Virtual reality environment for validating prosthetic designs with physical conditions similar to the real world.

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Abstract— **This abstract presents an approach utilizing virtual reality (VR) technology for simulating prosthetic hands and conducting electromyography (EMG) tests. The aim is to provide a functional replacement for a lost hand, promoting independence and autonomy for individuals. By leveraging VR technology, realistic simulations and EMG testing can be conducted, enhancing the development and evaluation of hand prostheses. The methodology involves integrating VR, EMG signals, and a prosthetic hand control system. The results obtained from the experiments are predominantly quantitative, facilitating a comprehensive assessment of the system's performance and effectiveness. The utilization of VR technology in simulating prosthetic hands and conducting EMG tests offers a promising avenue for advancing the development and evaluation of hand prostheses.**

Keywords— **Virtual Reality, Electromyography (EMG), Prosthesis, Communication protocols, Virtual rehabilitation.**

I. Introduction

The hand prostheses play a key role in promoting independence and autonomy [1]. By providing a functional replacement for a lost hand, prosthetic hands allow the user to regain essential skills and perform a variety of everyday tasks [2]. Furthermore, in recent years, virtual reality (VR) technology has been employed to simulate the functionality of hand prostheses and conduct tests with EMG. VR provides a realistic and immersive environment where users can interact with virtual representations of their prosthetic hands. By using motion tracking and haptic feedback, individuals can perform various tasks and movements, allowing them to assess the functionality and usability of the prosthetic hand [3]

VR technology enables controlled and repeatable EMG testing by integrating sensors into virtual environments [4]. Users generate EMG signals through muscle contractions, evaluating the accuracy and precision of the control system and different hand prosthesis designs. VR-based testing improves prosthetic design and functionality [5], offering a safe and cost-effective alternative for rapid prototyping. Well-designed hand prostheses allow users to perform various tasks, enhancing daily activities and social integration [2]. They promote acceptance, reduce stigma, and enable engagement in recreational activities such as music, sports, and crafts [6]. By leveraging VR technology, prosthetic systems can significantly enhance the lives of individuals with limb loss.

The functional hand prosthesis is vital in professional contexts because it provides the independence needed to operate equipment, perform precise manipulations, and engage in profession-specific activities. The prosthesis significantly enhances the user's quality of life [7], boosting self-esteem, self-confidence, and overall well-being. By enabling daily activities, social interactions, hobbies, and independent work, it empowers the user, leading to a higher quality of life.

II. METHODS

A. Data acquisition

Initially, data from EMG of the biceps brachii muscle were collected using OpenVIBE and processed in OpenVibe Designer. Following the baseline collection, a bandpass filter, rectification, and enveloping were applied to the signal. The data were divided into 0.5-second windows, and the mean was calculated within each window. Using the mean and standard deviation from the baseline, the data were normalized. The processed data were then sent to Unity through a Python script, enabling control of the virtual prosthesis. This approach enhances the development of prosthetics and improves users' quality of life by providing more efficient and realistic control of the prostheses. The integration of electromyography with virtual reality technology holds possibilities for enhancing the functionality of hand prostheses and increasing users' independence and autonomy. This method offers a more precise and immersive solution for prosthetic control, contributing to overall improvements in users' quality of life.

B. Framework

The system architecture was designed to facilitate the connection between OpenViBE and Unity, allowing for the control of a virtual prosthetic hand through EMG signals. The EMG data was acquired using the V-amp® device, while the integration with the Virtual Reality environment involved the use of OpenViBE®, Unity, the VIVE Cosmos Elite Kit®, and two cameras for spatial tracking. The software structure consisted of two layers. The first layer utilized the MQTT protocol for connectivity between OpenViBE and Unity, employing Python scripts for data transmission. The second layer encompassed C sharp scripts and prefabs in Unity for visual connections and integration of the systems via the MQTT protocol. Configuring MQTT parameters ensured smooth communication among the components.

C. Virtual reality environment

This environment was designed using virtual reality assets and specifications provided by the Vive Cosmos Elite Kit®. The initial setup consists of a robotic arm with divisions for each finger and arm segment. By utilizing the data sent from OpenViBE® to Unity®, which is related to arm movement, there is a corresponding change in the angles of the virtual arm. This enables the virtual arm to mimic the movement of the human arm based on EMG data.

III. RESULTS

A virtual reality environment was developed to validate upper limb prosthetic designs by incorporating physical constraints. This environment allows for the testing of prototypes in a realistic scenario prior to their physical production, involving end-users in the design cycle and enabling rapid iteration of prosthesis versions. Additionally, a real-time muscular electric signal processing pipeline was developed, which is not specific to any particular amputation condition. By utilizing machine learning techniques in signal processing, it is expected that the same pipeline can be applied across diverse patient amputation conditions.

IV. CONCLUSION

In summary, hand prostheses significantly enhance independence and quality of life for individuals by providing functional replacements for lost hands. These prosthetics enable users to regain essential skills, perform daily tasks, and engage in various activities autonomously. The integration of virtual reality technology in simulating prosthetic hands and conducting EMG tests further advances the field by offering realistic and immersive experiences for evaluation and refinement. This combination of well-designed prostheses and VR-based testing holds immense potential for driving innovation, empowering individuals, and fostering social integration.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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