VR Serious Game for Myoelectric Prosthesis Training with Tactile Feedback*

Reidner Santos Cavalcante†
Faculty of Electrical Engineering
Federal University of Uberlândia
Uberlândia, Brazil
reidnersc@outlook.com

Aya Gaballa
Mechanical and Industrial Engineering Dept
Qatar University
Doha, Qatar
aya.gaballa@qu.edu.qa

John-Jonh Cabibihan
Mechanical and Industrial Engineering Dept
Qatar University
Doha, Qatar
john.cabibihan@qu.edu.qa

Alcimar Soares
Faculty of Electrical Engineering
Federal University of Uberlândia
Uberlândia, Brazil
alcimar@ufu.br

Edgard Lamounier
Faculty of Electrical Engineering
Federal University of Uberlândia
Uberlândia, Brazil
lamounier@ufu.br

ABSTRACT

In recent years, Virtual Reality (VR) applications have attracted increasing attention for preparing amputees to properly use a prosthesis. In this paper, we propose an SG-based system that uses immersive Virtual Reality (iVR) and EMG signal processing to provide a training environment for amputees who are supposed to use myoelectric prostheses. This type of prosthesis requires a more complex control system. The system described in this paper runs on a Vive Pro System using a Vive Tracker to track the user's arm position and orientation and mirror the movement into a virtual prosthesis. EMG signals control the opening and closing of the virtual prosthesis, and vibrational elements placed on the user's forearm provide sensory feedback. The proposed system acts as a useful therapeutic tool for amputee rehabilitation. Our results show that virtual training can be greatly improved when proper tactile feedback is provided, especially for myoelectric controlled prostheses.

CCS CONCEPTS

• Computing methodologies ~ Modeling and simulation ~ Simulation support systems ~ Simulation environments

KEYWORDS

Tactile feedback, Immersive Virtual Reality, myoelectric prosthesis, prosthetic training.

1 Introduction

Limb amputation is a traumatic event capable of triggering major changes in all areas of the subject's life. Usually, after amputation, a surgical procedure is performed to create new functional perspectives for the remaining segment of the amputated limb (usually referred to as stump) [1].

In the past years, Virtual Reality (VR) has been considered a potential approach for prosthetic training [2]. However, most VR-based upper-limb prosthetic training systems, reported in the literature, are based on non-immersive environments [3]. In fact, in many initiatives, users only visualize a virtual prosthesis, at a distance, on a flat screen. Unfortunately, this lacks intuition for real-life prosthetic control. Furthermore, sole visual feedback drastically limits the immersive experience for prosthesis training, which requires users to reach and manipulate different objects.

For instance, even without tactile feedback, users may rely on the vibration promoted by the prosthesis motors and the torque imposed on the stump when manipulating objects.

It is important to provide users with the feeling of touch to enhance the embodiment experience and potentially provide sensations usually present when training with real devices. Such feedback is especially crucial for myoelectric prostheses.

This paper presents the development of a virtual training environment for rehabilitation of upper limb amputee with tactile feedback. We hypothesize that such integration can provide the user with a high immersion level in the virtual space.

The central motivation of this research is based on the search for a solution that can help the training of amputees of prostheses, from the development of an immersive virtual environment equipped with sensory feedback, to significantly reduce the disadvantages mentioned above.

2 Materials and Methods

To evaluate this proposal, an iVR system has been designed. The system's main components are HTC Vive Pro, Vive Tracker, EMG controller (data acquisition and pattern recognition), vibrational armband, and a computer. The user interacts with the virtual environment by moving and contracting the stump muscles. In the case of nonamputee volunteers, forearm muscles are used.

The Vive Tracker, located in the forearm, provides information so that the virtual prosthesis moves within the virtual environment as the user moves his/her forearm. The EMG module processes the contractions of the stump (or forearm) muscles and sends setpoint values to the virtual environment to indicate when the virtual prosthesis must open or close.

The vibrational armband, and the EMG sensors are also positioned on the user's forearm. Whenever the user grabs an object in the virtual environment (Fig. 1), vibration feedback is sent to the user to convey touch. If the object is dropped or released, the feedback stops.

Three virtual environments have been developed, based on traditional tests: Box and Blocks, Nine Hole Peg and Clothespin Relocation. Each one is based on a different test to evaluate functionality and users' performance. The settings for each environment can be configured by a therapist accessing a secondary system, where the data from the therapist, patient and each session are recorded.

For this study, eight non-amputee male volunteers, ages between 20 and 40, were recruited. These volunteers were divided into two groups: G1 - performed the B&B tasks while receiving visual and vibrational tactile feedback; G2 - performed the B&B tasks while receiving only visual feedback. For this study, tests were performed only in the Box and Blocks environment.

In this experiment we performed four trials using the box and blocks environment with the experimental group receiving tactile feedback (G1). No tactile feedback was given to the control group (G2). In each trial the volunteers were asked to move all blocks from one side of the box to the other as fast as possible. The time to complete each trial was registered.


Press the Green button to Start.

Ready to start the trial phase

Points: 0

Figure 1: iVR environment for the Box and Blocks Test


Press the Green button to Start.

Ready to start the trial phase

Points: 0

Figure 2: iVR environment for the Nine Hole Peg Test

3 Conclusion

In this paper, we investigated the importance of sensory feedback to enhance embodiment during myoelectric prostheses using iVR. Three different environments were implemented, allowing the user to train to use a myoelectric prosthesis. The dynamic of the game intends to simulate the use of a real prosthesis on common daily tasks, such as grab an object.

A trial experiment using the Box and Blocks environment was performed with one group using visual and tactile feedback and another group using only visual feedback.

Although both experimental groups showed improvement in the control of the myoelectric virtual prosthesis over the trials, participants of the group using tactile vibrational feedback showed better performance as the trials progressed, compared with the group that did not use tactile feedback.

Those results indicate that sensory feedback is indeed capable of providing a better overall experience while optimizing training sessions using immersive virtual reality environments.

Future steps for this work involve extensive tests with amputee subjects in all three environments seeking to perfect the system with that population.

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