VR による上肢リハビリテーションシステムに関する研究

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A VR-based Upper Limb Rehabilitation System

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Abstract: This paper proposed a Virtual Reality (VR)-based self-rehabilitation system which utilize the virtual training model rendered by OpenGL and collects electromyography (EMG) signals from the subjects to perform hand motion recognition. Combining sEMG with VR Technology, the proposed self-rehabilitation system could provide enhanced visual feedback about movement trajectory which is beneficial to improve motor function task learning and execution compared with traditional therapy. Through the proposed system, stroke patients can realize the self-rehabilitation training of upper limb at homr. The effectiveness of the proposed rehabilitation system has been verified by the virtual ball gripping experiment.

1. Introduction

Aging population ratio in japan is the highest among 17 other countries and it is said it will continue increasing and will exceed 30% by 2025[1]. The increase in the number of elderly people contribute to the increase of illness due to aging and injury. Thus, the support for persons with physical disabilities becomes a big problem. Along with this, it is said that the number of patients with cerebrovascular disease will increase as the population ages. Cerebrovascular disease is often accompanied by sequelae such as unilateral paralysis, and it is thought that it can be recovered by continuous rehabilitation. However, as the number of patients increases due to aging, the number of caregivers and therapists is insufficient for the huge number of patients. Therefore, we proposed a novel rehabilitation system which can provide the active self-training to assist the therapists.

2. Research purpose and approaches

In this study, we aim to construct an active upper limb rehabilitation system for hemiplegia patients through collecting sEMG signals and using hand model created in virtual reality (VR) to perform the recovery training with haptic feedback. The proposed system consisting of an A/D board, a computer, a haptic device, and an EMG collector. Thus, a recording of sEMG signals is taken, and the raw sEMG signals will be processed in order to remove the noises and remaining the high fidelity of EMG signal which will be used a lot in this proposed system. Next, to determine the suitable threshold value needed to be set up in the hand grasp rehabilitation using phantom haptic device, the relationship of the gripping force and myoelectrical potential is also shown. Then, the threshold value is set up in the proposed system as an assistant level parameter and the phantom device handle gripping following a virtual ball experiment is done to verify the performance.

3. sEMG Signal processing

The sEMG is a recording of potential changes and myoelectric potentials that accompany muscle activities. The sEMG signals will be detected and recorded by passing it through the electrode and this information can be useful in force estimation and rehabilitation assessment [2].

In this study, the Butterworth filter which is a low-pass filter that exhibits the maximum average amplitude characteristics in the passband is incorporated to process the sEMG signal.

4. Gripping Force Evaluation

To show the relationship of gripping force and EMG to determine the suitable threshold force needed to be set in the constructed rehabilitation system using the phantom device, the sEMG signal of flexor digitorum superficialis muscle is measured with the same method above by using the hand-held dynamometer. The data was collected at every 5kg of force exerted. The result is shown in Table I and the sEMG signal taken for the 5kg (minimum force exerted) and 35kg (maximum force exerted) are shown in Fig.1.

Table I sEMG Signal from 5 kg until 35kg Exerted

force(kg)	sEMG(mV)
5	0.06
10	0.063
15	0.065
20	0.073
25	0.081
30	0.085
35	0.09

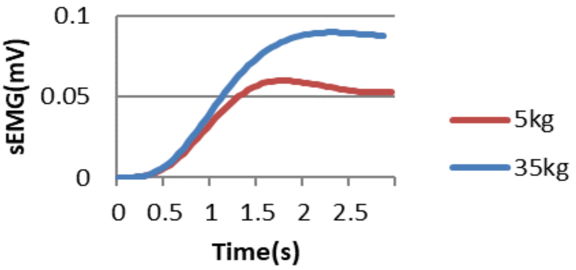

Fig.1. The Comparison of sEMG Signal of Minimum 5kg and Maximum 35 kg of Force Exerted

It shows that the value of myoelectric potential increases in proportion to the increase of gripping force. The minimum sEMG signal value recorded at 5kg exerted force which is 0.06mV is set as the threshold value in virtual ball grasping experiment.

5. Rehabilitation System using Phantom device

The neurorehabilitation using VR is proposed and the phantom device handle gripping following a virtual ball experiment is done. Virtual Reality has been applied in the proposed rehabilitation system for the purpose of enhancing the sense judgement and raising training interest. The procedure of the proposed training system is described in Fig.2.

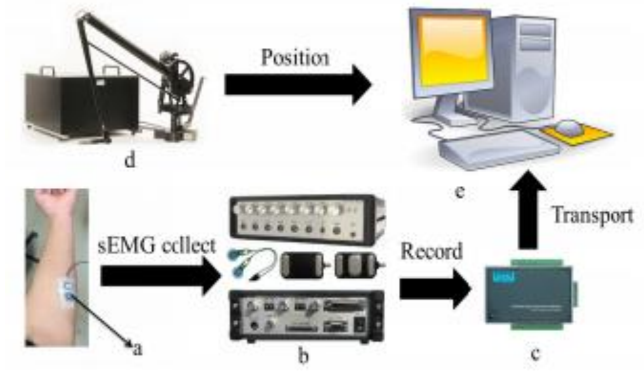

Fig.2. Schematic of the proposed rehabilitation system (a:dry electrode; b:signal acquisition device and filter box; c:A/D board; d:Phantom Premium; e:computer)

In this rehabilitation system, surface EMG of Digitorum Superficialis Muscle were collected by a dry electrode which was attached on the subject's skin. The subject manipulates the handle of phantom to control the virtual hand model rendered by OpenGL and displayed on the computer's screen to reach the target's position in which there is a virtual ball and complete the action of grasping the ball. If the gripping force exerted by the subject are higher than the set threshold value which is 0.06mV, the virtual ball on the screen will disappear. The state is shown in Fig.3 and Fig.4 and the result of the experiment is shown in Fig.5 and Fig.6.

6. Conclusion up to now

In this research, the upper limb rehabilitation system using VR is proposed which can provide the active self-training to the hemiplegia. To reduce the noise signals, the signal processing is carried out. To show the relationship between grip strength and sEMG signals, a measurement experiment using a hand-held dynamometer was conducted. As a result of the experiment, it was confirmed that the value of sEMG signals increased in proportion to the gripping force and the minimum value obtained is set as the threshold in the Phantom Device Handle Gripping following a Virtual Ball Experiment. As the result of the experiment, the system worked according to the set threshold and the sEMG obtained will be helpful in rehabilitation training progress evaluation. Future tasks include adding a few types of force feedback to cater different severe level of hemiplegia patients and creating a new VR rehabilitation game to increase the training sensation and interest.

Fig.3. Movement of Handle State

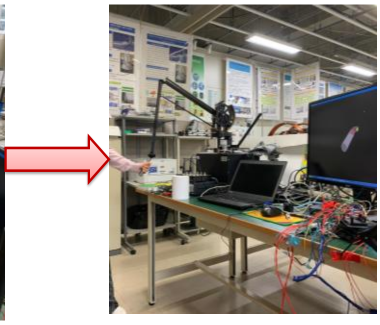

Fig.4. Gripping of Handle State

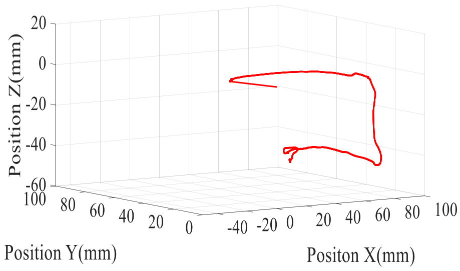

Fig.5. Trajectory of Hand Position

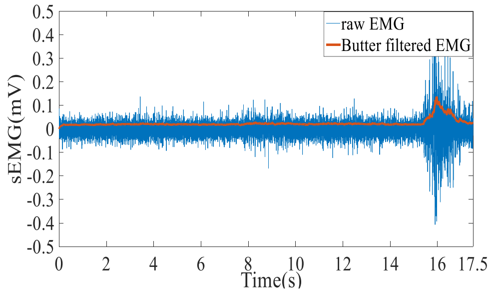

Fig.6. Obtained sEMG Signal

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