ECE1778 FINAL REPORT

SuperFit

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Contents

1. Background

Resistance training is a form of physical exercising that involves users adding resistance to their target muscles, such as performing weighted squats. Since each individual has a unique physique, there are various methods to measure the weight/resistance specific for that person. For instance, Borg scale is a qualitative measurement used to rate the amount of exertion in order to perform an exercise [2] , while %RM (rep-max) is a quantitative measurement of the weight that the user can perform (i.e. 100%RM means user can only perform a single repetition) [6]. Hence, it is clear to see that the %RM value can be determined from conducting a test at 100%RM, also known as one-rep-max test. In particular, different %RM ranges designated at specific sets/reps can target different muscle fibre groups hence yield various physiological results.

1.1 App Motivation

There are many people around the world who are improving their overall well-beings. While resistance training provides many benefits such as increasing muscle size and muscular endurance the lack of knowledge in training method could result in ineffective workouts, and not knowing %RM could lead to musculoskeletal injuries by lifting too heavy. While %RM test (see Background section) can be performed, it is dangerous for inexperienced individuals due to the resistance being extremely heavy; potential musculoskeletal injuries could occur. As the number of injuries in resistance training is increasing[5], there are no available apps that direct focus on keeping users safe.

1.2 App Goal

SuperFit first suggests an appropriate weight for the user to lift based on user's fitness goal by determining his/her %RM. Finding user's %RM will require user to perform a test at a much lighter weight. In doing so, it prevents user from lifting a weight that's likely to cause injuries. Secondly, for every recommended weight SuperFit matches it with a corresponding number of sets and repetitions for the user to add to his/her workout. As result, the user can reach his/her fitness goal with minimum amount of time.

2. Overall design

2.1 Coding Structure

From the perspective of coding structure, these functions will be written in the packages of common, controller, DAO, object, profile, service, utils accordingly.(Fig.2.1) The current structure facilitate the introduction of future functionalities. For example, to support an extra exercise we only need to provide user interface in the controller package, using the exercise object to convey details and realizing specific functions in service package. We can introduce one service interface layer to increase the expansibility; however, the structure is able to maintain the existing functions clearly and consistently.

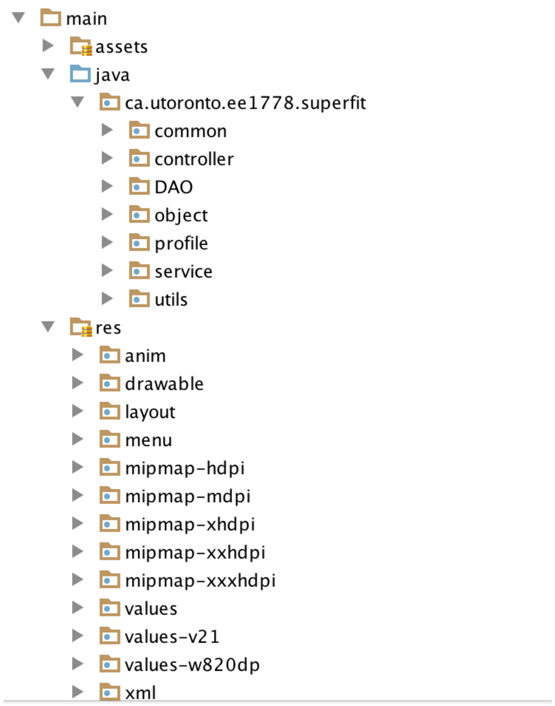

FIGURE 2.1: Code Structure of SuperFit

2.2 Code Block Diagram

From the perspective of system structure, the codes of SuperFit contains several functional modules which are listed in the code block diagram.(Fig.2.2) Currently, the major technical module of SuperFit is Weight Recommendation Assessment, which relies on Borg Scale Mapping and Motion Analysis modules.

User Management – This module provides functions of create/edit users' name, age and weight information. The user profile will be used in the weight recommendation assessment, as well as the management of schedules and history tracker.

Schedule Management – Manages the schedules for current user, including the exercise, sets per day, repetitions per set, desired weight, etc. After a successful weight

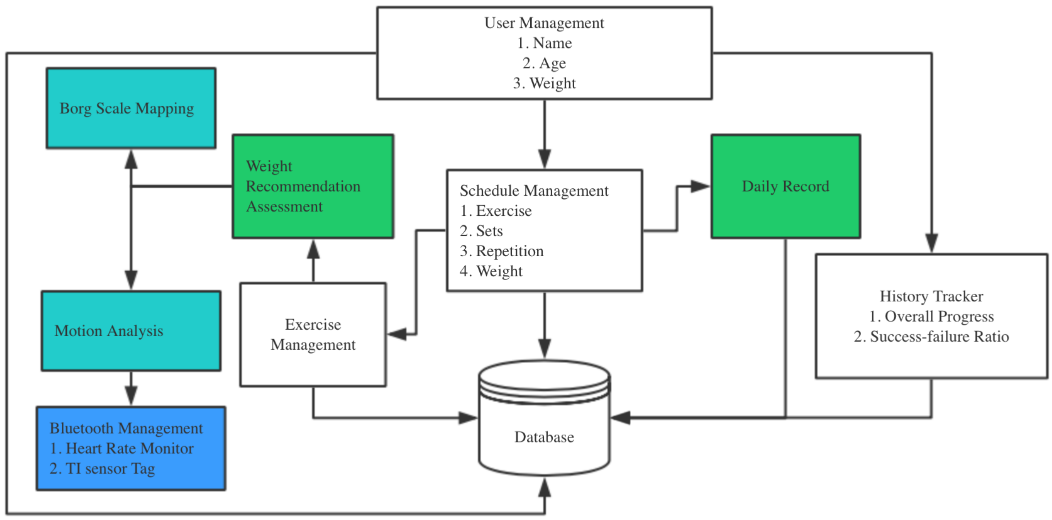

FIGURE 2.2: Code Block Diagram of SuperFit

recommendation, a schedule will be generated and stored for the current user.

Weight Recommendation Assessment – This module will monitor the heart rate and postures during weight recommendation assessment, counting the successful and failed times of movement for the user, and then it implements Borg Scale Mapping depending on the user's age, heart rate, etc, to decide the appropriate weight the user. It is the major functional module of SuperFit.

Borg Scale Mapping and Motion Analysis – The Borg Scale Mapping is based on the Borg Scale Model. The motion analysis depends on the data retrieved from the TI Sensor Tag[3]. Every time when the TI Sensor Tag sends one serials of data to the Motion Analysis module, the ExerciseSerivce class is called to calculate the tiles and to decide whether the posture is within a reasonable range of angle or not.[4] Then the final result will be presented on the user interface.

Bluetooth Device Management – This module provides the functions for the system to maintain the connection status of multiple devices. In the BluetoothLeService class[3][1], a list of bluetooth GATTs will be maintained to represent the connected devices. The requests of operating the bluetooth devices will be put into a blocking queue to wait for to be executed. The original open source code from TI only provides management for exactly one device, the SuperFit can connect to no more than 7 devices at the same time, which allows us to support more devices and complicate movements in the future.

Daily Record and History Tracker – SuperFit also provides the function of recording everyday's progress for user to trace back the overall performance. Overall progress and success-failure ratio for the past 10 days are presented by visually circle bar and bar chart, which is easy for user to see the history data.

2.3 Database Design

SuperFit will maintain the user profile, exercise collection, schedules, and daily record in the SQLite database.(Fig.2.3) The user table and exercise table are used to distinct different users who are using the app and various supported exercises. Currently, SuperFit provides the assessment of specifically one exercise: the Dumbbell Bicep Curl. The schedule table is used to maintain the exercise schedules for every user. The original purpose of developing this table is to record the fitness programs for users; however, currently it supports one exercise for one specified user.

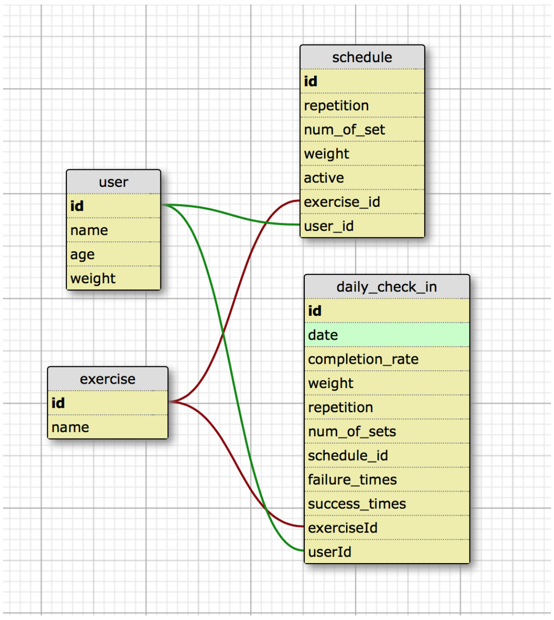

FIGURE 2.3: Database Design of SuperFit

The *daily_check_in* table allows the user to trace back their daily achievements. For example, the overall progress of the current schedule, or the success-failure rate in the past workouts.

2.4 Movement Measurement

The method we are using for movement measurement is based on the assumption that at least at starting and ending postions of movement, the accelerometer is in the state of equilibrium.

We believe this assumption is reasonable because at these postions, the speed of motion is quite slow. Once in the state of equilibrum, we can know that the output values of accelerometer at three axises are actually the projection of gravity force. Then we use the triangle of forces to calculate the angle between the upper surface of accelerometer and the earth horizontal plane.(see Fig.2.4)

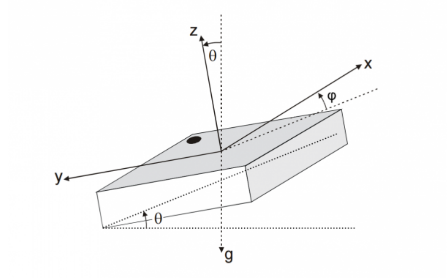

FIGURE 2.4: The angle between the upper surface of accelerometer is equal to one between z output vector and gravity force vector

In this version, SuperFit only cares about if the user can perform the required range of motion. Therefore, the tilt measurement at starting and ending postions is quite important. We can use either $arcsin$ or $arctan$ to do this job. $arcsin$ was first chosen because of its simplicity, where the denomitor is always gravity force and output value will always be valid. However, during the testing of SuperFit, we found this appealing $arcsin$ method suffered from unacceptable error in measuring angle from 60 to 90 degrees, where the margin error was around 15 degrees. It is a disaster since the measurement of angle in this range is crucial for some exercise, like Dumbbell Bicep Curl. Fortunately, the problem can be easily solved when we transfer to $arctan$ relationship. The following figure(Fig.2.4) show these two functions. We can find arcsin has a quite sharp slope when used to measure angles from 60 to 90 degrees, which means if there is any noise or slight tilt, the result would be hugly affected in this range. Finally SuperFit chooses to use $arctan$, which can reduce margin error down to only 2 degrees. Therefore, $\theta = arctan(z/(x^2 + y^2)^{1/2})$

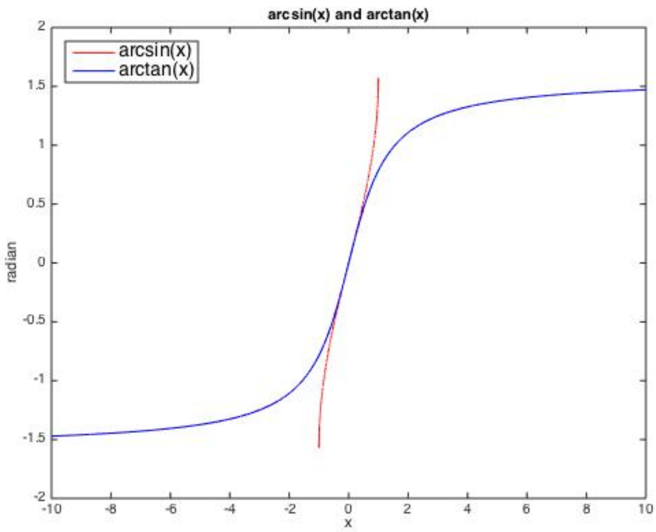

FIGURE 2.5: The plot curve of $arcsin(x)$ and $arctan(x)$

As for the movement procedure, we keep track of previous data sampled by acclerometer and combine it with current data, we can determine the movement direction and also know when the accelerometer enter in or leave out the available testing zone.

3. Statement of functionality

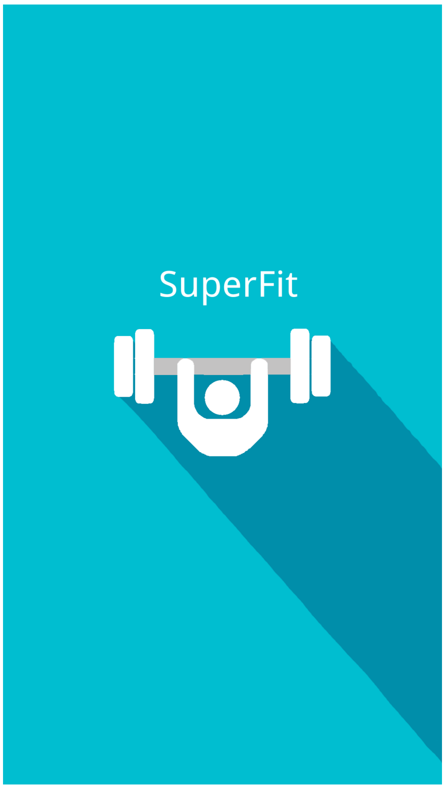

FIGURE 3.1: Welcome Screen of SuperFit

User Profile – Using SuperFit at the first time, a user profile mush be created, including the information of name, age and weight.

Bluetooth Connection – The functions provided by SuperFit rely on Wahoo heart rate monitor and TI Sensor Tag. Before utilizing SuperFit, the user should connect to the sensors first.

Weight Recommendation/Evaluation – SuperFit will count the successful repetition and give a warning message by a green/red bubble. The real time heart rate and tiles of posture will be presented on this page as well.

Record Daily and History Tracker – SuperFit allows user to record their daily progress, and gives feedbacks in terms of overall progress as well as success-failure rate to show user's performance on their schedule.

Edit Your Schedule – SuperFit also allows the user to modify their current schedule, in terms of sets/repetition/weight to meet different goals.

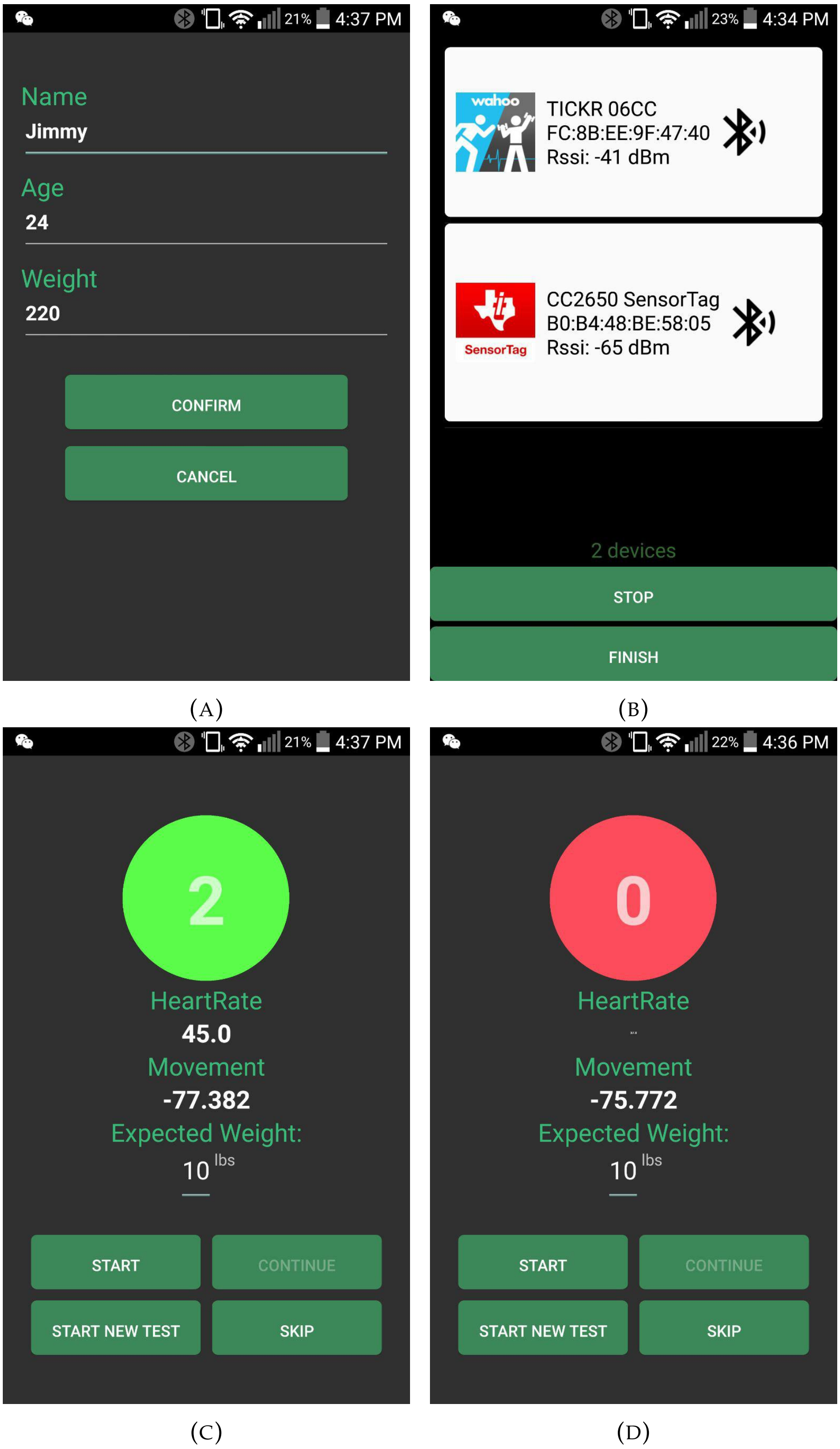

FIGURE 3.2: (A)Create Profile, (B)BLE Connect, (C)Assessment Pass, (D)Assessment Fail

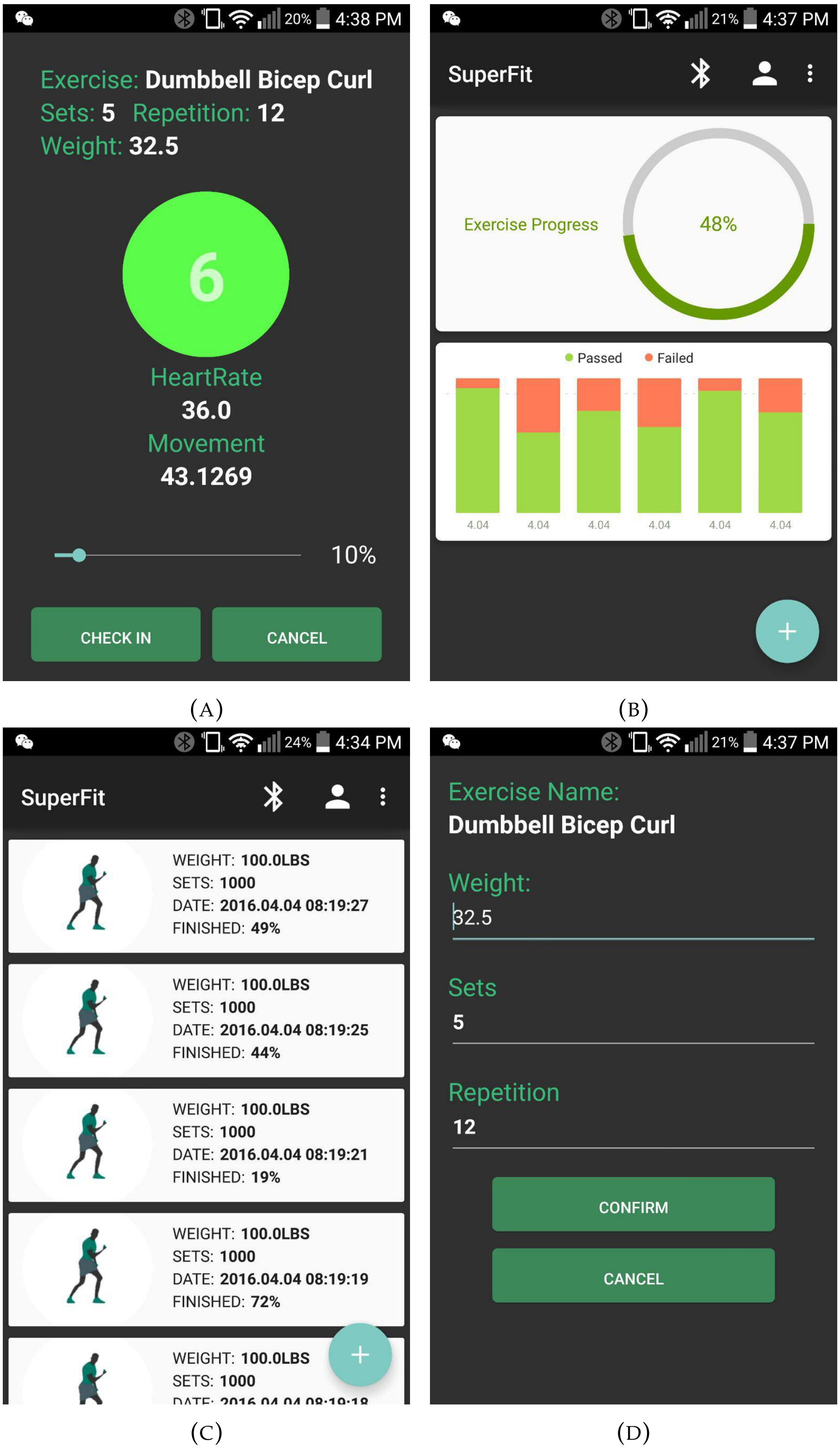

FIGURE 3.3: (A)Daily Checkin, (B)History, (C)Main, (D)Edit Exercise

4. What did we learn

4.1 Specialist

I have consolidated my knowledge in measurements of training intensities from a non-traditional fashion through doing literature reviews on various models that directly relate to digital measurements. I have also been familiarized with the concept of UX design and its associated software applications.

4.2 Programmers

- Technical Improvement: We are getting familiar with the Android lifecycle, and functions including BLE, the interaction between activities and fragments, definition of customized adapter, various layouts such as Relative Layout and CardView, etc. Also, the Bluetooth sensors gave us knowledge and further inspiration of the use of of hardware to achieve some fantastic goal. Get knowledge of impacts of different sampling rates on connections of different BLE device. Get hands on experience on movement detection, measurement. Improve the analysis ability of different measurement methods and errors. Get experience on how to determine the direction and procedure of movement by keeping track of both previous and current data. Get exprience on potential oscillation during converging and how to avoid it.

- Non-technical Improvement: We learnt how to drive a project consistently. By dividing the project into different stages, we achieved the small goals step by step, which gave us the sense of project management as well. Team work is important. In this project, programmers solved the problems of those they are good at in a short time, finished the tasks accordingly, we have never hided a single problem without telling each others, which is the major reason for us to meet a common goal together.

5. Team Contributions

Shu Qing Wang

- Provided idea and insight into developing the mobile app
- Helped conceptualizing design user interface, workflow, and optimization
- Performed literature reviews on research studies to obtain a weight recommendation model
- Completed the UX project on InVision for app future works
- Perfected app logo through several revisions
- Acted as test subject for app testing

Wenyang Liu

- Designed the overall system, coding structure and database relationships to facilitate the testing and division of responsibilities, as well as the scalability for future works.
- Investigated and implemented the BLE technology provided by Android, including scanning, connecting, releasing, data update notification, as well as multi devices connection.
- Realized overall UI functions, including main screen, assessment, daily log, history tracker, and any other views.
- Tested and verified the assumptions based on Borg Scale Model with the specialist, adjusted the input and recommendation according to the verification experiment as well as research reviews.
- Planned the spirals with specialist, including the schedules for finishing specific cluster of functions, user interfaces.
- Prepared the slides and practiced the presentations with specialist.

Jiaxin Chen

- Analyzed the principle of accelerometer to achieve tilt measurement in the state of equilibrium.
- Improved the tilt measurement accuracy and make comparisions of performance between $arcsin$ and $arctan$ methods under different situations.
- Determined the direction of movement and when the accelerometer enter in or leave out available testing zones by combining information from previous data and current data sampled by accelerometer.
- Implemented Borg Scale Model for Dumbbell Bicep Curl. Trace the changes of recommended weights for testing iteration and make corresponding decisions to avoid potential oscillation.

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Analyzed the feasibility of implementation of Borg Scale Model, including possible inputs, mapping logics, as well as the relationship between sub-models of final recommendation of Borg Scale Model.

6. Apper Context

The developments of this app can greatly increase people's awareness on possible injuries from lifting too heavy during exercising and how to avoid them. By scientifically informing users the weight they should be lifting, the app is indirectly allowing users understand their physical capabilities. Also by providing workout effectiveness by recommending number of sets/reps for each exercise, the app can lead to a strong motivation for the users keep exercising and improving their bodies. Furthermore, SuperFit can also empower users' knowledge in fitness as they use the app more and more frequently. This is because user can observe a specific pattern behind a particular workout program. By doing so, users can potentially fit two fitness goals in a single (custom) program as they desire; this can result in many possibilities in one's workout routine. In the end, the users only need weight recommendation function of the app and no longer require program design from SuperFit.

7. Future works

For the future works, we will bring more exercises to finish our original goal of SuperFit : program recommendation for professional fitness user. Thus, it requires the detection and measurement of various complicated postures. Also, a mature and user-friendly interface is needed for an attractive app, we will try our best to polish the UI design.

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