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Wearable Hand Rehabilitation Training System

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***Abstract*—This study applies real-time visual feedback game to increase the rehabilitation intention of patients, which allows patients to perform related upper limb training movements during game. 6-axis-accelerometer/gyroscope is used as wearable device and submits values to a tablet computer through Bluetooth. In this system, patients wear the device on hand. The system is combined with hand rehabilitation training game APP to make patients practice wrist range of motion, wrist stretch and forearm pronation and supination during rehabilitation. This system can not only improve hand agility but also increase connection with life.**

Keywords—accelerometer/gyroscope, hand rehabilitation, APP

I. Introduction

The percentage of ageing population in Taiwan has grown rapidly in recent years. Each rehabilitation therapist needs to face twenty patients every day, which increases the burden of rehabilitation therapists. Previous rehabilitation methods were easy to make patients lose intention and patience due to repetitive movements, which resulted in ineffective training [1].

Due to the increasing use of smartphones and tablet computers nowadays, some studies have combined APPs with rehabilitation training, which allows patients to perform pre-planned training items in an easy and interesting way, and makes users receive real-time visual feedback during rehabilitation, raising the interest and attention of patients in rehabilitation training [2-4]. The proposed system contains a wireless wearable device and a tablet computer. Users can perform rehabilitation training at home without limitation of place or time, which can provide convenient treatment for patients with disabilities or those who can't go to hospitals because of other reasons.

The main training part of the proposed system is human hand. The increase of hand agility in daily life can help patients to live life more normally. The device of the proposed system has extremely high sensitivity and can sense tiny movements, while the pictures on APP screen changes according to different movements, which can achieve planned training purpose. Rehabilitation training movements adopt common movements in daily life as pre-planned training items, such as wrist range of motion, wrist stretch and forearm pronation and supination.

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II. System Architecture

Wearable Hand rehabilitation training system consists of wearable sensor device and hand rehabilitation training game APP. Users wears the device on hand during rehabilitation training. The device can detect the movement change of user's hand and submit values to tablet computer through Bluetooth. The app can analyze sensing signals to determine movements, which controls game screen with somatosensory system.

A. *Wearable Sensor Device*

The wearable sensor device contains a battery, a 6-axis-accelerometer/gyroscope, a Bluetooth module and a Microchip microcontroller. The whole device is fixed to a tie, which ties to the back of hand to detect hand movement, as shown in Figure 1.

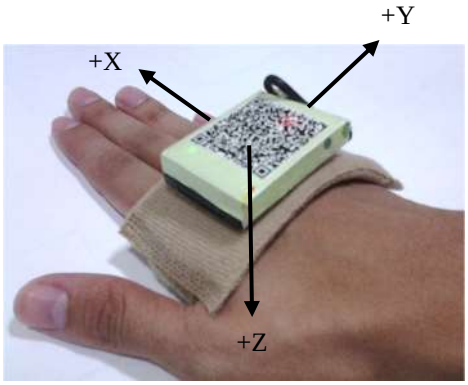

Figure 1. Wearable sensor device

B. *Hand rehabilitation training game APP*

The Hand rehabilitation training game APP (Hand-RTG APP) contains four training game parts, as shown in Figure 2. Users can choose right hand or left hand according to the rehabilitation part that needs training. The parameter settings, such as increasing, moving and decreasing can be adjusted according to self condition.

Figure 2. Main APP Menu

C. *Data Flow*

Figure 3-4 are flow charts of wearable sensor device side and tablet APP side. The variation of acceleration and angular velocity is observed in each training movement, which helps to develop movement determination algorithm.

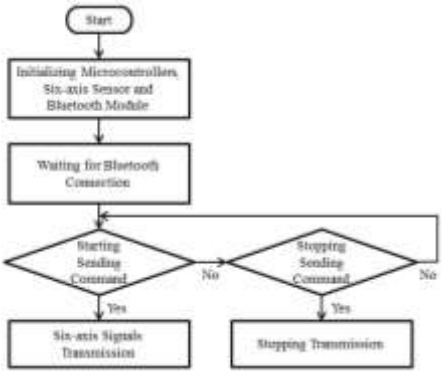

Figure 3. Wearable sensor device side flow chart

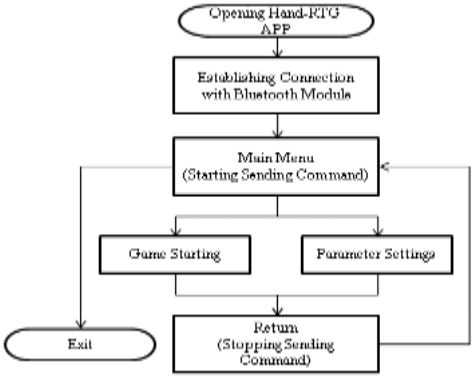

Figure 4. Hand-RTG APP flow chart

Opening door game is used as an example in fig. 5. In the beginning, hand is ready to open door, so signals have non-obvious change before A. A is rotating door handle, where x, y and z axes present reverse change. Rotating door handle to a certain angle and opening door are between A and B. B is hand rotation and back to original movement.

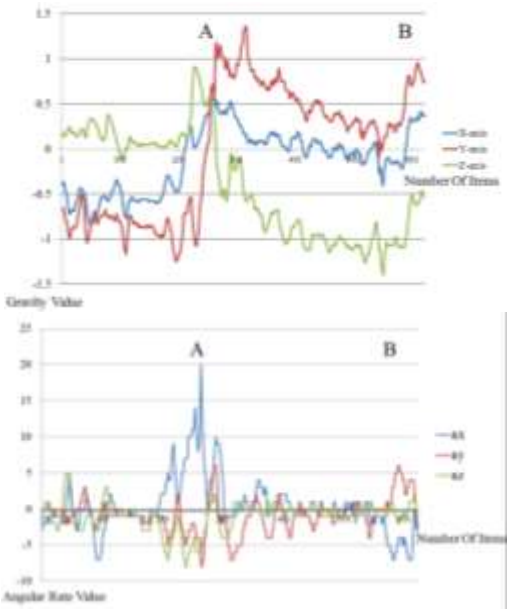

Figure 5. X, Y and Z axes data chart in opening door game

III. Implementation Results

The wearable sensor device can achieve following three rehabilitation purpose:

1. Wrist range of motion: Wrist joint moving forward, backward, leftward and rightward
2. Wrist stretch: Wrist stretching forward and backward
3. Forearm pronation and supination: Wrist joint performing pronation and supination.

A. *Training Game APP*

1) Game Start

After opening Hand Rehabilitation Training Game APP and connecting it with Bluetooth of wearable sensor device, users can start training game choice.

2) Training Game: Wiping Table

When users move hands to perform the movement of wiping table, the proposed device detects the amount of change in the level. With more amount of change in the level, the stains on table in the game disappear faster. When all stains disappear, the game is over. The rehabilitation movement of this training game is wrist range of motion, which is similar to wiping table in reality and makes users feel real during rehabilitation, as shown in Figure 6

Figure 6. Picture of Wiping Table

3) Training Game: Pouring Water

Users do the movement of holding a cup of water and choose a basin. Then users move hands as the cup of water on the screen moves in the same way. Users imitate the movement of poring water above the basin, while the cup on the screen pours out water at the same time. Users should stop when the basin is filled with water. The movement of pouring water can be determined according to the previously chosen hand (right hand or left hand) for rehabilitation in the beginning of game, which determines that right hand should perform left rotation and left hand should perform right rotation.

The rehabilitation movement of this training game is forearm pronation and supination. With imitating the movement of pouring water in real life, the training game can help users perform rehabilitation movements without worrying about the problem of spilling water in practical training, which is shown in Figure 7

Figure 7. Picture of Pouring Water

4) Training Game: Taking Things

Users choose a ring to move. When red frame appears round the ring, it represents that the ring can be taken. This rehabilitation game can be divided into three parts, including moving upward, moving rightward and leftward, and moving downward. After a complete training game finishes, the three rings are moved to one side and can be moved to the other side again. This rehabilitation game simulates the situation of taking things in real life, which can help users practice the three basic movements easily, as shown in Figure 8.

Figure 8. Picture of Taking Things

5) Training Game: Opening Door

Users should choose a door to open. When red frame appears round the door, users can imitate the movement of opening door with door handle on the screen rotating and door opening at the same time. The rehabilitation game finishes after the two doors are opened correctly. This training game is for simulating the movements of hand rotation for opening door in reality, as shown in Figure 9.

Figure 9. Picture of Opening Door

IV. Conclusion

The wearable hand rehabilitation training system proposed in this study can apply to hand rehabilitation for patients to improve hand agility and proficiency, increasing connection with life gradually. The entire system combines wireless transmission, wearable device and APP, using 6-axis-accelerometer/gyroscope to quantify value of hand movements, and applying tablet computer to operate and determine movements, which improves confidence and rehabilitation effectiveness for patients with visual feedback. The proposed device can simulate common movements in real life and increase the connection between rehabilitation and life. In addition, patients with disabilities can perform rehabilitation training at home without limitation of place or time.

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