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Advances in Smart Touch based Wheelchair Technology

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Abstract: *In the technologically developing world patients with some intellectual disabilities and impairment must be provided with smart wheelchair systems for their easy exploration and safety. This paper will describe the wheelchair technology system with a user-friendly touch screen interface. this interface allows the disabled person to have automatic advancement to the indoor or outdoor network their destination via preordained paths. Implementation of touch-screen body movement and less muscle strain that we have in all world (wheelchairs which are used from ages). The capability of the between manual operation mode and predefined operation mode uniquely present capacity of the wheelchair in multiple environments operate. Obstacle avoidance facility enables to drive safely in the unknown as well as dynamic environments keeping in mind this we determined to design a touch-screen powered wheelchair which is more accessible technology thatruns on the dual touch screen and less force is need for operation i.e. single finger is operating a wheelchair as touchscreen technology is acquiring highest peak as commercial developing goods.*

Key Word: *Wheelchair technology, touch-based wheelchair, user-friendly technology.*

I.INTRODUCTION

With the rise of the ageing and the immobilized people, a variety of support programs and newly built equipment were developed to help improve their quality of life. Many of the patients who are unable to use their arms in the wheelchair due to lack of force face major issues such as acclimatization, mobility, and safety. There are different types of wheelchairs, for example, manual or self-driving wheelchairs, which are manufactured [1-9]. This is a common wheelchair configuration on both sides of the chair that helps manually move patients and Joy-stick controlled wheelchair that uses a joystick to operate in.

- Speech Recognition-Recognizes the patient's verbal command and moves the wheelchair accordingly.
- Acquisition of Images-Uses camera to track hands According to its movement and movement happen.
- Controlled sensor- In such sensors as accelerometer sensor and flex sensor.

It is fine in terms of continuity, but it needs a high degree of precision when designing and programming Taking all in this in mind we have chosen to do a touch-screen powered wheelchair. User-friendly technology that operates on touch screen 2 needs less operating power, i.e. one finger is necessary to operate a wheelchair. As touch-screen technology acquires the highest level of interest in various science and commercially developed products, its use in patient-friendly devices such as wheelchairs will lead to improved service quality. Who is known as Disability? Any inability or loss of capacity to carry out an operation within the range deemed natural for humans as a result of injury is called disability. Disability is a critical public health issue, particularly in India, where more than 60 percent of people with disabilities live in rural areas.

National Sample Survey Organization (NSSO) Disability Survey (2002) estimated India's disabled population at 18.5 million, representing 2.13 percent of the overall population. India's population with disabilities increased by 22.4 percent from 2001 to 2011 [10-25]. Historically it denied fundamental human and civil rights to disabled citizens Those with disabilities face difficulties. So if we see that How many people in the world have a physical disability and require a wheelchair? We remember that in the 34 developed countries we see that 1% or 10,000,000 people need a wheelchair. In the 156 developing countries, it is estimated that at least 2% or 121,800,000 people need a wheelchair and we see the overall scenario of the 7,091,500,000 people in the world, almost 131,800,000 or 1.85% need a wheelchair. Now, look at the people with a physical disability how many have wheelchair access? More than 95 percent of people in the developing world who use a wheelchair use one. Less than 10% of people in developing countries who need a wheelchair approach one. That is equal to a population of 2.1 percent.

Table:1 Percentage of disabled person in India

Disabled Population	Population	Percentage(%)
Total population	1,028,610,328	100.0
Total disabled population	21,906,769	2.1
Disability rate (per lakh population)	2,130	--

So how many people around the world need a wheelchair but have not one? Second, if we look at developing countries and see them, the number is less than 500,000 (5 percent of 10 million). The number is at least 109,620,000 in developing countries (90 percent of 121.8 million). We get over 110,000,000 an enormous total. The other question is how the criteria for wheelchairs change? We see that the world population is rising by 187,500 per day; there is an increasing demand for nearly 3,500 wheelchairs every day (1.85 percent of the world 's population), hours a day.

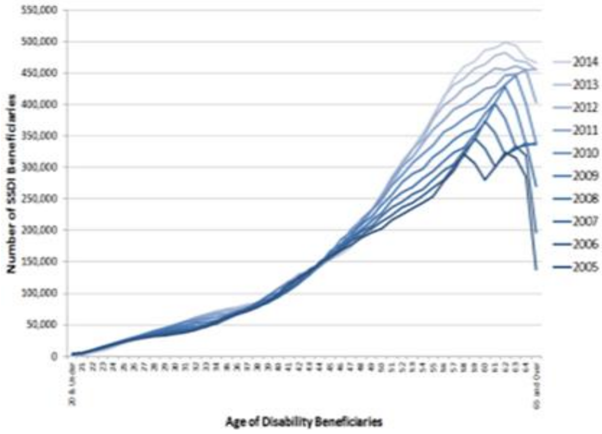

Fig:1 Growth rate of disabled person in India

II. PURPOSE

Changes in wheeled mobility user populations and technologies over the past 30 years demonstrate the need for standards to improve accessibility for people with disabilities, especially those who use wheelchairs. A key component is the wheelchair's maneuverability which defines the clear space within the setting required for travel. Past work has used rating scales to assess the maneuverability of wheelchair users in a built-up environment. These will be complemented by direct maneuverability steps. Having wheelchair users perform self-paced control tasks is a possible method to meet the requirement for both lateral and longitudinal tasks. This work validated a methodology for measuring steering controllability and controllability of wheelchair start/stop, so that future studies can use this method to check environmental or wheelchair designs. For wheelchair users, the same speed/accuracy associations were observed as had been observed for a number of vehicles previously.

Locomotion is one of the basic needs of people who lack the ability to move from one place to another using wheelchair. The aim of this project is to support these people by automating the process of moving in any direction using the Different Methods of ATmega168 Arduino which allows the disabled to operate the wheelchair easily.

III.METHODOLOGY

Touch screen technology is a technique based on direct manipulation guided by gestures. A switch is mounted on the wheelchair to perform two different operating forms, i.e. either the movement of the wheelchair or the operation of the appliances in the room. Our research offers a touch screen human-machine interface for driving an electric wheelchair. In our experiment three patients aged 15 to 66 participated. We were asked to operate the electric wheelchair using two types of an interface according to the existing protocol (the traditional mechanical joystick and the intelligent touch screen joystick that we offer). This helped us to reap the benefits of using the optimized touch interface for wheelchair movements. The benefit of this control is that it allows the patient with less effort to move the wheelchair at an accurate variable speed, like a conventional motorized joystick.

IV.PROPOSED DESIGN OF THE SYSTEM

In the proposed design of the system the following components are required:

- ***Arduino UNO (at-mega 168)***- At Mega 168 microcontroller-ATmega168 is an 8-bit AVR microcontroller that comes in three packages called PDIP, MLF, and TQFP, where the first two contain 28 pins on each module while the other comes with a 32-pin interface.

- ***Lm7805 IC***- It is a voltage regulator with a + 5-volt output. The last two digits of the number are a convenient way to recall the voltage output of a set of voltage regulators from the LM78XX. An LM7805 ends with '05;' therefore, 5 volts is output.

- ***DC Motor***- The motor consists of a stator, an armature, a rotor, and a switch for brushing. The opposite polarity of the two magnetic fields enables it to turn inside the motor. DC motors are the simplest type of motor and are used in household appliances, such as electrical razors, and car windows.

- ***Touchscreen (AKA digitizer)***- It is a thin, transparent plastic layer that reads the signal from the contact and carries it to the processing system. It's the component you can handle without getting the unit disassembled. The LCD screen is the panel that shows the image inside the unit.

- ***Bridge Rectifier IC***- A bridge rectifier is an electrical system that converts the alternating current (AC) to the direct current (DC) that flows in one direction at a regular interval.

- ***L293D*** –It is a standard Motor Driver or Motor Driver IC for driving in either direction. The SENSOR IS a 16pin IC which can power 2 DC motors in either direction simultaneously, which means you can control two DC motors with one single sensor, Dual H-bridge motor driver IC.

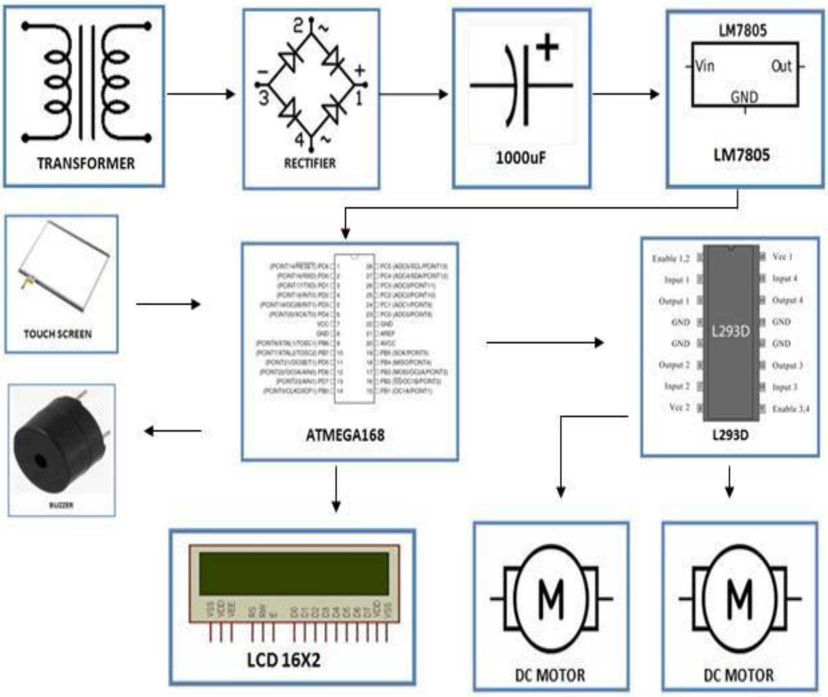

Fig: 2 Proposed Design System

- ***Analog to digital converter***: The LPC 1768 is composed of a successive A / D converter style approximation. It consists of a comparator, successive registers for approximation (SAR), output latches, and a D / A converter. The circuit's main component is the 8-bit SAR which has an output of 8-bit D / A converters. The analog output Va for the D / A converter is then compared to an analog signal Vin by the comparator. The comparator output is a serial entry of data into the SAR. The SAR changes itself until the SAR digital output (8 bits) is equal to the analog input Vin. At the end of the conversation, the 8-bit latch holds on to the resulting digital data output.

- ***Relays:*** Relays are used to turn the wheelchair motors ON and OFF according to motor controller unit output 4 relays are used.

- ***Power supply***: Battery is the power source. The battery is charged from the 230V, 50Hz power supply which is commonly available. For the power supply, there was a two 12V, 7Ah battery. Engines are powered directly from the battery.

- ***Power charger:*** Recharge the power using a battery charger. The converter requires an AC to DC circuit. The input is 230 240V AC and the output is 13,6 Volts DC.

V.PROPOSED METHOD

The main aim of the project is to create the safest access control system for wheelchair use by a patient using a touch screen. This project is running it using a touch screen technology that consumes less power from the user, so even the patient can function without stress. The wheelchair movement can be operated in the reverse forward direction, both left and right. The most frequently spelled term is in the area of electronics automation. The quest for automation has brought a great deal of innovation to modern technologies. The user-friendly touch screen interface is one of the devices with the most advances. The project uses a microcontroller (atmega168), which is programmed using an embedded instruction on the system. It may work with both modules for input and output. The touch-based sensor adds information to the Arduino. The system then uses a GLCD that shows all the directions. To control the direction of taking medication from the wheelchair, the controller is interfaced with 2 dc motors that are attached to the wheelchair. A graph between speed and torque in fig 3 indicates that DC series motor has a very high speed at no load and high torque at low speed. Using four pushbuttons, where each select features are available. It uses the first push button to advise against taking medication once a day. Use the second push button to warn twice a day, and use the third push-button to warn thrice a day. The fourth push-button is used when the user has heeded the signal to stop the buzzer.

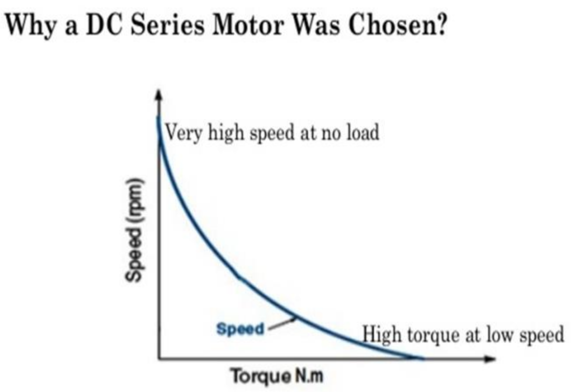

Fig: 3 Drive Unit

We have used two motors attached to its wheel and this allows us to move the chair in a different direction as shown in table 2.

Table:2 Chair movement in different direction

DIRECTIONS	RIGHT MOTORS	LEFT MOTORS
FORWARD	ON(CW)	ON(CW)
BACKWARD	ON(CCW)	ON(CCW)
LEFT	OFF	ON(CW)
RIGHT	ON(CW)	OFF

THE WHEELCHAIR DIRECTION AND MOVEMENT POSSIBLE BELOW:

- FORWARD :BOTH MOTOR ARE IN FORWARD DIRECTION.
- REVERSE: BOTH MOTORS ARE IN REVERSE DIRECTION .
- LEFT: LEFT MOTOR STOPPED AND RIGHT MOTORS IN FORWARD DIRECTION.
- RIGHT: RIGHT MOTORS STOPPED AND LEFT MOTOR IN FORWARD DIRECTION.
- STOP: BOTH THE MOTORS ARE STOPPED.

6.1 Ways to make it multifunctional smart wheelchair

- Temperature Sensor-The LM35 series are accurate, integrated circuit temperature sensors whose output voltage is linearly proportional to the temperature at Celsius (Centigrade). Consequently, the LM35 has a benefit over linear temperature sensors measured in ° Kelvin, because the consumer is not needed to deduct a significant constant voltage from its output to obtain convenient Centigrade scaling. The LM35 requires no external calibration or trimming to provide typical accuracies of ±1⁄4 ° C at room temperature and ±3⁄4 ° Cover a full range of −55 to +150 ° C. The low output impedance, linear output and accurate inherent calibration of the LM35 make it particularly easy to interface to read or control circuitry. It has scale factor Linear + 10.0 mV/ ° C

- C.GSM Module -Here we use SIM900 to track patients. SIM900 offers GSM / GPRS 850/900/1800/1900MHz output in a small form factor for audio, SMS, Data, and Fax, with low power consumption. For a compact setup, it uses less space. This module carries a holder of SIM cards where a SIM must be mounted to communicate. The baud rate is adjustable from 1200 bps to 115200 bps [13-18]. The Built-in RS232 level converter makes microcontrollers easy to work with. Here we monitor it using regular AT commands.

- Bluetooth module HC05- Here we use a Bluetooth module HC-05 together with an Android phone as a voice recognition device. Frequency ranges from 2.4GHz to 2.48GHz [11]. This module addresses standard AT commands, too. By using these AT commands, we can set parameters such as baud rate, and we can also set a particular port as input or output.
- Line follower: The line follower circuit is designed to push the wheelchair in a predefined direction in the black strip. We use four S1, S2, S3, and S4 infrared sensors for this circuit which are mounted on the bottom of the wheelchair. In practice, several of the conditions are set out below.

- The location of the sensors above the black strip is indicated by ‘0’and ‘1’. Here '0' means no light has reflected the sensors and '1' means light has completely reflected the sensors and their status thus determines the movement of the wheelchair in a particular direction. Table 1, shows some of the conditions in practice.

- Obstacle Detector An HC-SR04 Ultrasonic sensor that is mounted in the front of the wheelchair conducts obstacle detection. Ultrasonic ranging module HC-SR04 has a non-contact measuring feature of 2 cm-400 cm, the ranging accuracy can reach up to 3 mm. Ultrasonic transmitters, receiver and control circuit are included in the package.

6.2Hardware

The ATmega32 is an 8-bit low-power CMOS microcontroller, based on the AVR-enhanced RISC architecture. The ATmega32 achieves approximate 1 MIPS per MHz through the execution of strong instructions in one clock cycle allowing the device configured to optimize power consumption versus processing speed. The Bluetooth controller connects to microcontroller port D (PD0 and PD1) for microcontroller interfacing. Controller port C is interfaced with IC (L293D) driver. It is a bidirectional IC providing rotation in the clockwise and anti-clockwise direction. Port A connects with an IR sensor. Fig 2 Microcontroller HC05 module is an easy-to-use Bluetooth SPP module for a transparent serial wireless connection setup. This IC is attached to controller port D. Pin 14 is the receiver, and the transmitter is pin 15. It receives input from the smartphone, and the controller controls its output. A signal conditioning circuit, like IR sensors, receives an analog signal from the sensor. This circuit's output is provided to the ADC in the controller. Hence the signal conditioner's analog output is converted into digital output. IR sensor is used to sense wheelchair barriers as they move. If some obstacle is detected, the controller receives the signal and sends the signal to the driver of the unit to stop the wheelchair when no obstacle is detected. The L293D is a quadruple high-current half-H driver designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Device drivers act as current amplifiers It is designed to drive DC motors, as well as other high-current/high-voltage loads in positive-supply applications.

Features

- ✓ Can be easily monitored
- ✓ Ease in understanding the working module
- ✓ Easy to operate
- ✓ Lower power consumption

6.3Software

- Perhaps the most common language for Embedded Systems programming among Embedded Programmers is Embedded C-Embedded C. There are several common programming languages like Assembly, BASIC, C++,etc. that are often used to build Embedded Systems but Embedded C remains popular because of its performance, less development time and portability.
- Keil IDE- Keil MDK is the full software development environment for a large variety of microcontroller devices based on Arm Cortex-M. MDK includes the debugger and vision IDE, Arm C / C++ compiler, and critical middleware modules. With more than 7,000 apps it supports all silicon vendors and is easy to know and use.
- Uc-Flash- Flash plugins can only be updated for all users of Android's UC browsers if you run version 4.0 or less. ... The new version of Flash Player available here is 11.1. For versions higher than this, you will not be able to get them on the Google Play Store, and you would have to focus on the official flash-player website.

VI. GLOBAL ELECTRIC WHEELCHAIR MARKET SIZE

The global electric wheelchair market size is projected to grow rapidly in the coming years, at a CAGR of 18.25 percent between 2018 and 2025. Fig 3 shows the global market size stood at USD 1.25 billion in 2017 and is expected to reach USD 2 billion by 2025. Alternatively, electrical wheelchairs are called electrical wheelchairs, or power seats. We do not need any human help for longevity, because they are powered by a battery. The most noticeable beneficial aspect of an electric wheelchair is that they are easy to understand and helpful. Such electric wheelchairs are useful for those who cannot use a manual wheelchair or who may need a wheelchair to travel long distances. Besides individuals with typical portability inability, it can also be used by individuals with cardiovascular disorders or who encounter certain unplanned conditions. Geographically, North America is expected to be the highest growing region on the global electric wheelchair market as indicated in fig 4.

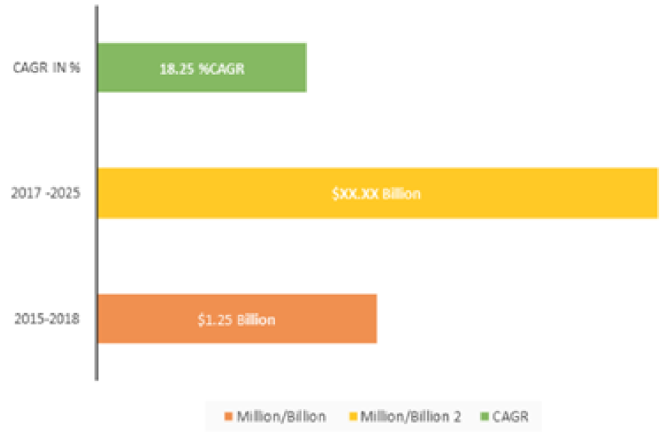

Fig: 3 Global Market Growth Opportunities (Revenue, Growth) by 2017-2025

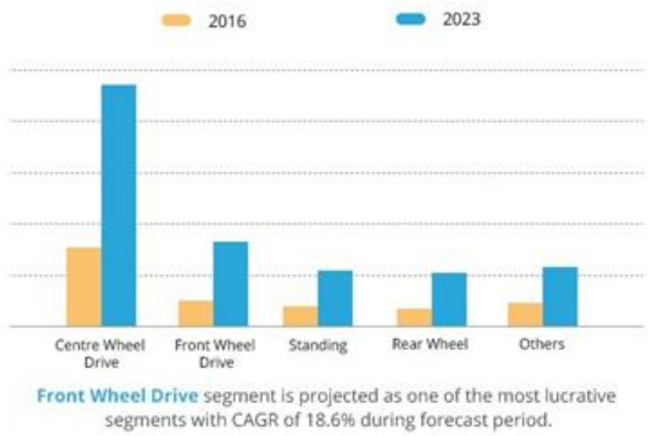

Fig:4 Global Electric Wheel Chair Market by chair market by Type

VII.APPLICATIONS

Since our project deals with the design of a system that enables the user to interact with the smart wheelchair at various levels of control for obstacle detection and collision avoidance, providing efficient risk management and an additional feature in which the smart wheelchair can be turned into a bed, this greatly reduces dependence on caregivers or family members It offers autonomous mobility for customers while enhancing opportunities for education and employment. The wheelchair protects by introducing features such as collision avoidance detection of obstacles and hollow detection to prevent hazards such as stairs, potholes, etc. There's even a buzzer available to help in emergencies. The key advantages of the integrated wheelchair system are that it is user friendly, especially helpful to people with stroke paralysis. It decreases human activity, improves mobility, improves manoeuvrability, increases the ability of people with disabilities to live independently and increases the number of people with disabilities in jobs while providing care and protection for those who are unable to work.

VIII. CURRENT DESIGN USP'S

Since our project deals with the creation of a device that allows the user to communicate with the smart wheelchair at different levels of control for obstacle detection and collision avoidance, providing efficient risk management and an additional function where the smart wheelchair can be transformed into a bed, this greatly reduces dependency on caregivers or family members. It offers autonomous mobility for customers while enhancing opportunities for education and employment. The wheelchair offers safety by introducing features such as collision avoidance detection of obstacles and hollow detection to avoid hazards such as stairs, potholes, etc. A buzzer is also available to help in emergencies.

The prototype designed only provides the user with the aid of simple switches for independent wheelchair movement. The switches are operated separately for both direction control and sleep mode operation. Hence the wheelchair is very easy to use. The greatest advantage of using this wheelchair is their ability to properly manage the risk. The obstacles in wheelchair movement are identified using IR sensors installed on wheelchairs and are avoided as needed. The IR-sensor employed here makes the device cost effective. This completely functioning smart wheelchair prototype can be converted to a bed whenever you wish. Additional keys are placed on wheelchair armrest for this reason. Separate keys are available for both the back and front panels; pairs of keys are issued for single operation. The inclination angle of the backrest and front panel can be changed accordingly. The direction keys are disabled during this process, to further increase protection.

Advantages:
1. Consumer Friendly and cheap
2. Useful for the paralysis stroke people who do not have much stamina in the hands
3. Reduces human activity and has two modes to control
4. Reduces physical strain

Disadvantages: Batteries need to be recharged periodically.

IX. EXISTING METHODOLOGY

1) K.Sudheer, T.V Janardhana rao, Ch. Shridevi M.s Madhan Mohan (2012): voice and gesture-based electronic wheelchair operated by ARM combined speech recognition and gesture recognition. Secret markov models are used in this speech recognition module. The MEMS sensor is used, and the angle of hand is sensed. The voice IC is used for Speech recognition.
2) M. Prathyusha, K.S Roy, Mahboob Ali sheikh (April 2013): wheelchair path based on voice and touch screen, and speed control. The speech recognition system uses a programmable circuit for voice recognition. The speed controller works by changing the mean voltage that is sent to the engine.
3) Rakhi A. Kalautri, D.K Chitre (2013): Used automated gesture recognition device based on the acceleration sensor used

here is 2-axis. By measuring the amount of tilt and tilt output, you can determine which way to go further.

4) Nurul Muthmainnah Mohd Noor, Salmiah Ahmad (2012): EOG-based wheelchair control: Electrically active cornea of the eye is connected to the back of the head, retina. The eye behaves as if it were a single dipole orientedfrom the retina to the cornea. Such cornea-retinalpotentials are well established and are in therange of 0.0.5-3.5mV. Eye Movements thusproduce a moving (rotating) dipole source andaccordingly, signals that are a measure of themovement may be obtained. The recording andinterpretation of the electrical activity of eye iscalled electro oculography. Its main applicationis in Ophthalmological diagnosis and inrecording eye movements. Electrodes such asgold surface electrode, Ag-Cl electrodes are usedto record the eye potential changes.

5) Alex Dev, Horizon C Chacko and Roshan Varghese, (ICCCE 2012): EYEBALL SENSING system for wheelchair control: the eye color is the fundamental concept of this direction sensing. In the human eyes there are two primary color pigments. That is, in black and white. The colorsshow different wavelengths in the spectrum.White being the farthest colour in emits thelowest wavelength. So the wavelength of whitelight is chosen as the standard parameter.

X.CONCLUSION AND FUTURE WORK

The built-in smart wheelchair enables wheelchair movement in any desired direction (forwards, backwards, right and left) with keypad support. The keypad is inserted to the reclining neck. This keypad makes its use even easier for portable use. The smart lying wheelchair can be transformed into a bed using separate keys included in the keyboard. The angle of the rear panel and the front panel can be changed as needed by the consumer. This greatly diminishes the reliance on family members and caregivers. The wheelchair also successfully handles danger across discovered barriers and avoids obstacles. The wheelchair has an LED to provide light when the ambient environment is dark, to provide the disabled with more protection. He / she can do this easily with the aid of a buzzer put on the wheelchair when the disabled person wants to warn every caregiver around him / her. The future direction is to make the present touch screen possible for all groups of people with disabilities, the touch screen can be made braille especially for the blind, so that the blind person can feel the touch pad and control the wheelchairs. The tactile screen has keys as input feature in the present prototype. Alternatively, the user can control the wheelchair itself by voice recognition. The use of ultrasonic high precision sensors will increase the sensing range further. The energy from wheel movement can be stored in a battery to save energy, and used whenever necessary. The wheelchair may be GSM enabled, where extra features will be accessible to the patient seated on the wheelchair. If the wheelchair patient feels anxious or has a health condition, he / she may send a message to his / her family or friends indicating the need for assistance. A much more secure and effective forum for the patient is built thereby. The wheelchair can be powered by the cost-free solar power which is a renewable source. This wheelchair currently runs on DC battery source but can be powered by solar power in the future that can be stored for day-night use.

Our wheelchair system has been helpful to a person with a disability in many respects but there is scope for change. Methods such as brain control, ball-eye control, can be combined with motion control. Our software is currently unable to climb stairs, but in this regard too we can make progress. The potential aim is to make the current touch screen accessible to all groups of disabled people, especially the blind, so that the blind person can feel the touch pad and operate the wheelchair as needed. The tactile panel has keys as mode of input in this prototype. Besides, the user can power the wheelchair by voice recognition themselves. The use of high-precision ultrasonic sensors would further expand sensor range. The energy from the wheel's rotation can be stored in a battery for energy saving, and used where necessary. The wheelchair could be equipped with GSM, where additional features will be required for the wheelchair sitting patient. Where the wheelchair user feels stressed or has a health condition, he / she might send a message to his / her family or friends suggesting the need for assistance. Therefore, a much more open and effective forum for the patient is developed. Cost-free solar power which is a renewable source will power the wheelchair. This wheelchair currently runs on a DC battery source but can be powered with solar power in the future which can be stored for daytime use Only the initial costs for such implementation must be taken into account, but should be fairly Voice and Touchscreen Powered Intelligent Wheelchair 2015-16 Dept. of Telecommunications Engineering, 58 sustainable in the longer term. The wheelchair can be marked with a specific route to reach established or important localities. Such implementation would include a smart sensor network to assist with the use of the image processing in the mapping phase. For the controller a definite route might have been designed to move the wheelchair in the direction indicated.

References

1. *R. C. Simpson, "Smart wheelchairs: A literature review", Journal of Rehabilitation Research & Development (JRRD), Vol 42, Number 4, pp. 423–436, July/August 2005.*
2. *G. Bourhis, K. Moumen, P. Pino, S. Rohmer and A. Pruski, "Assisted navigation for a powered wheelchair. Systems Engineering in the Service of Humans", Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, France, pp. 553–558, 1993.*
3. *J. Connell and P. Viola, "Cooperative control of a semi-autonomous mobile robot. Robotics and Automation", Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Cincinnati, Ohio, USA, pp. 1118–1121, 1990.*
4. *S. Guo, R. A. Cooper and G. G. Grindle, "Development of Head-Operated, Isometric Controls for Powered Mobility", Proceedings of RESNA 27th International Annual Conference, Orlando, Florida, 2004.*
5. *Macfarlane J. Other physical consequences of disability. Handbook of Clinical Neurology. 2013; 110:315-22. doi: 10.1016/b978-0-444-52901-5.00026-5.*
6. *Hoeven TA, Leening MJ, Bindels PJ, Castano-Betancourt M, van Meurs JB, Franco OH, et al. Disability and not osteoarthritis-tis predicts cardiovascular disease: A prospective population-based cohort study.*
7. *Rosso AL, Wisdom JP, Horner-Johnson W, McGee MG, Michael YL. Aging with a disability: a systematic review of cardiovascular disease and osteoporosis among women ag-ing with a physical disability. Maturitas. 2011; 68(1):65-72. doi: 10.1016/j.maturitas.2010.10.00.*

8. *J. Kim et al., "The Tongue Enables Computer and Wheelchair Control for People with Spinal Cord Injury", Science Translational Medicine, Vol 5, Issue 213, 27 November 2013.*
9. *M.E. Lund et al., "Inductive tongue control ofpowered wheelchairs", Proceedings of Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Buenos Aires, Argentina, pp. 3361 - 3364, 2010.*
10. *E.M. Giesbrecht, W.C. Miller, B.T. Jin, I.M. Mitchell, and J.J. Eng.Rehab on wheels: A pilot study of tablet-based wheelchair training forolder adults. JMIR Rehabil. and Assistive Technol., 2, Apr. 2015.*
11. *M. Urbano, J. Fonseca, U. Nunes, and H. Zeilinger. Extending a smart wheelchair navigation by stress sensors. In IEEE 16th Conf. Emerg.Technol. & Factory Auto., pages 1–4, Toulouse, Sept. 2011.*
12. *C. Balaguer, A. Jardon, C.A. Monje, F. Bonsignorio, M.F. Stoelen S. Martinez, and J.G. Victores. Sultan: Simultaneous user learning andtask execution, and its application in assistive robotics. In WorkshopNew and Emerg. Technol. in Assistive Robot., San Francisco, CA, USA,Sept. 2011.*
13. *E. B. Van Der Poorten, E. Demeester, E. Reekmans, and J. Philips.Powered wheelchair navigation assistance through kinematically correctenvironmental haptic feedback. In IEEE Int. Conf. Robot. and Auto.,pages 3706–3712, Saint Paul, MN, USA, May 2012.*
14. *R. Tang, X. Chen, M. Hayes, and I. Palmer. Develop. of a navigationsystem for semi-autonomous operation of wheelchairs. In IEEE/ASMEInt. Conf. Mechatronics and Embedded Syst. and Applicat., pages 257–262, Suzhou, Jul. 2012.*
15. *F. Carrino, J. Dumoulin, E. Mugellini, O. Khaled, and R. Ingold. Aself-paced bci system to control an electric wheelchair: evaluation of acommercial, low-cost eeg device. In ISSNIP Biosignals and Bio Robotics Conf., pages 1–6, Manaus, Jan. 2012.*
16. *J. S. Nguyen. A Smart Wheelchair System using a Combination ofStereoscopic and Spherical Vision Cameras. PhD thesis, Univ. Technol., Sydney, 2012.*
17. *S. Cockrell, G. Lee, and W. Newman. Determining navigability ofterrain using point cloud data. In Proc. IEEE Int. Conf. Rehabil. Robot.,pages 1–6, Seattle Washington, Jun. 2013.*
18. *J. Tavares, J. Barbosa, and C. Costa. A smart wheelchair based onubiquitous computing. In Proc. 6th Int. Conf. Pervasive Technol. Relatedto Assistive Environments, pages 1–4, New York, NY, USA, May 2013.*
19. *A.R. Trivedi, A.K. Singh, S. T. Digumarti, D. Fulwani, and S. Kumar.Design and implementation of a smart wheelchair. In Proc. Conf. Adv.In Robot., pages 1–6, New York, NY, USA, 2013.*
20. *J. Leaman and H. M. La, "A comprehensive review of smart wheelchairs: past, present, and future," IEEE Transactions on Human-Machine Systems, vol. 47, no. 4, pp. 486–489, 2017.*
21. *C. T. Lin, C. Euler, P. Wang, and A. Mekhtarian, "Indoor and outdoor mobility for an intelligent autonomous wheelchair," in Proceedings of the 13th ICCHP, International Conference on Computers Helping People with Special Needs, 2012.*
22. *C. A. Rockey, E. M. Perko, and W. S. Newman, "An evaluation of low-cost sensors for smart swheelchairs," in Proceedings of the 2013 IEEE International Conference on Automation Science and Engineering, CASE 2013, pp. 249–254, USA, August 2013.*
23. *S. Desai, S. S. Mantha, and V. M. Phalle, "Advances in smart wheelchair technology," in Proceedings of the 2017 International Conference on Nascent Technologies in Engineering, ICNTE 2017, pp. 1–7, Navi Mumbai, India, January 2017.*
24. *R. C. Simpson, D. Poirot, and F. Baxter, "The hephaestus smart wheelchair system," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 10, no. 2, pp. 118–122, 2002.*
25. *P. Wang, N. R. Keyawa, and C. Euler, "Radial polar histogram: obstacle avoidance and path planning for robotic cognition and motion control," in Proceedings of the SPIE 8301, Intelligent Robots and Computer Vision XXIX: Algorithms and Techniques, Burlingame, Calif, USA, 2012.*