Final Paper

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ECE 1778 – Creative Applications for Mobile Devices

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1. Introduction

What: The goal of Dynasway: Concussion is to act as a quantitative balance assessment tool for athletes, coaches, and trainers to use after a concussion has been sustained. Our goal is achieved with the following features:

- Dynamic and static balance tests
    - Centre of mass tracking (accelerometer-based method)
    - Velocity tracking (camera-based method)
- Account creation and login for both athlete profiles and coach profiles
    - Ability to share results between profiles using a QR code

Why: Balance assessment is of particular interest due to high prevalence of balance deficits (30% of cases experience balance deficits[1]) after concussion and increased requirement during sporting activity. Current accessible concussion assessment tools rely on athletes self-reporting their symptoms, neuropsychological tests, and the completion of a simple standing balance test in either eyes open or eyes closed conditions. These balance tests may not be sensitive enough to detect balance deficits in athletes, who naturally have better balance and coordination abilities due to their years of physical training[2]. This has given athletes the ability to under-report their symptoms in order to return to play, which leads to subsequent musculoskeletal and head injury[3,4]. There are balance tests which give quantitative numbers however, these require a laboratory and expensive technology to complete. Therefore, there has been a need for an affordable, and accessible balance test which produces quantitative data in order to assess balance post-concussion.

2. Statement of Functionality & Screen Shots from App

The app is intended as a measurement tool for coaches and trainers to use throughout the season for their athletes who suffer concussions. It is capable of measuring two main variables: center of mass acceleration (m^2/s), denoted "Static Test" and walking velocity (m/s), denoted "Dynamic Test". For specific details regarding the algorithms behind these calculations, please refer to Section 3.

Each test is broken down further by stance type (regular/tandem) and cognitive task type (none/serial counting), resulting in 4 tests for each category as illustrated in *Figure 1*. Clicking on each specific test gives the user specific instructions on how to complete that test as depicted in *Figure 2*.

The athletes are able to conduct each test as a "baseline" (intended to be completed during preseason) or "post-injury" (intended to be done daily post-concussion). The results of each post-injury test is then plotted with respect to date in a calendar page as shown in *Figure 3*.

Coaches using this app would have the ability to view the calendar page of all their athletes that they are connected with. A connection between two profiles can be made by having one party reveal their profile QR code by clicking "My Profile Code" and have the other party scan it with the "Connect to a Coach/Athlete" through their device camera (*Figure 4*). Once the connection is made, the athlete's name would show up under the coach's connections which can be clicked to navigate to the athlete's calendar. If an athlete has recently suffered a concussion, he/she can select "Log New Concussion" (via home page).

Lastly, athletes can learn more concussions and how the app works through links available on the home page under "About the App" and "External Sources on Concussions" as shown in *Figure 5*.

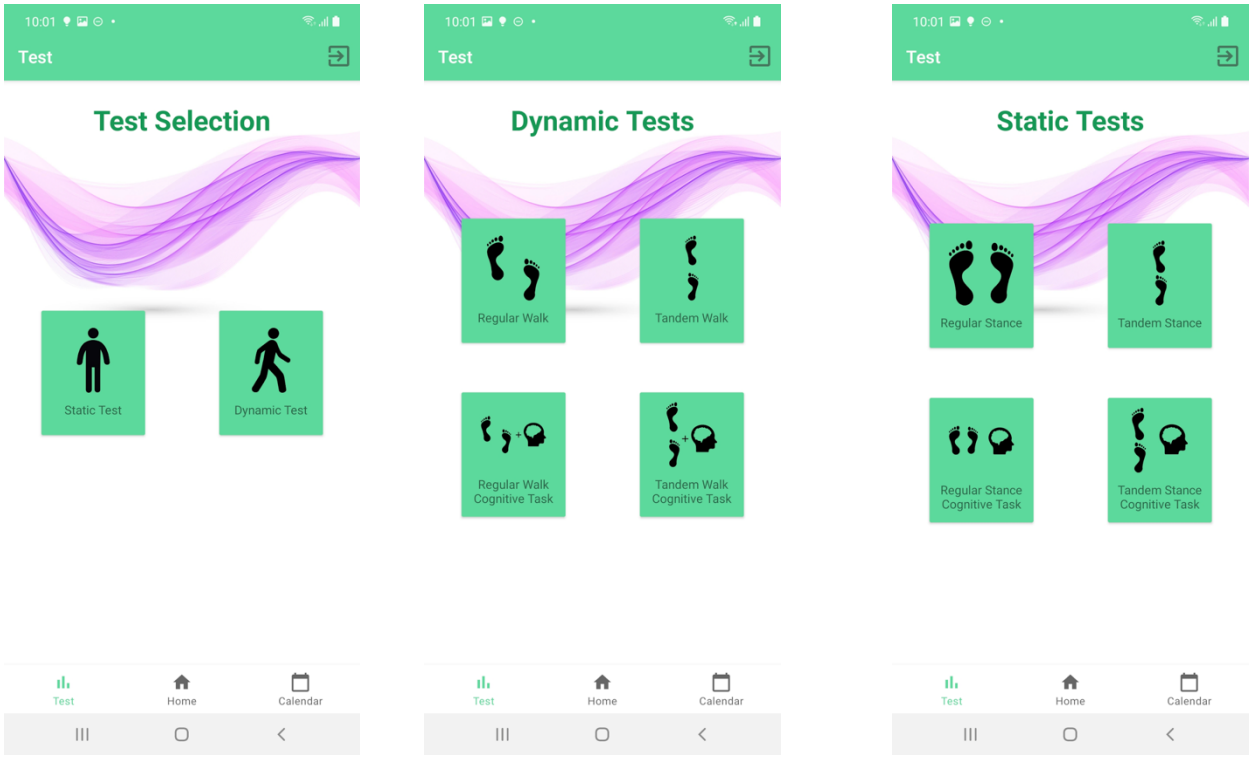

Figure 1 - Test types

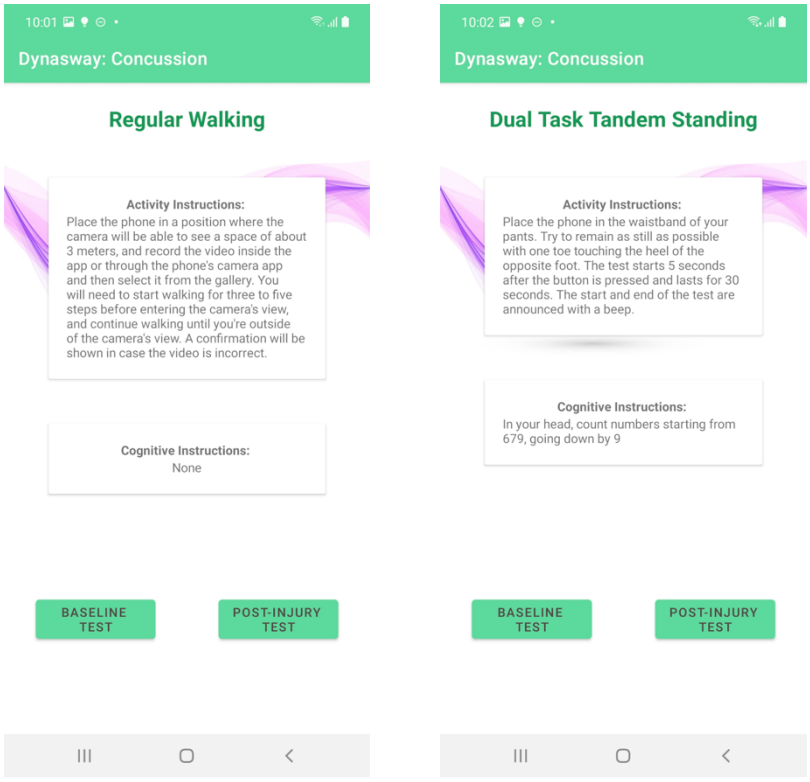

Figure 2 - Test Instructions

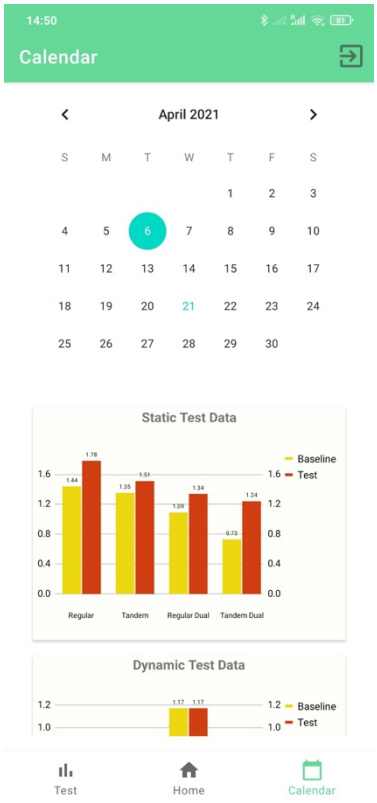

Figure 3 - Calendar

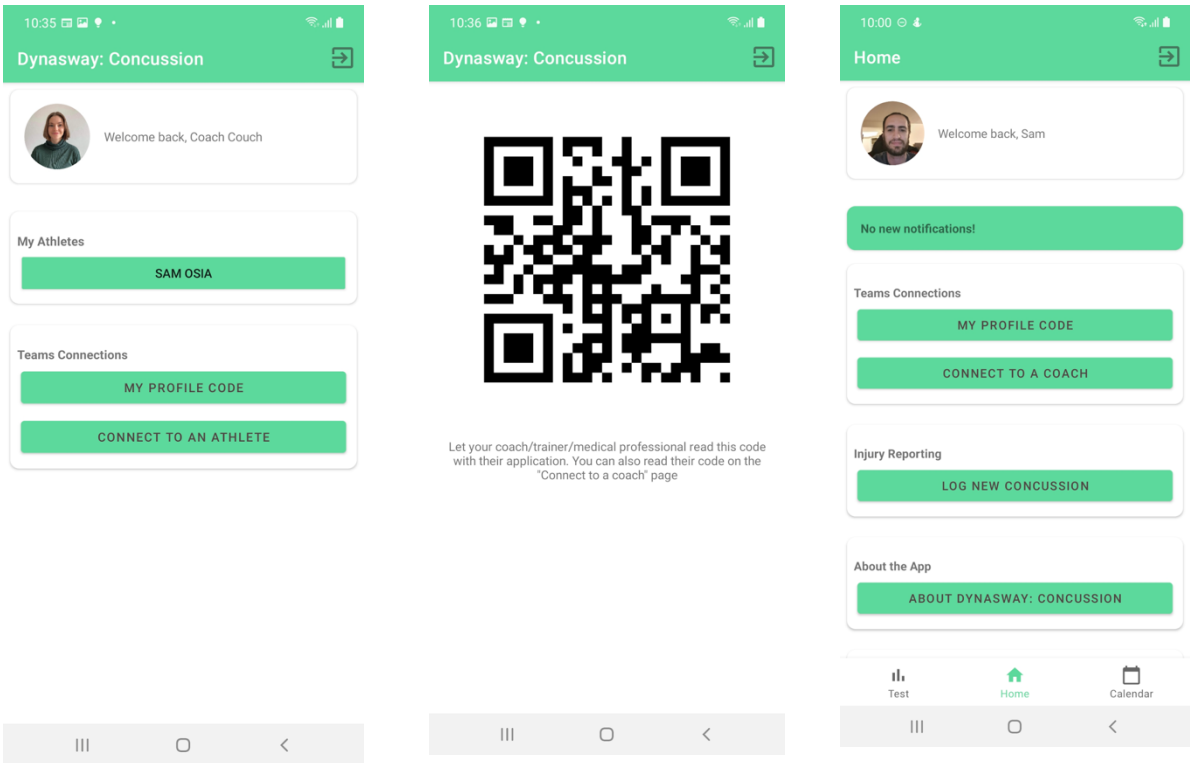

Figure 4 - Teams Connections

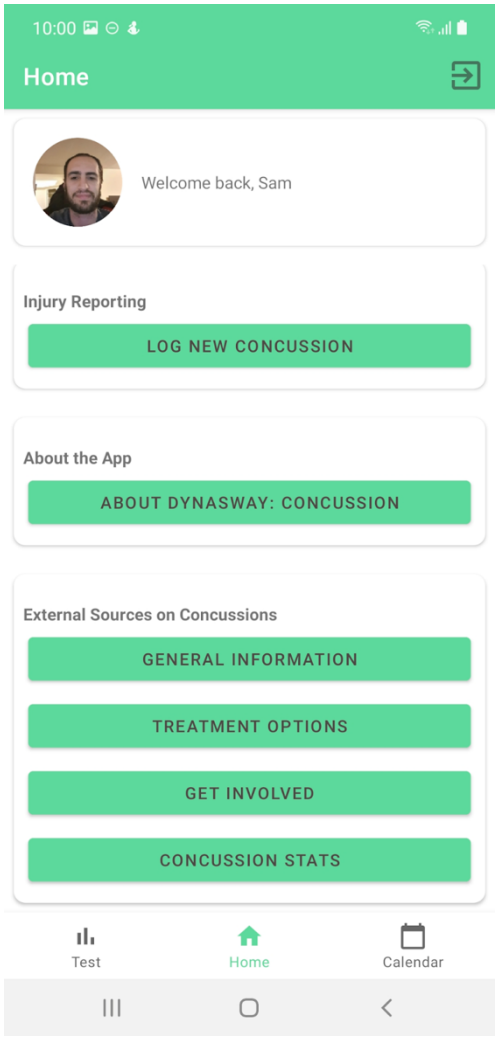

Figure 5 - External resources on concussions

3. Overall Design

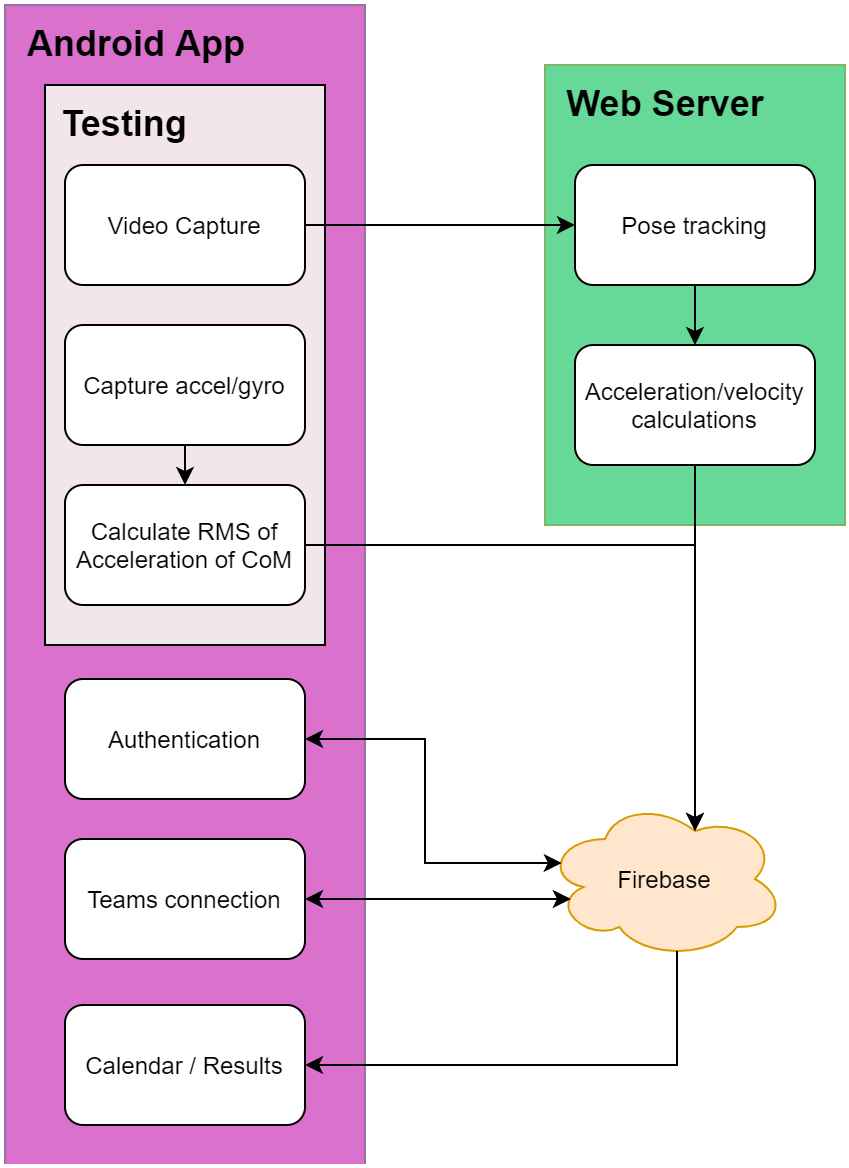

Figure 6 – Block Diagram

The Dynasway: Concussion application is divided into two main blocks of software, the actual android application and a web server.

The Android's application main module is the Testing module. This module contains all the libraries related to static and dynamic concussion testing, and as such is divided into three modules. The first module is the Video Capture module. This module includes the implementation to allow users to record walking videos inside the app, or to choose a video from the gallery of their smartphone for dynamic testing. This video is then sent to the server to be analyzed, this will be explained in more detail below.

The Accelerometer module allows capturing acceleration data from the smartphone's accelerometer sensor. This data is then sent to the center of mass (CoM) acceleration calculation module, which calculates the root mean square (RMS) of the vector sum of acceleration in 3 orthogonal axes to assign a single number to score each test. The formula for this test is as follows:

$$let\ N = number\ of\ measurements$$
$$n = measurement\ index$$
$$x = acceleration\ in\ x\ coordinate$$
$$y = acceleration\ in\ y\ coordinate$$
$$z = acceleration\ in\ z\ coordinate$$

$$\sqrt{\frac{\sum_{n=1}^{N}(\sqrt{x_n^2 + y_n^2 + z_n^2})}{N}}$$

The Testing module provides implementations for both baseline and after concussion testing. The values produced by tests are stored in Firebase Firestore, which is the storage solution chosen for the application.

The Android application also has other modules like the authentication module, which connects to Firebase Auth; or the Teams Connection module, which provides QR code generation and scanning to link coaches/trainers/medical professionals with athletes. Finally, there's the Calendar or Results module, which allows the user to visualize the testing data through time with a calendar view and bar graphs.

On the server side of the application, there is the pose tracking module, which uses a machine learning algorithm and toolkit called AlphaPose. This toolkit provides joint coordinates through every frame in a video, which are given to the Velocity Calculation module. This module, in coordination with known physical parameters from the user (upper arm length), calculates walking velocity for dynamic testing. These results are stored in Firebase Firestore.

The velocity is calculated by taking joint coordinates from frame to frame, calculating raw pixel movement, and transposing it to a smooth derived function as seen in Figure 7. This is then normalized to the upper arm length of the person in pixels, and converted from pixels per frame to meters per second by taking into account frame rate and the real upper arm length of the person.

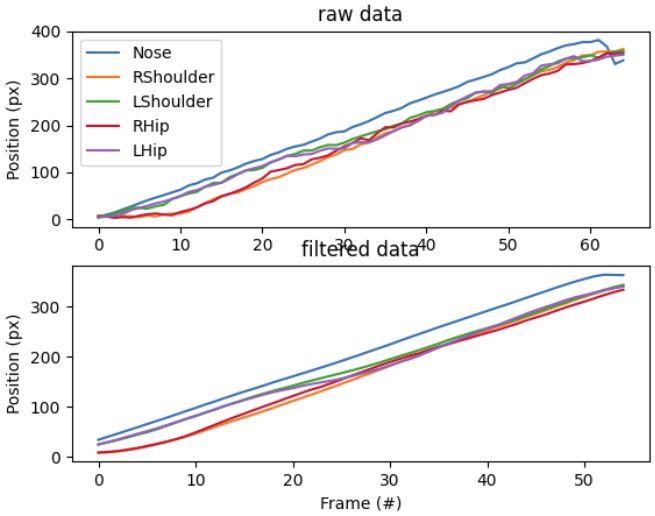

Figure 7 – Joint Coordinate tracking

4. Reflection: What did you learn - what would you do differently?

This experience has taught us a lot about working in teams with people from very different backgrounds, from the specialist to the programmers, but even within the programmers. With this in mind we made sure when discussing ideas to do it in “non-jargon” terms to make sure everyone was following.

If we were to start again, we would focus on implementing the image-based pose tracking from the beginning. This was our original idea however, we were timid and it was suggested that we try a different technique first. This ended up not giving us an accurate result for velocity, so we decided to switch back to plan A and implement the pose tracking velocity test. With that being said next time we would re-evaluate the time necessary for the creation of these functions mid-way through the project. Our original estimates were less than what was actually required for the final product.

Developing an application, or any type of software with an agile method such as Spirals, provides a faster and more manageable approach to big projects such as the one accomplished by the group. It puts more focus on frequent meetings with the client (the specialist in this case) and the other project members. Also, during the app creation, we learnt that data management and ethics are really important when dealing with personal information from people, and thus the video recording part of the application had to be very well thought of and explained to the user.

Finally, having very frequent short progress meetings is incredibly valuable when team members are doing tasks in parallel. Consistently confirming your expectations of what other team members are working on allows you to easier merge your work.

5. Contribution by Each Group Member

Calaina Brooke (Specialist)

- Responsible for original vision. Used research and knowledge background to provide feedback and suggestions throughout the app creation period
- Researched existing balance apps in relation to concussion in order to have a novel and necessary idea
- Created original colour scheme, UI mock-up design, and logo
- Created app content such as the writing on the information page, the links on the main page, and the instructions and guidelines for each test
- Primarily responsible for project management, goal setting, meeting organization, deadlines

Enrique Torres (Programmer)

- Authentication system
- QR code scanning and generation
- Home page
- Video recording and selection from gallery
- Video uploading from the phone
- Video receiving through HTTP on the server
- Data downloading and part of the inner workings of the Calendar page

Sam Osia (Programmer)

- General UI/Navigation
- Static tests
- Calendar structure/view
- Coach mode UI + navigation to different athletes' data
- Python/Bash scripts on server to take uploaded video, run pose tracking and return a walking velocity

6. Specialist Context

My field of research is gait and balance in those who have sustained sports-related concussions (SRC). Balance is an important measure in SRC due to its high requirement in sporting environments. It has been demonstrated that after concussion, athletes have a 2 times increased likelihood of sustaining lower body injuries[4]. This has been attributed to a deficit in balance which outlasts the current return to play assessments[4]. Balance is often tested in a standing static posture; however, this may not be sensitive enough to determine if balance has recovered from concussion for athletes. This is because an athlete will never be standing still during training or in a game, therefore, static balance is not enough. The measurement of dynamic balance has been proven to detect deficits upwards of 30 days after concussion[5]. The evidence has shown that if an athlete was asked to perform a counting task (distraction dual task) their balance and gait stability was further affected[5]. The combination of walking and a dual task may be sensitive to long term deficits after concussion[6]. There has been need for an accessible balance assessment tool with increased difficulty to detect balance deficits after concussion in order to prevent athletes from returning to sport too early and potentially sustaining further injuries. Our application fills this gap. The use of both a static and dynamic balance task, in combination with a cognitive counting dual task creates situations where balance deficits have been provoked in the literature. Yet they will not need access to expensive laboratory equipment the user will now have a platform to complete these tests by simply using an app on their phone. This app would act as an additional testing tool for coaches/trainers to use when assessing their athletes concussion recovery and return to play eligibility. Our app could have an impact on this field of research by allowing coaches and trainers to obtain quantitative balance assessments of their athletes in order to prevent early return to play, and subsequent injury. Further, use of our app allows constant back and forth communication between athlete and coach/trainer in order to create transparency of their recovery, rather than relying on the athlete self-report of symptoms.

7. Future Work

In the future we would allow the user to have the option to save the video with the joint coordinates on it. This would be beneficial for the coach or trainer to watch the video to 1) see if there is visible instability in their athletes walk and 2) see their athletes face to in order to get an idea of how they are feeling during the testing. Further we would like the pose tracking to be processed locally and eliminate the dependency on an external server.

Pose tracking using cameras is becoming a more common tool in gait and balance research. This generally requires one or more cameras set up around an individual in a lab to perform the pose tracking. Now having this capability on a phone, it makes it portable and a potential tool for clinicians to use in their practice. For example, physiotherapists and rehabilitation therapists could use this to analyze a patient's gait, in order to determine the correct program to create for treatment. This could have uses in falls prevention measures in populations such as dementia, Parkinson's, and incomplete spinal cord injury. Further this could be used as a training tool for sports therapists and team trainers. They could analyze the joint movements of activities (ie. Squats and lunges) and provide corrections, and this could happen all virtually which could be extra helpful now in times of the COVID-19 pandemic.

State if OK or not to post each of the following on the Course Website:

	Sam Osia	Enrique Torres	Calaina Brooke
Video of Final Presentation	Yes	Yes	Yes
Report	Yes	Yes	Yes
Source Code	Yes	Yes	Yes

References

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