ANNEXURE

Specifications of Hardware Component:

Sensor Characteristics and Data Acquisition

Kinect v2 sensor is composed of two cameras, namely a RGB and an infrared (IR) camera. The active illumination of the observed scene is insured by three IR projectors. Some features of the sensor are summarized in Table 1. For example, given the specifications, at 2 m range a pixel size of 5 mm can be obtained. As mentioned on the Microsoft website, the Kinect v2 sensor is based on ToF principle. Even though time-of-flight range imaging is a quite recent technology, many books deal with its principles and its applications. The basic principle is as follows: knowing the speed of light, the distance to be measured is proportional to the time needed by the active illumination source to travel from emitter to target. Thus, matricial ToF cameras enable the acquisition of a distance-to-object measurement, for each pixel of its output data. It should be noted that, unlike other ToF cameras, it is impossible to act on the modulation frequency or within the integration time of the input parameters of the Kinect v2 sensor.

Sensor item	Specification
Depth stream range	4–11.5 ft (1.2–3.5 m)
Skeletal tracking range	4–11.5 ft (1.2–3.5 m)
Viewing angle	43° vertical by 57° horizontal field of view
Mechanized tilt range (vertical)	±28°
Frame rate (depth and color stream)	30 frames per second (FPS)
Resolution, depth stream	QVGA (320 × 240)
Resolution, color stream	VGA (640 × 480)
Audio format	16 kHz, 16 bit mono pulse code modulation (PCM)
Audio input characteristics	A four-microphone array with 24-bit analog-to-digital converter (ADC) and Kinect-resident signal processing, such as acoustic echo cancellation and noise suppression

Table 1. Specification of sensor

Database Classes Setup:

MongoDB saves data in a JSON type format (called BSON with MongoDB) which is represented as such:

```
{
"_id" : ObjectId("55061623ee97182214c35f00"),
"PUserName" : "SarahF",
"Name" : "Sarah Farron",
"Email" : "farron@gmail.com",
"Address" : "12 Sunnybank Avenue, Dundrum",
"DateOfBirth" : ISODate("1981-09-25T21:00:00.000Z"),
"PhoneNumber" : "00353878128789",
"FitnessLevel" : 3,
"Condition" : "Ischemic heart disease",
"WeightKG" : 71,
"IsMale" : false,
"Workout s" : [],
"Diagnosis" : [],
"Messages" : []
}
```

Code 1: PatientDetails BSON

The JSON data display above (PatientDetails BSON), relates to data within the PatientDetails class, which holds the patient's information as well as their Workout information as a list, their Diagnosis information and messages sent to the patient. The class in C# is as follows:

```
public class PatientDetails
{
 [BsonId]
public ObjectId Id { get; set; }
public string PUserName { get; set; }
public string Name { get; set; }
public string Email { get; set; }
public string Address { get; set; }
public DateTime DateOfBirth { get; set; }
public string PhoneNumber { get; set; }
public int FitnessLevel { get; set; }
 public string Condition { get; set; }
public int WeightKG { get; set; }
public bool IsMale { get; set; }
public IList<PatientWorkout> Workouts { get; set; }
public IList<PatientDiagnosis> Diagnosis { get; set; }
public IList<PatientMessages> Messages { get; set; }
 }
```

Code 2: PatientDetails Class

Database Connection Class

```
public class MongoHelper<T> where T : class
{
        public MongoCollection<T> Collection { get; private set; }
        public MongoHelper(string connectionString)
        {

        MongoUrl mongoUrl = new MongoUrl(connectionString);
        MongoClient client = new MongoClient(mongoUrl);
        MongoServer server = client.GetServer();
        server.Connect();
        MongoDatabase provider = server.GetDatabase(mongoUrl.DatabaseName,
        WriteConcern.Acknowledged);
        Collection = provider.GetCollection<T>(typeof(T).Name.ToLower());
        }
}
```

Code 3: MongoHelper Class

Basic Workout :

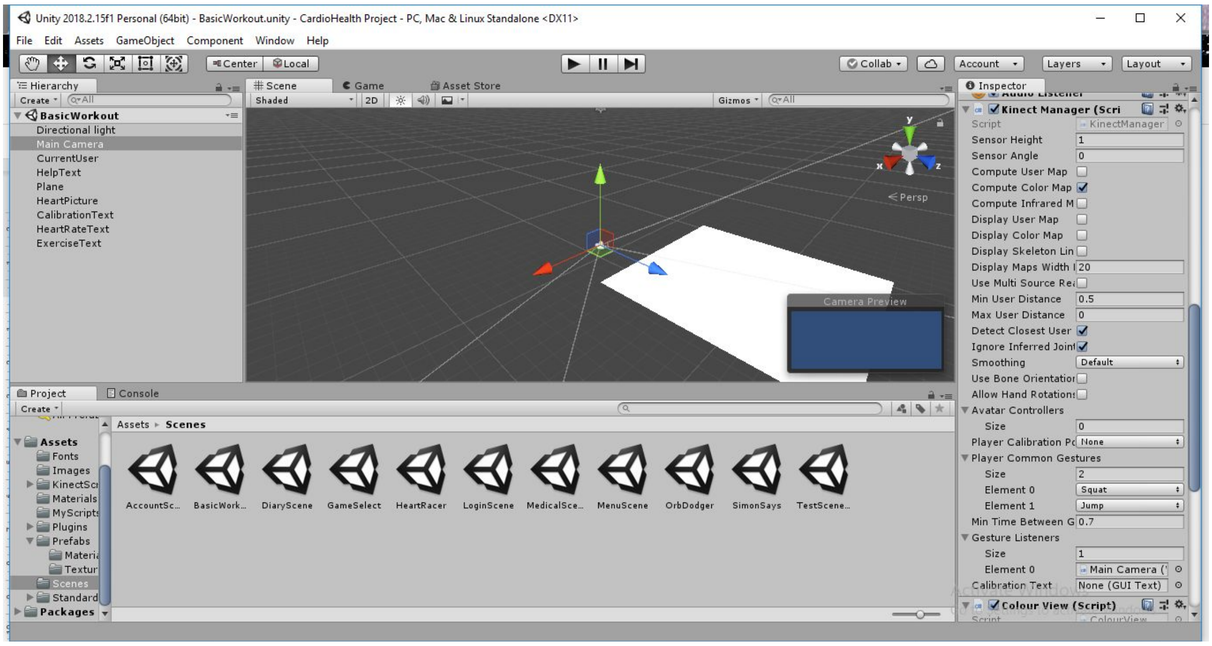

Figure: *Basic Workout Scene implementation on Unity*

- **Workout Gesture Listener:**
  Another class was to be created to detect workouts; the main two workouts which are to be used within the project are Squats and Jumping Jacks. The class created WorkoutListener inherited from the KinectGestures.GestureListenerInterface class. The KinectGestures.GestureListenerInterface contained the list of gestures which could be detected by the Kinect.

```
if (gesture == KinectGestures.Gestures.Squat)
{
        SquatNum++;
        Camera.main.transform.SendMessage ("SquatPerformed");
}
else if (gesture == KinectGestures.Gestures.Jump)
{
          JumpNum++;
          Camera.main.transform.SendMessage ("JumpPerformed");
 }
```

Code 4: Gesture Detection Code

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Title:

CardioHealth - A Home Based Rehabilitation System For Patients With Cardiovascular Diseases

Authors:

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[1]

CardioHealth - A Home Based Rehabilitation System For Patients With Cardiovascular Diseases

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Abstract— **Cardiovascular diseases are said to be the leading cause of increase in financial resources in the medical sector. A significant portion of the recovery process is the cardiovascular rehabilitation program. The large and ever increasing pressure on medical organizations around the world requires health care professionals to be prescribing home-based exercise rehabilitation treatments to allow patients to carry out rehabilitation with constant monitoring with the added convenience of performing exercises at home. Home-based exercise rehabilitation approaches have shown to be effectual and successful in treating conditions such as Cardiovascular Disease (CVD). Nonetheless, adhering to home-based exercise rehabilitation systems seems to remain low. Possible reasons for this are that since patients are not monitored by their respective representatives, they are not completely confident that they are performing the exercises properly or in a correct and accurate manner and that they do not receive feedback.This paper proposes CardioHealth, an interesting, gamified exercise rehabilitation platform that can help address the issue of adherence to these programmes. CardioHealth aims to be a home-based rehabilitation system for patients in rehabilitation of cardiovascular diseases with a user-friendly interface and also a doctor-patient interaction system for doctors/physiotherapists to diagnose and examine patients without face-to-face interaction. CardioHealth utilizes the Kinect V2, patients must perform exercises in front of the Kinect and results are sent straight to the patient's doctor/Physiotherapist.**

Keywords- cardiovascular diseases, kinect, rehabilitation, serious games

I. INTRODUCTION

Physical inactivity is the one of the leading risk factor for global mortality. 1.5 billion adults worldwide are insufficiently active and as a result many suffer from Coronary Heart Disease (CHD), Cardiovascular Diseases, obesity, diabetes and other preventable heart conditions. Exercise along with proper diet and patient's psychological conditions are a crucial component in the management and prevention of such conditions. Patient's adherence to exercises prescribed is important for both rehabilitation and disease prevention .[1].

Cardiovascular rehabilitation (CVR) programmes focuses on exercise as its key component. This rehabilitation follows multidisciplinary approach and is a long-term procedure, aimed to inform the patient of the pathology, educate about the ways to control and prevent cardiovascular risk factors, prescribe exercises and improve the capacity and quality of life, as well as the prognosis by adopting healthy lifestyles. These CVR programmes are seen as a continuous evolution through successive phases with long-term follow-up period.[2].

CVR is required to alleviate the symptoms but it could become demotivating in the long run, due to the insufficient skills and knowledge of the staff in most hospitals or the lack of access to the required facilities in rural areas . It is estimated that 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 . A possible solution to this is to have home based system for the therapy, but the patients do not strictly adhere to the exercises and ignore the treatment . Another major issue is patients who were prescribed home based therapy exercises were not sure as to how the exercises has to be performed properly and there was no monitoring on their progress . With the use of Microsoft Kinect camera in the home based therapy, a powerful and more accurate recognition of a patient's movement while performing prescribed exercises at home is possible. Kinect has a depth sensor that allows to track the movements of the patient in 3 dimensions. Kinect SDKs can be used in an application to track and assess the skeletal structure of a fully clothed patient. Low cost and relatively good motion sensing accuracy makes the Kinect a viable solution in home based therapy. Feedback can be provided to the patient through the application so that the patient can know if the exercises are done properly. The use of technologies such as the Microsoft Kinect application could motivate the patient to continuously perform the routine while diverting the patient's attention away from the pain. The physical therapist can be more accurately informed of the patient's progress by monitoring and recording the patient's exercises.[3].

II. RELATED WORK

In [4] , the authors of the referred paper have come to the conclusion that the rate of accuracy in motion detection using the Microsoft Kinect sensor is more than 80% after testing their application in different situations and in patients with different levels of rehabilitation.The test patients indicated that the technology helped them in increasing their motivation to participate in rehabilitation, while the therapists rated the

[1]

technology positively intimating that this kind of a tool would reduce their labour burden by a good lot.
.
In [5], the authors put forward a tool for rehabilitation using the Nintendo Wii, added with an application that is web-based, to allow monitoring exercises to track the progress of the patient.
The applications based on Kinect sensors also allow the therapists to adjust and customise the physiotherapy process to be carried out by the patient and give more freedom of movement.

In [6] , the authors propose a platform that ensures rehabilitation from home is possible in the post-hospital phase. The platform consists of a web based database and client software, which enables health staff to manage the sessions without legal liability and real-time connection. The complete management of a bike (web transmission, data recording and training session settings) via a PC connection is permitted to the client software. Health personnel can access and evaluate the patient's data and deduce results, with updated physical activity protocols. The heart rate and other parameters of interest (i.e., arterial pressure) are recorded and acquired by the client software and forwarded to a web-based database.

III. SYSTEM DESCRIPTION

CardioHealth is a home-based rehabilitation system which uses the Xbox Kinect 2. Users of the system are usually patients in treatment of any type of Cardiovascular disease. User must perform exercises in front of the Kinect. Exercises are played out in the form of a game, different exercises are provided and patient's heart rate is monitored. The System is also connected online to the database for patient's doctor /physiotherapist to view. Doctor / physiotherapist views how well exercises are performed and also keeps up to date with the patient without the need of continuous doctor visits.
Exercises may include: Squats, Jumping Jacks, Various Stretches and Basic Body Movements.

A. User types

Patient's System: Computer with Game/Rehabilitation Application and Kinect 2 attached.
Patient's System will have the game and rehabilitation workout routines. Patient logs into their user-account (which is set up by Doctor) and application commences. Patient has ability to commence normal workouts, perform workouts in Gamified environment or view records from previous workouts as well as comments from Doctor.
Admin/Doctor's System: Computer with Admin Application.

B. Monitoring and feedback

Admin/Doctor's System will be a Doctor check-up system. Doctor logs into system, can view patients, create account for patient, can view specific patient records and send comment to patient on record to give progress. There may also be an ability to view exact patient workout.

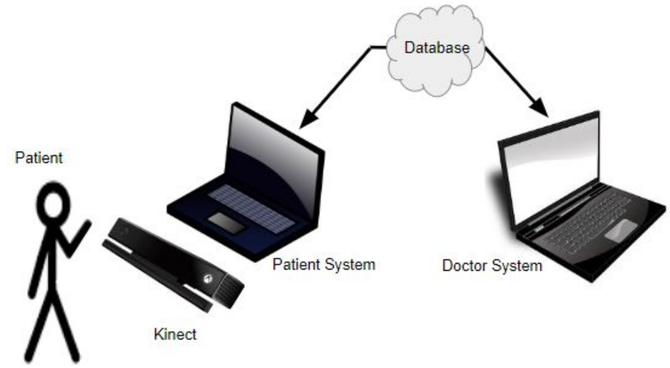

Fig. 1. System Overview.

IV. SYSTEM ARCHITECTURE

Different technologies can be chosen for different functions. A motion capture device, a gaming engine, a Server-side language for the website and database management software are required.

A. System architecture diagram

The system architecture presented in Fig. 2. is for the users connecting to the system as a doctor or a patient. The patient's role only has access to the Patient system which is a Unity3D application while the doctor's role only having access to the Doctor system which is an ASP.NET application and is accessed by means of a web browser. The ASP.NET application manages requests to-and-from the server with the doctors application. The server-side application retrieves data from the MongoDB database. The patients system is connected directly to the MongoDB database in terms of managing requests for data and storing data.

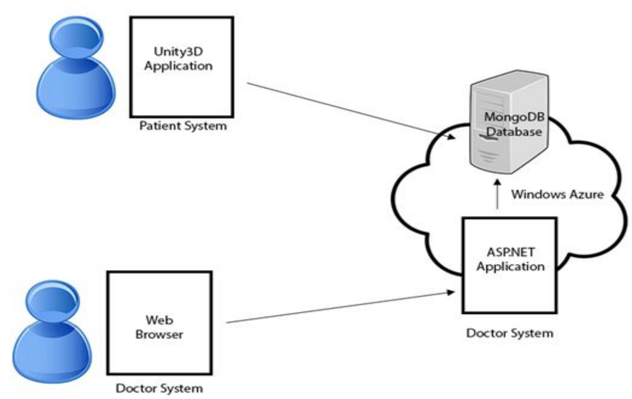

Fig. 2. System Architecture.

B. Setup

1. Kinect

Kinect V2 is a motion sensing input developed by Microsoft as the predecessor to the Kinect. It is developed for the Xbox One console and Windows PCs. It has the ability of heart-rate tracking by using its infrared sensor.

2. Gaming engine

Unity3D (or just Unity) is a cross-platform game creation system with its own game engine and a built-in Integrated Development Environment (IDE) developed by Unity Technologies. Developers can program in scripts like C#, JavaScript or Boo (Python inspired syntax). MonoDevelop is the IDE built into Unity. Unity3D has plugins to implement many different types of motion capture. Microsoft has released their own plugins for Unity to implement Kinect Version 1 and Version 2 projects.

3. Database model

MongoDB is the most popular open source document-oriented database. Classified as a NoSQL database, MongoDB performs differently to the normal table-based relational database structure of most popular databases and stores data in JSON (JavaScript Object Notation) documents (known as BSON with MongoDB). Fig. 3. illustrates the database classes created.

C. CardioHealth Kinect

The CardioHealth Kinect (Application) is created using Unity3D and each class is written in C#. The application itself (as an executable) can be downloaded from the CardioHealth Website . The application is also connected to the same MongoDB database which is hosted on Windows Azure.

The application's main function is the Patient's rehabilitation. The patient can log into the application with their username created by the doctor on the CardioHealth Website (there must be an internet connection to do this), from there they can play any of the four exercise games available, of a Basic Workout, Simon Says, Heart Racer or an Orb Dodger type game. The Patient can also view their specific workouts records, view the Doctor's information, as well as view their own information and edit it. Workout information is recorded from the Basic Workout, Simon Says and Heart Racer games, the Orb dodger game is treated as a warmup type game.

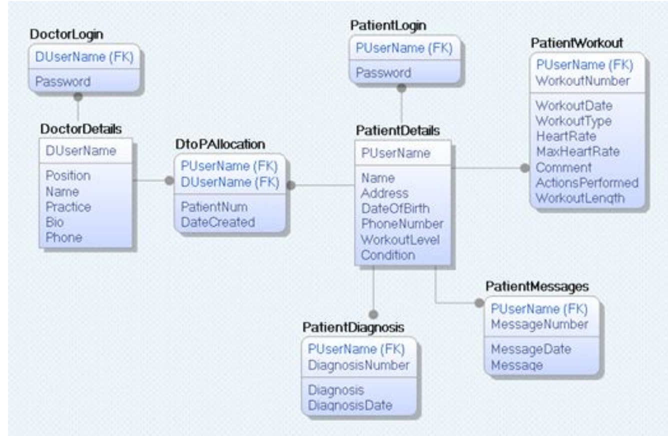

Fig. 3. Relationship entity Diagram.

D. CardioHealth Application

The CardioHealth Website is created using ASP.NET in Visual Studio 2013. It is also hosted on Windows Azure. The website is connected to a MongoDB database which is also hosted on Windows Azure.

The website's main function is the Doctor/Physiotherapist administration of their patient's. Doctors/Physiotherapists can register an account on the website, and once their account is created, they have the ability to create Patient Accounts. The Patient uses the Account to log into the CardioHealth Application with this account. Each Patient Account created can be viewed, edited and work out details respective of each patient can be viewed. Messages can be also be sent directly to the patient, (which can be viewed within the application) and a diagnosis of the patient can be made to keep updates on the patient's progress which can only be viewed by the doctor. The Doctor/Physiotherapist can also comment on specific workouts to provide feedback to the patient. The use case diagram in Fig. 4. represents the same.

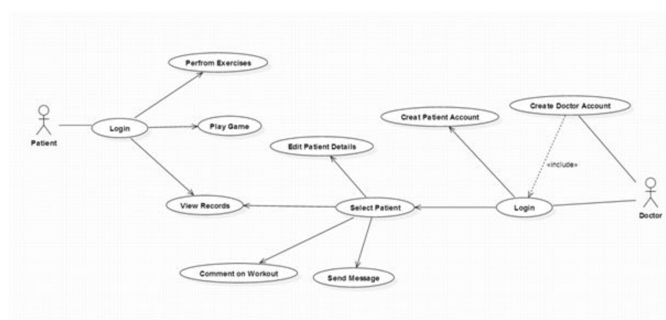

Fig. 4. Use case Diagram.

V. Conclusion

In the current practice of cardiac rehabilitation, where the patient is required to perform exercises at home, without ongoing feedback from the doctor/physiotherapist, the patient may lose the motivation to adhere to their program and hence lose out on a very important phase in recovery. The patient may also be faced with the inconvenience of visiting the doctor frequently just to convey the state of progress. This research strives to propose a Kinect-based framework complemented by a doctor-patient interaction system to tackle the issue. The system is designed to be low cost, easy to use, capable to support new learning styles and to ensure to the best of its abilities to provide the patient with a smooth and more successful road to recovery.

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Base Papers:

S.No	Title
1.	R. K. Y. Chang , S. H. Lau , K. S. Sim ,M.S.M Too, “Kinect-based framework for motor rehabilitation”, International Conference on Robotics, Automation and Sciences (ICORAS),2016
2.	Nuno Duarte, Octavian Postolache, Octavian Postolache, “KSGphysio – Kinect Serious Game for Physiotherapy” , 2014 International Conference on Electrical and Power Engineering (EPE 2014) Iasi, Romania, October 16-18, 2014

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.

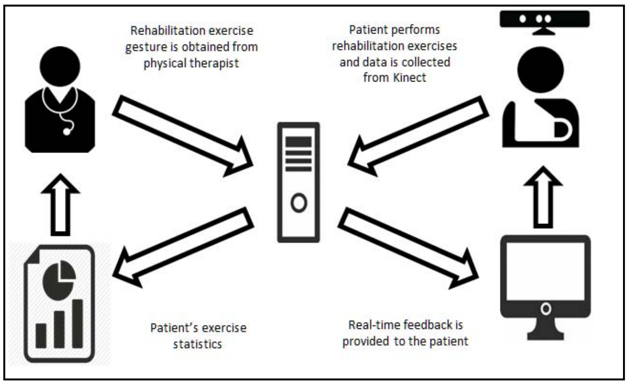

Fig. 1. System Design.

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

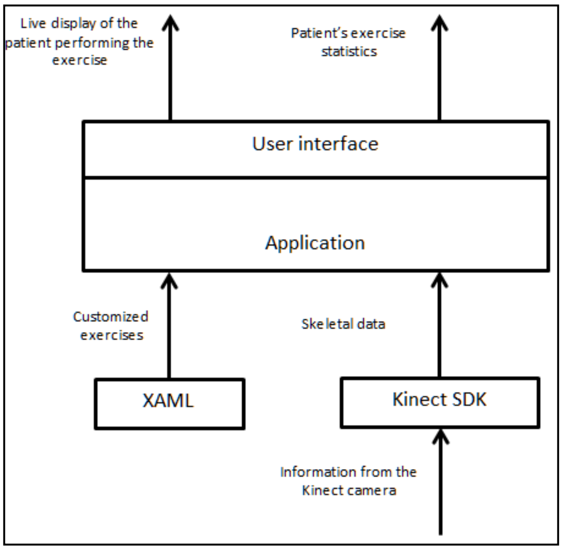

Fig. 2. System Architecture.

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,

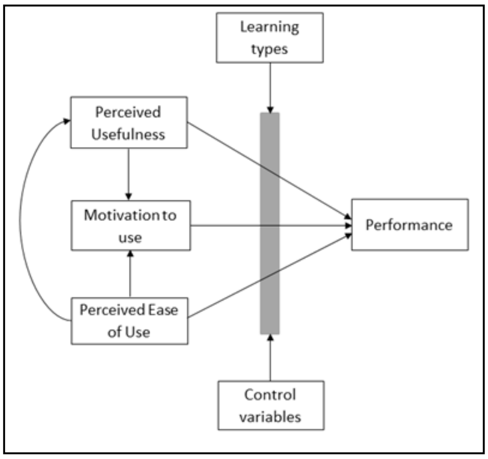

Fig. 3. Evaluation Framework.

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.

ACKNOWLEDGMENT

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KSGphysio – Kinect Serious Game for Physiotherapy

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KSGphysio – Kinect Serious Game for Physiotherapy

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Abstract— **Serious games fall under a set of applications capable of improving recovery times by increasing the player's engagement. In this paper we focus on the possibility of joining thatcapacity to Microsoft Kinect sensors ability to collect data without the need of additional sensorsand present an application capable of giving proper feedback about the player's behavior during a rehabilitation session. Using an Android OS mobile platform as interface for the collected data,the proposed solution is a prototype that aims to facilitate the analysis of the patient'sprogress during rehabilitation sessions using serious games. Results associated with arm rehabilitation through serious gameare included in the present work.**

Keywords- remote physical rehabilitation, serious games, pervasive computing, virtual reality, personalized medicine

I. INTRODUCTION

In a world where it is increasingly common to integrate virtual environments in real-life situations rehabilitation is no exception. It is increasingly common to use video games to create greater engagement on the user increasing the physiotherapy efficiency. However, because they are adapted games and are not specifically designed for rehabilitation, many therapists prefer to just use them more as a complement to a physical therapy session rather than an integral part of the session. These games are very limited because they are not configurable or accessories are needed to interact with it, which sometimes makes it impossible to use in a rehabilitation session of a more impaired user. Do not allow tracking progress and in most cases there is a lack of feedback to the therapist and to the patients under rehabilitation process [1].

Research suggests that repeated execution of an exercise is sufficient to stimulate the brain to remodel and promote better motor control of the limbs [2]. However, the number of exercises performed during a rehabilitation session is not sufficient for this to happen which suggests the need for patients to practice these exercises at home. However 65% of patients self-reporting being non-adherent or partially adherent to their home programs [3], which in most cases represents a regression of the patient. Adherence embraces 2 elements: being compliant with the frequency of the suggested exercises and carrying out each exercise with the correct biomechanical alignment.

This study aims to produce an application that improves the quality of rehabilitation sessionsin the clinic or at home, while enabling data collection and communication so that we can track the patient physical rehabilitation progress.

II. RELATED WORK

Virtual reality is increasingly used in areas such as rehabilitation through motion-based games. This new generation of tools for rehabilitation has grown up rapidly in the past few years. However, many of these games require wearing a number of sensors attached to the body or use extra material to detect the movements of the patient [4, 5].

In [1], authors propose a rehabilitation tool based on Nintendo Wii complemented with a web-based application that allow motion capture and monitoring exercises to track patient's progression.

Applications based on Kinect sensors natural interaction without the need of additional sensors allow therapists to customize and adjust the physiotherapy training to be performed by the patientand give more freedom of movement.

In [2], after testing with Kinect-based applications in different situations and in patients with different levels of rehabilitation, the authors concluded that the accuracy rate in the detection of motion using a Microsoft Kinect sensor is more than 80%. Therapists rated the technology positively indicating that this kind of tool would reduce their labouring burden and improve rehabilitation efficiency, while patients indicated that this technology has helped to increase their motivation to participate in rehabilitation reducing the time affected by this process.

In [6], authors show their concern about the lack of arguments that validate rigorously the technical performance of Kinect sensor as a rehabilitation tool, although previous works prove the potential of Kinect sensor in this area. They studied the trajectories of the joints at the right hand, right elbow, and right shoulder when performing motor task External Rotation, Scapular Retraction and Shoulder Abduction and compared the results of a Kinect sensor with the results of a OptiTrack that is a marker-based system which requires users to wear reflective markers such that their movements can be tracked by an array of cameras. They also evaluate the timing performance of both systems.

In [7], authors present the results of Kinect applications used in physical rehabilitation tests and foresee that Kinectsensor technology will be widely applied in medical care fields.

III. SYSTEM DESCRIPTION

The proposed system is divided in three parts, asare presented in Figure 1. The first one is a game that uses the Microsoft Kinect motion sensor to allow data collection during rehabilitation sessions. Every time a patient start his session, a particular game that was previously configured by the therapist who defined some aspects of the game as the speed, the angle that must be performed by a particular limb or the difficulty level of the game given the patient's condition. Using the Microsoft Kinect SDK and a C# wrapper for Unity 3D we can detect automatically the patient joints position and send that information frame-by-frame to the database. Each time a special event occurs, the patient joints positions also are sent to the database. It is understood as special event every time the patient accomplishes a game objective like catching a specific object. In that way we can relate the position of the picked up object and the position of patient's joints and compute physical rehabilitation parameters such as velocity, angles or limbs rotations and compare them with those previously given by therapist through the game configuration interface. The Kinect sensor isconnected to a computer with an Intel core i5-4250U processor, an Intel HD Graphics 5000 and 8G of memory RAM. The computer characteristicsare important to guarantee that the performance of the game is not compromised.The second one is the server, which includes a database, an API and a data processing application to work over the collected data. The API allows every component of the system to communicate with the databasethrough a set of GET and POST methods. The other component held in the server is the data processing application that will translate the frame-by-frame the data collected during the session into metrics that can be easily interpreted by the therapist.

The third component is the mobile application developed for Android OS devicesthat behaves as a client. The application connected to the database and running on the deviceallows the therapist to consult patient's recordsthrough charts, analyze the data collectedfrom previous sessions,do comparisons between session's data, configure new sessions and add reports related to the patient evaluation.

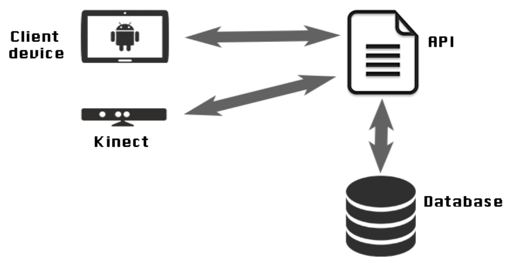


Figure 1 - System architecture

A. *Kinect Sensor*

Kinect is a motion-sensing device that was originally developed for Microsoft's Xbox360 gaming console. The main feature that distinguishes it among others in this gender is that it is not a hand-controlled device, but rather detects your body position, motion and voice. It replaces the controller that was once the heart of a gaming device by your body.

The idea of developing the Kinect sensor began to take shape when Microsoft engineers realized that the traditional game controller was the main barrier to making video gaming into a mainstream activity.They quickly realized that the solution was getting a device to track users' bodies as they move.

The core of Microsoft Kinect sensor technology came from a Israeli startup named PrimeSense that figured out how to encode patterns in the light beams and then measuring the changes in those patterns it's possible to give a particularly accurate view of a room [8].

The Kinect sensor(has now outgrown its Xbox roots and is no longer limited to only gaming after Microsoft release Kinect for Windows, a version designed specifically for PC that helps developers to write their own code and develop real-life applications like serious games for rehabilitation purposes with human gestures and body motions.

The Kinect sensor includes a color sensor (Figure 2), an infrared (IR) emitter, a IR depth sensor, a set of microphones and a LED. Additionally has a small motor working as the base that enables the device to be tilted in a horizontal direction.The color camera is responsible for capturing and streaming the color video data. The Kinect color stream supports a speed of 30 frames per second (FPS) at a resolution of 640x480 pixels, and a maximum resolution of 1280x960 pixels at up to 12 FPS.

The IR emitter and the IR depth sensor work together to make things happen. The IR emitter constantly emits a infrared light in a "pseudo-random dot" pattern over everything in front of it, as seen in Figure 3, and the depth sensor reads the reflection of the dotted light in the objects and converts them into depth information by measuring the distance between the sensor and the object from the IR dot was read from [9].

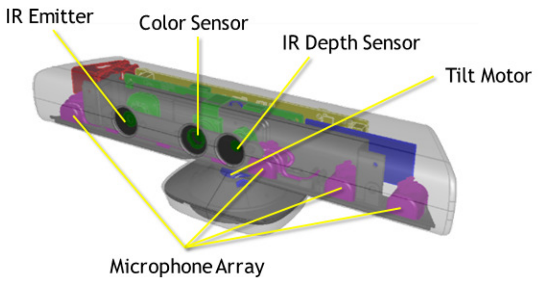


Figure 2 - Microsoft Kinect architecture

Figure 3 - Pseudo-random dot pattern

B. 3D Game

There are a variety of game engines that can be used to develop 3D games as RAGE (Rockstar Advanced Game Engine) or CryENGINE, this two have been used to create some of the best video games that exist nowadays [10].

To develop the game we used a game engine named Unity 3D that is a powerful rendering engine fully integrated with a complete set of tools and rapid workflows to create interactive 3D and 2D content that has C# as primary language [11]. Unity has a very simple, uncluttered interface for development that allows you to develop games quickly and have a very good integration with Microsoft Kinect sensor. It is also a game engine quite well documented with a strong Asset Store where you can buy scripts, tools and textures to use in the game. Has amazing third party solutions for Audio and Physics and the code is well architectured to reduce the amount of errors done by programmers.

The game environment is based on an orchard composed by rows of trees on both sidesand intends to simulate a harvesting of apples where the user must catch as many apples as possible for a defined period of time, due to this fact the game focuses on the upper limbs of the patient. There aretwo different kinds of apples, the red ones and the green ones. Different kinds of objectsto choosefrom permits us to define different weights for those objects, whichallows the therapist to understand the cognitive capacities and the patient behavior in situations where he has to take decisions.In this case, the red apples add 100 points to the game score and the green ones add 50 points, as seen in Figure 4, so the patient has to decide if he prefers to catch the green apple that is easier to catch and get only 50 point or if he prefers to catch the red one and reach the goal defined by the therapist faster.

The main difference between this game and the other games mentioned in Related Work is that the parameters related to the rehabilitation process are configurable by the therapist. Using the mobile interface (D) the therapist can define rehabilitation parameters such as the speed, the angle that must be performed by a particular limb, session duration, if the user should execute rotation of the body or not, the difficulty level of the game given the patient's condition and the minimum number of points to do at a session setting up a goal for the patient to commit with.This last parameter is used to compare the performance of the patient between sessions. Every time the patient picks up and object some points are added to the patient’s score, in the end of each session the score should be equal or bigger than the minimum defined by the therapist, a lower score may portray a regression of patient's condition.All of these aspects will contribute to help us mapping the patient’s progress during the rehab time.

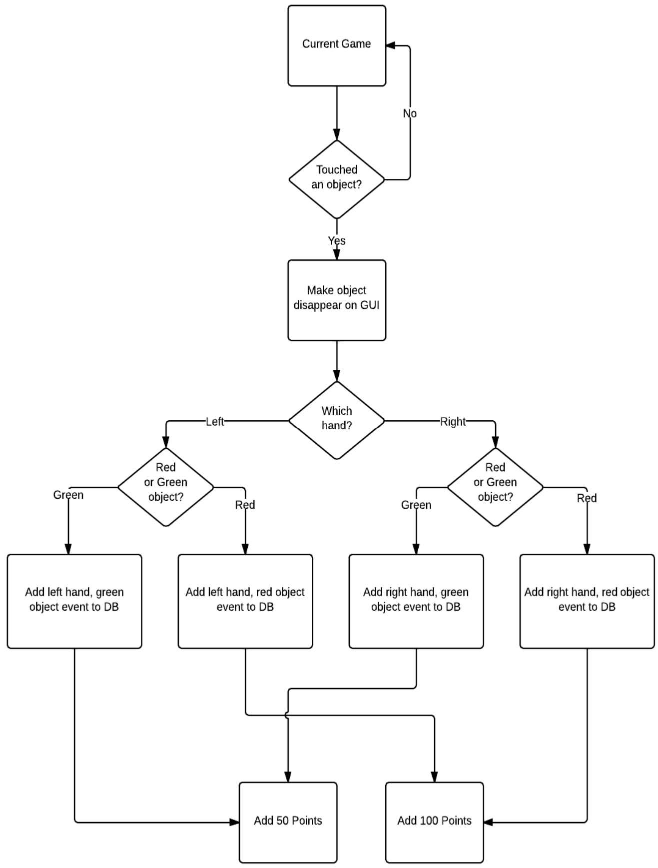


Figure 4 - Pick up object flowchart

C. Database model

For database we used a relational database management system (RDBMS) named MySQL [12] that has no GUI tools to administer databases or manage data contained within the databases. For that reason a front-end tool named MySQL Workbench [14] was used to enable us to graphically create and manage the tables of our database.

We can divide de data stored in the database in two main data types. The first type is the one that can be added to database using the mobile application interface: patient's personal data, notes written by the therapist, prescribed plans and game configurations. The second type is the data collected by the Kinect sensor like limbs positions.

The system users identificationsare stored in the database grouped in two types:therapists and patients. Each therapist has a set of patients that he can manage through the mobile application.Each patient can have a set of plans associated to his profile that are defined by their therapist. These plans have an associated configuration defined by the therapist during the creation the plan that will be used in the construction of the 3D game scene when the user starts a session in the game. Each plan consists in a set of sessions organized in time, which in turn consist of a collection of scenes.

Each frame collected by Kinect sensor represents a scene and consists in a group of three-dimensional vectors (x, y, z) corresponding to the position of each member during that scene. In addition to the data collected by the sensor frame by frame, there are special events like picking up an apple, that are saved so that we can map the evolution of the patient,by comparing the number of picked up apples between a set of sessions performed by the patient. If the number of picked up apples increase, that could mean that the patient is improving.

D. Physiotherapist's Mobile Interface

The Android OS is one of the most used operating systems on mobile devices by virtue of being open-source and still growing. Well positioned on the market Android achieved the 81.1% market share in the first quarter of 2014 [13].The mobile application was designed to permit the interaction between physiotherapist and the data provided the client and stored on the serverside. It is important that the application can display the data in a clear, synthesized and objective way so that the therapist can easily understand them. To achieve that we use a set of different types of charts as line charts, pie charts, bar charts and radar charts to display the data graphically.To create the charts we useHoloGraphLibrarylibrary was used [15] that is simple to use and to integrate with the application. It uses Android Canvas, which works as an interface to the actual surface upon which the graphics will be draw. It's the best choice when the application needs to regularly re-draw itself.

The communication between the mobile application deployed in Android device and the server is done using a networking library named Volley [16] that speeds up and facilitates that communication by allowing asynchronous HTTP requests and dealing with cache.

The interface splits the data in two types: data concerning to the game goals and data concerning to the limbs behave. The first type is important to understand the evolution of the cognitive capacities of the patient by showing to therapist statistics like the percentage of green and red apples picked up during a session, comparison between the number of picked up apples in the last 5 sessions, score progression, percentage of sessions where the patient achieved the minimum score defined. Data are presented in a generic way by making an overview of the patient's progress, but the therapist can also select a specific session and analyse every session individually. The second type represents the behaviour of the patient's limbs, using the data collected by the Kinect sensor we can compare the limbs performance, understand which limb is more frequently used to pick up apples, the progression of each member, correctly execution of an angle, the average velocity of the session and distinguish if the patient did more points with his left hand or his right hand.

The mobile software, which flowchart is presented in Figure 5, permits to the therapist to execute other tasks as add new patients, to create plans related to a patient's profile and configure them, this configuration will allow the system to adapt the game according to the patient's needs, add general notes or notes related to a specific session.

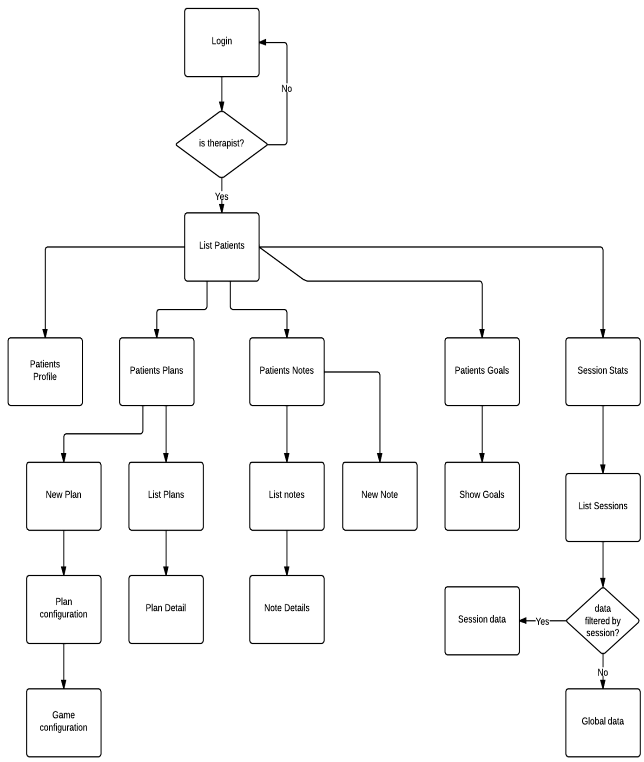


Figure 5 - Mobile application flowchart

IV. RESULTS AND DISCUSSIONS

In this section, are presented the results associated with the tests made using the Kinect based systemand the developed rehabilitation game for different users. Was tested the capacity of the designed and implemented system to collect data related to range, as it seen in Figures 6 and 7, and velocity, as seen in Figures 8 and 9,while patientsplayed the game. The represented data was normalized.The developed mobile interface is also presented with some results concerning the EHR and physiotherapy training data visualization.

We carried out this study with two male participants. Each participant played the pick up apples game during two minutes. We choose eighty-seven seconds of the collected data to evaluate the performance of the system regarding to patient's hands range and velocity.To perform the test, each participant was standing up three meters away in front of the Kinect sensor.

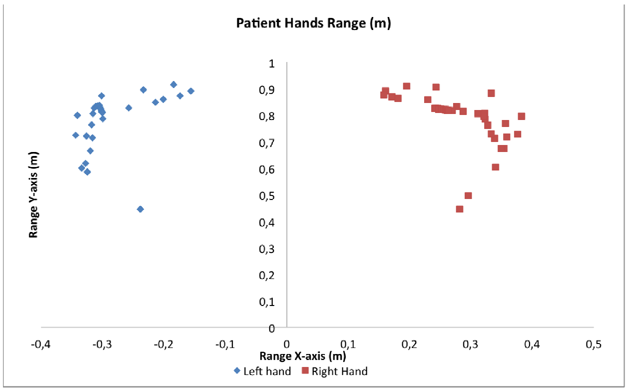


Figure 6–Left Hand/ Right Hand range test patient 1

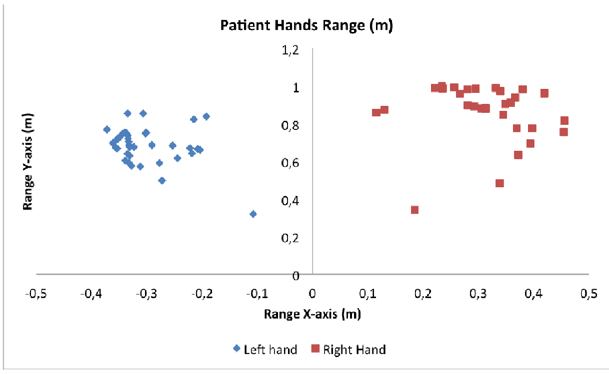
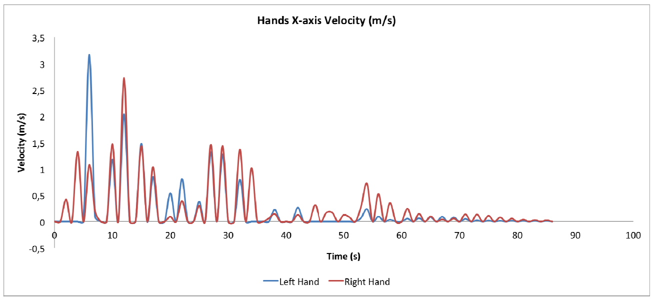
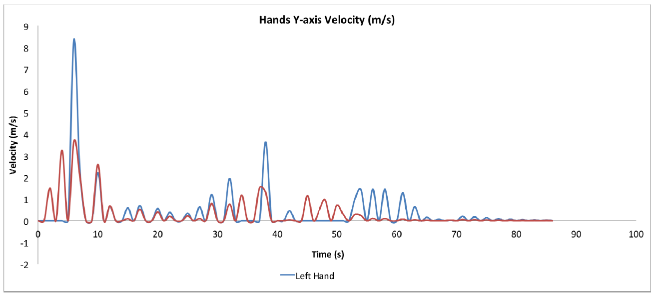


Figure 7 - Left Hand/ Right Hand range test patient2

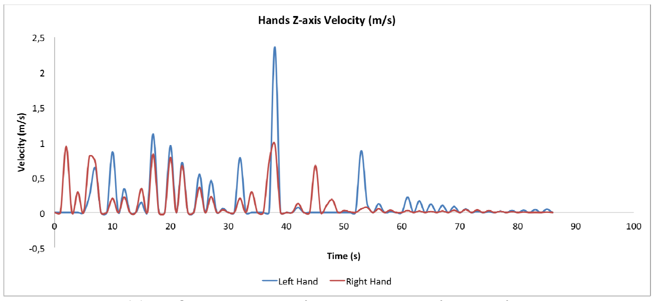
Figures 6 and 7 represents the ranges associated to left hand and right handmotion performed during a rehabilitation session showing that Kinect sensor has the capacity to collect sufficient data that can be used to track the evolution of the patient's hands range.Acquiring data from consecutive sessions performed by the same patient may help to analyze the values of the measured ranges during different physiotherapy sessions of the range and evaluate the rehabilitation evolution process.



(a) Left hand and Right hand X-axis velocity

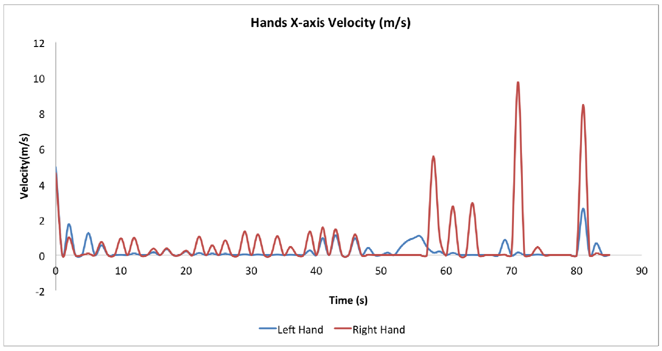


(b) Left hand and Right hand Y-axis velocity

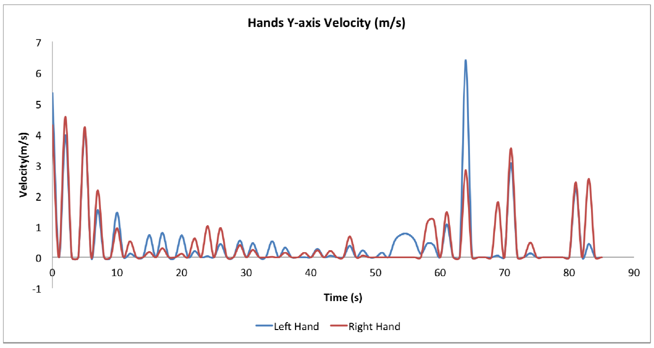


(c) Left hand and Right hand Z-axis velocity

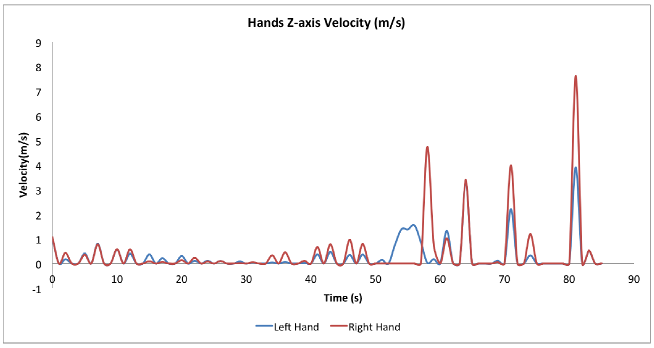
Figure 8 - X-axis, Y-axis, Z-axis patient 1 hands velocity performing a game session



(a) Left hand and Right hand X-axis velocity



(b) Left and Right hand Y-axis velocity



(c) Left hand and Right hand Z-axis velocity

Figure 9 – X-axis, Y-axis, Z-axis patient 2 hands velocity performing a game session

In a similar manner, using the Kinect sensor we can calculate the velocity of the left and right hands regarding to X-axis, Y-axis and Z-axis. Given the velocity values in different axis may help to understand the mobility of a patient's arm in different orientations.

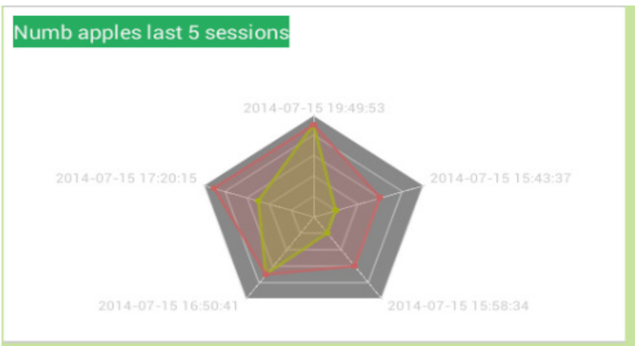


Figure 10–Mobile application graphic comparing the number of red apples and green apples picked up between patient's last 5 sessions

Figure 11 - Mobile application showing patient's progression in last 5 sessions

Using the mobile application the therapist has the access to statistics regarding patient's rehabilitation sessions.Figure 10 and 11 illustrate some of that statistics, in Figure 10 we can see the comparison between the number of objects picked up by the patient in the last five sessions sorted by colors, so the therapistcan compare the patient performance and cognitive capacity. In Figure 11 we can see the user interface showingan overview of the patient's progression in the last five sessions,in terms ofpoints obtained in each session, and the number of red and green apples caught.

V. CONCLUSIONS

Microsoft Kinect sensor is an appropriate tool for data collection because it enables an appropriate analysis of patient's behaviour during a rehabilitation session.The advantagesof combining the Kinect sensor with the rendering engine Unity3D and mobile applications to create 3D serious games capable of being configurable and adapted to the patient's needs are undeniable. Using Unity3D allows us to replicate real life situations, which facilitates the transition between virtual and real world. The mobile application brings mobility to data analysis allowing the therapist to see relevant statistics of a patient session, enables a single therapist to monitor several patients at the same time and allows him to configure specific parameters as velocity or angles of a session according to the patient's needs. Both, game and mobile applicationwere presented during demonstration workshops and proved to have a good acceptance in the therapist community.

The ongoing work is focused on an evaluation of the effectiveness and usefulness of the system, using two control groups: a group of therapists to test the mobile application and a group of patients to test the game represents.

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