano, J. Minguez, M. Diaz, and S. Bhaskar, "Lessons learned in integration for sensor-based robot navigation systems"; International Journal of Advanced Robotic Systems, vol. 3, no. 1, pp. 8591, 2006.

[3] J. Minguez and L. Montano, "Nearness Diagram (ND) Navigation: Collision Avoidance in Troublesome Scenarios"; IEEE Transactions on Robotics and Automation, vol. 20, no. 1, pp. 4559, 2004.

[4] Richard C. Simpson, Simon P. Levine, David A. Bell, Lincoln A. Jaros, Yoram Koren, and Johann Borenstein, "NavChair: An Assistive Wheelchair Navigation System with Automatic Adaptation."

[5] J. Min, K. Lee, S. Lim and D. Kwon, "Human-Friendly Interfaces of Wheelchair Robotic System for Handicapped Persons" ,Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems, vol.2, pp.1505-1510, 2002.