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April 06, 2021

Dr. Craig Scratchley,
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia, V5A 1S6

RE: ENSC 405W/440 Project Proposal for the Pro-Tek

Dear Dr. Scratchley,

The attached document outlines a proposal for the design and implementation of the Pro-Tek. This wearable tracking device is aimed to monitor body posture during workouts (such as Deadlifts, Bench Press and Squats) and will notify the user if body posture is wrong using an Android app on the user's phone, LED and vibration on the module itself. It will also display exercise history and repetition on the app.

This proposal aims to provide a high-level overview of our product. This will include: an early-stage prototype design; projected risks and benefits associated with the product; a preliminary analysis of the market with a focus on where we see our product positioned; a list of tentative component and material costs required to produce our initial prototype; and, lastly, a project schedule to illustrate the expected workflow.

GymSmart is composed of six engineering science students: Junjie Xu, Pei Ning, Kwok Liang Lee, Xiaoyi Zhao, Mitch Edema and Harpreet Kaur. Every team member possesses different skills and contributed based on their extensive hardware and software experience.

Our company members appreciate the time you have taken to review our design specifications document. If you have any comments or questions about our product, please feel free to contact me by direct line at (604)805.4001 or via hharpree@sfu.ca.

Sincerely,

Harpreet Kaur
Chief Communications Officer
GymSmart Inc.

Product Proposal:

Pro-Tek

Making Proper Form the New Norm

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Issue Date:
April 06, 2021

Executive Summary

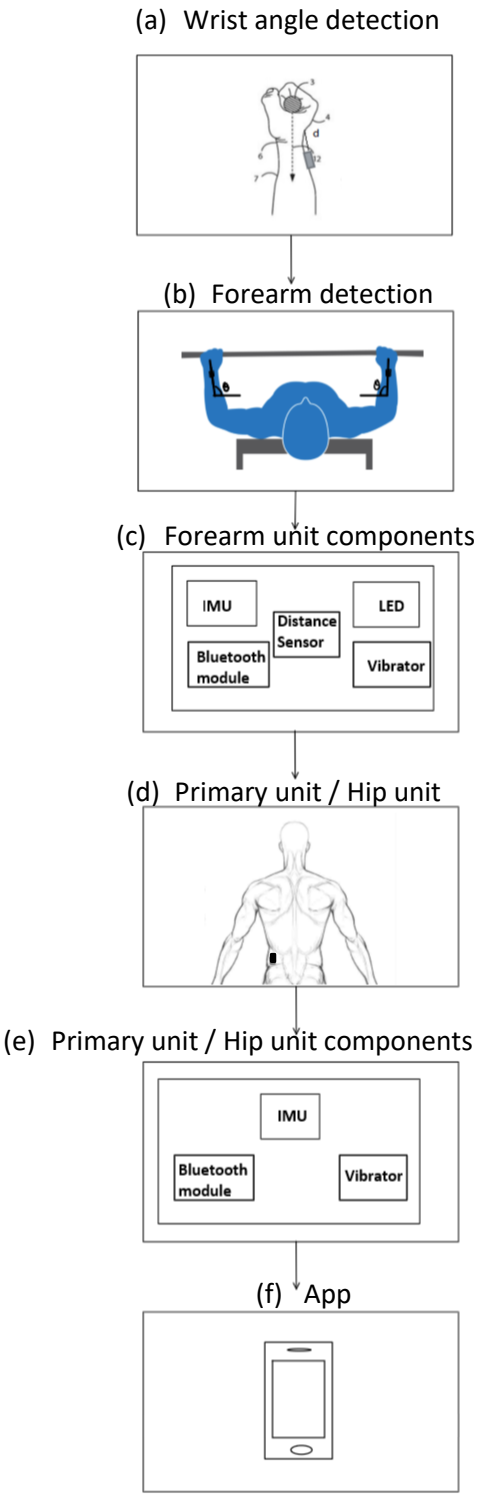


Figure i: Overview diagram of Pro-Tek

Physical exercise is one of the most imperative activities an individual can engage in to help improve their physical health. However, injuries sustained during this essential pastime can be devastating to the health and progress of an individual. Our product aims to mitigate workout injuries and provide a useful interface for ensuring proper workout posture.

The Pro-Tek form trainer was developed to detect improper exercise form instances and notify the user. In doing so, the user can have tangible feedback if an incorrect posture is detected. The system achieves this functionality by using inertial measurement units (IMU), capable of measuring the orientation of the attached limb segment. An optical distance sensor is also involved, used in estimating the angle of the wrist (Figure i.a). To notify the user, LED and vibration sequences are employed depending on the type of improper form detected.

Pro-Tek is made up of 3 individual units, one unit fixed on each forearm (Figure i.b) and one fixed to the hip (Figure i.d). Though these units are only fixed to upper body segments, the complete system can be used to measure exercises that engage the entire body.

Each forearm unit (Figure i.c) has 6 main components, a processing unit, an orientation sensor (IMU), a distance sensor, an indicator LED, a vibration motor, and a Bluetooth module. The hip unit has the same components minus the distance sensor and an LED. These components work together to provide form analysis and user notification during an instance of incorrect posture. They also participate in the transfer of data between the units and a smartphone application.

The smartphone application (Figure i.f) is the means of interfacing with the units. The app allows the user to specify their desired exercise for form detection and provides them with useful information of proper postures characteristics. It can act as a guidance mechanism, ensuring proactively that the user is aware of proper form for the specific exercise. After an exercise session is completed, its essential data will be stored in the app, available for further observation by the user.

GymSmart exemplifies the attributes of a hard-working, motivated group of individuals. We are composed of an interdisciplinary group of engineering students, having experience spanning the breadth of hardware and software implementations. Our desire is to provide the world with an effective solution that will aid in preventing the prevalent injuries that plague the exercising community. GymSmart will intently work on the development of this product with the goal of improving the lives of many using technological solutions.

Table of Contents

List of Figures

List of Tables

Glossary

TERM	DEFINITION
Light-emitting diode (LED)	It is a semiconductor light source that emits light when current flows through it.
Inertial measurement unit (IMU)	It is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the orientation of the body, using a combination of accelerometers, gyroscopes, and sometimes magnetometers.
Microcontroller	Compact integrated circuit designed to govern a specific operation in an embedded system.

Section 1 - Introduction

Whether you have been exercising for years or are just starting a fitness program, it is important to avoid injuries so you can keep moving closer to your fitness goals. The most common way of getting injured is improper form while weightlifting exercises, especially when the wrong form continued for a longer period. The Pro-Tek form trainer is a device that can prevent such injuries by providing notification to the user when they are performing an exercise in a bad posture. It allows the user to keep track of exercise repetitions as well.

The Pro-Tek is a wearable device that contains IMU, Bluetooth modules and optical sensors to measure joint angles and orientations. It has three main subsystems: First, once the device is ready to go, exercise data is collected through forearm modules (secondary units) and hip module (primary unit); afterwards, the detection algorithms are used to check if the exercise form is correct and to track the exercise repetitions. The notification will be displayed using LED and vibration on the module itself. Lastly, the data is displayed on the user's device through an app that is connected to the primary module through the Bluetooth connection.

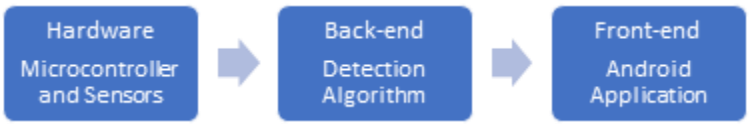


Figure 1: Main stages of system

The purpose of this proposal is to provide a high-level overview of our product and prototype, as seen in Section 2. In Section 3, the risks and benefits associated with our product are outlined. Additionally, a comprehensive analysis of the market and possible competition is provided. In Section 4, we list the costs for each component in the prototype to provide a rough estimate of the required funding. Lastly, Section 5 provides a schedule at which each stage of the project will be completed.

Section 2 – Product Overview

2.1 Background

Exercise is one of the most important activities that human beings can engage in. Exercise aims to sustain and improve the health of an individual, providing them with a better overall quality of life. Our device intends to augment the exercise experience of its users and allow them to improve their health while ensuring it is done the correct way.

The main problem to be solved by our device is injuries sustained during weightlifting. In the United States alone, over 100,000 weightlifting injuries were incurred in 2016. This was an even greater number than in 2010, suggesting that the rate of injuries is only increasing over the years [3]. Our proposed solution is to quantitatively analyze the user's form by measuring the orientations of certain upper body limb segments. If the user's form is incorrect, the Pro-Tek system will provide the user with real-time feedback, indicating that their form is incorrect.

This system was designed to have a relatively small footprint, such that the user could wear 3 individual units held within a compression shirt. The first unit, called the primary unit, is placed on the hip, whereas the other units are fixed to the forearms. These units would be held tightly to the user and would be calibrated to the distinct physical characteristics of the individual. While active, each unit would perform processing on its measured orientation, and generate a notification if the determined orientation were improper. Concurrently with form detection, the units also count repetitions to automatically keep track of the user's workouts. All information acquired by the units is sent to a smartphone application, storing the data for future reference.

The intent of developing this device is to aid in injury prevention during weightlifting. Due to the dynamic and intense nature of this activity, injuries are all too easy to develop. Exercising is extremely important and should not be impeded by injuries, as these injuries can immediately halt further exercise. Our system will hopefully achieve this goal and facilitate the improvement of health for many individuals.

2.2 Scope

The development phase of this project is divided into the Alpha phase, Beta phase, and Final product. Moving along different development stages of our product, Pro-Tek, specific requirement and design requirements will be met. As in this document, the scope will mainly focus on the design, functionality, and detection of the prototype.

The prototype will be able to detect improper user forms during the exercise period. The detection can be realized due to the initial calibration phase that extracts basic information of the user. Second, an algorithm is written in the microcontroller of each module. In addition, each module can turn on different LED lights as an indicator according to different body parts and activates the vibration motor to remind the user.

The prototype will also be able to collect and display angular information on the mobile app via Bluetooth connection with the primary module. After each set of exercises is completed, information captured in each module will be transferred to user's device for display. Messages or warnings related to the improper form in each set can be review and saved in the user's device.

Each of the Pro-Tek modules will be approximately 60 mm long, 40mm wide, and 20 mm high. As mentioned above, the designs and functionalities will get changed when moving from Alpha stage to Beta or final product. As this being said, the size of each module will get smaller, and the shape will be modified to increase the comfort level. The available exercise for improper forms detection on the mobile app will also increase.

Finally, before showcasing our prototype, testing on data collection, detection accuracy, and data display on the mobile app will be performed and the prototype shall have no problem passing all the tests.

2.3 System Overview

The Pro-Tek form trainer is designed to detect improper weightlifting form with the intent of preventing physical injuries. There are three units that are fixed to each forearm and the torso, providing real time orientation measurements for each limb segment. These measurements are processed by the hardware modules onboard each unit, detecting the presence of improper exercise form. In the event of a detected form issue, the units will notify the user through LED and vibration notifications. All of this data is transferred by Bluetooth and stored in a smartphone, allowing the user to reference their prior workout information at a later time.

This system requires three main components, the hardware, software and user interface. The hardware consists of the various sensors and microcontrollers used in acquiring and processing the data respectively. It also includes the LED lights and vibration motors that provide visual and tactile notifications to the user. For communication between the units and the smartphone, Bluetooth is utilised. In terms of the software, the primary component is the detection algorithms that take in the measured data and ensure that it is within specified ranges. Finally, the user interface is how the end user interacts with the system, allowing them to select various exercises or view the data of their previous exercises. A visual depiction of this interconnected system is shown below.

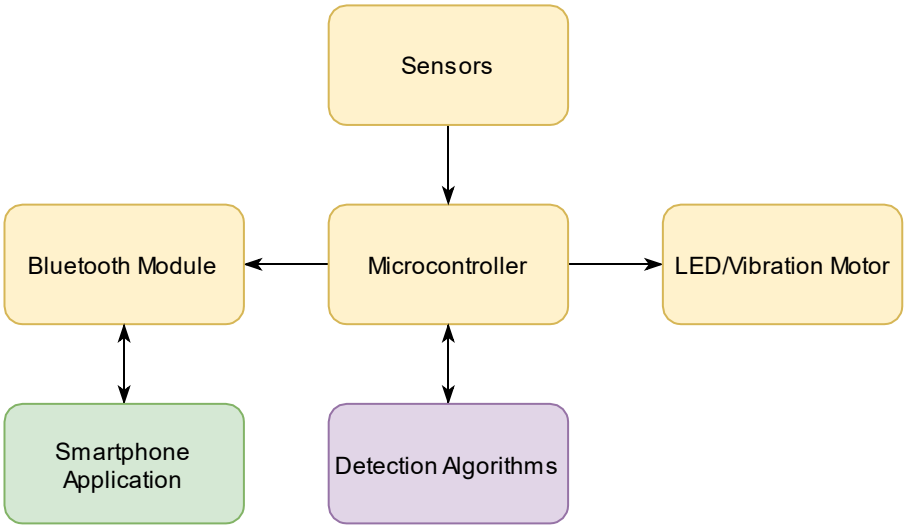


Figure 2.3: High-level system diagram of Pro-Tek (Colour code: Hardware, Software, User Interface)

2.3.1 Hardware

The primary functions of the hardware components are to facilitate the acquiring, processing, and transferring of data. In terms of acquiring data, the inertial measurement units (IMU) and the optical distance sensors provide orientation measurements for the forearm, torso, and wrist. This data needs to be processed such that notifications can be made to the user in specific situations. The microcontroller performs this data processing and outputs commands to the LED and vibration motors during improper form events. To transfer this data to a

longer-term storage location, a Bluetooth module is required. This module interfaces with the microcontroller, making it capable of Bluetooth communication with the smartphone. Each of these components is crucial in achieving a real-time detection and notification system, capable of wireless communication.

2.3.2 Software

The software contains the desired behaviours and functions that are required in the Pro-Tek system. Any procedures such as calibrations, detections, notifications, and data transmission are specified in the software. The main software component is the algorithms responsible for detecting improper form events, due to improper limb orientations. Some basic biomechanical modelling in conjunction with calibration data is used to provide an accurate measure of improper form. If the algorithm detects an improper form event, it sends a command to the LED and vibration motors, activating these components in a specific colour and sequence corresponding to the limb responsible for the improper form. The software and hardware work closely together to achieve the desired system functionality. After a detection session, the algorithm will store and improper form events and transmit the information to the smartphone for display.

2.3.3 Smartphone Application

The final component, responsible for user interaction, is the smartphone application. This application allows the user to communicate with the Pro-Tek units and apply them to their various exercises. The interface has been designed to provide the user with an intuitive and seamless experience, not requiring a complex knowledge of the underlying systems. From this app, the user can select their desired exercise. Subsequently, the app will convey this decision to the units over Bluetooth, informing them to prepare for an exercise set. Upon completion of a given exercise set, the information obtained by the units are sent back to the smartphone and displayed in the interface. Indications of improper form events and the repetition during which they occurred can be viewed here. Also, automatically counted repetitions for each exercise set can be observed. All of this data is stored within the app, allowing the user to access their prior workout data at any time. The data will be presented in an effective manner, maximizing the utility and intuitiveness of the acquired information.

Section 3 – Product Justification

3.1 Risks

The main risk of our product is its ability to properly identify improper form and convey this information to the user. Due to the various calibrations that are required at different instances during a workout, our product will ensure that it is applying its detections in a standardized manner. Also, the detection algorithms will be robustly researched and tested to ensure general safety for varying users. Our product will never enforce a user to engage in improper form but ensure that they never exceed an improper limb orientation.

3.1.1 Generality of Detection

Because there is such large variability between different individuals in terms of physical characteristics, any attempt to measure biometrics can be quite difficult. A simple solution to

this issue is a calibration. Calibrations are done at different points during an exercise session, once at the beginning, and once before certain exercise sets. Because some postures in certain exercises rely heavily on the anthropometry of the user, it is very difficult to devise a general standard for proper form. This calibration instructs the user to set themselves up in the proper form, then takes a measurement to establish a baseline for future comparison. The system becomes tailored to a specific user's biomechanics, increasing the accuracy and reliability of the detection algorithms. Some simple models are also used, where the metrics are more predictable and easily measured. Reasonable approximations are made to create these models, further ensuring the reliability of detection.

3.1.2 Human Factors

Because this device is to be used by the general public, the risk of human factors becomes quite present. Users are required to activate the units and connect them to a smartphone through Bluetooth, also needing to operate the smartphone application itself. If any of these procedures are too complex and unable to be completed, it can incapacitate the system from functioning properly. The main solution to this issue is having an intuitive user interface, allowing for the system to be operated with relative ease. If users are able to operate the system without great complexity, the margin of error is largely reduced and provides the user with an optimal experience. Much consideration has gone into the development of the user interface and testing will be completed to ensure its validity.

3.1.3 Waterproofing Issues

Due to this being a system used during strenuous exercise, sweat and moisture can potentially become an issue for the electronic components. The primary way to combat this issue is to have a waterproof enclosure capable of withstanding the presence of sweat. This can effectively shield the components from water and protect the electronic components for an extended period of time.

3.1.4 Connectivity Issues

Because all 3 modules are wirelessly connected, issues can occur due to the nature of this transmission type. Wireless interference can diminish the integrity of the signal therefore potentially not conveying the proper information. To combat this, the primary units will ensure that the forearm units are actively connected by requiring periodic responses from each of these modules. The smartphone will also ensure that the connection with the primary unit is active in a similar manner. If at any point a message is sent without a response, or a unit is disconnected, the system will notify the user and display a notification in the app. It is critical that all units are properly connected for the optimal functioning of the system.

3.2 Benefits

Except the main purpose of Pro-Tek, which is to prevent body injuries sustained while working out, the proposed product has the potential to extend several more benefits to its investors and end users. As more people has picked up the habit of working out, we firmly believe our product have a tremendous potential among weightlifting community. With continually improvement of our product and perfecting its interaction with the mobile app, Pro-Tek would attract larger attention in the targeted market.

3.2.1 Flexibility

On the one hand, none of the existing devices in the market offer selfsame functions as Pro-Tek. In addition to keeping track of repetitions performed for a given exercise, we provide performance tracking and user form monitoring functions. Regarding the various kinds of exercises that can be performed, we also aim to bring more options in the future through improving the algorithms. Our vision is that every novice exerciser is competent to perform proper forms on their own, which is an unexplored and valuable market.

On the other hand, Pro-Tek consists of three separate modules, one primary and two secondaries. The proposed product can be inserted into designated pockets to reduce discomfort to the user during exercising. Due to this design, our product doesn't limit the location and the surrounding space. Users can choose any of their exercise locations at the same time enjoy the course without being worried to get injured.

3.2.2 Cost Reduction

From the perspective of end users, our product saves themselves a lot of money compared to book a personal trainer. Pro-Tek implements a number of capabilities in the same way as trainer does and avoid the existences of improper forms during common exercise. In the viewpoint of shareholder, the initial Alpha phase needs investments for separated sensors and microcontroller, but the product price is certain to decrease upon massive production.

3.2.3 Health and Safety

As mentioned above, exercise injuries have a direct influence on the results of training. And in most cases, maintaining good postures and keeping the back or wrist in a proper alignment can effectively avoid those common weightlifting injuries. Our system will monitor the forms specific to different positions and timely notify users once they are incorrect. These could hopefully have a great positive effect on health and safety for many users. Under some circumstances, such as coronavirus COVID-19 pandemic, Pro-Tek also avoid the unnecessary of getting in touch with personal trainers. With the help of Pro-Tek, the users could exercise independently and correctly. Moreover,

3.2.4 Reliability and Quality of Service

We ensure that each module pass constant testing before launching on the market. Not only does the strict calibration ensure that Pro-Tek is produced to satisfy varying users, but also the adequate battery life and waterproof functions ensure each module work well for users. Besides, we affirmed the users of a great user experience. Through LED and vibration notifications, the users can prevent injuries adequately, timely and effectively. By interfacing with mobile app, the users can trace and analyze their prior workout information.

3.3 Market Analysis

Based on the report from National Safety Council (NSC), exercise injuries with or without equipment is the most common kind of injuries among sports and creation. In 2019, the amount is up to 468,000, which is even higher than the injuries happened during bicycling, basketball or football. [4] Therefore, it indicated that we have a great need of such device to monitor the proper form during exercise.

We did interview several personal trainers as well. They mentioned that they have seen some electronic detectors which could detect the heart beating or calorie consumption and but have never seen similar device as ours. They believe our device would be helpful for beginners and assist them to prevent injuries. One of them believe that different from other smartwatches which are mostly focused on cardio-training with body displacement calculation (running, cycling, climbing and so on), Pro-Tek will have a significant market.

3.4 Competition

There are a few existed products in the market which provide the functionality of monitoring exercise information, such as Atlas Wearables and Beast Sensor, as shown in Figure 3.4 below. To be specific, Atlas Wearables have the function of measuring repetitions and detecting exercise types, but it cannot measure the wrist angle in order to cautioning the improper form. In like manner, Beast Sensor can be used to recording repetitions and sets power, omitting the form tracking feature.

Figure 3.4: Beast sensor (left) [5] and Atlas Wearables(right) [6]

Though, the biggest competitor will be Oynx. This is an iOS app that detects the form of user with the assistance of phone camera. The detection of improper forms is realized by using the 3D motion capture system built in the phone. However, Oynx can only be used by iOS users and it is required to cooperate with a phone camera. This will limit the users to home workout or having a phone stand due to the space and angle requirement for video capturing. Therefore, Pro-Tek that provides more flexibility on usage experience with from detection makes our product to stand out from the rest of the competitors.

Section 4 – Finances

4.1 Cost Analysis

Table 1 below illustrates the cost of components used in the proof-of-concept phase and Beta phase. An estimation of total cost which have every component including delivery fee and taxes will also be included. Pro-Tek is a system of modules which includes a primary unit and two secondary units, so some components are duplicated.

Component	Quantity	Description	Cost for single unit (CAD)
IMU	3	The IMU combines with accelerometer, gyroscope and magnetometer. It has 9 DOF.	27.1
Distance sensor	2	Adafruit VL6180: Time of flight distance ranging sensor.	17.55
Microcontroller	3	Microcontroller with Bluetooth module support BLE protocol. Compatible with Arduino IDE.	24.38
Bluetooth module	3	DSD TECH HM-10: Bluetooth module with BLE 4.0 communication protocol.	12.99
Vibrator	3	Vibration ERM MTR 10000 RPM 3V: This mini vibration motor worked at 3V.	1.74
LEDs	3	Tiny LEDs has full 24-bit color ability.	2.70
Battery	3	Pro Trinket Li-Battery Backpack: Battery for ITSYBITSY microcontroller.	6.72
Shipping		Shipping fees +Taxes.	79.31
Total			248.12

Table1: Cost of components of Pro-Tek

4.2 Funding

4.2.1 The Engineering Science Student Endowment Fund

The Engineering Science Student Endowment Fund (ESSEF) will be given for projects proposed by undergraduate engineering students in Simon Fraser University. Category B – Entrepreneurial and Category C – Class is available for Capstone project. ESSEF applications will be open for this project when students enrolled ENSC 440.

4.2.2 Wighton Engineering Development Fund

Wighton Fund aims to encourage the projects which benefiting the society. It will be released for students' project on a competitive basis. A project proposal is required for application. Fund will only be available for the projects with successful proposal.

Section 5 – Project Scheduling

5.1 Gantt Chart

Figure 5.1 shows the Gantt chart which encapsulates the team's scheduling for the duration of ENSC 405W and ENSC 440.

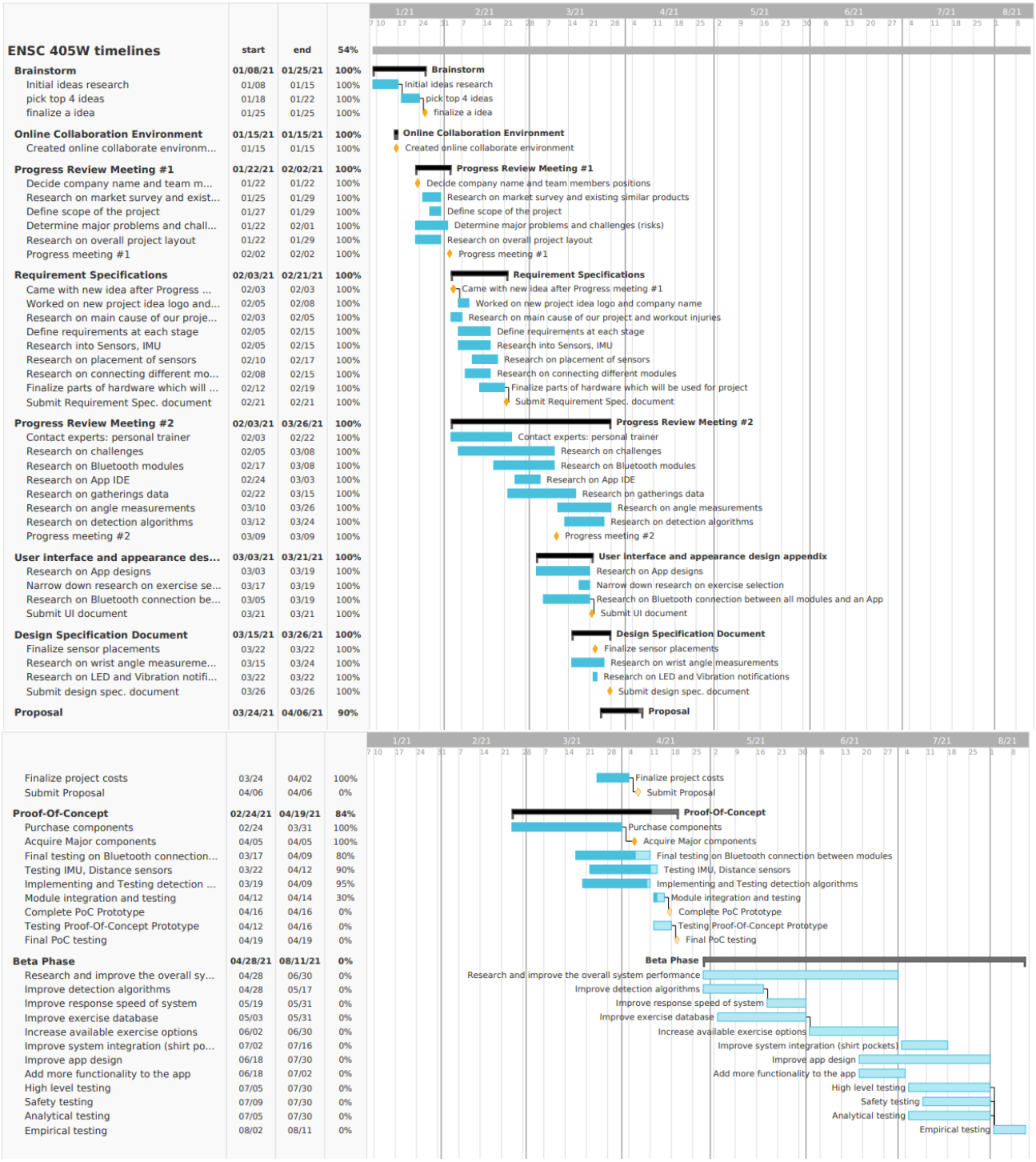


Figure 5.1 Gantt chart for project scheduling

Section 6 – Company Overview

We are GymSmart, a start-up gym wearable device company. GymSmart was founded in 2021 by 6 like-minded engineering students at Simon Fraser University. Our First prototype, the Pro-Tek, is a portable, affordable wearable form trainer device expected to be completed in August 2021. Joint and equal team effort was put into the production of this project proposal.

6.1 The Team

Xiaoyi Zhao, CEO

Xiaoyi Zhao is a 4th year Engineering Science student at Simon Fraser University. Majoring in Computer Engineering, he has a passion of solving problems using his analytical skills. Xiaoyi Z. has worked in Functional & Anatomical Imaging & Shape Analysis Lab at SFU as a Data Quality Assurance where he observed the duty of checking data integrity and developing data visualizing program. Currently he is working on the connection protocol between Pro-Tek's modules. He also loves listening to orchestra at his leisure.

Mitch Edema, CTO

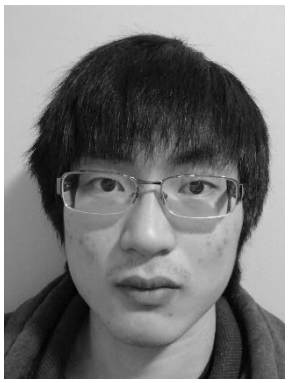
Mitch is a 5th year biomedical engineering student at Simon Fraser University. He is greatly inclined by the prospect of applying engineering methodologies to biological systems, for the purpose of improving quality of life. Currently, Mitch is completing his undergraduate thesis in the Functional & Anatomical Imaging & Shape Analysis Lab, implementing a database system to be used in the pipeline of medical imaging analyses. He is responsible for the inertial sensor and microcontroller integration, as well as developing the detection algorithms for the IMU data. In his free time, he enjoys both watching and playing various sports.

Junjie Xu, CFO

Junjie is a 5th year system engineering student at Simon Fraser University with a strong interest in sensor detection and App development. He previous work experience include USRA researcher in Nanodevice Fabrication Group in SFU and coop worker in Algo Communication Products Ltd. With his research experience and positive working attitude, Junjie will put his efforts on testing distance sensor and developing Android App.

Pei Ning, CIO

Pei Ning is a 5th year Systems Engineering student interested in mechanical solutions, image processing and APP development. He has worked as a research assistant at SFU and at Micmotor New Energy Automobile Co. Ltd, which were mainly accountable for integrating face detection with existing SDK and examining the components of new energy vehicle respectively. Pei is working primarily on implementing the Android APP for Pro-Tek and developing its distance sensor algorithms.



Kwok Liang Lee, CPO

Kwok Liang is a fifth-year Biomedical Engineering student at Simon Fraser University with interests in biomedical devices and software system. He has worked in 3D design and circuit design in his past work experience. He will be responsible on working mobile app for Pro-Tek and system integration.

Harpreet Kaur, CCO

Harpreet is a 5th Systems Engineering Science student at Simon Fraser University. She has a strong interest in the development and improvement of medical and telecommunications devices. She has experience working with databases, servers, testing microwave radio systems and WiMAX lab. she will use her expertise with helping the Pro-Tek team with the database, Pro-Tek App, system integration, and testing the prototypes. She loves going to beaches to enjoy the beauty of nature with her family.

Section 7 – Conclusion

Pro-Tek is a unique accessory for weightlifting and hopes to reduce the exercise injuries related to weightlifting. This functionality is obtained by combining the data collected with several sensors such as IMU and distance sensor. The Pro-Tek modules will monitor the form of user during the whole exercise session and alerts user with LED lights, vibration and warning messages on user's device via mobile app. All the collected data will be stored in user's device locally only and can be reviewed once save. Therefore, users have the ability to track which part of movement needs more attention.

The Pro-Tek module doesn't required any camera feature and can be easily wear on specified body parts with the straps along with the products. These straps are used to increase the stability will doing the calibration before user starts exercising.

This document provides a brief background and introduction of Pro-Tek functions, implementations, as well as a timeline for the scheduled product delivery. Besides that, analysis of current market for similar products is conducted. The result shows the amount of people suffering from improper forms during workouts is very large and currently there is little of presence of products like our Pro-Tek.

The GymSmart's Engineering Team is a group of professional and talented people consisted of system, biomedical and computer engineers, who devoted themselves to bringing Pro-Tek to the public and aiming to allow more people to be free from workout injuries while having the joy of exercising.

References

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