Gesture Control Gaming for Motoric Post-Stroke Rehabilitation

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Summary
The hospital situation, timing, and patient restrictions have become obstacles to an optimum therapy session. The crowdedness of the hospital might lead to a tight schedule and a shorter period of therapy. This condition might strike a post-stroke patient in a dilemma where they need regular treatment to recover their nervous system. In this work, we propose an in-house and uncomplex serious game system that can be used for physical therapy. The Kinect camera is used to capture the depth image stream of a human skeleton. Afterwards, the user might use their hand gesture to control the game. Voice recognition is deployed to ease them with play. Users must complete the given challenge to obtain a more significant outcome from this therapy system. Subjects will use their upper limb and hands to capture the 3D objects with different speeds and positions. The more substantial challenge, speed, and location will be increased and random. Each delegated entity will raise the scores. Afterwards, the scores will be further evaluated to correlate with therapy progress. Users are delighted with the system and eager to use it as their daily exercise. The experimental studies show a comparison between score and difficulty that represent characteristics of user and game. Users tend to quickly adapt to easy and medium levels, while high level requires better focus and proper synchronization between hand and eye to capture the 3D objects. The statistical analysis with a confidence rate(α:0.05) of the usability test shows that the proposed gaming is accessible, even without specialized training. It is not only for therapy but also for fitness because it can be used for body exercise. The result of the experiment is very satisfying. Most users enjoy and familiarize themselves quickly. The evaluation study demonstrates user satisfaction and perception during testing. Future work of the proposed serious game might involve haptic devices to stimulate their physical sensation.
Keywords:
Gesture control, post stroke, rehabilitation, Gaming

1. Introduction

People with physical impairment, due to strokes, require extensive physical therapy in hospitals. This condition strives them to find an alternative of treatment at their home, due to the higher risk of getting therapy at hospitals during pandemic. The extensive study related to the rehabilitation with Artificial Intelligence (AI) and gaming has become intense along with the growth of technology, telemedicine and telerehabilitation, thus become the excellent choice to be used at home.[1,2, 3]. AI may help a user with automation and adjust the system profile to be in line with user's behavior and consequently it minimizing the intervention from the clinicians [4].

Telerehabilitation should cover the patient with minor to a major case of stroke. The achievement of a patient needs to be measured precisely, and the goal accomplishment must be realistic and doesn't dishearten the patient[5]. This paper consists of several sections. Section 1 depicts the problem background, while section 2 presenting current and previous works. Section 3 portraying methodology of the research, while Chapter 4 preseting the results of the study. Finally, Part 5 give conclusions of research study and offers suggestions for future work to be undertaken in upcoming research.

2. Related Works

Post-stroke users require adaptive level of challenge that fits their conscious level[6, 7]. Wii board also being used for analyzing the balancing and fall risk assessment of post-stroke patient[8]. The Wii board sensor can detect the power of both legs and predict whether the user will fall down or not. In the meantime, Serious Game it's a kind of game with genre for teaching and learning through computer based system[9].

On the other hand, the serious game with a therapeutic concept is expected to endorse home telerehabilitation. This concept is changing the conventional therapy model into gameplay model [10-14]. The patient with brain injury usually experiencing the navigation diminishing. The serious game might help recover their sense of navigation by moving the 3D objects inside virtual setting [15]. The controllers such as mouse and keyboard are both compared to each other. While text-based and video-based guideline also performed and analyzedto obtain user achievements [15, 16]. Their experiments show that stroke patient prefers video-based guidance instead of text. However, the overall evaluation shows that users are satisfied and expect that serious game can be conducted in more realistic ways [15]. The Virtual Reality (VR) has also moved closer to clinical testing to help the patient regain their gait and balance as well as other motoric function exercises [17, 18]. Home-based training VR-application are helping outpatient with stroke therapy to regain access to exercise in more preferably ways [19-22]. Also, another researcher

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provides a framework for assisting motoric treatment to improve the balancing and gait handling for a patient with cerebral palsy. The arm rehabilitation for multiple sclerosis also being initiated with a serious game or virtual reality approach, and by using gesture tracking with Kinect camera [23-29]. VR seems very capable of motoric rehabilitation of stroke outpatient from mild to severe case. The randomized clinical trial using this method has been discussed in several studies [30-34]. Exoskeleton and robotic is an improvement that can assist stroke patient in grasping real objects. The robot might be controlled through a Brain-Computer Interface (BCI) to ease the patient [26, 27]. Most of the previous works have present various jobs of virtual rehabilitation through serious gaming, robotic, AI, etc. This paper focus on providing an innovative solution by using home-based gaming for stroke rehabilitation that can be controlled through voice and gesture recognition. User/patient can increase the level of difficulty by increase the speed and change the position of the 3D objects that need to be captured.

3. Research Method and Material

The problem formulation is initiated to find the research gap that will act as the motivation of our study. The data gathering for acquiring the command from the user is collected through a depth image recording of Kinect camera. Once the gesture data collected and analyzed, the program will be executed based on the user gesture. The Kinect camera will track the skeleton of the user so they can capture the virtual object, only by moving their hand and give a voice command, refer to Fig.1.

Using the Kinect SDK will start monitoring the skeleton of the user. Finally using the 3D library, the 3D virtual human model is developed to simulate user actions, refer to use case diagram in Fig.2.

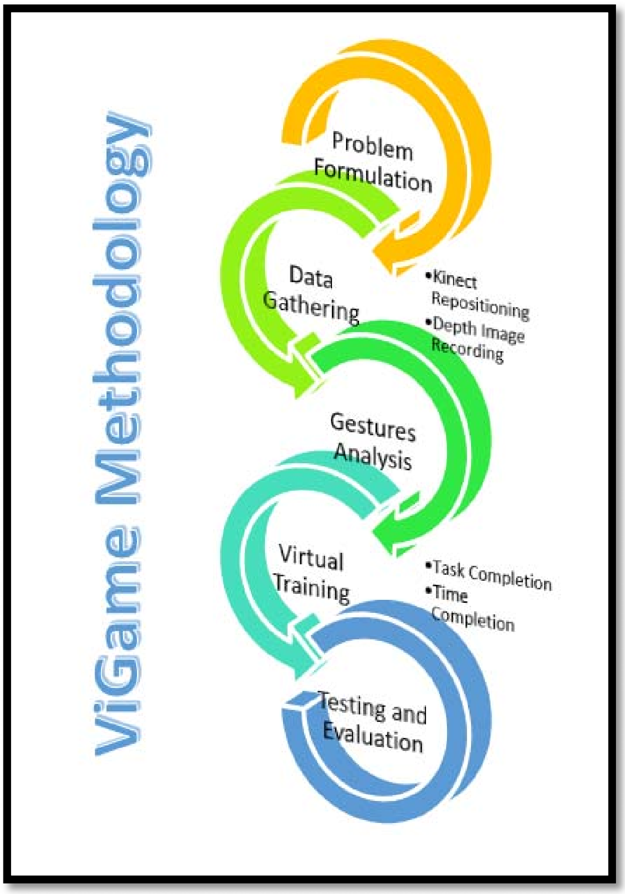

Fig.1. Research Methodology

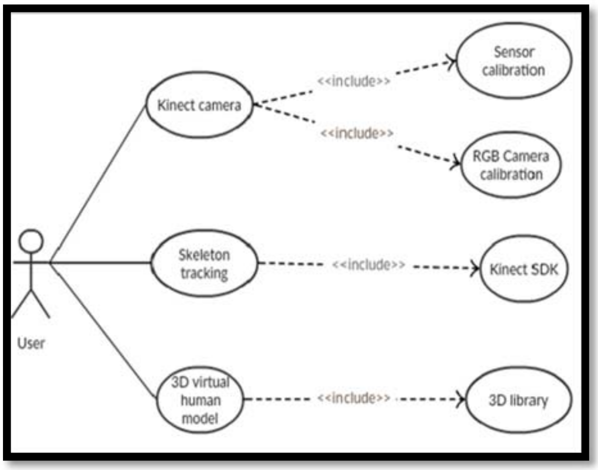

Fig. 2. Use case Diagram of the system

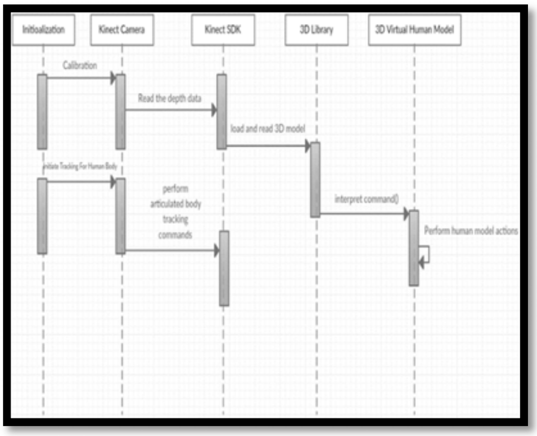

Fig.3. Sequence Diagram of ViGame

The sequence diagram in Fig.3 depict the process by initiating the camera devices, then capture image stream. Afterwards, 3D model is created by 3D controller to produce a virtual human that will mimic the user movement accordingly.

4 Result and Discussion

The first implementation is by building the shape game using the OpenNI framework and continued by providing full-body tracking to the user. User body will be tracked through an IR sensor, and a depth image of the RGB camera then analyzedto give real-time feedback. The tracked skeleton of the players and shapes (circles, triangles, stars, and so on) will be falling from the sky. Players can move their arms and legs to bump into shapes, make them change direction, or even explode. Players can give voice commands, such as "make bigger" or "make smaller", to increase or decrease the size of the shapes. Players can say other controls, such as "show yellow stars", to change the colour and type of the falling 3D objects.

The research has two main goals, such as real-time tracking for hand by capturing the depth data emitted from infrared and image vision from streaming video; the human hand can be tracked simultaneously. The second goal is producing a virtual training for patients, so they can do exercise as well as do rehabilitation at the same time. If a user wants to start the application, they need to click the play button, as shown in Fig.4. There are two main buttons: first is the video of rehabilitation and the second button is to run the Game. The tracking will be started by lifting both hands, refer to Fig.5.

Fig. 4. Main interface for ViGame-1

Fig.5. Main interface for ViGame-2

To control the game and make it easier, the patient will give some commands using voice. By default, the shapes will fall from the centre of the sky, but the patient wants to train the right hand so that he will say the phrase "To the right" then the shapes will fall from the right of the centre by the specific range and so on or use the word "bigger" for larger 3D objects, examples of the list of voice-commands to control settings of game are giving in Fig. 6.

```
public class SpeechRecognizer : IDisposable
{
    private readonly Dictionary<string, WhatSaid> gameplayPhrases = new Dictionary<string, WhatSaid>
        {
            { "Faster", new WhatSaid { Verb = Verbs.Faster } },
            { "To The Right", new WhatSaid { Verb = Verbs.Right } },
            { "To The Left", new WhatSaid { Verb = Verbs.Left } },
            { "Center", new WhatSaid { Verb = Verbs.Middle } },
            { "Finish", new WhatSaid { Verb = Verbs.Finish } },
            { "Slower", new WhatSaid { Verb = Verbs.Slower } },
            { "Bigger Shapes", new WhatSaid { Verb = Verbs.Bigger } },
            { "Bigger", new WhatSaid { Verb = Verbs.Bigger } },
            { "Larger", new WhatSaid { Verb = Verbs.Bigger } },
            { "Huge", new WhatSaid { Verb = Verbs.Biggest } },
            { "Giant", new WhatSaid { Verb = Verbs.Biggest } },
            { "Biggest", new WhatSaid { Verb = Verbs.Biggest } },
            { "Super Big", new WhatSaid { Verb = Verbs.Biggest } },
            { "Smaller", new WhatSaid { Verb = Verbs.Smaller } },
            { "Tiny", new WhatSaid { Verb = Verbs.Smallest } },
            { "Super Small", new WhatSaid { Verb = Verbs.Smallest } },
            { "Smallest", new WhatSaid { Verb = Verbs.Smallest } },
            { "More Shapes", new WhatSaid { Verb = Verbs.More } },
            { "More", new WhatSaid { Verb = Verbs.More } },
            { "Less", new WhatSaid { Verb = Verbs.Fewer } },
            { "Fewer", new WhatSaid { Verb = Verbs.Fewer } },
        };
```

Fig. 6. Voice command control code

User may control the force of the object falling by setting the gravity of the system, as shown in the code Fig.7.

```
case SpeechRecognizer.Verbs.Faster:
    this.dropGravity *= 1.25;
    if (this.dropGravity > 4.0)
    {
        this.dropGravity = 4.0;
    }

    this.myFallingThings.SetGravity(this.dropGravity);
    break;
case SpeechRecognizer.Verbs.Slower:
    this.dropGravity /= 1.25;
    if (this.dropGravity < 0.25)
    {
        this.dropGravity = 0.25;
    }

    this.myFallingThings.SetGravity(this.dropGravity);
    break;
```

Fig. 7. Voice command control code

After the ViGame started, the shapes will start falling down, and the user will move the right or left hand to push them up. Fig.8 shows the movement of user's hand at 90 degrees, and it causes hitting every shape in the right position of the screen. The same thing occurred when the user tried to turn to left. Additionally Figure 9 displays how the user performs voice command to control the falling object speed.

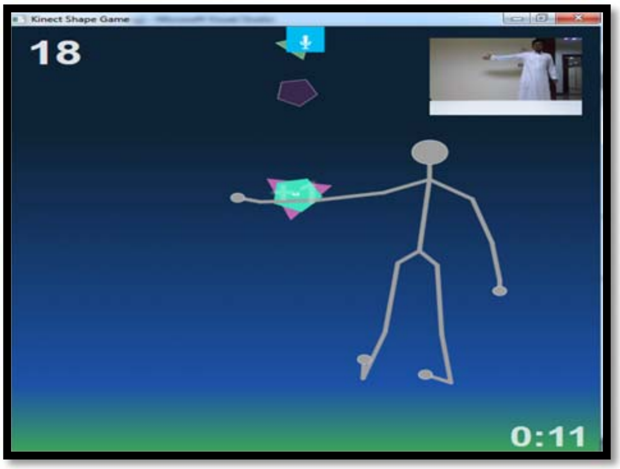

Fig. 8. Game- User capture trying to capture 3D objects

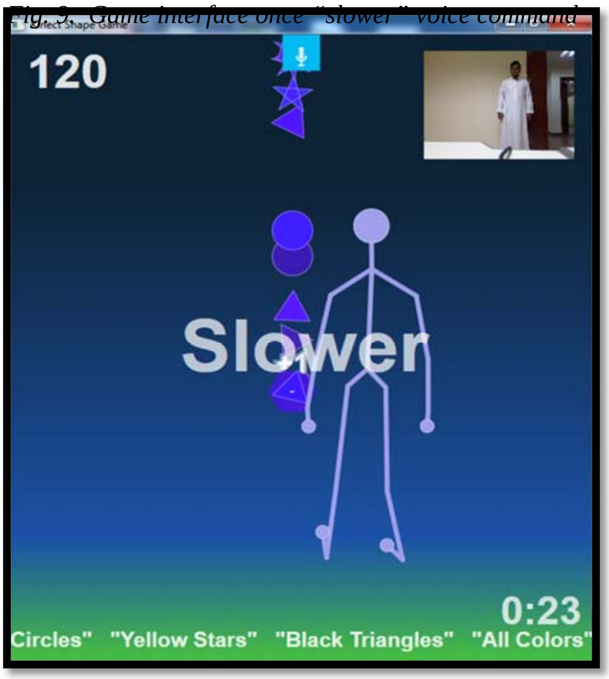

Fig. 9. Game interface once "slower" voice command activated

The usability testing toward 21 health subjects is presented to give an accountable evaluation of ViGame functionality and efficiency.

Table 1 displays the demographics data of the subjects.

Table 1. Demographic typical of subjects

	SD	Mean
Age	19.5 ± 1.21	19.9
Repeat	4 ± 1.14	3.60
Completion Time	179.0 ± 47.23	181.6
Score	268 ± 91.57	284.6

Fig.10 and 11 represent the correlation of Difficulty elements of ViGame with Scores and Completion Time. It is shown that Medium level has the highest density, followed by Low and High level.

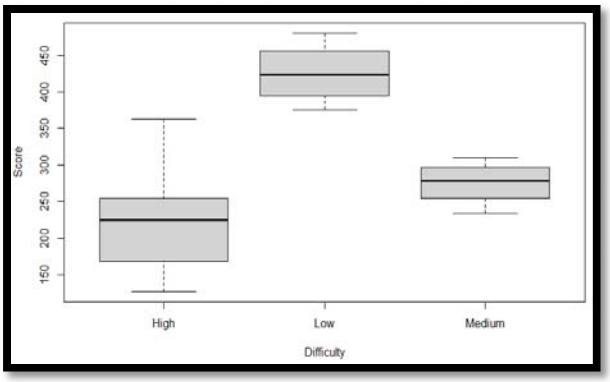

Fig.10. Box plot diagram of Scores~Difficulty

These mean subjects are not having difficulty starting the ViGame and played it until it reaches the medium level. However, High-Level challenge requires more hand coordination in term of speed and accuracy to capture the falling 3D objects.

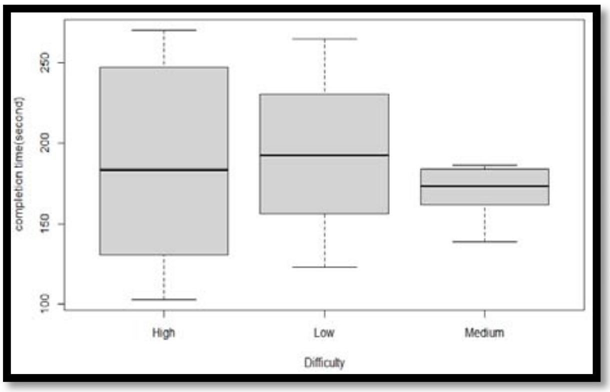

Fig.11. Box plot diagram of Completion Times~Difficulty

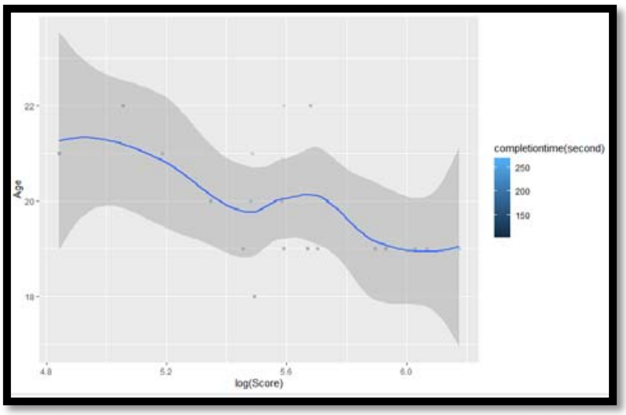

Figure 12. Plot diagram of Score~Age

Fig.12 and 13 describe the comparison graph between score with Age and completion time. The younger age seems able to obtain more score than the older ones.

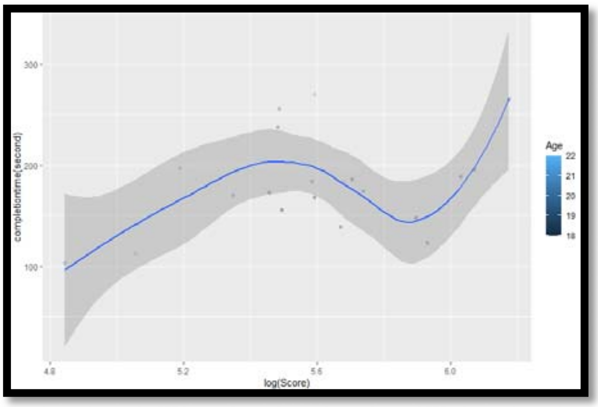

Fig.13. Plot diagram of Score~Completion Time

To evaluate the proposed ViGame system, we did statistical analysis toward usability test. Table 2 shows the descriptive statistical data of our experiment. We did develop a hypothesis of the test:

H_0: Subjects obtain a good Training before use The Game

H_1: Subjects without a good Training before use The Game

Table 2. Descriptive statistic of ViGame Usability test

Score		***Score without training***	
an	284.60	Mean	275.05
Standard Error	20.48	Standard Error	20.92
Median	268.00	Median	250.00
Mode	268.00	Mode	#N/A
Standard Deviation	91.57	Standard Deviation	93.55
Sample Variance	8384.67	Sample Variance	8751.21
Kurtosis	-0.06	Kurtosis	0.15
Skewness	0.47	Skewness	0.56
Range	353.00	Range	374.00
Minimum	127.00	Minimum	112.00
Maximum	480.00	Maximum	486.00
Sum	5692.00	Sum	5501.00
Count	20.00	Count	20.00

The T-test was also performed and its shown that we can reject the null hypothesis because T Start < T(1 tail), refer to Table 3. It means there is no significant difference between who receive prior training and not receiving any training. Furthermore, it also means that our system is easy to use, and subjects didn't have difficulty of using ViGame.

Table 3. T-test result of ViGame Usability test

Score		***Score without training***
Mean	284.6	275.05
Variance	8384.673684	8751.207895
Observations	20	20
Pooled Variance	8567.940789	
Hypothesized Mean Difference	0	
df	38	
t Stat	0.326260985	
P(T<=t) one-tail	0.373008505	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.74601701	
t Critical two-tail	2.024394164	

The score of subjects with training(M=284,6,SD=91.57, count=20) was hypothesized to have similar result with Score of subjects without good training(275.05, SD=93.55, =20). This difference was insignificant, t(38)=2.02, p=0.37(1 tail).

5 Conclusion

Most of the time, rehabilitation is done using expensive tools and dull environments. On the other hand, Gaming is usually used for fitness purposes. In this paper, we proposed an innovative solution with low-cost equipment that users can buy without much effort. Users/patients can also set up the therapy in their homes and do the exercise even without guidance from an expert. Giving those who survived a stroke a chance to regain their moves with less costly equipment and a less tedious and friendly environment is challenging and fascinating. The proposed system is equipped with voice and gesture commands suitable for a natural interface for the user. Natural interaction through gesture tracking has become popular recently. This project succeeds in providing users with a simple exercise game that can help the patient or user move their hand to hit a particular object frequently and control the object's position from their voice command. The statistical analysis with confidence rate α 95% shows that users are easy to use the system even without prior training. The features of the system can be enhanced and integrated with a simple haptic device that can stimulate the nerve of the patient and give haptic sensation to them..

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