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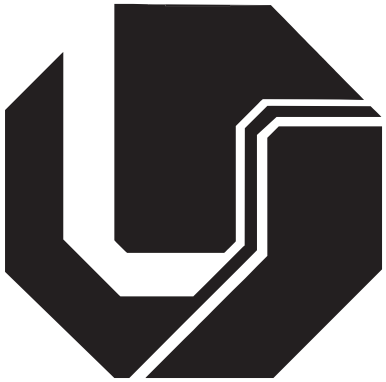

An Augmented Reality-based Telerehabilitation Architecture for Supporting the Training of Powered Wheelchair Users

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We often believe that we develop a job for someone, to benefit someone! However, in the middle of the process, we are feeling that we are the ones being worked. About how to look, how to develop our feelings and sensibility, in the strengthening of ties, which makes us grow as human beings. I thank of my entire self, for having had the opportunity to be with each one of you, volunteers, professionals, who enriched me and made it possible, to better understand one of these facets of the silent pain experienced by the powered wheelchair users.

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“Everything begins with choice!
Matrix Reloaded - 2003”

Abstract

Many people worldwide have been experimenting a decrease in their mobility as a result of aging, accidents and degenerative diseases. In many cases, a Powered Wheelchair (PW) is an alternative help. Currently, in Brazil, patients can receive a PW from the Unified Health System, following prescription criteria. However, they do not have an appropriate previous training for driving the PW. Consequently, users might suffer accidents since a customized training protocol is not available. Nevertheless, due to financial and/or health limitations, many users are unable to attend a rehabilitation center. To overcome these limitations, we developed an Augmented Reality (AR) Telerehabilitation System Architecture based on the Power Mobility Road Test (PMRT), for supporting PW user's training. In this system, the therapists can remotely customize and evaluate training tasks and the user can perform the training in safer conditions. Video stream and data transfer between each environment were made possible through UDP (User Datagram Protocol). To evaluate and present the system architecture potential, a preliminary test was conducted with 3 spinal cord injury participants. They performed 3 basic training protocols defined by a therapist. The following metrics were adopted for evaluation: number of control commands; elapsed time; number of collisions; biosignals and a questionary was used to evaluate system features by participants. Results demonstrate the specific needs of individuals using a PW, thanks to adopted (qualitative and emotional) metrics. Also, the results have shown the potential of the training system with customizable protocols to fulfill these needs. User's evaluation demonstrates that the combination of AR techniques with PMRT adaptations, increases user's well-being after training sessions. Furthermore, a training experience helps users to overcome their displacement problems, as well as for appointing challenges before large scale use. The proposed system architecture allows further studies on telerehabilitation of PW users.

Keywords

Powered Wheelchair Training, Augmented Reality, Telerehabilitation, Power Mobility Road Test, Biosignals.

Resumo

Muitas pessoas em todo o mundo estão vivenciando uma diminuição de sua mobilidade como resultado de envelhecimento, acidentes e doenças degenerativas. Em muitos casos, uma cadeira de rodas motorizada (CRM) é uma ajuda alternativa. Atualmente, no Brasil, os pacientes podem receber uma CRM do Sistema Único de Saúde, seguindo os critérios de prescrição. No entanto, eles não têm um treinamento prévio apropriado para dirigir a CRM. Conseqüentemente, os usuários podem sofrer acidentes, pois um protocolo de treinamento personalizado não está disponível. Além disto, devido a limitações financeiras e / ou de saúde, muitos usuários não podem comparecer a um centro de reabilitação. Para superar essas limitações, desenvolvemos uma arquitetura de sistema de telereabilitação com Realidade Aumentada (RA) baseado no PMRT (Power Mobility Road Test), para apoiar o treinamento de usuários de CRM. Nesse sistema, os terapeutas podem personalizar e avaliar remotamente as tarefas de treinamento e o usuário pode realizar o treinamento em condições mais seguras. O fluxo de vídeo e a transferência de dados entre cada ambiente foram possíveis através do UDP (User Datagram Protocol). Para avaliar e apresentar o potencial da arquitetura do sistema, foi realizado um teste preliminar de três participantes com lesão medular. Eles realizaram três protocolos básicos de treinamento definidos por um terapeuta. As seguintes métricas adotadas para avaliação foram: número de comandos de controle; tempo decorrido; número de colisões e biossinais. Além disso, um questionário foi usado para avaliar os recursos do sistema. Os resultados demonstram as necessidades específicas dos indivíduos que usam uma CRM, graças às métricas adotadas (qualitativas e emocionais). Além disso, os resultados mostraram o potencial do sistema de treinamento com protocolos personalizáveis para atender a essas necessidades. A avaliação do usuário demonstra que a combinação de técnicas de RA com adaptações PMRT aumenta o bem-estar do usuário após as sessões de treinamento. Além disso, esta experiência de treinamento ajuda os usuários a superar seus problemas de deslocamento, bem como a apontar desafios antes do uso em larga escala. A arquitetura de sistema proposta, permite estudos adicionais sobre a telerreabilitação de usuários de CRM.

Palavras Chave

Treinamento em Cadeira de Rodas Motorizada, Realidade Aumentada, Telerreabilitação, Power Mobility Road Test, Biosinais.

Publications

The following are publications resulted by this work:

1. Caetano, D.S.D.; Valentini, Caroline; Mattioli, Fernando; Camargos, Paulo; Sá, Thiago; Cardoso, Alexandre; Lamounier, Edgard; Naves, Eduardo. **Proposal of an Augmented Reality Telerehabilitation System for Powered Wheelchair User's Training**. In: Journal of Communication and Information System, v. 35, p. 51-60, 2020.

2. Mattioli, Fernando; Caetano, D.S.D.; Cardoso, Alexandre; Naves, Eduardo; Lamounier, Edgard. **An Experiment on the Use of Genetic Algorithms for Topology Selection in Deep Learning**. In: Journal of Electrical and Computer Engineering, v. 2019, p. 1-12, 2019.

3. Caetano, D.S.D.; Mattioli, Fernando; Lamounier, Edgard; Cardoso, Alexandre; Naves, Eduardo. **Adaptação de uma Interface USB para Joystick VR2 aplicada ao Treinamento de Usuários de Cadeiras de Rodas**. In: Tecnologia Assistiva Desenvolvimento e Aplicação: Canal 6 - Bauru, Ed. 1, p. 267-273, 2018.

4. Caetano, D.S.D.; Mattioli, Fernando; Lamounier, Edgard; Barbosa, A. S. **O Uso de Realidade Aumentada em Treinamento de Cadeirantes por Telereabilitação**. In: Tendências e Técnicas em Realidade Virtual e Aumentada. Tendências e Técnicas em Realidade Virtual e Aumentada, v. 5, p. 102-120, 2015.

5. Caetano, D.S.D.; Mattioli, Fernando; Cardoso, Alexandre; Lamounier, Edgard. **[DEMO] On the use of augmented reality techniques in a telerehabilitation environment for wheelchair users' training**. In: 2014 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2014, Munich, p. 329.

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List of abbreviations and acronyms

ADL	Activities of Daily Living
ALS	Amyotrophic Lateral Sclerosis
ANOVA	Analysis Of Variance
AP	Access Point
AR	Augmented Reality
ARSAWP	Augmented Reality System for the Assistance of Wheelchair People
ARTESH	Augmented Reality Based Telerehabilitation System With Haptics
AT	Assistive Technology
ATDs	Assistive Technology Devices
BVP	Blood Volume Pulse
CDA	Continuous Decomposition Analysis
EDA	Electrodermal Activity
ES	Embedded Systems
GLTF	GL Transmission Format
GPS	Global Positioning System
GSM	Global System for Mobile
GPRS	General Packet Radio Service
IADL	Instrumental Activities of Daily Life
IBI	Inter Beat Interval
ISCR	Integrated Skin Conductance Response
ICC	Intraclass Correlation Coefficient
IoT	Internet of Things
IP	Internet Protocol Address

HDMI	High-Definition Multimedia Interface
HMD	Head-Mounted Display
HMI	Human Machine Interface
HRV	Heart Rate Variability
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
MVC	Model-View-Controller
NASA-TLX	Task Load Index developed by the National Aeronautics and Space Administration
OT	Occupational Therapists
PerMMA	Personal Mobility and Manipulation Appliance
PCDA	Power Mobility Community Driving Assessment
PIDA	Power Mobility Indoor Driving Assessment
PMRT	Power Mobility Road Test
PW	Powered Wheelchair
PWS	Powered Wheelchair Simulator
RT	Real-time
RT-WiFi	Real Time WiFi
RSI	Robot Service Initiative
RSNP	Robot Service Network Protocol
SCR	Skin Conductance Response
SD	Sequence Diagram
SI	Stress Index
SPR	Skin Potential Response
SSQ	Simulator Sickness Questionnaire
UDP	User Datagram Protocol

UML	Unified Modeling Language
USB	Universal Serial Bus
URL	Uniform Resource Locator
VE	Virtual Environment
VR	Virtual Reality
VRE	Virtual Reality Environment
VRSIM-2	Virtual Reality-Based Simulator-2
WebGL	Web Graphics Library
WebRTC	Web Real-Time Communication
WLAN	Wireless Local Area Network
WSTP	Wheelchair Skills Training Program

1 Introduction

1.1 Motivation

In Brazil, more than 45 million people have some motor limitation. Among these, 2.33 percent (1 million people) have a severe motor disability, according to the 2010 census (GONZAGA, 2023). Mostly are elderly people whose autonomy is seriously affected by a decline in their motor function and cognitive performance. Also, it includes individuals who have suffered a stroke or injury (GONZAGA, 2023). According to the Census of England and Wales, carried out in 2011, 1.9 percent of the population use a wheelchair, an estimated 1.2 million people (GONZAGA, 2023). Other countries will have, proportionally, similar numbers within their population.

1.2 Objectives and Goals

The objective of this research is to evaluate the viability of a telerehabilitation environment with augmented reality techniques for the training of PW driving skills. To achieve this, the following goals were defined:

- To condute a literature review;
- To elucidate the main components of computer assisted rehabilitation systems, applied to PW training;
- To propose the main components to be used in each environment;
- To develop a web-server responsible for handling, measuring and saving information generated within the environments;
- To perform tests to assess the main application;
- To evaluate the solution with potential users; and
- To evaluate qualitative and emotional PW users training experience.

1.3 Thesis organization

The present thesis is composed of seven chapters, described as follows.

- Chapter 1 describes the motivation, aim, and objectives of this work;

- Chapter 2 introduces the background of the concepts used in the Presented solution;
- Chapter 3 presents related work;
- In Chapter 4 and 5 present, materials/methods, and implementation details;
- In Chapter 6, the preliminary results obtained in this research are discussed and;
- Finally, Chapter 7 presents the conclusions and future developments of this research.

Bibliography

GONZAGA, L. G. Identificação e medição de defeitos em produtos automotivos usando visão computacional. Serra, 2023. Citado na página 1.