Sitting to Standing and Walking Therapy for Post-Stroke Patients using Virtual Reality System

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***Abstract*—generally, post-stroke patients suffer physical disorder or paralysis in various level. Common treatment to restore the functionality of the paralyzed limb is by doing motoric therapy. This therapy was done in hospital and was monitored by therapists. However, most of the post-stroke patients choose not to do therapy since their access to hospital is difficult or their motivation to do therapy is low. To overcome the limitations of traditional therapy methods some interactive game-based therapy systems were introduced i.e: AR-therapy and Wii-based movement therapy. Unfortunately, their performance is low due to user ergonomic factor problem.**

In this study, we proposed a virtual reality system for sitting to standing and walking therapy for post-stroke patients called KOMY. This application is integrated with Kinect technology. Four VR game-based training tasks were adopted from sitting to standing therapy and walking therapy that was done by therapist. These tasks are sitting-standing-sitting, moving leg aside, moving leg freely, and walking. Each task has tree difficulty level. From observation that involving post-stroke patient, elderly healthy people, and therapist, we find that all of them give positive comment to this application. They said that this application not only can be used for therapy of post-stroke patients but also can be used for exercise to elderly. Further, KOMY can be used as alternative for playing therapy and home education therapy.

Keywords—Sitting and Standing Therapy; Walking Therapy; Kinect; Virtual Reality.

I. INTRODUCTION

Stroke is a desease that causes motoric nervous system disorder. It is happen when the distribution of blood to the brain is disturbed. In a year, almost fifteen million people over the world suffer of stroke. In Indonesia, the number of stroke patient is increasing every year, it reaches 500.000 people. Based on data from Stroke Foundation of Indonesia in 2009, it is the largest in the world [1]. In Indonesia, stroke mostly attacks 35,8% elderly patients and 12,9% of them ends with death [2].

Ninety percent of those who survive suffer of paralysis with different levels [3]. Usually, the paralysis occurs in the limb either hand or feet. Common treatment to restore the functionality of the paralyzed limb is by doing motoric therapy. This therapy was done in hospital and was monitored by therapists. However, most of the post-stroke patients choose to not do therapy bacause of some reasons i.e: the therapy facilities only available in certain hospital that difficult for patient with low mobility to access it; the motivation of patient during therapy process is low.

To overcome the limitations of traditional therapy methods some interactive game-based therapy systems were introduced [4] [5] [6]. These systems was able to motivate patients in doing therapy regularly.

A post-stroke therapy application based on augmented reality, AR-therapy, was developed. This application was used for therapy of limb hand [4]. Here, a marker was laid in patients hand to show up 3D object in the screen. However, this application only limited on the movement of hand from elbow to finger. Further, the use of marker is less effective because the patients hand is unstable.

In 2013, NeuRA (Neuroscience Research Australia) developed a stroke therapy system based on Wii called Wii-Based Movement Therapy [5]. This application looks like a fun game. However, in this system patients must hold Wii console which is difficult for them who has arm muscle weakness.

In the same year, Handayani developed a post-stroke therapy that used Kinect technology called KIMOST [6]. By using Kinect, patient were not burdened to hold something and their movement were free. This application only focus on therapy for arm movement.

Whereas post-stroke therapy not only limited for arm movement therapy. There are another therapy such as feet movement therapy. This study used Kinect technology to create a sitting to standing and walking therapy for post-stroke patients using virtual reality system. In this application, the use of Kinect make patients move freely and the pleasant training environment improves patients motivation. The remainder of this paper is organized as follows; section two describes the refferences of this research, in section III, methods are presented. Section IV presents implementation. Section V and VI present experiments and conclussion respectively.

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II. REFERENCES

A. Post-Stroke Therapy

Limbs therapy such as hand movement and feet movement are very important. The goal is to make limb get used to doing certain movement in order to improve muscle strength and dexterity. This therapy, post-stroke therapy, should fit the ability of patient. Carr grouped the post-stroke therapy movement into seven movements. These are supine to side lying, supine to sitting over side of bed, balanced sitting, sitting to standing, walking, upper arm function, and hand movements [7]. Each group was divided into several level based on patient ability.

The leveling of sitting to standing therapy and walking therapy was shown in Table 1. Both sitting to standing therapy and walking therapy has six levels. Therapist can put patients in a certain level based on the description of the table. The higher the level of a patient the better his condition.

Table 1 Sitting to standing therapy and walking therapy leveling

Therapy	Level	Description
Sitting to standing	1	Gets to standing with help from theapist
	2	Gets to standing with hand support
	3	Gets to standing independently
	4	Gets to standing and stands for 5 seconds
	5	Sitting to standing to sitting
	6	Sitting to standing to sitting three timess in 10 seconds
Walking	1	Stands on affected leg and steps forward with other leg
	2	Walk with stand-by help from one person
	3	Walks 3 m alone
	4	Walks 5 m in 15 seconds
	5	Walks 10 m with no aid, picks up a small sandbag from floor, turns around and walks back in 25 seconds
	6	Walks up and down four steps three times in 35 seconds

Sitting to standing therapy is important in walking preparation. After patients pass sitting to standing therapy, they must do balancing practice before doing walking therapy. When the patients are able to stand well, the next therapy is walking therapy. This therapy is done gradually based on distance that must be passed by the patients.

About intensity of therapy, consensus of National Institute for Health Clinical Excellence recommended a patients with stroke should do a minimum 45 minutes approprite therapy in a day, for a minimum of 5 days a week. This intensity enable patients to meet their goal as long as they are continuing the therapy [8].

B. Kinect for Windows SDK Based on Skeleton

Kinect is a technology that can be used in virtual reality system. Kinect can detect specific points on the body as shown in Fig. 1. The coordinate of these points can be used to determine the position of user's body hence they can interact with artificial objects that was displayed in the screen. Further, Kinect can recognize the movements of user in front of it in real time [9].

To develop an application that integrated with Kinect requires Kinnect SDK (Software Developement Kits). Kinnect SDK provide developers with the foundation needed to create and deploy an interactive application that respond to user's movement and gesture. It can be used to develop an application that based on C, C# , or VB.NET programming language.

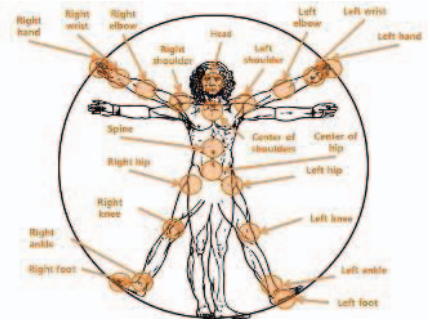

Figure 1. Kinect Skeleton Model

III. METHODS

A. System Architecture

This proposed interactive therapy system consists of a Kinect and Virtual Reality (VR) game-based training system. Four VR game-based training tasks were adopted from sitting to standing therapy and walking therapy that was done by therapist. These tasks are sitting-standing-sitting, moving leg aside, moving leg freely, and walking [10].

Each task of the training has difficulty level. The parameters of it are shown in Table 2.

Table 2 Difficulty level's parameter

Task	Parameter to set difficulty level
Sitting-standing-sitting	Height of movement from sitting to standing
Moving leg aside	Changing potition frequency displaying object between right side position and left side position
Moving leg freely	Time duration displying target coin
Walking	Distance of walking area

This proposed application is dekstop-based application that integrated with Kinect technology. During developing this

application, Windows SDK library that utilize skeleton-based Kinect function and depth camera function was used. The system architecture of this proposed application was shown in Fig. 2.

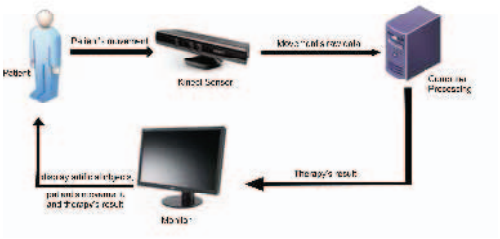

Figure 2. System Architecture

B. System Design

There are four tasks in this application. Each task consist of three levels based on parameter shown in Table 2. The levels in each task indicate the level of difficulty of the task. The higher the level the more difficult the task.

Actors involved in this application are patient and therapist. The role of therapist can be replaced by family member. Use-case diagram of this application was shown in Fig. 3.

Figure 3. Aplication's Use Case Diagram

IV. IMPLEMENTATION

Before doing training, there is a calibration process that is used to retrieve the coordinates of head, right leg, and left leg position of patient. These coordinates will be used as reference to display object during training. In this process patients was asked to do certain movement then his coordinate position was saved in local variables. This process will be done each time patients doing therapy because some time their place to do therapy is changing.

The various tasks that was applied in this application are follows:

1. Task 1: sitting-standing-sitting

This training is intended to patient that was reach state sitting to standing level 3, get to standing independently. In this task, this application will display artificial object that placed according to the height of the patient. Here, patient, who initially was in a sitting state, was asked to stand up reach displayed object. This movement was repeated three times. The score was computed based on the time that was required for heading these three objects.

Each object is displayed in duration 10 seconds. If patient able to reach the object when the object displayed tree times then his level will increase. The difficulty of each level is based on the height of the object position. In level 1 the height of the object is 85% of the patient's height. In level 2 and level 3, the height of the object is 90% of the patient's and 100% of patient's height consequently.

Figure 4. Task 1 Example

2. Task 2: Moving leg aside

This training is adressed to patients who are at stage of walking level 1, stands on affected leg and steps forward with other leg. The purpose of this task is to train the balance of patients before learning to walk. At this task, an artificial object will be displayed next to the patient's right and left legs alternately as shown in Fig. 5. Patient who is in stand up position was asked to kick the displayed object. Assessment of this level was based on the number of successfully kicked object within a period of one minute.

The leveling in this task is based on changing potition frequency displaying object between right side position and left side position. For level 1, an object will be displayed in right side three times then it will be displayed in left side tree times also. This process will be done continually until the time ended. In level 2, the object will be displayed in right side two times and in right side two times. While in level 3, the object will be displayed in right side and left side alternately until the time ended.

Figure 5. Task 2 Example

3. Task 3: Moving leg freely

This training is intended for patients whose stage are at stage of walking level 1. The purpose is to familiarize the patient's legs with moving. Moreover, this task can improve patienst's balance. At this stage, three coins will be displayed, two coins with red colour and one coin with green colour. The appearance of this task was shown in Fig. 6.

In this task, patient who was in the standing position is asked to kick a green colored coin among red colored coin. Assessment of this task is based on the number of obtained coin. If the patient kick green coin, the point is increased with five. Meanwhile, if the patients kick red coin, the point will be decreased with five. The higher the level, the appearance duration of these coins the shorter.

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Figure 6. Task 3 Example

4. Task 4: walking

This task is intended for patients who are at the stage of walking level 2, walk with stand-by help from one person. At this stage, system will display a vertical green colour path on the screen as shown in Fig. 7. There is an object represented patient's position at this path. Here, patient is asked to stand up at a certain distance and then slowly walking from start to finish. Assessment was based on the required time to walk from start point to finish point. The distance between start and finish are 1 m for level 1, 2 m for level 2, and 3 m for level 3.

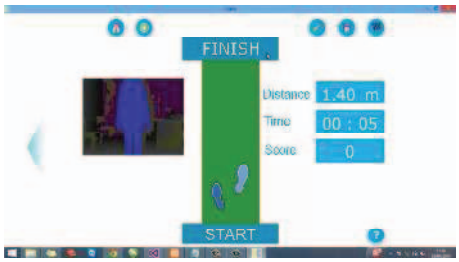

Figure 7. Task 4 Example

To monitor the patient's progress, therapist can see patient's history training reports. These reports are patients history training, patient's condition progress graphics, and therapist comments. Patient's condition progress graphics will show five newest training history from patient's training at each task. The example of the graphics was shown in Fig. 8.

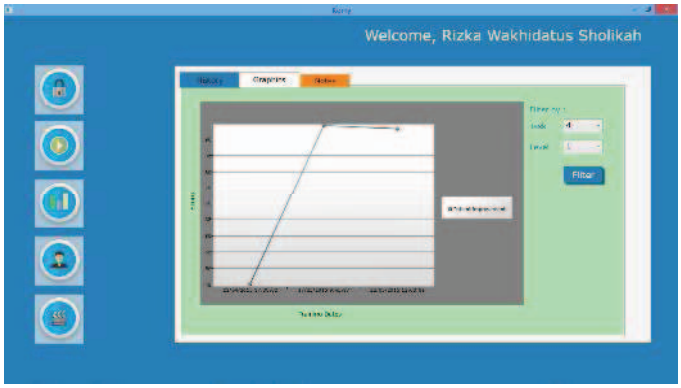

Figure 8. Patient's Condition Progress Graphic

V. EXPERIMENT

Two elderly healthy people and a post-stroke patient were recruited in this experiment. These elderly pople are over 45 years old and the post-stroke patient is 60 years old. The post-stroke patient is at stage walking level 2.

In this experiment, they tried this application in different places. Each participant did training one time in each task and their score were recorded. And after the training they were asked to give comments about the application.

The propose of this experiment is to find out average score of training in each level from both elderly healthy people and stroke patient. Further, these scores will be compared. The result of the experiment was shown in Fig. 9. The figure showed that the patient's score is lower than the healthy people's score. The healthy people's score almost reach the maximum score of the system. It means that if patient's score reach maximum score of the system, his performance close to healthy people's performance.

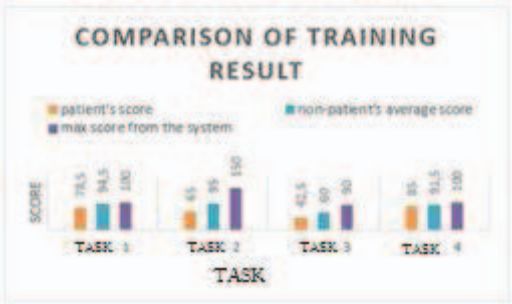

Figure 9. Comparison of Training Score between Stroke's Patients and Healthy People

Apart from that, the comment of these participants were positive. These healthy people participant said that this application can be used as exercise tool for movement practice and balancing practice for elderly.

Further, this application not anly being test to post-stroke patients and healthy people but also being demonstrated to two fisiotherapist from local hospital in Surabaya at different time. Both of them give positive response to this application. They said that the idea of this application can be applied as play therapy at hospital and home therapy education that can be done independently at home.

VI. CONCLUSSION

This post-stroke therapy application, KOMY, was built using Kinect technology. This application can be used to do therapy for post-stroke patients at stage sitting to standing level 3, gets to standing independently. It is helpful for patients with low mobility because they can do therapy at their home independently.

Task design in this application was inspired by therapy for post-stroke patient that was run by therapist. Further, the interesting artificial environment attract the patients feeling and improve patients motivation. In this application, therapist and family member can see the improvement of patients because it shows the history of training.

From interview, elderly people, post-stroke patients, and fisiotherapist give positive response of this application. This application not only can be used for therapy of post-stroke patients but also can be used for exercise to elderly. Further, KOMY can be used as alternative for plying therapy and home education therapy.

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