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Multimodal System for Training at Distance in a Virtual or Augmented Reality Environment for Users of Electric-Powered Wheelchairs

Ludymila R. Borges*, Felipe R. Martins*, Eduardo L. M. Naves*, Teodiano F. Bastos, Vicente F. Lucena Jr*****

** Federal University of Uberlandia, Uberlândia, MG 38400-902 Brazil (e-mail: borges.ludymila@gmail.com)*
*** Federal University of Espirito Santo, Vitoria, ES 29075-910 Brazil (e-mail: teodiano.bastos@ufes.br)*
**** Federal University of Amazonas, Manaus, AM 69077-000 Brazil (e-mail: vicente@ufam.edu.br)*

Abstract: Recently, important progresses for controlling electric-powered wheelchair were made for people with disabilities. However, a significant amount of people affected by severe physical disabilities still cannot take advantage of autonomous mobility. For those situations, the use of biological signals to control the assisted environment emerges as a possible solution. In this scenario, the act of driving an electric-powered wheelchair without training can appear as a serious safety risk, which can be solved by using a virtual driving simulator. Nevertheless, when using biomedical signals as commands (eg.: brain-computer interface – BCIs), it is not possible to ensure a continuous and reliable control of the wheelchair due to state of the art of this technology, being necessary to associate it with features such as semi-automatic obstacle detection or contour, which are difficult and costly to reproduce. Thus, it is interesting to offer to new wheelchair's users the possibility of using a simulator that allows them to learn to drive the wheelchair prototype at distance, making use of appropriated telematics techniques, which is the proposal of this work. This research joints complementary skills from the following universities: Federal University of Amazonas (UFAM), Federal University of Espirito Santo (UFES) and Federal University of Uberlandia (UFU), with the collaboration of researches from the University of Lorraine (UL) in Metz-France.

Keywords: Assistive Technology, Augmented Reality, Electric-Powered Wheelchair, Multimodal System, Virtual Reality, Telematics Control.

1. INTRODUCTION

Electric-powered wheelchair (EPW), also known as motorized wheelchair, is an indispensable assistive technology device created to aid the mobility of people with severe motor disabilities from different pathologies (cerebral palsy, multiple sclerosis, myopathy, amyotrophic lateral sclerosis, etc.). Such devices can be dangerous to the user or other people when not properly managed. In order to use them safely, it is necessary to evaluate the driving capabilities of the user, right after the prescription of the EPW, after a learning phase for driving. It is also assumed a customization of the EPW, like the choice of sensors for human-machine interface and especially the regulation of driving parameters. In addition, a large number of potential EPWs' users have trouble conducting or are unable to drive them [Fehr2000] [Simpson2008]. In fact, the adaptation of current wheelchairs and the evaluation of the resulting human-machine interface are one of the biggest problems in the field.

In any kind of application (prescription, driving learning, customization or adaptation), driving tests with the users are a necessity. Whereas those users have severe physical disabilities, testing with real wheelchairs may involve some safety risks. It is also technically difficult to obtain non-trivial quantitative parameters such as the distance from an ideal trajectory, for example. From the early 90s some studies were developed addressing the design of EPW driving simulators, allowing the realization of experiments and evaluation of EPW in several driving situations with complete safety [Erren2007] [Pithon2009].

The first simulators for driving electric-powered wheelchairs were developed [Lefkowicz1993] [Swan1994] [Inman1994]. Originally as 2D representations, now they are mostly developed in 3D, due to the evolution of 3D model technology made it possible by the increased processing power of computers. Among the most successful simulators, there is the Wheelsim [Rnt2008, Lifetool2008] and Accessim [Ceremh2011]. There are even other simulator designs that use mechanical platforms in order to increase the sense of immersion in the virtual environment [Ito2009] [Gonçalvez2012]. An example of 3D simulator for driving EPWs is ViEW (Virtual Electric Wheelchair), which was created by the French laboratory LCOMS, and has several goals: safe driving learning, test of driving skills, aid in the customization process of the wheelchair, and test of new functionalities and methods in a safe environment [Morere2011] [Morere2012] [Morere2014].

The possible applications for wheelchair driving simulators are varied, such as learning to drive [Adeola2009] [Hasdai1997] [Harrison2002] [Archambault2012] or aid in the development of automatic functions of mobility [Braga2011]. One of the main interests of the simulation is the measurement of performance rates while driving: time spent performing a given task, number of movements made with the joystick [Archambault2012], spectral analysis of the movements [Niniss2006], average speed, average distance from a

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reference trajectory [Spaeth2008], distance of a route [Webster2001] or number of collisions.

In this context, the main objective of this work is to investigate the application of virtual and augmented reality techniques and biomedical signals in a tele-rehabilitation processes of wheelchair users. The final goal is to offer to new wheelchair users the possibility to learn how to drive this equipment in diverse stages, first trough simulators locally, second by using virtual/augmented reality, and finally by controlling a real wheelchair at distance (and receiving proper feedback).

2. METHODOLOGY

In order to achieve the proposed goal, a prototype is being developed to allow communication between two distinct environments: 1) a control room (CR), in which the user can visualize the training environment and remotely control a wheelchair through a joystick or biomedical signals; 2) a training room (TR), in which the wheelchair is positioned, along with a number of real and virtual obstacles to represent the difficulties faced by wheelchair users on a daily basis. An illustrative diagram of the prototype is shown in Figure 1.

The specific objectives of this research are:

- Develop and test new wheelchair control methods based on biomedical signals, such as sEMG, EEG, EOG, among others. The choice of the optimal input mode will be done for a person given the performance results on the human-machine system presented.
- Develop a set of interactive tools for tele-rehabilitation (or e-rehabilitation) as a way of communication and transmission of signals for remote control of the simulator.
- Develop and improve augmented reality processing techniques for interaction between environment and user.
- Develop techniques to measure performance at driving the electric-powered wheelchair through biomedical signals.

2.1 Driving simulators in virtual and augmented reality

Adopting the same methodology shown in [Silva2013], firstly sEMG (surface electromyographic), EOG (eletrooculographic) and EEG (electroencephalographic) biomedical signals will be used to conduct the ViEW simulator. After that, the simulator will be modified/replaced by an Augmented Reality (AR). This technique will make possible to combine the real world and virtual objects generated on the computer, making it possible to create environments containing both types of information. The goal is to allow the user to drive the wheelchair from the distance (i.e., safely). The use of AR will allow create different dynamic scenarios for driving in order for integration of virtual components in the real scene viewed by the user. The part of teleoperation allows a safe practice optimizing immersion thanks to the AR, thus allowing this system improve the immersion in the driving tests in tele- rehabilitation, which could be considered an augmented tele-immersion [DeFanti2001].

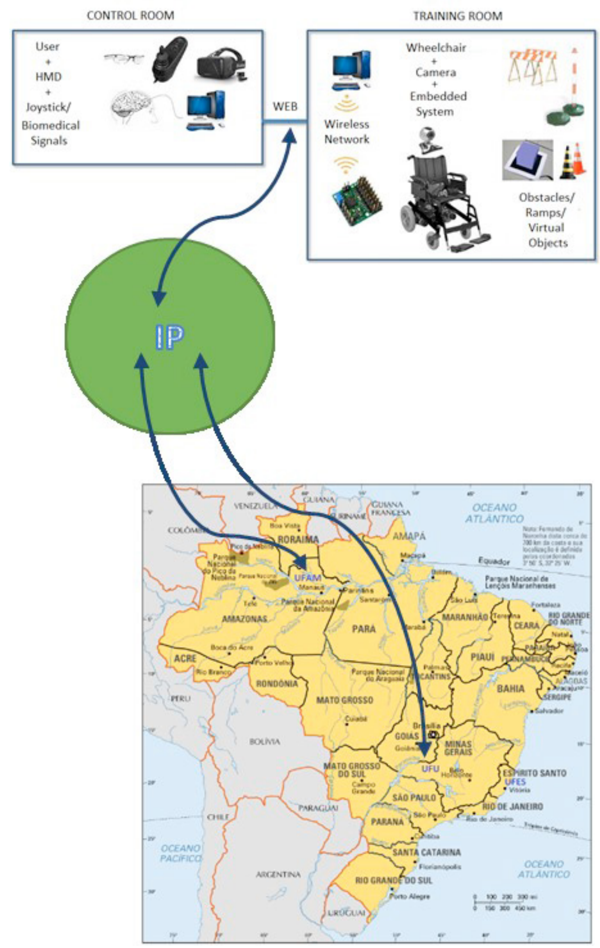

Fig. 1. Example of the architecture to control a wheelchair located in Manaus from Uberlandia.

2.2 Acquisition and processing of biomedical signals

For people suffering from severe physical disabilities (tetraplegia, amyotrophic lateral sclerosis, etc.) the biomedical signals are often one of the last possible methods to control an assistive technology device [Galvao2011]. As such, sEMG signals derived from the muscle activity, used for decades to control prosthetic limbs, can also be used as a control interface of the electric-powered wheelchair. Muscles used are those located on the face (masseter, frontal, etc.) and the sensors, for practical reasons, are non-invasive surface electrodes. For some people, the direction of the gaze is the only physical element controllable, and in this case, it can be used through eye-tracking devices (Video oculography – VOG) or through the acquisition and processing of EOG signals. Finally, if the person is no longer able to control the muscle contractions with reliability, the acquisition and processing of EEG signals are plausible resources (BCI – Brain Computer Interface), still in the form of non-invasive surface electrodes.