Redundant Mobility System Design for Impaired People

Mauricio Plaza Torres
Universidad Militar Nueva Granada, Bogotá, Colombia
Email: Mauricio.plaza@unimilitar.edu.co

***Abstract*—Mobility is important factor for a good quality of life. Injury on back spine produce loss of self-mobility and need of additional help from other people include the family members or medical nurse staff.**
The aim of the project is a design a system for provide independent mobility for disabled people. The final system would be a design for a Handicapped person with spinal cord injury those who could not move their hands as well as legs, with a new human-machine interface for controlling a wheelchair by head movements. It is a good alternative to self-movement when other parts of the body have mobility problems. It has been found that this project can be used by not only the Quadriplegics, but also by all those who are mobility impaired.
Quadriplegics are limited in lower and upper member movement and need a specific device to communicate with a system like wheel chair for mobility without assistance. Design mechanism for quadriplegics to provide movement in a specific biomechanical area and independence is the main goal of the project.
The system is a following head tilt movement that produces a signal for control a wheelchair that could operate in any direction using head movements. This system is complemented with movement intention sensor software. The software read the intention and matches the order to double check the movement order.
Additional to this software, the system has a program to help the person to follow a specific trajectory and the control of the position to avoid injury for a mismatch order.

***Index Terms*—Mobility system, impaired people, tilt movement, control wheelchair, intention, trajectory**

I. Introduction

For people with disability is important to have an autonomic system with multiple check verification because is not possible for this people to respond very quickly under alert in the trajectory. The final propose is an autonomic system that receive orders from a person with mobility limitation and follow a trajectory in very safe and autonomic way.

Research groups worldwide work on projects to design system for mobility for disabled persons with the aim of increasing the quality of life and the autonomy and independency lifestyle and promotes the social integration.

Manuscript received October 1, 2018; revised December 4, 2018.

The project system was design with a microcontroller to assist in controlling the motion of a wheelchair and a home automation system using head movements for people with disabilities. With this system, the person with movement limitation can control the displacement and the comfort on a specific area. [1]

The system can assist quadriplegic handicapped people with limitation on arm and leg movement to steer an automated wheelchair and home automation system. [2]

The system includes a head position recognition technique based on infrared sensor with redundant pressure system. The sensor device sends the signal to a computer system that processes the information, include redundant information from the software to avoid mistake for incorrect order o reading information. The system measures orientation angles and send a signal of converted position into adequate steering commands. Additionally, the system has a software verification system to avoid damage or movement problems in specific areas. The system can be used with several types of standard electrical powered wheelchairs.

We introduce a different approach for head control for electric wheelchairs. The signals are received and converted into proportional signals that control the wheelchair position and speed. Sensors are used to monitor the changes due to the intentional head motions of the patient and deduce the order to control de Wheelchair with approve of the control software that monitor the trajectory and take an additional decision to follow a correct trajectory. The software interface control generates signals connected to the interface to control wheelchair with minimum head movement. [3]

After the software design was finished, all users where adapted to the control algorithm very quickly and intuitive and were able to follow trajectories on different places without problems. The interface does not require any attachments to the head [4].

II. Background

Quadriplegia is because injury or illness that affect the spinal cord or the nerve system, results in the partial or total loss of mobility in the use of the limbs. Additional to spine cord lesion, there are some nerve illness that affect the mobility, results on partial or total immobilization of the several part of the body [5].

The paralysis it a result of a damage in the brain or the spinal cord at a high level C1 – C7 losing function of all

doi: 10.18178/joace.6.2.53-56

limbs [6]. The only self-movement that the patient can archive is the head muscles and sometimes partial control of the one finger. Those movements are monitoring to control the displacement on the wheelchair [7].

The gold of the project is to help patient to move more independent using a control system monitoring the head movement and additional variable to avoid accident in the wheelchair trajectory [8]. Those systems are intention movement software, pressure sensor, infrared sensor and trajectory optimization software. Review the state of the art on system for quadriplegic movement, the system designed only use one system to control de movement, exposing the user to possible damage for mismatch reading and loss of control.

The design on this project use redundant system to ensure the best way to following a trajectory in specific area [9]. The movement of the head in quadriplegic people is to slow to respond a specific order in alert situation. For this reason, is important to have software control, redundant signal information to archive the specific order or trajectory without damage o problem in people with movement limitation. [10]

III. Problem Statement

Quadriplegia limits the mobility as a result the patients are forced to depend on other persons causing emotional stress, limited to do the day to day activity.

The research project addresses the limited mobility problem intended to make the patient independent in some limited areas in safe way, using redundant system (hardware and software) to ensure the correct translation.

VI. Motivation and Prior Work

Thera are some previous works related with wheelchair control.

Figure1. Attendant controlled electric power wheelchair

The attendant controlled electric power wheelchair allows an attendant or care giver to drive & control the wheelchair while walking behind it as the patient or handicap individual is riding in the wheelchair. This system needs assistance for translation (Fig. 1).

System using accelerometer readings input position and sends it to a laptop via Bluetooth, which send information to several micro controllers that handle a joystick accordingly to steer the vehicle

Wheelchair driven by the tongue movement is another alternative but not hygienic way and no comfortable for the user. Patients must be navigated through a powered wheelchair control by blowing into a plastic straw to execute basic functions (Fig 2).

The Tongue Drive System uses a magnetic stud into patients' tongues, allowing them to use the muscle as a joystick for their wheelchairs [11].

Sensors in the tongue can communicate one of six basic functions for the wheelchair. The system allows users to control their wheelchair, and other system connected [12].

Those of that system can fail producing possible damage on the quadriplegic people. The way proposed in the project is the use of additional system to reduce the probability to have wrong orders because the bad reading signals [13].

V. Physical Prototype

The initial test system use a Mindstorms EV3 Lego kit, which is a set of elements with sensors, motors and a programmable module that allows creating and controlling robots. The scale physical prototype was design to simulate a smart wheelchair, using two independent coupled motors in to two axes, similar to the wheelchair real system, that move one wheel at a time for easily control on four possible directions (forward, back, right and left). It is assembled with an idler located at the rear center for stability in the movement of the device. The physical model has a chassis and a simulated chair formed by many supports to maintain its structural integrity, finally has a wooden dummy sitting on the scale prototype that will simulate the user position. In Figure 1 we can observe the physical model of the wheelchair to control [14, 15].

Figure 2. Scale prototype

A. Control System

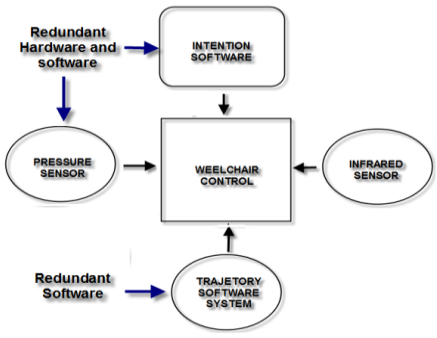

Figure 3. Control system

An infrared optical sensor TrackIR 3-Pro, manufactured by Natural Point, was initially implemented to help people with disabilities. The signal was sent to a computer with software in Matlab in order

to control the prototype and the automatization home system. The TrackIR3 follows a visual field of 32 degrees front (or back if you want to configure it that way). The device follows the movement a reflective marker located in a user's glasses and the position of the point translates it into mouse movements in the computer. The physical system is shown in Fig. 3 [16,17,18].

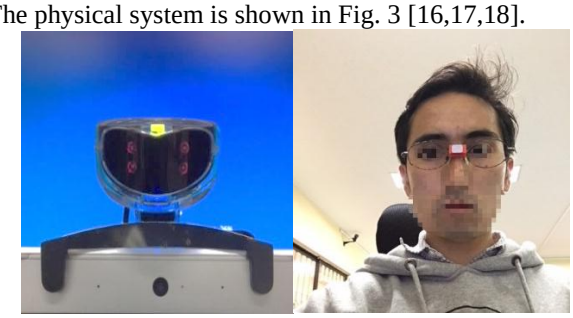

Figure 4. System physic TrackIR3

The main control software consists of 4 phases: Control (Cursor position), Variable Operation, Actuation (signals sent to the actuators or software) and finally the page break to the main menu. In Fig. 3 the diagram of the final system, divided into three phases mentioned above (Fig 4).

B. *Control Software*

In the control step, by means of 5 transparent boxes located on top of the 5 buttons of the user interface (Front Panel) of the intelligent wheelchair, events were created depending on the location of the wheelchair, mouse and pointer. The system is activated simultaneously without press and specific button; since the users to whom the system is focused have only autonomy in head movements. In Fig. 4 the block diagram of the control system and the activation of a button from the step of the pointer over the button can be observed [19] (Fig 6).

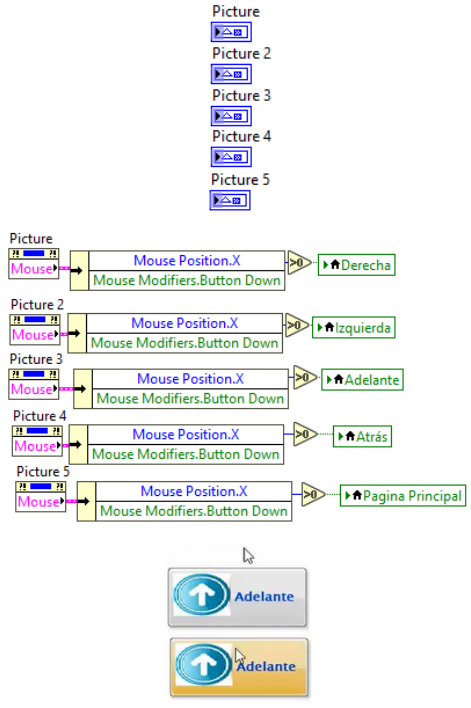

Figure 5. Control software

C. *Variable Operation*

In the operation phase, the Boolean values of the different buttons that are activated to move the intelligent wheelchair, are grouped to build an array value depending on its activation status (0 or 1), after this, applies a function of conversion of Boolean arrangement to number to obtain at the exit a single numeric value depending on which of the buttons is being activated in the following way: 1 (forward), 2 (backward), 4 (right) and 8 (left), finally to this numerical value a char conversion function is applied to it and it is saved in a type variable called State. In the fig ... the block diagram of the operation phase of variables is shown (Fig 5).

VIII. Movement Intention Software

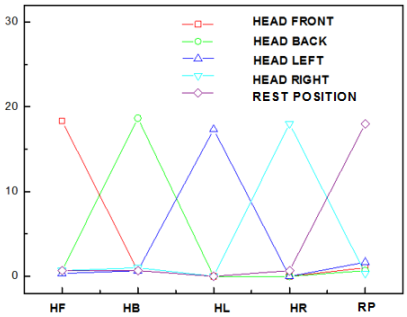

Figure 6. Control software

The table is the results obtained for calculated head movement, the hits and false positive results were found. The statistic results on the signal vs order are very precise, but there are few mismatch results. The mismatch results could be a wrong driven order and therefore the patient cannot respond with this head movement on time to correct the path. This mistake could produce several damages on the driver. It result on the need of the use redundant signal y more control software verification; this is the motivation on the current project and design (Fig 6).

VI. Our Contribution

In the current project, the infrared sensors and the pressure sensors reading the tilt of the patient's head, with this signal the system controls the motor driven wheelchair.

The pressure sensor is placed on wheelchair back which is to be worn by the patient. It is connected to the micro-controller system when the patient wants to translate, he must tilt his head in the appropriate direction.

Reading the patient's head movement, the signal is sent to the micro-controller system and a control signal sends signal to the motors that are attached to the two wheels of the wheelchair.

To translate at any point, the person must move his head in this direction. Control system provides zero voltage to one motor and full voltage to another motor depends on the direction selected. Additional redundant system is used to avoid mismatch order, the software read the movement intention to confirm the patient order.

Another software unit help the user to follow a specific trajectory based on optimum path and to avoid obstacles. This contribution in the design is the best way to have a system tolerance to fail to be in any kind of field and follow any trajectory with low possibility to damage on the user.

The prototype has been tested on different people in the Biomechanical center in the UMNG facilities lab and was found to be working according with the order of the driver.

VII. Conclusion

The wheelchair follows the order send by the patient's head.

There are several redundant systems to avoid false position or mismatch order. The system uses an infrared system and the pressure system in redundant way to send the information order. Additional there are a control software that verify the trajectory and validate the order send by the till head reading. A sensor in the head, the system can read the intention of the movement to verify the signal of head movement.

The prototype has been tested on different voluntary people in the biomechanical center in the UMNG College and was found to be working well.

VIII. Future Work

In further testing, the prototype controls plan to incorporate a remote control for blinking people and algorithm trajectory system control.

In the field test, the need of free head movement without wheelchair movement was present. It includes the need of suspend the translation system by specific position on the display. Now the person would be free to move the head with power circuit off.

Acknowledgement:

Funding by IMP ING 2659 UMNG research unit.

To Ing. Yeison Fuquene, Ing. Andres Cifuentes and Ing. Freddy Bernal for your contribution in the protocol information.

References

[1] M. Maier, "Head movements based control of an intelligent wheelchair in an indoor environment," in *Proc. 2012 IEEE International Conference on Robotics and Biomimetics (ROBIO),* 11-14 Dec. 2012

[2] M. Davy, R. Deepa, "Hardware implementation based on head movement using accelerometer sensor," *Int. Journal of Applied Sciences and Engineering Research,* 1EEE Department, K.S.R College of Engineering –Tiruchengode, India, vol. 3, no. 1, 2014.

[3] S. N. Vignesh, K. Vivek, B. Kannan, "Head motion controlled robotic wheel chair," *International Journal of Emerging Technology and Innovative Engineering,* vol. I, no. 3, March 2015.

[4] K. H. Kim, H. K. Kim, J. S. Kim, W. Son, and S.Y. Lee, "A biosignal-based human interface controlling a power-wheelchair for people with motor disabilities," *ETRI Journal*, vol. 28, no. 1, pp. 111-114, 2006.

[5] T. Carlson and J. D. R. Millan, "Brain–controlled wheelchairs: A robotic architecture," *IEEE Robotics and Automation Magazine*, vol. 20, no. 1, pp. 65-73, 2013.

[6] S. Shaheen and A. Umamakeswari, "Intelligent wheelchair for people with disabilities," *International Journal of Engineering and Technology,* vol. 5, no. 1, pp. 391-397, 2013.

[7] M. Palankar, K. J. De Laurentis, R. Alqasemi, E. Veras, R. Dubey, Y. Arbel, and E. Donchin, "Control of a 9DoF wheelchair-mounted robotic arm system using a P300 brain computer interface: Initial experiments," in *Proc. 2008. ROBIO 2008. IEEE International Conference* on *Robotics and Biomimetics*, pp. 348-353, 2008.

[8] I. Moon, M. Lee, J. Chu, and M. Mun, "Wearable EMG-based HCI for electric-powered wheelchair users with motor disabilities," in *Proc. the 2005 IEEE International Conference on Robotics and Automation*, pp. 2649-2654, 2005.

[9] J. A. Pajkanović1, B. Dokić1, "Wheelchair control by head motion," *Serbian Journal of Electrical Engineering*, vol. 10, no. 1, February 2013,pp. 135-151.

[10] S. P. Levine, D. A. Bell, L. A. Jaros, R. C. Simpson, Y. Koren, and J. Borenstein, "The NavChair assistive wheelchair navigation system," *IEEE Transactions on Rehabilitation Engineering*, vol. 7, no. 4, pp. 443-451.

[11] X. Huo and M. Ghovanloo, "Using unconstrained tongue motion as an alternative control mechanism for wheeled mobility," *IEEE Transactions on Biomedical Engineering*, vol. 56, no. 6, pp. 1719-1726, 2009.

[12] V. K. Narayanan, B. F. Pasteau, C. M Marchal, A. Krupa, M. Babel, "Vision-based adaptive assistance and haptic guidance for safe wheelchair corridor following," *Computer Vision and Image Understanding*, vol. 49, 2016, pp. 171-185.

[13] P. Falcon, A. Barreiro, M. Cacho, and E. Delgado, "Passive teleoperation of mobile robot with input-output linearization and dynamic extension," in *Proc. the 4th Annual IEEE International Conference on Cyber Technology in Automation, Control and Intelligent Systems*, June 4-7, 2014, Hong Kong, China

[14] D. Droeschel, M. Schwarz, and S. Behnke, "Continuous mapping and localization for autonomous navigation I rough terrain using a 3D laser scanner," *Robotics and Autonomous Systems*, vol. 88, 2017, pp. 104-115.

[15] A. Vasilijevic, D. Nad, N. Miskovic, Z. Vukic, "Auditory interface for teleoperation – Path following experimental results," in *Proc. the 19th World Congress the International Federation of Automatic Control Cape Town*, South Africa. August 24-29, 2014.

[16] B. Sauvet, T. Lalibert é, and C. Gosselin, "Design, analysis and experimental validation of an ungrounded haptic interface using a piezoelectric actuator," *Mechatronics*, vol. 45, 2017, pp. 100-109.

[17] B. Shiml Young-Mok KOOI, Moon-Youl Park, Jun-Seok Yangl, In-Man Park, Won-Jun Hwang, and Sung-Hyun Han, "A study on travelling control of humanoid type mobile robot with three wheel," in *Proc. 2014 14th International Conference on Control,* Automation *and Systems (ICCAS 2014)* Oct. 22-25, 2014 in KINTEX, Gyeonggi-do, Korea

[18] F. Ingrand and Malik Ghallab, "Deliberation for autonomous robots: A survey," Artificial *Intelligence*, vol. 247, 2017, pp. 10-44

[19] L. B. Davide A. Cucci Matteo Matteucci, "Kinematic trajectory tracking controller for an all-terrain Ackermann steering vehicle!, *IFAC*-PapersOnLine 49-15 (2016) 013–018.

Professor Mauricio Plaza PhD. Electrical Engineering. Universidad de los Andes (Colombia), PhD on Technical Science with emphasis on biomedical applications. 1993-2000 Engineer manager on Johnson And Johnson Medical Inc. for Andina Region. Professor on Universidad Militar Nueva Granada. 4 patents developed on Biomechanical system. Manager of the Biomechanical Center in UMNG (Universidad Militar Nueva Granada). Director of the Posgradute Institute (UMNG)