Augmented Reality Based Reaching Exercise for shoulder Rehabilitation

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ABSTRACT

Stroke or cerebrovascular accident (CVA) causes disability and affected the person's quality of life. The rehabilitation therapies are normally conducted for post stroke patients to promote their quality of life and daily living standard. Among rehabilitation exercises, shoulder range of motion (ROM) exercise and muscle strengthening exercise are the most important rehabilitation therapies for post stroke patients as this can improve their activities of daily life. Among the shoulder ROM exercises, the reaching exercise is normally conducted with checkerboard in rehabilitation centre as a traditional therapy which becomes boring after trained for few times. To overcome this problem, same exercise with augmented reality (AR) based game like style incorporate with motivated visual and audio feedbacks has developed and details of the system is presented in this paper. The AR based reaching exercise has developed within the normal average range of motion. The system includes personal computer or laptop, webcam, marker and BioGraph Infiniti system. Thus, it can be used at home without modifying anything and patient can use easily by himself without extra help. The developed system has integrated with biofeedback system to become more effective in rehabilitation. The integrated system has already tested with healthy subject and worked perfectly with positive feedbacks.

Keywords

Human-Computer Interface; AR Games; Colour Tracking; Biofeedback; Upper-Limb Stroke Rehabilitation

1. INTRODUCTION

Stroke is one of the most leading causes of disability in all over the world. The consequences of stroke are very devastating such as loss of balance, hemiplegia, loss of coordination, etc. These consequences effect on post stroke patient's quality of life. The effected quality of life can be improved with rehabilitation therapy for post stroke patients so that they can regain back their normal social life in the community. In terms of rehabilitation therapy, traditional rehabilitation therapies are normally mundane as time goes by that make the patients are feeling poor and less engorging to practice the rehabilitation exercise, this was the motivation for the researchers to investigate AR based rehabilitation systems which are motivating and inspire the patients' mind to accept and interact with the long rehabilitation time. The low cost webcam based game therapy that is a part of augmented reality based rehabilitation game systems make popular nowadays. This paper presents an integrating with AR technology with shoulder rehabilitation exercise for post stroke patients. The shoulder has chosen since the shoulder joint is one of the major joints to perform the daily life activities such as eating, holding, wearing and etc. The shoulder rehabilitation such as reaching exercise aims on two major aspects which are range of motion (flexibility) and muscle strengthening. The progress of these trained muscles can be monitored and controlled with biofeedback signal. Adding of the biofeedback system to the rehabilitation therapy contributes positively during training [1-3]. Therefore, integrating the biofeedback system to AR based reaching exercise for shoulder rehabilitation became one of the main objectives in this work.

The remainder of the paper are organized as follow: related work has reported in section 2, shoulder and arm anatomy is enlightened in section 3, shoulder range of motion exercise is stated in section 4, detail of augmented reality (AR) based rehabilitation exercise has explicated in section 5 and conclusion and future work have presented in section 6.

2. RELATED WORK

There are a lot of interventions for reaching exercises such as manipulator based exercises, exoskeleton based exercises and augmented reality based reaching exercises.

The manipulator [4-7] or exoskeleton [8-10] based reaching exercises have been developed for upper limb rehabilitation. All of the developed systems have used different approach such as planar robotic technology, exoskeleton or combination of robotic and virtual reality technology to train the shoulder joint and arm muscles. Although the evaluations of these developments have proven the positive results in shoulder and arm muscle rehabilitation, the complete system is bulky and some of them are not friendly to be used by patients themselves. The virtual reality that integrated with that planar robot system is purely computer-generated virtual world which need to interact with patient by means of data glove, head mount display and etc. Thus, the

patient has to wear additional devices during rehabilitation exercise which will cause the inconvenience to the patient.

Moving forward from this, researchers are integrated the surface electromyography (sEMG) biofeedback system to manipulator or exoskeleton with virtual environment exercise. The sEMG based manipulators or exoskeletons for shoulder rehabilitation system allow the patients to choose either passive or active training according to their degree of impairment as can be found in [1-3].

Although virtual reality contributes positively to the rehabilitation therapy, it strives for totally immersive environment where users may not feel the real effective interaction. In contrast, augmented reality (AR) system provide the combination of real and virtual world scene where user can monitor himself merging with virtual image on display screen. The augmented reality based rehabilitation games have developed by J. W. Burke [11] and A. Alamri [12] for upper limb stroke rehabilitation. Both developments are webcam based games to train the activities of daily life such as picking up the cup and placing on the shelf. Although both systems have proven the AR technique offers motivating and encouraging rehabilitation exercise to overcome bored and tedious traditional rehabilitation exercise, it has yet to provide the biofeedback from subjects' biological signal. Thus, we have developed AR based reaching exercise with biofeedback system to complete the higher quality of rehabilitation therapy.

3. ANATOMY OF SHOULDER AND ARM

Human shoulder is made up of clavicle bone, scapula bone and humerus bone with associated muscles, tendons and ligaments. There are three joints: the glenohumeral (GH), the acromioclavicular (AC) and the sternoclavicular (SC) joints where the human upper extremity is attached to the trunk as illustrated in figure 1. Shoulder joint or glenohumeral (GH) joint is one of the most important joints to mobile for daily life activities. It is a ball and socket joint which allows wide range of motions with three degree of freedom (DOF) such as abduction and adduction (yaw), flexion and extension (pitch) and lateral and medial rotation (roll). The movement of range of motions is completed when contracting the specific muscles of the upper arm.

Our AR based reaching exercise targeted to train the shoulder flexion and horizontal adduction movements. The muscles that support to move shoulder flexion are coracobrachialis, pectoralis major, anterior deltoid and biceps brachii. The horizontal adduction movement is achieved by contracting of coracobrachialis, pectoralis major and anterior deltoid as figure 2 shown.

4. SHOULDER RANGE OF MOTION EXERCISE

Conventional range of motion and muscle strengthening exercises are traditional methods for motor deficits rehabilitation. Range of motions becomes limited after stroke and it leads to pain, limited the patients' daily life, risk of skin breakdown and pressure sores. Thus, range of motion exercises as rehabilitation therapy for stroke patients become very important. There are three types of range of motion exercises can be practiced namely active exercise, active-assistive exercise and passive exercise. In this paper, active exercise has chosen for shoulder range of motion exercise where patient needs to train his muscles and joint without any assistant. The average normal range of motion of shoulder flexion and horizontal adduction is 0º to 170º and 0º to 130º. [13]. The

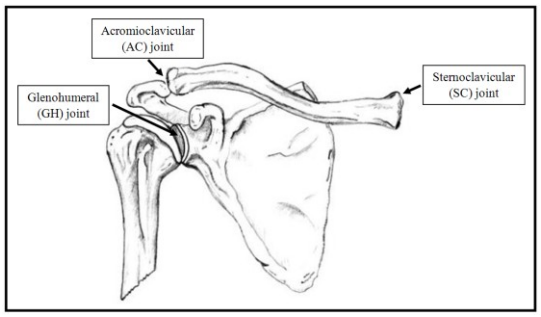

Figure. 1. Shoulder Anatomy

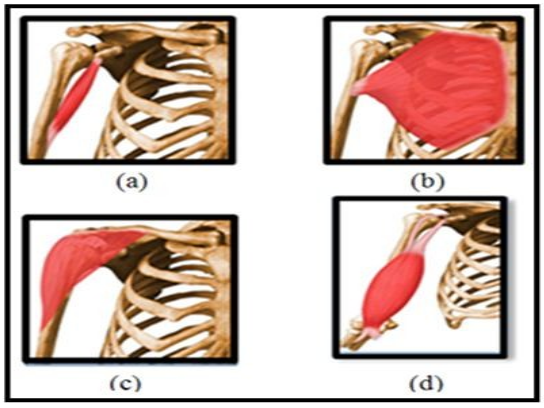

Figure 2. Muscles that contribute to shoulder flexion and horizontal adduction movements (a) Coracobrachialis (b) Pectoralis Major (c) Anterior Deltoid (d) Biceps Brachii

developed system is aimed to train for shoulder flexion and horizontal adduction within average normal range of motion explained in [13] and detail will enlighten in next session. The occupational therapy (reaching exercise) that used to train and strength for shoulder and arm muscles is illustrated in figure 3. Inspired by these exercises, augmented reality based reaching game has developed in this work to improve the shoulder and arm muscles and range of motion of shoulder joint. Unlike traditional reaching exercise, the developed system has better motivation as patient can monitor their own movements, game like reaching exercise which patient will receive the visual and audio feedback directly.

5. AUGMENTED REALITY (AR) BASED REACHING EXERCISE

5.1 Hardware Setup

The system includes personal computer (Dell 22" monitor and CPU), webcam (logitech), Biograph Infiniti package for biofeedback signal and marker. The overall system experimental setup is shown in figure 4. Patient is asked to sit with the distance of 800 mm between computer monitor and shoulder joint. Then, patient is asked to wear four sEMG electrode on four muscles namely coracobrachialis, pectoralis major, anterior deltoid and biceps brachii which are responsible for shoulder flexion and horizontal adduction movements. The sensor positions of these muscles are depicted in figure 5. The marker is also attached to patient thumb in order to track the real time position of patient's arm. The hardware setup is completed by attaching the sensors

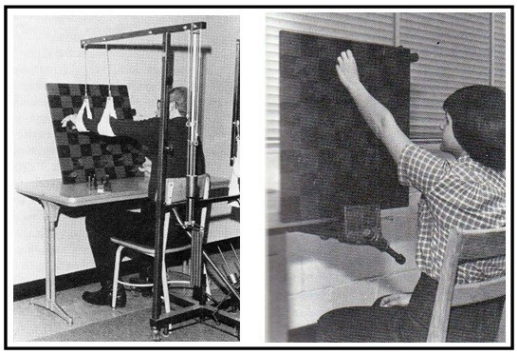

Figure 3. Occupational Therapy for Post-stroke Patient in Rehabilitation Centre

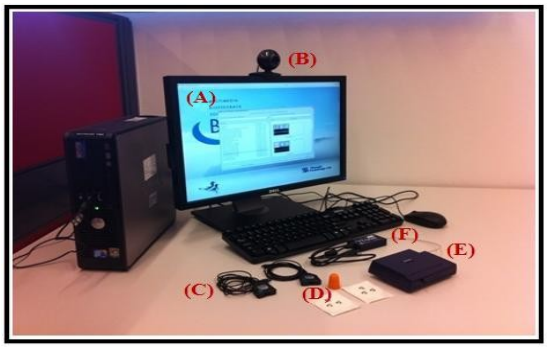

Figure 4. Overall system experimental setup (A) Personal Computer (B) webcam (C) sEMG Electrodes (D) Finger Glove Marker (E) FlexComp Encoder (F) TT-USB Interface with USB and Fiber Optic Cable

and wearing the marker, which make patient ready to practice for AR reaching exercise and follow the instruction on the screen.

5.2 Reaching Exercise Development

The AR reaching exercise had developed with adobe flash professional software and according to game design fundamentals to motivate patient's interest[14]. There are five different shape solid elements at the bottom and same shape but hollow elements at the top row of the monitor on the game stage. The aim of this exercise is to pick up one of the solid element at each time and place at the same shape of hollow elements. These elements are spread out by 80mm. The maximum horizontal distances between these elements are 320mm. Thus, the maximum shoulder horizontal adduction movement for AR reaching exercise is 22º which is within the average normal range of motion for horizontal adduction as mention in previous section. The vertical height between two rows is 200mm and therefore shoulder flexion angle for AR reaching exercise is 14º which is within the maximum range of motion for shoulder flexion angle described in previous session. The schematic diagram of AR reaching exercise distance is shown in figure 6. The exercise is AR based and thus the movement of shoulder and arm can be easily monitor with an aid of webcam feed image. Adding of timer, score and audio feedback inspire the patient's interest during playing of reaching exercise. Therefore, the developed AR reaching exercise is aiming to replace the traditional reaching therapy which is easily bored and lost interest after trained for few times.

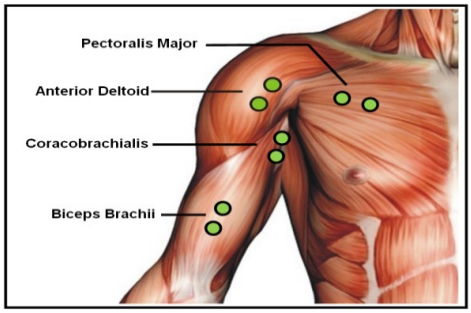

Figure 5. SEMG Electrode Sites

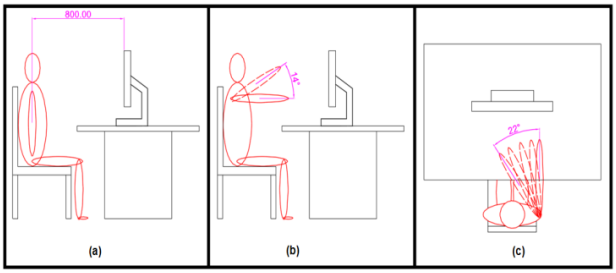

Figure 6. (a) Distance between Shoulder Joint and Display Screen (b-c) Shoulder Flexion and Horizontal Adduction ROM

5.3 Integration with BioGraph Infiniti

Biofeedback provides positive contribution in rehabilitation therapy in general. There are many studies have done to prove the benefit of biofeedback for upper extremity [1-3]. Hence, our system has integrated with BioGraph Infiniti biofeedback system [15] to become more effective rehabilitation system for shoulder and arm rehabilitation. There are two screens for integrated reaching exercise. Screen-1 includes four line graphs to monitor individual muscle performance, display box for current sEMG value and mean value for individual muscle. While screen-2 consists of AR reaching exercise, shoulder and arm muscle animation and bar graph at lower right corner which defined threshold value for each muscle with audio feedback. The screen shots are illustrated in figure 7. The surface electromyography (sEMG) sensors are used to collect the signal from patient muscle and monitor the performance of the active of each muscle during training. The sEMG sensors are placed on the specified muscles of shoulder and arm as explained in previous session.

6. EXPERIMENT AND RESULT

The developed AR based reaching exercise has tested with healthy subject and screen shots are as shown in figure 8. The subject was asked to be seated according to the figure 6. The EMG sensors were attached to the subject's arm muscles to record the muscle performance during rehabilitation exercise. The marker was attached to the subject thumb to track the subject hand position. During performing the transfer game exercise, the subject found to be concentrated in the game to compete the timer which will result in subject win. The present of trained muscle animation which is located top right corner and audio feedback signal threshold which is located bottom right corner provide the additional information of the trained muscles to the subject. The data of EMG signals which are displaying on screen 1 were recorded during every exercise. The aim is to compare the muscle performance after few routines of rehabilitation exercise by

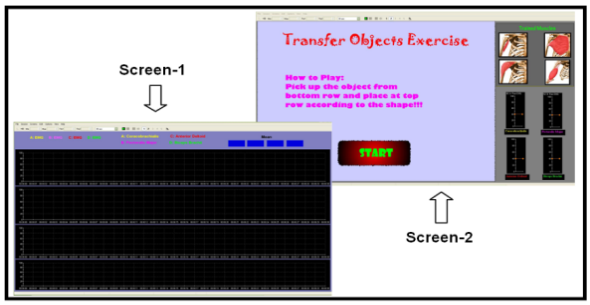

Figure 7. Screen Shots of Integrated Biofeedback System for AR Based Reaching Exercise

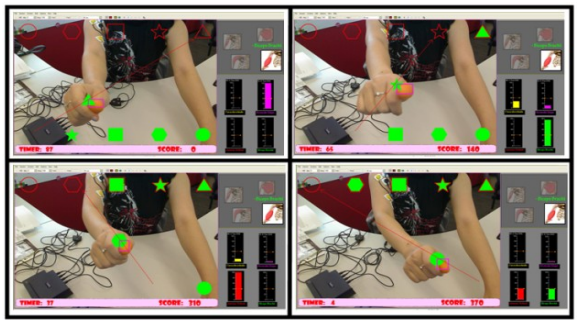

Figure 8. Different Screen Shots of Reaching Exercise during Testing

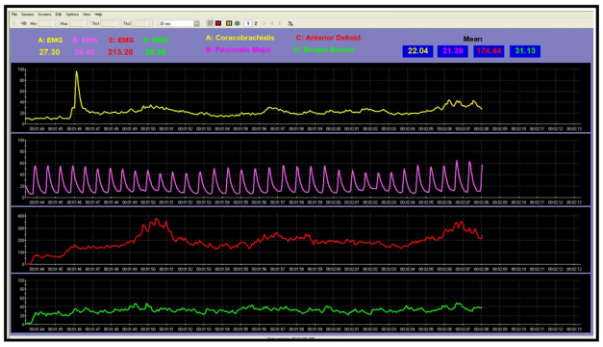

Figure 9. Muscles' Performance during Transfer Game Exercise

therapist or even patients or their families who have knowledge about reading EMG signals. The screen shot of recorded EMG data is illustrated in figure 9. These data will be analyzed for the progress of trained muscles in current development and will be extracted the recorded sEMG data and report for further process in future development.

7. CONCLUSION AND FUTURE WORK

The AR based reaching exercise has developed and integrated with BioGraph Infiniti system to promote the shoulder range of motion and strengthen the shoulder and arm muscles. The developed system is to replace the bored and repetitive traditional reaching exercise at stroke rehabilitation centers. The developed system has tested with healthy subject and the system worked perfectly. The test has to be done with stroke patient for developed system in near future. The real time muscle animation which is driven by subject's recorded EMG signals will be developed as a next step of development.

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