Development of Serious Game for the Upper Arms Rehabilitation: "Balance Ball Rhythm Game" Case Study

Sung-Taek Chung[1], Sung-Wook Shin[1], and C.J. Lim[2(✉)]

[1] Department of Computer Engineering, Korea Polytechnic University, Seoul, Korea
{unitaek, napalza}@kpu.ac.kr
[2] Department of Game and Multimedia Engineering, Korea Polytechnic University, Seoul, Korea
scjlim@gmail.com

Abstract. Accuracy, repeatability and activity are very critical factors for rehabilitation of hemiplegic patients. Rehabilitation exercise should be done regardless of space, time and cost. Recently, interesting functional games, which induce active participation, have gained increasing attention. In the current study, a balance ball has been developed that can contract the user muscle and help in natural joint rotation by stimulating the upper arm muscle of hemiplegic patients. Additionally, a functional game was also developed that can engage the patients with rhythm game and training contents. The balance ball can detect the upper arm motion by an acceleration sensor and offered sense of reality and immersion with buttons and haptic sensors. The game applied Fitt's law to test accurate motion and two tutorial contents that induced their motion based on MFT. The level of difficulty can also be chosen to help intensive training for the motion with low scores from the tutorials and the patients can even do the upper arm rehabilitation exercise while listening to music.

Keywords: Motion detect · Accelerometer · MFT (Manual function Test) · Serious game · User interface

1 Introduction

'Stroke' refers to cerebrovascular disease or accident in general. It is the most common neurological disease whose incidence rate increases with people's age and is known as the second cause of death after cancer [1]. Although development of modern medicine increased the survival rate of the stroke patients, 90 % or more of them suffer from certain types of disabilities, such as movement disorder, sensory disorder or cognitive disorder followed by chronic health problem called as hemiplegia [2]. Hemiplegia causes weakness in the muscles of upper and lower arm or face, muscle modulation disorder, weakened muscle tone and subsequent paralysis from unilateral brain damage as well as synergy where several groups of muscles move at the same time, instead of a single muscle [3, 4]. Hemiplegic patients need early rehabilitation exercise within three to seven days of its occurrence before spasticity develops, which is the biggest obstacle

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to normal movement. Functional reorganization of cerebral activation area by brain plasticity has been acknowledged as the most influential hypothesis on movement function recovery [5]. To facilitate the functional reorganization of the brain during rehabilitation, factors, such as activity, accuracy and repeatability of patients are important to consider. Among these, accuracy and repeatability can be achieved through rehabilitation exercise performed with the subjective viewpoint of the therapist; however, such exercise is not enough to generate a patient's interest and invoke his/her active participation [6]. This implies that it is difficult to execute continuous and steady rehabilitation exercise. As a solution to this problem, serious game is gaining attention which can improve motion detect ability of the brain and perform rehabilitation exercise among others [7]. The serious game uses body senses more than the general games and increases a patient's will to participate by maximizing user satisfaction [8]. However, the existing content of the serious game was designed for those without hemiplegia and is thus very difficult for the hemiplegic patients to use. Therefore, a customized content is necessary which would have a reasonable difficulty level and an easy interface.

In the current work, a spherical device was developed with the aid of which the hemiplegic patients who cannot move their upper arms can undergo easy upper arm rehabilitation exercise. This device would enable only light muscle contraction and natural joint rotation with minimal pain through stimulation of upper arm muscles along with free movement of hand, wrist and arm. It would also try to engage the patients in the rehabilitation exercise that may be boring and repeating by combining intriguing contents with a rhythm game.

2 Development of Balance Ball Device

Figure 1 shows the balance ball designed in this study. The patients can do upper arm rehabilitation exercise by placing their hand on the top of the ball (Fig. 1a) and tilting it in the direction they want, with the movement of their wrist, elbow and shoulder as if it is rolling. The device can help the patients to tilt their weakened upper arm and again return it to the center. The device has a fixed pendulum in the middle so that the patient's hand and wrist can rest on it comfortably. It also has five buttons that can increase the variety of the content and test finger movement or gripping power depending on certain events. Besides, the switch would allow changing the set up depending on the hand used, which means that both right and left hand can be used. It applies a haptic sensor that can provide force feedback for the users to transmit information realistically and heighten sense of immersion. Through extension, abduction, radial deviation and ulnar deviation movement of wrist with the device, the patients can reduce pain through light muscle contraction and natural joint rotation and prevent spasticity. Figure 1b shows the hardware inside the balance ball. The gradient of the balance ball can be calculated with acceleration sensor (ADXL335 3 axis acceleration sensor module) and acceleration data of X, Y and Z axis that have ±3.6 dps(deg/s). Acceleration and gradient were estimated using Eqs. (1) and (2).

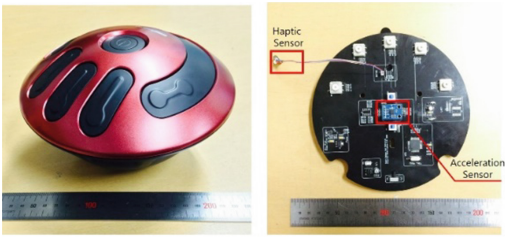

Fig. 1. (a) External, and (b) internal appearance of fabricated balance ball

$$a_i = \frac{V_{out} - V_{offset}}{S} \tag{1}$$

$$\theta_i = \text{asin}(a_i) * \frac{180}{\pi} \tag{2}$$

Where a_i is the i acceleration value of each axis, V_{out} is the current output value of the sensor that changes by gravitational acceleration, V_{offset} is the sensor value when gradient is '0', S is the sensor sensitivity, θ_i is the angle that was obtained from the acceleration value of each axis. The angle value was obtained from acceleration sensor output value by gradients and the movement of the balance ball was mapped on a two-dimensional plane.

3 Rehabilitation Contents Development

With increasing aged population, the number of incidence of stroke is also rising. About 56 % or more of the patients suffer from hemiplegia, having everyday life quite challenging [9] and most of them face great difficulties in finding suitable treatment facilities.

The current work developed rehabilitation contents that can induce upper arm movement using the balance ball wirelessly connected to PC, a proper platform for treatment and rehabilitation exercise of hemiplegic patients regardless of space, time and cost. The balance ball gives feedback using vision, hearing and touch. The patients can also enjoy the treatment process themselves while performing tasks with enhanced motives under a safe environment. With the purpose for rehabilitation of hemiplegic patients, the current approach used minimum resources with 2D, comprising balance ball device test, two staged tutorial and rhythm game. The flow chart is shown in Fig. 2.

In order to test whether the balance ball operates satisfactorily or not, the balance ball device examine the contents, created for the hemiplegic patients, using the Fitt's law (see Fig. 3). Fitt's law is a certified tool that can evaluate cursor movement and clicks on the computer screen. The test used distance (D), width (W) and angle (A) between the cursor and the target to set up the level of difficulty. The values used

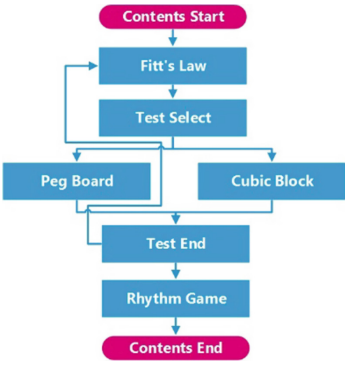

Fig. 2. Game flow chart

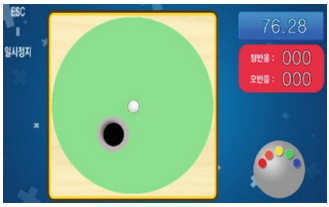

Fig. 3. Fitt's law testing screen

were as follows: D = 125, 250 and 375 pixels, W = 50 and 100 pixels, A = 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. Depending on the randomly decided location of holes by stages, forward reaction and backward reaction were measured and at the end of the balance ball device test was a tutorial.

Tutorial 1 of Fig. 4 calculated the number of goals made into the basket in 30 s. The score was saved at the end of the game before Tutorial 2 appeared in Fig. 5. Tutorial 2 calculated the number of hitting the balls, which came out randomly within the circle in 30 s, by pressing the button of the matching color. For scoring, MFT (Manual Function Test) was applied. Different scores recorded during the training can verify the effect of

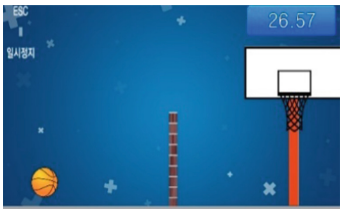

Fig. 4. Tutorial 1: cubic block training screen

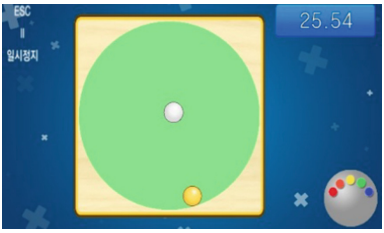

Fig. 5. Tutorial 2: peg board training screen

Fig. 6. Difficulty level choice screen for rhythm game

the rehabilitation as the user's measuring reference. Added scores of Tutorial 1 and 2 decide the level of difficulty for the rhythm game, as shown in Fig. 6. The level can be chosen as easy, normal or hard. Furthermore, this game was designed to focus on the training of those who obtained a relatively low total score from the sum of tutorial 1 and 2 (Fig. 7).

The rhythm game has two songs from which the user can choose. When the nodes come down in the song, the user has to move toward the node direction through the movement of the balance ball and presses the button for the corresponding node. The score consists of Perfect, Good, Miss and Max Combo in order and is leveled after the game is over.

Fig. 7. Playing screen of rhythm game

4 Conclusions

The paper presented a rehabilitation device that used acceleration sensor for upper arm rehabilitation of hemiplegic patients. The spherical balance ball helped the user pay attention to the activity by providing force feedback with a vibration motor. It also measured accurate angle of device tilting through motion using the acceleration sensor. Since both hands can be used and the device can induce upper arm joint rotation and muscle contraction, it is expected to be a proper model for upper arm rehabilitation that reduces pain and helps to overcome spasticity.

Future studies should be performed in the direction that allows various motions that use gyro sensor as well as acceleration sensor and a wide range of rehabilitation exercise.

This study also developed rehabilitation contents using the balance ball for rehabilitation of the hemiplegic patients. The game, based on the upper arm rehabilitation, uses vision, hearing and touch to provide feedback, thus lets the patients enjoy and engage in the treatment process. It also promotes motives under a safe environment. The system is expected to help the patients' rehabilitation exercise.

Additionally, analysis on the effect of rehabilitation contents on treatment should be performed. For wide applicability of the rehabilitation contents, development of tailored training contents, which emphasize gaming aspect for rehabilitation patients that cannot perform difficult motions, should also be targeted through basic analysis.

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