CHAPTER 1: 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 . 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]

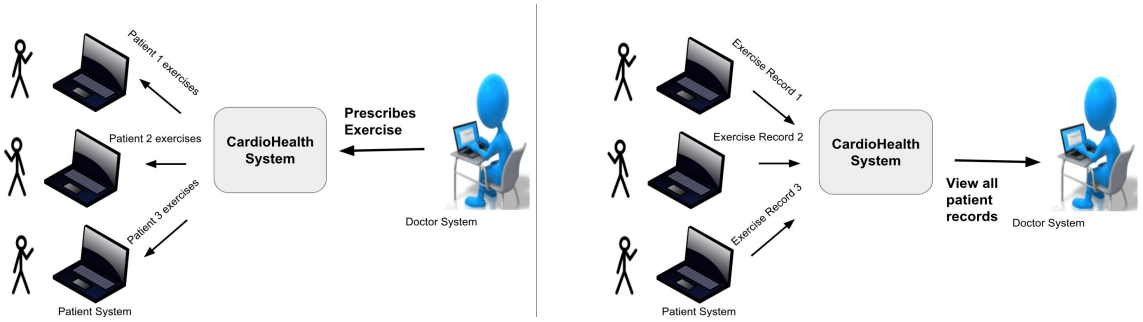

Figure 1. Doctor patient interaction System

1.1 BACKGROUND

1.1.1 Cardiovascular Diseases

The main area of rehabilitation focused on for this project is rehabilitation of people with cardiovascular diseases. Cardiovascular Disease (or Heart disease) is a class of diseases that involve the heart, the blood vessels (arteries, capillaries, and veins) or both. Patients that require rehabilitation for cardiovascular diseases must perform consistent exercises as a crucial element in their overall physical and mental rehabilitation. These exercises help the patient in many ways: [4]

Strengthens your heart

- ➔ May improve congestive heart failure symptoms
- ➔ Lowers your blood pressure
- ➔ Makes you stronger
- ➔ Helps you reach (and stay at) a healthy weight
- ➔ Helps manage stress
- ➔ Boosts your mood and self-esteem

➔ Improves sleep

However patients at home tend to either only follow their programmes for a short period of time or do not follow them at all. By using Serious Games with this project, patients are expected to follow their exercise programmes regularly and to view it as a fun activity.

1.1.2 Doctor-Patient Interaction

Communication between doctor and patient is a key success factor in medical treatment. And as such the doctor–patient relationship is central to the practice of healthcare and is essential for the delivery of high-quality health care in the diagnosis and treatment of disease or rehabilitation. Doctors must maintain a professional rapport with patients, uphold patients' dignity, and respect their privacy.

In terms of online medical systems between doctors and patients, there has been an emergence of websites set up for booking appointments, order repeat prescriptions and view an individual's medical record with certain Doctors/General Practitioners depending on if they choose to use the website. The proposed system will be similar to these online medical systems between doctors and patients except that results taken from patient's exercises will be sent straight to the doctor without the need for direct communication and check-ups and to allow for their exercise and rehabilitation to be performed from home.[5]

1.1.3 Serious Games

Serious games can be thought of as any game based interfaces that have been designed for any purpose other than entertainment. Serious games have been researched in the areas of: military, health, government and education.[6] . In this case, Serious Games can be used in the area of healthcare. The Serious games aspect may be a solution to motivate patients to continue exercises in an engaging way. Patients are immersed in the game simulation and play the games regularly and as such attribute to their rehabilitation.

Lot of research has been carried out in using serious games in terms of rehabilitation. Effective rehabilitation must be early, intensive and repetitive. Serious games provide a means to maintain motivation for people undergoing therapy[7] by means of exercises. Games of virtual reality and imaging of webcam-based games are usually the solution to provide an engaging and motivating tool for physical rehabilitation.[8]

1.2 MOTIVATION :

Cardiovascular diseases (CVDs) have now become the leading cause of mortality in India. A quarter of all mortality is attributable to CVD. Ischemic heart disease and stroke are the predominant causes and are responsible for >80% of CVD deaths as per NCBI. The Global Burden of Disease study estimate of age-standardized CVD death rate of 272 per 100,000 population in India is higher than the global average of 235 per 100,000 population. Some aspects of the CVD epidemic in India are particular causes of concern, including its accelerated buildup, the early age of disease onset in the population, and the high case fatality rate. [9]

	Death per 100000 Population			DALYs per 100000 Population		
Diseases	Male	Female	Total	Male	Female	Total
Ischemic heart disease	178 (128)	112 (85)	144 (106)	3783 (2577)	2053 (1406)	2917 (1972)
Cerebrovascular disease	90 (99)	75 (79)	82 (88)	1605 (1838)	1240 (1295)	1420 (1554)
Rheumatic heart disease	11 (5)	10 (5)	10 (5)	300 (148)	269 (155)	285 (151)
Hypertensive heart disease	18 (14)	15 (13)	17 (13)	343 (252)	270 (215)	306 (233)
Cardiomyopathy and myocarditis	10 (8)	5 (4)	8 (6)	266 (221)	126 (112)	197 (166)
Atrial fibrillation and flutter	1 (2)	1 (2)	1 (2)	49 (65)	36 (46)	42 (55)
Aortic aneurysms	2 (4)	1 (2)	2 (3)	44 (70)	25 (29)	35 (48)
Peripheral vascular disease	<1 (1)	<1 (1)	<1(1)	10 (16)	8 (14)	9 (15)
Endocarditis	1 (1)	1 (1)	1 (1)	18 (27)	18 (19)	18 (23)
Others	10 (12)	5 (9)	7 (10)	229 (272)	196 (239)	210 (254)
Total cardiovascular diseases	321 (273)	225 (200)	272 (235)	6648 (5486)	4241 (3530)	5438 (4471)

Numbers in parentheses are the global average.

Table 1. *Age Standardized Death and Disability Rates of CVD in India (Global Burden of Disease 2010 Estimates)*

As per AHA journals, Patients with diagnosed heart disease who participate in an exercise program report an earlier return to work and improvements in other measures of quality of life, such as more self-confidence, lower stress, and less anxiety. Importantly, by combining controlled studies, researchers have found that for heart attack patients who participated in a formal exercise program, the death rate is reduced by 20% to 25%. This is strong evidence in support of physical activity for patients with heart disease. [10]

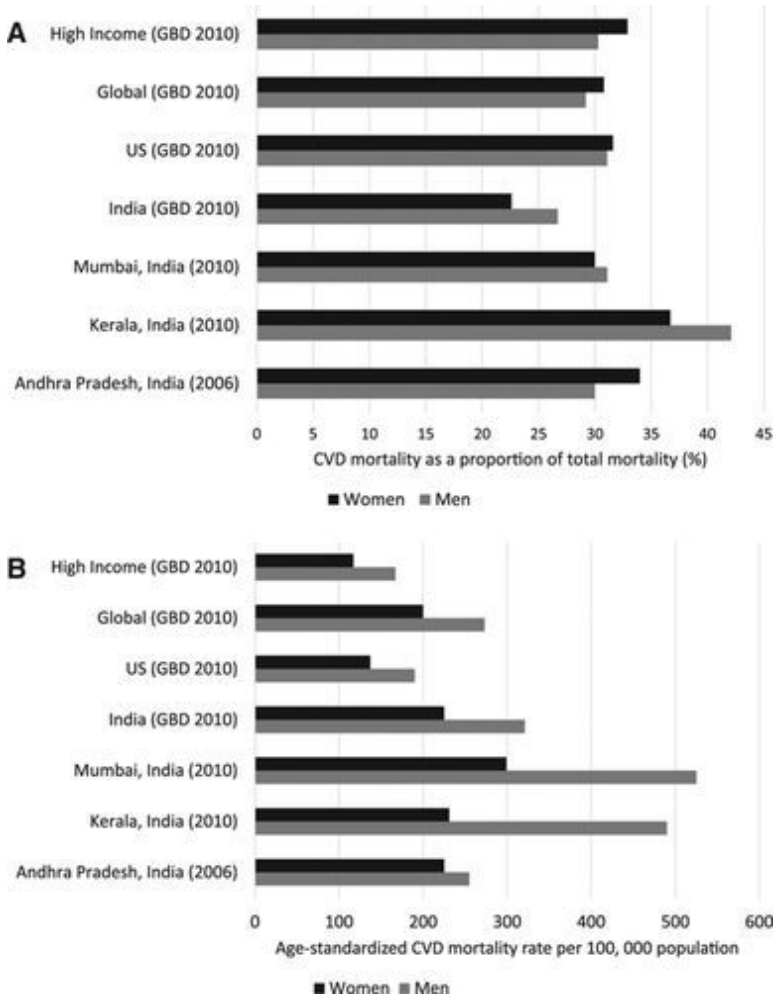

Figure 2. : Proportion of cardiovascular disease mortality in India based on data from available prospective studies and Global Burden of Disease estimates.

CHAPTER 2: LITERATURE SURVEY

1. Wenbing Zhao, Hai Feng , Roanna Lun , Deborah D. Espy , M. Ann Reinthal, "A Kinect-based rehabilitation exercise monitoring and guidance system", IEEE 5th International Conference on Software Engineering and Service Science, 2014.

PROPOSED WORK: In this paper, the design and implementation of a Kinect-based system for rehabilitation exercises, monitoring and guidance is described. The use of Unity framework to implement the system was chosen because it enables the use of virtual reality techniques to demonstrate detailed movements to the patient, and to facilitate examination of the quality and quantity of the patient sessions by the clinician. The avatar-based rendering of motion also preserves the privacy of the patients, which is essential for healthcare systems..

OUTCOME: The key contribution of the research is a rule-based approach to realtime exercise quality assessment and feedback. A set of basic rule elements that can be used to express the correctness rules for common rehabilitation exercises was developed.

2. Param Uttarwar, Deepak Mishra, "Development of a kinect-based physical rehabilitation system", Third International Conference on Image Information Processing (ICIIP), 2015.

PROPOSED WORK: Shoulder injuries are very common in sports and certain labour intensive occupations. While some injuries are minor and full recovery is within 1-2 weeks, some major injuries requires the person to consult a physiotherapist and follow an exercise plan for months for full recovery. With the advent of consumer accessible motion capture (MoCap) technologies, the task of conducting daily rehabilitation routine and evaluation which was previously done by a trained physiotherapist can be now done with computers which can be set up in home.

OUTCOME: In this paper, a system for medical rehabilitation of patients suffering from shoulder injuries was proposed. Hidden Markov Models (HMM) for recognition and a histogram-based comparison for computing the accuracy score was used. The Microsoft Kinect sensor is used to obtain 3D coordinates of human joints. The system recognizes different exercises performed by the patient and assigns an accuracy score for each exercise carried out in a session. It intends to help the patient by keeping track of daily exercise routine, advising for improvements and maintaining records for doctor to access.

3. 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.

PROPOSED WORK: 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.

OUTCOME: 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.

4. Intan Irnanda, Achmad Basuki, Fadilah Fahrul Hardiansyah, "Physical Exercise for The Elderly People using Kinect Technology" , International Electronics Symposium on Knowledge Creation and Intelligent Computing (IES-KCIC), 2018.

PROPOSED WORK: Using the game concept in rehabilitation process has the potential to provide the elderly with a fun,motivating, and challenging therapy. This research presents a new model of therapy for the elderly in physical rehabilitation, which might be boring, to be more interesting and motivated. The main purpose of this research is to create a home-based physical therapy tool that can assisting the elderly in the correct execution of movements through stimulation from interactive elements of digital games based on the procedures of the physiotherapist.

OUTCOME: This research is designed by using unity game engine and kinect hardware. Kinect is used for taking the coordinates of the user using the skeletal tracking method. Main theme of the game that is designed is to get as many points as possible in each movement. After the elderly has done physical therapy, there will be a development chart to monitor the condition of the elderly. The result of this research shows a development graph of physical therapy results that have been done by the elderly.

CHAPTER 3: RESEARCH TOPICS

Topics to be covered within creation of the CardioHealth system are Heart Rates and how they are measured.

3.1 HEART RATE

The heart rate is one of the 'vital signs,' or the important indicators of health in the human body. It measures the number of times per minute that the heart contracts or beats.

Heart rates are never a stable value and every person has a different heart rate relative to different factors. Heart rates decrease or increase to maintain equilibrium within the human body between requirement and delivery of oxygen and nutrients. The rates at which heart rate is assessed are a person's Resting Heart Rate, their Maximum Heart Rate and their Target Heart Rate. [10]

3.1.1 Resting Heart Rate

Resting Heart Rate is a person's heart rate while not active in exercise, in a neutrally temperate environment, and not under any form of stress or surprise. The typical resting heart rate for an adult is generally 60-100 beats per minute. However Resting Heart Rates are very much dependant on the person's state such as their age, their level of fitness (such as if they are athletic) and their gender.

3.1.2 Maximum Heart Rate

Maximum Heart Rate is the highest heart rate a person can achieve. Maximum heart rates in a person decrease by age. Weight as well as a person's level of fitness can also decrease a person's Maximum heart rate.

3.1.3 Target Heart Rate

Target Heart Rates are generally used to find a desired range of heart rate reached during an exercise. They are taken into account to ensure an exercise is done properly and enables a person's heart and lungs to gain the most benefit from a workout.

Average heart rates by age		
Age in years	Average maximum heart rate in beats per minute	Target heart rate range in beats per minute
40	180	90 to 153
45	175	88 to 149
50	170	85 to 145
55	165	83 to 140
60	160	80 to 136
65	155	78 to 132
70	150	75 to 128
Source: American Heart Association.		

Table 2: *Average heart rates by age*

3.2 ADDITIONAL RESEARCH

3.2.1 Interaction with Cardiologist

Cardiologist : Dr Narayana Murthy N - Interventional Cardiologist, Sagar Hospitals -DSI, Kumaraswamy Layout

Dr Narayana Murthy N is an interventional cardiologist working full time at Sagar Hospitals - DSI, Kumaraswamy Layout and was previously the Director of CATH. Lab and Chief of Cardiology at PES Narayana Hrudayalaya. Dr Murthy has acquired his MBBS from Bangalore Medical College,India and his MD from Rostov State Medical University, Russia.

Dr Narayan Murthy was kind enough to remove some time off his busy schedule to answer some doubts and questions that we had before moving on with this project. We had a brief discussion about the state of cardiovascular diseases in India and the existing treatments and procedures. The importance of exercise in the treatment of CVDs was also discussed as follows:

1. Is exercise important for patients suffering from CVDs?

Yes! Exercise is very important for a healthy heart. There are basically even exercise tests to evaluate cardiac fitness. So yes exercise is very important. Exercise shows how much improvement the heart has made based on your exercise capacity. First standard tests are carried out are to measure the capability-various exercise tests like treadmill test,6 minute test, walk test,6 minute stair climbing test. These tests measure the heart capacity and then basic set of exercises are prescribed for the patient to perform himself based on the capacity.

2. Is exercise prescribed for patients with CVDs especially post-surgery?

Yes we do prescribe exercise to the patients. After the surgery, it's a graded exercise. So, we ask them to take it step by step, ask them to do one thing at a time, take it from there and increase it as and when. So we expect them to go back home and come back with the progress.

3. Any harm in not doing the prescribed exercise?

Yes. Exercise is very, very important especially post surgery exercises. One way of determining their heart's improvement is by determining how much they're capable of walking and how much workout they can do.

4. Is rehabilitation important post-surgery?

Yes. It's very important. After 3 weeks post surgery we put them back on the treadmill test. There's nothing better than exercise to give them fitness to know if the patient is fit enough to carry on with his daily routine. We need to make sure their heart is not over exerted. That's what we call as the functional capacity.

5. What is Cardiac Rehabilitation and is it an important in the rest of the world?

When we were trained in the west we had a proper unit in the form of cardiac rehab. Which was headed by a physiotherapist and a group of dieticians and clinical psychiatrists. They were a part of a team. It's not an individual work.

Yes. I very much think so. The set of things we were trained in and I have had opportunities to work in and the current set of things I have here is absolutely different.

6. Does India have Cardiac Rehab units integrated in hospitals?

Here in india we don't have such a concept still. Of course in many of the centres we do have some facilities. Here there's no concept of cardiac rehab. It is just that we tell the patients to do the exercise and that is cardiac rehab which is not fair.

7. Why is Cardiac Rehab still not that prevalent in Indian Hospitals?

It doesn't happen down here for a simple reason, it all boils down to the cost and so many other factors.

OUTCOME: Exercises are of great importance in treatment and prevention of cardiovascular diseases. Exercises are prescribed as a program for CVD patients but in the current setting, patients lose motivation and lack adherence to the prescribed program.

3.2.2 Interaction with the physiotherapist

Physiotherapist : Dr. Shrihari Sharma - Department of Physiotherapy, DSU

1. **What are cardiovascular diseases?**

   Heart has got 4 chambers which has got blood it in and it acts as a pumping mechanism where it distributes to the whole body. The heart itself has got blood supply for its functioning

   What happens in some of the lifestyle diseases we are encountering now, because of stress, the various lifestyles, food habits, cigarette smoking, alcohol consumption, diabetes and hypertension. These are called as risk factors for cardiac diseases.

2. **Which are the conditions that can be benefitted from exercises?**

   The diseases benefitted from exercises are - coronary artery diseases, blockage in artery.

   Complete blockage cuts of the supply of the blood. The severity of the disease depends on how much blockage is present, and how many arteries have been blocked. This can be managed in 2 ways.

   One is conservative medication if its in the preliminary stage and second is the surgical management. Which is called the CABG - coronary artery bypass grafting. Anyone under conservative or surgical method both are eligible for cardiac rehab.

3. **When does the cardiovascular patients require rehab?**

In cardiac rehab there are Phase 1 to Phase 4. **Phase 1** - early rehab, restricted to hospital stay of the patient for a week or 10 days of the event.the person will be under constant medication so it is called as in patient care. Usual protocol he is discharged on the 10th day. Then he has to visit the hospital for monitored exercise program. **Phase 2** - monitored rehab. Once in 2 days or a week depends on where he is taking the cardiac rehab under the guidance of physiotherapist and this may last from 10 days to 3 months

4. **How are exercises prescribed to cardiac patients?**

   Exercise cardiac rehab. Here we mainly prescribe exercise. But it is not only the exercise. We have to also take care of exercise, diet, psychological factors, lifestyle modifications, risk factor management. All these factors can be taken care by lectures and counselling sessions. But exercise is skill oriented which the patient has to learn certain exercises.

   Phase 3 is not monitored and lasts upto 3 months to 1 year. Attending the hospital once a month to change the intensity of the exercise and get advice

   Phase 4 lifelong management/ maintenance program. If the exercises are not done properly reversibility does not happen.

   Phase 2 and 3 are crucial and this is where the device could be useful.

5. **How is the program tailored?**

   Exercises - treadmill, bicycle ergometer, staircase

   Monitor the patient's resting and target heart rate during the exercise and the intensity is chosen.

   Mode Intensity Duration Frequency are the parameters to be determined.

   Mode - type of exercise

   Intensity- how intense by monitoring heart rate

   Duration - how long the exercise has to performed

   Frequency - how many times the exercises should be done a week. At least 3 to 4 times. Otherwise he is not actually targeting the heart. Tailor made program for each patient. Intensity level is calculated based on his age, gender, fitness level.

6. Any advice you would like to give us in carrying out our project?

You should concentrate whether the patient is doing the exercise daily, because motivation is very important. If you don't have motivation you don't do it. Especially when patients have comorbidities they don't do it regularly. So it has to be monitored. If the patient knows he's being monitored probably he will do it regularly. And the patient's diet has to be strictly monitored. So if these things are there in your device which can be accessed by the doctor it will be useful.

OUTCOME: Doctors will not be the main users of Doctor-Patient system, physiotherapists will mostly be in charge of patient check-ups, however for this project, doctors will be used to refer to the group of physiotherapists, doctors, general practitioners and whoever else may make use of the system. There may be different levels of exercises depending on the patient to be implemented in both exercise and serious game of patient's system, on patient account creation doctor (Physiotherapist) will specify correct level.

CHAPTER 4: PROJECT OVERVIEW

4.1 AIM

Research and Deliver 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 to diagnose and examine patients without frequent face-to-face interaction.

4.2 OBJECTIVES

- ➢ Research if project is feasible, to find similar technologies to determine user requirements and to select most appropriate implementation of this project
- ➢ Implement exercise tracking and serious game in patient system
- ➢ Implement doctor system and Heart-rate tracking in patient system

4.3 SYSTEM REQUIREMENT

The system requirements for the proposed project are:

S.No	Requirement	Description	User
1.	Log In (Patient System)	Login to Patient system, Account created by Doctor	Patient
2.	Perform Basic Exercise	Perform basic exercises in front of Kinect, results are recorded	Patient
3.	Play Game	Play game-based exercises in front of Kinect, results are recorded	Patient
4.	View Records (Workouts)	Patient/Doctor Can view results of patient workout, Doctor comments also available	Patient, Doctor

5.	Create Doctor Account	Create account on Doctor system	Doctor
6.	Log In (Doctor System)	Login to doctor system	Doctor
7.	Create Patient Account	Create user account for patient	Doctor
8.	Select Patient	Select specific patient account	Doctor
9.	Edit Patient Details	Can edit selected patient account	Doctor
10.	Send Message	Send message to patient	Doctor
11.	Comment On Workout	Comment on specific workout by patient	Doctor

Table 3. System Requirements

4.4 SYSTEM OUTLINE:

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.The system overview can be visualized by Figure 3. Exercises may include: Squats, Jumping Jacks, Various Stretches and Basic Body Movements.

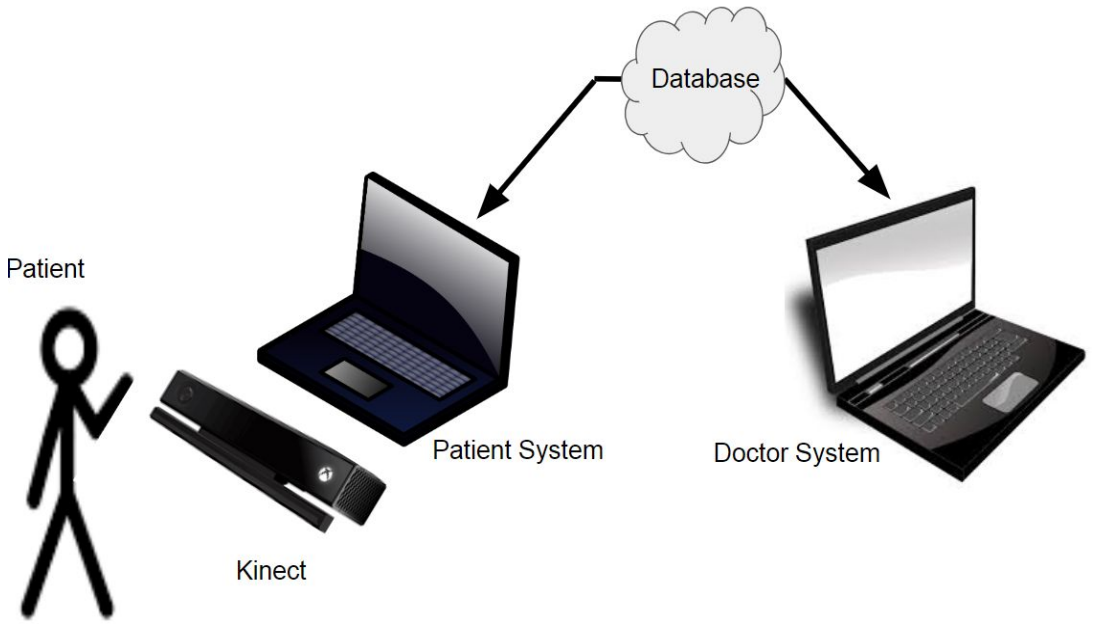

Figure 3: *System Outline*

4.4.1 : Monitoring and Feedback

Communication between doctor and patient is a key success factor in medical treatment. And as such the doctor–patient relationship is central to the practice of healthcare and is essential for the delivery of high-quality health care in the diagnosis and treatment of disease or rehabilitation. Doctors must maintain a professional rapport with patients, uphold patients' dignity, and respect their privacy.

4.4.2 Project Components

Patient's System: Computer with Game/Rehabilitation Application and Kinect 2 attached

Admin/Doctor's System: Computer with Admin Application

Patient's System: 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: 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.

CHAPTER 5: CURRENT TECHNOLOGIES

The system can be split into sections depending on how each function was made with what technology or what technology is used for a function. Different technologies can be chosen for:

- The game engine that is used to make the application
- The motion capture device that is used to capture the data
- The cloud service that is used to host the website
- The database management system that is used to store the data
- The server-side language is used to make the website

5.1 GAME ENGINES

The patient application which includes the serious game aspect of the system was decided to be built using a game engine as game engines contain all the tool available for building game-based systems without the need of coding them which would take a large amount of time. Deciding on the proper game engines is important as different game engines may or not be able to implement some aspects of the system. Some game engines are not able to support the motion capture device of the Xbox Kinect which may be a big deciding factor on whether it will be used in implementation of the system.

➢ **Unity**

Figure 4: *Unity Logo*

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. Games built using Unity can be made for PC platforms like Windows and Mac, or consoles like the Xbox 360 and PlayStation 3, and even mobile devices like Android and iPhone.[12]

Developers can program in scripts like C#, JavaScript or Boo (Python inspired syntax). MonoDevelop is the IDE built into Unity. Scripts do not need to be written with the built-in MonoDevelop, however MonoDevelop necessary to debug them.

Unity3D has many plugins to implement many different types of motion capture. In terms of Microsoft's Kinect, Microsoft has released their own plugins for Unity to implement Kinect Version 1 and Version 2 projects.

➢ **Unreal Engine**

Figure 5: *Unreal Engine Logo*

The Unreal Engine is a game engine developed by Epic Games. The Unreal Engine also comes with the Unreal Development Kit, a game creation system for developing Unreal Engine games. The current release is Unreal Engine 4. Unreal Engine 4 uses C++ for scripting.

★ Unity was chosen over Unreal Engine as it was more user friendly and easy to understand. In addition, Microsoft officially released Kinect plugins for Unity.

5.2 MOTION CAPTURE:

Deciding on the right motion capture device and software is very important in this project. The Xbox Kinect being the main open-source motion capture device is primarily chosen. However depending on the version of the kinect certain aspects are required for the project such as the whichever version of the kinect has the ability of heart rate monitoring, a necessary component of this project.

➢ **Kinect**

Figure 6: *Kinect v1*

The Kinect (Kinect version 1) is a motion sensing input device developed by Microsoft and PrimeSense for the Xbox 360 console and Windows PCs. Based on a webcam style peripheral device, it acts as an alternative type of input and allows users to interact with interact with their console/computer without the need of a game controller.

➢ **Kinect 2**

Figure 7: *Kinect v2*

The Kinect V2 (Figure 5) 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 holds most of the same functions as its predecessor except many new features as well as upgraded features. It has the ability of heart-rate tracking by using its infrared sensor. [14]

★ Kinect V2 was chosen over the first version as it has many additional features and can track more joints.

5.3 CLOUD SERVICES

Cloud Services for the system need to be decided upon in terms of web-hosting of the Doctor's System as well as database storage of Patient-Doctor account credentials as well as patient exercise results.

Choosing the correct cloud service depends on which programming languages it supports to facilitate the application we have to deploy. In cloud computing terms this is known as Platform-as-a-Service, which means that an application is created using tool and/or libraries from the provider. The provider provides the network, servers, storage and other services that are required to host an application.

➢ Windows Azure

Figure 8: *Windows Azure logo*

Windows Azure is Microsoft's cloud-computing platform. Consumers of Windows Azure can build, deploy and manage applications through a global network of Microsoft-managed data centres. It also provides web-hosting and the ability to create and deploy Virtual Machines. Users can develop applications in Java, PHP, Python, ASP.NET and Node.js. Windows Azure has the ability to allow any language or framework, to be deployed onto the cloud however middleware must be used for some to work, and client libraries are available on GitHub. [13]

➢ Amazon Web Services

Figure 9: *Amazon Web Services logo*

Amazon's solution to cloud computing is Amazon Elastic Compute Cloud (EC2) which is part of Amazon's Web Services. Amazon Web Services holds many tools especially for developers such as load balancers, relational databases add-ons, caching systems, notification systems and content delivery networks. These are constantly being optimized

by Amazon and more services and online tools are constantly being added. It also provides support for every major programming language. [14]

★ Windows Azure was chosen over Amazon web services as it is more beginner friendly and compatible with Visual Studio

5.4 SERVER-SIDE LANGUAGES

Communication between the client and server is an essential part of the Doctor's System. The Doctor's System must perform many specific functions such as creating patient accounts, viewing patient accounts and view patient workout results and heart rate condition. Server side languages perform the programming functions of the system on the server. Once the task has been completed here, the result is returned to the client through the front end.

➢ **PHP**

Figure 10: *PHP logo*

PHP is scripting language also used as a programming language. PHP is probably one of the most popular languages in terms of creating server side web applications. PHP's syntax is very similar to that of languages like Java and C++, making PHP familiar and easy to learn. It can be considered as an option as I am very familiar with it, however it is considered outdated by many because of the more recent web frameworks available which allow for less code and faster completion.[11]

➢ **ASP.NET**

Figure 11: *ASP.NET logo*

ASP.NET is an open source web application framework designed for web development to produce dynamic web pages. It was developed by Microsoft to allow programmers to build dynamic web sites, web applications and web services. Any .Net language can be used along with ASP.NET. ASP.NET can be also used with HTML, CSS and JavaScript. There are different types of frameworks to be used with ASP.NET of ASP.NET MVC Framework. Since 2010 a new type of syntax has been developed to be used with ASP.net of Razor view engine. It was released along with ASP.NET MVC 3 and allows for creation of dynamic webpages using C#, it uses a new filename extension of .cshtml, which allows execution of C# code within web pages. [16]

★ ASP.NET was chosen over PHP as server side language since it is written in C# which is the same language Unity scripts are also written in.

5.5 DATABASE MANAGEMENT SYSTEM

Deciding on the right database management is crucial to how the whole system operates. The system requires a Database management system to keep track of doctor accounts, patient accounts and patient records. One of the main deciding factors on picking the right Database management system is that will it be compatible with each component in the system. For example if the Cloud service support it, if the patient application connect to it, if the doctor system connect to and if it the best Database management system to organise and store the data in.

Of the two examples compared, a comparison is done of whether to use a NoSQL Database and a Relational Database, which is also a point to be consider in choosing the correct database**.**

➢ **MongoDB (JSON)**

Figure 12: *MongoDB logo*

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). Being a different type of database management system to the traditional relational database system MongoDB does contain some limitations such it cannot join different data types across the database, a functions which is commonly used in most relational databases, however it does allow for data querying. [17]

➢ **MySQL**

Figure 13: *MySQL Logo*

MySQL is an open-source relational database management system. MySQL is one of the most popular database management systems in the world with being open source a big part of the reason. Large organisations such as Facebook, Google and YouTube still make use of MySQL databases. A thing to note is that SQL Developer can also be used as a front end solution to interface with the MySQL backend. [18]

★ MongoDB was chosen as it was a good opportunity to learn a NoSQL type database. MongoDB was also chosen because of its scalability, flexibility, speed and dynamic schema.

CHAPTER 6: 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.

6.1 SYSTEM ARCHITECTURE DIAGRAM

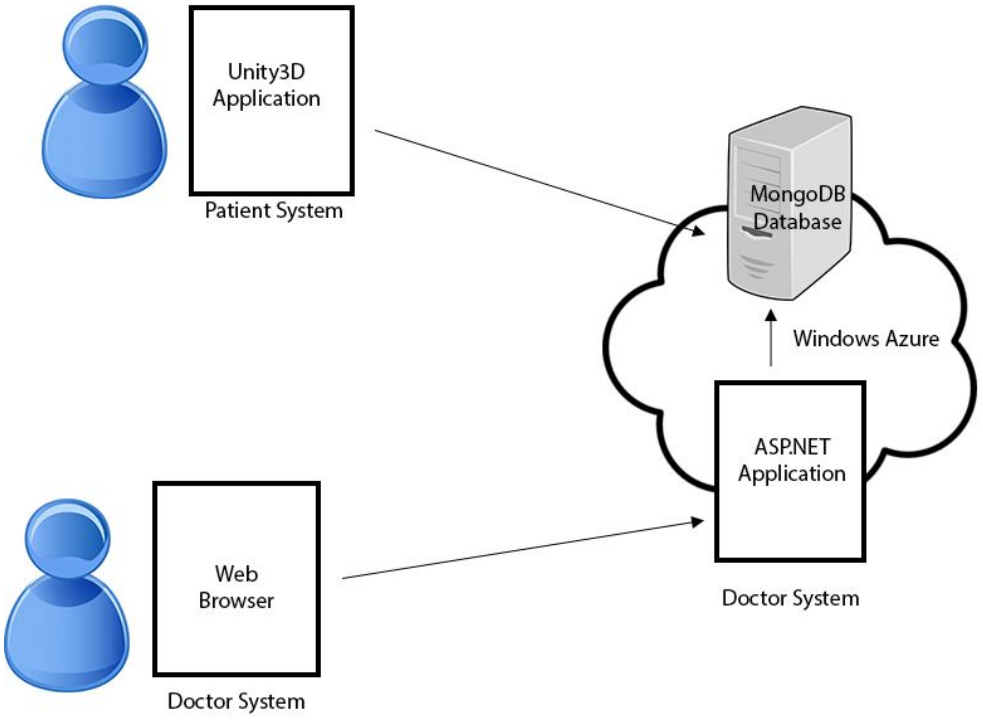

Figure 14: *System Architecture Diagram*

The system architecture presented in Fig. 14. is for the users connecting to the system as a doctor or a patient. The patients 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.

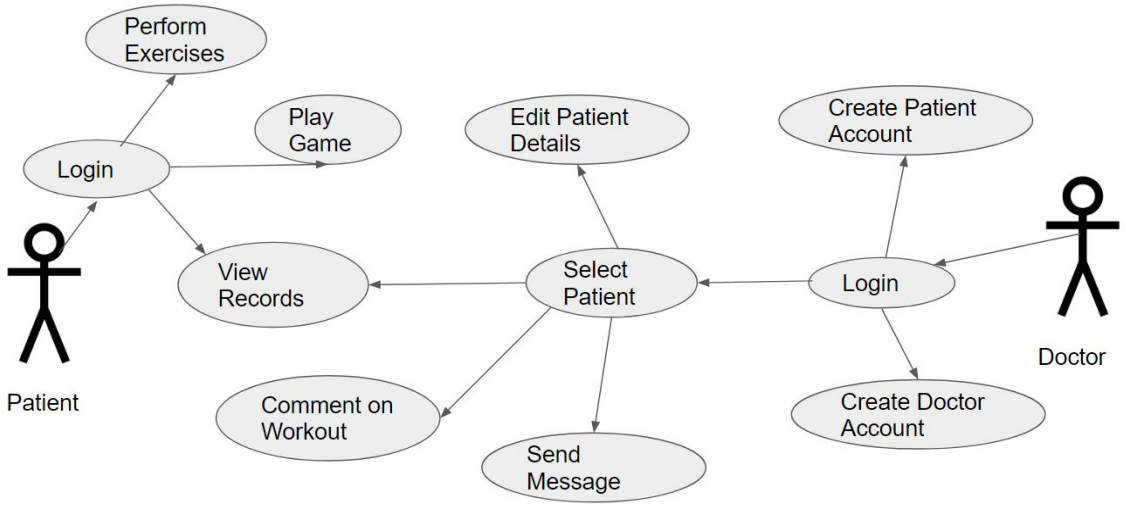

Figure 15: *Use-Case Diagram*

The use case diagram above (Figure 15) illustrates the initial use-case to be implemented in the system. The requirements were gathered through research and how the system will be logically implemented. Based on the methodology chosen, the use-case requirements were subject to change.

6.2 SETUP

6.2.1 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.

6.2.2 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.

6.2.3 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).

Figure 16 illustrates the database classes created.

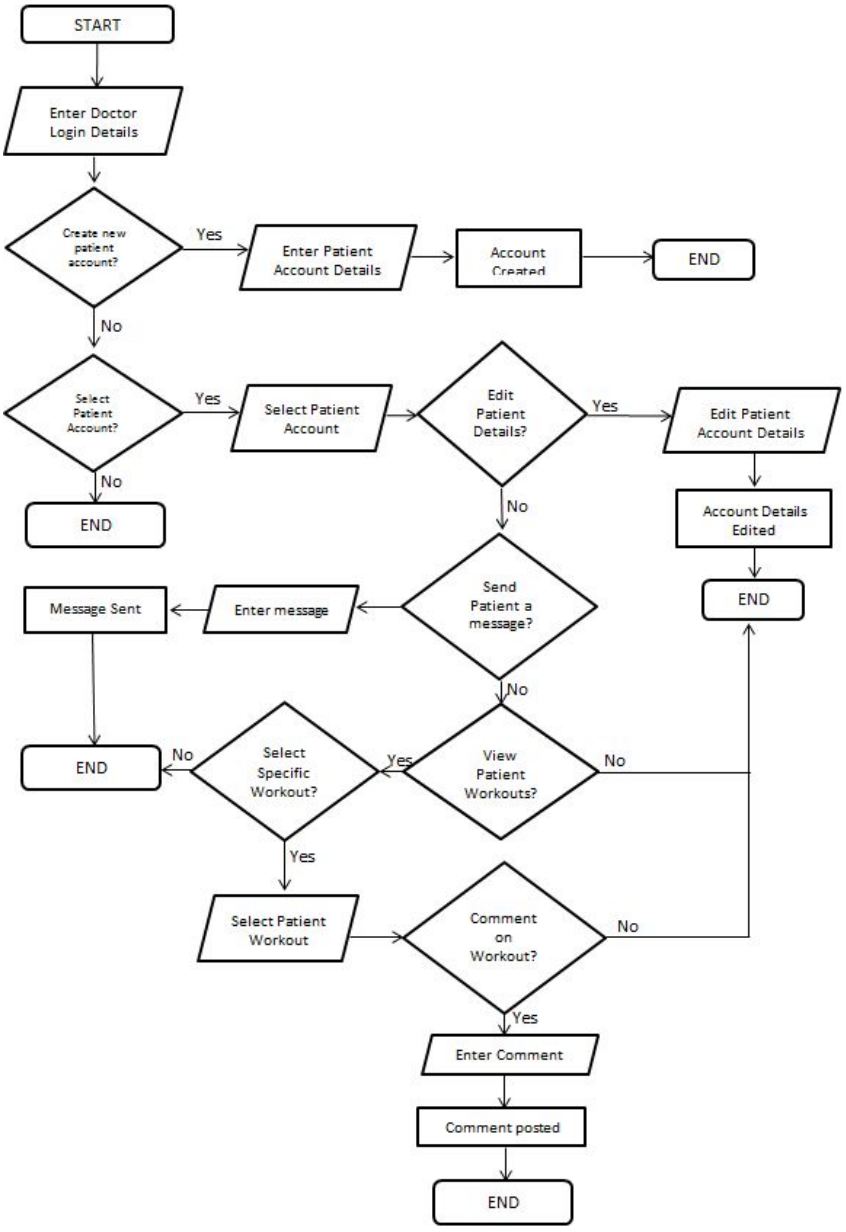

Figure 16: *Flowchart of classes in database*

6.3 SYSTEM OVERVIEW

Following the methodology chosen where the entire system was split into components, the obvious two systems of the Patients system and the Doctors system are seen as components of the entire project however part of these systems are split into sub-components. The three main components of the system are:

- Database Connection classes
- Website classes (CardioHealth Website)
- Application classes (CardioHealth Kinect).

6.3.1 Database Connection Implementation

The Database Connection classes comprise of the classes used for the database connection to the online Mongo Atlas database, hosted on Windows Azure. Both the CardioHealth Application and Website use these classes for database connection.

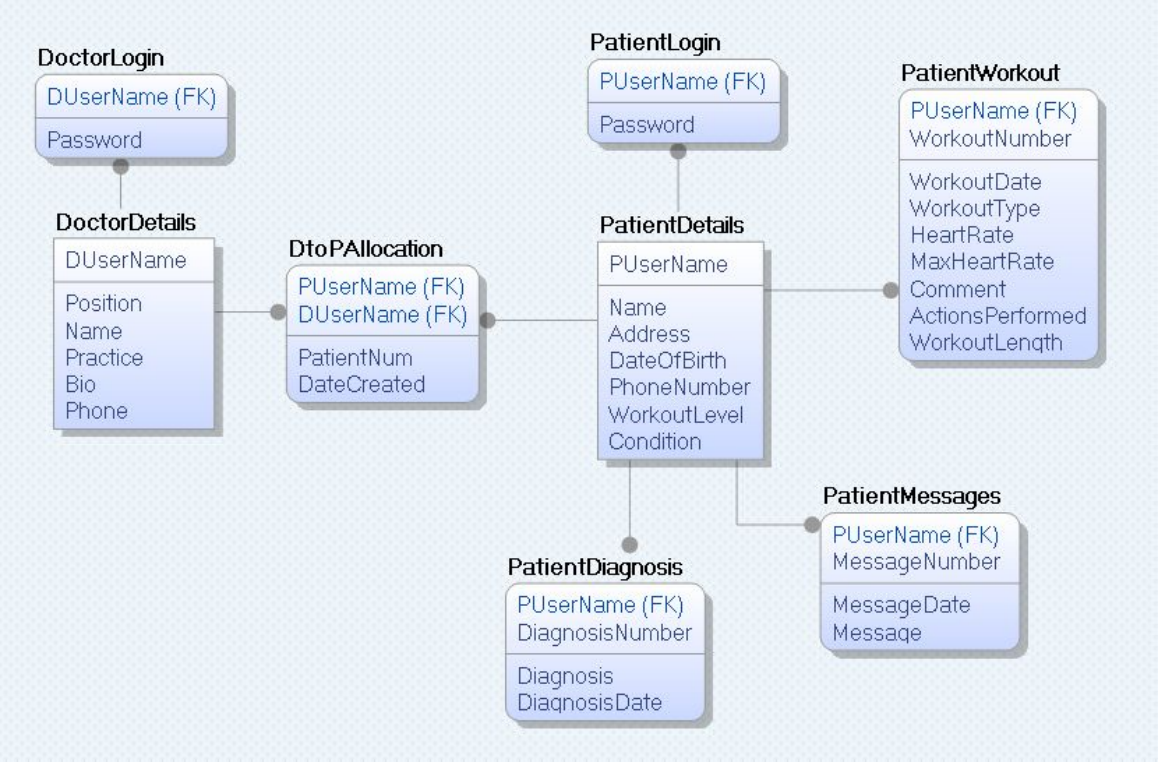

***Figure 17**: Relationship entity Diagram*

The Entity Relation Diagram or ERD is a model of mapping relational data sets together and to determine how each data set interacts with one another by means of querying. It is used to as a design to how the database's data set are to be laid out. The ERD used for the database implementation is given as in Figure 17.

6.3.2 CardioHealth Website Application

The CardioHealth Website is created using ASP.NET in Visual Studio 2017. It is also hosted on Windows Azure as seen in Figure 18 and Figure 19. The website is connected to a MongoDB database which is also hosted on Windows Azure through Mongo Atlas. The website's main function is the Doctor/Physiotherapist administration of their patient's. Doctors/Physiotherapists can login (Figure 20) or register an account on the website (Figure 21), and once their account is created, they have the ability to create Patient Accounts (Figure 22). The doctor can view all the patients under him (Figure 23). 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.

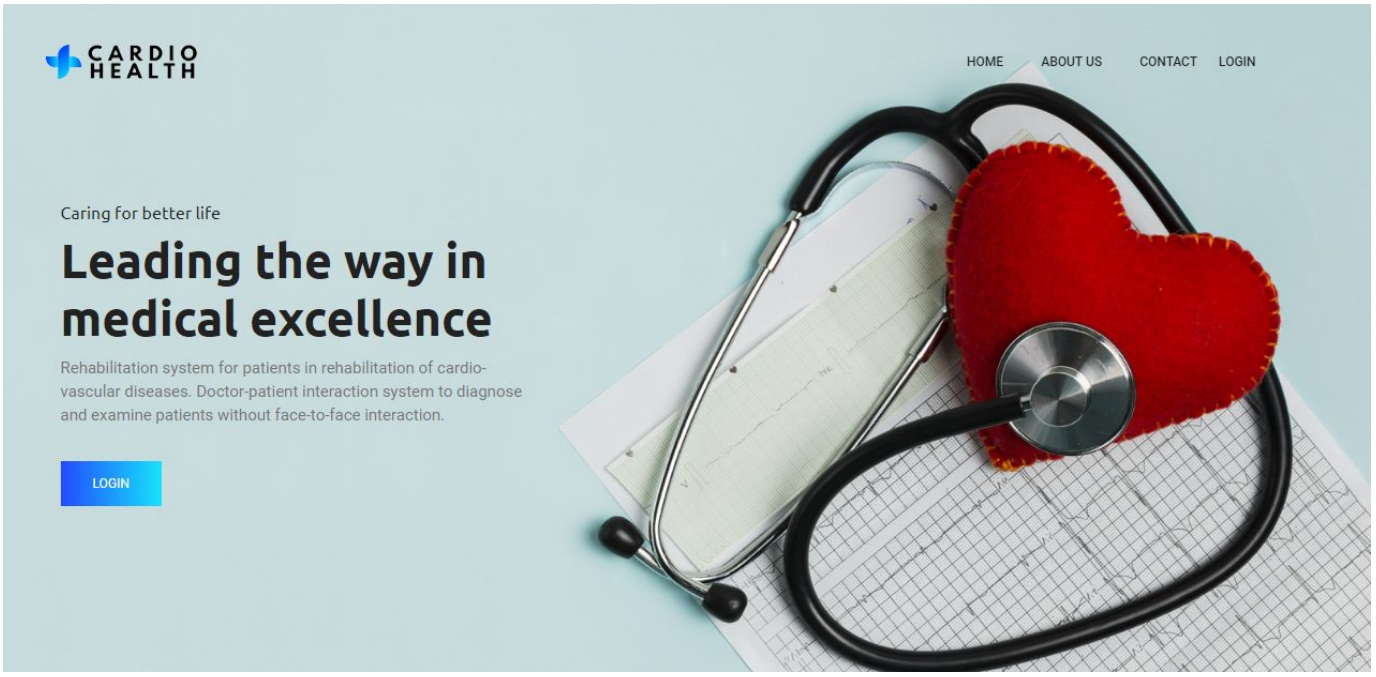

Figure 18: *CardioHealth Website Home Page (i)*

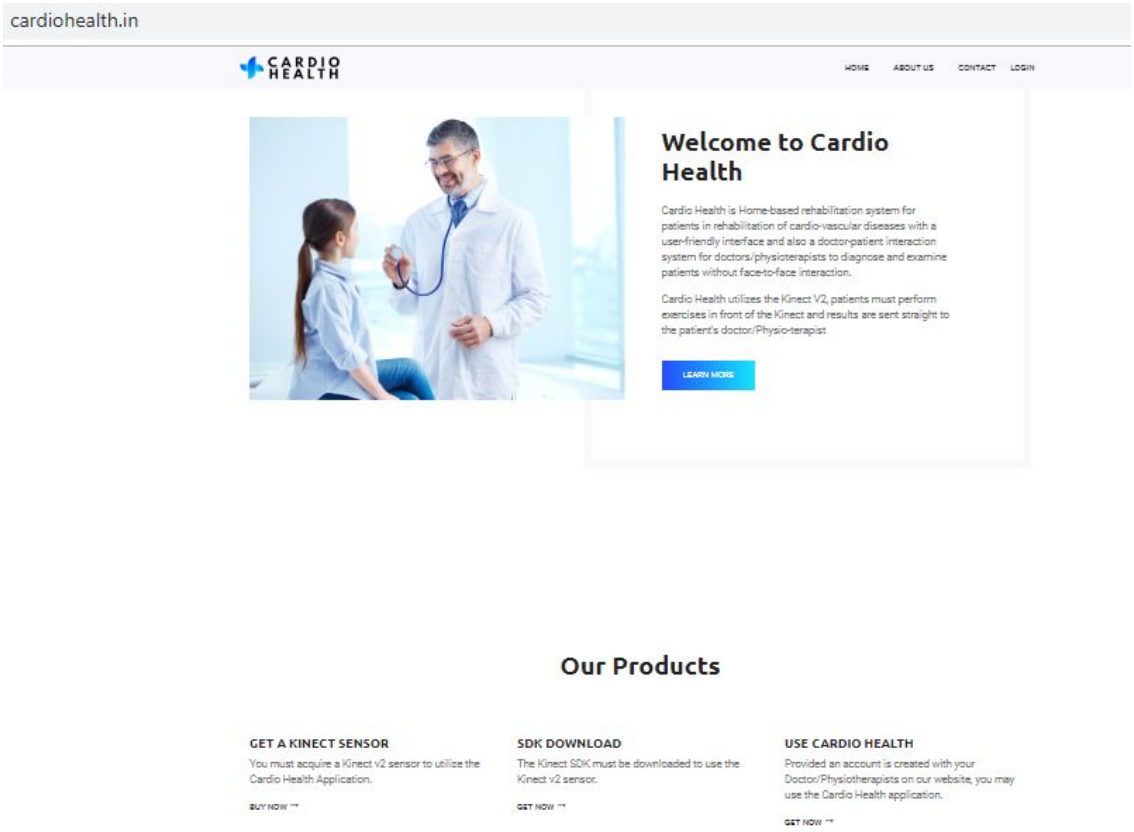

***Figure 19**: CardioHealth Website Home Page (ii)*

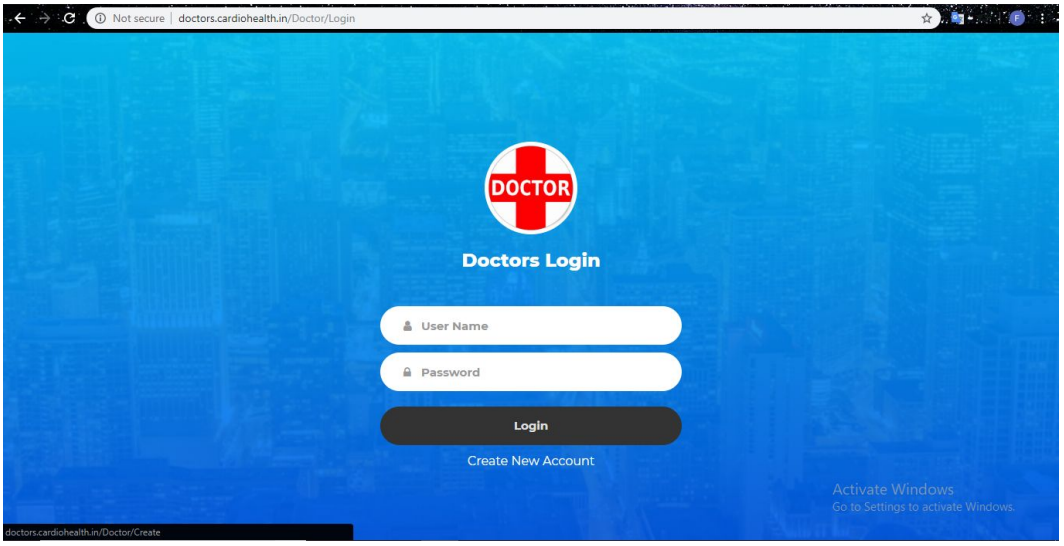

***Figure 20:** Doctor Login page*

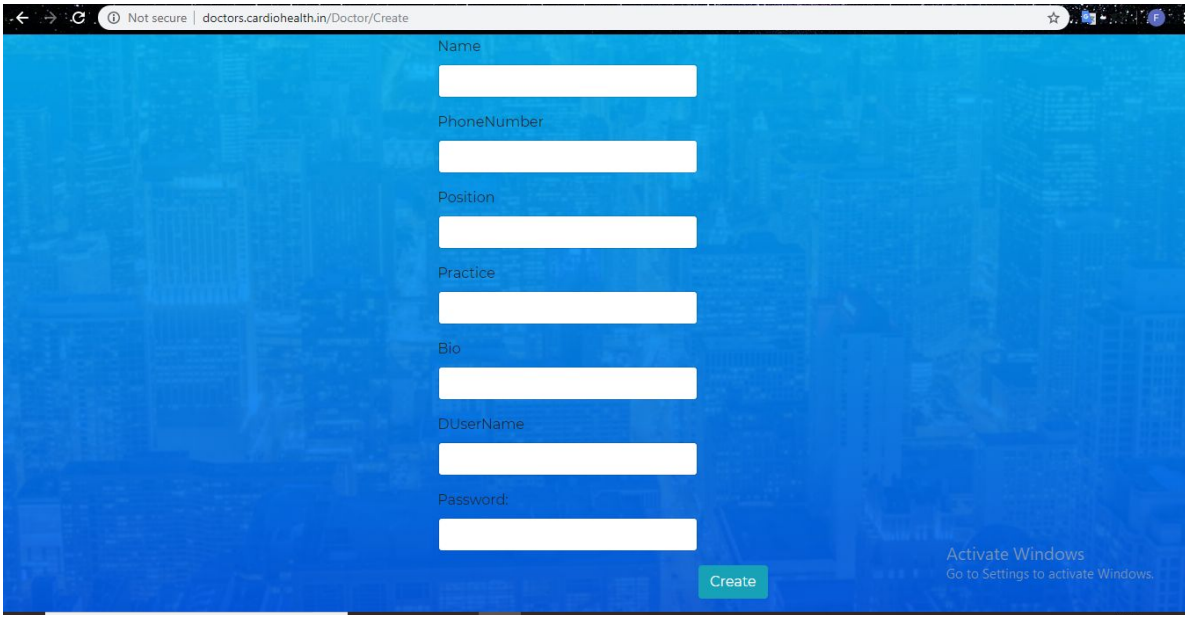

Figure 21: *Doctor - Create New Account Page*

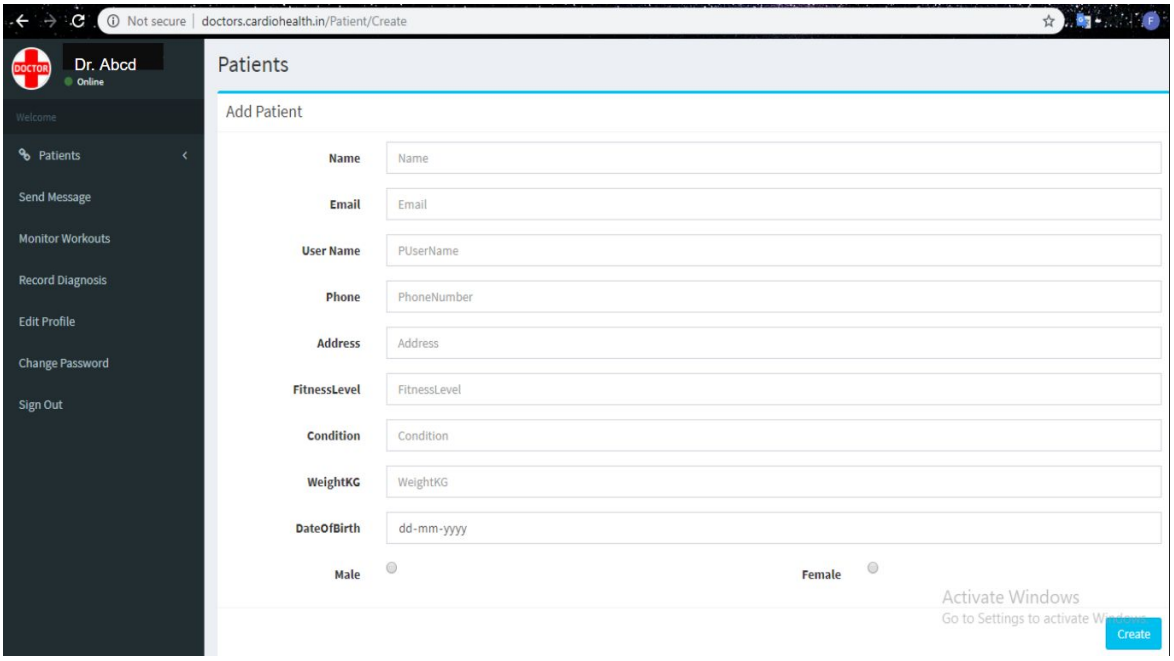

Figure 22: *Patient-create new page*

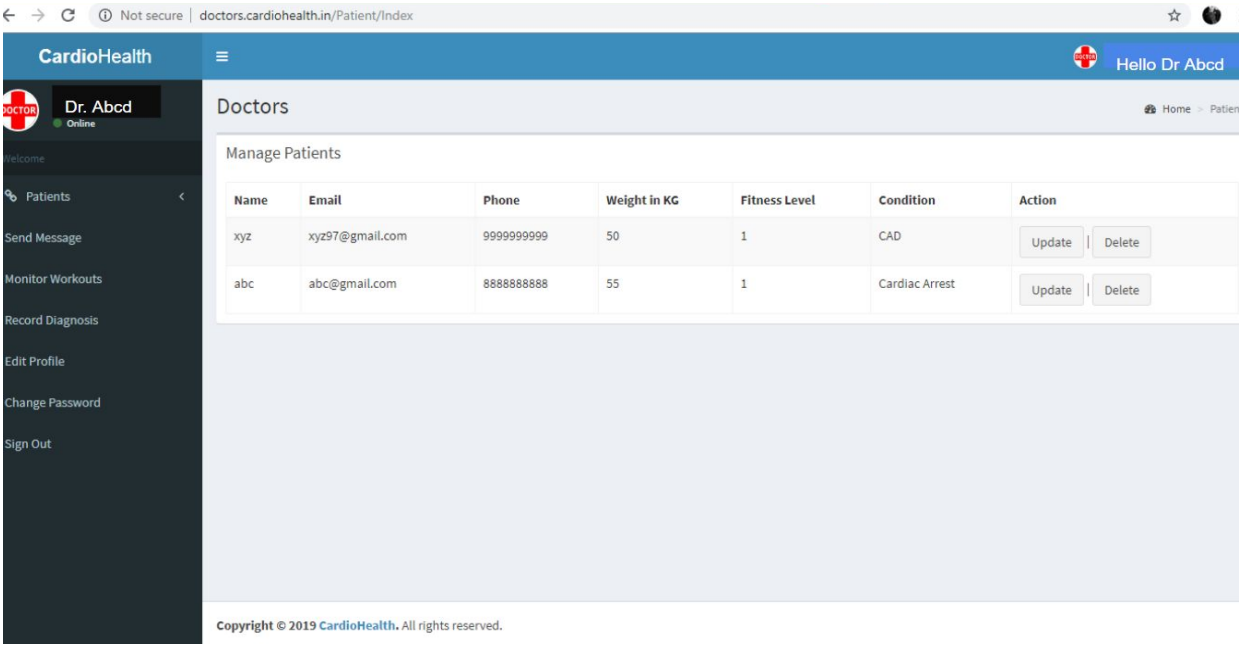

Figure 23: *View all patients page*

6.3.3 CardioHealth Kinect Application

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.

Application Login

On start-up of the application, the login screen is introduced where the patient must login with their username provided by the Doctor/Physiotherapist as seen in Figure 24. If it is the patients first login, they do not have to enter a password, just their username, once entered they choose their own password.

Figure 24: *CardioHealth patient application Login Screen*

Menu Scene:

The Menu scene as scene in Figure 25, has menu buttons. Each menu button leads to the respective scene it has been designed for.

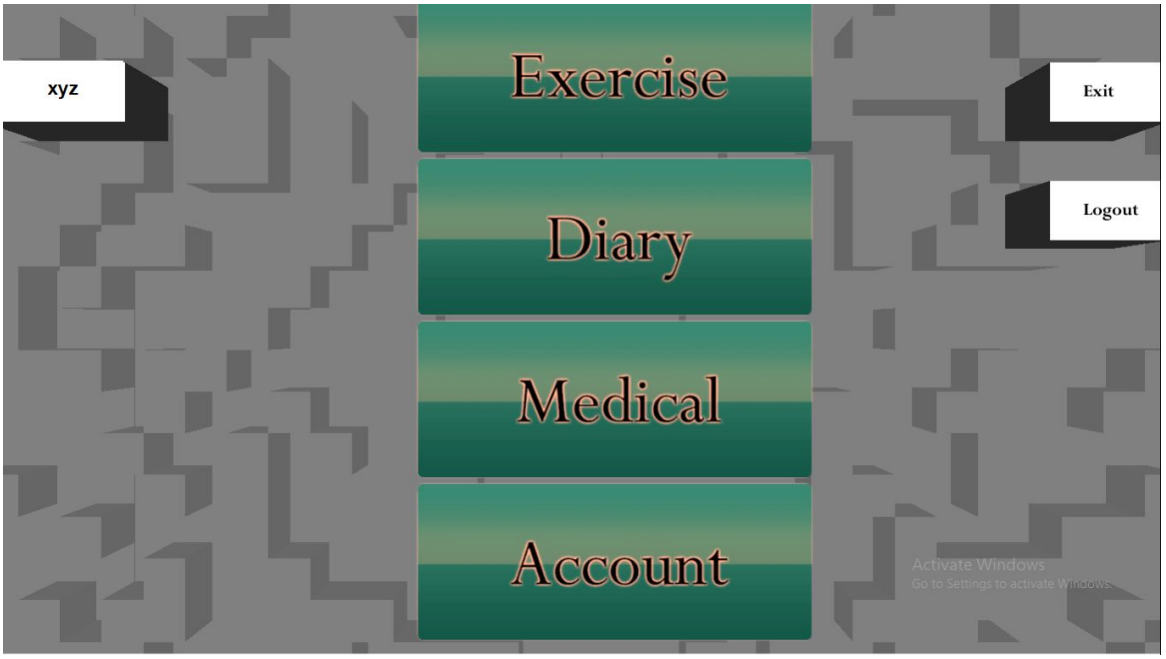

Figure 25: *CardioHealth Application Menu Screen*

Game Selector Scene:

The game selector scene allows the user to select the exercise mode from the four options- Basic Exercise, Simon Says, Heart Racer and Orbs. A small description of each mode is also given when the user navigates to the mode button. Figure 26 shows the game selector screen.

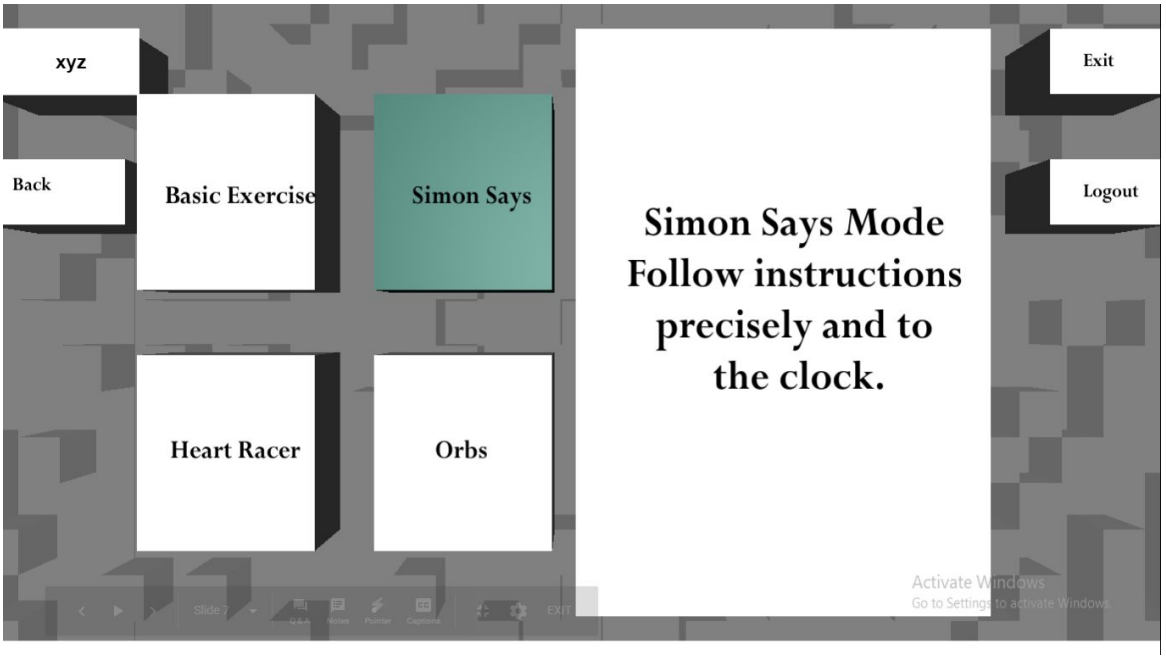

Figure 26: *CardioHealth Application Game Selector Screen*

Basic Exercise Mode:

In this mode, the patient can perform basic exercises like squats and jumping jacks. The number of squats or jumping jacks performed is counted.

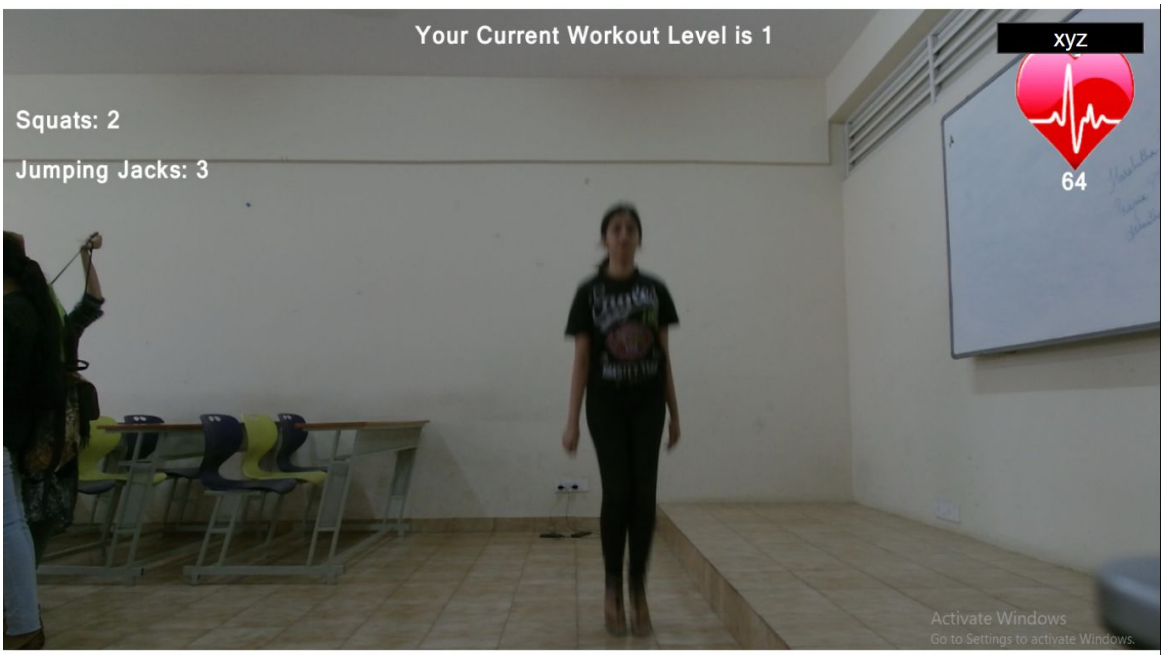

Figure 27: *CardioHealth Application Basic Exercise Mode*

Simon Says Mode:

A simple "Simon Says" game was also created, where gestures must be performed on time and correctly to progress through the game. The gestures detected are squats, jumping jacks, raising right/left hand, waving with both hands.

Figure 28: *CardioHealth Application Simon Says Mode*

Orbs Mode:

The final game available is an Orb Dodger type game based off the prototype game made during learning stage. The game is made specifically for a warmup and does not record workout data. It uses the AvatarController class to control an Avatar and dodge incoming red orbs and acquire green orbs.

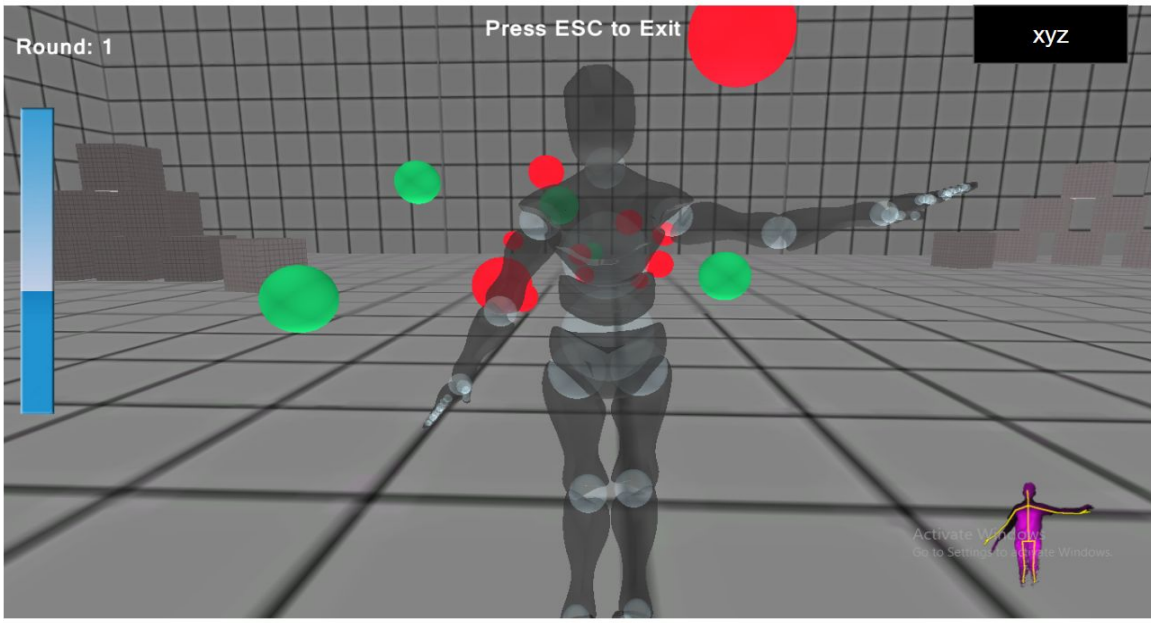

Figure 29(a): *CardioHealth Application Orbs Mode - During Workout*

Figure 29(b): *CardioHealth Application Orbs Mode - Round Complete*

Heart Racer Mode:

A Heart Racer game was also created, the premise of the game is to accelerate the heart rate to a certain range within a short amount of time. This is done using the HeartRateEstimation class.

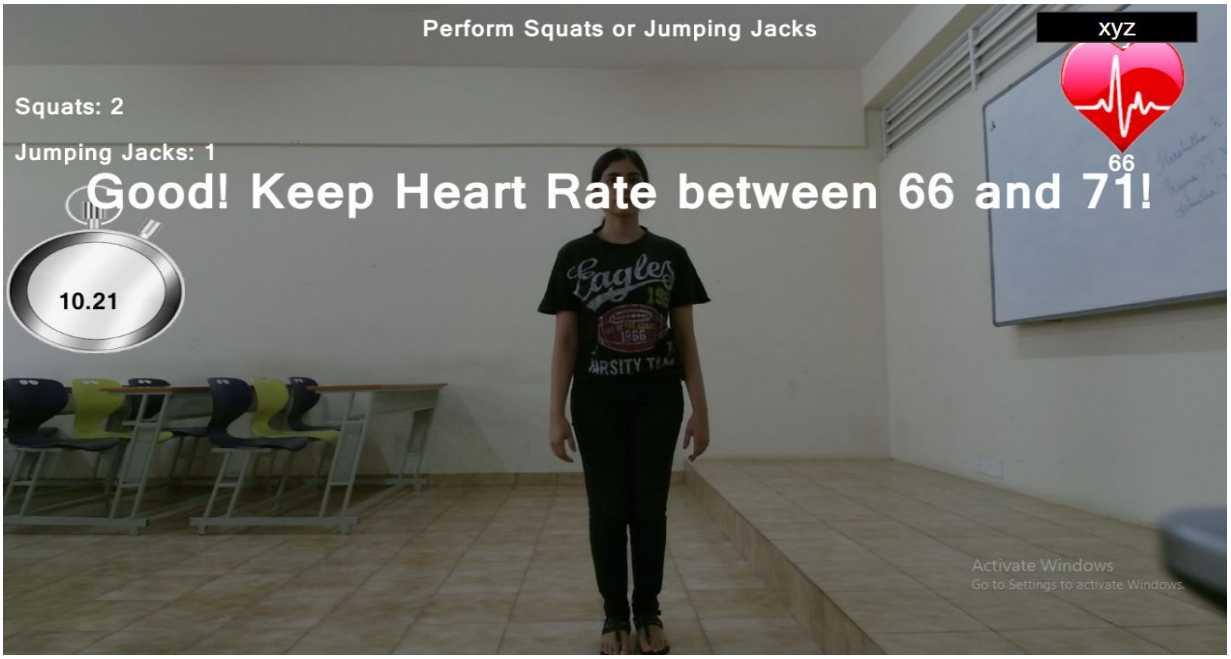

Figure 30: *CardioHealth Application Heart Racer Mode*

Diary:

The details recorded during the workouts are saved and displayed in the diary scene.

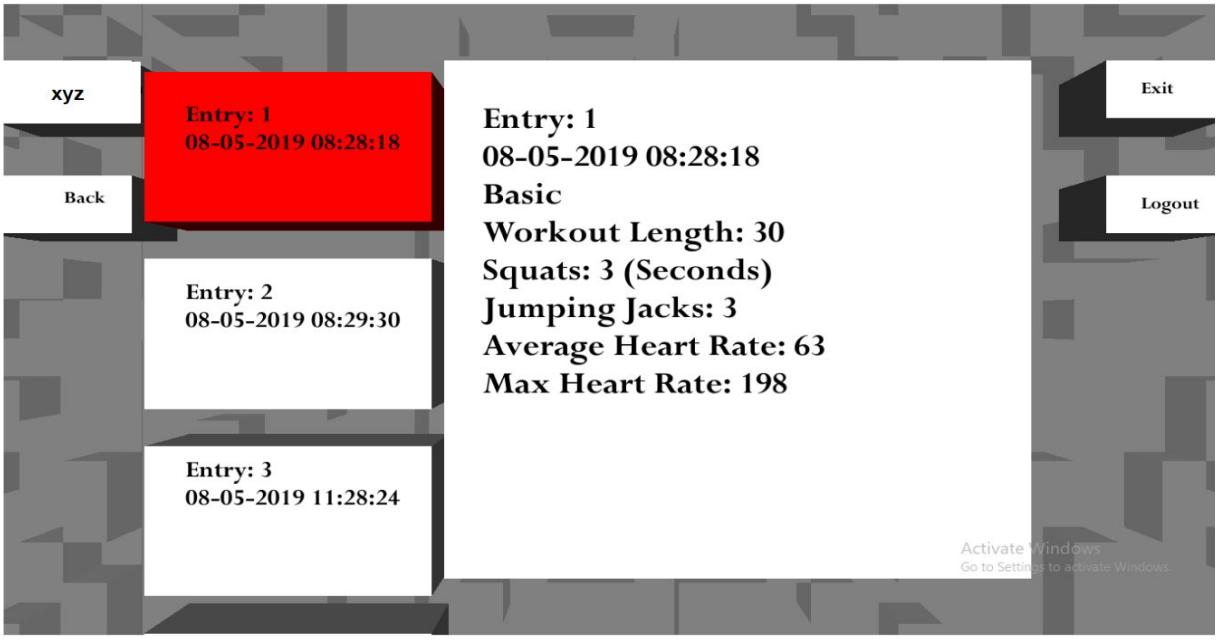

Figure 31: *CardioHealth Application Diary Screen*

Medical:

The details of the medical professional handling the patient is displayed here. The comments/ messages made by the professional to the patient are also shown in this screen.

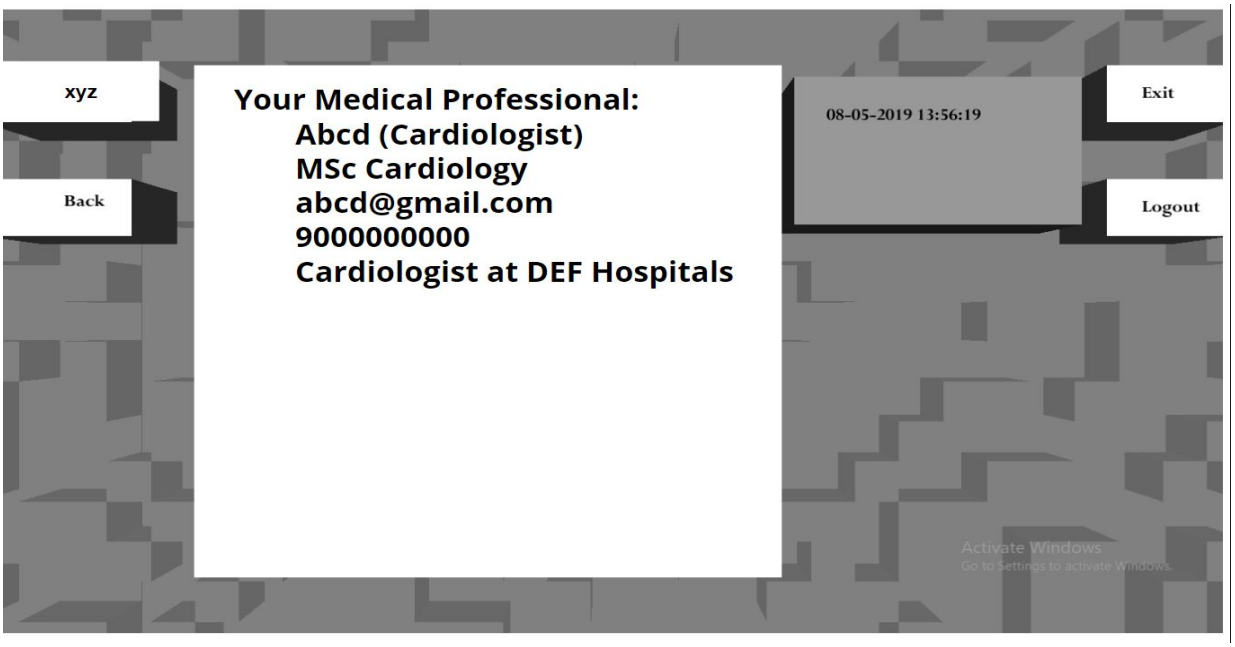

Figure 32: *CardioHealth Application Medical Screen*

Account:

Patients can view their account details here. Patients also have the option to edit their some fields within their account information and can also change the password.

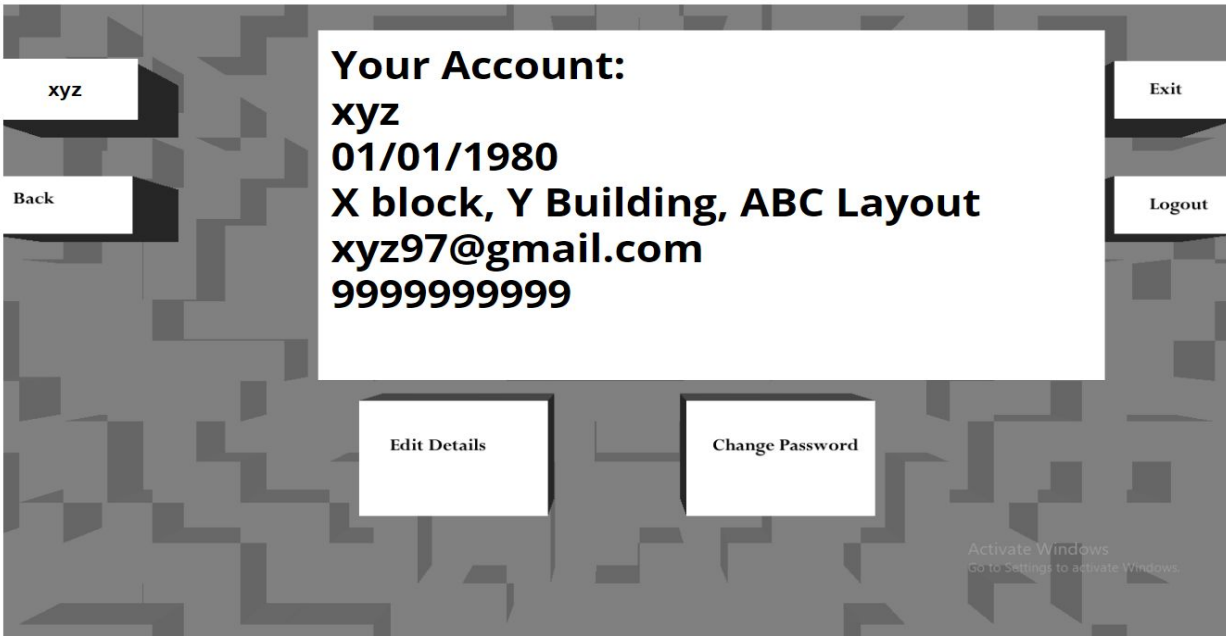

Figure 33: *CardioHealth Application Account Screen*

6.4 HEART RATE ESTIMATION

It was intended to incorporate the Kinect v2 capability at heart rate monitoring into the project, this was to be done by using the Kinects v2 Infrared sensor to detect heat signatures from the users face and as such that data could be used to assume heart rate. However it could not get implemented and as such an alternative had to be made, and as such the HeartRateEstimation class was made to estimate the current patient's heart rate based off factors such as the Patients Age, Weight in Kilograms (KG), their Gender, and their Fitness Level, (Athletic, Average, Poor). These fields were added to the PatientDetails database class and were taken on the Patient Account created. For the heart rate estimation, statistics needed to be taken such as finding the average Resting Heart Rate, Target Heart Rate and Maximum Heart Rate for people of Age, Sex, weight, and fitness level.

Resting Heart Rates:

Resting heart rate chart

Resting heart rate chart for men							
By Age	Heartbeats Per Minute						
	Athlete	Excellent	Good	Above Average	Average	Below Average	Poor
18-25	49-55	56-61	62-65	66-69	70-73	74-81	82+
26-35	49-54	55-61	62-65	66-70	71-74	75-81	82+
36-45	50-56	57-62	63-66	67-70	71-75	76-82	83+
46-55	50-57	58-63	64-67	68-71	72-76	77-83	84+
56-65	51-56	57-61	62-67	68-71	72-75	76-81	82+
65+	50-55	56-61	62-65	66-69	70-73	74-79	80+

Resting heart rate chart for women							
By Age	Heartbeats Per Minute						
	Athlete	Excellent	Good	Above Average	Average	Below Average	Poor
18-25	49-55	56-61	62-65	66-69	70-73	74-81	82+
26-35	54-59	60-64	65-68	69-72	73-76	77-82	83+
36-45	54-59	60-64	65-69	70-73	74-78	79-84	85+
46-55	54-60	61-65	66-69	70-73	74-77	78-83	84+
56-65	54-59	60-64	65-68	69-73	74-77	78-83	84+
65+	54-59	60-64	65-68	69-72	73-76	77-84	84+

Figure 34 : *Resting Heart Rate Chart*

The following resting heart rates provided a close estimation as to a user's resting heart rate based on their age, sex and fitness level and as such a function was made within the HeartRateEstimation class:

```
private int GetRestingHeartRate (int Age, int FitnessLevel, bool IsMale)
  {
   int RestingHeartRate = 0;
  // FitnessLevels 1 (Athelete/Excellent) 2 (average) 3 (Poor)
  if (IsMale)
          RestingHeartRate += 5;
  else
          RestingHeartRate += 8;

  if (FitnessLevel == 1)
          RestingHeartRate += 48;
  else if (FitnessLevel == 2)
          RestingHeartRate += 59;
  else if (FitnessLevel == 3)
          RestingHeartRate += 69;

  if (Age < 25)
          RestingHeartRate += 4;
  else if ((Age > 25)&&(Age <= 35))
          RestingHeartRate += 5;
  else if ((Age > 35)&&(Age <= 45))
          RestingHeartRate += 5;
  else if ((Age > 45)&&(Age <= 55))
          RestingHeartRate += 7;
  else if ((Age > 55)&&(Age <= 65))
          RestingHeartRate += 6;
  else if (Age > 65)
          RestingHeartRate += 7;
  return RestingHeartRate;
}
```

6.4.1 Maximum Heart Rate Estimation

In finding an estimation of a patient's Maximum Heart rate (MHR), there are three different formulas available to measure Max heart rate based on different measurements. These formulas consist of the Fetal Heart Rate method which is the most basic, Karovonen Method and the Heil Method. The Fetal Heart Rate Method (FHR) [15]
bases a person's maximum heart rate at either 220 for men or 226 for women, and their age is subtracted from that and as such their Max heart rate is calculated (With FHR being 220 or 226):

MHR = FHR – age

This method can be further elaborated on to include a user's fitness level:[19]

Male:

MHR = 205-Age/2 (Athletic)

MHR = 220-Age (Average)

MHR = 214-0.8*Age (Poor)

Female:

MHR = 211-Age/2 (Athletic)

MHR = 226-Age (Average)

MHR = 209-0.7*Age (Poor)

Of the three methods, both the Fetal and Heil Method were used to most accurately acquire the maximum heart rate. Within the system both method are average to get the most accurate result:

```
int MaxHeartRate = 0;
        if (IsMale) {
            if (FitnessLevel == 1) {
                MaxHeartRate = 205 - Age / 2;
            } else if (FitnessLevel == 2)

            {
                MaxHeartRate = 220 - Age;
            }
            else if (FitnessLevel == 3) {
```

```
                float num = 0.8f * Age;
                MaxHeartRate = 214 - (int)num;
        }
                }
         else {
        if (FitnessLevel == 1) {
                MaxHeartRate = 211 - Age / 2;
        }
         else if (FitnessLevel == 2) {
                MaxHeartRate = 226 - Age;
        }
        else if (FitnessLevel == 3) {
                float num = 0.7f * Age;
                MaxHeartRate = 209 - (int)num;
        }
                }
return  MaxHeartRate;
}
```

6.4.2 Target Heart Rate Estimation

In terms of exercising and why monitoring your heart rate is beneficial to exercise and finding out if (based on heart rate) a person is doing too much or not enough in a work out, Target Heart Rates are important. Target Heart Rates are found by getting a percentage of the Maximum Heart Rate, such as some people (or personal trainers) consider for a workout the Target Heart Rate Zone of between 50% and 85% of the Maximum Heart Rate.

In terms of the Heart Health system Target Heart Rate is split up into 3 different Workout levels or Zones, based on the patient's own preference as to how hard they want to work:

- Zone 1 (50% - 65% of MHR) Zone 1 is ideal for people who are new to exercise or are starting again after a break

- Zone 2 (65% - 80% of MHR) Zone 2 is ideal for people who want to lose weight. At this level, fat is the source of energy for the body. It will also improve a person's fitness and endurance
- Zone 3 (80% - 95% of MHR) Zone 3 will help get a person's body used to exercising at a faster pace. Lung capacity will improve. This level of intensity will also help with weight control

Target Heart Rates are displayed within the system to encourage users to work harder within their workout. It also noted that once a user's works towards their target heart rate it gets more difficult to raise it, this is taken into consideration within the heart health system.

CHAPTER 7: CONCLUSION AND FUTURE WORKS:

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 status. CardioHealth 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.

The proposed system can further utilize the Kinect V2 heart rate monitoring capabilities and incorporating it into the system instead of the heart rate estimation. If the heart rate monitoring can be successfully implemented, an alarm system could also be incorporated where an alarm would be sent to both, the doctor system and patient system to alert if the patient was over exerting the heart by going over the safe heart rate level. The website application could also be made into a mobile application to increase the mobility of the doctor system.

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