Kinect-based Framework for Motor Rehabilitation

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***Abstract*— The number of people suffering from motor impairment is increasing as incidence involving limb injuries can easily happen. These injuries may be traumatic injuries, congenital deformities, neurological and arthritic conditions or regional pain syndrome. Some of these injuries need operative procedure, whilst others use interventive methods. Regardless of the treatment performed, a vital component in the road to recovery should include physical rehabilitation. This paper proposes the design of a Kinect-based framework for motor rehabilitation. Originally introduced as an add-on for the Xbox gaming console, Kinect offers the capability to track the motion of a human body in real time. This research makes use of that capability to combine the Kinect with an easily modifiable application to produce an individually customized home rehabilitation system that will motivate, provide feedback and track the progress of the rehabilitation patient. This paper also proposes an evaluation framework to evaluate the Kinect based home rehabilitation system based on the technology acceptance, the motivation of the patient, and the patient's learning style.**

Keywords—Kinect, Rehabilitation, Motor disability, Framework

I. INTRODUCTION

As human beings, it is important for us to have normal functioning limbs so we can lead an independent and active life. Unfortunately, according to the fact sheet of disability and health released by WHO Media centre, over a billion people are estimated to have some form of disability [1] and around 150 million people exhibit significant difficulties in functioning of limbs [2]. Rehabilitation is needed to alleviate the symptoms but becomes demotivating due to the inadequate skills and knowledge of the health workers in most hospitals or the lack of access in rural areas [3]. An estimated 80% of all people with disabilities in the world live in rural areas of developing countries and have limited or no access to services they need [4]. While a possible solution to this is to have home based therapy, patients do not feel obligated to do the exercises and ignore the treatment [5]. Moreover another issue is patients who were prescribed home based therapy exercises were not sure how to do the exercises properly and there was no monitoring on their progress [5], [6].

With the advent of Microsoft Kinect camera, a more accurate and powerful live recognition of a patient's movement whilst performing rehabilitation exercises at home is possible. Kinect comes with a depth sensor that is capable to track the movements of the patient in 3 dimensions. Using the Kinect SDK, an application can assess the skeletal structure of a fully clothed patient. Kinect is a viable solution to home based therapy due to its low cost and relatively good motion sensing accuracy [7].

There are many types of rehabilitation, namely conventional, sensor based, robot aided, using visual markers and marker free visual based. The conventional method obviously requires licensed physical therapist and has rigid meeting schedules. Using sensors or visual markers require adherence to the human body and setup needs to be done correctly to be effective. Robot aided are usually bulky and costly thus not viable for home usage.

This research aims for the maker free visual based category to design the framework for a home based therapy program using Microsoft Kinect application that will enable proper monitoring of the patient's progress. The application will also provide feedback to the patient so that the patient can know if the exercises are done properly. By use of technologies such as the Microsoft Kinect application, it can motivate the patient to continuously engage in the therapy while diverting the patient's attention away from the pain [8]. By monitoring and recording the patient's exercises, the physical therapist can be more accurately informed of the patient's progress as well. An evaluation framework is also proposed to ensure the home based therapy program using Microsoft Kinect application is actually well received by the patient and is useful in aiding a more conducive home based rehabilitation.

II. SYSTEM DESCRIPTION

A. User Types

The system design is presented in Fig. 1. There are two types of user in the system, the physical therapist and the patient. The physical therapist will use their expertise and customize the rehabilitation exercises to be done by the patient. The patient will perform the rehabilitation exercises in front of the Kinect camera which will capture all the information and pass it to the C# application via the Kinect SDK. The entire body of the patient is represented as an avatar in the application which helps stimulate brain activity and enhance the voluntary movement of the affected limb [3].

B. Monitoring and Feedback

The application will monitor the patient and provide feedback in terms of the correctness of the exercises being performed and also monitor the patient's progress. For example when performing a shoulder abduction exercise correctly, there will be a count increase shown, an audio playback to indicate the movement is correct with encouragements, and a pie chart that gradually changes color to green as the range-of-motion degree nears the acceptable value set by the physical therapist. If the exercise is done incorrectly or the degree of movement is insufficient, the pie chart will remain red and the count will not increase if it does not at least pass the minimum threshold. When a particular exercise is completed, an audio is played to congratulate the user for completing it. By providing live feedback to the patient, the patient will feel more motivated and accountable to perform the rehabilitation exercises properly. The entire patient's exercise statistics is kept and ordered by exercise sessions, for evaluation by the physical therapist. This will enable the physical therapist to get an unbiased and accurate depiction of the patient's progress.

C. Setup

The system is easy to deploy at home, only requiring the low cost Microsoft Kinect camera, a Windows enabled processing unit and a display. The Kinect camera connects to the processing unit via a USB slot and the application is an executable file that runs on the processing unit. Information is then displayed live to help stimulate the patient. No sensors or markers are needed to be placed on the body of the patient, so setup can be done without fuss and requires no expertise. The Kinect application also requires no calibration to suit the patient because the patient is using their own body movements to perform the exercise. And since there are no robotic aids, then risk of bodily harm is not posed by the system.

D. Architecture

On the system architecture side, the application will be coded in C# and requires the .Net framework to operate. This was chosen simply due to the fact that Windows has the greatest share of the operating systems market, ensuring the application will be compatible to operate on most patients' existing home computing environment. This will give the patient a more familiar environment and be less resistant to change. The application will access the information from the Kinect camera through the Kinect SDK. All the raw data is processed and the skeletal information is passed to the application. The Kinect SDK can provide the X, Y and Z-coordinates for 20 joints in the human body. In the application, rules will be written to measure if a performed rehabilitation exercise is correct or incorrect. The number of repetitions will also be monitored.

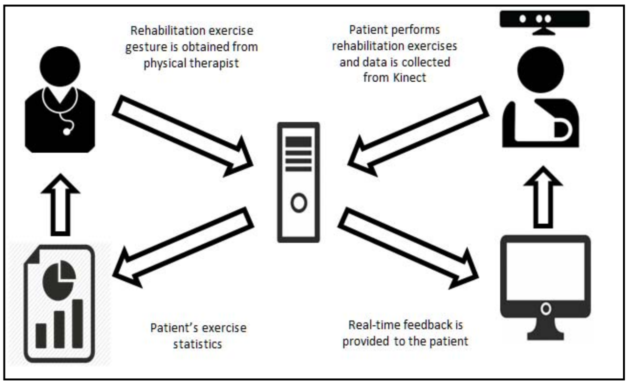

Fig. 1. System Design.

To allow the physical therapist to use the same application for a multitude of patients, XAML files are used to provide individual configurations for the exercises. For example in case of treating frozen shoulder, a less severe patient may be tasked to performed a greater range-of-motion exercise compared to a patient with a severe case. The underlying rules in the application remains, but based on the minimum degree to pass and the maximum degree to strive for, from the XAML file, a patient's exercise may be deemed correct or incorrect. Physical therapist can quickly replicate the XAML files and make modifications, if necessary, to cater specifically for the individual patient without doing any modification to the application. This separation is crucial as it will allow the system to be widely used and customized for the individual patient rather than a generic one that is supposed to fit all patients. The XAML file can just be placed in the same folder as the application's executable file. The system architecture is shown in Fig. 2.

III. EVALUATION FRAMEWORK

To evaluate the home based therapy program using Microsoft Kinect camera, few issues need to be discussed. Firstly, the patient needs to be categorized by learning types; visual, aural, read/write or kinesthetic. Then how easy to use does the patient perceive the system to be and also the system's usefulness in assisting with the patient's rehabilitation process. Finally, the patient's motivation to use the home based system is also ascertained. At the end of the rehabilitation period, a performance test needs to be conducted by the physical therapist to determine how well the patient has recovered or improved. The independent variables will be the perceived usefulness, the perceived ease of use, and the motivation to use the new system. The

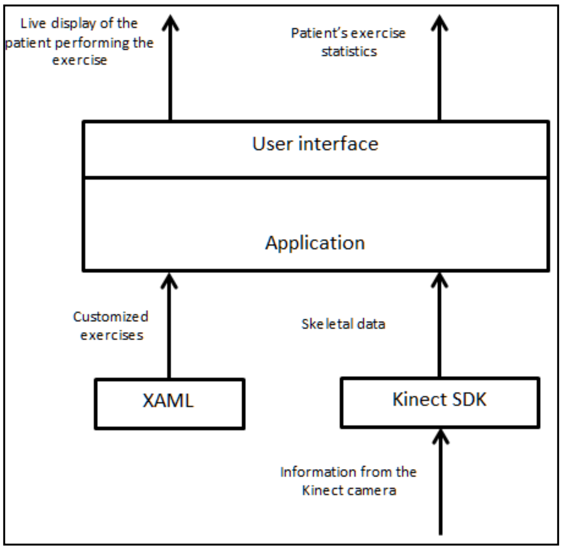

Fig. 2. System Architecture.

moderating variables will be the learning types and the control variables, which will be the physical therapist, the environment, the rehabilitation period, and the rehabilitation exercises. Lastly the dependent variable will be the performance outcome. The evaluation framework is shown in Fig. 3.

A. Technology Acceptance

Since the home based rehabilitation program using the Microsoft Kinect camera is not a widely used method, it is important to gauge how the patient will accept and use the new system. For this purpose the Technology Acceptance Model (TAM) by Davis [9] was employed. TAM measures the user's technology acceptance using the perceived usefulness and the perceived ease of use. Both variables are significant predictors of attitude towards technology use and the intention to use [10], [11]. TAM provides a valid and reliable measure that predicts the acceptance or adoption of new technologies by end users [9], [12]. TAM is also a commonly used model to measure technology acceptance [13]. By using TAM, the performance result can be analyzed to ascertain how the acceptance of the patient on using a new rehabilitation system affects the patient's rehabilitation performance. If a low acceptance score also reduces the patient's performance, then changes must be made to the system to further increase the technology acceptance score amongst patients prescribed the Kinect based home rehabilitation system.

B. Motivation

As stated before the motivation level of the patient is also important while performing the rehabilitation exercises, therefore the Intrinsic Motivation Inventory (IMI) by Ryan [14] was employed. IMI assesses the patient's Interest / Enjoyment, Perceived Competence, Effort, Value / Usefulness, Pressure / Tension, Relatedness, and Perceived Choice. Although there are seven subscales, the Interest / Enjoyment subscale is more directly involved in measuring the intrinsic motivation. As a result of that, this subscale usually has more items on it compared to the others. IMI is flexible in that items that appear redundant may be removed from the questionnaire [15]. According to the situation, different options can be taken with regard to the subscales to be used depending on their relevance to the issues researchers are exploring [15]. Given the flexibility and adaptability of the IMI coupled with fact that it is reliable and validated [16], the IMI was chosen. Measuring the motivation of the patient is equally important when analyzing the performance. If the motivation to use the Kinect based system is low, it means the patient's interest or enjoyment whilst using the system is low. This could explain for a lower performance score. May be a redesign of the user interface should be considered, utilizing their learning style preference, to help increase the patient's motivation to use the system.

C. Learning Styles

The next part in the evaluation framework is the learning styles. Learning in the classroom or learning a rehabilitation exercise is not that much different. An individual's learning style is the style that is most conducive for an individual to learn. Although there are numerous learning styles, usually there is one that best characterizes the individual. But there are individuals who learn equally well in any style. VARK by Fleming [17] suggested four modalities that reflect the learning style of an individual. The visual learning style includes preference for information depicted in some form,

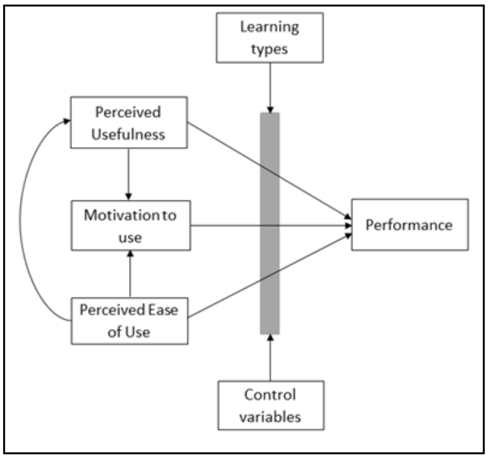

Fig. 3. Evaluation Framework.

like graphs, flow charts, diagram with meaningful symbols, but not still pictures of reality nor PowerPoint slides. Next is the aural learning style (or auditory) that describe a preference for information that is spoken or heard, even including repeating what has been said or in the individual's own way. The read / write learning style is the most preferred as this is the traditional method information is conveyed. In this instance, information is displayed as words. The final group is the kinesthetic learning style. There is a preference to the use of experience and practice. Individuals that fall into this group learn through experience of doing. VARK was chosen because it is validated [18], able to categorize all four learning styles and it is free for research use. The Kinect based system can accommodate multiple learning styles as proposed by VARK. The important feature that separates Kinect from other traditional methods is the capability to convey information though the kinesthetic modality. By utilizing the VARK scores, it can provide an insight if certain learning style is scoring significantly lower performance compared to others. This may point to insufficient stimuli with regards to a particular way the information is displayed. For example, if patients with the aural learning style are consistently scoring lower performance than the other styles, the system may need to increase the number of audio encouragements or audio data.

The technology acceptance, the motivation and the learning styles must be measured / identified to study how they affect the performance of the patient in using the Kinect based home rehabilitation system. Only by analyzing those variables, can the proposed Kinect based framework for motor rehabilitation be judged effective as a viable solution for home rehabilitation. The proposed evaluation framework can also be used to help improve the Kinect based system by improving parts that score lower than the average.

IV. CONCLUSION

As there are numerous issues with the current practice of motor rehabilitation, namely lack of access especially in rural areas, the patient's lack of motivation and obligation to complete prescribed rehabilitation exercises, and the uncertainty if exercises performed are correct, this research strived to propose a Kinect based framework for motor rehabilitation. Home based approach towards rehabilitation solves the issue of lack of access but brings its own disadvantages. To that end, a home rehabilitation system using Kinect is low-cost, easy to deploy, capable of supporting multiple learning styles, will motivate the patient better through accounting and live feedback, and provide a better tool for the physical therapist to monitor the patient's progress. Though more study needs to be done to compare the current methods of performance evaluation and the Kinect based application to determine the agreement between them, the Kinect based application has shown a lot of promise as the new tool for home based motor rehabilitation.

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