Kinect in Physiotherapy

FYP12013 | Detailed Intermediate Report

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1 PROJECT OVERVIEW

1.1 Background

Many hospitals and homes for elderly use ceiling hoist for assisted gait training of patients with mobility difficulties. Physiotherapists assess and prescribe training sessions to individual patients with very simple record such as whether the training has been carried out and how long the training lasted.

To enhance the monitor of these training sessions, accurate measurement of user performance and recording is needed to facilitate daily training and monitor progress of each individual. In some hospitals, sophisticated equipment were installed for this purpose. However, many other organizations might not have the budget for such large-scale system and hence a more inexpensive tool is needed to serve the same purpose.

With the aid of motion sensing system, we hope to build a system which can identify users, measure and record distance walked, time spent, cadence of steps, length of steps and other relevant data for better quality care and control. With the collection of these data, further analysis can be carried out by the system to assist physiotherapists in examining the performance of each individual or each session.

1.2 Related Work

In the real world, there are numerous of medical organizations making use of the powerful functionalities of Kinect to assist their daily duties, like the Royal Berkshire Hospital[1] used the skeletal tracking function of Kinect to provide rehabilitation practice for stroke and other brain

FIG. 1.2.1 – KINECT IN ROYAL BERKSHIRE HOSPITAL

[1] Stroke Patients at Royal Berkshire Benefit from Playing Kinect (http://www.xbox.com/en-US/Kinect/Kinect-Effect)

injury patients. Likewise the Tokyo Women's Medical University in Japan[2], or Tedesys, a Spanish I.T. company, designed numerous of software to make use of Kinect in hospitals to assist the surgeons during surgery by Kinect's motion sensing function.[3] All of these examples show the potential of Kinect in medical use is tremendous and feasible, and the value is considerable.

FIG. 1.2.2 – USE OF KINECT IN SURGERY

FIG. 1.2.3 – IT COMPANY TEDESYS USES KINECT

1.3 Role of Kinect in this project

In physiotherapy world, there are many standard tests to determine ones' mobility. For example, Berg Balance Scale[4], Elderly Mobility Scale[5], Six-Minute Walk Test[6] etc. All of these provide an objective scale and conclusion to the performance of the participants. With the help of Kinect, the testing process can be recorded accurately and automatically, and it will be stored in database and be processed later.

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[2] Opect (http://www.nichiiweb.jp/medical/category/hospital/opect.html)
[3] Tedesys Uses Kinect in Hospitals (http://www.xbox.com/en-US/Kinect/Kinect-Effect)
[4] American Academy of Health and Fitness (http://www.aahf.info/pdf/Berg_Balance_Scale.pdf)
[5] Chartered Society of Physiotherapy, UK (http://www.csp.org.uk/sites/files/csp/secure/agile_outcome_measures_ems_v2.pdf)
[6] American Thoracic Society (http://www.thoracic.org/statements/resources/pfet/sixminute.pdf)

2 OBJECTIVE

The objective for this project is to:

1) Automate the collection of raw data from walking, e.g. coordinates of joints, time spent etc.;
2) Compute and analyze the collected data to produce relevant results, e.g. distance walked, step length etc.; and
3) Provide a user interface for accessing analyzed data.

A motion-sensing tool (Kinect for Windows) is used to gather data for further analysis. Actions of targets are captured and measure, which will then undergo the system's computation and analysis to produce useful information.

It is hoped that through this project, a low-cost system can be set up to provide instant feedback for both patients and therapists.

3 TASKS

In order to accomplish the goal of the project, the objective of this project can be further broken down into smaller tasks.

Objective ! - Automate the collection of raw data from walking

Automating data input is important as human is error-prone and it saves time and effort by gathering data automatically, and errors are as well eliminated. The raw data being collected includes, but not limit to, the coordinates of joints given by the Kinect and time spent. Various equipment may also be used in collecting the data, e.g. Kinect, timer, camera etc.

Objective 2 - Compute and analyze the collected data to produce relevant results

With the collected raw data, relevant results can be produced after computation and analysis. Step length, distance walked, speed etc. can be computed, which are all useful measurements in assessing the walking motion according to research and physiotherapists' opinions.

Objective 3 - Provide a user interface for accessing analyzed data

Analyzed data may be presented in the form of a high-level summary, a direct report or even knowledge discovered. These data are used for communicating with users in a more effective way. Besides analyzed data, user information can also be accessed from the user interface of the system, which stored related personal information for each patient for identification and recording purpose.

4 IMPLEMENTATION – *PHYSIOTHERAPY RECORDING CONSOLE USING KINECT (PRCK)*

To realize the objectives, we created a system named Physiotherapy Recording Console using Kinect (PRCK).

4.1 Development Environment

Programming Language	**C#, MySQL, XAML**
Software Tool	Kinect SDK v1.6, Kinect Developer Toolkit v.16, Visual Studio 2010, MySQL Connector Net 6.25
Version Control	Git, GitHub

For the developing environment, Microsoft Kinect SDK v1.6 (latest version) with Developer Toolkit is used as the development platform. These two kits are adopted since it is the official platform provided by the Kinect manufacturer, Microsoft.

In addition, C# is adopted as the programming language of our main program. Codes are in C# and XAML in Visual Studio which is an integrated development environment for Kinect Programming. XAML is a XML-based user-interface markup language. It defines UI elements, events and other features in the program.

MySQL is the query language for the database. In order to make Visual studio works with MySQL, MySQL connector is served as a supplementary library in the program.

PRCK is a large-scale project with a lot of functionalities. A logical way is needed to organize and control system revision. Git is a distributed revision control and source code management system and GitHub is the web-based hosting service for project using Git revision control system. We combine these two elements as a version control system for PRCK throughout the development cycle.

4.2 Introduction to Kinect

FIG 4.2.1 – KINECT SENSOR

Kinect sensor provides 3 streams: Image, depth and audio where only the first two are adopted for the development of the program.

The middle camera is a RGB camera. It provides image stream that is delivered as a set of continuous still-image frames for the application.

The leftmost one is the infrared light source and there is an infrared depth-finding camera with standard CMOS sensor on the right. They mainly provide the depth data stream. This stream provides frames identifying the distance from the nearest object at that particular x and y coordinates in depth sensor's view.

4.3 Capture and Record

4.3.1 Interface

After studying the developer toolkit offered by the Microsoft, we modified the Kinect Explorer to become the Main Screen of PRCK. We keep basic features like the Setting panel on the right and the position of the Color Stream and Depth Stream.

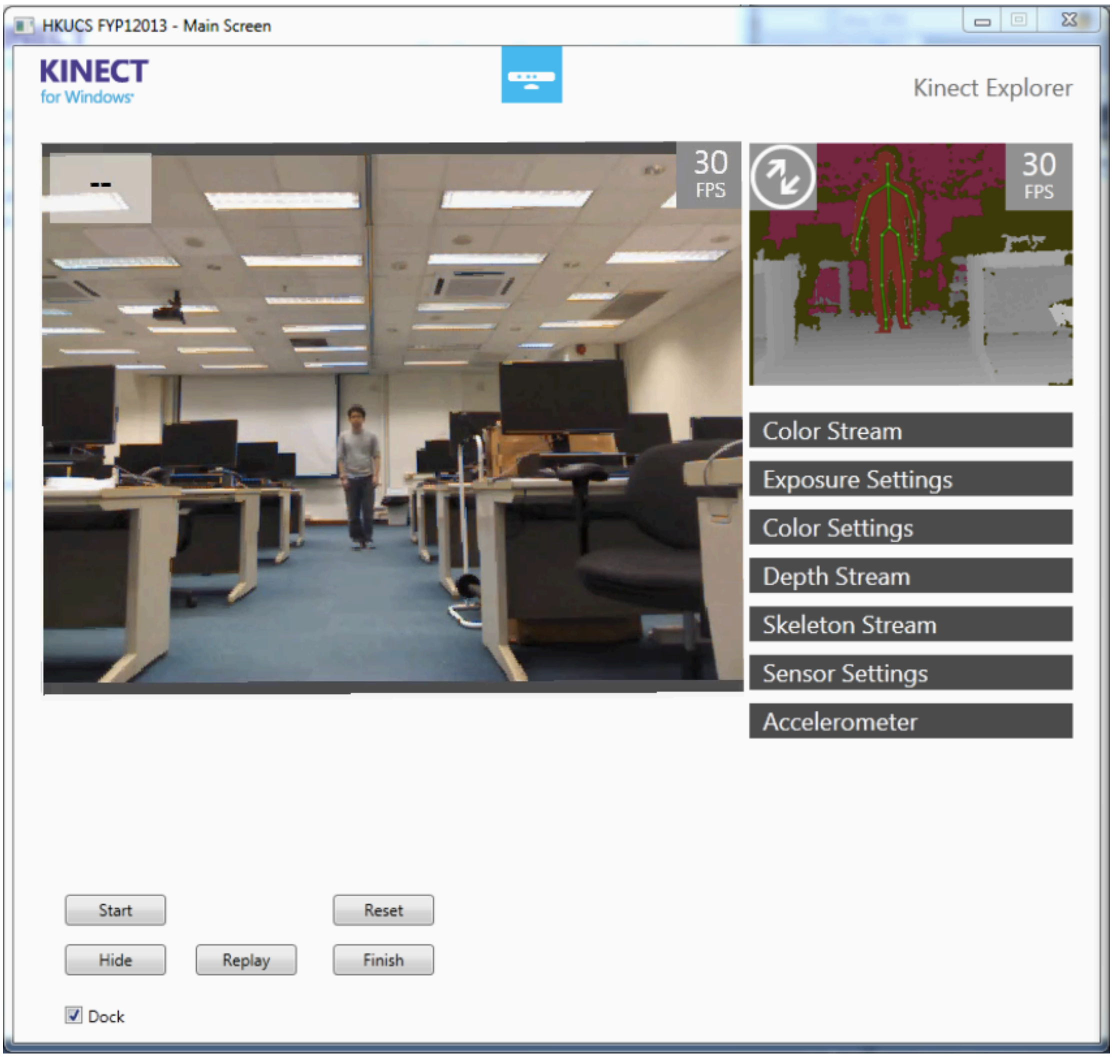


FIG 4.3.1 – MAIN SCREEN

CONTROL PANEL (5 BUTTONS AT THE BOTTOM)

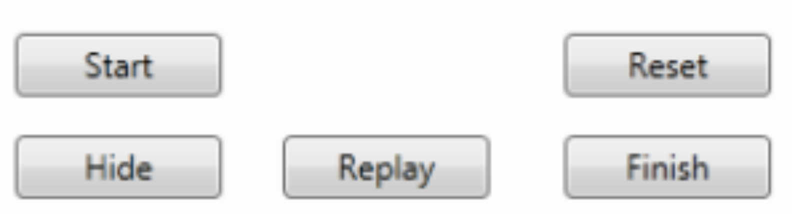


FIG 4.3.2 – CONTROL PANEL

This control panel is the first feature implemented by us, it can connect to the Data Analysis Window, Replay Window and also the Database User Interface. It act as a linkage for the three parts of the project.

Start button would call the Database User Interface to grasp the data of the client and start a new activity. Finish Button is for stopping the recent activity. Show/Hide and Reset buttons are responsible for the Analysis Window. Replay button would show a replay window after choosing the replay file in the Open File dialog.

COLOR FRAME WINDOW

There is a set of 20 joints skeleton shown in color frame in real time when the patient is in a suitable distance from the sensor.

In implementation of coding, the skeleton data structure consists of joints and bones. Joints and skeletons both own a variable for the tracking state. There are three kinds of tracking state: Tracked, Inferred and Not Tracked. The accuracy of the skeleton model increases along the number of "Tracked" joints, so we need to ensure the client is always in the best sensing range.

From the specification by Microsoft, the significant sensing range of a Kinect is from 1.2 meters to 3.9 meters. We found that the best detecting distance should be 2.5 meters after conducting some experiments.

In order to keep track of the distance between the sensor and patient, a box showing the distance was added at the top left corner of Color Frame Window. The color of the number is in green only when it is in a good sensing range. It helps to indicate the accuracy of the data collected from Kinect. The client can adjust their position to get more reliable data.

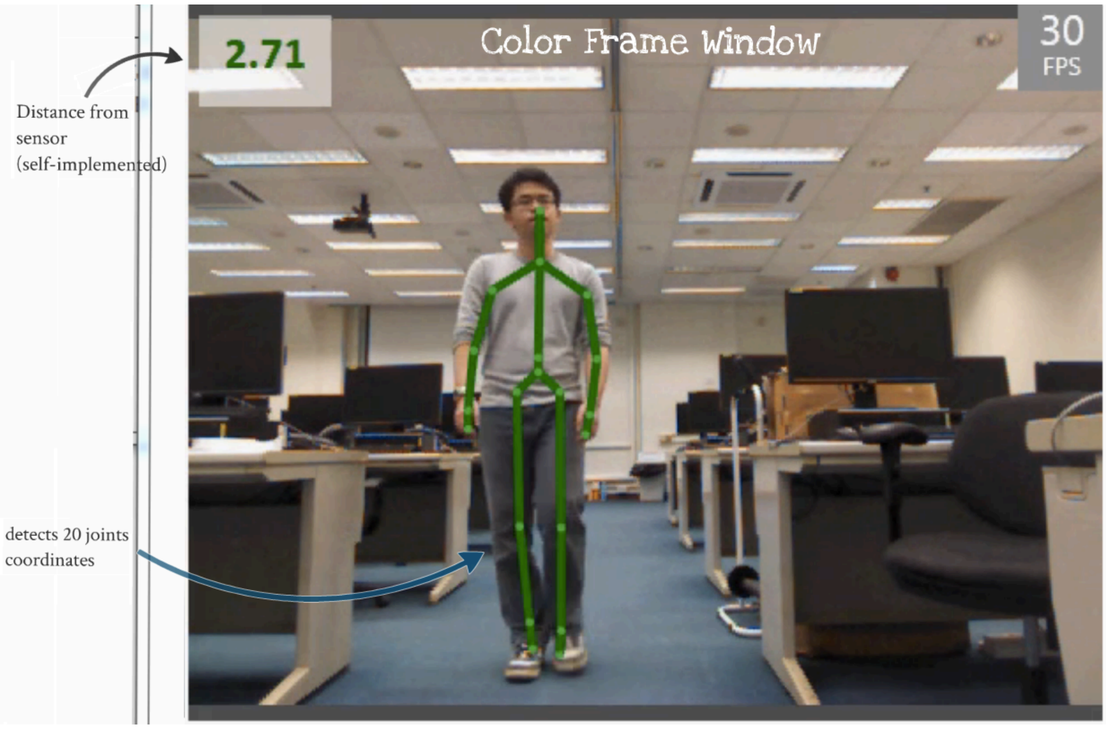


FIG 4.3.3 – COLOR FRAME WINDOW

Since the x, y, z position are stored in the joints of the skeleton, so they are recorded as the color frame window is playing for replay usage.

DEATH FRAME WINDOW

With the help of the infrared projector and sensor, Kinect provides Depth Stream other than Color Stream. By the color contrast and the color depth, we can see how Kinect identify the individuals and objects.

Depth Frame Window does not help much in PRCK, but the depth frame is responsible for recognizing the object and client. Then the skeleton matching the Color Frame Window would also be shown in Depth Frame Window.

The Button on the up left corner is for interchanging the Color Frame Window and Depth Frame Window. Since the Depth Frame Window is not as significant as the Color Frame Window, we keep the larger window in Main Screen as Color Frame Window.

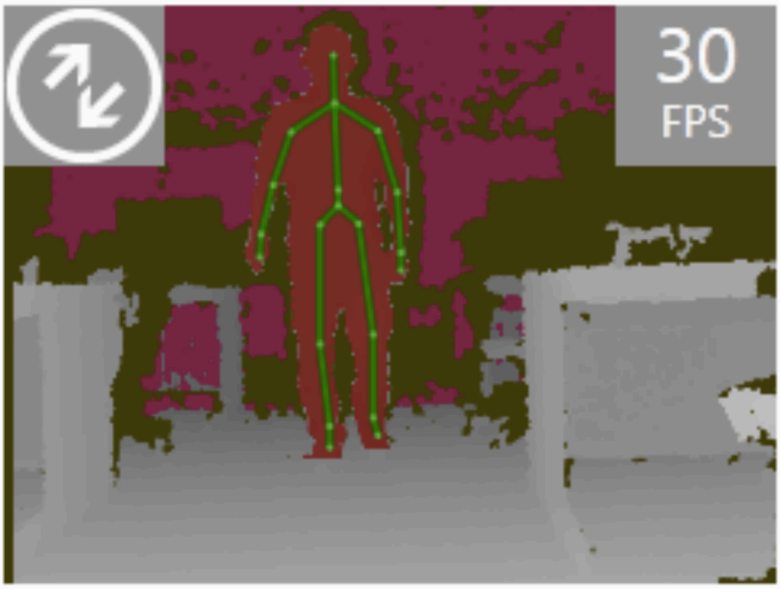


FIG 4.3.4 – DEPTH FRAME WINDOW

REPLAY WINDOW

Kinect captures and draws the skeleton image on the screen. However it is not the raw data needed, so we further studied and modified the program. PRCK can record the set of coordinates corresponding to its joint once Kinect starts capturing the movement of the target.

By using the saved file consists of a list of joint record, PRCK can generate a skeleton replay, which is identical to the original one.

The principle behind is that we can save the skeleton record with a zero-based time. When we activate the replay function, the whole coordinate set from file or database would be input into the system. Next, the program would start a new zero-based timer and keeping track of the coordinates being fed into the program. When the zero-based timer matches the reading of the timer, it would call the draw skeleton method (similar to the original one in color frame window provided). Then we can visualize the whole activity process and give out transformed information from the raw data (set the joint coordinates).

The Replay Window comprises a skeleton window, a track bar and a Play/Pause button. With the track bar and pause button, the physiotherapist can freely access to a particular point of the replay and focus on the feature he/she is interested in.

With the concern of data storage, we decided to record the skeleton frame but not the whole video. We believe that the skeleton can show the complete posture and some detailed features like the degree between two connecting bones. It may help the physiotherapist to do observation and data collection.

Though it may not be as helpful as recording the whole video (color frame and skeleton), it is still a strong proof that we can realize the whole process of the exercise once we got the raw data. It also means that we can analyze our data even when the target is not working with our program.

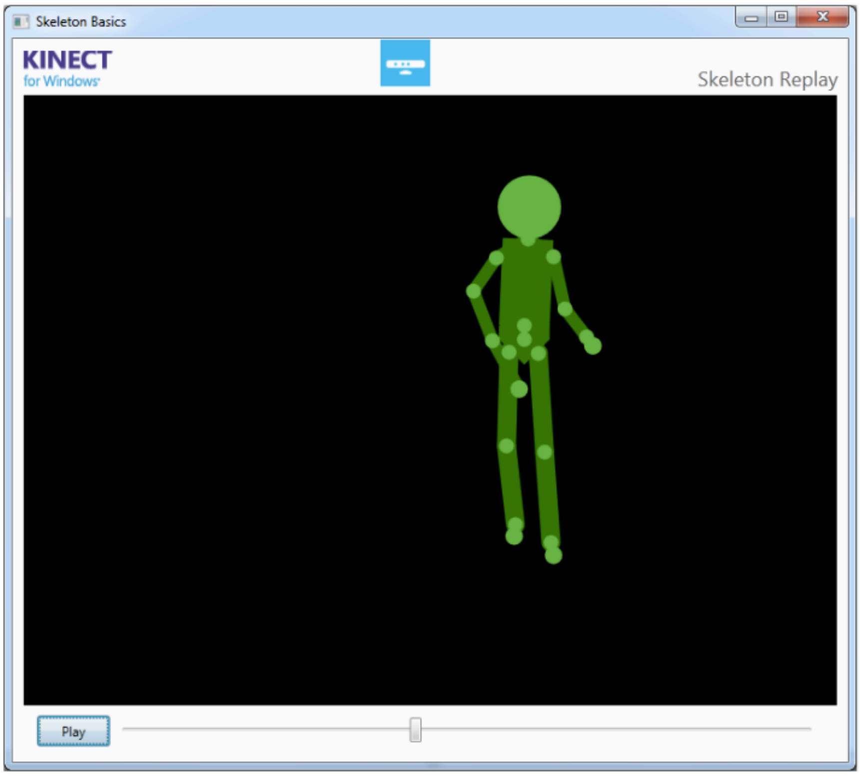


FIG 4.3.5 – REPLAY WINDOW

With the Color Frame and Depth Frame, we can successfully capture the movement of the client and the Replay function can also completes the goal of measuring the data since we can always revise the saved data.

4.4 Computation and Analysis

4.4.1 Interface

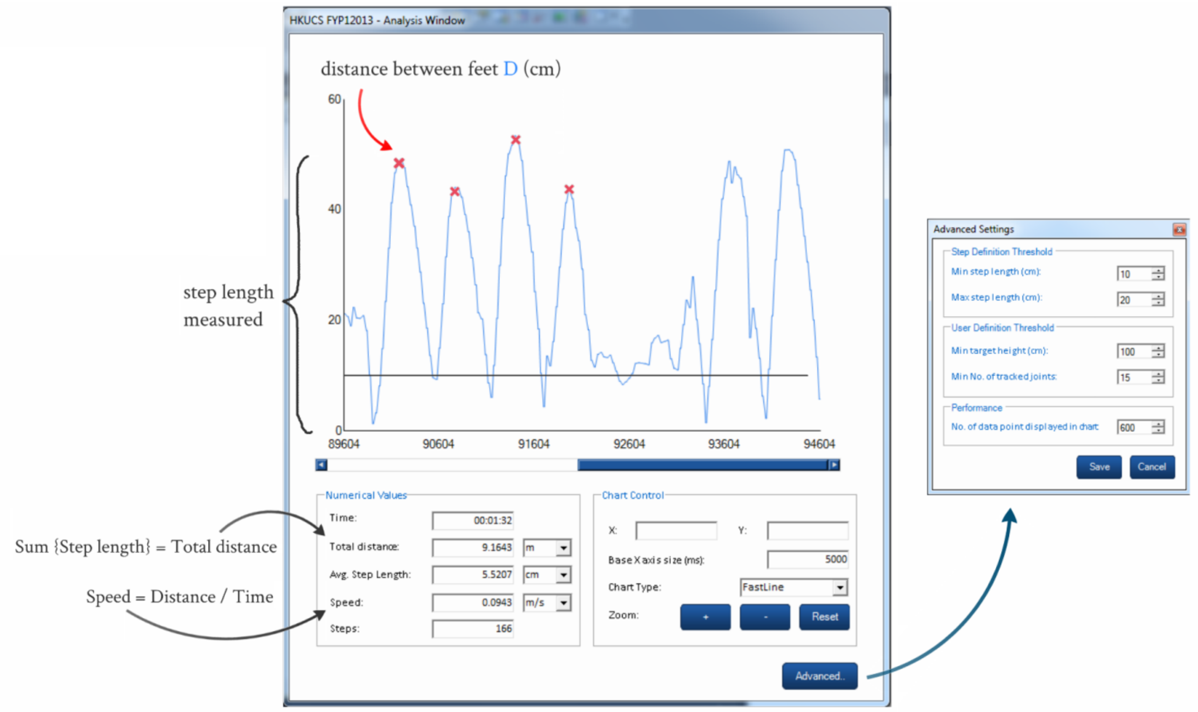


FIGURE 4.4.1 ANALYSIS WINDOW

Figure 4.4.1 shows an analysis window optimized for walking exercise. This window is fully developed by our team. Due to limited time and resources, our team has to choose one exercise to be our main focus. Therefore we had chosen walking because our partner physiotherapist Ken told us walking is the most commonly used method of analysis. Other types of exercise can be added as additional modules in later time.

The window is divided into three main areas. On the upper part of the window there is a chart. This chart is showing the distance (in centimeter) between two feet D changing with time (in millisecond).

This chart actually represents the measurement of step length. More details of the model of calculation would be described in the next section.

The bottom left corner is the area of numerical values. Most of these values are derived from the step length measured including total distance walked (which is the summation of step lengths), average step length, speed (which is the total distance walked over time) and the number of steps. These are just features that are already implemented. More information can be added as the development continues.

Lastly, there is a control panel of the chart. User can select a data point and get the X, Y values of it. An input field enables user to set how many milliseconds are shown in x-axis. User can set the type of chart to be displayed to suit specific need. Zoom in/out can be done by clicking the corresponding button. In the bottom right corner there is a button named advanced. When the user clicks it, an advanced setting panel would pop up.

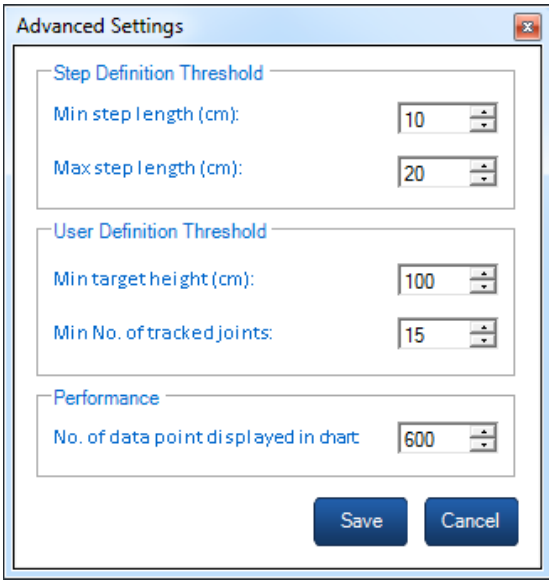


FIGURE 4.4.2 ADVANCED SETTINGS

Figure 4.4.2 shows the panel which enables the physiotherapist to modify some background settings. First section is titled Step Definition. User can set a range of reasonable step length to ignore any measurement error in further calculation. Secondly, there are settings for User Definition Threshold. We have experienced that the Kinect misrecognized some objects such as table as a human. In these cases the resulting skeletons are usually very small. So we introduced a minimum height threshold to ignore these objects. Kinect associates a joint detection state showing it is tracked, inferred or not tracked. The minimum number of tracked joints must be fulfilled before the skeleton is considered to be under detection. The last section is performance setting. We noticed that when time goes on, the chart that builds up in real time would store thousands of data points resulting in serious lag. This value decides how many data points are stored at an instance. These sections are all still under development. More values would be added to make our analysis more reliable and error-free.

4.4.2 Model of step length measurement

Although the Kinect can measure depth directly, but the maximum detection length is only 4 meters. We cannot simply use the depth information provided as the distance walked because the exercise requires about 30 meters of walking. As a result, the Kinect has to move with the target for the whole detection process. In this case, absolute coordinates and absolute distance cannot be used as the coordination base is changing. We constructed a model making use of the relative distance between two feet to calculate the step length. By using relative distance, the error caused by changing coordination base is cancelled out as coordinates of left and right ankles are recorded at the same time. They always share the same base.

A walking cycle is shown in figure 4.4.3. The lower part is a chart showing the change of distance between feet in the walk cycle. The distance reaches maximum when a step ends. The ankle joint is used for calculation because it is not too free to move and is able to represent the location of the whole foot. Here, distance means Y and Z components only, the horizontal component X is safely ignored for walking straightly. The X component is cancelled out during left and right foot consecutive movement. Ignoring X component helps minimizing error and simplifies the model. The algorithm is as followed:

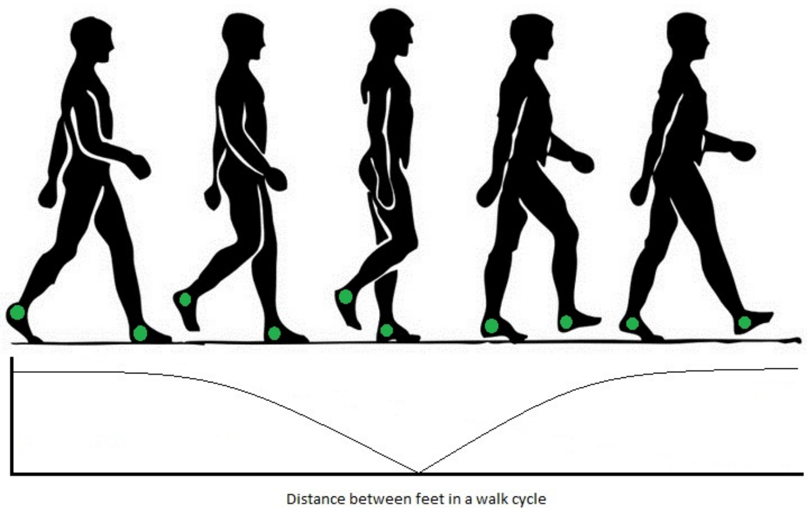


FIGURE 4.4.3 WALK CYCLE

```
Function disBtwFeet(){
    return sqrt(sq(leftAnkleY-rightAnkleY)+ sq(leftAnkleZ-rightAnkleZ));
}

Function underStepLenThres(){
    return disBtwFeet() < minStepLenThres;
}

Function OneStep{
    while underStepLenThres(){
        //do nothing
    }
    repeat{
        If (disBtwFeet()<maxStepLenThres)
            stepLen = max(disBtwFeet(), stepLen);
    }until underStepLenThres();
    return stepLen;
}
```

The main idea is that we defines a step as started with movement of one feet away from another, reaches the place, and ended when the other foot joins it again. In the view of distance between two ankles D, it starts from minimum, reaches maximum which equals to the length of this step, and finally go back to minimum again. From Figure 4.4.3, we can observe that the minimum D is not constant. Therefore we introduced a threshold line in our model which is D = minStepLenThres. When D falls below the threshold line, we consider the step has ended and the maximum just found is counted as the length of the step. The value of minStepLenThres is set to 10 cm by trial-and-error. Physiotherapist is free to change it in the advanced settings panel shown above.

4.5 Designing the Database and User Interface

4.5.1 Objective

At the beginning of the project, we have been struggling between storing all raw data recorded in a database and in the local drive. In the real implementation, using database would mean our client, the elderly home, is required to buy an additional server, and hires staffs to be responsible for the maintenance, unless she purchases a cloud database service. The fact is no matter how they are implemented, using database is still implying an extra monthly expenditure. However, while we consider the ***mobility, accessibility, data reusability and development sustainability*** of our system, it is clear to see that cost is far less an important criterion comparing to these four criteria. In other words, implementing with database in our project enables the physiotherapists to review, to compare, to analyze the participants' performance anywhere they can use our system, and not only the one who are responsible for the exercise but all of the physiotherapists can access the database to extract the record. They can also share the recorded data to their colleagues so as to arrange a better treatment to the participant. After the database grows bigger, with the help of some data mining techniques like prediction or classification, the accuracy and the reliability of our system will rise significantly. Moreover, because of the database design, the types of exercises that our system can analyze are not limited to walking only. The physiotherapist can add additional exercise types later on in order to enhance the analytical power of our system.

4.5.2 Database Design

In the current stage of the project, we created six tables for storing the data that we need for the analysis part. The following is the Entity-Relationship Diagram of the database schema.

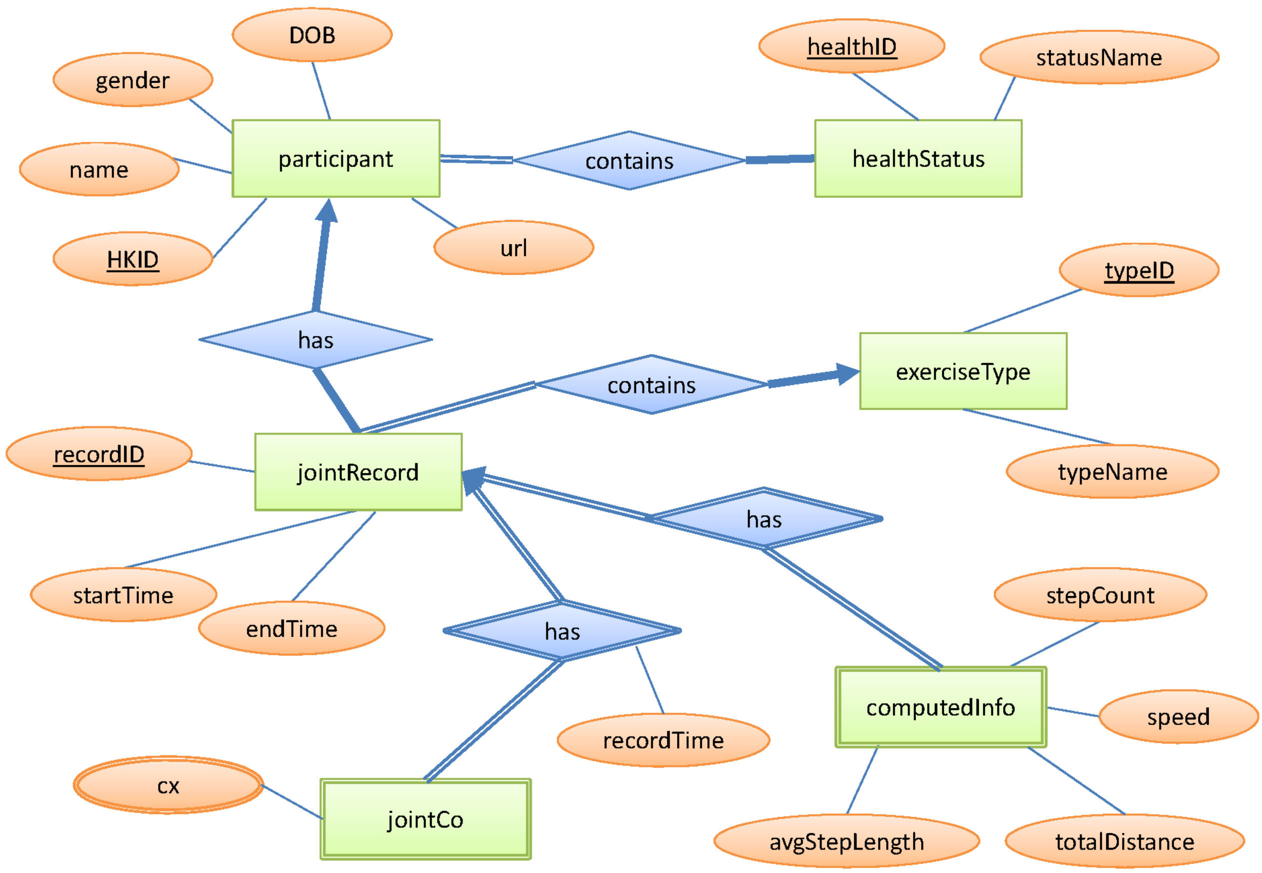


FIG 4.5.1 – ER DIAGRAM

healthID	statusName
1	Amblyopia
2	Diabetes
3	Dumb
4	Handicapped
5	Hearing Impaired
6	Heart Disease
7	Hepatitis
8	Obese
9	Stroke History

FIG 4.5.2 – healthStatus TABLE

A few points worth mentioning are, first, the table “healthStatus” stored a list of common elderly diseases suggested by physiotherapists. By comparing participants who have the same disease, we can conclude numerous of useful information that will assist the physiotherapists to arrange treatment, e.g. whether the performance of the participant is becoming worse, is it up to the average performance, or even the possibility that the participant has a certain disease etc. In addition, by using the user interface that will be introduced later, physiotherapists can update new diseases into the database. As such our system can analyze and conclude more diseases.

Similarly, the table "exerciseType" stored a list of exercises arranged by the physiotherapists. Each exercise has its own calculation algorithm on the joint coordinates. Therefore, more exercise types mean more powerful the functionality of our system is, and the development sustainability of the system is unlimited.

For the rest of the tables, they are responsible for one of the most fundamental functions of our system. As mentioned, we will store the exercise records and the corresponding joint coordinates into the database for future usage. The table "jointRecord" and "jointCo" are responsible to these respectively.

recordID	participant_HKID	startTime	endTime	exerciseID
1	Y034600	2013/01/13 21:53:58	2013/01/13 21:54:31	1
34	Y034600	2013/01/14 19:59:14	2013/01/14 20:00:50	1

FIG 4.5.3 – jointRecord TABLE

jointRecord_rec...	recordTime	c1	c2
1	2013/01/13 21:54:20:467	0.08418336,-0.2658876,2.345453,Tracked	0.06890257,-0.2183005,2.314903,Tracked
1	2013/01/13 21:54:20:474	0.08418336,-0.2658876,2.345453,Tracked	0.06890257,-0.2183005,2.314903,Tracked
1	2013/01/13 21:54:20:494	0.07590623,-0.2600109,2.313975,Tracked	0.06256463,-0.2134937,2.287874,Tracked
1	2013/01/13 21:54:20:497	0.07590623,-0.2600109,2.313975,Tracked	0.06256463,-0.2134937,2.287874,Tracked
1	2013/01/13 21:54:20:530	0.07095398,-0.251784,2.287511,Tracked	0.05935138,-0.2082391,2.267869,Tracked
1	2013/01/13 21:54:20:534	0.07095398,-0.251784,2.287511,Tracked	0.05935138,-0.2082391,2.267869,Tracked
1	2013/01/13 21:54:20:562	0.03446453,-0.1979275,2.219847,Tracked	0.03150415,-0.1663385,2.21084,Tracked

FIG 4.5.4 – jointCo TABLE

Every time the participant did an exercise, the exercise record and the joint coordinates will be properly stored. Using the replay function in the interface, we can replay the exercise that performed few weeks ago and compare it with the one performed this week to see the difference and progress. Moreover, in order to handle a foreseeable large data size and data flow, we have optimized the query and created necessary indices in the table, like the "startTime", "endTime", "recordTime" etc. so as

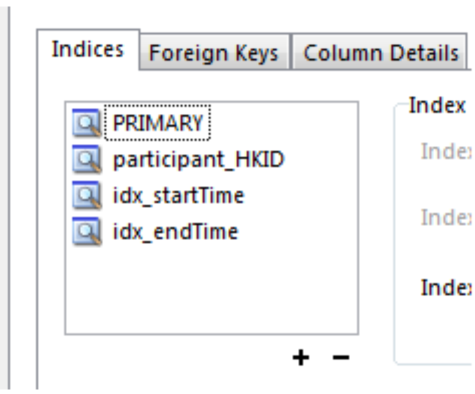


FIG 4.5.5 – INDICES

to minimize the query bottleneck that might occur, if there are millions or even billions of records, as using indices can prevent the query from searching from the first record.

Other than that, the analyzed information in the real time exercise is stored in the table "computedInfo". As such, while we want to know the statistics of one entire exercise, we are not required to compute from the all joint co-ordinates. If the statistics of a specific time range are needed, we can compute it from the co-ordinates and then show it to the physiotherapist after the analysis is done.

4.5.3 User Interface Design

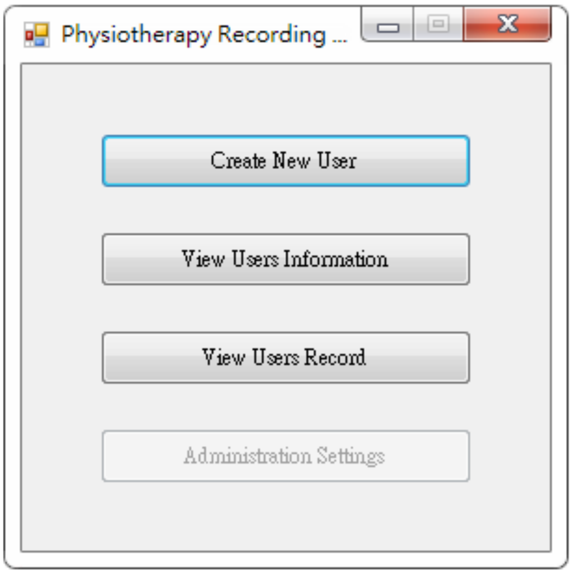
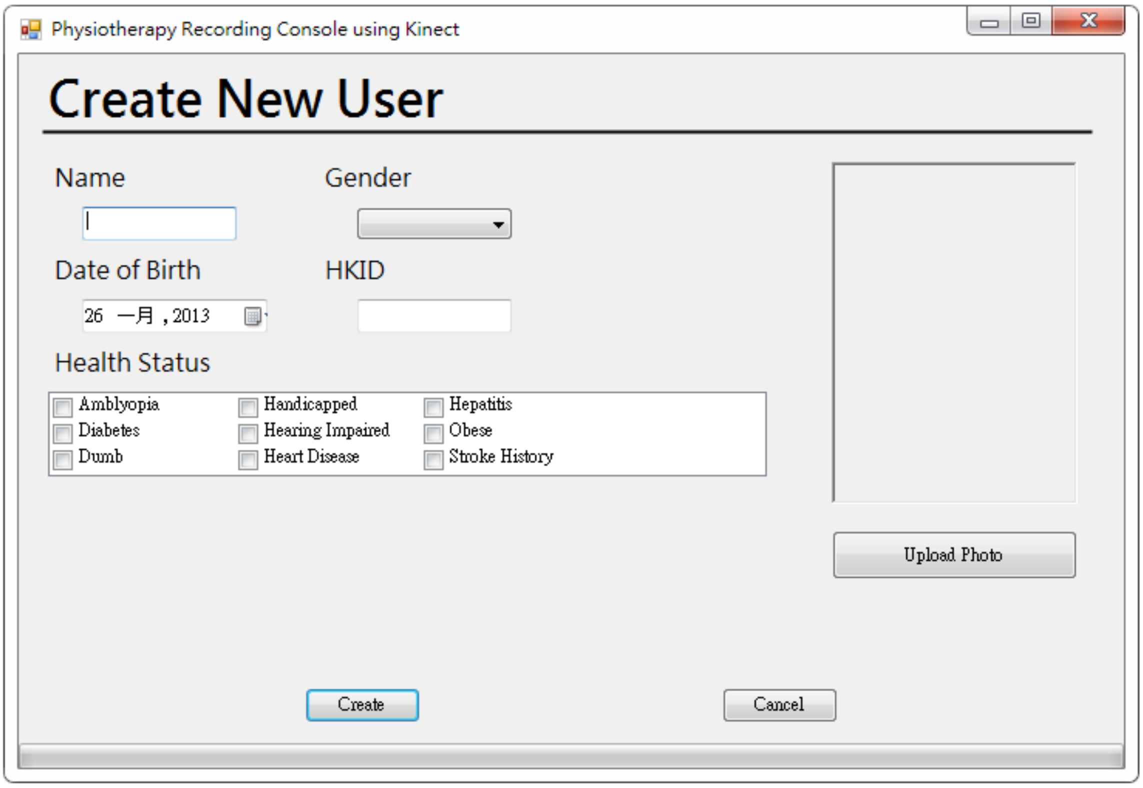


FIG 4.5.6 – USER INTERFACE MENU

4.5.4 Use Case Analysis

To make the course of using the user interface clearer, we listed the following use case analysis.



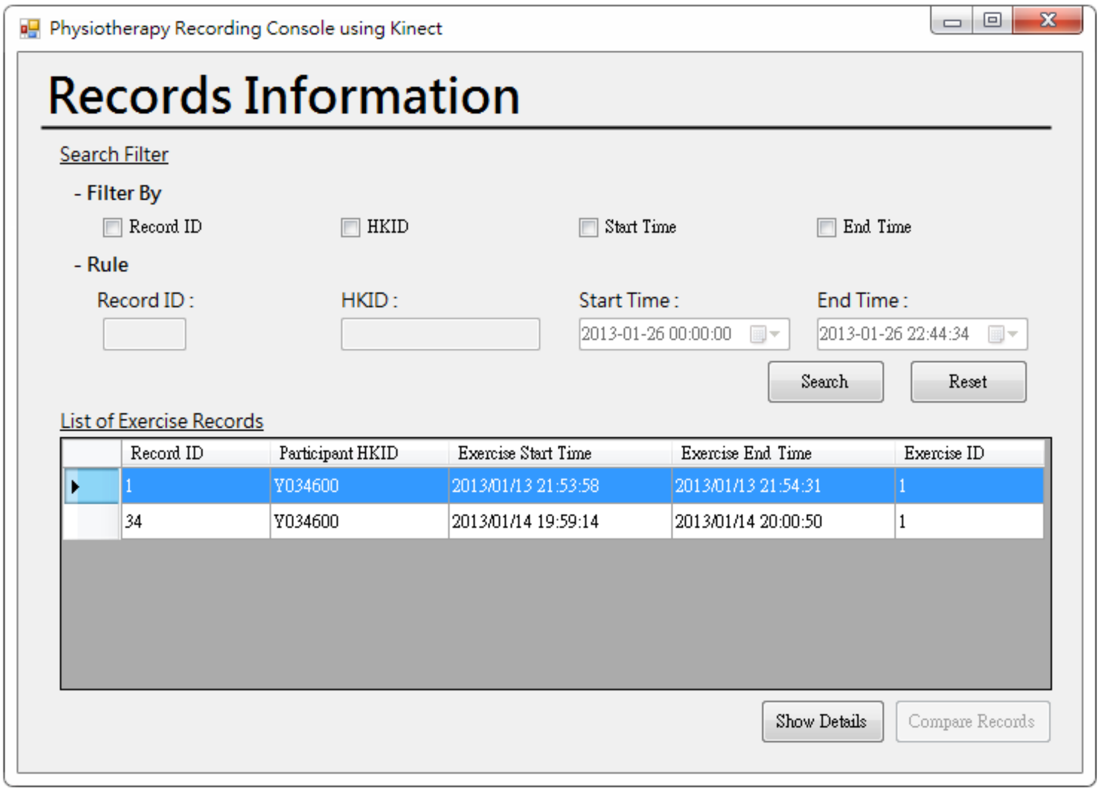
Use Case Name:	**Create New User**
Actor(s):	Participant
Description:	This use case describes the process of a participant of the system creating a new user for exercise in the future. On completion, the participant will see a notification that the user was successfully created.
Reference:	UI-1

Typical Course of Events:	Actor Action	System Response
	Step 1: Initiate this use case when the participant clicks the Create New User button.	**Step 2:** The Create New User panel pops up.
	Step 3: Input all the required information into the panel, and upload the photo	
		Step 4: Check whether every field is filled
		Step 5: Process of creating new user starts, process bar runs.
		Step 6: Compare and validate the participant's HKID with the existing users' HKID.
		Step 7: Upload the selected photo
		Step 8: Pop up a notification to show the process is successfully done.
	Step 9: Conclude this use case when the participant sees the notification.	

Alternative Courses:	**Step 5:** If there is unfilled field, warning will be pop up and return to step 3. **Step 7:** If the participant's HKID has already existed in the database, warning will be pop up and return to step 3.
Precondition:	Participant is new to the system.
Postcondition:	Participant has been registered as a user of the system.
Assumptions:	Participant has HKID.

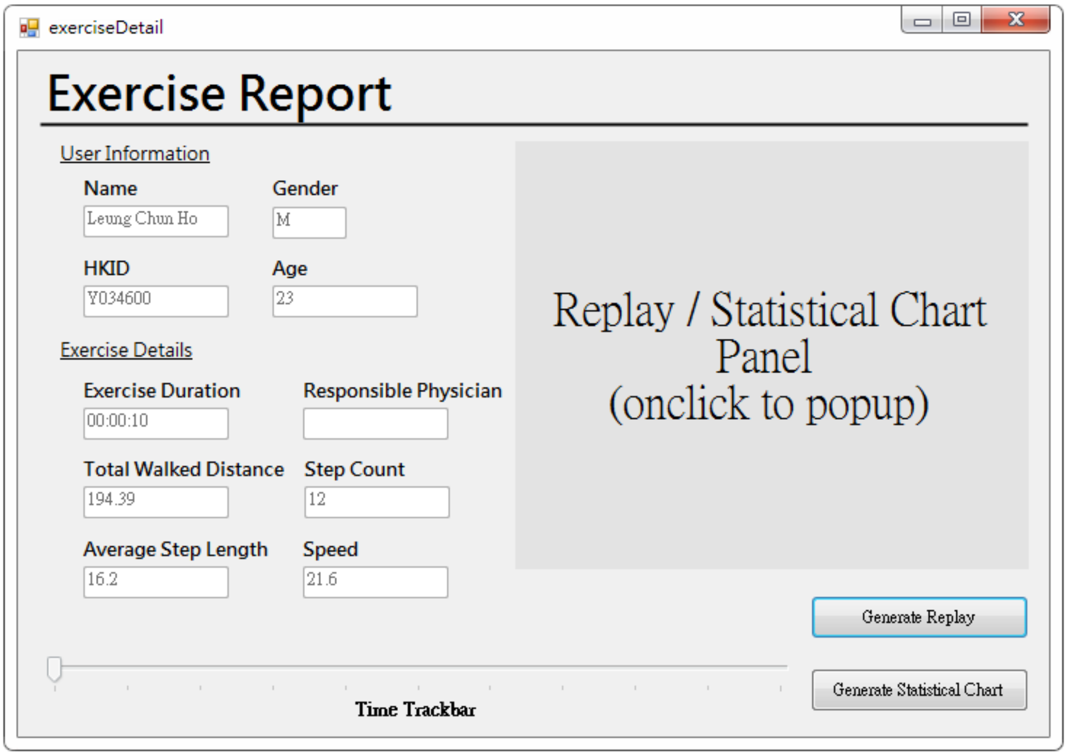
Use Case Name:	**View User Information**
Actor(s):	Administrator or Physiotherapist
Description:	This use case describes the process of the administrator of the system or physiotherapist wanting to view the user information. On completion, the users of the system can see the user's information and all his or her exercise records.
Reference:	UI-2

Typical Course of Events:	Actor Action	System Response
	Step 1: Initiate this use case when either the administrator or the physiotherapist clicks the View User Information button.	**Step 2:** The Input HKID panel pops up.
	Step 3: Input the HKID of the user that want to check	**Step 4:** Check whether the HKID exists in the database
		Step 5: Fetch the user's information and display in the panel
	Step 6: Conclude this use case when the user's information is shown.	
Alternative Courses:	**Step 5:** If the HKID inputted does not exist in the database, No Such User message will pop up, then return to step 3. **Step 6:** If the administrator or the physiotherapist wants to see the detailed exercise record, click the Show Details button to invoke the use case View Users Record.	
Precondition:	Administrator or physiotherapist wants to check a user's information by a HKID.	
Postcondition:	User Information is shown on the panel.	
Assumptions:	None at this time.	



Use Case Name:	**View Users Record**
Actor(s):	Physiotherapist
Description:	This use case describes the process of the physiotherapist wanting to view the record information. On completion, the physiotherapist can see the record information, or do comparison among records if required.
Reference:	UI-3

Typical Course of Events:	Actor Action	System Response
	Step 1: Initiate this use case when the physiotherapist clicks the View Users Record button.	**Step 2:** The Record Information panel pops up.
	Step 3: Select one of the records and click Show Details	
	Step 5: Conclude this use case when the record details are shown.	**Step 4:** Invoke use case View Record Details
Alternative Courses:	**Step 3:** If records with specific criteria are required to filter out, input the corresponding information into the search filter function. **Step 4:** Filter out mismatch records and refresh the table and return to the original step 3. **Step 3:** If multiple records are selected, click Compare Records instead of Show Details to invoke the use case Compare Records	
Precondition:	Physiotherapist wants to check a record details or do comparison among records	
Postcondition:	Record details are shown in the panel.	
Assumptions:	None at this time.	



Use Case Name:	**View Record Details**
Actor(s):	Physiotherapist
Description:	This use case describes the process of the physiotherapist wanting to view the details of a record. On completion, the physiotherapist can see the details of the record, and generate replay or statistical chart if they want.
Reference:	UI-4

Typical Course of Events:	**Actor Action**	**System Response**
	Step 1: Initiate this use case when the physiotherapist clicks the Show Details button in the View Users Record panel	**Step 2:** The details of the record will be shown.
	Step 3: Select Generate Replay button to see the replay of the that exercise record	
		Step 4: Invoke use case Generate Replay
	Step 5: Conclude this use case when the replay is shown.	
Alternative Courses:	**Step 3:** If the physiotherapists want to see the statistical chart instead of the replay, click Generate Statistical Chart button. **Step 4:** Invoke use case Generate Statistical Chart	
Precondition:	Physiotherapist wants to see the details of a record, or watch the replay or the statistical chart of that exercise.	
Postcondition:	Replay or Statistical Chart will be shown in the panel.	
Assumptions:	None at this time.	

5 FURTHER DEVELOPMENT

In the next stage of development, we are going to focus on the further analysis of the data collected. We have implemented the computation and analysis of data in walking exercise and stored them into database. Then we will make use of the data collected for two types of analysis, progressive analysis and interpersonal analysis.

5.1 Progressive analysis

We would adopt some scoring and rating scales proposed by physiotherapists. There are two systems we have found feasible to be used with Kinect in research papers. For the full list of detailed items please refer to Appendix. The first one is a frequently referenced scaling system called GARSM[7]. It consists of 7 items each in a 3-point scale. High score means high level of risk of falling during walking. We believe that all of items except 4th item can be computed making use of Kinect. The 4th item concerns about the degree to which heel strikes the ground before the forefoot. As Kinect cannot detect forefoot, it is hard to be evaluated. Yet this item can easily be recorded by the physiotherapist controlling the system since it does not require numerical calculation. Others concerning about angle and percentage of time can all be done by Kinect and it certainly helps the physiotherapist a lot. Another useful scaling system is AWS[8]. This scheme contains 42 items each at most scores 1. High score means good performance. This scaling is more suitable to be implemented in form of different tasks instead of an overall score of walking like GARSM. As this scaling contains too many items, although many of them can be detected by the Kinect, we may not have time to implement it.

[7] Modified Gait Abnormality Rating Scale (PHYS THER. 1996; 76:994-1002)
[8] Assessment of Walking Skills (J Neurol Neurosurg Psychiatry 2004;75:196–201)

5.2 Interpersonal analysis

With the database storing walking data and user information, we aim at creating a classification model which can alert user the risk of having certain kind of disease. News shows that physiotherapist proved that "slowed walking speed may be early predictor of Alzheimer's decline" (AD)[9]. There are also research papers discussing this phenomenon. One says AD patients "walk with slow and irregular steps, hard to negotiate turns, climb onto a stepping stool, avoid obstacles in their path, or lie down and rise from the doctor's couch"[10]. Another physiotherapist says that patients with Parkinson's disease (PD) "may walk slowly with their chest bent forward, with short fast "shuffling" steps, and with less arm and body movement"[11]. We trust that these symptoms can be detected by Kinect. We are going to construct a database of walking pattern of AD and PD patients. Then we can use this database to build a model to compare the walking pattern of a new target with these patients. Lastly by Bayesian classification for example, we can result in a probability of the target having AD or PD.

[9] Slowed walking speed may be early predictor of Alzheimer's decline (CBS News, July 16, 2012, 10:35AM)
[10] J Neurol Neurosurg Psychiatry 2004;75:196–201
[11] Parkinson's Disease and Walking (American Physical Therapy Association, Section on Neurology)

APPENDIX

Modified Gait Abnormality Rating Scale (GARS-M)[a]

1. Variability—a measure of inconsistency and arrhythmicity of stepping and/or arm movements
   0 = fluid and predictably paced limb movements
   1 = occasional interruptions (changes in speed) approximately 25% of the time
   2 = unpredictability of rhythm approximately 25%–75% of the time
   3 = random timing of limb movements
2. Guardedness—hesistancy, slowness, diminished propulsion, and lack of commitment in stepping and arm swing
   0 = good forward momentum and lack of apprehension in propulsion
   1 = center of gravity of head, arms, and trunk (HAT) projects only slightly in front of push-off, but still good arm-leg coordination
   2 = HAT held over anterior aspect of foot and some moderate loss of smooth reciprocation
   3 = HAT held over rear aspect of stance-phase foot and great tentativeness in stepping
3. Staggering—sudden and unexpected laterally directed partial losses of balance
   0 = no losses of balance to side
   1 = a single lurch to side
   2 = two lurches to side
   3 = three or more lurches to side
4. Foot contact—the degree to which heel strikes the ground before the forefoot
   0 = very obvious angle of impact of heel on ground
   1 = barely visible contact of heel before forefoot
   2 = entire foot lands flat on ground
   3 = anterior aspect of foot strikes ground before heel
5. Hip ROM—the degree of loss of hip range of motion seen during a gait cycle
   0 = obvious angulation of thigh backward during double support (10°)
   1 = just barely visible angulation backward from vertical
   2 = thigh in line with vertical projection from ground
   3 = thigh angled forward from vertical at maximum posterior excursion
6. Shoulder extension—a measure of the decrease of shoulder range of motion
   0 = clearly seen movement of upper arm anterior (15°) and posterior (20°) to vertical axis of trunk
   1 = shoulder flexes slightly anterior to vertical axis
   2 = shoulder comes only to vertical axis or slightly posterior to it during flexion
   3 = shoulder stays well behind vertical axis during entire excursion
7. Arm–heel-strike synchrony—the extent to which the contralateral movements of an arm and leg are out of phase
   0 = good temporal conjunction of arm and contralateral leg at apex of shoulder and hip excursions all of the time
   1 = arm and leg slightly out of phase 25% of the time
   2 = arm and leg moderately out of phase 25%–50% of the time
   3 = little or no temporal coherence of arm and leg

Items contained in each component of the AWS test

Walking	
Examples:	Walk with right hand on stomach and left hand on back
	Walk with left hand on stomach and right hand on back
1	Walk on the spot
2	Walk forward
3	Walk with a wide stance (legs apart)
4	Walk to the right while facing forward
5	Walk crossing your legs over
6	Walk backwards
7	Walk with your feet diverging (pointing out)
8	Walk to the left while facing forward
9	Walk on your heels
10	Walk with feet converging (pointing in)
11	Walk with your trunk laterally bent to the left
12	Walk with your left arm stretched out and your right arm hanging by your side
13	Walk with arms folded
14	Walk with your trunk bent forward
15	Walk with your right arm stretched out and your left arm hanging by your side
16	Walk with your trunk laterally bent to the right
17	Walk with your hands behind the nape of your neck
18	Walk with your arms still alongside your trunk
19	Walk with your trunk extended backwards
20	Walk stepping over an imaginary obstacle
Trunk	
Examples:	Sit down (on the right edge of the bed)
	Sit on the edge of the bed
21	Anterior flexion of head
22	Rotate head to the left
23	Right lateral flexion
24	Posterior flexion
25	Rotate head to the right
26	Left lateral flexion
27	Anterior flexion of trunk
28	Shrug shoulders
29	Hold stomach in
30	Left lateral flexion of trunk
31	Posterior flexion of trunk
32	Right anterior flexion
33	Push stomach out
34	Sit down
35	Lie supine (starting from the right side of the bed)
36	Lie prone (starting from the right side of the bed)
37	Turn from prone to supine
38	Turn from supine to prone
39	Prone, get up
40	Lie supine (starting from the left side of the bed)
41	While supine, hug both knees
42	Lie prone (starting from the left edge of the bed)