International Journal of Computer Information Systems and Industrial Management Applications.
ISSN 2150-7988 Volume 5 (2013) pp. 550-556

Neuromotor Rehabilitation System with Real-Time Biofeedback

Yee Mon Aung[1] and Adel Al-Jumaily[1]

[1] School of Electrical, Mechanical and Mechatronic Systems, University of Technology Sydney,
PO Box 123 Broadway, NSW 2007, Australia
yee.m.aung@student.uts.edu.au and adel.al-jumaily@uts.edu.au

***Abstract*: Physical disabilities which caused by neuromotor impairment due to Traumatic Brain Injury (TBI), Spinal Cord Injury (SCI) and Cerebrovascular Accident (CVA) affect the person's quality of life. Therefore, physical rehabilitations are required to be performed for the restoration of lost functions as a core treatment for such disabilities. However, the physical rehabilitations are too labor-intensive due to the nature of one-to-one attention in healthcare sectors. Moreover, this kind of injuries and accident cost over $10 billion per annum in healthcare sectors. To overcome above mentioned problems, this paper presents the development of intelligent biofeedback neuromotor rehabilitation system with low cost and motivational approach to close the gap in shortage of therapists, high healthcare cost of TBI, SCI and CVA. Our system designed for user motivation to perform the exercise longer and be used with minimum therapist supervision at home. The rehabilitation exercise aims to increase the upper limb range of motion, and strengthen the associate muscles. Our system utilized sEMG signals as a biofeedback. The user's sEMG signals will attain and detect the therapist' defined sEMG threshold level to display active muscle in real time during performing exercises. While the system works to retrain the elastic brain via fast recovery method, it will close the gap for the required information, by therapists, about monitoring and tracks the user's muscle performance. The effectiveness of the proposed system has been evaluated by performing usability test.**

Keywords: upper-limb rehabilitation, home-based therapy, augmented reality game, sEMG, real-time muscle simulation, human computer interaction**.**

I. Introduction

Traumatic Brain Injury (TBI), Spinal Cord Injury (SCI) and Cerebrovascular Accident (CVA) are major causes of disability in all over the world. The consequences of these diseases are not only effect on patient's quality of life but also restricted their performance of daily life activities. The life time cost for TBI and SCI in Australia was estimated 10.5 billion in 2008 based on Western Australian Institute for Medical Research [1] while the cost of CVA was estimated 2.14 billion per year according to National Stroke Foundation in 2011 [2]. Moreover, the shortage of therapists in rehabilitation hospitals and centers are also becoming major problems as rehabilitation training is on one to one basic and stroke patients are increasing annually. The studies have proven that the motor impairment can be treated by intense use of active movement in repetitive tasks and task-orientated activities which will result in improving motor skills and muscular strength by preventing muscle spasticity, muscle atrophy and osteoporosis [3]. In addition to that, Huang et al. reported that integration with biofeedback system provides improvement during retraining of muscles strength [4]. Therefore, this paper proposes a low cost, motivated and convenient rehabilitation system with biofeedback.

This paper is organized in following manner: in session II related works are highlighted while session III details the implementation, followed by experiment and results in session IV. Finally, session V provides conclusion and future work. Appendix for questionnaire is presented at the end of the paper.

II. Related Works

A. Virtual Reality (VR) based Rehabilitation

To replace the boring and repetitive of traditional rehabilitation exercises, VR rehabilitation systems were developed. Research studies have confirmed that the embedded of Virtual Reality (VR) in rehabilitation system provides positive results. There are numerous numbers of motor-function rehabilitation systems based on virtual reality based exoskeleton for brain-damage therapy [5, 6]. There is a report for EMG based VR system [7, 8] which improved the upper limb rehabilitation through making user EMG signals to directly control the VR object rotation and shooting in VR environment.

B. Augmented Reality (AR) based Rehabilitation

Although the VR developments had proven with positive results, bulkiness and total immersive in virtual world is inconvenient for some patients. If the patient is a child, total immersive environment is not safety for them as a training environment. Therefore, Augmented Reality (AR) was developed as an alternative option for rehabilitation which is safer and more interact with real environment. Augmented reality is the combination of real world and virtual world that enhance the user perception of reality. According to Ronald Azuma et al. [9], AR system must have following properties: combines real and virtual objects in real environment, runs interactively and in real time, and registers (aligns) real and virtual objects with each other. There are two basic types of display for AR system namely see-through AR display and monitor based AR display [10]. In the context of see-through display, user can see the display medium directly to the real world surrounding whereby perceiving both the maximal possible extent of presence and the ultimate degree of image replacement. In monitor based display, user can view the computer generated virtual world which is overlaid on top of real environment via captured real-time video images. In our proposed system, we employed monitor based display for rehabilitation exercise. As far as monitor based AR display for upper limb rehabilitation system is concerned, Ubi-REHAB system was developed by Choi [11]. His development is an android-based portable augmented reality with eGlove for stroke patients. Development of Alamri et al. [12] was aimed to train for upper limb reaching movement, and grasp and release by shelf exercise and cup exercise which is AR based rehabilitation system. Another development of AR based training was done by Burke et al. [13]; this development was training for reaching, grasping, lifting and release movement with Brick'a'Break and Shelf Stack exercises. Alternative AR drink, AR dance and AR fold rehabilitation exercises were developed by [14]. The system has developed to train the patients' upper limb for daily life activities such as drinking, dancing and folding via virtual objects. Another AR based work; Pong and Goal Keeper games were developed for upper limb rehabilitation [15]. While in other development, AR based rehabilitation therapies were not only developed for adult but also for child with CP or TBI [16-18]. However, all the current AR developments were concentrated only on game design principles, user convenient and just to train for upper limb movements but did not consider for any biofeedback to user or for therapist. The studies have proven that biofeedback is benefit for retraining muscles strengthening by [4]. Therefore, we have been developing upper limb rehabilitation system with biofeedback [19, 20] . In this paper, the developed system is integrated with real-time biofeedback simulation system to retrain the plasticity of the brain via fast recovery method, close the gap for shortage of therapists, and reduce the cost.

C. Electromyography (EMG)

Electromyography (EMG) is an electrical activity which is produced by skeletal muscles. It can detect the abnormalities and activation level of human movement through analyzing the shape, size, and frequency of the motor unit potentials generated by muscle cells. Therefore, it becomes very important information in many clinical and biomedical applications. There are numerous applications of EMG signals such as controlling of prosthesis or orthotic device movement [21, 22], detection of user intended movement [23, 24], controlling of virtual models [7]. The signal can be measure in two ways: surface EMG (sEMG) where electrodes are attached to the patient's skin and intramuscular EMG where needle electrodes are inserted through skin into muscle tissue. In our rehabilitation system, surface EMG electrodes are used to extract the signals. The real-time muscle simulation module in our system employs the sEMG signals to detect the activation level of muscle performance to trigger the muscle simulation. This module provides with very useful information to user as a motivational tool and therapists to monitor and track the patient's muscle performance.

III. System Implementation

The complete system consists of personal computer (PC), low cost webcam, colour marker, BioGraph Infiniti biofeedback system from Thought Technology [25] as shown in Fig 1. The research has been proven that reaching exercise as a rehabilitation therapy provides fast recovery [26]. Therefore, we have developed reaching exercise as our rehabilitation exercises to train the upper limb muscles: anterior and posterior deltoids, biceps brachii and pectoralis major as well as train for wider range of movement at shoulder joint. The exercise was developed with Adobe Flash Professional CS5. Actionscript 3.0 from Flash Professional CS5 was used to capture the video, display the virtual objects, tracking the colour marker for interaction and collision detection. In this work, 24-bit RGB true colour space is chosen as it is the most effective way to track the colour according to Gonzalez et al. [27]. In our system, the 24-bit RGB colour space was assigned as follow:

```
aRed [i] = value <<16;     …… (1)
aGreen [i] = value << 8;   …… (2)
aBlue [i] = value;         …… (3)
```

Selected colour was recognized in the system and updated every frame to detect the current position of that colour in order to track the marker based on below commend:

```
redCount += (0.01 * speed.length);       .........(4)
greenCount += (0.005 * speed.length);    .........(5)
blueCount += (0.015 * speed.length);     .........(6)
```

The marker will be surrounded by colour rectangular shape which appears as a visual feedback to patients. Collision detection was realized by checking the pixel distance of between center of the marker and center of the interactive game element (object) as follow:

```
Point.distance (objectPoint, rectPoint) < 10;    ……. (7)
```

If the difference is less than defined distance value, in our case is pixel distance of 10, marker and interactive game element consider hit and will proceed to next function. The developed

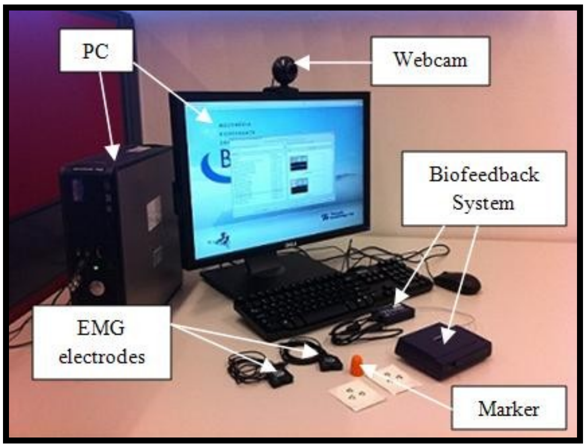


Figure 1. Biofeedback System

exercise has integrated with biofeedback module in MATLAB environment. BioGraph Infiniti biofeedback system consists of 10 high-speed channels to acquire the data from surface electromyography (sEMG) electrodes. In our development, EMG MyoScan sensors were used to attain the sEMG signals from users' arm muscles. These signals are extracted as live data with Thought Technology Limited Application Programming Interface (TTLAPI) SDK and imported to MATLAB platform. These live data were used as an input for real-time muscle activation module. Display of real-time muscle activation is implemented in MATLAB R2010b. There is one main module and six sub modules were built namely initialization, setups, read data, plot data, muscle animation and close connections in MATLAB to exhibit as real-time muscle activation. The display of muscle animation which is changing the muscle color will activate where the threshold value of sEMG live value is above the predefined sEMG value. The threshold value of sEMG signals is variable and can be defined by therapist according to the user performance.

A. Rehabilitation Exercises

Two augmented reality exercises, Transfer Object Exercise (TOE) and Feeding Animal Exercise (FAE) were developed as shoulder rehabilitation exercises [28]. The exercises were designed according to game design principles: discernible and integrated where former represents the real-time feedback and latter represents the increasing of challenge [29].

1) Transfer Object Exercise (TOE)

TOE rehabilitation exercise is intended to train the shoulder flexion, extension and horizontal adduction movements and to strengthen the associated muscles which are Anterior Deltoid (AD), Posterior Deltoid (PD), Biceps Brachii (BB) and Pectoralis Major (PM). The aim of the game is to collect the solid object and place into the same shape hollow object. The blinking object represents the active object that user need to interact. If the user places the object correctly, score will increase. There is a timer which user needs to accomplish the task within the specific time. The detail of this game can be found in [19].

2) Feeding Animal Exercise (FAE)

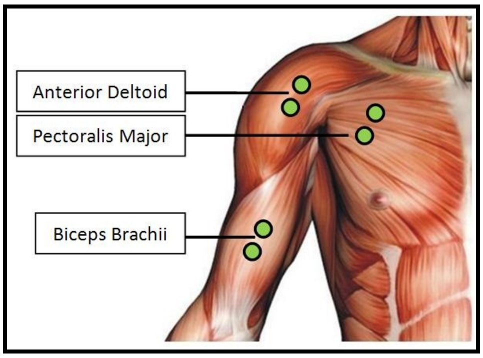
FAE rehabilitation exercise has developed to train the shoulder range of motion and strengthen the arm muscles: AD, PD, BB and PM. The objective of the game is to pick up the food from the bottom row of the monitor screen and placing into the indicated food plate. This exercise is made up of the dog which is looking for the food around the screen, the food plate where dog food is to be placed, and the food which user will interact with color marker. The exercise can be played either left or right hand. The user is asked to define the color as a marker to track the current position of the user hand as a first step. After defining the marker, the user is asked to pick up the food which indicate with red colour arrow and place in the food plate which indicated with green colour arrow. The different height of the placement of food plate will train the user for arm reaching movements which is normally conducted as a traditional way. When the user places the food correctly into food plate, the score will be increased. The user is required to pick up and place all the food into food plate within the time specified. The time period can be adjusted based on the patient ability. The present of visual feedback motivate the long training without boring. The rehabilitation purpose of FAE is intended to increase the arm range of motions as well as to increase strength of the muscles in use.

B. Real-Time Muscle Simulation

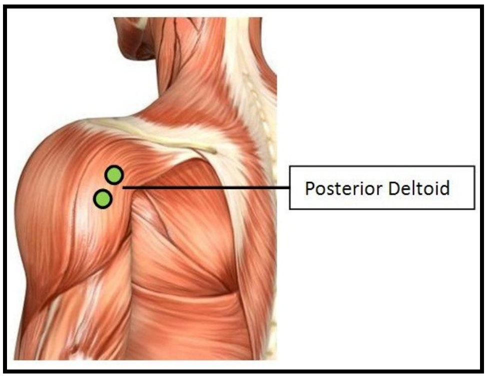
BioGraph Infiniti system from Thought Technology is used to collect the muscle signals from user to monitor the active muscle performance during performing the exercise. In developed system, there are four signals to collect from user's muscles and electrode sites are as shown in Fig. 2. The collected signals are displayed as line graphs in MATLAB environment and also used as an input for real-time muscle activation. However, it is difficult to utilize the information of raw sEMG signal. Therefore, useful information from the sEMG signal was extracted by means of Root Mean Square (RMS) by calculating the amplitude. The equation of the RMS represents as follow:

$$EMG_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} sEMG(i)^2} \quad (1)$$

where sEMG(i) is the amplitude of the signal in i^{th} sampling, N is the number of samples. The number of samples is set to be 256 in this study. Four sEMG signals are recorded from shoulder joint motion during performing rehabilitation exercise. The real-time muscle activation is representing by changing of muscle color. When the sEMG signals are above predefined threshold value, the muscle color will change to represent the current active muscles so that patient and the



(a)



(b)

Figure 2. Electrode sites for TOE and FAE (a) Anterior view (b) Posterior view

therapist will observe current active muscle. On the display screen, there are two muscle display windows and four line graphs of sEMG signals data. Muscle display windows represent the front and back view of the arm muscle where animation is occurred. Four line graphs represent the real-time activity of four muscles performances for TOE and FAE accordingly. An example of muscle animation output is portrayed in Fig. 3 (left).

IV. Experiments

A. Rehabilitation Exercises

The test has conducted with ten healthy subjects. The screen shot of TOE training with real-time muscle simulation is depicted in Fig. 3 (right). The four sEMG electrodes were attached to train the strength of muscles as illustrated in Fig. 2 for TOE and FAE. The marker was worn to the subject's thumb to track the subject's arm current position. When the rehabilitation exercise starts, subject is asked to select the color marker. After that the system tracks the current position of the arm that interacts with solid object and hollow object for TOE, and food and food plate for FAE. The present of feedbacks such as scores and timer were motivating the subject during training. The muscle animation window which is displayed at the left region of the display screen was monitored by subject for real-time muscles simulation as well as the muscle performance as a line graph signal during training. From the right region of the display screen, it provides with TOE or FAE rehabilitation exercise where color tracking take place. We requested from every subject to answer the questionnaire which is described in Appendix A at the end of the exercise. From the analysis of the questionnaire, subjects were expressed their interest, excitement and motivation without any major discomfort during the exercise. The analysis can be found in Fig. 4 and 5. The main objectives of the rehabilitation exercise which increase the subjects' motivation and interest for long term training was achieved.

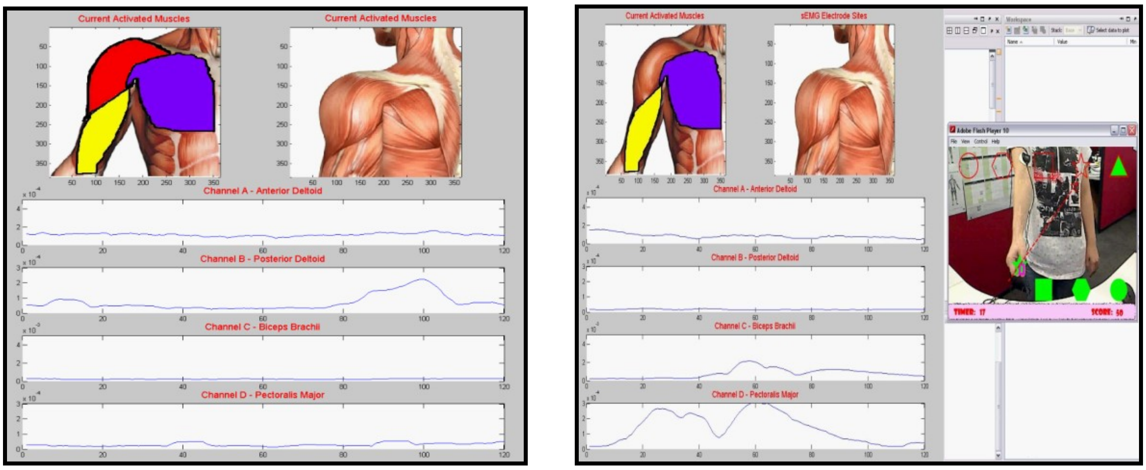


Figure 3. Screen shot of real-time muscle simulation (Left) and with TOE training (Right)

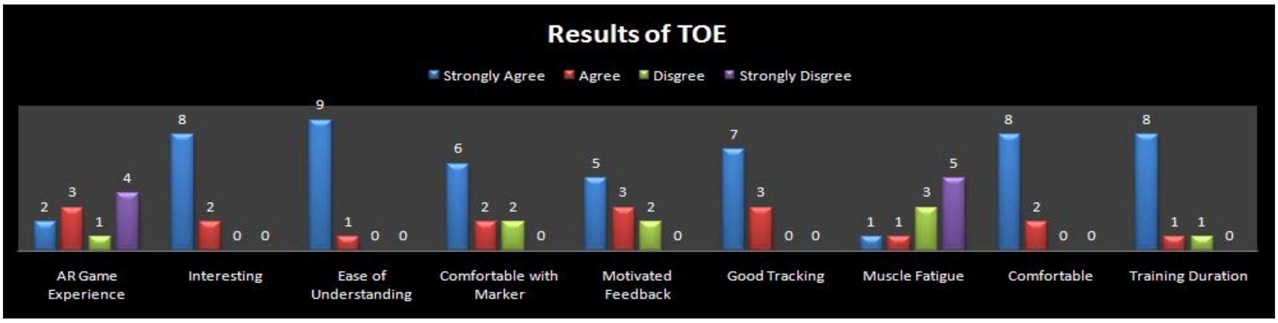


Figure 4. Questionnair responses for TOE

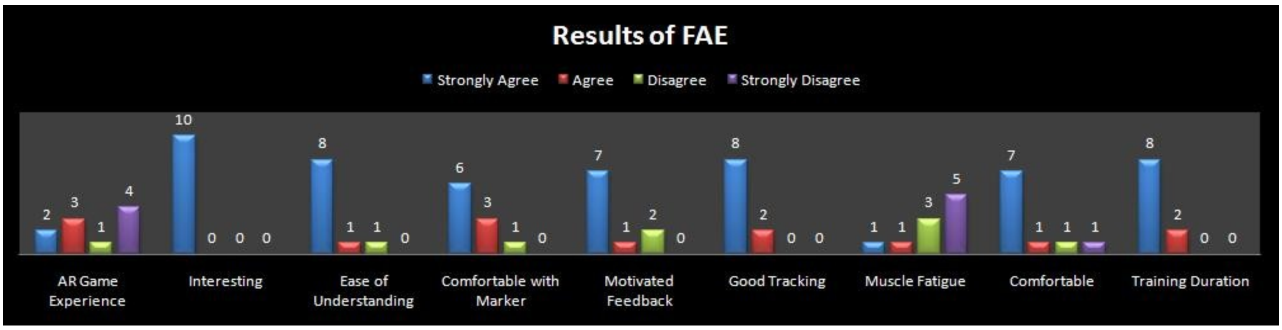


Figure 5. Questionnair responses for FAE

B. Real-Time Muscle Simulation

Experiments were carried out to present the effective rehabilitation system for shoulder rehabilitation. First, we verified the significant contribution of the muscles for certain arm movements to increase shoulder range of motion. Experiment was done with a healthy subject to attain the sEMG signals from left upper arm muscles. Four muscle signals were recorded during Shoulder Flexion (SF) motion, Shoulder Abduction (SAB) motion, Horizontal Adduction (HAD) motion and Horizontal Abduction (HAB) motion and extracted by calculating of Root Mean Square (RMS). During SF motion, AD muscle contracted more than that of PD and PM. as shown in Fig. 6(a). This shows that moving of VF will train the strength of the AD muscle. In Fig. 6(b), AD and PD muscles contributed more in SAB motion. During HAD movement, AD and PM muscles are contracted which can be found in Fig. 6(c). In Fig. 6(d), HAB motion was attained by contracting of AD and PD muscles. Although biceps brachii (BB) contributed for all of the above mentioned movements, it contracted more during HAD motion as shown in Fig. 6(c). To summarize, SF motion trains for AD and BB muscles, SAB and HAB motions train for AD, PD and BB muscles, HAD motion trains for AD, BB and PM muscles. Our developed rehabilitation exercises were tested with a healthy subject and results can be found in Fig. 7. The developed exercises are trained not only to increase the range of motion at the shoulder joint, but also in muscle strength. According to the TOE and FAE training results all of the four muscles: AD, PD, BB and PM are trained. Thus, the main objective of the muscle

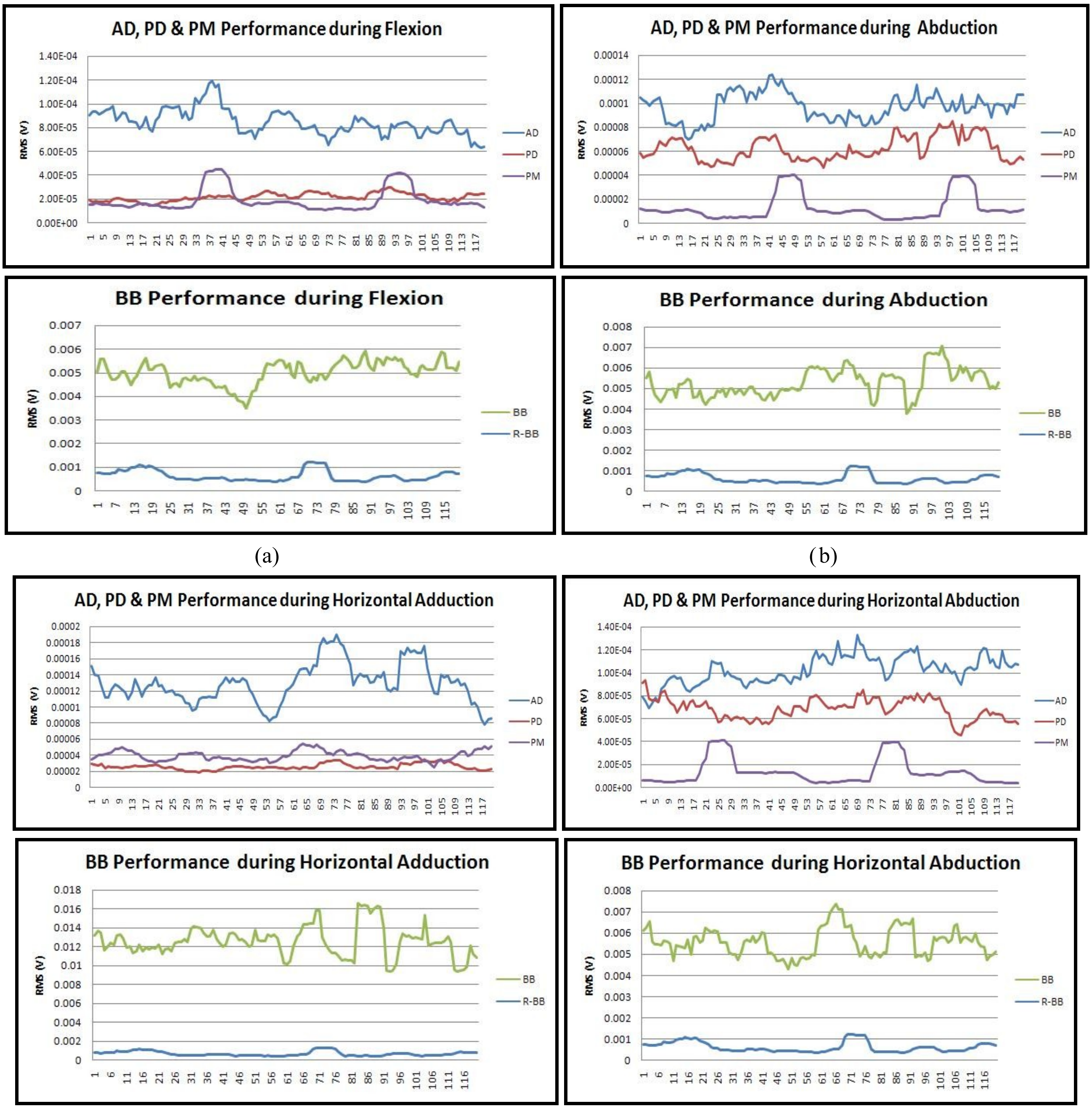


Figure 6. Experimental results of (a) Shoulder Flexion (b) Shoulder Abduction (c) Horizontal Adduction (d) Horizontal Abduction motions

simulation, that used to monitor the muscle activity and the performance in real-time, has been achieved. The experiments of the proposed rehabilitation exercises have strengthened the arm muscles and increase the range of arm motion by

V. Conclusion and Future Work

The major achievement of this development is that subjects are allowed to monitor their trained muscles performances not only in real-time signal displays but also in real-time muscles animation form while performing AR based rehabilitation exercise. The subjects are able to interact with the rehabilitation exercise easily via worn colour marker and follow the indication to complete the game. Therefore, the developed system is not only for adult rehabilitation but also for children with disabilities can be trained. The present of visual feedback such as scoring and timing are additional features to prolong the subject interest in exercise. The test has conducted with healthy subject to monitor the real-time muscle simulation during the exercise and provided with positive results based on questionnaire and results. The experiments were done to confirm the type of movements and muscle contribution for developed rehabilitation exercises. As far as future work is concerned, clinical trial at Port Kembla Rehabilitation Hospital will be conducted for our development for validation.

Appendix - Questionnaire

The questions for the questionnaire were as shown as below. The subjects responded the following questions based on numerical score where 4 represents strongly agree and 1 represents strongly disagree.

1. I have tried Augmented Reality games before.
2. The game is motivated and interested.
3. The given information and guide are easy to understand.
4. It is comfortable to wear the marker.
5. Tracking of the colour marker is good.
6. The present of feedback such as timer and scoring system are motivating.
7. It can feel the arm muscles fatigue.
8. It is comfortable throughout the exercise.
9. The benchmark time for healthy/ stroke person is appropriate.
10. Other feedbacks and suggestions.

References

[1] Waimr. (August 2011). *Neurotrauma Statistics*. Available: http://www.nrp.org.au/statistics.html

[2] StrokeFoundation. (2011, August). *Facts, figures and statistics*. Available: http://www.strokefoundation.com.au/facts-figures-and-stats

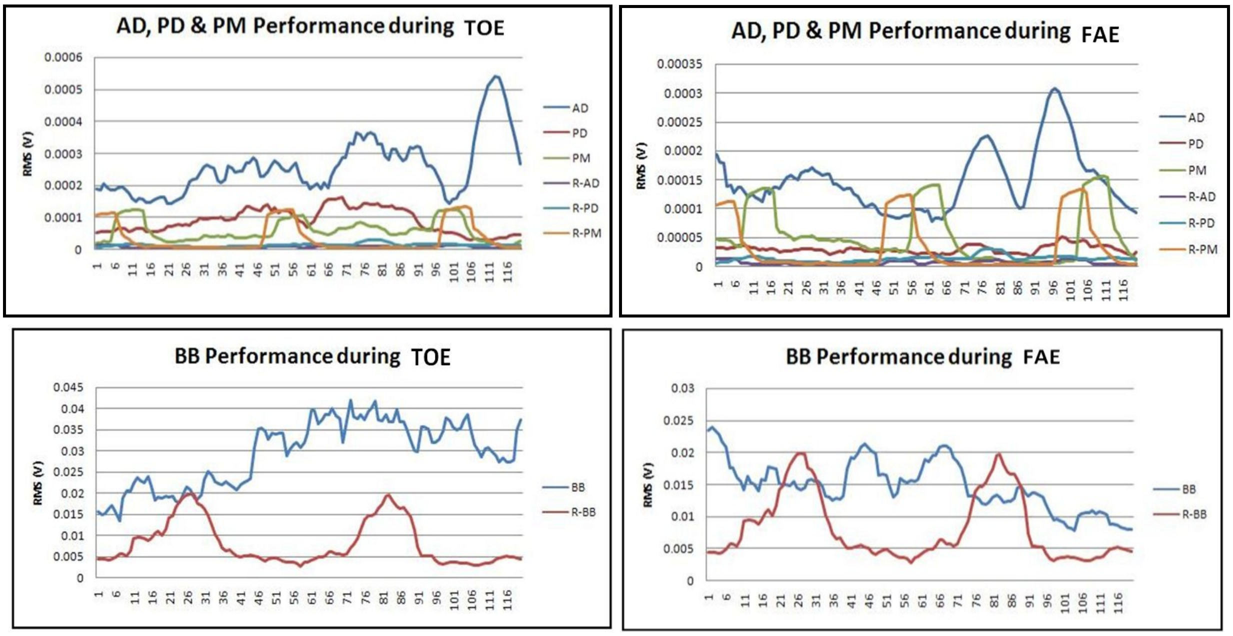
[3] R. Riener, M. Frey, M. Bernhardt, T. Nef, and G. Colombo, "Human-centered rehabilitation robotics," in *Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on*, 2005, pp. 319-322.

[4] H. Huang, S. Wolf, and J. He, "Recent developments in biofeedback for neuromotor rehabilitation," *Journal of NeuroEngineering and Rehabilitation,* vol. 3, p. 11, 2006.

[5] M. Mihelj, T. Nef, and R. Riener, "ARMin II - 7 DoF rehabilitation robot: mechanics and kinematics," in *Robotics and Automation, 2007 IEEE International Conference on*, 2007, pp. 4120-4125.

[6] J. C. Perry, J. Rosen, and S. Burns, "Upper-Limb Powered Exoskeleton Design," *Mechatronics, IEEE/ASME Transactions on,* vol. 12, pp. 408-417, 2007.

[7] M. Sha, M. Varley, S. Lik-Kwan, and J. Richards, "EMG Biofeedback Based VR System for Hand Rotation and Grasping Rehabilitation," in *Information Visualisation (IV), 2010 14th International Conference*, 2010, pp. 479-484.



(a) (b)

Figure 7. Experimental results of (a) TOE and (b) FAE

[8] C. Kaluarachchi, A. Yee Mon, and A. Al-Jumaily, "Virtual games based self rehabilitation for home therapy system," in *Hybrid Intelligent Systems (HIS), 2011 11th International Conference on*, 2011, pp. 653-657.
[9] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, "Recent advances in augmented reality," *Computer Graphics and Applications, IEEE,* vol. 21, pp. 34-47, 2001.
[10] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented Reality - A class of displays on the reality-virtuality continuum " *Telemanipulator and Telepresence Technologies, Proceedings of SPIE,* vol. 2351, pp. 282-292, 1995.
[11] Y. Choi, "Ubi-REHAB: An android-based portable Augmented Reality stroke rehabilitation system using the eGlove for multiple participants," in *Virtual Rehabilitation (ICVR), 2011 International Conference on*, 2011, pp. 1-2.
[12] A. Alamri, C. Jongeun, and A. El Saddik, "AR-REHAB: An Augmented Reality Framework for Poststroke-Patient Rehabilitation," *Instrumentation and Measurement, IEEE Transactions on,* vol. 59, pp. 2554-2563, 2010.
[13] J. W. Burke, M. D. J. McNeill, D. K. Charles, P. J. Morrow, J. H. Crosbie, and S. M. McDonough, "Augmented Reality Games for Upper-Limb Stroke Rehabilitation," in *Games and Virtual Worlds for Serious Applications (VS-GAMES), 2010 Second International Conference on*, 2010, pp. 75-78.
[14] A. Toh, L. Jiang, and E. K. Lua, "Augmented Reality Gaming for Rehab@Home," in *5th International Convention on Rehabilitation Engineering & Assistive Technology*, Bangkok, Thailand, 2011.
[15] A. Dinevan, A. Yee Mon, and A. Al-Jumaily, "Human computer interactive system for fast recovery based stroke rehabilitation," in *Hybrid Intelligent Systems (HIS), 2011 11th International Conference on*, 2011, pp. 647-652.
[16] T. Chau, C. Eaton, A. Lamont, H. Schwellnus, and C. Tam, "Augmented environments for pediatric rehabilitation," *Technology & Disability,* vol. 18, pp. 167-171, 2006.
[17] A. G. D. Correa, I. K. Ficheman, M. do Nascimento, and R. de Deus Lopes, "Computer Assisted Music Therapy: A Case Study of an Augmented Reality Musical System for Children with Cerebral Palsy Rehabilitation," in *Advanced Learning Technologies, 2009. ICALT 2009. Ninth IEEE International Conference on*, 2009, pp. 218-220.
[18] C. Schonauer, T. Pintaric, and H. Kaufmann, "Full body interaction for serious games in motor rehabilitation," presented at the Proceedings of the 2nd Augmented Human International Conference, Tokyo, Japan, 2011.
[19] A. Yee Mon and A. Al-Jumaily, "Augmented Reality Based Reaching Exercise for Shoulder Rehabilitation," in *5th International Convention on Rehabilitation Engineering & Assistive Technology*, Bangkok, Thailand, 2011.
[20] A. Yee Mon and A. Al-Jumaily, "Development of Augmented Reality Rehabilitation Games Integrated with Biofeedback for Upper Limb," in *5th International Convention on Rehabilitation Engineering & Assistive Technology*, Bangkok, Thailand, 2011.
[21] N. S. K. Ho, K. Y. Tong, X. L. Hu, K. L. Fung, X. J. Wei, W. Rong, and E. A. Susanto, "An EMG-driven exoskeleton hand robotic training device on chronic stroke subjects: Task training system for stroke rehabilitation," in *Rehabilitation Robotics (ICORR), 2011 IEEE International Conference on*, 2011, pp. 1-5.
[22] L. Fraiwan, M. Awwad, M. Mahdawi, and S. Jamous, "Real time virtual prosthetic hand controlled using EMG signals," in *Biomedical Engineering (MECBME), 2011 1st Middle East Conference on*, 2011, pp. 225-227.
[23] J. W. L. Pau, H. Saini, S. S. Q. Xie, A. J. Pullan, and G. Mallinson, "An EMG-driven neuromuscular interface for human elbow joint," in *Biomedical Robotics and Biomechatronics (BioRob), 2010 3rd IEEE RAS and EMBS International Conference on*, 2010, pp. 156-161.
[24] D. Qichuan, Z. Xingang, X. Anbin, and H. Jianda, "A Novel Motion Estimate Method of Human Joint with EMG-Driven Model," in *Bioinformatics and Biomedical Engineering, (iCBBE) 2011 5th International Conference on*, 2011, pp. 1-5.
[25] ThoughtTechonology. (August, 2011). Available: http://www.thoughttechnology.com/
[26] L. Straker, A. Campbell, L. Jensen, D. Metcalf, A. Smith, R. Abbott, C. Pollock, and J. Piek, "Rationale, design and methods for a randomised and controlled trial of the impact of virtual reality games on motor competence, physical activity, and mental health in children with developmental coordination disorder," *BMC Public Health,* vol. 11, p. 654, 2011.
[27] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 2nd ed.: Pearson Education, 2001.
[28] A. Yee Mon and A. Al-Jumaily, "Rehabilitation exercise with real-time muscle simulation based EMG and AR," in *Hybrid Intelligent Systems (HIS), 2011 11th International Conference on*, 2011, pp. 641-646.
[29] K. Salen and E. Zimmerman, *Rules of Play: Game Design Fundamentals*. Cambridge: MIT Press, 2004.

Author Biographies

Yee Mon Aung received her B.E degree in Mechanical Engineering and M.Sc degree in Biomedical Engineering both from Nanyang Technological University, Singapore in 2008 and 2010, respectively. She is currently working towards her Ph.D degree, at University of Technology Sydney, Australia.

Adel Al-Jumaily received the Ph.D. Degree in electrical engineering (AI). He is Associate Professor in Faculty of Engineering and Information Technology, University of Technology, Sydney (UTS), Australia. His research interests include fields of artificial intelligent systems, healthcare and biomedical engineering.