
ECE1778 FINAL REPORT: iANKLE

WORD COUNT

Apper Context Only (max 500): 491

Remainder of Report (max 2500): 2493

Entire Report: 2984

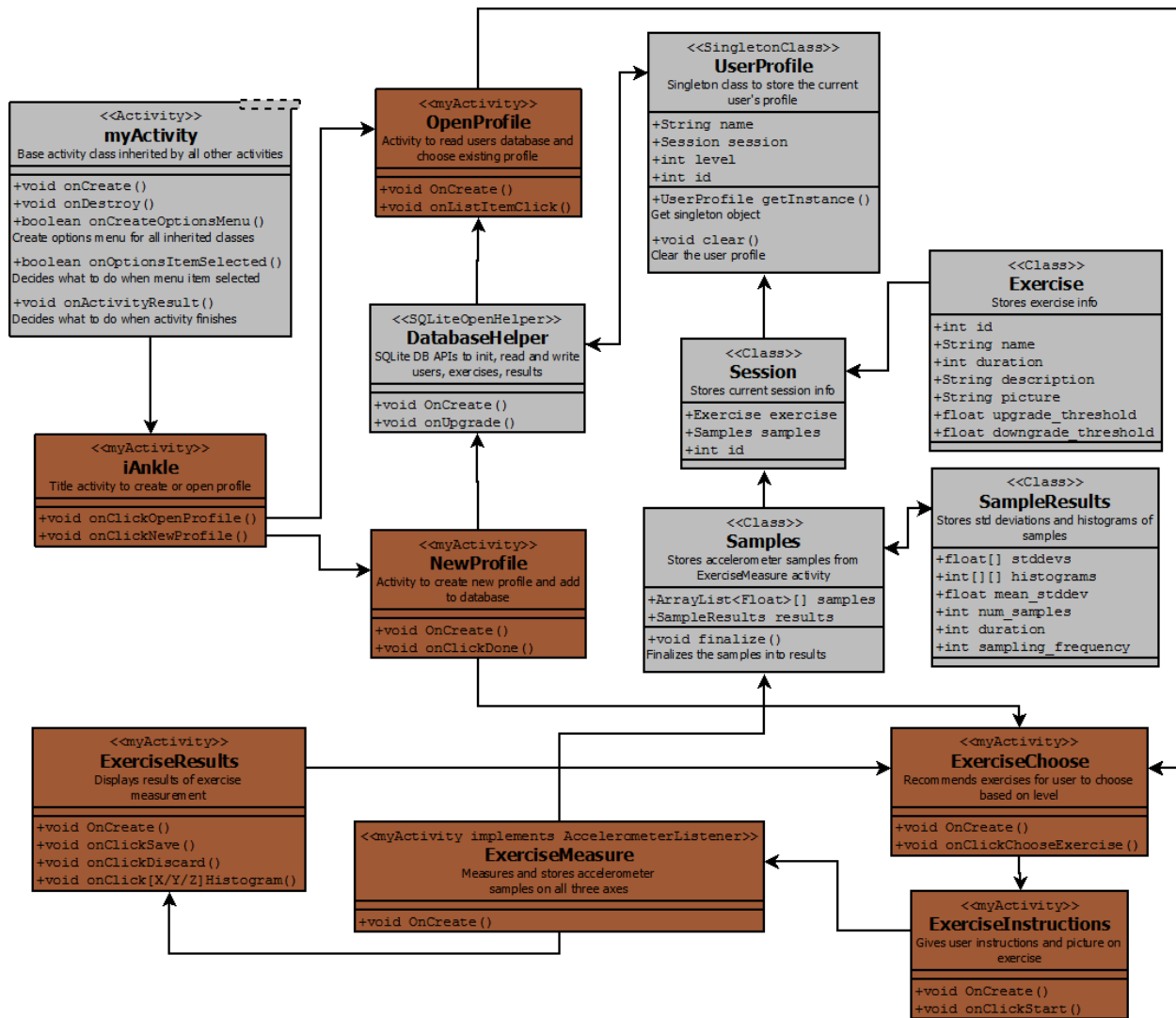
INTRODUCTION

The goal of our application is to assist users to improve their ankle stability. The application seeks to accomplish this task by measuring, analyzing, and subsequently suggesting specific ankle stability exercises. The user has the ability to enter data about their injury status and can then choose to perform exercises as recommended by the application or choose their own stability exercise from a list. While performing a stability exercise the user attempts to stay in a stationary position and have the ankle move as little as possible for a set interval while the accelerometer measures deviations in the x, y and z axis. Based on the extent of the deviations the application recommends that the user either upgrade, downgrade, or remain at the same level of stability.

This application can be used by people who want to improve their ankle stability following injury, for injury prevention, or enhancing their sport or exercise performance as it relates to ankle stability. Health care professionals can also utilize this application in the clinical setting to measure ankle stability, track progress over time, compare various groups of patients with ankle dysfunctions and perform clinical research. This application also helps to quantify progress during the rehabilitation process for ankle stability.

OVERALL DESIGN

The following software block diagram describes the major activities and classes that make up the iAnkle Android application. The brown boxes are the activities corresponding to the screenshots provided in a later section, and the grey boxes are the supporting classes.



MYACTIVITY

The myActivity is the base activity inherited by all other activities. It contains common functions like the menu and result processing.

IANKLE

The iAnkle activity is the initial entry point for the app where the user decides whether they would like to create a new profile or work off an existing profile already in the database.

NEWPROFILE

The NewProfile activity contains fields for the user to enter personal information about their physical health and ankle injuries. This activity then decides the best difficulty level for the user based on this personal information.

OPENPROFILE

The OpenProfile activity displays a list of existing profiles in the database for the current user to select and use in this session.

DATABASEHELPER

The DatabaseHelper class holds the SQLite database implementation to store user profiles, exercises, sessions and results.

USERPROFILE

The UserProfile class is used to store the current user's information in memory for accessing when determining level, recommended exercises and retrieving and storing measurements.

SESSION

The Session class is created as part of the UserProfile to track statistics about the measurement session like accelerometer samples and results of the session.

EXERCISE

The Exercise class is used to store attributes of each exercise in memory. The thresholds are used to determine when a user should be upgraded or downgraded a level. These thresholds will be described further in the ExerciseResults Activity.

EXERCISECHOOSE

The ExerciseChoose activity accesses the UserProfile and then goes through the exercise database to decide which exercises to recommend for the user's level. Upon choosing an exercise the Session info in the UserProfile will be updated to include the details of the exercise chosen.

EXERCISEINSTRUCTIONS

The ExerciseInstructions Activity loads the appropriate picture and instructions of the chosen exercise from the database.

EXERCISEMEASURE

The ExerciseMeasure Activity implements a listener to the AccelerometeListener to detect and sample changes in acceleration. Each time a change in acceleration is detected it stores the x, y, and z acceleration values in the Samples.

SAMPLES

The Samples class stores the information about the samples taken from the Accelerometer manager. It is essentially 3 arrays of floats for representing samples taken on each axis.

SAMPLERESULTS

The SampleResults class stores the resulting information from the Samples class like std deviations, means, histogram data etc.

EXERCISERESULTS

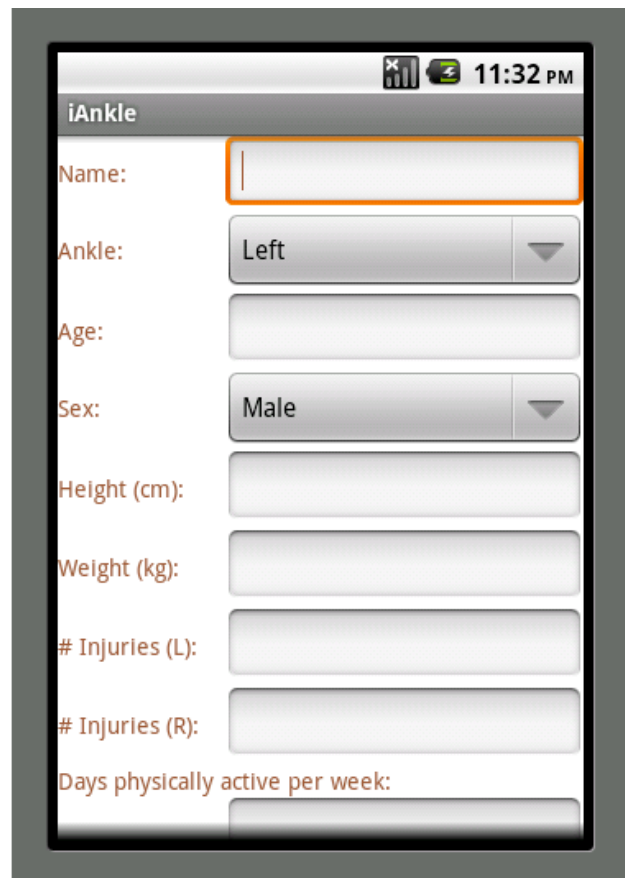
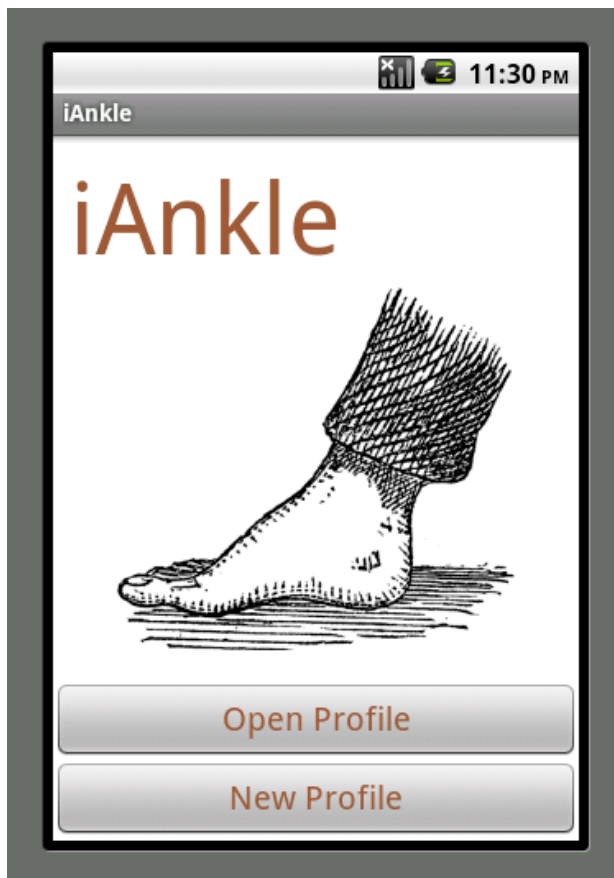
The ExerciseResults activity processes the samples by creating histogram data out of the samples for each axis and finding the standard deviation of the samples in each axis. It also calculates the mean standard deviation of all three axes. It displays this along with other useful sampling information to the user and saves the information to the SampleResults class. The activity then compares the mean standard deviation to predetermined thresholds for the exercise. If the mean standard deviation is lower than the upgrade_threshold, the app would upgrade the user's level. If the mean standard deviation is higher than the downgrade_threshold, the app would downgrade the user's level. All this information is displayed to the user in this Activity and the user has the option to discard or save the results into the database file for retrieval in the next session.

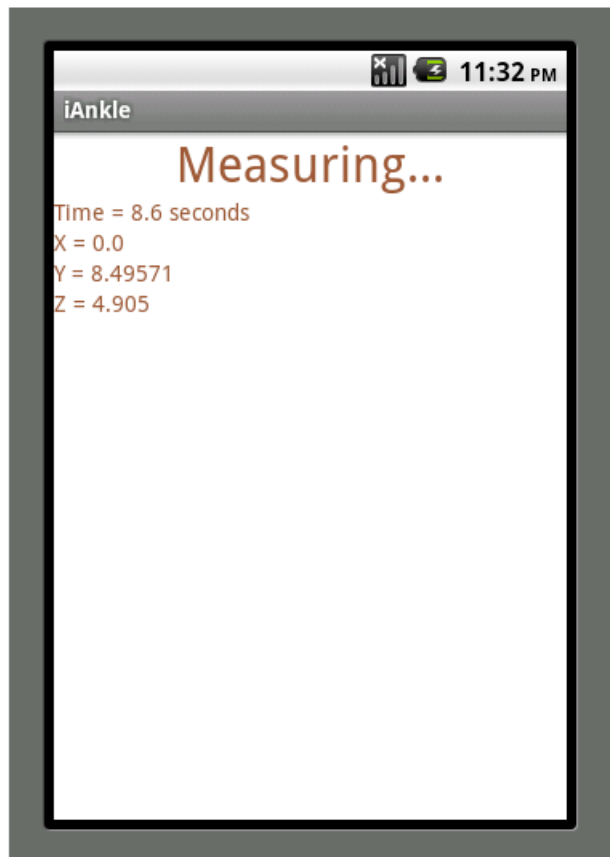
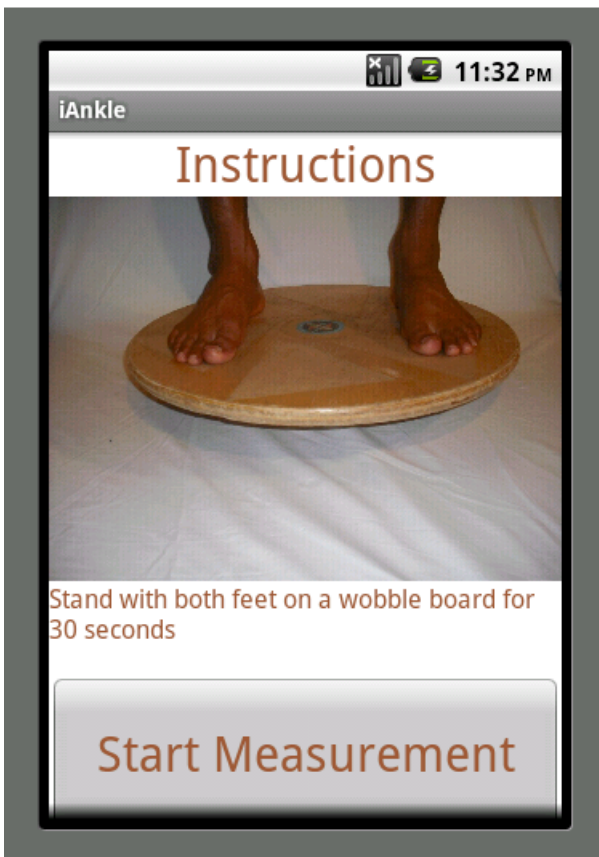
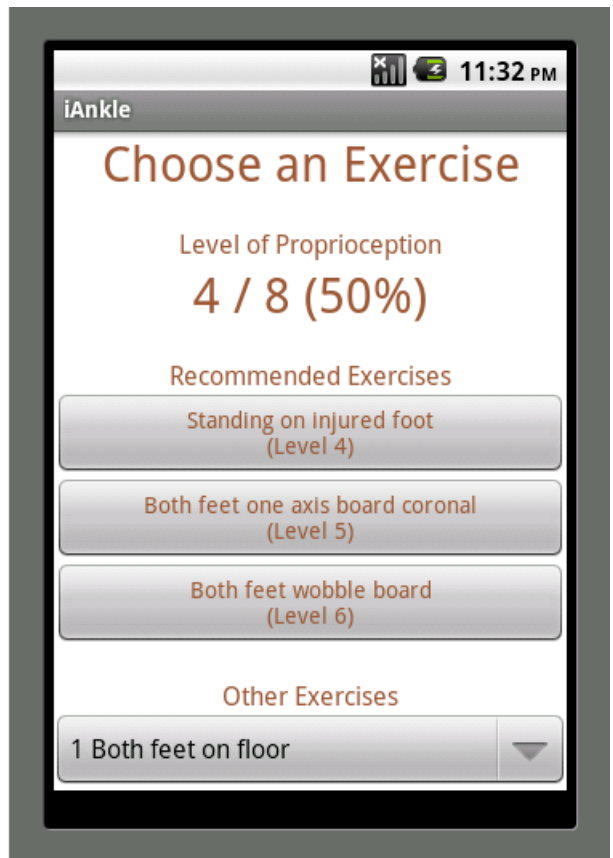
STATEMENT OF FUNCTIONALITY

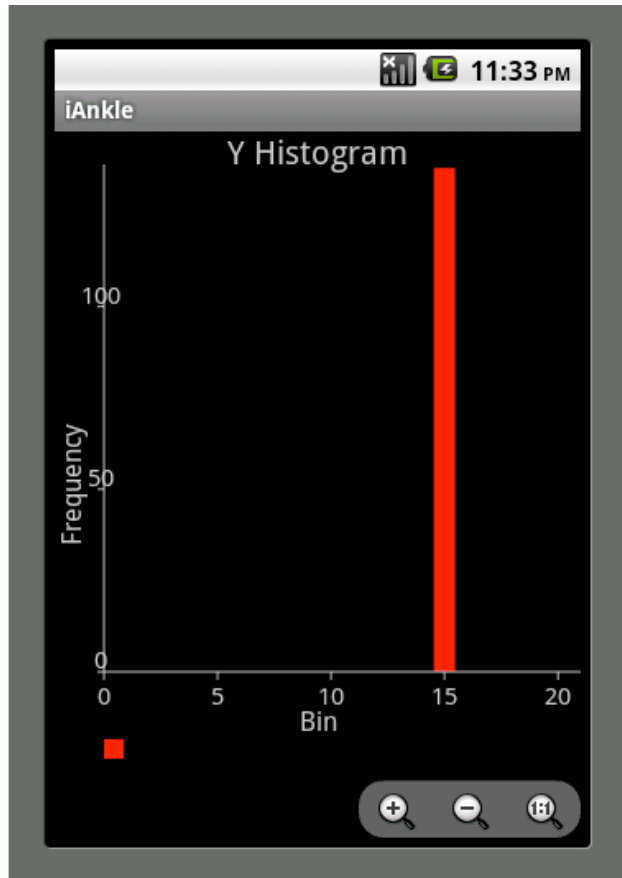
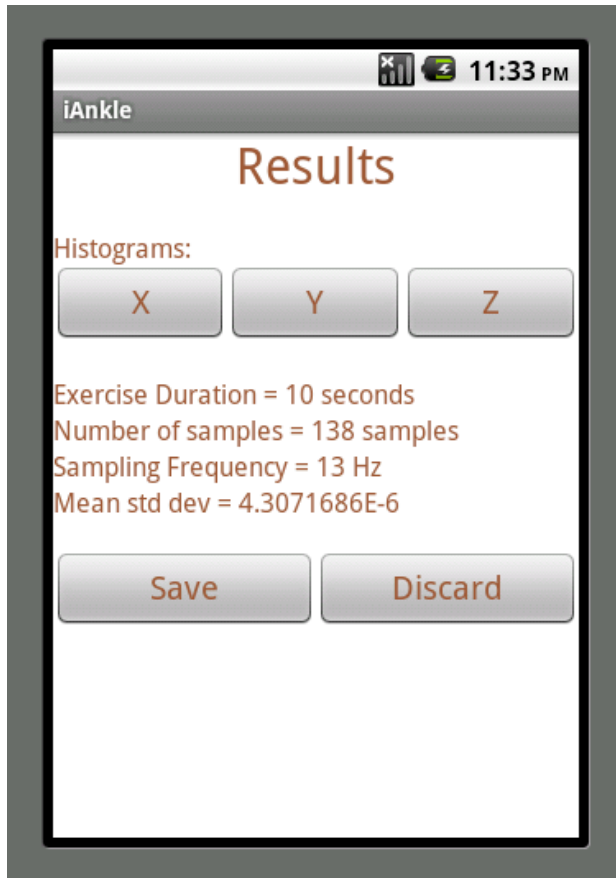
Our application works to the specification laid out in the plan. Functionality of the app is listed below.

1. Profile management—this provides support for multiple users of the app on the same smart phone, and tracks the progress of each user individually.
2. Exercise suggestion—the app suggests three exercises that are appropriate for the user's progress.
3. Ankle stability measurement—the app uses the accelerometer to measure the user's lower leg position during an exercise.

4. Ankle stability analysis—the raw data gathered from measurements are analyzed by calculating the mean deviation of the 3 accelerometer axes, which is used to upgrade or downgrade the user's level.
5. Result visualization—the measurements of each exercise is plotted in a bar graph to show the deviation of the leg's position from the centre.







LESSONS LEARNED

APPER

If we were to start again the main thing we would change would be applying for ethics approval for this project at the outset. Until our spiral two presentation we did not consider the possibility that we would require ethics approval to test our application. The ethics review process is lengthy and it requires a minimum of one month. Not accounting for the ethics review process inhibited our ability to perform clinical testing of the app.

We also learned the importance of having a testable version of the app early in the process of project design. The simplest version of the app with the working accelerometer and the ability to access the raw data captured by the accelerometer in the x, y, and z axes allowed us to determine the most meaningful number to utilize to determine the user's ankle stability. As the apper I have not had previous experience working in the spiral method and I found it to be very effective in producing a working app very early in the project planning phase.

Based on some of my literature review I learned that the true definition of ankle proprioception is the smallest degree of change in passive joint position that the individual is able to perceive. Proprioception can also be defined as the individual's ability to reproduce a specific joint angle without the use of vision. Based on this definition the iAnkle app does not strictly measure ankle proprioception. Without the benefit of extensive testing our current assumption is that the app measures ankle stability which is the combination of proprioception, kinesthesia and spinal reflex feedback. Kinesthesia is the ability of a joint to detect movement and the spinal reflex is what allows for quick corrections when the ankle moves in one direction such that the individual does not fall over. This assumption would require extensive testing to demonstrate that the app can both accurately and consistently produce meaningful results. We hope to continue our work on this app in the form of further testing to prove some of these assumptions.

PROGRAMMER

Graphic design and UI responsiveness is an integral part of creating a good app. The best apps on the market do not just have a great idea or useful functionality, they also have a good looking UI that responds quickly to user interaction. Initially our app started off as a very functional prototype with limited concentration on UI. During the testing phases, certain activities would take a long time to start, stop or process information. This proved to be frustrating so we spent some time turning the compute intensive functions into background threads which greatly improved the use of the app. The app also started out black and grey using the stock android colours and buttons. This was later modified to a white background to prevent glare and a warmer skin tone text colour which was appropriate for an app that focuses on the human body. After these upgrades it became much easier to use the app for future development and testing.

GROUP MEMBER CONTRIBUTION

We all are unanimous in saying that every group member contributed significantly and equally to the success of this app. The group dynamic is outstanding and provided constant constructive discussions and feedback by everyone in the team to both the apper and programmer aspects of the project.

NIRTAL

Nirtal thought of the initial concept of the iAnkle app and the applicability of such an app in the realm of rehabilitation. The idea was refined and modified after forming a group with Lyndon and Ivan who both provided input into the design and functionality of the app. While developing this app Nirtal reviewed the literature on ankle proprioception to gain a deeper understanding of how it is measured and quantified. Nirtal also performed a literature search

to determine some of the commonly prescribed proprioception exercises for ankle rehabilitation. Nirtal worked with Lyndon and Ivan to determine which measurement would be a meaningful value to determine ankle stability. Currently it seems that the mean standard deviation of the x, y, and z axes is the most meaningful measure but this has yet to be tested to determine reliability and validity. Nirtal provided the exercise list, pictures and the mean standard deviation levels for the app that would indicate to the user that the exercise needs to be upgraded or downgraded.

After a review of the literature Nirtal did not find a repertoire of proprioception exercises which progressed from easier to more difficult exercises and as such he developed a sequence based on clinical experience and guided by the information in the literature. Whether or not this repertoire is appropriate will be determined in the future based on clinical testing of the app. Nirtal also performed some baseline testing of the app to determine the clinical relevance of the results. Based on limited testing it appears that by utilizing the mean standard deviation in all three axes this measure is able to identify the difference between an easy proprioception exercise (lower number) and a more difficult proprioception exercise (higher number). The same seems to be true for an injured ankle (higher mean standard deviation) when compared to an uninjured ankle on the same individual. Nirtal also applied for ethics approval through the ethics review board at the University of Toronto. At the time of writing this report final approval by the ethics board was still pending.

LYNDON

Lyndon contributed many aspects of documentation, presentation, programming and high level guidance on the development of the app. He incorporated all the data processing on the accelerometer samples to come up with various standard deviations, mean, upper and lower bounds for the data. He also integrated an open source graphing package into the app to graph the processed data. He wrote the Spiral 4 full program activity flow along with UI upgrades and colour themes. He upgraded the flow to use threads for slow compute intensive functions. Lyndon also setup the exercises into the database to be recommended or chosen by the user.

IVAN

At the beginning of the project, Ivan suggested a few metrics of measuring the ankle stability, of which all members voted for the mean standard deviation of the three axes. He delivered the preliminary version of the app, which records the accelerometer readings and saves the raw data to CSV files. This was instrumental in proving our concept by Nirtal's experiments on himself (uninjured ankles) and Braiden (injured left ankle). Working towards the final product, he designed and implemented the database schema and its interaction with the software. He

also wrote the algorithm that upgrades or downgrades the user's level based on his or her performance on previous stability exercises.

APPER CONTEXT

This app will make a significant contribution to the field of physical therapy since it has the ability to quantify ankle stability. Currently, I use visual assessment to determine if an individual has adequate ankle stability after injury to return to sports and physical activity. This app allows me to compare the injured and uninjured ankle stability to have a quantifiable measure that justifies the individual returning to sport or waiting for further rehabilitation. There are currently force plates and potentiometers that are utilized to measure various aspects of ankle stability, however, most rehabilitation clinics (including the sport medicine clinic at UofT) do not have access to these measuring tool. This app does not replace such tools but it does provide a feasible alternative to these costly and inaccessible devices. Once there is greater exposure of what this app can do and following some clinical testing, I anticipate that every physiotherapy and sports medicine clinic will want to utilize it in their daily practice. Like myself, most physiotherapists only use visual assessment to determine an individual's ankle stability and now we will be able to provide them a way to have a quantifiable outcome.

Another major contribution to my field is that this app can act to empower the patient with information they would normally not have access to. In many aspects of rehabilitation we perform exercises and treatments that cannot be reproduced by the patient at home which can result in poor outcomes and a lack of compliance. In this case the app provides the patient with immediate and more objective feedback than what would be provided by a physiotherapist's visual assessment and as such has the potential of improving patient outcomes and compliance.

This app can also make a major contribution to the field of research in rehabilitation. This app can be a cost effective, valid and reliable measure of ankle stability which can be reproduced in various clinical settings and can be tested on various populations of patients. If after initial testing this app proves to be reliable and valid it can be utilized in the rehabilitation process to document progress, outcomes and to test the effectiveness of various treatments which are currently used to treat ankle instability. Utilizing this app for the purpose of research is the aspect of this project that excites me the most. In addition to the app's utility in the sport medicine world, there can be varied uses for neurological conditions that increase postural sway such as multiple sclerosis and Parkinsons and the effects of these conditions on ankle stability can be tested, quantified and monitored over time. This would serve as important information with the condition to signal to them how to improve their ankle stability as it relates to their neurological condition. I think we have only scratched the surface with the current app in terms of it's broad applicability and future uses in the world of rehabilitation research.

WHAT NEXT?

The list of potential technical improvements to this app is significant:

1. UI upgrades:
 - a. Present the data with different graphing options
 - b. Incorporate better graphics, pictures, icons and animations into each activity
2. User friendliness:
 - a. Audible beeps to indicate when the measurement starts and stops
 - b. Audible noises when a user is deviating from stationary position
 - c. Grace periods between exercise measurements to allow user to setup for the exercise
 - d. Scheduling support with the phone's calendar
 - e. Interface to add and delete exercises from the database
 - f. Cloud support for sharing data with health care professionals
3. Sensor improvements:
 - a. Improve accelerometer hardware for better sampling frequencies, sensitivity and precision to capture both high and low frequency deviations
 - b. Add gyroscope functionality to get more accurate and more complicated readings for exercises that require complex movements

Although the future direction of this app goes beyond the scope of this course it seems that our group has a tentative agreement to continue working on this app. The first step that needs to be taken is to receive full ethics approval so that we can start testing the app extensively for the validity and reliability. For this app to be successful and to have any clinical relevance we need to perform testing to ensure that it is producing meaningful results. We anticipate that testing the app may take up to several months and this testing will lead to some refinements in the app design and functionality.

The utility of this app is very broad and can include clinical use, individual use for injury prevention or rehabilitation, in the older population for fall prevention, specific populations with neurological impairments such as Parkinsons which are known to compromise postural stability, providing quantitative measurements for clinical research, and used for performance

enhancement for sport and physical activity. If our measure of ankle stability proves to be valid we can apply the same concept to multiple joints such as the knee, hip, and lower back. Again testing would be required at each of these joints to prove the validity and reliability of these measures.

Our group does intend to commercialize this app and we are still debating as to how best to pursue this opportunity. Our initial thoughts are to make it available on the android marketplace after some preliminary testing. We are currently thinking of designing two versions of the app. The first version would be appropriate for the general public and would be free or very low cost. The second “pro” version could be utilized by health care professionals and would provide the user with more details about the performance on each exercise and the ability to access all of the raw data used to calculate the individuals stability. This version would be available to health care professionals at a higher cost.