Towards an Assistive Interface to Command Robotic Wheelchairs and Interact with Environment Through Eye Gaze

Conference Paper · January 2018

DOI: 10.29327/cobecseb.78867

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Anais do V Congresso Brasileiro de Eletromiografia e Cinesiologia e X Simpósio de Engenharia Biomédica - ISBN: 978-85-5722-065-2 - DOI: 10.29327/cobecseb.78867

TOWARDS AN ASSISTIVE INTERFACE TO COMMAND ROBOTIC WHEELCHAIRS AND INTERACT WITH ENVIRONMENT THROUGH EYE GAZE

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Abstract: *This work presents an intuitive and customizable assistive technology based on eye gaze, which is an integration of a previous multimodal assistive domotics system developed for the UFES robotic wheelchair. Users with motor disabilities are able to control home devices, communicate with family or caregiver through short phrases, and navigate a wheelchair by means of eye gaze. The interface is easy to use, in which there is a computer and a screen monitor on board the wheelchair, displaying some options for the user to select. This selection is made using an eye tracker. Experimental results with volunteers showed good performance in terms of the system usability. The main goal of this system is to improve life quality for users, providing augmented and alternative communication, mobility assistance and enhancement on activities of daily living.*

Keywords: *Assistive Technology, Wheelchair, Domotics, Eye Gaze.*

Introduction

There has been a major growth in the development and application of assistive technology for people with disabilities during the last decades. The main goal is to reduce their discomfort in a variety of tasks, mainly routine activities, by providing more self-sufficiency and reducing the dependency on external help [1]. For some severely disabled people, the main element to promote life improvement is an electric-powered wheelchair (EPW). According to the United States census, 3.6 million people currently use a wheelchair for everyday activities [2]. However, many individuals with motor-related diseases, or who suffered some accidents, as spinal cord injury, traumatic brain injury, multiple sclerosis, congenital problems, quadriplegia, or cerebral palsy have no possibility of using conventional manual controlled wheelchair [3], or even remote control or smartphones, in some cases, even voice control may be difficult.

For severely disabled people, their intention can be recognized either invasively or non-invasively to command devices and promote life-improvement [4]. To command electric-powered wheelchairs, a wide variety of approaches have been proposed, among: joysticks [5], EEG [6], EMG [7], hybrid EEG/EMG [8], and even a multi-modal interface, with flexibility to choose different modalities for communication (eye blinks, eye movements, head movements, by blowing or sucking a straw, and through brain signals), depending on the user's different level of disability [9]. Nonetheless, even with the advances on the state-of-the-art, assistive technologies struggle to become a handy tool. The signal acquisition equipment represents one of the main obstacles for a biosignals-based system in order to make their way out of the research labs.

Wheelchair users usually spend a substantial part of their time at home. There is a wide interest in assistive systems that, while seated on a wheelchair, allows the user to operate several common home appliances. The combination of assistive technology and home automation is an active field of study, often called assistive domotics [10]. Thus, the design of a SMAD (System for Multimodal Assistive Domotics) addresses everyday problems, improving functionality and activities of daily living (ADL). Recent research of NTA/UFES developed this SMAD, in which the control is achieved by means of biological signals [11]. In particular, some improvements were made on the control system modality, and it is possible to control the SMAD through eye gaze [12]. On the other hand, a virtual reality system for EPW driving training purposes and testing of control interfaces, the SimCadRoM (Electric-Powered Wheelchair Simulator) was used to test and validate the prototype to be used on a real wheelchair. Studies about the impact on the quality of life of people with amyotrophic lateral sclerosis, a neurodegenerative disease, caused by the use of systems based on eye gaze, are presented in [13].

The current work presents the online control of a robotic wheelchair and the connected equipment through the SMAD's SmartBox, using an eye gaze tracking system. The system is attached to the wheelchair, as well as a computer and a monitor screen, also on board, to allow the user to navigate through several screens and select a desired functionality to be performed. This research provides the users an easy and practical way to manage their activities of daily living.

Developed System

In this research, some tests with healthy volunteers, carried out in compliance with Helsinki declaration, and the experiments were performed according to the rules of the ethics committee of UFES/Brazil, under registration number CEP-048/08. They were conducted to evaluate the developed system, testing the guidance of the robotic wheelchair and the control of equipments on the environment.

The system is based on eye gaze, and uses the Eye Tribe Tracker, a cheap and easy to install commercial product. Figure 1 shows the whole system architecture, in where it is possible to understand how the robotic wheelchair, the user interface and the SMAD's SmartBox are linked.

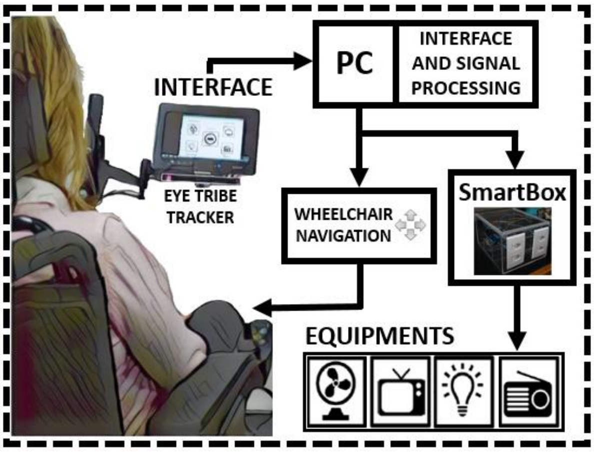

Figure 1: Developed system diagram.

One part of the system containing the eye tracking device, a computer and a monitor is installed on the wheelchair, as well as an Arduino board that commands the wheelchair motors through a connection on the wheelchair's joystick. This Arduino also communicates with the SmartBox through a Radio Frequency (RF) link, sending the desired tasks to be activated, related to the equipment selected. The other part is the SmartBox itself, which is an external acrylic box where the home appliances are connected, also developed on Arduino board. Each device is plugged into the box through a socket, with an associated electrical relay. The SmartBox has four available sockets, thus four different devices are possible to be commanded. Observing the diagram in Figure 1, a loop structure starts from the user, whose biosignals are the primary input, and ends with the wheelchair navigation and control of the environment.

The Eye Tribe Tracker was installed bellow the computer monitor, strategically positioned to provide a more comfortable use and to properly recognize the user's gaze. Eye Tribe Tracker is an eye tracking system that can calculate the gaze location using information extracted from the user's face and eyes. The eye gaze coordinates are calculated based on the screen the person is looking at, and are represented by a pair of (x, y) coordinates given on the screen coordinate system. All the system is based on the combination of Eye Tribe Tracker and the computer mouse control. For correct use of the Eye Tracker, it is necessary to calibrate the equipment always before using. Calibration is simple and takes less than 1 minute. The total time duration to recognize a command was set to 2 seconds.

The icons containing the control interface options have the dimensions of 5x5 cm. Figure 2 shows some of the control interface menu that the user can navigate through and select the desired option.

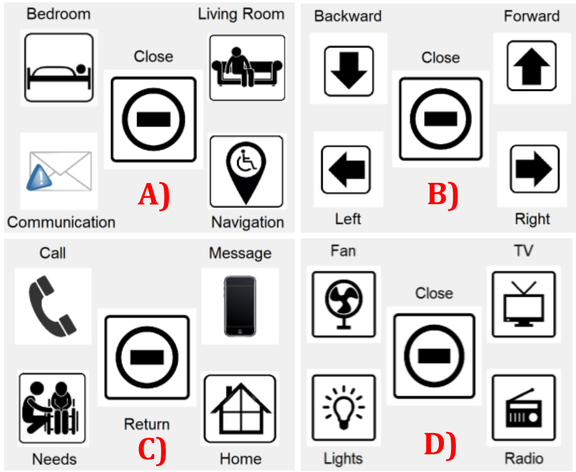

Figure 2: Some User's display interface options. A) Home Screen. B) Navigation Screen. C) Communication Screen. D) Living Room or Bedroom Screen.

As the use of the SmartBox is implemented, the user can select the desired options by looking at the specific icon on the menu interface. For example, by selecting the living room, it opens another window and gives the option to turn on/off the radio, lights, and fan, control the TV, or whatever is configured and connected to the outputs of the SmartBox. The interface windows are configurable for each room and user. The selection and command to turn on/off a fan is shown in Figure 3.

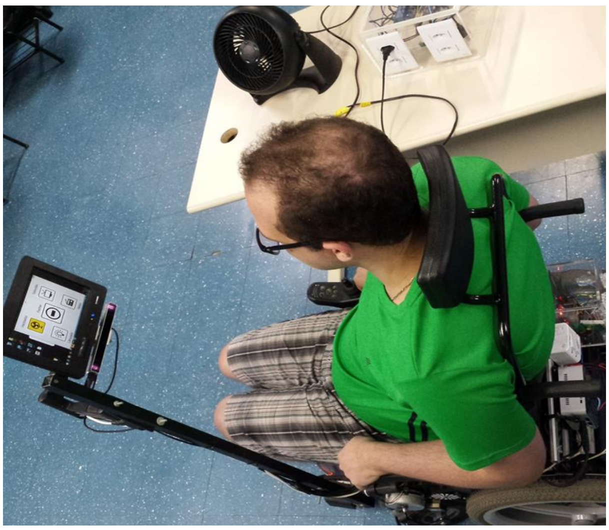

Figure 3: Example of desired user's selection.

There is an infrared (IR) receiver embedded into the SmartBox, from which the system decodes the pulses and interprets the corresponding command for the TV. Using a transmitter, it allows besides turning on/off the TV, to change the channels and turn the volume up or down.

A mobile interface application was also developed, making possible to receive commands on a smartphone. From the communication window in Figure 2, there are options that interact with the user's smartphone, sending messages, starting calls, and expressing their feelings to the family or caregiver.

Another very important interface of the system is the wheelchair guidance. With the selected Navigation window, the user has the options to turn it right or left, and to move forward or backwards. As mentioned before, the recognition time was set to 2 seconds. The wheelchair movement is based on discrete steps. However, if the user continues gazing a command icon repeatedly, the selected command becomes fixed and continuous, as long as the user remains focusing on it. The wheelchair navigation was tested with healthy volunteers, and Figure 4 exemplifies some of these tests.

Figure 4: Eye tracker navigation on a real wheelchair.

It is notorious the positive functioning of the system for different users, with an accuracy of 100%, taking into consideration height, weight, and whether they are glasses users or not. The volunteers were suggested to drive the wheelchair along a designed path at NTA/UFES laboratory, similar to the one shown in Figure 5.

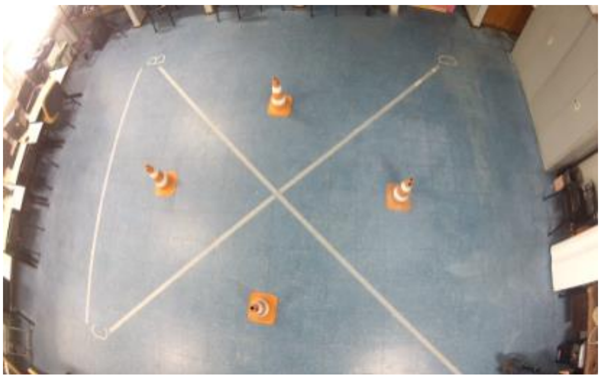

Figure 5: Desired path for wheelchair volunteer's navigation.

The desired path consists in easy maneuvers that simulates some possible situations an EPW user could face. The subject should leave the initial position A, cross the path through the letter B and C, reaching the final destination D.

All the volunteers performed very well this task and were able to select all the desired command icons. Besides, none of them complained about the use of the eye tracker interface, however, two of them reported difficulty to accomplish a proper turn on B and C. To overcome this situation, these users were trained for more time than the other volunteers. After the training, they were able to perform a much better wheelchair guidance.

Conclusions and Future Work

This work introduced the navigation of the UFES robotic wheelchair using an eye gaze interface, also used to control external equipments on the environment. The SmartBox communication with wheelchair worked successfully. It was also possible to confirm the convenience and ease way to use the developed system.

All the volunteers could perform all the tasks, and the tests to control the equipment were successful as well. The wheelchair navigation tests guided with the eye tracker were 100% effective.

However, two volunteers had difficulties to perform the turning maneuver initially, some because they were not familiar with the wheelchair use and guidance, and did not master the system faster. This was solved within minutes of use.

Feedback from users was very positive, no one complained about the initial device calibration. Unfortunately, one negative point that has been highlighted is due to the fact of watching the monitor screen for a long amount of time, which reduces a little the individual's field of vision.

Nevertheless, this assistive device is being developed for an end user who has no body movement, much less head movement. With this system, users are able to not only get around easily driving the wheelchair, but also to communicate with the family, interact with the home appliances that, until then, was absent to be operated by them.

As this research project continues under development, many improvements may be applied on the wheelchair and the system in general. Future works are related to the safety of wheelchair guidance, which will be applied from previous research [14]. Other strategy is to implement autonomous path guidance, in which the destination may be selected by the wheelchair users, and as the environment is previous mapped, an autonomous navigation mode can be set [15], and there is the possibility to implement SLAM algorithms on the wheelchair [16].

Tests with severe disabled people from CREFES and the University Hospital will be also considered, and a proper evaluation with the final user will be fulfilled.

Acknowledgment

The authors thank UFES for the laboratory structure and instruments, CNPQ and CAPES (Brazil) for financial support and scholarships.

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