Assignment #8 - Deployable Prototype Documentation

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Senior Citizen’s Sway and Compliance to the Otago Program

Group 4

Members: Daniel Diaz, Tyler Fox, Jesse Root, Allen Chau

Instructor - Russell Tatro

TABLE OF CONTENTS

EXECUTIVE SUMMARY………………………………………………………………….. iv
ABSTRACT…………………………………………………………………………………. 1
I. INTRODUCTION……………………………………………………………………….. 1
II. OUR SOCIETAL PROBLEM…………………………………………………………….. 4
A. Issue of Balance and Fall Rate……………………………………………………….. 5
B. Issues with Data Gathering…………………………………………………………… 5
C. Causes of Imbalance………………………………………………………………….. 6
D. Severity of Falling……………………………………………………………………. 6
E. Injuries Associated with Falling……………………………………………………… 6
F. Mental Effects of Falling…………………………………………………………….. 6
G. Cost of Falling………………………………………………………………………… 7
H. Measuring balance…………………………………………………………………… 7
I. Benefits of Improving Balance………………………………………………………. 7
J. Methods of Improving Balance………………………………………………………. 8
K. Compliance/Adherence……………………………………………………………… 8
L. Factors That Predict Low Compliance……………………………………………… 9
M. Issues with Lack of Compliance……………………………………………………. 10
N. Solutions to Compliance……………………………………………………………. 10
O. New Project Understanding…………………………………………………………. 11
III. REVIEW OF DESIGN IDEA CONTRACT…………………………………………… 13
IV. FUNDINGS FOR PROJECT…………………………………………………………… 16
V. PROJECT MILESTONES……………………………………………………………….. 18
VI. PROJECT WORK BREAKDOWN STRUCTURE AND TASKS ASSIGNED…………. 19
VII. RISK ASSESSMENT AND MITIGATION IN WORK BREAKDOWN STRUCTURE…. 22
B. Website and Database……………………………………………………………….. 23
C. Balance Measuring Device…………………………………………………………... 23
VIII. DESIGN PHILOSOPHY……………………………………………………………… 25
A. Low Cost……………………………………………………………………………… 25
B. Low Impact…………………………………………………………………………… 26
C. Clinician Focused with Users in Mind……………………………………………… 26
D. Simple and Easy……………………………………………………………………… 27
IX. DEPLOYABLE PROTOTYPE STATUS……………………………………………… 27

A. Exercise Tracker App……………………………………………………………………. 27
B. Online Accessible Data…………………………………………………………………. 28
C. Balance Measurement Device…………………………………………………………. 29
X. DEPLOYABLE PROTOTYPE MARKETABILITY FORECAST……………………………. 30
A. Testing……………………………………………………………………………………. 31
B. Hardware Changes……………………………………………………………………. 32
C. Software Changes……………………………………………………………………. 33
XI. CONCLUSION……………………………………………………………………….. 34
APPENDIX A. ………………………………………………………………………………… A-1
APPENDIX B. ………………………………………………………………………………… B-1
APPENDIX C. ……………………………………………………………………………….. C-1
APPENDIX D. ……………………………………………………………………………….. D-1
APPENDIX E. ……………………………………………………………………………….. E-1
APPENDIX F. ………………………………………………………………………………... F-1
APPENDIX G. ……………………………………………………………………………….. G-1

TABLE OF FIGURES

FIG. 1: LEVEL OF COMPLIANCE……………………………………………………………8
FIG. 2: REASONS FOR MISSING MEDICATIONS………………………...……………..9
FIG. A-1: APPLICATION CLIENT SIDE 1…....…………………………..…..…………...A-1
FIG. A-2: APPLICATION CLIENT SIDE 2………………………………….….……......A-2
FIG. A-3: APPLICATION CLIENT SIDE 3…………………………………….……..…...A-3
FIG. C-1: WEBSITE FLOWCHART………………………………..…..……….....…..C-1
FIG. B-1: HARDWARE SCHEMATIC……………………....………..………….........B-1
FIG. A-4: DEVICE OFF……………………………..…………………………………..A-4
FIG. A-5: DEVICE ON…………………………….....…..……………………………A-4
FIG. A-6: MICROSD CARD INSERTION SLOT…..…………………………….....……A-5
FIG. A-7: MICROUSB CABLE..………………………………………………...……..A-5
FIG. A-8: MICROUSB CABLE INSERTION SLOT...…………………………………..A-5
FIG. D-1: TOP-DOWN VIEW OF ENCLOSURE BOX…..………………………………D-1
FIG. D-2: SIDE VIEW OF ENCLOSURE BOX…………………………………...……D-1
FIG. D-3: LID TO COVER THE ENCLOSURE BOX…..……………………………..…..D-2
FIG. B-2: SRAM DATA TRANSFER RATE……..…………………...…………….…..B-1
FIG. B-3: MICROSD DATA TRANSFER RATE...………………….………………..B-2
FIG. 18: DATASET FROM ALLEN (LEFT) AND DANIEL (RIGHT)……...…………....32

TABLES OF TABLES

TABLE I - GROUP 4 ESTIMATED BUDGET……………………...…………..…...……16
TABLE II - GROUP 4 FINAL COST FOR PROJECT…………………………………...17
TABLE III - PROJECT WORK BREAKDOWN STRUCTURE AND HOURS……...…..20
TABLE IV - RISK ASSESSMENT MATRIX FOR WBS………………...………………22

EXECUTIVE SUMMARY

This report summarizes the work that went into creating our overall project. Topics such as our societal problem, design idea contract, risk assessment, and design overview are all covered in different sections of this report. The goal of our project is to tackle the overall problem with lack of compliance from participants within the Otago exercise program. By creating easy to use software and a non-intrusive measuring device we planned on making gathering data easy for the participants while they perform their prescribed exercises.

Our societal problem focuses on what the issue that our project was designing to solve. Here we discuss the physical aspects of why our project is needed to help improve gathering of data to improve a participant’s balance. This section covers the importance of a person’s balance and what can cause it to degrade. Factors such as age and injuries are discussed here along with how the data gathered by our hardware can help clinicians better understand the progress of the participants that use it.

Our idea contract in this report lays out what aspects our project aims to achieve which in turn solves our societal problem. Topics such as hardware components and what they are used for is described here. Software components such as button size and color coordination are explained here to give an understanding of how this project makes it easy for the participant to comply with the program’s requirements. Since compliance is a main focus of this project this section is important as it explains what the participant interacts with directly and how this project aims to make their process easier which in turn will improve their willingness to progress in the program.

Project work breakdown and the tasks assigned is also transcribed in this report. This section lays out which member of the group was responsible for each aspect of the project. Each component of the project focused on creating a feature that would in turn solve our overall societal problem. Here the overall project is broken into 3 sections; the sway measuring device, online database, and the mobile application. Each of these components are explained to why they were designed to their current state and why they are important to the overall project.

Risk assessment and mitigation are also discussed within this report. This topic breaks down how important each section of the project is and the risks of it failing. We give possible reasons of each of these components to fail in actual use and discuss ways that our design tries to prevent it. Focusing on mitigating the risk to each component is explained here along with the impact that it has on the overall project.

Lastly, we explain the projects overall marketability. This section covers the real-world application of our project and how it can be used to solve our societal problem. Subjects such as changes to the online database, hardware and software due to the results that we obtained through our testing is discussed here. Explanation for each change due to testing is laid out to show how our project has developed from an idea to conform to a usable product.

ABSTRACT

This report dives into the development of our final deployable prototype. Throughout the development of this deployable prototype we worked hand in hand with Dr. Lazaro from Sacramento State's Physical Therapy Department and the clients in the Otago Program, a program aimed to improve the balance in those aged 65 and above. Each section in this report will breakdown what was developed over the course of our project. Every component of our project was intended to improve overall compliance of participants in the Otago exercise program and to aid their clinicians with accurate data on their balance. In order to achieve this goal, we have developed a cost-effective balance measuring device that is intended to gather data on the balance of the participants in the program while they performed their prescribed exercises.

Keyword Index - Otago Exercise Program, Final Deployable Prototype, Balance measuring device, prescribed exercises

I. INTRODUCTION

From the first day of our course we set out to design a product that would help improve the compliance of member so the Otago exercise program and aid their clinicians with accurate data on their balance progression. We set out to design both a hardware and software solution to these needs. Through the use of a simple mobile application in conjunction with an online database we allowed easier access for both the participants and their clinicians to stay current on progression through the program.

Participant progression is the goal of the Otago program and to aid with that idea we also designed a wearable hardware device that records their 3-dimensional movement when performing their prescribed exercises. This data is used to aid the clinician in deciding which exercises to prescribe to the participant along with giving them a deeper understanding on how much the participant is progressing in the program.

Improving compliance and accurate data collection are the main focuses of our project. These factors are important for the fact that one of the main reasons why people in the program do not succeed in improving their balance is due to not fully complying with the program requirements. The current issue with participants in the Otago program not fully complying with the regime is the fact that overall it is not very user friendly.

Since the target group of people who are participants in the Otago program are over the age of 65 and often have vision impairment amongst other physical impairments making improvements to the way they interact with recording of data is important. By making a simple recording application for each of their exercise sessions this project inherently will increase the participant's willingness to complete their data recording.

Each of the exercises in the Otago program are prescribed based on the participant's physical capabilities when they begin the program. As a participant progresses through the program they will be assigned different exercises or have the difficulty of the exercise increased. Currently the exercise increase determination by the clinician is based on what the participant tells them over a 6-month period this can lead to best guess determination. Using the wearable device that we have created the participant can wear it during their prescribed exercises and have it gather data on their balance without it interfering with their movements.

The data that is collected and is stored on the device which then can be uploaded to the online database at a later time. This data that is collected through our device will allow the clinician to better prescribe exercises to the participant which in turn will also improve rate of success in the program. By having the data transferred to the clinician through the online database it allows more access to the data than just relying on physical visits of the participant to the clinician.

This report will describe each part of our prototype development and the components of each part. Each of these parts serve a purpose in our project with the goal in mind of solving our societal problem. By explaining each developmental step of our prototype, we show the progression of the idea of what we had hoped to accomplish to our final deployable prototype.

Funding of our project was done all through the team members. The goal was to create a cost-effective device as this would be a main focus for our marketability in the future. All of the components purchased for this project were relatively cheap as to keep costs down. The software components did not cost anything since we did not develop in an environment that required a license fee. Throughout the development of the project different components for the hardware device were purchased. These components were purchased after actually working with the initial components purchased and provided more stability and accuracy. These new components only impacted the overall cost of the project slightly, so we were still able to produce a deployable prototype that is cost effective. In our report we break down in more detail the components used and why they were chosen to meet this goal.

In this report we also explain the milestones that needed to be overcome when developing this product. These milestones were not as severe as they could have been when developing a larger scale product. These milestones were mainly issues with accuracy with the first type of IMU that was purchased as it led to lots of drifting when idle. Software didn’t have many issues as the development environment for the mobile application already had an integration with the online database. We explain in more detail what these milestones were and how we overcame them.

With developing any project there are risks that arise. In this report we explain the risks that we foresee happening in real life use of the deployable prototype. We also go in depth with the mitigation options that we have utilized for these risks in this report. By making sure that when developing the software components of this project with robust functionality in mind we would only have to consider the internet connection between the mobile application and the online database to go down as a risk. This is not something that is controlled by our project so that is a risk that we can only mitigate through the use of local storage of the mobile application. The hardware device has physical parts that all work together to where if one component fails then the system itself fails. We address this in more detail in this section of the report.

Our design philosophy is a simple one, create a low-cost balance measuring device and a simple to use mobile application. By sticking to this idea through the development of the deployable prototype we were able to create the final product that met these requirements. The reason for this philosophy was to make sure that the overall product would not cost too much to the point that only a select few people would be able to obtain it. By making it cost effective we create a much larger pool of people that would benefit from the end product. Having a simple to use interface that the participant uses also increases the products desirability.

If the mobile application is too difficult to use, then it would be hard for the target group to learn and want to continue using our product. Since the target age group that this product aims for is above the age of 65 having simple and easy to use components are the key for this project's success. In this report we go more in depth to why we had this mentality when developing the product along with the benefits that it provides to the target user.

As of now our deployable prototype is fully functioning. The prototype meets all the required features that we set out to achieve when we first started to develop it. Our deployable prototype set out to be an accurate balance measuring device and simple to use mobile application. Our hardware accurately records the pitch roll and yaw of the participant in the Otago program when worn. The device successfully stores that gathered data onto an internal removable microSD card.

The mobile application has buttons that are much larger than the standard button size that applications typically have. The mobile application also has a simple and linear interface to avoid making recording the required data on the prescribed exercises too difficult. A notification can be set by the clinician for any time of the day and it successfully repeats at that same time every day. Positive feedback displays as intended within the application once an exercise is completed.

Uploading the data both from the removable microSD card from the device along with the recorded data from the application also works as intended. This data then successfully uploads to the online database that is active at any time in the day. This data can be displayed in raw form or through graphical charts through the online database. These are all components of the project that meet or exceed the expected goals that we set out to make when starting this project.

By sticking to our budget and work breakdown structure of components we have successfully implemented our feature set for the product. All of our features that we have implemented all attempt to tackle improving compliance for participants in the Otago exercise program. By focusing on the target user pretty much the whole time when developing this product, we feel we feel we have achieved the goal of meeting all of the features set which in turn achieved the goal of providing a solution to our societal problem.

II. OUR SOCIETAL PROBLEM

Falling is very common among senior citizens, those above 65, over the past years. It's one of the leading factors of mortalities and yet an underestimated issue. According to the National Center for Injury Prevention and Control and a report from Morbidity and Mortality Weekly Report, in 2016, a total of 29,668 U.S. residents aged >65 years died as a result of a fall in [1]. Balance and stability have been proven to be indicative of overall health. As the general population grows older with time, our bodies start to deteriorate. Cells in our bodies start to die off affecting our overall capabilities of doing a task. A person who's in their seventies won't have the same physical and cognitive abilities as they were in their twenties. Our bones become weak, physical abilities decline, and even our balance becomes off. Once people hit the later part of life, they won't feel the same way as they were at their peak. Even maintaining an erect position while moving around is already a stress on our bodies as it keeps balance. Cognitive abilities become rough and worn down to the point where we lose sense of body positioning leading to fall injuries. Other factors such as inactivity plays a role in falls as well. That's why maintaining overall health, as we age, becomes important.

The issue of falls and its risks revolve around the elderly, those above the age of 65, who require assistance in their daily lives. Falls are often overlooked, and solutions may appear simple but there's more to it. Lack of balance is the main underlying source of falls. The issue is that improving balance needs a specific exercise regime that's specifically tailored to the individual based on physical capabilities. Assuming senior citizens commit to the plan, fall rates can drop and balance can be restored.

Their dependencies stem from being unable to keep their balance determined by tests such as standing in an upright position from a seated position or keeping their posture sitting on an exercise ball. There have been alleviations to help mitigate this issue such as a walking cane or a walker, but the main issue of self-balance still lays beneath. They still don't have the ability to balance themselves properly without relying on some tool. Even so, those aids mentioned earlier require some strength in the arms and legs to keep the main body upright. It's better to tackle the underlying cause of balance by restoring their ability to do so which is where my group and I come in.

In terms of our paper, we'll discuss the issue of balance and fall rate and what factors come to play. Factors such as old age and deteriorating effects on the body are detrimental issues that needs to be considered. As a result, the elderly will be prone to falls causing injuries such as bone fractures or even head injuries. Recovery will be slow and even death may come if an individual fall multiple time.

Data gathering may also be a viable issue if the individual has trouble with modern technology and needs a simpler interface or even having a product to wear that's comfortable and stylish. Factors like these causes a low compliance rate which raises another issue.

Signs such as a history of injuries, impaired cognitive abilities, and balance are key factors to knowing why elderly patients fall. The severity that comes when falling is also important to talk about as its labeled one of the factors of mortality. A simple fall may seem that way but, it can cause significant pain or damage to the body. A hip fracture from falling can cause impaired movements correlating to imbalance.

Not only are there physical effects that comes from falling, emotional affect come into play as well. Once someone falls, they can feel distressed being functionally impaired. The individual that fell may experience fear in falling again and damaging their body. This eventually leads to a state of depression and possibly even death when reaching a certain point. There are many resulting effects that come from falling and some ideas that may alleviate the aftermath of falling which is later discussed in this paper.

Towards the end, we'll talk about our current prototype and its functions and features. We'll give a detailed explanation of our better understanding of compliance and the importance of senior citizen's balance.

A. Issue of Balance and Fall Rate

As we get older our overall health becomes much more important to maintain. As the body ages the ability to protect against disease and other negative health effects becomes more difficult. Along with illness the body also has a harder time recovering from physical injuries as well. This difficulty of the elderly having longer recovery times for physical impacts to the body, if they can recover at all, can lead to higher mortality results. Focusing on how issues with balance can directly affect fall rate can give a better understanding on how to reduce it overall. These issues need to be considered when trying to find new ways of being able to determine how likely an elderly patient is to fall. This can help reduce how often they fall. Falling is the leading death rate for elderly population over the age of 65. Even when a fall is not fatal on its own, it is common for an elderly patient to sustain an injury from that fall raising their mortality rate in the near future.

One out of five falls causes a serious injury such as broken bones or a head injury shown in [2]. These injuries lead to costly hospital trips, medication and physical therapy. After a fall it is very likely that the individual will fall again which may lead to even more treatment or a further sustained injury.

B. Issues with Data Gathering

People over the age of 65 are more prone to having a serious injury due to falling. This group gives especially difficult challenges when trying to tackle the issue of falling. Factors such as lack of knowledge of some modern technology can make gathering and utilizing knowledge of how to prevent falling difficult. Personal pride may also be a reason why falling may not be recorded in the first place and can lead to less serious injuries to go unnoticed for long periods of time. Finding ways of conveying to the elderly population why improving balance can help with their overall health can be a challenge. Using modern technology such as apps for recording can be a solution but it needs to be tailored to be extremely simple. Another issue with using technology to record things such as balance in an elderly patient is that they may refuse to want to wear something that they feel is "unfashionable." This issue may not seem to be a big deal when the scope is an individual's well-being, but it does play a factor. Finding an effective way of gathering data that will not intrude on their personal wants can prove to be challenging. The patients that the data will be collected from will have a sense of style and self that they may not want to have intruded by certain things such as wearable monitoring devices.

C. *Causes of Imbalance*

There are a lot of different factors that can lead to an elderly patient having poor balance. Previous injuries that their body has not recovered from entirely can lead to an overall imbalance when moving or standing. Overall aging of the inner ear can also be responsible for lack of balance in the elderly. These are just a few more common reasons why over time an elderly patient may have problems with their balance.

Some of these reasons can be seen without the need of special testing such as those reasons which cause limited movement in the body. Other reasons require a further look and testing to find the cause such as neurological disorders. The main issue is that not all reasons are clear to see what causes imbalance so new ways of gathering data may be needed to diagnose more accurately.

D. *Severity of Falling*

· Falling is one of the leading factors in mortality rates in people over the age of 65. The cause of falling in people in this age group can be due to multiple factors such as previous injuries that obstruct movement, impaired vision, and lack of balance. The main focus of the issue will be on balance. Balance can be used as an early indicator for the elderly and their possible chances of falling. Lack of balance in an elderly patient can mean a lot of things including a neurological illness or a physical issue such as a fracture to the hip bone. Falling is a preventable issue that is connected to the highest reason for mortality rates in people over the age of 65. When a fall isn't fatal the result can still limit or cause a significant difficulty in the life of the person who fell. "Soft tissue injuries or minor fractures can cause significant functional impairment, pain, and distress. Even "minor" falls can trigger a fear of falling in older persons, leading them to limit their activity and lose their strength and independence as mentioned in [2]. Outside of falls being the main reason for mortality in the elderly, falling can impede on their way of life.

E. *Injuries Associated with Falling*

There are many types of injuries that can result from the elderly falling. Small injuries that may not be serious on their own can lead up to a more serious injury as time progresses. Eventually a fall will lead to a larger more serious injury that can be due to many factors such as the environment that the fall occurred. Fractures are the most common types of injuries sustained by the elderly when they fall [3]. Common bones that are injured include their hip bone. This is probably the most devastating bone for an elderly person to fracture due to a fall. This injury can easily cause imbalance in movement for the person that has the injury. Often times after this type of injury an elderly patient will not be able to live at home without some sort of daily care. Other injuries that are common to the elderly after a fall include fractures to their spine, leg and ankles. These injuries also can interfere with an elderly person's balance which in turn can lead to more falls. If an elderly patient finds themselves in a situation where they are unable to get up on their own the result can be fatal.

F. *Mental Effects of Falling*

For the elderly falling can just be as emotionally rehabilitating as it can be physically. The idea of not being able to move around as easily or as safely as they once were able to can lead to emotional distress which can in turn cause even more of health issue for them. Depression or lack of motivation to do just simple activities can be a result from having an injury from a fall. It is not uncommon to have an elderly patient who suffers from chronic pain from the result of a fall to have depression. This issue is not as easily seen as an injury that is a direct result from a fall. Depression is a common illness that is seen in the elderly population which has been shown to lead to higher risk of other medical illness [4]. When this occurs, a prescription for this depression may be made to combat the depression which can cause the issue to increase. The management of depression in fall-prone individuals is challenging, since antidepressant medications can increase the risk of falls, selective serotonin reuptake inhibitors may increase the risk of fragility fractures, and data are lacking about the effect of fall rehabilitation programs on clinically significant depression [5]. A good representation of how falling and depression is a problem that can end up hand in hand is below [6].

G. *Cost of Falling*

Cost is another factor to consider when bringing up the subject of elderly population falling [7]. Hospital trips as a result to accidents due to falling happen quite often. The cost for healthcare due to falls is significant which can be reduced by reducing fall rate. According to the report "The direct costs of fatal and non-fatal falls among older adults - United States", "Direct medical costs totaled $616.5 million for fatal and $30.3 billion for non-fatal injuries in 2012 and rose to $637.5 million and $31.3 billion, respectively, in 2015." [8]. This goes to show that overall the cost of falling in the elderly population in the United States is continuing to increase. With the increasing elderly population due to people having longer and healthier overall lifespan the economic burden of falling show no sign of slowing down.

H. *Measuring balance*

Being able to measure how much a patient moves from side to side while they are sitting or standing can lead to an estimate of how likely they are to fall. Being able to prevent falls from occurring instead of finding ways to deal with them is a far more effective way of handling this problem. If a physician is able to see the rate of sway back and forth while an elderly patient is in the sitting position, they are able to determine their likelihood of falling in the future. These measurements can also be used in other balance determining exercises such as the 'get-up and go test" which also can be early indicator for falling. The "get-up and go test" requires patients to stand up from a chair, walk a short distance, turnaround, return, and sit down again [9]. This test has been so far viewed as a successful way of determining the balance of an elderly patient. Even with the agreed success of utilizing the "get-up to go test" there are still a significant amount of the elderly population that suffers from falling due to balance issues. In order to attempt to combat this issue a furthermore detailed test of an elderly person's balance should be considered. Small swaying back and forth while a patient is sitting may lead to furthermore meaningful diagnoses of why the imbalance is occurring.

I. *Benefits of Improving Balance*

The benefits in proving balance can be very good for the overall health and longevity of the elderly. Besides physical benefit to improving balance, mental health can benefit as well. A lot of elderly people choose to live at home as opposed to living where in a housing situation where they have constant medical observation. Sometimes they live alone which can be extremely difficult when the risk of falling is an everyday fear due to lack of balance. The confidence that is obtained in the ability to be self-sufficient in everyday tasks that are required to live in their own home can be a major mental benefit.

J. Methods of Improving Balance

There are different ways to help improve balance in the elderly. Simple exercises that can be done at home that are recommended by their physician are probably the most effective and simple ways of improving balance in elderly patients. The main issue that comes from self-recording and conveying of completion of these exercises is that they may not be accurate. When exercises are set by an elderly person's physician to improve balance it is very important to make sure that these exercises are completed. An issue that often happens is that the patient may say they have completed all the exercise prescribed by their physician when in fact they have not. This can be due to having forgotten their actual completed amount or not being able to keep track of how many needs to be completed. Having a simple app to record the amount of exercises that the elderly patient has completed can be quite useful in making sure that the needed amount of exercises was completed and not just an estimate.

K. Compliance/Adherence

It has been established that senior citizens are subject to a wide variety of very serious diseases and conditions such as diabetes, heart disease, and limited balance. Thanks to modern medicine there exists very effective forms of treatment for most issues correlating with health. However, an obstacle arises in the fact that adherence to medicine and treatment regiments is fairly low in senior citizens. In fact, according to a study conducted by Shruthi and Jyothi at the Tertiary Care Hospital on 251 subjects, only about 45% of senior citizens comply with their personal medications and prescriptions [10]. This shows that over half of senior citizens do not comply with medical regiments tasked to them. The percentage of senior citizens in the study whose adherence to medication was deemed "poor" was at a remarkable 19%.

Level of compliance.

Level of Compliance*	n (%)
Good	114(45.41)
Moderate	89 (35.45)
Poor	48 (19.12)

(n=251)

*Assessed by pretested structured questionnaire as per modified Morisky Adherence Scale: 0 - 5 (very poor); 6-10 (poor); 11-15 (moderate); 16-20 (good)

Fig. 1: Level of Compliance [11]

The issue of adherence and compliance stems further than just senior citizens not taking their medication. Compliance becomes an issue with prescribed recommended exercises and physical regiments as well. Because of the constant decline in the human body as we age senior citizens are often tasked with exercises that go along with their selected treatments of their disease. The physical components of these treatments are crucial to the effectiveness of the overall treatment.

Reasons for missing the medications.

Reasons	Number of subjects
Forgetfulness	14
Polypharmacy	9
Complexity of regime	6
Lack of time	4
Side effects/Adverse events	3
Dependency on caretaker	1
Financial constraints	3
Non availability of medications	7
Negligence	2

Fig. 2: Reasons for Missing Medications [12]

Lack of compliance in senior citizens stems overwhelmingly from the mental decline of senior citizens, however many other reasons contribute. Figure # shows the reasons with the largest impact for lack of compliance. The study from the Tertiary Care Hospital shows that forgetfulness is the number one reason for non-compliance [10]. Memory is possibly one of the clearest forms of mental decline that can be observed in a senior citizen. If an individual cannot remember to take their pill, then they won't take their pill leading to non-compliance even if it is not desired. This issue is magnified dramatically because of the overall complexity of some of the medical regiments senior citizens may have. It is not rare for senior citizens to be taking multiple pills a day each with their own requirements. One pill may need to be taken early in the morning while another may need to be taken later in the evening. Certain pills even require that they be taken on an empty stomach or right after a meal. Exercise regimen can also be quite complicated. Some regiments will require multiple different exercises to be completed at a certain time. The amount of repetitions to be completed for each exercise adds to the complexity. All of these requirements of medication and physical exercise create an overall medical regiment that may be hard to follow for senior citizens who already have declined memory ability. So, despite desire to complete a regiment, some senior citizens are not able to correctly complete them due to their own limitations.

L. Factors That Predict Low Compliance

There are a number of factors that can be used to fairly accurately predict general compliance to medical regimens. The most indicative factor that demonstrates general compliance is age. According to the study performed at Tertiary Care Hospital, senior citizens between 60-70 have the highest compliance rate that can be labeled as "good" at 55% [10]. This number drops dramatically for the ages 71-80 at 25% and an astounding 0% at ages greater than 81. While this study is relatively small when it comes down to participants, it still demonstrates certain trends that would certainly be present in a larger study. Age being such a predictive factor makes complete sense simply because of the limitations that arise as individual's age. Both the mental and physical decline contribute to the general lack of compliance in medical regiments.

Highest level of education was also a factor that was fairly indicative of general compliance. Individuals who are better educated are much more likely to understand the significance of their prescribed regiments. This understanding of the significance is absolutely crucial because the individuals are aware of the consequences of failing to follow their medical regiments. For less educated individuals these consequences may not be as well-known and therefore not feared.

Another factor that accurately predicts how compliant individuals are with their medical regiment is their family status. That is, whether or not the senior citizens live alone or live with someone else. Individuals who live alone have a very low "good" compliance level at only 18%. This compared to 54% for senior citizens who live with a spouse. That is a very large discrepancy that supports the idea that senior citizens are better off not living alone in terms of following medical regiments.

M. Issues with Lack of Compliance

Lack of compliance is often ignored as a serious issue however lack of compliance is an issue that affects many different aspects of society. The first way that it is a major problem is the immediate effect which is a decline in the health of senior citizens. The health of every member of society is a valuable thing so the fact that many senior citizens do not comply with their medical regiments is a net negative for society. Aside from the huge impact on the individual from lack of compliance is the impact on society. The less healthy that senior citizens are on average, the larger the strain that senior citizens put on hospitals and doctors' offices. If compliance were to increase overall health of senior citizens would as well. This would lead to a medical environment where hospitals are not as congested as they are now. This would alleviate the stress on these medical facilities and the employees that work on them. This would allow for patients at these facilities to receive more attention from the doctors and the nurses. Things such as donor organ lists would also be less impacted. Medical facilities would immediately view the benefits of having senior citizens comply more with their medical regiments.

Programs such as Medicare would also see the immediate effects of senior citizens complying with their medical regiments. At the moment, there are thousands of senior citizens who health care depends solely on the support of Medicare. Medicare is a health care program that is funded directly through the government. This means that Medicare costs the taxpayers money. While this isn't an issue in itself, it becomes an issue when senior citizens do not comply with the medical regiments that are funded or subsidized through these government programs. Essentially if senior citizens do not comply with their prescribed regimen then the money that is spent on them is wasted. Additionally, if senior citizens do not comply with their regiments then their health suffers. When their health suffers they become an even larger strain on the medical world. This waste of money is not something that should be overlooked as Medicare is a fairly large portion of the national budget. With increased compliance of senior citizens, the money spent here would potentially not be as needed as much and therefore could be allocated to other programs. The fact is, that a lack of compliance in senior citizens is a waste of resources. These resources are limited and very valuable and should not be taken for granted.

N. Solutions to Compliance

There are many possible ways to tackling the issues of compliance. However, many of these methods are very costly and are potentially unjustifiable because of their large costs. One of the largest ways would be through human supervision of senior citizens to ensure compliance. This is possibly the most effective of the solutions to compliance. However, this solution also provides the largest cost. Caregiving is a huge industry in this country, but it is far from affordable to everyone. While it would be fantastic to have a caregiver with every senior citizen to monitor them and ensure their adherence to their medical regiments, it is simply beyond the realm of possibility. Most people cannot afford to have a caregiver to this extent.

A slightly more reasonable solution is a retirement home. In most retirement homes, the senior citizens receive some sort extent of supervision. This supervision could be used as a way to remind the senior citizens of the medications and tasks they need to complete in order to follow their medical regiments. As discussed before, memory is the largest hindrance to compliance, so a reminder from a partial caregiver would work wonders toward combatting lack of compliance. This method, while also very costly, is much more reasonable than having a personal caregiver.

With the advances made in technology, new ways of tackling compliance are constantly being made. For example, there are different devices that are beginning to arise that remind and allocate the proper medication for senior citizens to take when they need to take them. This removes the memory issue for senior citizens completely. It also solves the issues of potentially very complex medical regiments. There are many other examples of technology that are being created to tackle the issue of senior citizen overall health.

We ourselves are attempting to design and create a product that will be used to improve compliance. While the ultimate goal of our project is to improve balance, we do so by improving compliance in the Otago Program. By improving compliance in the Otago program, which has been proven to improve balance, we indirectly improve balance. By giving senior citizens a chance and method of recording their progress in the Otago Program we hope that they will be more inclined to adhere to the program.

O. New Project Understanding

Through development of the project, compliance seems to be the main way to combat the issue with patients being able to complete the program. Originally gathering useful data from the deplorable prototype while the patient actively performs their prescribed exercises was the main focus of the project design. Through the course of developing the relationship of the device and the application in tandem with the online database it became clear that this project will aid more so on the compliance aspect for patients rather than directly being able to influence their balance.

The data that is gathered from the device is useful as a secondary view on the health and progression that the patient has when actively going through their prescribed exercises. Since the exercises themselves are what directly affects the patients, the data that is gathered is more of a secondary progression insight. The gathered data allows the clinician to see if the regimen that has been prescribed is working appropriately or determine if further changes need to be made.

The companion application that is being developed for this project has always had the main focus of making compliance with the program easier. Since the patients that are a part of the Otago program are mainly in the age group 65 and older and have a higher possibility to have vision impairment interactive applications can be a challenge for them to use. Through the development of its features it is clear that making the application as simple and linear as possible will lead to patients using it more often and adhering to the program. If the application was designed to be too complex or have inputs that are difficult to see the patient may not use the application correctly or at all which will do the opposite of what we hope to accomplish.

Since starting this project, we have come to realize that the main reason why patients to do not complete this program all the way is due to how not user friendly the whole process is to them. Whether it is the complexity of the way that exercises are prescribed or how they have to convey their progress to their clinician compliance is the greatest issue. Constant research is being done to reduce the complexity of this project to the patient that will be using it. From different ways that the patient will be able to wear the hardware device in a comfortable non-intrusive fashion to how the patient will be presented the feedback from their overall progress ease of use will directly lead to use of the project.

Overall falling among the elderly is a major issue in modern society [11]. Falling raises the mortality rate of the elderly in many ways [12]. The physical injury itself doesn't often cause death by itself but the following effects do. The most common of this is sickness while being unable to move during recovery. Not only is there a large negative effect and a raised chance due to lack of balance, there is also the issue of osteoporosis and other bone degradation effects which makes injury nearly unpreventable without proper fitness. As the largest generation of this century gets older it raises issues never faced on such a large scale. Advancement in the medical field has led to further issues as people are living longer than ever. The size of this population raises the need for a solution or reduction of falling. There are numerous causes for falling among the elderly but the largest of these comes from lack of balance. This lack of balance can come from a variety of effects. Some have injuries from earlier in life, arthritis, or, the most common of the causes, aging of the inner ear. Because the inner ear is where the organs are located which are responsible for balance, this aging can cause overall imbalance. Even with the technology advancement to date, there are other issues inhibiting their application in this field. The first of these is having effective ways of measurement and application. The measurement of balance and stability has been evolving slowly over time, but it does not have a definite solution as of yet. The most common ways of measurement currently in use are measuring sitting stability and utilizing other exercises to determine a baseline. These baselines are useful primarily for tracking improvement but can be difficult to use for a diagnosis as the general rules aren't particularly specific. Although there can be some difficulty taking measurements there is shown improvement in balance following assigned workout regiments. This improvement in balance reduces the chances of falling in the future as long as the person sticks to the workout plan. This raises the largest issue which is adherence to the program which usually drops off as soon as the physician is not around. As stated before, within the prescription field adherence is only 45% which can be people not following the instructions entirely or not taking medication at all. This lack of adherence is a multipart problem which is not easily corrected. The first of these issues is people being forgetful or having difficulties applying the prescription to their lifestyle. The next can be difficulties with application or embarrassment in certain situations especially when extra equipment or aids are required. When pertaining to monitoring balance improvement this can become difficult when a percentage of the elderly will not use the equipment due to the way it looks or the way it is worn. This proves especially difficult with measuring balance due to the placement needed to be the most precise. The final issue with adherence is the problem of a small portion of the population who choose to not follow the prescription. This is not a large part of the group because most people who are given a prescription are asking for a solution to a problem. This does begin to happen in certain groups due to many different reasons, but they are generally case by case situations. The most comparable factor has to do with age. As people get older they often get more complacent due to not seeing a point in doing it or having too many other physical problems inhibiting them. In addition to difficulties with application and measurement there become resource struggles due to the size of the current population. The most difficult resource to have are the people to monitor clients. For an accurate prescription it is important to have people educated specifically on the elderly and with the knowledge to prescribe an effective plan. Although it isn't possible to make one solution to solve all of these problems it is possible to reduce them across the board. One of the most recent plans made to help improve balance of the elderly is the Otago plan. This is made up of assigned levels each with specific exercises meant to reduce the chance of falling. This allows for a standard which can be set across a large population and make improvements easier to track. In addition to this plan, it is easier than ever to implement technology in order to monitor activity and falls. The most practical implementation is through the use of smartphones due to the popularity of them. Currently there are applications similar to this but none of them cater to the elderly which makes it difficult for them to use them with ease. In addition, having an application specially built for this removes some stress on the physicians since it provides all of the information without the need for an appointment for each client. It also allows a more independent approach which makes decisions based on what information is given. This includes monitoring trends, reporting falls, and updating workout plans. Another potential electronic aid is a device capable of measuring balance or stability for diagnosis and prescription updates. The main advantage provided by such monitoring is a direct connection between the clinician and the client. This connection can provide the clinician with the capability of assuring user compliance without frequent appointments as is the case with the Otago Program. The improvement in compliance is the most effective way to assure that the client is improving through the exercises provided by improving the capabilities of the clinician to monitor the client's participation.

III. REVIEW OF DESIGN IDEA CONTRACT

Our project's goal was to not only to provide clinicians with accurate data of the participants during their exercises, but to also improve overall compliance in the program. As a group we decided to work on the idea of combining a physical device to record proper and accurate measurements and an easy to use application to walk through the user's specified exercise regimen. Based on the Otago Program, there hasn't been an implementation of this physical device and app to do the data collection. In addition, this idea will decrease the number of visits a training instructor or assistant care needs to come and monitor the elder doing their exercise.

The first part of our idea contract started with a notification appearing on a participant's mobile device to remind them of exercises to do for the day. A color band would appear on the app to indicate the exercise whether it's been completed before or still needs to complete. This allows the individual to know right away which exercise is being asked for. The user begins by pressing a start button. The first exercise will load up ideally showing the user how the exercise is done. The user would input if they have completed the exercise fully and proceed to the next exercise. After all the exercises are complete, there will be a brief words of encouragement on the mobile device. Eventually, the user will connect their mobile device with the physical measurement device via USB adapter to the micro SD card to allow data transferring to a cloud storage. The raw data will then be analyzed and presented to the physician where they can tailor the exercise regime and maybe give a call to the user to discuss further progression. To complete our idea contract, we needed both the hardware and the software components of the project to have subsections that that would support it.

In order to measure sway and balance our device must have a sensor that is able to measure movement and angle. The obvious choice for a device like this is to use combination gyroscope and accelerometer. We decided to use an IMU which had both of these components combined as one unit. In order to make use of the readings gathered by the IMU we also used a microcontroller. This microcontroller was the brain of the hardware device and provided the basis of where our hardware code would be stored and utilized. The goal of the physical device is to be a data logger and the microcontroller provided the ability to do that all internally.

In order to store the data gathered by the IMU the microcontroller needed memory, so we decided to go with a microSD card. This allowed the memory to be expandable and also accessed separately from the device if needed. The microSD card could be removed from the device and placed inside of an adapter that can allow the data to be transferred to a pc directly or to a mobile phone in our case. The device was also required to be powered for at least 8 hours so in order to achieve this we powered the device with an internal battery. We went with a Li-ion battery since they are lightweight and have long lasting power storage. All of the hardware components were placed inside of a 3d printed case which provides a sturdy and lightweight enclosure. This housing is then placed inside of harness with a custom pouch that is meant for the user to wear on their back. This harness also serves a dual purpose as this harness was initially designed to be a posture correcting apparatus.

The software interface is what the target user interacts with the most. Since the target user is going to be the elderly population the interface needed to be simple and easy to use. One of the biggest reasons to why this program is being designed is to be an easy and simple way of recording progress of participants for the "Otago" program. Large icons that clearly ask whether or not the exercise was completed were implemented to achieve this.

At the end of each recorded exercise session positive feedback will be given to the target user. This is to always insure that the target user always feels positive about their progress. Of course, the more positive feedback will be for the target user that has completed their exercise session completely. For the target user that have not completed their exercise sessions the feedback will be encouraging and letting them know to complete the exercises next time. The importance of positive feedback is to avoid making the target patient feel bad about their progress and to encourage them to do their exercises. Having a positive overall attitude is important when participating in a program such as this and this software interface aims to do that along with its recording feature.

The exercises that will be required for the target patient to complete will have an individual acknowledgement page asking if the target patient has completed their exercises. In order to help the target patient, know which exercise that they are being asked about a dedicated color will be used. Depending on the exercise being asked for completion a single color will be used to indicate that exercise that will not be used for any other. This allows target patient that have vision impairment to not have to only rely on reading the exercise name that is being asked. Color is usually easier to distinguish when a target patient may have a hard time to read text on a screen.

Daily notifications to the user was also part of our idea design contract. This was achieved through setting an alarm through the mobile application and having that alarm occur every day at that set time. This would allow the participant to know when their clinician wishes them to begin their prescribed exercises.

At the end of each exercise confirmation page of the software interface the app will connect to an online cloud storage medium to keep a record of their progress. This online storage will allow a secondary recording storage for the program so that in the case the app gets deleted off of the mobile device the progress of the target patient will still be saved. This online database was required for our design idea contract and allows the clinician to view the progress of the participant any time.

IV. FUNDINGS FOR PROJECT

Our group did some initial research to figure out the basic hardware components that we need, and an estimated cost as shown in [13]. We initially planned to chip in as much as $100 each person considering that we're covering the extremities of going for better hardware components down the road. This was done back in the fall semester and surely enough, our project has evolved since then. We've adjusted our hardware components to be more specific and surely enough, our cost rose.

TABLE I
GROUP 4 ESTIMATED BUDGET [13]

Part	Quantity	Cost per Unit
Microcontroller PIC24F16KA301	2	$2.11
Inertial Measurement Unit MPU-6050	2	$3.00
External SRAM Memory Chip 23K256	2	$1.15
MicroSD Card Board	2	$5.85
16GB MicroSD Card	2	$5.00
LD1117V33 3.3V Voltage Regulator Chip	2	$0.55
Ni\MH 2000 mAh AAA Rechargeable Batteries	2	$2.75
Wires: 22 AWG	100 ft	$5.83
USB Type C Cable	2	$3.00
3D Printed Housing	2	$5.00
Total Cost:		**~$62.65**
Total Cost per Device:		**~$29.24**

TABLE II
GROUP 4 FINAL COST FOR PROJECT [14]

Part	**Cost**
Micro-LiPo Charger for LiPo Battery	$6.95
32GB Sandisk SD Card	$5.00
MicroSD Card Breakout Board	$7.50
BNO-055 9 DOF IMU Sensor	$34.95
Arduino Pro Mini 3.3V @8MHz	$5.62
3.7V 1200mAh Li-Polymer Battery	$9.95
PCB Boards	$5.00
Direct Project Cost:	**74.97**

Our project was funded entirely by us, the members of team 4. We were very fortunately to have great professors who offered to help us in our journey either through advice or funding. Those professors are Dr. Smith from the EEE Department at Sacramento State University and Dr. Lazaro from the Physical Therapy Department at Sacramento State University. Even with the generous offers, we decided to fund the project ourselves and split the cost evenly. Our total cost for just the deployable prototype comes out to be around $75 as shown in [14]. If we include the backup device and accessories, such as a programmer, PCB boards, and even extra jumper wires, then our cost would be around $175. The cost wasn't much of a concern, but we did want to contribute a decent pool of money to get a good IMU which is the bulk of the cost of a deployable prototype. As a result, we were able to concentrate on working on the project and meeting our goal.

V. PROJECT MILESTONES

Throughout the fall 2018 and spring 2019 semester, our group has accomplished many feats that got us to where we are now. Our project started off as a rough patch that needed to be polished as time went on. We decided that we wanted to integrate a working mobile application to improve compliance, a data collection device, and an interactive website for clinicians to view and adjust their respective clients.

One of our major events in our senior design was working with Dr. Lazaro, from the Physical Therapy Department at Sacramento State University, where we collected our ideas together to come up with a societal issue that can be solved with our engineering background during the fall semester. We wanted to involve technology in improving compliance as well as gather data of participants in the Otago Program as they did their daily exercises. Dr. Lazaro was kind enough to provide us any assistance we needed whether it be reasonable funding for the project or any advice. This laid the foundation of our project giving us a great head start in the process. We had the basics settled down and all we had to focus on was implementing the solution to the societal issue.

Further on in the fall semester, as we worked on getting a laboratory prototype, our group was able to get each individual part of the project components working. The mobile application was able to accommodate the Otago Program and provide simple and clear instructions in navigating through it. The website and database had an interactive login screen and took in comma separated value files to display the participant's data. The sway measuring device was able to pick up on user movements, make calculations to achieve pitch and roll angles, and store it into an external memory card. This was an incredible feat because it shows signs of improvement and promise towards completing the project.

Heading into the beginning of the spring semester, our group was able to integrate our parts together and achieve a better laboratory prototype. This was our group's hardest task because not everything works when you throw it together. Our group learned that lesson throughout this process. The more we dug into the integration process, the more problems that occurred like edge cases or even getting a printed-out circuit board in time. We also thought about the what-if scenarios, but we had to make clear assumptions and back it up whether it be words from Dr. Lazaro or even online resources. During the integration process, the mobile application was able to implement notifications to the user informing them to complete their daily exercises. It also accommodated for test cases to ensure participants weren't able to mess up when inputting their responses. This way, we ensure there is no input that is out of the range. The website was able to implement a graph that shows pitch and roll angles of user's data. This gave our project more visuals providing us something to guide users with. Visuals are way better than a thousand words. The website was also able to allow clinicians to access the raw content coming from the user's data. Even though clinicians may not use it, it's there for reference but they will most likely view the calculated pitch and roll angles that we've done. The sway measuring device was able to improve its accuracy giving the clinician better data to work with. We've also added a lithium-ion polymer rechargeable battery which could run for a few days without the user needing to charge it. Overall, the integration process was a huge leap in our progression timeline. This was the decisive moment that determined whether our project would be able to continue on or not. In the end, the integration was successful but there were changes that still needed to be made such as more accuracy improvements, mobile application and website ease of use.

Another successful major milestone was transitioning from breadboard design to PCB board and developing an enclosure and harness for the device. Transitioning from breadboard design to PCB board was time consuming and frustrating because one little wrong rewiring and the entire circuit won't work. We'd constantly have to check for continuity and proper voltage being applied across each hardware component. If something was wrong, we'd have to trace the soldering. Just to mention, these components are tiny and hard to deal with. One wrong move and we could burn out a chip. Developing the 3D printed design took time and careful measurements. We had to compact the enclosure box to ensure when the user is wearing the harness with the device, it's not a bother to them. We also had to fit each component so there isn't any movement within the box. This way, we achieve better IMU readings and not have to account for tiny movements within the box. Developing the harness was just a matter of having a strap on harness and sow on a pouch to perfectly fit the device to ensure the device moves exactly with the user. Even though this major milestone was one of the most challenging ones, it was the most rewarding. We were able to go from a breadboard with wires sticking out and hardware components exposed to a nice fit enclosure and harness that users can wear. Ultimately, these were the major milestones that our group felt were most important and crucial in this senior design.

VI. PROJECT WORK BREAKDOWN STRUCTURE AND TASKS ASSIGNED

Each feature is broken down into further subtasks. We listed only the main tasks of our projects and left out the activities under the subtask due to its extensive list. Features such as the exercise tracker app, online accessible data, and fall detection were each handled by an individual member. The main feature, that's composed of our hardware components, is the balance measurement device. This was handled by a few group members working hand in hand to integrate the components. Overall, our group spent approximately 1000 hours over the course of two semesters. This is not including the senior design assignments. More information on the main tasks and hours worked by each group members can be found below in [15].

TABLE III
PROJECT WORK BREAKDOWN STRUCTURE AND HOURS [15]

Project Task	**Total Hours on Project Task**	**Jesse**	**Tyler**	**Daniel**	**Allen**
Graphical User Interface	75	75			
Progression Tracker	38	38			
Notification and Feedback System	18	18			
Connectivity with Balance Measuring Device	30	30			
Connectivity with the Cloud Storage	20	20			
Setup Online Data Storage for Application	92		92		
Develop Web Access to Data	105		105		
Organize Local and Online Data Storage	55		55		
Create Arduino Prototype to Test IMU	129			129	
Data Transfer Through USB to Application	20			20	
Set Up Data Storage on SD Card	49				49
Set Up Static Random-Access Memory	72				72
Set Up Final Deployable Prototype	88			44	44
Design 3D Device Housing	35				35
Fine Tuning and Testing	260	70	60	80	50
Total Project Hours	**1086**	**251**	**312**	**273**	**250**

The hours for each task and the respective members are roughly estimated off the activity reports and what's stated on the work breakdown structure. Each task has its importance in the project. For the mobile application, the first step was getting a graphical user interface (GUI) which allowed users of the application to interact with. We discussed with Dr. Lazaro and concluded that we're working with individuals who are familiar with mobile applications. This takes out a few concerns like how to navigate on the phone or even what to press. Jesse spent most of the hours on developing this interface so that users won't have a huge issue with working the device. The progression tracker is also another vital component to the mobile application because it tallies up the user's exercises which then clinicians can access and discuss any adjustments. We spoke with Dr. Lazaro about this and he definitely agreed with the implementation since it's more information that clinicians can use. This leads to the next task which was notification and feedback system where we want to encourage participants by providing kind and gentle messages after they complete the exercises. We aimed to not give any negative feedbacks and focus more on neutral or good feedbacks. That way, we don't discourage the users. The participants will also be notification through a phone banner informing them to complete their daily prescribed exercises from the clinician. This way, we are setting up a reminder in case they forget. Another crucial task was integrating with the cloud storage and sway monitor device. We want the stored sway data from the micro SD card plugged into the phone that holds the mobile application, so data can be uploaded to the cloud. This way, clinicians can view each section and do further analysis.

In terms of the website and database, we wanted clinicians to have access to their respective participants. In order to begin, the website had to be set up and connected to the mobile application. This was crucial for getting uploaded data from the phone. There was constant back and forth conversations with Tyler and Jesse with their respective parts so that the integration process can go smoother once they know their issues. Another task was to have the website functional and a login page to store accounts. In addition, we wanted the website to be user-friendly to the clinicians, so they don't have a hard time looking for information on their participants.

The physical sway measuring device was the most important part of the project because that's where were getting our processed data from. The initial step of building the hardware design was to test with any microcontroller just to see if we can get a functional IMU and eventually run it together with the other hardware components like the SD Card and SRAM. We also wanted to make sure we could integrate it with the mobile application, so we could upload data. The next step was to transition from breadboard design to PCB board. Soldering and testing for continuity played a critical role in have the final deployable prototype to function as expected. We had a hard time soldering since we're working with a tiny PCB board and the solder would sometimes connect together when we don't want it to cause more time to be wasted. This was something that we planned to do since the beginning of the fall semester. We wanted a better design prototype instead of a simple breadboard design. The last task that made the prototype perfectly fit and be stable without any jittery movements was designing the 3D printed housing. Having this fit comfortably with the harness, that participants will wear, is something we had to consider. Ultimately, the tasks that we set upon the group to accomplish the deployable prototype were carefully chosen knowing that each component is dependent on each other.

VII. RISK ASSESSMENT AND MITIGATION IN WORK BREAKDOWN STRUCTURE

Risk assessment is such an important tool needed to determine whether our project can succeed or not. The reason being is that risk assessment is part of testing and without that, we're blindly walking into trouble. In our project, we can categorize our risks in terms of software risks, hardware risks, and mechanical risks but more specifically towards the mobile application, website and database, and sway measuring device as shown in [16].

TABLE IV
RISK ASSESSMENT MATRIX FOR WBS [16]

PROBABILITY						
	80%-100%					-Environmental Disaster
	60%-79%					
	40%-59%	-False Positive Fall Detections		-App Failure. -Does not detect every fall.	-Unable to connect App to Balance Measuring Device.	-Bricked Android Device.
	20%-39%	-User data accessible by other sources.	-Incompatible Code. -Unable to Program MCU.		-Unable to read/write to SRAM.	-Unable to compensate for drift of IMU.
	0-19%		-Lack of database features limiting project features. -IMU is not sensitive enough. -Unable to write values to SD.	-Disconnected from Cloud Service. -Cloud Server down.		-Unable to detect falls. -3D device housing deteriorates due to environmental issues.
		Level 1	Level 2	Level 3	Level 4	Level 5
		IMPACT				

A. Mobile Application

In terms of the mobile application, it is the median between the sway measuring device and the website. Without the others, it would be a standalone device that only shows exercises and a notification but no real data of pitch and roll angles will be uploaded to the website. This broadly shows how each component is dependent on each other.

A potential risk that may occur on the mobile application is disconnecting from the cloud service that links to the website. If users are unable to upload their data for clinicians to view, then that would cause a delay in the program schedule with time being wasted. Even though this doesn't have a high chance of happening, if the event occurred, then its impact will be severe. A mitigation technique to solve this would be to properly code the connection to the website and ensure it is reliable through a couple trial runs. Another potential issue is bricking the android device. This is a very serious risk that essentially ends your phone's life. There is a medium probability level that this may occur, but proper coding and logical tests should prevent any risk to the device.

B. Website and Database

When it comes to risks related to the website and database, we tend to focus on accessibility and reliability. We want clinicians to be able to access the data knowing that there haven't been any fake uploads ensuring a sense of security. We also want clinicians to know that the website is reliable in a sense that they will still be able to access it at any given time. Even though we would like to ensure these features, there are risks around websites and databases that needs to be addressed.

One risk to mention is security risks revolving around data being public. If our project was actually implemented in a big company and data was open to the public that would cause a lot of damage and violations towards privacy of the individual in the program. In addition, someone could create a new clinician account and access the available data and manipulate it for various intentions. The probability of this happening is on the low side since there isn't much sensitive data there and we will implement our mitigation techniques to reduce this amount. In order to mitigate this issue, a user identification and password will be required to authorize access to the website. Another risk would be the cloud server being down. This is unavoidable since all servers has some sort of downtime whether it be for maintenance or cause by something unexpected. To mitigate this risk, we would allow user to working offline and waiting until the device connects to the internet in order to upload any new data. Another mitigation to this risk would be having the database do a backup once in a while to prevent any data loss if it ever occurs. This provides insurance knowing that the data is still available.

C. Balance Measuring Device

When it comes to the physical hardware components of our project, there are a few risks that are involved but nothing too severe in terms of impact. One of the risks involve the issue of being unable to write to the microSD card or to the SRAM. If we're unable to write to the microSD card, then surely, we won't have any data to be stored and eventually uploaded. In terms of the

SRAM not functioning, this shouldn't be too big of an issue since its external RAM. There is still leftover internal RAM on the MCU that can be used for data processing. The probability of the hardware not functioning is in the low range along with the impact. This is because the mitigation technique would be to adjust the code to ensure functionality. There isn't much to do besides edit the code to make the hardware run. A potential risk that is a little more impactful would be the inability to compensate for the IMU's drift. If drift became a larger number, it would definitely account the accuracy of the data. We wouldn't want users having large roll and pitch angles that doesn't seem reasonable. As a result, if there's no fix to the drift, then it would impact the entire project's goal greatly. In order to compensate for this, we spent more money on a better IMU which does the calculations for you instead of manually entering it in the code. The new IMU, which is the BNO-055 9DOF sensor, provides 9 axis measurements that cover accelerometer, magnetometer, and gyroscope values. Having all three combined reduces the drift in a way by distinguishing direction. With this intact, we wouldn't have to worry so much about the gradual drift affecting our data.

In addition to the sway measuring device, we have to consider the what-if scenarios of detecting falls. We want to cover false positives, detecting every fall, and even the case of not being able to detect any falls and minimize these risks. In order to prevent false falls, we would revise our code in a way that sets the boundaries of the accelerometer 3 axis. If falls happen at a certain speed, then we can put a threshold where anything higher than the range will be considered a fall while the rest are considered false positives. In the case of not detecting every fall, we would have to consider real world cases like if falls could happen back to back in a short amount of time or other similar scenarios. If we're not able to capture every fall, then clinicians won't necessarily be up to date on what's happening to their participants. The probability of this happening is on the higher side, but the impact is not as severe. This is because if we ensure at about 90% accuracy, then essentially, we served our project's purpose as a fall detector. In the case where absolutely no falls being detected, that would raise serious concerns because it's one of our features on the punch list. This is something that is definitely required to be handled because clinicians need to know if their participants have fell over the past week or so. Even though this can severely impact our project, the probability of this occurring is low. This is because we're fairly certain our IMU's accelerometer can pick up accurate data removing most of the drift. If we use those values and set our threshold, then we're guaranteed to have a working fall detection feature.

Another risk that's more general is environmental disasters. Whether it be from a flood or a fire, these all have a slight possibility of happening. Once it does, things can be flipped upside down. During the fall semester, Sacramento State was shut down for a while due to Paradise Fire up north. This devastating event lasted for weeks affecting progress for many groups in senior design. This was uncalled for and emergency meetings arose for faculty and for senior design groups to discuss further progression.

Fortunately for our group, we didn't have anything left at school so there was no trouble in continuing our project. One thing to note here is to prepare for the worst and knowing how to continue from there. It's best if you can at least take into consideration any possible events so they aren't that big of a surprise and you know how to handle it. Even though this event was detrimental in terms of time and progress, we eventually pulled through and continued our project schedule.

Ultimately, risk assessment is one of the most important qualities in having a successful project. This lets you know what could potentially happen and how severe it could be. Without taking this into consideration, you'd essentially be working on a project blindfolded. The risks would be unknown, and everything would seem well until you encounter one of them that causes havoc and ruins the project. Taking these risks into thought, while working on the features, will provide a carefully planned and successful execution of the project.

VIII. DESIGN PHILOSOPHY

With our well-established societal problem in mind, we were able to create a general design philosophy that we wanted to work by for the creation of the project.

A. Low Cost

The first big element of our design philosophy was to keep the cost low. Through some research, we found out that there are products similar to ours at very high price points. In fact, the device that's closest to ours has a price of a few thousand dollars which is incredible. We realized that in order for our device to be usable by a large quantity of people we needed to get the price low. Many senior citizens are on fixed incomes, so we wanted to keep the price low so that the price would not be a burden on anyone. This element of our design philosophy led us to look for very inexpensive parts. Many of the parts that were looking at, such as the MCU and battery, did not vary in price too much so big decisions were not made there. However, when it came to the IMU, there were huge price variances between different models. Initially, while browsing through the different choices for IMU we decided to go with the cheapest option. The cheapest option at the time was the MPU-9250 at about 9 dollars each. The MPU-9250 was our IMU for the majority of the project. The IMU was fairly noisy and difficult to get decent values from. It took a lot of time but eventually we were able to get some good readings out of the device. However, when we decided to integrate the IMU with our MCU, we ran into a variety of issues. The amount of computing that was being done on the MCU to compute the absolute orientation angles was creating instability. The system would read values that were incorrect which obviously was not acceptable for our project. Within the last few weeks of our project we decided to switch IMU's. We instead chose to use the Bno055 which was significantly more expensive at about $40. This decision was difficult because we did not want to increase the price of our project by a significant amount, but we ultimately decided that it was necessary. While we did have to compromise our design goal of keeping a low cost, the project still remained extremely inexpensive and affordable. The small price difference helped finalize our project and improve it dramatically.

B. Low Impact

The next big element in our design philosophy was that we wanted to make the device as low impact as possible. We know that style and appearance are important to people and we wanted to reflect that in our design. We did not want our product to be an eye sore while wearing because that would limit how much people would want to actually use the device. In addition to the appearance, we really wanted to limit the size and weight of the device. If the device was too large or too heavy, people would not want to use it. Obviously one of the focuses of our project is to improve compliance, so if we made the device not easy to use, chances are we are only adding to the compliance issue.

Our initial prototype for the device was created for an Arduino Mega. While this worked for prototyping, we knew that it would not work for our final design. The Arduino Mega measures 4x2 inches which was extremely large for what we wanted our end result to be. We knew that we had to choose a new MCU that would be able to fulfill our design philosophy of low impact. We researched different MCU's and found that the possibilities were endless. In order to preserve our code at the time, we decided to use the Arduino Pro Mini. The Arduino Pro Mini was a fantastic choice because it met the power requirements of all of our other devices, with the capability of being run at 3.3V. To run it at 3.3 V we had to lower the clock speed from 16MHz to 8 MHz, but this was sufficient for our project. The Pro Mini had a size of 1.2 inches by .6 inches which was significantly smaller than the Mega. We knew that the size of the Pro Mini would allow us to create the device with our low impact design philosophy intact.

C. Clinician Focused with Users in Mind

This philosophy was not clear to us the entire duration of the project. Originally, we were focusing on the user rather than the clinician. While this seemed like the correct philosophy at the time, as time passed, and our project became clearer we realized we were on the wrong path. We realized that instead of making users the focus of our project we needed to focus on clinicians. Targeting a product served at improving compliance to the people who were not complying with their prescribed program in the first place seemed misguided. We needed to make this product attractive to clinicians who often feel as though their patients are not compliant to the programs they give. This isn't to say that we did not want to appeal to the user as well, but our main focus was making the device desirable to clinicians.

This shift in philosophy can be most clearly seen with the way that we made the device wearable. Originally, we wanted the device to be hidden. We wanted to somehow attach the device to clothing so that the device could be worn all day without the user feeling like everyone could see it. We struggled with this a fair amount. In our attempts to solve the problem we kept reevaluating what our societal problem truly was. We landed on the decision that clinicians were actually our target audience since the goal of the project was to solve compliance. We then decided that we could make the harness for the device a bit more visible, going against the low impact goal, in order to ensure the project worked as intended. However, the user was not completely disregarded as we made the harness as ergonomic as possible. The harness can also be worn under clothing if the visibility of the device is a huge issue.

The key to this element of our design philosophy was to find a happy balance between the needs of the clinician and the needs of the user. Thankfully, with the help of Dr. Lazaro we were really able to figure out exactly what were the important qualities on both sides. Clinician's wanted as much information as possible and users wanted a simple and easy experience.

D. Simple and Easy

Another element of our design philosophy is that we wanted to create a product that was simple and easy to use. We wanted this to be reflected in both the app and the device. Senior Citizens tend to have issues using certain forms of technology and smartphones are no exception. If the app and device were too difficult to use, then we would likely to find difficulty getting people to use the product. In order to simplify the app, we used a very linear process with very large buttons. The large buttons provide users, who may struggle with vision issues, the ability to capture all the information with minimal effort. The large buttons also make the linear process seem even more linear, as the most important steps of the app are the largest buttons.

In addition, to the app, we also worked to have the device be simple to use. Our device only has a single switch which makes it extremely easy to use. Simply flip the switch, put the device in the harness, and put on the harness. Aside from that there isn't too much more about the device. It can be charged via a USB cable and all the information can be found on the SD card.

IX. DEPLOYABLE PROTOTYPE STATUS

As a result of all of our hard work in the last year, we have been able to fully complete our deployable prototype. Tons of work was required but we were able to complete our deployable prototype as intended, meeting all measurable metrics required. We will outline each of the measurable metrics below, and detail how they have been achieved.

A. Exercise Tracker App

The first feature from our design contract was the exercise tracker app. The app was developed for Android 9.0-Pie. We wanted an app that would give senior citizens a simple interface in order to track their exercises. In the past, participants of the Otago Program had to use a journal, but the app allows for them to do things with just their phone. The app has been built to run on the latest version of android. With the help of a user manual, the user should be able to get through the exercises easily [17, 18, 19].

One of the metrics that the app had to meet was having a graphic user interface (GUI) that used large buttons (~1 cm x ~1 cm). The purpose of this was to ensure that senior citizens, who may have vision issues have the ability to use the app without any issue. All of the buttons in the app are over the desired size which makes using the app very easy. In fact, the two participants that we were able to test the product with really praised the large buttons because it made it extremely easy to use. The large buttons were easy to press, despite them claiming that they tend to have issues with touch screens.

The next metric that was met in our app was the ability to track a user's progress through levels of the Otago Program. Progression, through the Otago Program is mostly determined by the clinician, so we wanted to leave this as adjustable. Currently we have the deployable prototype app to progress a user's level after 4 successful completions of an exercise regimen. Obviously, this may not be the requirement in the real program, but for our purposes it works.

In addition to this, there is positive feedback that the app gives to the user. The feedback will be based how much of the prescribed exercises were completed. There are subtle differences between the feedbacks received if all the exercises are completed vs only 10% completed. Although there are differences between the feedbacks, the feedback will always be positive. There are multiple different messages that the app cycles through.

The last metric that the app needed to complete was phone notifications. Currently, we have the notification set to 10:00 am every day. Although this notification is currently set to 10:00 am, we are making it adjustable by the clinician. This would give the clinician the ability to discuss with the user over what time they plan on doing their exercises every day. The customizability of the notification is a great addition because it really allows our project to better serve individual people. The notification is a reminder so that participants using our project do not forget to complete their exercises. By doing this we can effectively improving compliance.

Ultimately, the app has fully met our goals from the beginning of the year. This isn't to say that further improvements couldn't be made, but at the moment it serves our purposes. We completely meet the measurable metrics for our app, we can consider the exercise tracking app as a success.

B. Online Accessible Data

Our next feature was "Online Accessible Data". While we debated a bit on how we should do this, ultimately, we agreed on an online website database with the logic flow shown in [20]. The website is currently hosted on GitHub and was created using firebase. The current version of the website runs very effectively and has no issues with uptime.

The website is setup so at first you see a login page. We have a few fake logins that lead to one of two different versions of the site. There is a participant version and a clinician version. The participant version is fairly simple, providing the user an additional ability to upload data. The website also provides useful contact information over the user's physician. The clinician side of the site has a bit more available since they need the data and information from the app and device. The only metric that we needed to meet for this feature was the ability to access the device data 24/7 for 365 days a week. Our website has no issues having a 100% uptime, so we meet that metric. The website has information on the average angles for roll and pitch along with a variety of other measurements from the accelerometer and gyroscope. We exceed the minimum requirement by providing many different sensor values.

C. Balance Measurement Device

The next feature that we had included in our design contract was the Balance Measurement Device. The schematic clearly shows the details and circuitry that went into the overall hardware design [21]. We had our microcontroller operating at a low 3.3V at 8MHz clock rate to manage the small design build. As a helpful guide, we created a user manual that the user will follow as depicted in [22, 23, 24, 25, 26]. This will be very helpful in case the user needs to troubleshoot or is lost in using the device. In addition, our device went inside a 3D printed enclosure box to ensure stability and protection [27, 28, 29]. We successfully completed this device as intended and even exceeded some expectations. We were having some fairly major issues until we decided to switch our IMU to the BNO055. With that, we met all of the measurable metrics that we outlined in our punch list and even added a few other things that improved our device.

The first measurable metric that we had was simply to make the device capable of being worn in some form. We struggled with this idea for a while because there were many different options, but we ultimately landed on creating a pouch sewn into a posture corrector. This made the device extremely easy to put on and take off with the additional benefit of correcting your posture while you do it. The device sits near the top of the spine where it measures body sway. The placement varies slightly depending on the height of the individual. The device sits slightly lower on shorter people than it does on taller people. This doesn't seem to be much of an issue but if it ever did seem to be one it could easily be corrected by creating custom harnesses for the device.

The next metric that we needed to meet was the ability to detect sway ranges by measuring pitch and roll. We had a few values that we found to be indicative of good balance from some research papers, but those values would be subject to change based off of further testing done on our part. The device currently has the ability to measure pitch, roll, and yaw of the body within 1 degree of accuracy. This is extremely accurate and completely meets our desired goal of being able to measure sway. The angle is calculated using measurements from the gyroscope and accelerometer. The gyroscope sensitivity auto adjusts and can range from 200°'s to 2000°'s which exceeds our goals dramatically. The accelerometer is capable of measuring 2G's to 16G's which also exceeds the desired value in our punch list.

At the moment, our device runs at about 60 mA at 3.3V. Our last measurable metric was to have at least an 8-hour run time. This run time was to ensure that a participant could wear the device over an extended period of time without any issue. We currently have a 1200 mAh battery in this device. This means that the device can run over 20 hours on a single battery charge. We exceeded our goal metric by over 12 hours. This means, that a user could use the device twice in a row, even if they forgot to charge it which is fantastic considering it is one less thing to worry about.

Although it is not in our measurable metrics, there is one last thing to note. Our data is roughly 700 bytes a second. This means that during an 8-hour day there will be 20 MB of data generated. This file size is extremely small and very manageable. Considering that we currently have a 32 GB SD card in the device, means that we could run the device every day for 4 years and be fine. Clearly this is above what is needed but it is still a very useful because it means that just in case users have difficulty with the process of removing the SD card from the device that they could simply wait for the clinician to do it during their scheduled visit.

In terms of test results for the microSD and Static Random-Access Memory (SRAM), there were clearly overheads that affected the data transfer rates. These came from things like print statements, for-loops, and function calls which in the end, didn't matter much. This is because we're transferring data larger than how much we're collecting. The microSD has a transfer rate at about 3600 Bytes/second which is relatively low due to overhead and not effective coding, but it surely gets the job done [31]. In terms of the SRAM, we get a data transfer rate at about 93,000 Bytes/second. SRAM doesn't have any interrupts occurring during a writing or reading phase which ultimately increases the rate [32]. In the end, due to changes in the hardware such as the IMU, the SRAM has been removed from the design. In response, we freed up internal RAM on the MCU to accommodate for the loss of data processing. The project still runs fine without the extra RAM so it will continue onwards.

Our device completely met our goal within our desired contract. As established we met every measurable metric and even exceed a few. We consider the balance measuring device to be an extreme success as we completed everything that we intended.

D. *Pattern Recognition*

The last feature that we had was pattern recognition. We left this feature as slightly broad because we wanted to leave the door open for many possibilities. However, the one pattern recognition that we committed to on the device prototype was fall detection. We fully completed the fall detection as we outlined in our design contract. We have the ability to detect falls with a very high success rate. Our fall detection works by measuring patterns indicative of falls in the accelerometer values. We use all three axis of the accelerometer to detect falls by measuring whether or not the values exceed a certain value. Currently from our own testing we have a 100% success rate with detecting falls. Of course, our own testing is limited because we have to "fake" the falls with our own bodies. These "fake" falls may not be exactly how a senior citizen would fall in real life which would mean that our fall detection would need some fine tuning. However, for what we need at the moment, our fall detection algorithm works fantastically. The fall detection algorithm has completely met what we wanted to accomplish with our design contract.

X. DEPLOYABLE PROTOTYPE MARKETABILITY FORECAST

Our project has come significant way from its inception. And while it definitely begins to tackle our societal problem, there is a long way to go before it is a confirmed solution to the problem. Thorough testing would be needed in order to confidently say that we address the societal problem at hand. Without this testing and a few additional changes, our project would be unable to be deployed into the market.

A. Testing

While we have tested our project thoroughly for its individual performance, we have not been able to test it much in the actual field. Thanks to Dr. Lazaro and his research team, we were able to test our project with two participants of the Otago Program. This testing was extremely useful and provided us with necessary insight to see the positives and negatives of what we had developed. Through this testing we also verified how little we know about the impact of this device and how to most effectively use it. Aside from using the device on ourselves, we have very few datasets to go off of. We have a very limited idea of what in our data constitutes good balance and what constitutes bad balance. We assume that the compactness of data points is the most indicative of good balance, but we don't necessarily have much proof. We would need to be able to test our project on more people to get better ideas of what good balance looks like vs. bad balance. The measurements of two of our team members, Daniel and Allen shown in [32]. We can see there are clear differences between the two datasets. Allen's (left) is much rounder, where pitch and roll sway tend to be fairly equal. Daniel, on the other hand, has a gait that seems to have a roll sway that is greater than pitch sway. As far as we are aware, both individuals have healthy balance, which makes it difficult to determine traits that are indicative of bad balance and what are simply traits of a person's gait. This is where further testing with people would be extremely helpful. With further testing we would likely be able to determine traits that are indicative of bad balance. We would need to make sure that we tested with a variety of people including individuals who have suffered with balance in the past. Individuals with bad balance would possibly be the most useful for our testing.

As it stands, it is extremely difficult for us to fully comprehend the data we are measuring. We can make assumptions about the data and what it means, but without definitive correlations, it is near impossible to determine anything with certainty. A

Another form of testing that would be extremely beneficial for the future of our project would be testing over time. In order to get a better idea of the nature of our project, testing over time would be required. Ideally these individuals would be people who suffered from balance issues and were joining the Otago Program to improve. If we were able to measure their balance over an extended period of time, we could see what type of changes we could expect from improved balance. We currently have no idea of what something like that would look like, so it would be interesting to be able to gather this kind of information from a variety of participants. If we knew exactly, what features suggest better balance then we could really have a better idea of the success of the Otago Program. This would improve our ability to measure compliance as well because we would know that if someone improved in their balance then it was likely because they were compliant with the Otago Program and completed all of their prescribed exercises. This type of information would be extremely valuable to a clinician would could use it as an extra for of compliance verification.

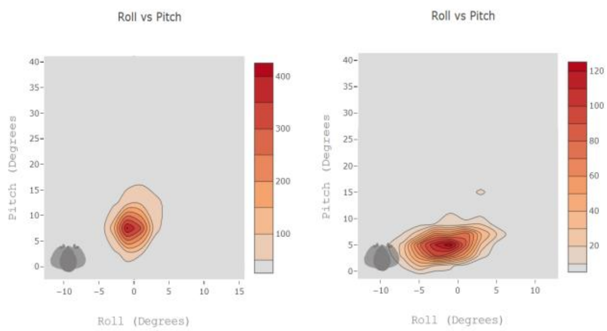

Fig. 16: Dataset from Allen (Left) and Daniel (right) [32]

B. Hardware Changes

There are a number of changes to the hardware that would be needed before our project could be on the market. As it stands, our project functions fine and meets all of our desired measurable metrics. However, there are always improvements that can be made. Below, we will list a variety of changes that we have come up with that would make the most significant improvements to our project.

The first improvement that could be made would be to include a real time clock. We attempted to include one into our project this semester but failed due to lack of time. The real time clock is a simple addition that would ultimately improve the effectiveness of the data by a significant amount. The real time clock would give clinicians additional information on what time participants were wearing the device. The information could also be used to track when the exercises were completed and how long it took to complete the exercise. This information would be extremely valuable to a clinician because it helps paint a picture of how much effort is being put into the Otago Program. Time recorded doing the exercises would ideally be long enough to demonstrate that an effort was made, but not too long as to suggest a difficulty in completion. This information would be extremely valuable to clinicians and would give them a better idea of whether or not the participant was being compliant and whether the specific exercises being assigned were sufficient for the capabilities of the patient.

In addition to the real time clock would be some sort of wireless communication between the device and the phone. At the moment, a microSD card is required in order to transfer the data from the device to the phone. This process is extremely inefficient and could prove to be difficult for some senior citizens who aren’t as technologically savvy. The obvious solution to this would be to make the communication wireless which would be beneficial to both the patient, by simplifying the process, and the clinician, by providing readings more often. In fact, this is the biggest change that was suggested to us by members of Dr. Lazaro’s research group. We feel that this step would be essentially necessary before this project could be an effective product in a market.

The third improvement is more of an optional one, albeit possibly a very useful one. The improvement would be to get the entire balance measurement device onto a custom PCB. This was also something that we had intentions of implementing but decided to focus on other elements of the project instead due to lack of time. This improvement could potentially reduce the size of the product drastically. While the size of our device currently is not very large, measuring 4 x 2 x 1 inches, we are confident that with an optimized PCB the size could be extremely small, and be even easier to wear than it currently is. The decrease in size would really help this product succeed in the market.

With these minimal changes to the hardware of our device, we think that our project would make an extremely successful product. We believe that our device has the potential of being a staple when it comes down to patients in balance improvement programs.

C. Software Changes

In addition to the hardware changes that would be beneficial to our project are software changes. The current extent of our software works very well and does everything that we originally hoped it would. That being said, there are still some additional things that could be done in order to improve the software elements of our device.

The first change that could be done is simply improved visuals for both the app and website. Both the app and website look fine as they are for a prototype, but if they were ever to be put on the market they would need serious visual overhauls. Work by a professional artist would be required to bring the visuals of the software up to the level that people expect from modern day apps and websites. Obviously, this change is a more of a luxury than a necessity, but it would still likely be needed if it were ever to be a real product.

One improvement that could be implemented into the system as a whole could be time-based analysis of the balance measurement device data. This ability would most likely be implemented into the database, but the app would be a possibility as well. Essentially, our system would be able to analyze whether an individual struggled with balance during certain periods of time of the day and relay that information back to the user. Imagine, getting a notification from your phone letting you know that you should take it easy for a certain period of the day because past records show that you have decreased balance during that time.

Another improvement that could be made would be adding the ability to detect patterns that might be representative of a future fall. This would be an extremely innovative feature that could potentially prevent many future falls. The device would be able to somehow alert the user that they are exhibiting features that might be emblematic of a fall. Obviously in order to develop something like this, massive amounts of testing would be required. However, something like this could potentially revolutionize senior citizen healthcare, since falls are one of the largest causes of senior citizen health issues. Imagine the lives that could be saved and the money that would be saved.

In order for the last improvement to work effectively, there is one software improvement that would be needed to be made on the app. The app would need to have the ability to receive information from the device. With the inclusion of the wireless improvement mentioned in the hardware section this should be possible, but the software would need to be added upon.

Our last large software improvement would likely be made to the website database. While we currently have ways to display the measured data from our device and exercise tracker app, it may not be the most refined. Clinicians want a quick and easy way to gather information without digging very much. At the moment we have all the information displayed by day. This means that in order for a clinician to gather information over a week, they would need to visit 7 different pages. It would be extremely effective to have a refined summary page for the benefit of the clinician.

Another improvement that could be made to the website would be for the ability to represent the data recorded in a 3d format. At the moment, we display the values in 2d graphs. Imagine if there was a 3d animation of a person walking that would represent the data recorded. This information would be extremely valuable for a clinician by giving them a much better idea of what the patient's gait looked like. Technology such as this could really change how clinician visits worked. Patients would no longer need to visit a clinician’s office as much because the clinician would essentially have all the information they need from the database. This would be extremely revolutionary and save a lot of people a lot of time. Patients would have fewer necessary visits to the clinician's office and clinicians could potentially serve a lot more people.

While most of these software changes aren’t directly necessary for the project to become an effective product, they would definitely make it better. Some of these software changes could really make a difference in making it a desirable product for a wide range of people.

XI. CONCLUSION

Through the course of this project we were hit with multiple problems to overcome but were still able to make a prototype which satisfies our punch list perfectly. At the beginning, we were initially tasked with finding a societal problem which we felt passionately enough to design a project around. With some help from the physical therapy department we settled on the problem of falling among the elderly. At the root of this problem was the lack of balance which begins to affect people as they get older for a multitude of reasons. These range from injuries sustained during the person's life to the more common issue of aging of the inner ear. This is something which has a massive impact on the mortality rate of elderly citizens all around the world. We then split this into what areas of this problem could be reduced most effectively. These areas started with diagnosis issues as there are currently very few products on the market covering balance. On top of this lack of applicable technology, there was also the issue with data gathering among the elderly because, for the most part, it requires the patient to be at a doctor’s office in order to get accurate results. On top of this, patients often have a subconscious effect which messes up data due to the client not being in a regular situation. As soon as the client is in the presence of a doctor, the chances of them showing signs which do not match up with their condition increases. In this case, clients can show that they have good balance even though they do not in everyday life. We then broke the results of falling into subareas.

These areas include the physical impact of falling and the mental impact of a fall. In both cases there are negative effects which come from a fall that even though they may not seem bad on the surface, can lead to more issues later in life. On top of these two effects came the financial effects of falling which ranges from a small injury to the cost of a care institute based on the severity of the falling and the condition of the patient. As a final part of our societal problem we began to touch on the Otago Program which is a workout regimen focused on improving the balance of the elderly while requiring less time at the doctor’s office. This seems to have a lot of potential, but it also comes with its own issues. The largest of these, and from what we had come to realize one of the most difficult to deal with, was the issue of compliance. By nature, there are issues with people which can lead to a lack of compliance. These included forgetfulness, lack of time, and dependent on a caretaker to list a few. In all, this negatively impacts the potential of the Otago program as it requires the patient to be self-sufficient and to stay up with all of their exercises in order to improve their chances of improvement. From this research of our societal issue we gained an understanding of what surrounds what was initially seen as a simple issue. We then decided to help solve this problem in two parts. The first of these parts was a device used to measure the balance of the client in order to track progress and to record a baseline. This was a large issue as the current market was primarily focused towards a larger scale and was not as affordable as one would hope. The second part of this was a smartphone application used to record weekly exercises in order to track compliance of the patient. In the standard Otago program, the main source of logging was done through the use of writing on sheets which the patient filled out when doing exercises at home. The problem with this was that this allowed for weeks of no exercising before the clinician would finally know that a patient was not sticking to their schedule. In order to link everything together we decided to create a website which would be used to view all uploaded exercises as well as a way for device data to be stored for later use. The breakdown of this plan was split in order to have two people working on the device and two people working on the application and website as they operate somewhat independently from each other at the start.

When we began designing our product we knew that we were going to be paying for the project entirely out of our own funds. Because of this, we simply broke down what was purchased between people and from our initial estimate we were way off from what we ended up using. In the initial project budget, we estimated a cost of just under $30 per device. As we worked on the project this cost stayed around the same price and did not increase heavily until the final weeks of the project. As we neared completion we determined that the IMU that we were using was going to be too difficult to use and we decided to change over to one better suited for the application. This increased the cost the most as we went from a three-dollar part to a thirty-five dollar part nearly doubling the cost overall. This did give us more capabilities however and allowed for us to use less memory and record better data that previously.

Milestones during this project were always satisfying to achieve as we started with the simplest ones and made greater improvements closer to completion. Our first meeting with Dr. Lazaro of the California State University, Sacramento Physical Therapy Department was the first of these milestones. This is what started the project and was a great guide towards achieving everything they were expecting from our project. The fall semester alone was full of milestones including getting the application to communicate with the website and achieving functionality with each component independently. By the end of this semester we had a prototype which wasn't very attractive or form factor but was capable of demonstrating the potential of this design. Moving into spring semester we began making even more progress towards a deployable version of our project with the website and application making massive improvements in functionality. Midway through the spring semester we created our wearable device which met us with many difficulties initially as none of us had made a PCB like what we decided on using. In the next week however, we created a second device which improved upon the design of the last one substantially in both size and resistance to wiring bugs. This led us into our main testing which gave us the opportunity to use the device on two clients within the Otago Program and showed us the capability of the device as a complete project. In terms of project hours, we ended up putting in over 1000 hours of time into this project. During initial planning there were tasks assigned which were not applicable to the final punch list however and were removed later in the semester to leave us with this amount of time

With there being so many parts to our project it is only reasonable that there would be some potential risk in our project. These risks range from connection issues to the server to bricking the android device being used to run the application. In most case however, there were potential backups which made for a fairly low risk project overall.

When coming up with our design philosophy there were a few areas which we cared about the most. The first of these was the emphasis on low cost. This was a primary point of our project as we could build a device for under $100 in order to give a more generic functionality compared to other high cost solutions. The second was that the wearable device should be low impact and not large in size in order to make it wearable by a client. Fairly late in our project we also realized that out user group needed to be adjusted from the user to the clinician in order to aid in the use of the device. This changed the overall design plan and fit better with our deployable prototype design.

At this moment we have our prototype functioning in a way which meets ever standard set forward at the beginning of the project. The device is capable or reading balance measurements and saving data to an SD card. The application is capable of recording exercises and sending them to the cloud, and the website is focused on the clinician and displays both exercise data as well as graphical interfaces capable of aiding in interpreting device uploads. The only area according to our punch list which needs slight improvement is the area of fall detection which currently works but is not as accurate as we would hope.

The final area of our device plan was testing. As individual components we tested each part of the device. This includes device components, application performance as well as website and database performance. In all cases tests showed that each meets the standards needed to work in this project. Through this testing we also realized some weak points in the project which we solved where possible in order to build a more complete prototype. Client testing is the area which would be needed the most at this point as we have only tested on ourselves and on the two Otago clients previously mentioned. In an actual test run it would be interesting to see the way that this project aids the clinician in a larger scale.

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[19] J. Root, *Application Client Side 3*, Sacramento, 2019.

[20] T. Fox, *Website Flowchart*, Sacramento, 2019.

[21] A. Chau, *Hardware Schematic*, Sacramento, 2019.

[22] A. Chau, *Device Off*, Sacramento, 2019.

[23] A. Chau, *Device On*, Sacramento, 2019.

[24] A. Chau, *MicroSD Card Insertion*, Sacramento, 2019.

[25] A. Chau, *MicroUSB Cable*, Sacramento, 2019.

[26] A. Chau, *MicroUSB Cable Insertion Slot*, Sacramento, 2019.

[27] A. Chau, *Top-down View of Enclosure Box*, Sacramento, 2019.

[28] A. Chau, *Side View of Enclosure Box*, Sacramento, 2019.

[29] A. Chau, *Lid to Cover the Enclosure Box*, Sacramento, 2019.

[30] D. Diaz, *Dataset from Allen (Left) and Daniel (right)*, Sacramento, 2019.

[31] A. Chau, *SRAM Data Transfer Rate*, Sacramento, 2019.

[32] A. Chau, *MicroSD Data Transfer Rate*, Sacramento, 2019.

Otago Program - A balance improvement program aimed to improve the balance in senior citizens through the course of a year

Secure Digital Card (SD Card) - Memory card typically used to store information

Static Random Access Memory (SRAM) - Memory chip that retains data bits in memory as long as power is being supplied

Inertial Measurement Unit (IMU) - A device capable of measuring movement through a collection of sensors

Microcontroller (MCU) - A programmable integrated circuit that can be used to control an embedded system

Gyroscope - Sensor that measures angular velocity

Accelerometer - Sensor that measures linear acceleration

Magnetometer - Sensor that measures magnetic field

APPENDIX A.

USER MANUAL

Fig. A-1: Application Client Side 1 [17]

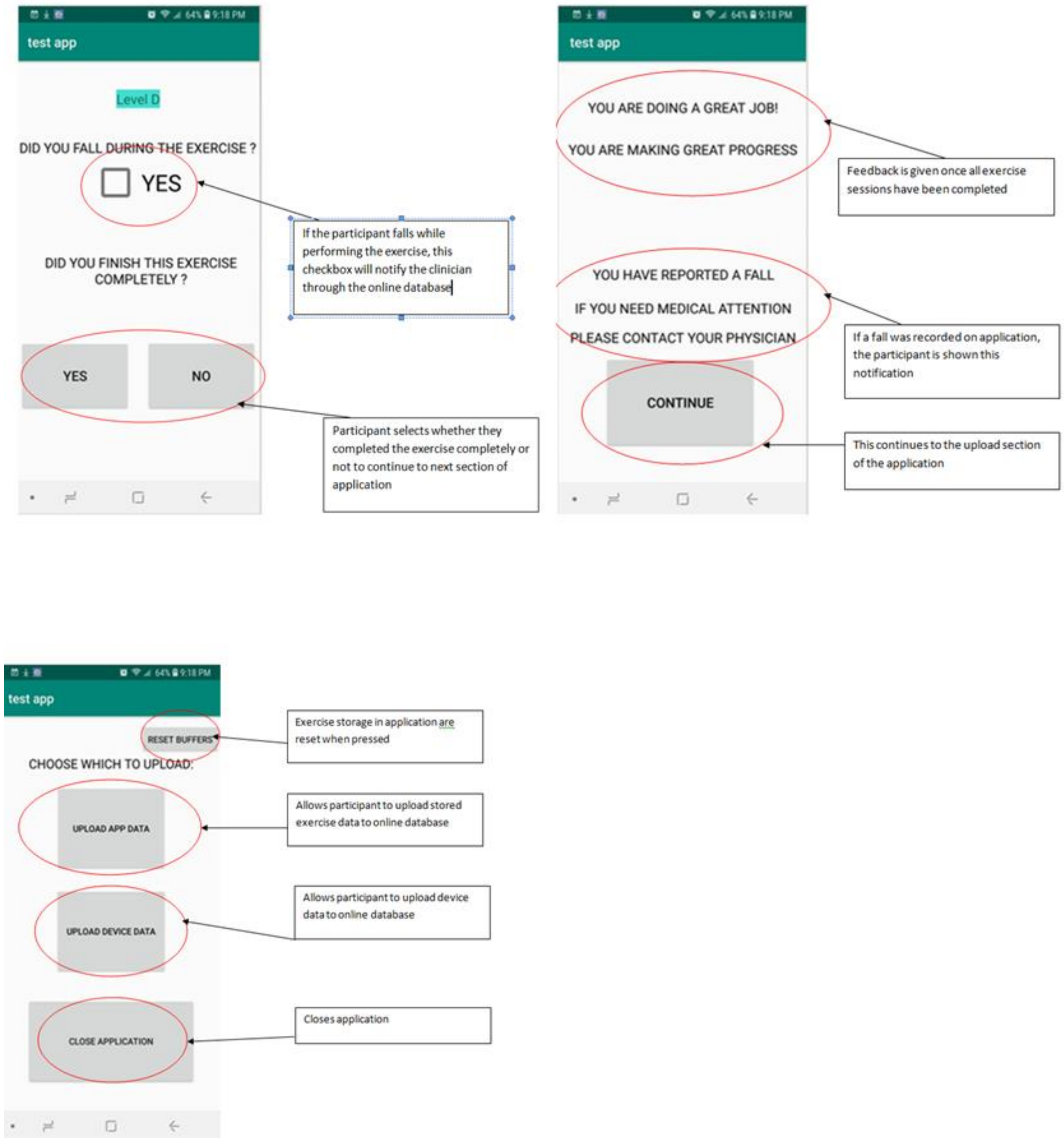

Fig. A-2: Application Client Side 2 [18]

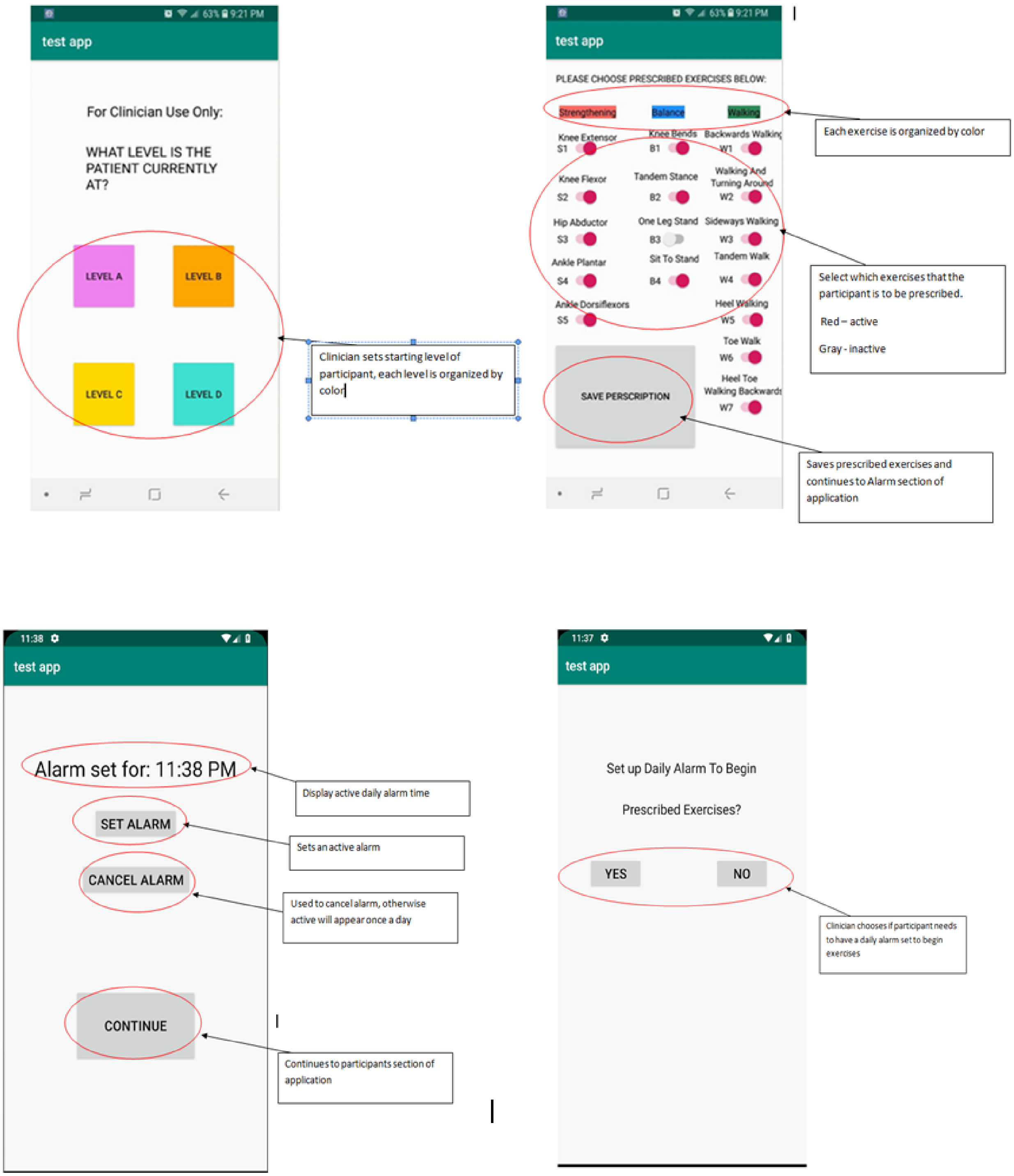

Fig. A-3: Application Clinician Side 3 [19]

Turning on the Device

In order to turn on the device, flip the switch next to the LED light as shown in Fig. A-4 and Fig. A-5.

Fig. A-4: Device Off [22]

Fig. A-5: Device On [23]

Taking Out the microSD Card

In order to take out the microSD card, simply push the microSD card so it pops out as shown in Fig. A-6.

Fig. A-6: MicroSD Card Insertion [24]

Charging the Device

In order to charge the device, simply connect a microUSB cable to the slot shown in Fig. A-8.

Fig. A-7: MicroUSB Cable [25]


Fig. A-8: MicroUSB Cable Insertion Slot [26]

APPENDIX B.

HARDWARE

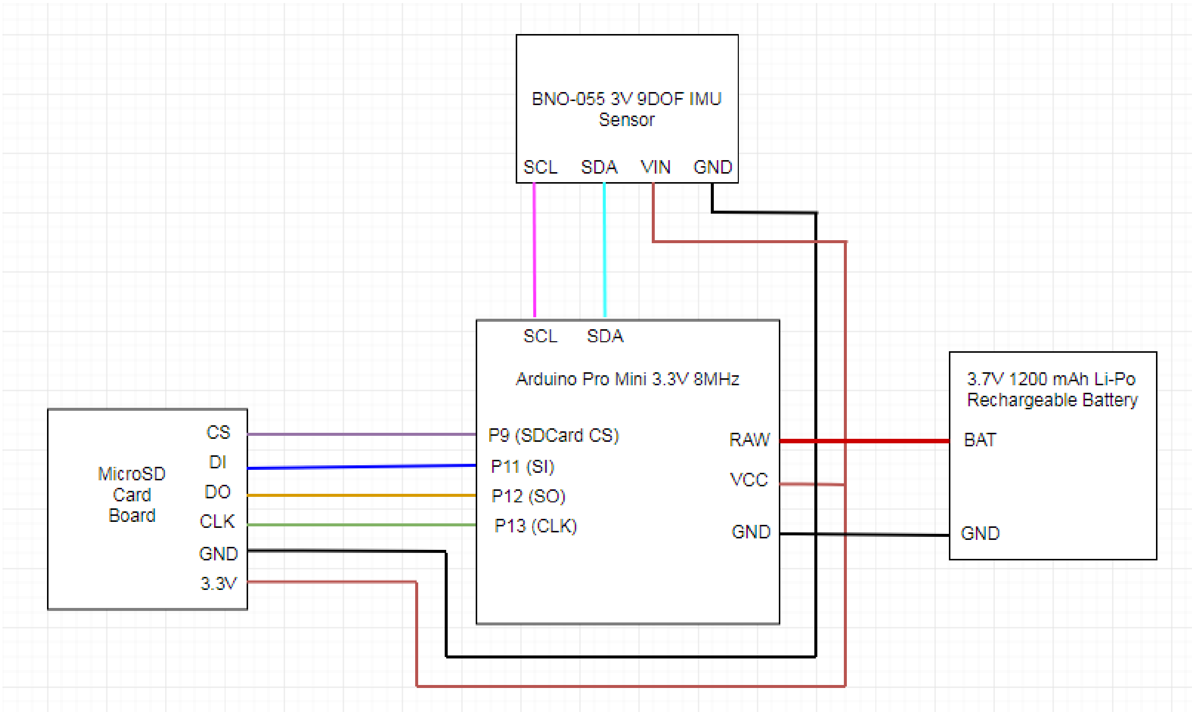

Fig. B-1: Hardware Schematic [21]

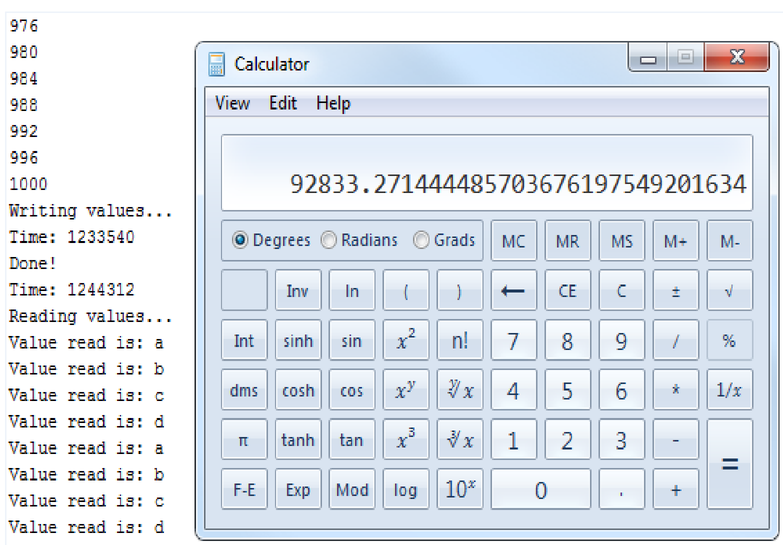

Fig. B-2: SRAM Data Transfer Rate [30]

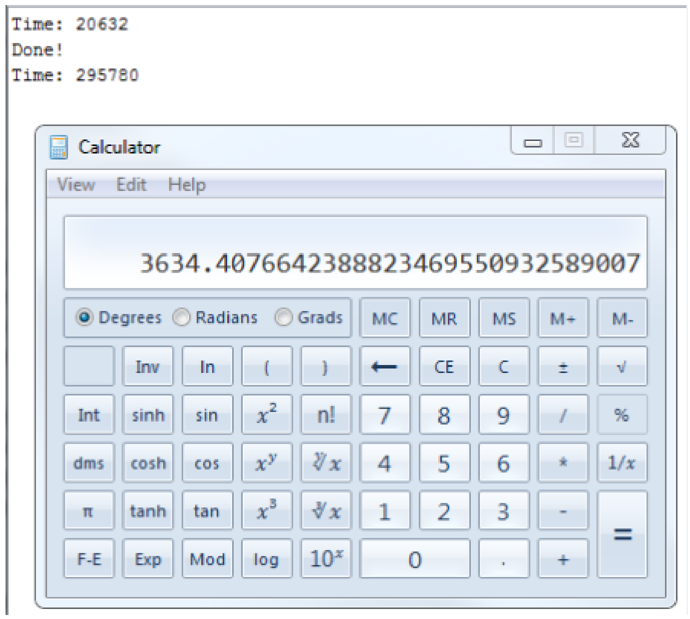

Fig. B-3: MicroSD Data Transfer Rate [31]

APPENDIX C.

SOFTWARE

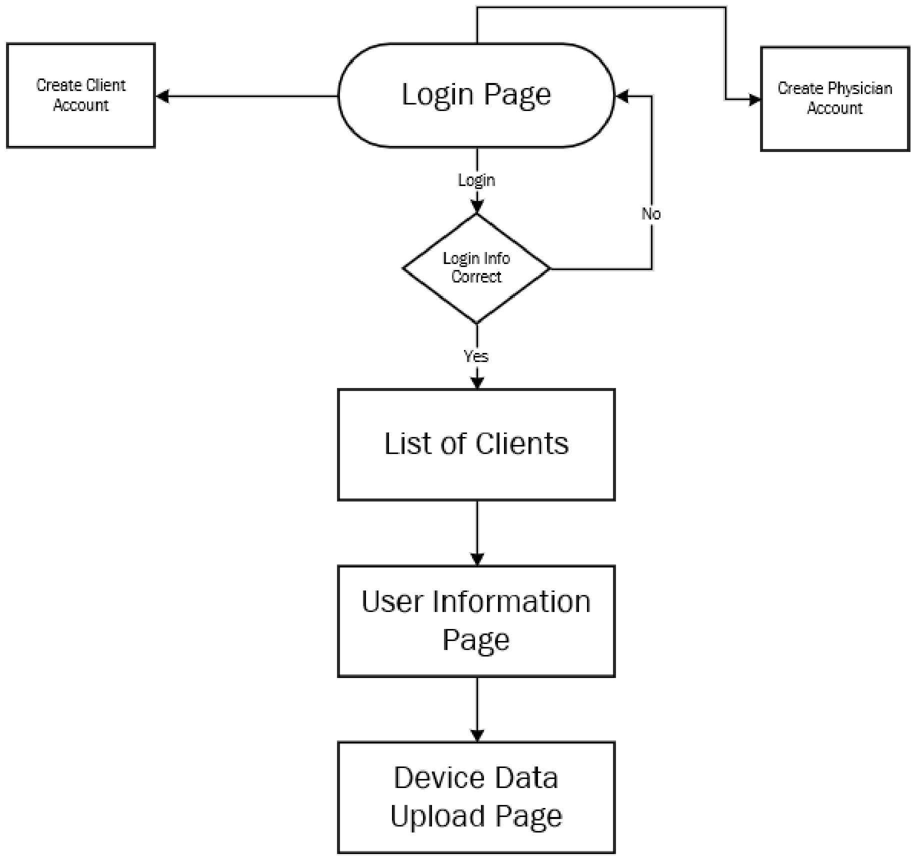

Fig. C-1: Website Flowchart [26]

APPENDIX D.

MECHANICAL

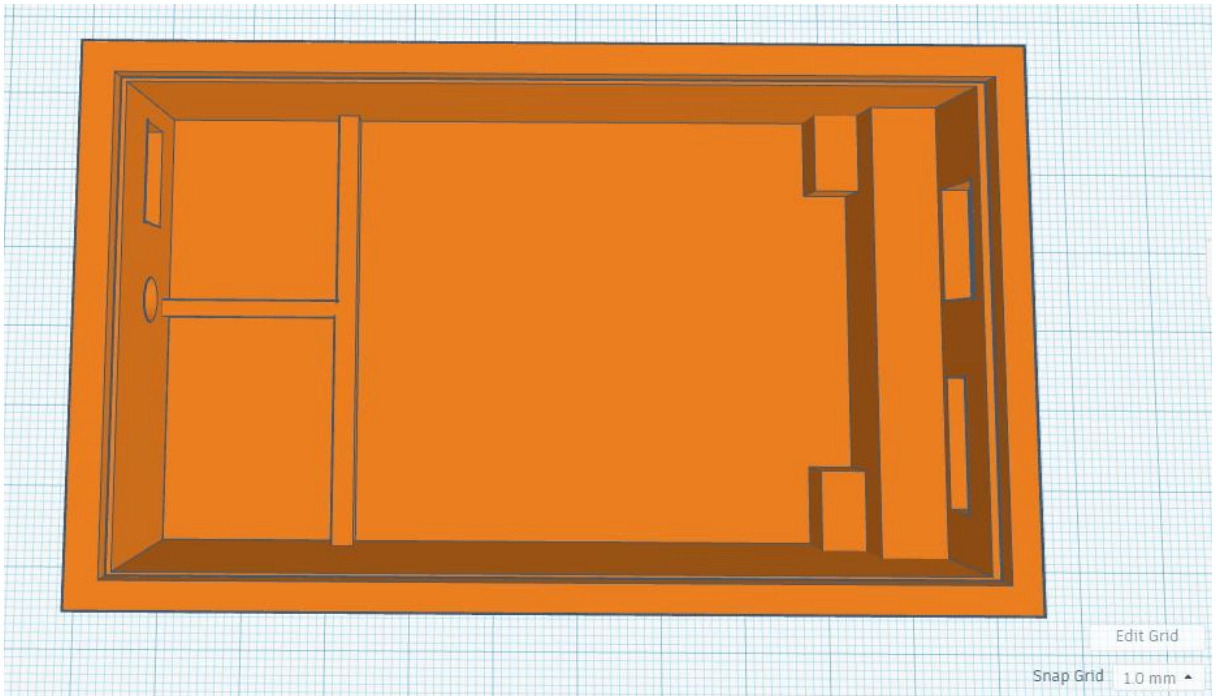

Fig. D-1: Top-down View of Enclosure Box [27]

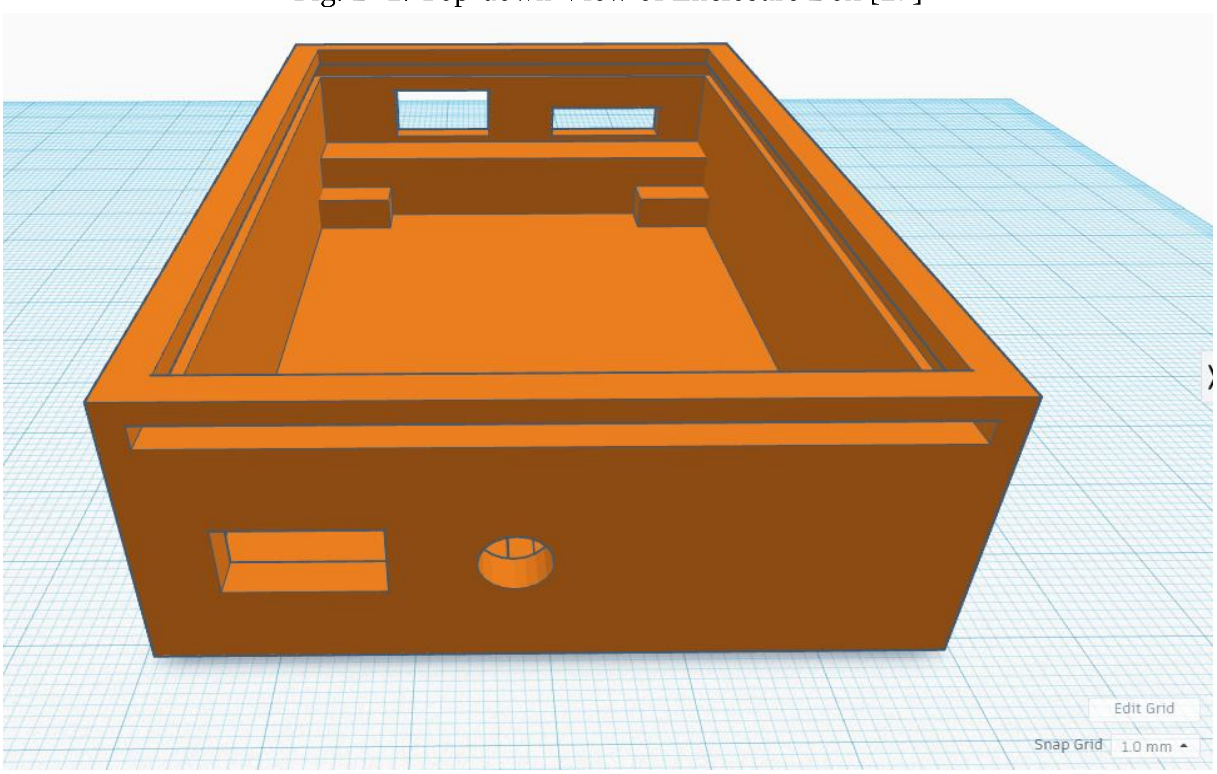

Fig. D-2: Side view of Enclosure Box [28]

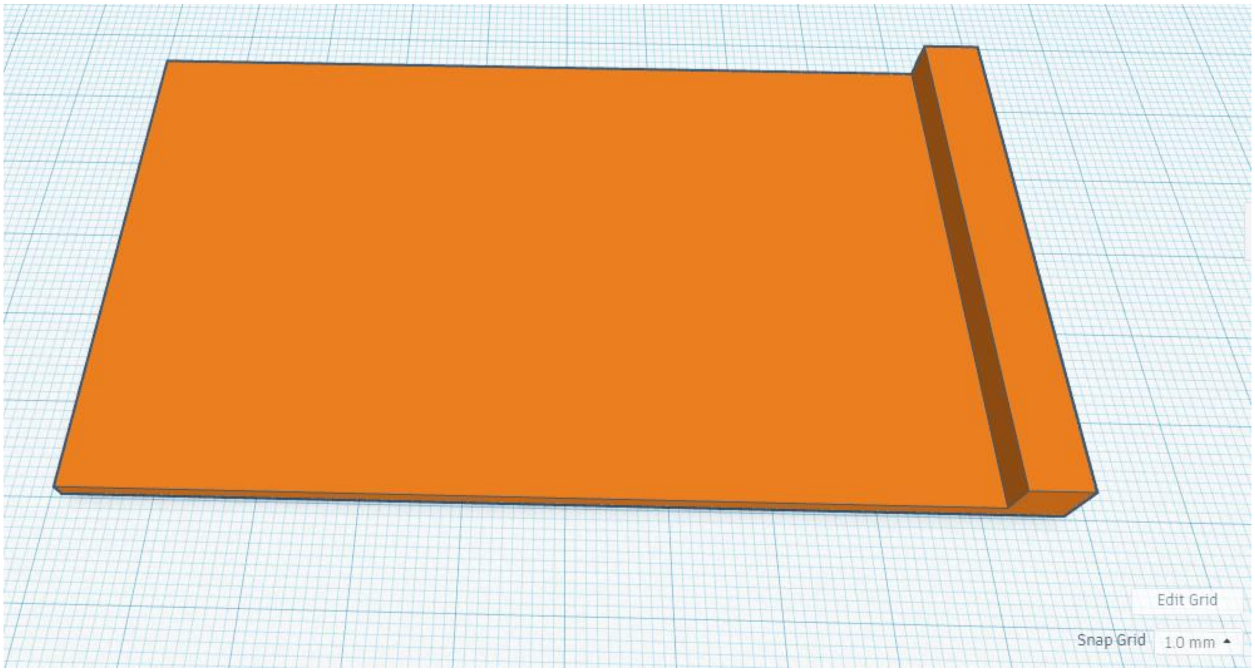

Fig. D-3: Lid to Cover the Enclosure Box [29]

APPENDIX E.

VENDOR CONTACTS

We are thankful to Dr. Smith, from the EEE Department at Sacramento State University, who has offered to fund our project. We are also thankful to Dr. Lazaro, from the Physical Therapy Department at Sacramento State University, who has also offered any assistance to our project. Though we were offered help from these two professors, our group funded the entire project ourselves.

APPENDIX F.

RESUMES

Allen Chau

Objective

- Motivated individual seeking a job opportunity to gain real world experience related to cyber security.

Education

- Pursuing a B.S. in **Computer Engineering** at **California State University, Sacramento**
- Expected Graduation: Spring 2019 **GPA: 3.75**

Projects

- **Remote Controlled Surveillance Bot** (April 2017 – May 2017)
  - Planned, designed, and simulated a Bluetooth controlled RC Car using C and Python
  - Facilitated meetings with group members to create efficiency and clear understandings
- **Simple Mail Client** (March 2015 – April 2015)
  - Python based email simulation that allows users to send emails to any recipient

Experience

- California Department of Public Health **Sacramento, CA**
  Student Assistant, Security Operations Center *June 2018 - Current*
  - Daily monitoring of California Department of Public Health's overall infrastructure with well-known security tools. Responsibilities include incident response handling, resolving known vulnerabilities within our systems, and deep analysis of internal user's ticket related to security issues
  - Working alongside experienced individuals in creating a security incident response plan to ensure there is a course of action to take upon a security event

- California Department of Public Health **Sacramento, CA**
  Student Assistant, Help Desk Specialist *February 2018 – June 2018*
  - Provided first tier technical support to the PEGA platform to users via telephone and emails
  - Grasped the essence of multitasking and work ethics from answering user questions

Organizations

- Tau Beta Pi Engineering Society, member *(September 2017 – Present)*
- Association for Computing Machinery, member *(Sept 2015 – Sept 2016)*
- Kiwanis's Educated Youth Club, Member *(2011 – 2014)*
  - 200+ hours of community volunteer service
  - Activity management for events

Honors

- Dean's List Recipient
  - Dean's List Recipient **8 times** since freshman year

Jesse Root

Education

- Major: Computer Engineering

Skills & Abilities

LEADERSHIP

- Former trainer for Utility Clerk position at Nuggets Market
- Park Staff Lead at Discovery Kingdom
- Project leader in development and research of academic projects and prototypes

ABILITIES

- Good people communication skill with extensive knowledge of inventory control
- Experienced in academic research
- Coordinating groups both large and small
- Experienced cashier
- Certified forklift driver

UTILITY CLERK | NUGGETS MARKET | 11/14/10 - 7/23/13

- I was a utility clerk at my previous job which its responsibilities included gathering carts, putting items away and also being a cashier.

PARK STAFF LEAD | DISCOVERY KINGDOM | 3/24/14 – 8/12/17

- Responsibilities include maintaining and organizing company products and office equipment.
- Keeping track of different teams in the department for designated duties and breaks.
- Knowing and upholding company policies for all team members under my supervision
- In charge of handling guest complaints and issues with service

Tyler Fox

EXPERIENCE

US Department of the Army, Sacramento, CA — *Cadet*

AUGUST 2014 - PRESENT

Taking part in training on group leadership as well as upper level coordination within an organization. Attended summer training events in order to prepare for commissioning following college graduation.

Staples, Sacramento, CA — *Sales Associate*

JUNE 2018 - OCTOBER 2018

Aided with customer service and the sale of office resources and equipment.

US Department of the Army, Columbia, SC — *Enlisted Soldier*

JULY 2013 - MARCH 2014

Took part in physically demanding, team building exercises. Worked with a variety of different people in terms of both peers and supervisors.

EDUCATION

California State University, Sacramento, Sacramento, CA — Bachelor of Science in *Computer Engineering*

AUGUST 2014 - MAY 2019

3.0 Overall GPA

Programming: Studies included multiple object oriented languages, mainly Java and C. Also experience using Assembly, VHDL, Verilog, as well as microcontroller languages used for PIC, Arduino, and Propeller.

Circuit Design: In depth education on logic gates and general electronics. CMOS and VLSI design and simulation using Cadence. Experience with PSpice, Multisim, and various other circuit simulation environments

SKILLS

Active Security Clearance

Self-Motivated

Fast Learning

Good Multitasker

Dependable

AWARDS

Army ROTC Scholarship Granted 3 Year Scholarship by the UC Davis-CSUS Army ROTC program

Dean's List Awarded Dean's list merit multiple times while at CSUS

DANIEL **DIAZ**

Highly motivated Electrical engineering graduate looking for an entry level position in order to further personal and professional experience.

EDUCATION

05/2019

B.S. ELECTRICAL ENGINEERING, CALIFORNIA STATE UNIVERSITY, SACRAMENTO

Emphasis: Controls

Coursework Includes:
Digital control System, Intro to Machine vision, Robotics, Intro to Feedback Systems, Modern Communication System, Power System Analysis, Signals & Systems, Circuits, and more

Senior Capstone Project: Wearable device capable of providing clinicians information on patient balance by measuring body trunk sway. Group project where my task was to implement the IMU and calculate absolute orientation from raw sensor values.

EXPERIENCE

OCT.2013- AUG.2015

ENGINEERING ASSISTANT/INTERN, ENERPRO INC.

- Responsible for testing various firing boards used for high power control systems
- Collaborated with supervising engineers on creating and testing custom systems
- Set up systems for R&D use

JAN. 2019-MAR.2019

ENGINEERS & ARTISTS, VERIZON & THE HIKER COMPANY

- Collaboration Project between engineers and artists, hosted by Verizon.
- Created machine vision system capable of tracking individuals in a given space in an art gallery. Information collected was used to create a digital art piece.
- Only student selected among 5 other engineering professionals.

JUNE. 2018-PRESENT

OFFICE INTERN, PLUMBING HEATING AND COOLING CONTRACTORS OF CALIFORNIA

- Set up automatic invoices in QuickBooks for accounting
- Created spreadsheets used in the revision of important Company documents

SKILLS

- **Electrical Equipment:** Oscilloscopes, Function Generator, DMMs, Transformers, Soldering Iron,
- **Teamwork, Creativity, Project Management**
- **Programming:** C, C++, MATLAB
- **Bilingual:** English, Spanish
- **Type** 60+ Words Per Minute

APPENDIX G.

OTAGO PROGRAM PARTICIPANT SURVEYS

Group 4 Fall 2018 Survey for those in the Otago Program

Summary: Our goal of this survey is to take in your personal opinion and experiences before and after the Otago Program. This will help us in statistics and motivation to pursue our senior project, a college course that tests our engineering and work ethic skills up to this point. Our project aims to help clinicians gather accurate data that is used in restoring balance in senior citizens through exercise adjustments and recommendations. Unfortunately, we were unable to test our project with you, but we greatly appreciate your input in this survey. We will work with the next group in the program to ensure a better end result.

IMPORTANT: The answers you provide to us will solely be used for our senior project allowing us to cater the project towards those in the Otago Program. You will remain anonymous, but we highly appreciate your honesty in this survey.

Please email if you have any questions or concerns!

(**Please fill in the blank**.)

- Please indicate your age. 67
- Please indicate your gender. male
- Please write down any disabilities you have. Arthritis (spinal) Meniere's Disease

(Please **circle a number or put an 'X' in the box** for each answer.)

- Prior to the start of the Otago Program, how would you rate your overall balance without any assistive equipment on a scale of 1-10?

(1 being very unbalanced while 10 being very well balanced)

1	2	3	(4)	5	6	7	8	9	10

- Prior to the start of the Otago Program, have you ever fell within the past 3 months and if so, how severe was it on a scale of 1-10? **If no, leave this blank.**

(1 being the little pain while 10 being serious pain/injury)

(1)	2	3	4	5	6	7	8	9	10

- How often do you engage in **each** of the following activities **per week**?

	Rarely/never	1-3 times	4-6 times	Daily
Mild Activity (For example: slow leisure walking, golf)				Daily
Moderate Activity (For example: speed walking, bicycling)				Daily
Vigorous Activity (For example: jogging/running, dancing)	Rarely			

(Please choose **Yes** or **No** for each question)

- Are you familiar with touch screen devices?

(Yes) No

- Are you comfortable reading font sizes like the ones in this survey?

(Yes) No

- In general, will color coating options help in terms of visibility and guidance?

Yes No

(Choose **ONE** of the following choices for each question)

- If you had to follow exercises in the Otago Program while having the physical device on your body, would you wear the device:
  - Center point of the back (shoulder level)
  - The side of your thigh
  - Center point of the chest area

- If you had to wear this device for about 8 hours through the day, would you start wearing it:
  - In the morning
  - Around noon
  - Afternoon
  - Other (Please give a precise starting time): ___________

End of Otago Program Experience

- Please rate the effectiveness of the Otago Program in terms of restoring your balance.

(1 being very poor while 10 being very good)

1	2	3	4	5	6	7	8	9	10

- Are you now able to complete the exercises in the Otago Program easier than when you first began?

Yes No

- Were you comfortable reporting any falls during the Otago Program?

Yes No

- Are you now able to easily do your daily activities after the end of the program? (For example: leisure walking or even speed walking)

Yes No

Group 4 Fall 2018 Survey for those in the Otago Program

Summary: Our goal of this survey is to take in your personal opinion and experiences before and after the Otago Program. This will help us in statistics and motivation to pursue our senior project, a college course that tests our engineering and work ethic skills up to this point. Our project aims to help clinicians gather accurate data that is used in restoring balance in senior citizens through exercise adjustments and recommendations. Unfortunately, we were unable to test our project with you, but we greatly appreciate your input in this survey. We will work with the next group in the program to ensure a better end result.

IMPORTANT: The answers you provide to us will solely be used for our senior project allowing us to cater the project towards those in the Otago Program. You will remain anonymous, but we highly appreciate your honesty in this survey.

Please email if you have any questions or concerns!

(**Please fill in the blank**.)

- Please indicate your age. 66
- Please indicate your gender. Female
- Please write down any disabilities you have. Multiple Sclerosis

(Please **circle a number or put an 'X' in the box** for each answer.)

- Prior to the start of the Otago Program, how would you rate your overall balance without any assistive equipment on a scale of 1-10?

(1 being very unbalanced while 10 being very well balanced)

1	2	3	4	5	6	7	8	(9)	10

- Prior to the start of the Otago Program, have you ever fell within the past 3 months and if so, how severe was it on a scale of 1-10? **If no, leave this blank.**

(1 being the little pain while 10 being serious pain/injury)

1	2	3	4	5	6	7	8	9	10

- How often do you engage in **each** of the following activities **per week**?

	Rarely/never	1-3 times	4-6 times	Daily
Mild Activity (For example: slow leisure walking, golf)				X
Moderate Activity (For example: speed walking, bicycling)		X		
Vigorous Activity (For example: jogging/running, dancing)	X			

(Please choose **Yes** or **No** for each question)

- Are you familiar with touch screen devices?
  (Yes) No
- Are you comfortable reading font sizes like the ones in this survey?
  (Yes) No
- In general, will color coating options help in terms of visibility and guidance?

Yes No

(Choose **ONE** of the following choices for each question)

- If you had to follow exercises in the Otago Program while having the physical device on your body, would you wear the device:
  - Center point of the back (shoulder level) ?
  - The side of your thigh
  - Center point of the chest area

- If you had to wear this device for about 8 hours through the day, would you start wearing it:
  - In the morning
  - Around noon
  - Afternoon
  - Other (Please give a precise starting time): __________

End of Otago Program Experience

- Please rate the effectiveness of the Otago Program in terms of restoring your balance.
  (1 being very poor while 10 being very good) My balance was pretty good to begin with. I don't think there was a change

1	2	3	4	5	6	7	8	9	10

- Are you now able to complete the exercises in the Otago Program easier than when you first began?
  Yes No

- Were you comfortable reporting any falls during the Otago Program?
  Yes N/A No

- Are you now able to easily do your daily activities after the end of the program? (For example: leisure walking or even speed walking)
  Yes No