CSUS CPE 191

DEPLOYABLE PROTOTYPE DOCUMENTATION

HELPING DIABETICS WITH FOOT COMPLICATIONS

Senior Design Group 9

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***Abstract* - Our team is focusing in developing a therapeutic shoe with integrated sensors that monitor the patient's structural movement. The system has been successfully developed by our team and all the functionalities have been implemented. Our project main goal is to integrate sensor technology into prescribed Pedorthic shoes to record useful information that can be used as a treatment device for a large scope of people not just diabetics. Diabetes is a common health issue in our present society. About 10% of the United States population are suffering from diabetes and all the conditions it carries. About 24 million people in the United States have been diagnosed with Diabetes. Our team is focusing in developing a therapeutic shoe with integrated sensors that monitor the patient's structural movement. Being able to monitor footwear for appropriate offloading is essential for the prevention and recovery of wounds. Our project main goal is to integrate sensor technology into prescribed Pedorthic shoes to record useful information that can be used as a treatment device for a large scope of people not just diabetics. We want the shoe to function as a treatment device for wounded veterans, military patients with diabetes and other alternative military use. Proper footwear can dramatically reduce healing time and lower extremity amputations. Our main goal is to incorporate sensors into the shoe that allows the system to track for plantar pressure while also being able to detect pronation and supination. We will also be incorporating a system for detecting low battery to safely end the data acquiring process and prevent data corruption. Another aspect of our system will be the development of software for an automated deployment system for programming multiple systems. Throughout the report, we discuss the elaboration process of the project and the prototype status.**

***Keywords* – Indicators, diabetes, foot complications, sensor system, circuits, skin, ulcer classification, Gantt chart, Pert diagram, microprocessors, biometrics, medical treatment, skin, ulcers, data collection, customer, humidity, temperature, enclosure, voltage, current, pressure, PCB, software, stability**

Table of Contents

List of Tables:

List of Figures:

EXECUTIVE SUMMARY

Diabetics and wounded veterans often face foot complication that can result in the development of foot ulcers. These foot ulcers can cause major health risks and can often lead to amputation. With the help of our sponsor, Sunrise Shoes, our project will use therapeutic shoes with sensors to help diabetics, and wounded veterans, walk without fear of foot ulcers or eventual amputation. This will be accomplished through the features of our project that sense pressure and bending in the shoe, visualize the recorded information, notify the wearer, and automate installations.

First there is the pressure sensing and bending of the shoe. This feature of our project will provide information to Sunrise Shoes so that they can adjust in pressure for each individual patient. Customizing footwear and patient behavior will help prevent the development of foot ulcers for each of the patients. This feature will also let wearers walk with peace of mind by knowing that their doctors have access to data about their activity and can provide them with feedback if necessary.

Second is the feature of visualizing recorded information. This is a necessary task because it allows Sunrise Shoes and doctors to quickly understand the information they are receiving. Understanding a labeled graph takes much less time than reading through a long table of values. The feature is also useful because it allows understanding of pressure duration. This means doctors will know not only how much force the patient applies to their foot, but also for how long this force is being applied.

Another feature of our project includes notifying the user about necessary information for using the shoe. This includes an indicator so that the patient knows when their shoe is low on power, and an indicator to let the patient know when they need to readjust the position of their foot.

Finally, there is the automatic installations. These will make all software installations in our project automatic, and will be able to install to multiple shoes. This will provide the groundwork for remote updates so that customizations for each patient will be easy and won't require the patient to visit their doctor in person. Overall, these features will work to make the lives of diabetics and wounded veterans easier.

I. INTRODUCTION

Our team will be working with Sunrise and Pedorthic Services to do research and implementation on ways to monitor musculoskeletal status as patients use therapeutic shoes. In the United Stated, diabetes is currently a huge health problem. Since the issue has many complications, we want to implement a system that can help monitor the effectiveness of the tools being used by patients. The goal of the shoe is to be used as a treatment device for diabetic patients, wounded veterans, and for any other military uses. In the United Stated, diabetes is currently a huge health problem. According to a report from 2014 by the National Diabetes Statistic, about 29.1 million people or nearly ten percent of the United States population suffers from diabetes [1]. Because of the large number of diabetics, there is a large number of people suffering from diabetic related complications. The diabetic population tend to be more prone to cardiovascular, musculoskeletal, and neuropathy diseases compared to the general population. One of the biggest groups suffering from complications with foot ulcers is the diabetic community. Diabetes has been highly linked with the occurrence of foot ulcers which can lead to even more severe health risks and sometimes even death. A 2009 Clinical Evidence Study stated that the annual rate of foot ulcers occurrence is as high as 2.5 – 10.7 percent of the diabetic population in wealthy countries [2]. Not only does diabetic diabetes and its related complications affect the health of the population, it also poses an economic problem to the community and for the country. Lowering the expenses for diabetic patients is an essential necessity in our present time. It is important to lower expenses caused by diabetes because the economic cost of diabetes in the year 2007 was estimated to be around 174 billion dollars. The diabetic community suffers from a range of medical problems, many of which still do not have a coherent process and solution. According to the article H-Fit Healing Shoe with Sensor Technologies, it states that current healing devices in the market, such as Darco Surgical Shoes, or CAM Walker Bledsoe System, either have no control of your musculoskeletal system, or they completely lock it up, resulting muscle atrophy, deformity, and subsequent ulcers [3]. The same article also stated that the current competitive wound care devices often extend of the pathology of the underlying conditions (Diabetes, aging, obesity, wounds), and often provide unsatisfactory prevention and prolonged and further disability [3]. We want to create an affordable system that is able to track diabetic foot status through pressure sensing and stability sensing. Some similar systems to the one we want to implement are expensive. For example, Tekscan has similar systems to the one we want to implement but it is too expensive. The Tekscan tethered F-scan is $9,995.00 and the wireless F-scan is $14,995.00. These systems are too expensive for patients to afford. We want to implement a system that is much more affordable to the user by reducing the price of the system greatly. With increasing knowledge and technology preventative steps, our system could help to free diabetics of future complications.

We will be working with the Sunrise therapeutic shoe to incorporate sensor technologies. The goal of the shoe is to be used as a treatment device for diabetic patients, wounded veterans, and for any other military uses. The shoe will be design to help and benefit wound care patients and military personnel. Our goal will be to implement circuits that can help diagnose the stability of the shoe to dramatically reduce healing time and lower the chance of an extremity amputation [3]. Our focus is to produce a circuit that monitors patients for musculoskeletal movement and neurological conditions using sensor technology integrated in the shoe. We care in monitoring symptoms since prevention is key when it comes to minimizing and preventing disabilities and health care cost. An issue we want to solve using sensors is to track the pressure distribution inside the shoe, that way they can diagnose if the shoe is relieving pressure in the areas it is supposed to. We also want to track the dynamic balance of the lower extremities since one of the goals of the show is to provide better balancing for the patient. It's important to track stability and balance because studies have demonstrated that footwear adjustments can influence balance and stability [6]. Adding the technology to the shoe will allow us to adjust the footwear by tracking plantar pressure so modifications can be made for relieve and comfort for the patient.

We have developed our project prototype. The prototype consists of the main features like the pressure sensor system, pronation and supination detection system, low battery detection system, and the data visualization system. During the fall semester, we decided to implement the most important components of the shoe. This will allow us to incorporate all the sensors into the shoe and have an idea if the circuits will fit in the sole of the shoe or if an ankle brace will be necessary. Most of the systems are ready to be incorporated into the shoe. The only problem we have faced is the size of the microcontroller since it's too big to be incorporated into the sole of the shoe. We decided to change the breakout board of the intel Edison to reduce the size and stack 3 ADC mini breakout boards to get enough inputs for all the sensors. We are also developing a printed circuit board for the acquisition circuit, so it can fit in the sole of the shoe. A few systems were postponed until this semester since they depended on other systems. Some of the systems that were postpone are data visualization and the automated deployment system. These two systems are currently being developed by the team. The status of the system is excellent since most of the required systems are ready to be incorporated into the shoe. We want to make the least modifications to the shoe because we don't want to hinder the stability of the shoe. This semester we are going to focus mostly in the visualization part of data since it's important to the user. Another area that we will focus on is developing the automated deployment system since we want to program the microcontrollers automatically using Wi-Fi connectivity. Our team is on track with our deadlines and assignments at this point of time. We hope to complete the deployable system early so we can work on the presentation of the system.

Another aspect we focused on was creating a timeline that portrayed the different tasks and assignments that needed to be completed. To produce this shoe successfully in the time span we were given we need to organize our duties so the entire team knows what to achieve and when to achieve it. By graphically showing the tasks in tables and diagrams, we can keep the team on track. Portraying the assignments and tasks in an organized manner is essential for keeping the team aware of deadlines. The information and deadlines will be traced out through a project deadline. The tasks and assignments will be organized using a Grantt chart and Pert diagram. Having a visual aid of the deadlines gives us a higher degree of success when completing the tasks and assignments. It allows us to quickly identify the tasks that need work and the ones that have been successfully completed. It also allows us to identify how close we are to the completion of the project. We want to spend our time wisely since we need to build an efficient system at a low cost since it's an important factor. To create a successful project, just like the different tasks and assignments need to be labeled in an organized manner, risk assessment needs to be taken into account as well. Assessing the different risks, the team might encounter is a way to prepare for the unexpected.

Many aspects of a project introduce potential risks that could be encountered. We discussed how reducing the cost of the system is important but trying to lower the cost of the system will introduce a level of risk to the system. Reducing cost means reducing the quality of the hardware while still achieving a quality system. One important goal our team is trying to accomplish is to increase the quality while reducing the cost as much as we can. Risk assessing is crucial because during development of the system, unpredictable outcomes can be encountered that might pose some risk to certain parts or the entire project as a whole. The main goal of the risk assessment report is to steer parts of the project to reduce risks while achieving maximum results. Since no projects are risk free, we need to identify the areas of the project that could cause severe risk implications. Since our project consists of multiple features, it introduces more areas of risk to the system. Some areas and sources of failures in our system are hardware, software, and organization failures. In order to successfully complete the project, we need to approach the project with risk resolutions in mind. In order to reduce the severity of risk, we need to begin risk management at the earliest stages since problems are easier to resolve. Risk management will continue throughout the process in order to try to reduce the risks. We will develop risk mitigation plans in order to solve any risks that we might encounter throughout the project. Since the multiple features of the system increase the complexity of the system, the risks increase as well. This calls for more formal tools and methods to manage risks that might occur. Being aware of any issues that might be encountered allows us to be prepared or even to implement a solution to completely avoid unnecessary risks.

A very essential aspect of the engineering process is testing the system. By testing, we will evaluate the system to make sure it satisfies the specified requirements. We have tested multiple areas of the system including hardware and software. Since some of the circuits are going to be inside the shoe, we made sure to test that they can resist changes in the environment. For example, the system had to resist changes in humidity as the shoe was exposed to moisture from the foot perspiration. The system also needs to resist changes in temperature as the sole of the shoes warms up as it contacts the concrete. We also tested that the data being collected is appropriate and with enough accuracy to the actual values. The flex sensors were also tested to decide if the values being produced were effectively addressing the issue. Another area we had to test was the data stability as the voltage fed from the battery decreases. The system had to make vary the values of the calculation depending on the voltage provided by the battery. If the voltage changed, the system had to identify the voltage change and status. The data visualizations also had to be tested since we need to track if the data is correctly being stored and identified. Many more aspects of the system were tested to ensure that the system is functioning properly and safely. As the system was developed and tested, we faced unexpected situations that forced us to make a few changes. These changes had to do with the stability of the shoe and with the system itself. Unexpected situations increased our work load because it required extra work and time. Many tests were run that focused in all the subsystems of the system. Some of the tests were not fully complete since they rely on other components that are not complete at the time. Most of the tests past without any issues but some issues were encountered that required attention. One of the main tests that still need to be complete is testing the system since not all the subsystems have been merged. Testing has allowed us to find issues soon in the development so we can fix them without causing any extra work.

We are trying to develop a system that can help evaluate the functionality of the shoe, while also monitoring certain aspects of the patient. Since we want to estimate if the product is going to be successful in the maker, we need to run a market review. Some questions we want to answer with the market review is if the there is any interest for the product, how much are the people willing to pay, and how much we can charge for the product. In the report, we want to estimate the customer interest for the product and if has any profitability potential. The goal is to produce a product that provides innovations in the Pedorthic market to increase its demand. Some similar products are available in the market but the problem is that they are expensive and aren't meant to be used in daily bases. We are aiming for a product innovation since we want to improve an existing product by reducing the cost while keeping the quality. We are using application innovation to produce the system since we are using existing technologies for a new purpose. The product will be introduced into the small market of Pedorthic shoes so it has plenty of space for growth. By introducing sensors into the shoe to check the effectiveness of the tool and to monitor the patient, we want to revolutionize the market for the shoes. If we can monitor and proof the effectiveness of the shoes, the clients will trust the product even more. A market review will allow us to determine the possibilities of the system for commercial success.

After both semester, we have developed our deployable prototype. The final prototype consists of all the main features like the pressure sensor system, pronation and supination detection system, low battery detection system, automated deployment system, and the data visualization system. During the fall semester, we decided to implement the most important components of the shoe. This allowed us to incorporate all the sensors into the shoe while concluding if the circuits will fit in the sole of the shoe or if an ankle brace will be necessary. During the spring semester, we developed the automated deployment system since it required the rest of the systems to be ready. In the spring semester, we focused mostly on testing the system and optimizing the software. All the systems are ready and incorporated into the shoe. The only problem we faced, was making the system look professional since it became a challenge hiding the wires from the shoe to the microcontroller. The status of the deployable prototype system is positive since the entire systems has been completed and verified throughout the development phase. We have resolved all the issue like reducing the size of the microcontroller and the acquisition circuit. We have also reduced the power to a single battery. One of the main goals during the implementation phase was to make the least modifications possible to the shoe because we didn't want to hinder the stability of the shoe. Our team was on track throughout both semester, deadlines and assignments were complete early most of the time. The system was implemented without any issues and is fully complete to be exposed to the sponsor.

II. SOCIETAL PROBLEM

Our project goal is to provide a tool to society that can help diagnose the effectiveness of their therapeutic shoes. Individuals suffering from diabetes use therapeutic shoes to prevent ulcers and skin conditions. Diabetes is currently a huge health problem in the United States. According the 2014 National Diabetes Statistics Report, 29.1 million people or nearly 9.3 percent of the United States population suffers from diabetes [3]. Because of the large number of diabetics, there is many people suffering from diabetes related complications. The diabetic population tends to show higher prevalence of musculoskeletal, neuropathy, and cardiovascular diseases compared to the general population. In fact, one of the biggest groups suffering from complications with foot ulcers is the diabetic community. According to a 2009 Clinical Evidence study, the annual rate of foot ulcers occurrence is as high as 2.5 to 10.7 percent of the diabetic population in wealthy countries [2]. Evidently, diabetes is highly linked with the occurrence of foot ulcers and these ulcers can lead to even more severe problems.

Not only does diabetes and its related complications impact the health of the population, it also poses an economic problem for the country. Lowering the expenses for diabetic patients is an essential necessity in our present time. The economic cost of diabetes in the year 2007 was estimated to be around 174 billion dollars. In the year 2012, the economic cost of diabetes grew to 245 billion dollars, an alarming 42% increase in just five years. [15] Finding ways to monitor symptoms and early detection for prevention of diabetes and its resulting complications is necessary for reducing the economic cost of diabetes. About 20% of the health money is spent in the diabetic area, with one out of five health dollars used on someone diagnosed with diabetes [15]. Some of the most common complications of diabetes are diabetic neuropathic arthropathy, osteomyelitis, and tendinopathies.

One of the main problems is that diabetics spend a lot of money as treatment. About twenty percent of the health money is spent in the diabetic area, with one out of five health dollars used on someone diagnosed with diabetes [3]. The diabetic population suffers many health issues, which is why early identification of symptoms is essential to help prevent severe health conditions. In cases, preventative measures can save extremities of diabetics and decrease mortality rates. The diabetic community suffers from a range of medical problems, many of which still do not have a coherent process and solution. According to the article H-Fit Healing Shoe with Sensor Technologies, it states that current healing devices in the market, such as Darco Surgical Shoes, or CAM Walker Bledsoe System, either have no control of your musculoskeletal system, or they completely lock it up, resulting muscle atrophy, deformity, and subsequent ulcers [5]. The same article also stated that the current competitive wound care devices often extend of the pathology of the underlying conditions (Diabetes, aging, obesity, wounds), and often provide unsatisfactory prevention and prolonged and further disability [5]. We want to create an affordable system that can track diabetic foot status through pressure sensing and stability sensing. Some similar systems to the one we want to implement are expensive. For example, Tekscan has similar systems to the one we want to implement but it is too expensive. The Tekscan tethered F-scan is $9,995.00 and the wireless F-scan is $14,995.00. These systems are too expensive for patients to afford. We want to implement a system that is much more affordable to the user by reducing the price of the system greatly.

A. *Issues with Diabetes*

The diabetic population suffer many health issues involving musculoskeletal conditions, skin conditions, and many more. Since the diabetic population is prone to suffer from health conditions they need tools that they can incorporate into their daily activities to help monitor possible conditions.

1. *Diabetes Musculoskeletal Conditions*

Diabetes long-term complications are developed gradually as patients grow careless about their blood sugar control for an extensive period. The longer the patient has diabetes while improperly supervising blood sugar level, the higher the risk of complications. One of the areas affected by improper control of blood glucose is the musculoskeletal system. The metabolic perturbations caused by uncontrolled diabetes can result in alteration of the connective tissue. Certain musculoskeletal complications are directly associated with diabetes and other are suggested but have not yet proven a direct association. Rheumatological and musculoskeletal manifestations observed in patients with diabetes are usually in their hands, shoulders, feet and muscles. The vulnerability of diabetic people is their hands and feet since the circulation of the extremities is severely hindered as diabetes becomes uncontrolled. Hands and feet are targets for numerous diabetes-related complications since diabetes causes bad circulation. Diabetic's hands usually experience diabetic cheiroarthropathy which is also known as limited joint mobility syndrome [4]. Figure 1 shows the prayer sign which indicates the presence of diabetic Cheiroarthropathy.

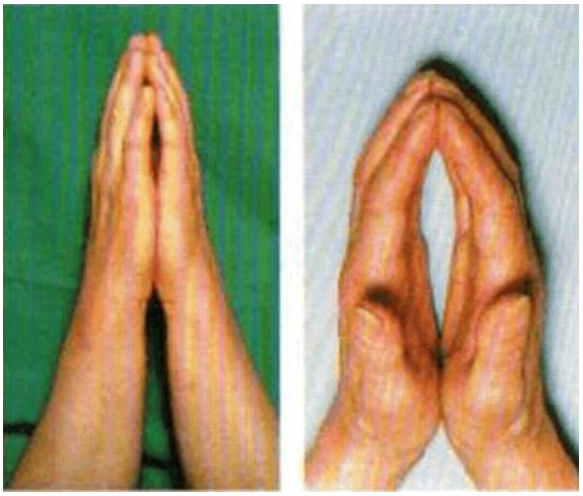


FIG. 1. THE PRAYER SIGN SYNDROME:
The prayer sign indicates the presence of diabetic cheiroarthropathy also known as diabetic stiff hand syndrome. This syndrome causes a limiting range of motion and sclerosis of tendon sheaths [4].

Limited joint mobility syndrome is caused by tight, thick, waxy skin reminiscent of scleroderma which results in limits the range of motion of the joints and sclerosis of tendon sheaths. This syndrome caused flexion contractures of the fingers as well as the patients' inability to completely press their palms together. Another part of the body affected by diabetes is the shoulders. About 19% of the diabetic patients experience adhesive capsulitis which causes the shoulder stiffness, as well as minimizing the range of motion of the shoulder [4]. Calcific periarthritis is another shoulder complication that causes calcium deposits outside the joints around the rotator cuff tendons. The feet are another major area affected by diabetes. Diabetics may suffer from diabetic osteoarthropathy which is also known as Charcot.

FIG. 2. FLEXOR TENOSYNOVITIS SYNDROME:
Shows a patient with flexor tenosynovitis also known as trigger finger. This cause some fingers to lock and cause pain in some of the cases [4].

Charcot is a condition that involves destructive and lytic join changes. This condition is extremely destructive because it's a form of degenerative arthritis that results in the loss of sensation in the surrounding joints. The loss of sensation causes repeated micro-trauma to the joints which then leads to degenerative changes. Figure 2 shows a case of trigger finger which is caused due to tendon problems. Figure 3 shows an illustration of what occurs to tendons during trigger finger syndrome. The loss of sensation leads to swelling, soft-tissue ulcers and joint deformation of the affected area. Another area of the body affected by diabetes is the muscles. Although it's a rare condition, diabetic muscle infraction might occur to a diabetic patient. This condition might occur spontaneously with no history of trauma. The condition tends to mostly affect patients with a record of uncontrolled diabetes. Patients that require insulin are more susceptible to suffer from diabetic muscle infraction, as well as patients suffering from multiple microvascular complications. The diabetic population suffers many health issues which is why early identification of symptoms is essential to help prevent severe health conditions. Lower extremity conditions have resulted in severe impairments for the diabetic community.

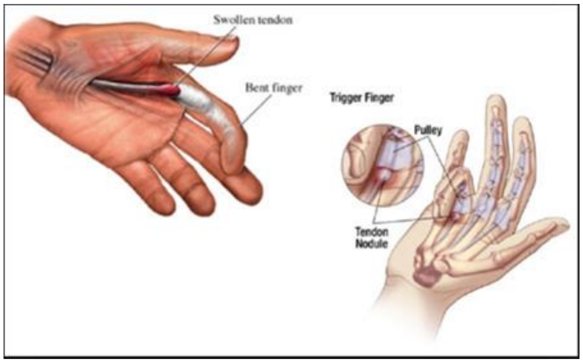


FIG. 3. TENDON ILLUSTRATION OF TRIGGER FINGER: It shows a diagram of what happens to the tendons of the hand when a patient gets trigger finger. Sometimes it can be caused by tendon problems and sometimes by swelling of the tendon [15].

Lack of mobility is prevalent in diabetics with severe foot conditions. Historically 15% of diabetics will experience an ulcer of some sorts [4]. Foot ulcers form from a myriad of reasons. Abnormal gait, lack of circulation and ill-fitting shoes are some reason for foot ulcer formation. The formation of a foot ulcer is seen in figure 1. A history of foot ulcers can be life threatening to people with diabetes. Figure 2 depicts a 10-year study conducted to find the relationship with a history of foot ulcers and mortality. In the diabetic study, people with a history of foot ulcers encountered a mortality rate 40% higher than their counterparts [1]. In the diabetic community foot complications, may be precursors to amputation. Foot ulcers can lead to infections and when those infections are left untreated amputation can be the only options. According to the 2014 National Diabetes Statistics report, roughly 60% of non-traumatic lower-limb amputations among people over 20 years occurred in patients diagnosed with diabetes [3]. Lower extremity amputation is debilitating to the human psyche. Upon notice of amputation patients go through a plethora of emotions. Denial fills their subconscious proceeded by anger and depression. Patients may often feel helpless and lack energy or vigor. Amputation is a life changing event and is a growing problem in the diabetic community. The University of Nottingham conducted a study to research the emotional and behavioral experiences of people who at risk of redeveloping a diabetic foot ulcer. The study revealed that patients experienced a lack of control over their situation. Those interviewed in the study revealed fears and worries about redeveloping foot ulcer, but more prominent they feared amputation. One patient said “it's been like an emotional rollercoaster. You’ve been at the bottom, 1 min you’re not, then you might lose your toes, then you don’t know, and then suddenly you’ve got away with just taking a bone out” [3]. Fear haunts the diabetic community especially those with a history of foot ulcers. The fear is perhaps said best by another patient from the study in which she said “I get anxious, worried, it [DFU] really does take over my life. Because I immediately start to think of things I can’t do… Just walking out to the kitchen, its simple things like standing [to put the kettle on]” [3]. Fear of social stigma associated with amputees is also present and many patient feel their very life being taken from them. Reintegration and assimilation can be extremely difficult for amputee patients. Foot complications in diabetic patient give rise to an amalgam of complication. These complications range from physical to emotional impairments as well as higher mortality rates.

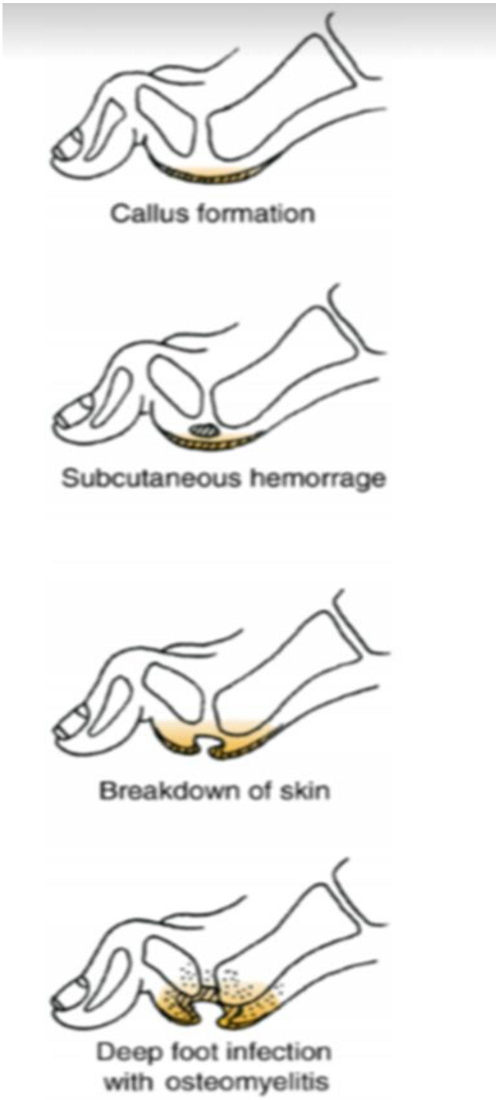


FIG. 4. FOOT INFECTION PROCESS:
It's a diagram of how skin injuries occur and how the breakdown of skin happens. This skin injury can cause deep foot infection with osteomyelitis [1].

The diabetic population suffers many health issues which is why early identification of symptoms is essential to help prevent severe health conditions. In cases preventative measures can save extremities of diabetics and decrease mortality rates. The diabetic community suffers from a range of medical problems, many of which still do not have a coherent process and solution. With increasing knowledge and technology preventative steps and system could help to free diabetics of future complications.

2. Diabetic Skin Conditions

One of the most common issues diabetic people suffer from is skin problems. About a third of the people diagnosed with diabetes develop a skin problem during some point in their life. Skin problems can sometimes be indicators of diabetes which help diagnose patients early when the problem can still be treated. If caught promptly, skin problems can be treated easily causing no real danger to the patient. One of the main reasons that diabetic people suffer from skin problems is because they do not keep proper control of their blood sugar [4]. It is important for diabetic people to keep control and monitor their sugar levels because it can prevent skin problems and many other diabetes symptoms. Individual diagnosed with diabetes are more prone to skin infections than healthy individuals. Diabetic people are more susceptible to boils, nails, eyelid infections, and carbuncles [4]. These skin problems cause the area around the infection to get red, hot, swollen and painful. By treating the affected area quickly with antibiotic creams and pills, the affected area should clear up the skin problem [4]. Again, the important part is being able to detect the problem as quickly as possible. Another major skin problem diabetic people suffer from is fungal infections. Figure 5 shows a typical eyelid infection that diabetic people tend to develop. This yeast-lime fungus known as *Candida Albicans* tend to create itchy, red rashes that are usually surrounded by small blisters. These fungal infections are usually found in warm, moist areas of the body like in between the toes and armpits.

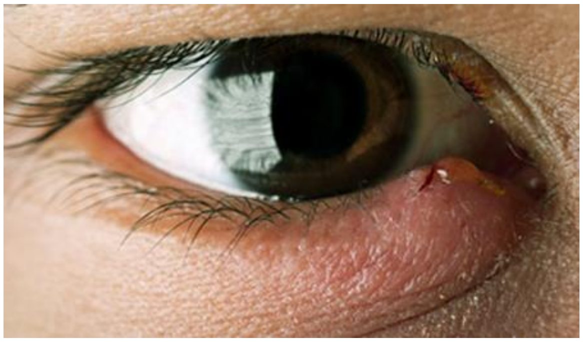


FIG. 5. DIABETIC EYELID INFECTION:
People suffering from diabetes tend to more develop infections that healthy people. This figure above shows an eyelid infection that is common with diabetic people [4].

People with diabetes also tend to suffer from itchy skin caused by dry skin, yeast infections, or bad circulation. When poor circulations is the culprit of the itching, the lower extremities tend to be the itchiest part of the body. In order to help reduce the itching it's important to bath using mild soaps and also considering bathing less often to reduce skin from crawling. Slathering moisturizing lotion is also essential to reducing itching as long as avoiding applying it between the toes. Diabetic blisters is another severe diabetic skin condition known as bullosis diabeticorum, which causes individuals to erupt in blisters. Blisters tend to appear on the hands, feet, toes, and on the forearms or legs. When the patient has diabetic neuropathy, it is more likely for them to develop these blisters which resemble burn blisters. The blisters usually heal on their own in a few weeks and are usually painless but for them to heal keeping the blood glucose under control is crucial. Erupted Xanthomatosis is another skin condition added to the list of diabetics. When diabetes gets out of control it can cause eruptive Xanthomatosis which causes yellow, firm, pea-like skin growths. These skin growths have a red halo around the bumps and then to be found on the back of feet, hands, and buttocks.

FIG. 6. BULLOSIS DIABETICORUM (DIABETIC BLISTERS):
Diabetic blisters are a severe condition that affects diabetic people when their blood glucose is being incorrectly monitored. Patients usually erupt in blisters [4].

This conditions targets mostly young man with type 1 diabetes that have high cholesterol levels and high levels of fat in the blood. Diabetic people can also develop another skin condition known as digital sclerosis which causes skin on the back of the hands, toes, and forehead to get thick, tight, and waxy. Controlling blood glucose levels is essential to treat this condition. Diabetic people are prone to many skin conditions if they do not track their blood glucose levels which might develop into more severe conditions. Not treating infections, wounds, or blisters might cause ulcers and severe infections that might lead to the imputation of extremities. Early detection of wounds and infections is essential for preventing surgical needs and medical cost.

3. *Forms of Detection or Indicators of the Problem*

Foot ulcerations stem from many roots. The most prominent reason for foot ulcerations is ill placed pressure and continuous damage to the foot. One reason for this ill placed pressure is abnormal gait. The way a person walks can lead to foot ulcerations. Unfitting shoes are also a cause for concern as uneven pressure is applied to the foot. Physical symptoms are present when identifying a foot ulcer in a diabetic patient. Blisters and sores can be the first line of indicators. These sores or blisters are often associated with pain, another indicator for foot ulceration. Discoloration of the feet is used for detecting foot ulcers. Diabetics suffering from foot ulceration experience blue and black tissue; Redness and swelling can also be present. An abnormal symptom associated with foot ulceration is a fever. Temperature variations in the foot are also indicative of a potential foot ulcer in many diabetic patients. Detection of foot ulcers is extremely important for the diabetic community. Early detection can prevent more serious complications such as amputation. When detected with adequate time the foot ulceration can be healed and be fairly safe, but when not detected ulcers can lead to infection and other serious issues. The diabetic community is in dire need of a preventative system to ensure and preserve their mobility and health.

4. Classification System

Once a foot ulcer is identified it can be classified to what stage it is in. Among popular classification tools two stand out on top, the Wagner Ulcer Classification System and University of Texas Wound Classification System. The Wagner System is one of the most popular tools focusing on wound depth and tissue damage. This system of classification however does not use the presence of an infection as a classification grade. The University of Texas System tackles this problem by using the presence of an infection to better classify ulcers. Both system have various levels of classification and are used to better understand severity of patients. The systems can be seen in figure 3. Foot ulcer classifications are important to help identify treatment solutions for patients and setting up checkups. Ulcers can pose severe complications for diabetics so setting up checkups depending on their classification is vital. Diabetics suffer from poor circulation and often healing of the wound suffers. Ideally daily checkups would be beneficial to ensure healing, but patients cannot live like that. The Diabetic community needs a way to help healing of wounds. Solutions exist such as specialized footwear, but the problem may lie in ensuring diabetics use them correctly and consistently.

TABLE I.
ULCER CLASSIFICATION SYSTEM

Table 1. Wagner Ulcer Classification System

Grade	Lesion
1	Superficial diabetic ulcer
2	Ulcer extension involving ligament, tendon, joint capsule, or fascia with no abscess or osteomyelitis
3	Deep ulcer with abscess or osteomyelitis
4	Gangrene to portion of forefoot
5	Extensive gangrene of foot

Table 2. University of Texas Wound Classification System

Stages	Description
Stage A	No infection or ischemia
Stage B	Infection present
Stage C	Ischemia present
Stage D	Infection and ischemia present
Grading	**Description**
Grade 0	Epithelialized wound
Grade 1	Superficial wound
Grade 2	Wound penetrates to tendon or capsule
Grade 3	Wound penetrates to bone or joint

Table was obtained from [16].

B. Existing Solutions

As diabetic foot ulcers remain a significant problem for the population, there have been many explored methods of prevention and treatment. One of these treatments is human skin equivalent. It consists of two layers of human skin cells, one of these layers is made up by dermal cells and the second layer is made up by epidermal cells [2]. A more detailed model of the human skin equivalent can be found in the figure below. Human skin equivalent also produces growth factors that improve the healing of the skin [2]. These attributes of human skin equivalent make it an effective treatment method for ulcers. When compared to a similar solution, saline-moistened gauze, human skin equivalent was shown to be both more effective at improving ulcer healing rates and reducing ulcer infection rates over the course of 12 weeks.

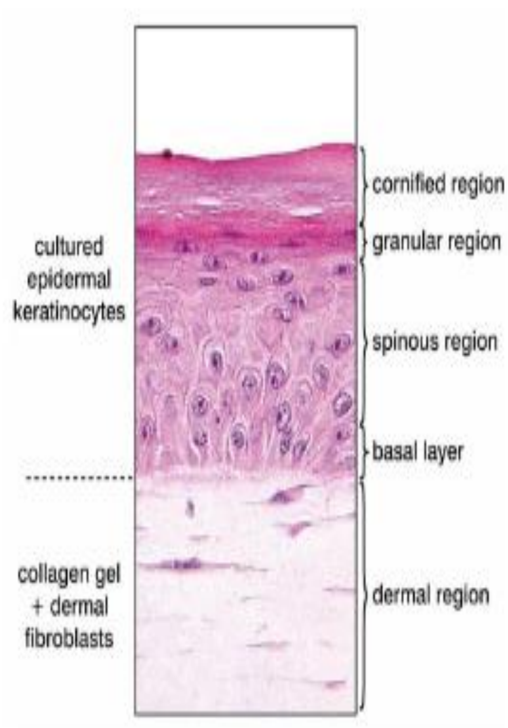


FIG. 7. HUMAN SKIN EQUIVALENT DIAGRAM:
The figure above shows a more detailed model of human skin equivalent [2].

The rate of wound closure for was found to be 56% for patients using human skin equivalent, and 38% for patients using the saline-moistened gauze [2]. As a result of healing and reducing infection rates, the use of human skin equivalent also decreases the chance that foot ulcers will eventually lead to amputation. Essentially, human skin equivalent is an important tool in helping diabetics recover from the incidence of foot ulcers.

While human skin equivalent is useful in ulcer treatment, it does not address the issue of the patients mobility. Another form of treatment for diabetic foot ulcers, that can improve mobility of the patient, is pressure off-loading with total contact casting. In this situation, different techniques are used in order to minimize the amount of force that is being applied to the ulcer site. Based on the severity of the patient's foot, pressure off-loading casts can even be specially made. In the treatment of diabetic foot ulcers, pressure off-loading casts have proven quite effective. In comparison with traditional wound dressing, pressure off-loading casts are better in improving ulcer healing rates as well as lowering ulcer infection rates. According to a 2009 Clinical Evidence report, a systematic review was conducted with 40 diabetics suffering from non-infected foot ulcers. The review found that pressure off-loading total contact casts, when compared to traditional wound dressing, led to healing of 91% of the patients as opposed to 32%. On top of this, the number of infections observed in those who used pressure offloading casts remained at 0 out of 21 people, while wound dressing resulted in infections in 6 out of 19 people [2]. Evidently from the results of this review, pressure offloading remains an effective method of treating diabetic foot ulcers. This is likely a result of removing force being placed on the ulcer and allowing healing to take place undisturbed. The rate of healing that results from pressure off-loading also appears to be greater than the rate resulting from human skin equivalent and these methods of treatment can even be used in conjunction. Essentially, pressure offloading serves as one of the most useful tools in addressing diabetic foot ulcers.

FIG. 8. PRESSURE OFF-LOADING CAST:
The picture above shows an example of a pressure off-loading cast [2].

Human skin equivalent and pressure off-loading work well in addressing the treatment of foot ulcers, but don't serve as well in the purpose of prevention. While these tools would theoretically work as tools for prevention, they would be excessive and perhaps even unnecessary. There are other tools for the purpose of prevention. An example of one of these tools would be therapeutic footwear. These are shoes or shoe inserts specially designed to try and prevent the development of foot complications in diabetics. They serve a similar purpose as pressure off-loading casts, in that they improve patient mobility, but are closer to regular shoes. While the purpose of therapeutic shoes is to prevent of foot ulcers, their effectiveness remains debatable. In a 2009 Clinical Evidence study, a group of 69 individuals with previous diabetic foot ulcer history were split into a control group that continued to wear their regular shoes, and a group wearing therapeutic footwear. Over the course of a year, the study found that the therapeutic footwear did indeed help stop the recurrence of ulcers with 27% recurrence from therapeutic footwear users as opposed to a 58% recurrence rate from regular users [2]. On the other hand, a subsequent study, this time with 400 individuals, found no significant difference between therapeutic footwear and regular footwear. Over the course of two years, the recurrence for ulcers in users of therapeutic footwear was 14%-15% and the rate of ulcer recurrence in regular users was only 17% [2]. Essentially, the studies only give a slight indication that therapeutic footwear could help in prevention of diabetic foot ulcers.

Overall, there are many forms of treatment and prevention for diabetic foot ulcers. While there seem to be some quite effective tools for the treatment of ulcers such as pressure off-loading casts and human skin equivalent, the best tools for prevention remain debatable. Therapeutic footwear may be beneficial, and at the very least is not detrimental, however early awareness of the risks and referral to health care clinics appear more clearly beneficial. Because of investigating existing solutions to the problem, it seems most beneficial to work on improving pressure off-loading casts since they seem to add the most direct benefits to patients suffering from diabetic foot ulcers.

C. Intended Solution

While the benefits of therapeutic shoes have found to be questionable, both the positive effects of pressure off-loading footwear and the focus of pressure in the incidence of diabetic foot ulcers open a space for therapeutic shoes. Using therapeutic shoes in conjunction with sensing technologies, patient treatment can be tracked and analyzed in near real time. Abnormal pressure to the foot is considered one of the leading reason for diabetic foot ulcers. The solution proposed to the widely persistent problem of foot ulcers is to incorporate pressure sensing into therapeutic shoes. By doing so treatment can be monitored to ensure wound healing and discourage abnormal gait. The other problem to consider is consistent use of therapeutic shoes and movement. Diabetics suffer from poor circulation and therefore should attempt to use specialized shoes whenever possible as well as maintain movement to promote circulation. As part of the solution, specialized technologies are to be implemented in therapeutic shoes to monitor consistent use of shoes and promote movement. Implementing technology into therapeutic shoes can bring about success in fighting against diabetic foot ulcers. Through consistency and tracking, therapeutic shoes may gain improved validation. The goal is to allow the diabetic community to remain free, to remain agile, and to keep ability to move intact. For diabetics, this solution could mean walking without constant fear of their own feet.

III. DESIGN IDEA CONTRACT

The healing shoe with sensor technologies will be implemented as a treatment device for patients with diabetes and wounded veterans. Diabetes is currently a huge health problem in the United States. Per the 2014 national Diabetes Statistics Report, 29.1 million people or nearly 10% of the United States population suffers from diabetes [3]. Diabetes has been highly linked with the occurrence of foot ulcers which can potentially lead to even more severe health issues. A 2009 Clinical Evidence Study stated that the annual rate of foot ulcers occurrence is as high as 2.5 – 10.7 percent of the diabetic population in wealthy countries [2]. Because of the large number of diabetics, there is many people suffering from diabetic related complications. In fact, one of the biggest groups suffering from complications with foot ulcers is the diabetic community. Finding ways to monitor symptoms and early detection for prevention of diabetes and its resulting complications is necessary for reducing the economic cost of diabetes. The diabetic population suffers many health issues, which is why early identification of symptoms is essential to help prevent severe health conditions. In cases, preventative measures can save extremities of diabetics and decrease mortality rates. The diabetic community suffers from a range of medical problems, many of which still do not have a coherent process and solution. With increasing knowledge and technology, preventative steps and systems could help to free diabetics of future complications. We will be working along with Sunrise and Pedorthic Services to do research and implementation for some of the functions of the shoe. The goal of the shoe is to be used as a prevention and treatment device for diabetic patients, wounded veterans, and for any other military uses. According to the article *H-Fit Healing Shoe with Sensor Technologies*, it states that current healing devices in the market, such as Darco Surgical Shoes, or CAM Walker Bledsoe System, either have no control of your musculoskeletal system, or they completely lock it up, resulting muscle atrophy, deformity, and subsequent ulcers [5]. The same article also stated that the current competitive wound care devices often extend of the pathology of the underlying conditions (Diabetes, aging, obesity, wounds), and often provide unsatisfactory prevention and prolonged and further disability [5]. We want to create an affordable system that is able to track diabetic foot status through pressure sensing and stability sensing. Some similar systems to the one we want to implement are expensive. For example, Tekscan has similar systems to the one we want to implement but it is too expensive. The Tekscan tethered F-scan is $9,995.00 and the wireless F-scan is $14,995.00. These systems are much too expensive and provide a space in the market for preventative therapeutic shoes. We want to implement a system that is much affordable and to the user by reducing the price of the system greatly.

The shoe will be design to help and benefit wound care patients and diabetics. Our goal will be to implement circuits that can help diagnose problems with the patient in order to dramatically reduce healing time and lower the chance of an extremity amputation. We care in monitoring symptoms since prevention is key when it comes to minimizing and preventing disabilities and health care cost. One of the issues Sunrise shoes wants us to track using sensors is if the patient is using the shoe as prescribed and how much is he/she actually using the shoe. Another issue they want to solve using sensors is to track the pressure distribution inside the shoe, that way they can diagnose if the shoe is relieving pressure in the areas it is supposed to. Pressure metrics inside the shoe are essential for determining patient usage and pressure distribution.

It’s also essential to monitor dynamic balance of the lower extremities since one of the goals of the shoe is to provide better balancing for the patient. Another of our main goals with the shoe is to be able to track neurological conditions as the patient wears the shoe like muscle activity including balance of the foot and pressure distribution. It’s important to track stability and balance because studies have demonstrated that footwear adjustments can influence balance and stability. Adding sensor technologies to the shoe will allow Sunrise Shoes to adjust the footwear based on plantar pressure for relief and comfort of the patient. The implementation of the shoe is to improve the lives of people who are suffering or are prone to suffer from ulcers on their feet due to diabetes. The shoe is meant to provide comfort to the patient’s foot when they walk with ulcers, while also providing peace of mind for those who fear ulcer recurrence. Essentially, patients using the shoe shall benefit from the prevention of ulcers and eventual amputations which can sometimes lead to death.

A. Project Concepts

The implementation of a shoe with sensor technology shall improve the lives of people suffering from ulcers on their feet due to diabetes. The shoe should monitor for proper offloading of the patient’s foot when they walk with ulcers. The purpose of monitoring the patient’s foot using a shoe with sensors is to decrease chances of ulcers getting worse and not leading the patient to get amputations. Using sensors, we want to be able to track if the shoe is providing the proper lateral stabilization, dynamic balancing, and heel absorption. The sensor technology inside the therapeutic shoe shall monitor musculoskeletal pressure and movement, as well as pronation and supination detection. This is important so we can conclude if the shoe is keeping the patient stable and also help group data that we collect. It is important to monitor the shoe since studies have demonstrated that footwear adjustments can influence balance and stability in healthy, wounded, or elderly patients. Integrating sensors into the H-Fit Healing Shoes will allow adjustments to be made into the patient's footwear. These adjustments will help the patient relieve plantar pressure, tingling in the lower limbs, and numbness. Having the possibility to make adjustment to the shoes as needed will also allow to create changes to the foot that are generally less dramatic, which are then expected to have a greater influence in the patient's postural stability. The sensors inside the shoe will help reduce injury secondary to inappropriate loading of the lower extremity. Proper offloading of the shoe will reduce clinical response time due to the effective offloading to the neuropathic lesions. The data the shoe provides for evaluation will allow the patient with wound care lesions to be evaluated. The shoe shall provide a more precise parameter for offloading. It will be a more effective offloading device for the management of neuropathic wounds. Monitoring the effectiveness of the shoe shall reduce the mortality, morbidity, and limb loss due to ineffective treatment of neuropathic lesions. This will cause a reduction of clinical cost and clinical utilization for wound management.

B. *Resources*

The resources that we need for this project consist primarily of lab space, parts, software and contact with consultants that have medical experience. Lab space provided by Professor Warren Smith has already been secured for this project in Riverside 5027. The parts that we need for this project primarily consist of therapeutic shoes, microcontrollers, pressure sensors, flex sensors, and a remote computer or server. For software, all of the software we are probable to use is freely available, but we will provision some money in our budget just in case we need another solution. Finally, for consultants we are currently in contact with Professor Warren Smith from Sacramento State and Peter Wong from Sunrise Shoes. It is possible that we will also need to find someone with additional understanding of the foot for advice on the metrics we should record.

For the parts, we will need multiple microcontrollers. The projected number of microcontrollers we will need is 3, likely Intel Edison, for testing purposes among members and to demonstrate our automation feature. For each microcontroller, we anticipate a need for a Wi-Fi dongle for communication purposes. For pressure sensors and flex sensors, we would like to get by with one set of 8 sensors, since we anticipate the need for 6 sensors, but will provision our budget for more than one set. For provisioning a server, we have many options, including another microcontroller or one of our personal devices, but now, we will provision some of our budget for using a cloud provider.

C. *Features of the Shoe*

Providing the proper offloading footwear to costumer can dramatically reduce healing time while lowering extremity amputations. Sensors allow monitoring patients for musculoskeletal movement and neurological conditions by using the integrated sensors in the shoe. Integration of sensor technology in shoes is vital development since it permits to monitor the musculoskeletal activities of patients during the foot ulceration period and the post-operation period before a need to amputate [5]. Monitoring people with diabetes is essential for patient disability prevention. A proper design of the Pedorthic shoe can promote proper musculoskeletal movement, as well as supporting accurate healing for health issues caused by neurological conditions [5]. Incorporation of pressure sensing technology inside the shoe is one of our goals since we want to be able to monitor the plantar pressure the shoe is exerting on the patient. We also want to integrate flex-sensing technologies into the shoe to determine patient's use of the shoe and other stress areas that the foot employs in the surroundings of the shoe. Maintaining the functionality of sensors during the use of the shoe is essential which is why we need to monitor battery life. Providing indication of battery status is another important function we want to develop in the shoe. On top of this, displaying the data we collect graphically is necessary for people to quickly make sense of the metrics the shoe collects. Finally, since the shoes are going to be mass-produced, we want to create an automated deployment system to program multiple shoes at the same time and hopefully lay the groundwork for Sunrise to create updates. Our main goal is to provide significant aid to diabetics in need. By helping diagnose the effectiveness of their therapeutic shoes we can allow them to enjoy more effective and comfortable equipment.

Our team is going to be working with the therapeutic healing shoe from Sunrise Shoes. The space we are going to be working with is very limited. Therefore, we must be able to develop effective and limited size circuits since we are working within a parameter of space. Sunrise Shoes Company provide is with a pair of deconstructed shoes to have a visual of the product we are going to be working with. Diagrams of the shoes are provided in the following figures. The sole of the shoe is going to change since the shoe size of every patients is different. This means that we should center most of the components in an area where most of the shoes can have the space for the sensors. If the sensors are centered toward the middle of the shoe, so they can satisfy the minimum requirement for the size of the shoe. The shoe will incorporate at least six pressure sensors to track the plantar pressure. The shoe will also incorporate at least two flex sensors to detect pronation and supination of the foot to track the balance of the patient as it wears the shoe. The shoe will have at least two gigabytes of memory to save the data before transferring to a database with an anticipated storage capacity of thirty gigabytes. The shoe will be able to detect low levels of battery so it can properly shut down to prevent data corruption. Automated deployment of software is also a feature we want to focus on to program multiple shoes with no problem. We are aiming to create a system that can function for at least two hours for every battery charge.

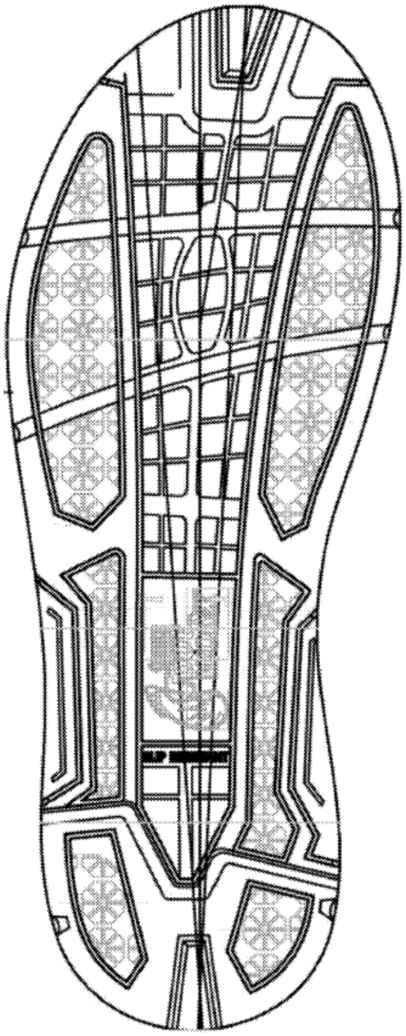


FIG. 9. OUTSOLE EMBODIMENT OF SHOE:
Outsole embodiment for the therapeutic show sole. [17]

It is important to know the dimensions of the sole since we need to optimize the size we use for our sensors and circuits. Since shoes provide most of the space for modifications in their sole, we need to space our design accurately so we can add the features with small modification of the sole. Since the component that might take most of the space available is the microcontroller, we might want to reserve the area of the sole for this component. Pressure sensors vary in size and weight; we might be able to incorporate those sensors as another layer of sole cushioning reducing the footprint of the sensor. The low battery indicator can be places around the shoe since the patient needs to be able to perceive the warning. The CEO from Sunrise Shoes, Peter Wang, provided us with a diagram where he would prefer the sensors we are going to be incorporating in the shoe.

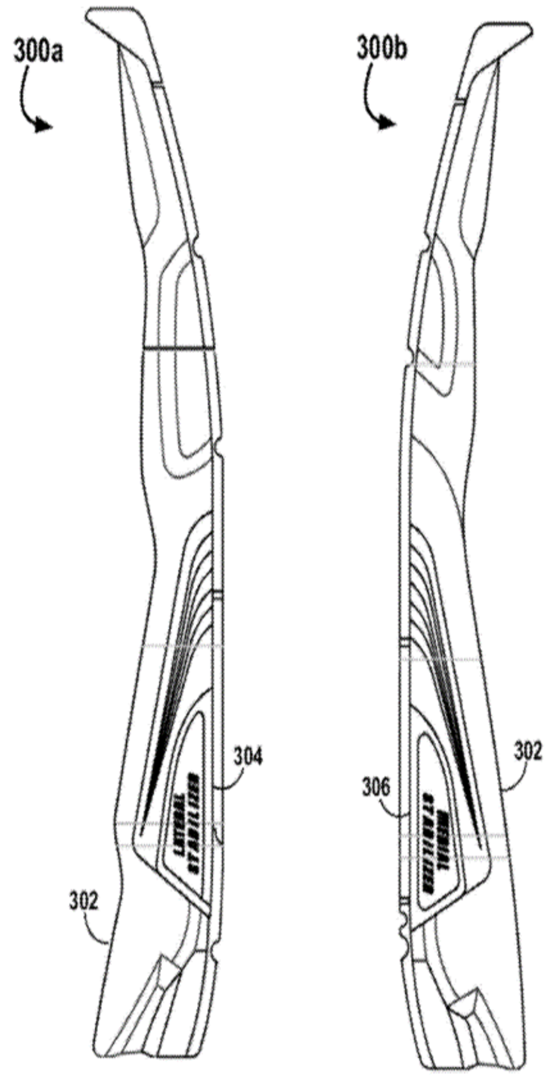


FIG. 10. THERAPEUTIC "ROCKER" SOLE:
Therapeutic “rocker” sole design: design of the sole from both sides. [17]

Based on the design Wang provide our team, it seems like he wants most of the pressure sensors towards the center and end of the shoe. Since we won’t be adding temperature sensors to our design, we have much more space to implement the pressure matrix around the shoe. The microcontroller can be integrated in the sole where the power source is located since we can externally power the shoe. Incorporating the battery into the shoe would be great but our priority is to integrate the microcontroller into the shoe due to the space limitations. One of our main priorities is to incorporate the components into the shoe and still keep maximum comfort of the shoe. We don't want to make so many modifications to the shoe that it ends up losing its therapeutic function. Low power components are essential to reduce space needed.

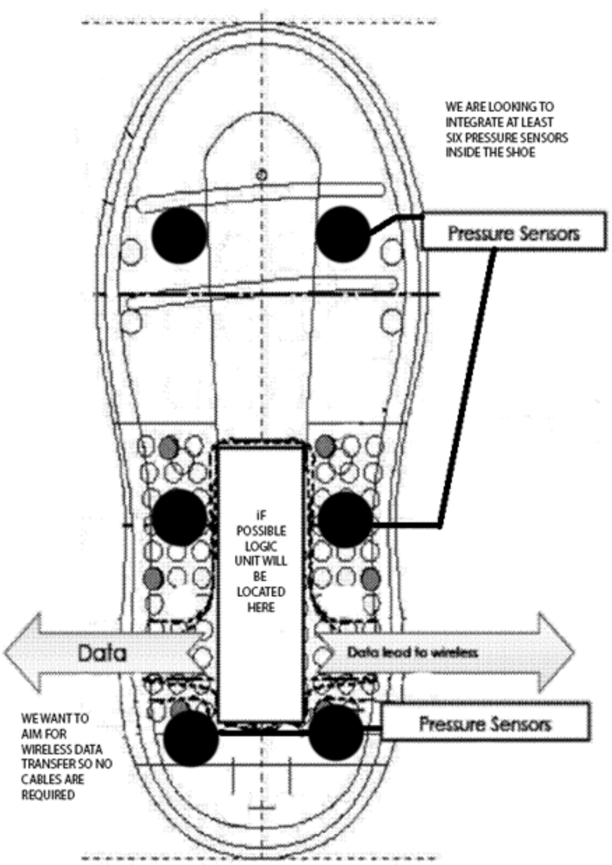


FIG. 11. POSSIBLE DISTRIBUTION OF PRESSURE SENSORS: Possible distribution of pressure sensors throughout the inside of the sole. The number of sensors we want to integrate into the shoe is at least six sensors but it can be possibly be more. [17]

1. *Plantar pressure Using Pressor Sensors*

Monitoring the pressure that the shoe exerts in the foot is essential to evaluating effectiveness of the shoe. Therapeutic shoes are meant to relieve pressure throughout the foot and distribute it more effectively throughout the leg.

a) *Features*

Monitoring plantar pressure is essential for Sunrise Shoes since they want to be able to determine of the show is relieving the offload on the proper areas of the shoe. We want to incorporate at least six pressure sensors into the shoe to track the pressure distribution of at least three of the major parts of the foot. During the sampling time the shoe shall calculate the pressure for each of the six sensors sequentially. The sensors need to be able to make measurements for an average person of about 100 – 160 lbs. This system is meant to track information of the pressure the shoe is experiencing as the patient wears the shoe. Pedorthic shoes are meant to relieve pressure from the heel and the inner and outer ball of the foot. At times, shoes are modified and personalized for a single individual to correct specific plantar conditions. Plantar pressure wants to be monitor in this cases to track the effectiveness of the pressure offload of the shoe design. This allows for modifications to be made as they are need it to achieve the patient's needs. The pressure is meant to be placed in the center of the foot in order to place the pressure in the entire leg so the wounds heal quicker and more efficiently. "Current healing devices in the market, such as Darco Surgical Shoes, or the CAM Walker Bledsoe Brace System, either have no control of your musculoskeletal system, or they completely lock it up, resulting muscle atrophy, deformity, and subsequent ulcers," stated the National Institute of Health- NIH [5]. Since Sunrise Shoes, success is partially due to efficient offloading its essential for us to monitor if the shoe is serving its purpose.

FIG. 12. AREA OF THE FOOT MONITORED:
A diagram of the areas of the foot. It helps illustrate some of the areas where we want to relieve pressure from the foot. It also labels the six possible areas where the sensors might be located. [18]

b) Hardware

The hardware needed to complete this task will be primarily the microcontroller for the therapeutic shoes and the pressure sensors. Our system will have at least six pressure sensors distributed throughout the shoe. The microcontroller will also have at least 2GB of memory to save the data being produced by the sensors. We project that each of the sensors need to be able to read up to about 445 N, which is about 100 pounds per sensor. This should be enough since the pressure will be distributed through the entire foot as the users moves. For the microcontroller, we don't have any hard constraints, but we have some desired characteristics from the microcontroller including small size and low power consumption. As a result, we have narrowed our options for the microcontroller to the Intel Edison and the Raspberry Pi Zero. Both of these microcontrollers are very small, low power and can run operating systems and software that our team feels comfortable working with. The benefit of the Raspberry Pi Zero, is that there are many existing projects that use the Raspberry Pi so it is less likely that we will need to reinvent the wheel. On top of this, the Raspberry Pi Zero is less expensive. On the other hand, the Intel Edison has more of the feature that we anticipate a need for including Wi-Fi. Because of this, it is currently more likely that we will use the Intel Edison.

For measuring pressure, we do not require any specific sensors, but we do have some in mind. After feedback from Professor Warren Smith, we are currently thinking of using Tekscan FlexiForce Sensors. Based on the specifications from Tekscan, the FlexiForce A301 Sensor and the FlexiForce A401 Sensor are the best models for our purpose. Both sensors support higher force ranges necessary for measuring pressure from the foot. Of the two sensors, the FlexiForce A301 Sensors are the most likely to be used. This is because they have a smaller force area and will fit better in the shoe.

c) Software

Once we have working sensors, the data from those sensors must be recorded with time and spatial positioning. To this some software must be employed. The role of the software would be merely to collect the data and we do not have any specific requirements on the type of software that we use to accomplish this, but we currently have some ideas.

Another technology that we have thought about using is Snap. Snap is an open source telemetry framework that helps simplify the collection of data for many purposes and then publish all sources of data to a single place [19]. Snap works on the concept of interchangeability. It can collect data, process that data, and then publish the data. The source of collection, the type of processing, and the publishing destination can all be interchanged through the use of plugins. This will be advantageous in our project, because it allows us to easily change our plans by changing plugins. For example, if we decide to skip the local storage of data and publish directly to a server for a live demonstration, we would only need to change the publisher plugin in Snap. The basic concept of Snap is reflected in the Figure 13.

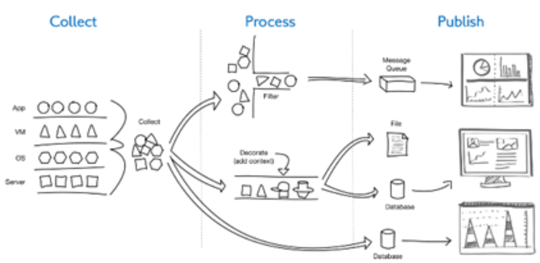


FIG. 13. BASIC IDEA BEHIND SNAP:
The above illustration summarizes the basic idea behind Snap. We can see multiple sources of metrics being published to many possible places after processing. [19]

Another advantage is access to existing processor plugins. For example, we could potentially make use of the existing anomaly detection processor to find impacts [19]. On the other hand, one of the disadvantages of using Snap is that we would need to create a custom collector. Right now, there is no existing collector for collecting pressure data. Overall, we do not have any restraints on the type of software that we use for this feature, but we anticipate that we will use either existing software from Sparkfun or create software to contribute to Snap.

d) Ownership

One of the members of the team, Eduardo Anaya, will be focusing the most since we have other features to complete. By the end of October, the sensor distribution and signal detection circuits were complete. Most of the work spent on the project was portioned to this area since it's the most important to the customer. The pressure sensors are going to be the main circuit developing the data being transferred to the user and medical expert or company for evaluation. This data is essential to the user since they want to be able to track if the plantar pressure is being distributed efficiently throughout the shoe. Therefore, it important for the team to quickly address this section of the project.

e) Estimated Hours and Outcome

This is the biggest feature of our project and has been the area where most of the hours were spent. The current estimated hours spend on this feature is around 200 hours. Another 100 – 150 hours are estimated to be required during the spring semester. Most of the tasks for the features are completed. Next semester we plan on integrating the system into the deployable prototype which might need modifications due to size issues.

This feature can collect pressure data from a therapeutic shoe and transferred that data to a local storage on our microcontroller which has 4 GBs of memory. The data contain three major pieces of information that allows it to be useful. This information includes a value for pressure in pounds, a value for the time this data was recorded, and a value indicating either which specific sensor or which position the data was collected from. For the hardware, we used six pressure sensors per shoe to capture data associated with plantar pressure. There is two pressure sensors in each of the three major areas of the foot labeled in figure 12. This includes the heel, inner/outer ball, and the inner/outer longitudinal arch. Our implementation is limited to one shoe for the time being since it can easily be integrated into the second shoe once the first shoe is complete. The pressure sensors can measure data for at least an adult male of 100-160 pounds. This is our test case. The microcontroller on the shoe can store at least two gigabytes of data produced by all the sensors incorporated in the shoe. The sampling rate of sensors is at least 10 Hz when the system is active. The amount of time that we project the system will be able to stay powered on and collect data is at least two hours.

2. Pronation and Supination Detection

The pronation and supination detection system is meant to detect the stability of the shoe. It will monitor the stability of the foot as the patient walks with the shoe. The implementation of the subsystem will incorporate flex sensors to measure the bending of the side shoe. The system will detect the bending of the shoe as the voltage reaches voltage triggers that indicate pronation, supination, or neutral.

a) Features

Monitoring how the shoe bends can give important information about how the patient is walking and supporting themselves. The user of the shoes is not always going to walk on flat and smooth ground. It is important to know that shoe is reacting properly when the user walks on uneven ground. Repeated abnormal patterns of stress may be indicators of uneven walking patterns of the user. For this reason, we want to incorporate technology into our design that will detect pronation and supination from the patient.

b) Hardware

A sensor was used to take measurements of how the shoe bends. One idea was to use a flex sensor. Flex sensors work with a specially designed resistor whose resistance varies based on the amount it bends as seen in Figure 6. This change in resistance gives a different voltage value across a voltage divider and gives an output to a microcontroller. The microcontroller is needed to record the data given by the sensor.

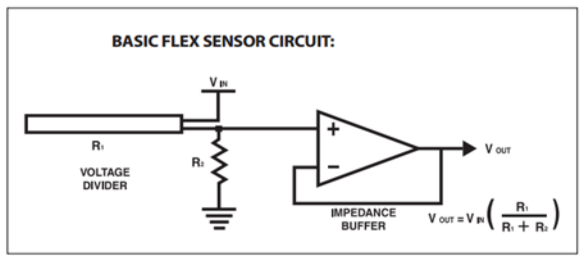


FIG. 14. BASIC FLEX SENSOR CIRCUIT:
The diagram displays how a typical flex sensor operates [20]

c) Software

The software portion of this subsystem is similar to the plantar pressure system. The code will read the value of the voltage using an ADC and based on the values it will conclude if there is anything unusual occurring. There will be voltage rail defined that indicate the different cases of pronation and supination. The subsystem will be centered at a neutral voltage that indicate that everything is normal.

d) Ownership

Phillip Dye is the primary owner of this feature. Phillip Dye is familiar with programming microcontrollers in C and building the necessary circuits, however he will need to take time to research about the shoe and supination and pronation of the foot.

e) Estimated Hours and Outcome

This feature is lower priority than measuring the pressure across the shoes. However, it is very connected to that feature, because most likely the sensors for both features will need to be operated by the same microcontroller. The number of hours spent for this feature is about 55 hours. The feature is functioning but needs to be modified to detect pronation and supination much more effective. Its estimated that during next semester, the feature will require about 50 more hours until completion.

This feature uses at minimum two flex sensors to determine the state of the foot. There are three states considered over-pronation, neutral and over-supination. At minimum one flex sensors is used per each side of the foot for a total of two flex sensors per shoe. A microcontroller id in charge of collecting data. Flex sensors must withstand a minimum of 10 trial cases. One trial case is one over-pronation and one over-supination. The sampling rate for these sensors is at least 10 Hz. This should be a more than high enough of a sample rate and matches our current projected sample rate for the pressure metrics.

3. Low Battery Indication

This feature will focus on protecting the system from power shortage. It will power the system safely when the battery is low to prevent data and system corruptions.

a) Features

Using instrumentation as a preventative and validator process is helpful while in use. Sensors and instrumentation are of no importance if they are not used. Energy from batteries are finite and therefore the availability of sensing data is constrained by the finite amount of energy in a battery. Low power electronics can extend the power time length, but eventually the life of the electronic device is still constrained and will eventually have an unplanned power off. Unplanned power loss can be harmful to electronic components. Low battery indication serves many purposes and is a vital feature. To ensure that the most amount of sensing data can be captured, the battery must have enough charge. A battery indicator would allow a user to know when it is time to remediate the battery situation however, that may be. If the user knows of a low battery situation, they are more likely to fix the situation. Additionally, a low battery indicator can serve another purpose Unplanned power loss and low voltage operations can be harmful to electronics. Unplanned shut off can cause problems such as corrupted files. Operating on dangerously low voltages is also problematic to the safety of the electronic component such as microcontrollers. Batteries suffer from cell damage when operating at low levels. One idea is to use a low power indicator to prevent these issues by preemptively powering down when approaching dangerous voltage levels.

b) Hardware

Implementations for measuring battery levels vary depending on equipment used. The microcontroller used onboard was used, but due to design unknowns, the team has yet to determine the final controller until next semester. An analog to digital converter was used in conjunction with a microcontroller to keep track of voltage and to power down the system when approaching low power levels. Another idea is to incorporate a cut-off circuit to protect the battery.

c) Software

To incorporate the feature, certain scripts were created to take track and maintain the data from the battery. Voltage regulation code was made to check so that the battery does not dip to dangerous levels. Additionally, the team implemented safe power off as means to shut down the system before low voltage levels cause unplanned power loss or corrupted device states. When voltages reach low levels, the user will be notified through a method which is yet to be determined.

d) Ownership

Ahriben Gonzalez will be primarily responsible for implementing this feature.

e) Estimated Hours and Outcome

This feature currently needs development on notify the user at least once of a low battery if the level is reached. That is the only task needed for this system. It also needs to be incorporated into the shoe but all that will be done in the spring semester. The level at which users is notified is 20% battery life. Additionally, the battery detection is able to safely and preemptively power off the microcontroller. The levels will be sampled at least every 30 min to ensure the battery is still good. It is anticipated that the sampling rate will likely increase as voltage level decreases. During this semester about 60 hours were spent developing this system. The estimated time for this feature during the spring semester is 50 plus hours. This feature can be implemented at any time as it does not require the sensor metrics. Implementation will begin and resumed during down times of the projects.

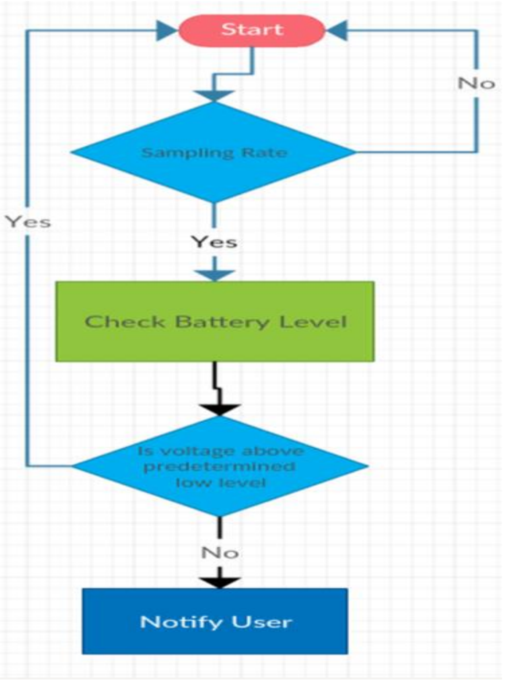


FIG. 15. FLOW CHART OF LOW BATTERY DETECTION: The flow chart displays the basic functionality of the low-level battery indication [12]

4. Visualization of Data

The data visualization part of the system is essential since we want to provide a vivid and easy way to interpret information. We want to provide graphs that make it easy for the user to interpret the information of the sensors. This was achieved by making different graphs for each of the sensors with the option to change between conversions.

a) Features

Another feature that we felt was necessary to implement was the visualization of our data. Visualization is important for making sense of the numbers we collect. Metrics can be taken but if not visualized well it can be meaningless. From a high-level view data is just numbers in the cloud. Data in a database can be difficult to decipher and manage for a non-technical user. Given sponsorship from a non-technical company, data should be presented in a way that is easy to access and visually appealing. Data in today's view has had an unprecedented appeal to businesses. It helps them make important decisions. In a 2009 paper, Michael Friendly, director of Statistical Consulting Service at York University, explains how “Tables, graphs, maps … provide some means to see what lies within, determine the answer to a question, find relations, and perhaps apprehend things which could not be seen so readily in other forms” [21]. Essentially data visualization provides a means to make sense and make decisions from large amounts of data. Data also validates a company and provides insight on users, but databases by themselves make it difficult to visualize data. Essentially, the intent of this feature is to improve visualization of data so that the data we collect is more fully utilized.

b) Hardware

The hardware that was needed for this feature was a separate microcontroller or server to handle all the tasks. Having it separate will help keep the microcontrollers in the shoes low power and would allow us to access all gathered metrics in one place.

c) Software

Visualization can occur in many ways from web pages to specialized metrics software. Currently the implementation is still be actively contested; therefore, the required software is still unknown. The team predicts it will need a connection to a database and a container to view the data. The container could be a custom webpage or a dashboard in a specialized software. These however are merely ideas and no implementation has been agreed upon.

First, we will cover the ideas for database options we currently have. To store the data being collected from our therapeutic shoe, we need to select a database. Databases make it easier to access and use the collected information. They also prevent problems when attempting to write data from multiple devices. For example, if we were to write our information to a file, this would require that we account for the possibility that two applications try to open the file at the same time. With modern databases, these conflicting cases are already handled.

InfluxDB is a time series database that was released in 2013. This means that the database useful for time series data. A time series is defined as “a sequence of data points, typically consisting of successive measurements made from the same source over a time interval.”[23] The data we will be collecting from the therapeutic shoe falls within this definition. This will likely make InfluxDB queries more powerful and its benefits could outweigh those of MongoDB.

We considered the types of technologies we could make use of for visualizing the data. One software that has been considered is Grafana. Grafana is specifically a visualization tool for time series data. It can be used to present professional analytics and dashboards. One con of Grafana is that customization beyond included features is not as easy as some other technologies. Preset visualization make it easy to implement but limits some of the freedom we would have with the design. On the other hand, because it is a time series specific tool, it already has built in support for InfluxDB [24].

FIG. 16. GRAFANA DASHBOARD EXAMPLE:
The image shows an example of what a Grafana dashboard looks like. It can be customized to show a variety of metrics on same webpage. [24]

d) Ownership

Ownership of this task was shared between Ahriben Gonzalez and Jose Aguirre. Ahriben Gonzalez has much of the needed web experience, including work experience with JavaScript, and Jose Aguirre has the most experience working with data and with the already implemented database.

e) Estimated Hours and Outcome

Visualization of data can be complex depending on the implementation. During this semester, the database has been developed as well as visual graphs for the data being collected. About 70 hours have been spent developing these features. As a team the estimated completion time would be for another 30 hours during the spring semester. The visualization was implemented after the sensor system was working. This feature was started by using mock data in a database.

For this feature to be considered complete. The visualization could be a web-based solution. Data for the visualization is currently stored in a database and the current capacity of this database is four gigabytes. The visualization displays each set of data per each sensor. This includes a minimum of six pressure metrics and two flex metrics. Visualization can be access easily and is user friendly. This means no coding whatsoever should be required for the user but this part will be implemented during the spring semester.

5. Automated Deployment of Software

The automated deployment system was developed to make it easier to set up systems and upload updates to all the systems.

a) Features

Another feature we wanted to implement was automated configuration of software on the microcontrollers inside our shoes. This means that it should be almost as easy to configure one shoe as it would be to configure 10 or 20 shoes. This would make it easier to have multiple shoes to test on, would backup any work we do, and would also make it possible for the manufacturer to easily produce these therapeutic shoes. Hopefully, would provide the groundwork for updates to be pushed out to users. Because this task is highly dependent on the completion of the other tasks, it would be nice, but would not be a possibility until next semester.

b) Hardware

The main hardware that we would need to implement this feature is at least 2 microcontrollers to demonstrate the feature on. We may also need Bluetooth or Wi-Fi dongles for each of the microcontrollers, but we don't have any hard requirements on the hardware used for this feature.

c) Software

This feature does not have any constraints to use specific software, but there are a few different ideas that we currently have. The first idea is to create bash scripts that install all the necessary dependencies. The problem with bash scripts however, is that they require a lot of effort to check for robustness.

Another idea would be to use Ansible, an automation engine from Red Hat. Ansible would connect to all of our microcontrollers from a host and push out what are called "Ansible modules" and remove them from each microcontroller when done. The nice thing about Ansible is that it checks the state of each machine ensuring robustness and meaning running the deployment twice won't cause any problems [25]. Although Ansible is a nice tool, even if it is used, it is likely that we will use a mixture of many technologies.

d) Ownership

Jose Aguirre will be primarily responsible for implementing this feature. He has the most experience in automation and feels this task would align best with his career goals. He also had direct experience with Ansible and with creating bash scripts.

e) Estimated Hours and Outcome

The estimated amount of time it will take to implement this feature is about 60 hours. Most of these hours will likely be done as we progress and after the prototype has been delivered.

This feature will require that at least 2 microcontrollers on the same network to be configurable at once or in rapid succession. The process of deployment must take place in under 30 minutes and must not require user interaction after the process has begun.

IV. FUNDING OF PROJECT

The estimated budget spend on this project is about 800 dollars. Most of the components used during last semester were reused during the spring semester. The project was sponsored by Sunrise Shoes so they provided the shoes that we modified. Our team finance the rest of the project to this point but we are hoping to get financial reimbursement at the end of the semester. We have financed all the components, sensors, tools, microcontrollers, and equipment to develop the system. Each team member has purchased their required components to build their part of the system. When choosing the components, we took in consideration the fact that we had to build an affordable system. The goal of the team was to keep the system under one thousand dollars for the team convenience and for the system affordability. The components we purchased involve affordable parts with an acceptable quality level. We want the system to last a few years without any issues since it is meant to be incorporated for medical use. Most of the funds were used on quality microcontrollers since we wanted to have a good processor that could provide reliable data without occupying much space. Since the company wants to incorporate the features into their shoes it is important to keep the cost low while being efficient. This will involve spending a lot of time building the features because we do not want to use top of the line components, to reduce the cost of the features. We are still aiming for efficient and reliable circuits, which is why we must spend many hours in the development of every feature. The final expenses of the system are shown below in Table II. The table splits the final cost in categories to show which sections had a higher expense.

TABLE II.
FINAL EXPENSES

Category:	Estimated Cost:
Pressure Sensors	$150.00
Flex Sensors	$50.00
Microcontrollers	$200.00
Microcontrollers Accessories	$150.00
Other Hardware	$150.00
Hosting	$70.00
Total	$770.00

This chart representing the expected expenses of the team was created by Jose Aguirre and Eduardo Anaya [12]

V. PROJECT MILESTONES

During the second semester of the project, a few modifications were made to the project milestones and timeline. Due to some new tasks that emerged, we had to add new milestones to accommodate the new task requirements. Some of these new tasks involved creating a printed circuit board, carving inside the shoe, and changing ADC block of the processor. Some of the milestones deadlines were modified to make time for the new tasks. This forced the team to work faster since we had more task to complete in the same amount of time. To prevent any issues from emerging, we tried to finish all the tasks earlier than the deadline so we could have more time for testing. Five different subsystems were developed and merged together to create the final system. The system that was developed was a therapeutic shoe with sensor technology that can track the status of the patient’s foot based on the structure of the shoe. This system helps conclude if the tools provided to the patient are of any aid or if they must be modified to properly complete the functionality. The different subsystems of the main systems are labeled throughout a timeline. The timeline had to be partially modified since we added a few new tasks this semester. One of the most important new tasks added was the development of a printed circuit board (PCB). This printed circuited board is being designed so it can fit inside the show more easily since it only contains the required components. We want to be able to fit this circuit board inside the shoe so it can be closer to the sensors. Adding new tasks involves adding new project milestones and modifying a few due dates to accommodate for the new tasks. Overall most of the tasks were kept the same and only a few of the tasks were prolonged or shorten to make room for the new tasks. Project milestones are essential to be overcome since they are significant events in our project. Multiple milestones were laid over the entire project timelines so we could assess the progress we had made. Milestones are an important tool used as project management that marks important points along the project timeline. These milestones signal anchors such as the start and the end of a task, which allows the team to review our progress and make modifications if needed. Milestones are reference markers that list the distance to completion of the project. The milestones include all project activities and the short-term steps needed to implement the project. Different milestones are scheduled for planning, development, construction, evaluation, and reporting of the status of the project. The dates incorporated into the milestones were projected dates based on approximated deadlines the team is trying to achieve. We wanted to implement a system that is much more affordable to the user by reducing the price of the system greatly. Since we can only choose two from time, cost, and quality, we have chosen to quality and cost. We want to increase the quality, while aiming for a low-cost system. In return, it will cost us a lot of time since we had sacrificed that choice. To complete this project successfully we had to implement a well-organized and accurate timeline. This timeline has all the project milestones that we had to overcome to successfully complete the project. To produce this shoe successfully in the time span we were given, we had to organize our duties so the entire team knew what to achieve and when to achieve it. By graphically showing the tasks in tables and diagrams, we kept the team on track. Portraying the assignments and tasks in an organized manner was essential for keeping the team aware of deadlines. The assignments, milestones and deadlines were traced out through a project timeline. The tasks and assignments were organized using a Grantt chart, Pert diagram, and tabular form. Having a visual aid of the deadlines gave us a higher degree of success when completing the tasks and assignments. It allowed us to quickly identify the tasks that needed work and the ones that had been successfully completed. It also allowed us to identify how close we were to the completion of the project.

The senior project consists of multiple areas we need to complete simultaneously. One of the areas is the assignments we need to complete that consist of reports and presentations. While completing the assignments, we also need to work in our project. One of the features of the shoe is to monitoring the pressure that the shoe exerts in the foot is essential to evaluating effectiveness of the shoe. Therapeutic shoes are meant to relieve pressure throughout the foot and distribute it more effectively throughout the leg. For the hardware we want to use at least six pressure sensors per shoe to capture data associated with plantar pressure. There will be about two pressure sensors in each of the three major areas of the foot labeled in figure four. This includes the heel, inner/outer ball, and the inner/outer longitudinal arch. Our implementation will be limited to one shoe for the time being since it can easily be integrated into the second shoe once the first shoe is complete. A microcontroller will be used to collect the data from the sensors and possibly transfer wirelessly. The pressure sensors must be able to measure data for at least an adult male and female of 100-160 pounds. Pressure data should be accurate within 15%

of the calculated mathematical value while operating at room temperature. The system will save at least 2GB of data produced by al the sensors incorporated in the shoe. The sampling rate of sensors should be at least 10 Hz when the system is active. Another of the shoe will be to detect pronation and supination. Use at minimum two flex sensors to determine the state of the foot. There are three states considered over-pronation, neutral and over-supination. At minimum one flex sensors will be used per each side of the foot for a total of two flex sensors. A microcontroller will collect data. Flex sensors must withstand a minimum of 10 trial cases. One trial case is one over-pronation and one over-supination. A third feature we are planning to implement is to notify user at least once of a low battery if the level is reached. The level at which users should be notified is 20%. Additionally, the battery detection must safely and preemptively power off the microcontroller. The levels will be sampled at least every 30 min to ensure the battery is still good. A fourth feature we are focusing on is automated deployment of software. This feature will require that at least 2 microcontrollers on the same network to be configurable at once or in rapid succession. The process of deployment must take place in under 30 minutes and must not require user interaction after the process has begun. This part will not be completed until second semester due to dependency on other features of the project. Automated deployment of software should provide an easy way for shoes to be configured. This means that it should be almost as easy to configure one shoe as it would be to configure 10 or 20 shoes. This would make it easier to update shoe feature, and would also make it possible for the manufacturer to easily produce these therapeutic shoes. This featured will be considered complete when it can be demonstrated that more than multiple microcontrollers on the same network can be either configured simultaneously or in rapid succession. An important aspect of the project is the visualization of data since it must be user friendly. The visualization could be a web based solution. Data for the visualization should be stored in a database and should be accessible through queries. The visualization must display each set of data per each sensor. This includes a minimum of six pressure metrics and two flex metrics. Visualization must be easy to access and user friendly. This means no coding whatsoever should be required for the user. All the subsystems making the entire system were distributed throughout the team members, which involved testing and implementation of subsystem.

The system is elaborated through many individual tasks that are labeled below in Table III. The table shows the different milestones placed throughout the system development time. These milestones were set to have deadlines for each of the development tasks. The milestones helped the team stay on track and allowed us to evaluate the progress of the project as the set points were met. Overall, the milestones helped the team keep a steady pace.

TABLE III.
PROJECT SYSTEM MILESTONES TABLE

Level 1	Level 2	Level 3	Milestone	Owner
Plantar Pressure			10/15/16 – 03/01/17	
	Create Circuit for sensors		10/15/16 - 10/31/16	
		Create initial circuit to determine functionality of sensors	10/15/16 - 10/22/16	Eduardo
		Adjust circuit to correct force values	10/15/16 - 10/31/16	Eduardo
	Collecting and storing data in local database		10/16/16 - 03/01/17	
		Collect initial metrics	10/15/16 - 10/22/16	Eduardo
		Write a program to collect pressure metrics	10/15/16 - 10/31/16	Eduardo
		Transfer metrics to a local database or remote database	10/31/16 - 11/16/16	Jose
		Testing robustness of metric collectors	02/24/16 - 03/01/17	Jose
	Fit pressure sensors and circuit into therapeutic shoe		11/21/16 - 03/01/17	
		Wire sensors into the sole of mock shoe	11/21/16 - 12/02/16	Eduardo
		Create layout for circuit board	1/23/17 – 2/4/17	Eduardo
		Get circuit board manufactured and installed	2/4/17 – 2/2/17	Eduardo

		Wire the sensors into the sole of the shoe	02/01/17 - 04/21/17	Eduardo
		Readjust sampling sampling rate based on the data from a test case	02/15/17 - 03/01/17	Eduardo
Pronation and supination detection			10/18/16 – 03/15/17	
	Create circuit for flex sensors		10/18/16 - 11/15/16	
		Customize resistors in circuit to optimize range of values of output	10/18/16 - 10/30/16	Phillip
		Amplify signal if necessary with op-amp circuit	11/01/16 - 11/15/16	Phillip
	Determine proper orientation of flex sensors		10/30/16 - 12/02/16	
		Orientation must differentiate between pronation and supination	10/30/16 - 12/02/16	Phillip
	Determine how sensors fit in the shoe		02/01/17 - 03/01/17	
		Location and method of holding sensors in place	02/01/17 - 03/01/17	Phillip
	Collecting and storing database		11/15/16 - 03/15/17	
		Microcontroller code to operate sensors	10/15/16 - 11/01/16	Phillip
		Write a program to collect and store flex metrics	10/22/16 - 11/15/16	Phillip
		Determine flex values that indicate pronation and supination for text case	02/24/17 - 03/015/17	Phillip

Data visualization			10/16/16 – 04/01/17	
	Get data from microcontroller to remote server		10/16/16 - 02/08/17	
		Configure remote server	10/16/16 - 11/08/16	Jose
		Configure database on the server	10/09/16 - 11/10/16	Jose
		Transfer data from microcontroller to remote database	11/16/16 - 11/23/16	Jose
		Set up authentication to database	02/01/17 - 02/08/17	Jose
	Link database to graphing application		10/09/16- 11/10/16	
		Create or use existing graphing application	10/09/16 - 11/8/16	Jose
		Configure graphing application to use our database as its data source	10/09/16 - 11/10/16	Jose
	Create graphs		02/01/17 - 04/01/17	
		Create graphs for pressure sensors	02/01/17 - 03/01/17	Jose
		Create graphs for flex sensors	02/01/17 - 04/01/17	Jose
Low battery detection			10/09/16 – 11/09/16	
	Low battery detection circuit		10/09/16 - 11/03/16	
		Create test circuit to test functionality of	10/09/16 - 10/20/16	Ahriben

		notification hardware: LED		
		Create test circuit to indicate low voltage	10/20/16 - 11/01/16	Ahriben
		Add notification components to the low battery detection circuit	11/01/16 - 11/03/16	Ahriben
	Preemptive power off		11/01/16 – 11/09/16	
		Create script to sample battery voltage	11/01/16 - 11/07/16	Ahriben
		Create script to test preemptive power off	10/16/16 - 10/26/16	Ahriben
		Add preemptive power off to the voltage sampling script	11/07/16 - 11/09/16	Ahriben
Automated Deployment			02/01/17 - 04/21/17	
	Create initial setup for single microcontroller		02/01/17 - 03/24/17	
		Install dependencies for microcontroller	02/01/17 - 03/07/17	Jose
		Configure microcontroller settings	03/07/17 - 03/14/17	Jose
		Ensure that programs is robust and repeatable	03/14/17 - 03/24/17	Jose
	Create setup that will run on multiple hosts		03/24/17 - 04/21/17	
		Configure connection over Wi-Fi or Bluetooth	03/24/17 - 04/10/17	Ahriben
		Run existing program on multiple hosts	04/14/17 - 04/21/17	Jose

Chart created by Eduardo Anaya and Jose Aguirre [8]

The project milestones are separated by the different subsystems that implement the main system. Each subsystem consists of different task that need to be done before the subsystem is complete. Each of these tasks are separate milestones because they need to be completed before we can proceed to other tasks. Some subsystems can be developed concurrently but other are dependent on other subsystems. The tasks within the subsystems are interconnected so they need to be completed before we continue with the development of the subsystem. The main system has five main subsystems which are plantar pressure mapping, pronation and supination detection, data visualization, lo battery detection, and automated deployment. For the whole system to be competed, each of these subsystems need to be developed and functioning. Each subsystem was partitioned into separate tasks so the team could divide and conquer. Each of the task was given a margin of time for it to be completed. These dates were set to keep the team members in the same page. In Table III, the different milestones are shown for each of the subsystems and tasks. The table shows the start and end dates that were given to each of the tasks. It also has estimated dates for when we plan to complete each of the subsystems. Other milestones that we need to overcome is project documentation. Throughout the project, our team must develop documentation involving the project. Each assignment is a milestone since they must be completed, as they are part of the engineering process. Table IV shows the different milestones involving assignments and documentation present in the fall and spring semester. All the fall semester milestones were completed last semester. For this spring semester, all the assignments were completed with our best ability since we wanted to create a good quality system for the sponsor Sunrise shoes. Since Sunrise shoes is sponsoring our project, we want to create a professional looking project. We want to hide as much of the components as possible without having to make many modifications to the shoe. To achieve this, we had to keep the system as small as possible while reducing the number of components needed by the system.

TABLE IV.
ASSIGNMENTS MILESTONES TABLE

Semester	Assignment	Milestone
Fall		
	Problem Statement	9/5/16 – 9/19/16
	Team Activity Report 1	9/5/16 – 9/19/16
	Design Idea Contract	9/19/16 – 10/03/16
	Team Activity Report 2	9/19/16 – 10/03/16

	Work Breakdown Structure	10/03/16 – 10/17/16
	Team Activity Report 3	10/03/16 – 10/17/16
	Project Timeline	10/17/16 – 10/24/16
	Risk Assessment	10/24/16 – 10/31/16
	Team Activity Report 4	10/17/16 – 10/31/16
	Outgoing Team Leader Report	10/24/16 – 10/31/16
	Team Activity Report 5	10/31/16 – 11/14/16
	Laboratory Prototype Documentation	10/31/16 – 11/28/16
	Laboratory Prototype Presentation	11/28/16 – 12/05/16
Spring		
	Outgoing Team Leader Report	1/22/17 – 1/22/17
	Weekly Report 1	12/05/16 – 1/22/17
	Elevator Pitch Presentation	1/22/17 – 1/30/17
	Revised Problem Statement and Timeline Report	1/22/17 – 1/30/17
	Revised Problem Statement and Timeline Presentation	1/22/17 – 1/30/17
	Weekly Report 2	1/22/17 – 1/29/17
	Device Test Plan	1/30/17 – 2/06/17
	Weekly Report 3	1/30/17 – 2/05/17
	Weekly Report 4	2/05/17 – 2/12/17
	Market Review 5	2/12/17 – 2/19/17

	Market Review Presentation	2/06/17 – 2/27/17
	Weekly Report 6	2/19/17 – 2/26/17
	Weekly Report 7	2/26/17 – 3/05/17
	Mid-Term Progress Review	2/27/17 – 3/13/17
	Testing Result Presentation	2/27/17 – 3/13/17
	Weekly Report 8	3/05/17 – 3/12/17
	Outgoing Team Leader Report	3/05/17 – 3/12/17
	Feature Presentation	3/13/17 – 3/27/17
	Weekly Report 9	3/12/17 – 3/26/17
	Weekly report 10	3/26/17 – 4/02/17
	Team Member Evaluation Report	4/02/17 – 4/15/17
	Weekly Report 11	4/02/17 – 4/09/17
	Deployable Prototype Technical Review	4/09/17 – 4/17/17
	Hardware Deadline for Credit	4/17/17
	Weekly Report 12	4/09/17 – 4/16/17
	Weekly Report 13	4/16/17 – 4/23/17
	Outgoing Team Leader Report	4/18/17 – 4/23/17
	Final Documentation Report Presentation	4/17/17 – 5/01/17
	Deployable Prototype Presentation	5/01/17 – 5/12/17

Chart created by Eduardo Anaya [12]

Overall, all the milestones were completed successfully and most of the deadlines were complete before the deadline was due. Being ahead of the schedule allowed us to have time to resolve any issues that emerged as we proceed through the project. All the fall and spring assignments were completed on time and successfully. The design was also completed in time which involved having the hardware ready to be deployed. Currently, the only things being modified are the software and the look of the system. We want to make the system look professional by hiding the wires as much as possible and reducing the number of components visible to the user.

VI. WORK BREAKDOWN STRUCTURE

One of the issues Sunrise shoes wants us to track using sensors is if the patient is using the shoe as prescript it and how much is he/she using the shoe. Another issue they want to solve using sensors is to track the pressure distribution inside the shoe, that way they can diagnose if the shoe is relieving pressure in the areas it is supposed to. Pressure distribution inside the shoe is essential for relieving wounds. It's also essential to monitor dynamic balance of the lower extremities since one of the goals of the shoe is to provide better balancing for the patient. Another of our main goals with the shoe is to be able to track neurological conditions as the patient wears the shoe like muscle activity including balance of the foot and pressure distribution. It's important to track stability and balance because studies have demonstrated that footwear adjustments can influence balance and stability. Adding the technology to the shoe will allow us to adjust the footwear by tracking plantar pressure so modifications can be made for relieve and comfort of the patient. The implementation of the shoe is to improve the lives of people who are suffering or are prone to suffer from ulcers on their feet due to diabetes. Patient's using the shoe shall benefit from ulcer getting worse, while preventing amputation which can sometimes lead to death. The shoe is meant to provide comfort to the patient's foot when they walk with ulcers, while providing them the ability to walk without any assistance. Our goal will be to implement circuits that can help diagnose problems with the patient to dramatically reduce healing time and lower the chance of an extremity amputation. The shoe will be design to help and benefit wound care patients and military personnel. We care in monitoring symptoms since prevention is key when it comes to minimizing and preventing disabilities and health care cost. Our focus will be in producing a circuit that monitors patients for musculoskeletal movement and neurological conditions using sensor technology integrated in the shoe. Figure 17 shows the breakdown structure of the system. It involves the major tasks of the top five main subsystems being developed. The structure shows the five subsystems that are constructing the top design being implemented by the team.

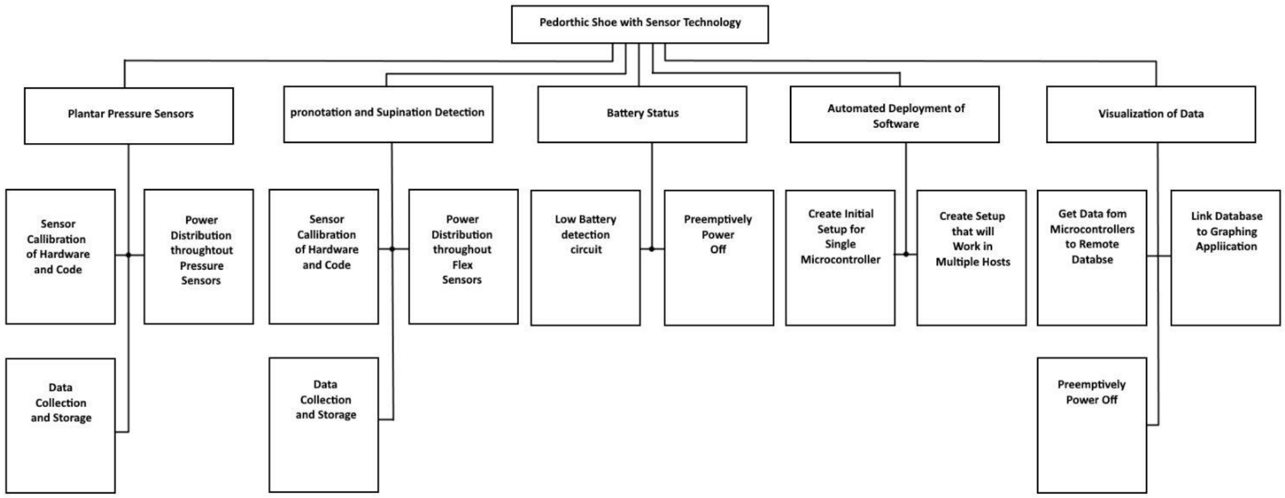


FIG. 17. WORK BREAKDOWN STRUCTURE OF MAIN SYSTEM:
This is the main work breakdown structure for each of the features of our project. The activities for each of the sub-feature are not included in the diagram. Those activities ae shown in the activity chart. [12]

A. Feature breakdown structure

Due to the partnership, our team has with Sunrise shoes, our team was giving resources to help develop the features in design. Some of the resources that we need for this project consist primarily of lab space, parts, software and contact with consultants that have medical experience. Lab space provided by Professor Warren Smith has already been secured for this project in Riverside 5027. The parts that we need for this project primarily consist of therapeutic shoes, microcontrollers, pressure sensors, flex sensors, and a remote computer or server. For software, all the software we are probable to use is freely available, but we will provision some money in our budget just in case we need another solution. Finally, for consultants we are currently in contact with Professor Warren Smith from Sacramento State and Peter Wong from Sunrise Shoes. It is possible that we will also need to find someone with additional understanding of the foot for advice on the metrics we should record. Some of the parts we will need are multiple microcontrollers. We will need at least three microcontrollers, likely Intel Edison, for testing purposes among members and to demonstrate our automation feature. For each microcontroller, we need a Wi-Fi dongle for communication purposes. For pressure sensors and flex sensors, we would like to get by with one set, but will provision our budget for more than one set. For provisioning a server, we have many options, including another microcontroller or one of our personal devices, but now, we will provision some of our budget for using a cloud provider.

One of the features of the shoe is to monitoring the pressure that the shoe exerts in the foot is essential to evaluating effectiveness of the shoe. Therapeutic shoes are meant to relieve pressure throughout the foot and distribute it more effectively throughout the leg. For the hardware we want to use at least six pressure sensors per shoe to capture data associated with plantar pressure. There will be about two pressure sensors in each of the three major areas of the foot labeled in figure four. This includes the heel, inner/outer ball, and the inner/outer longitudinal arch. Our implementation will be limited to one shoe for the time being since it can easily be integrated into the second shoe once the first shoe is complete. A microcontroller will be used to collect the data from the sensors and possibly transfer wirelessly. The pressure sensors must be able to measure data for at least an adult male and female of 100-160 pounds. Pressure data should be accurate within 15% of the calculated mathematical value while operating at room temperature. The system will save at least 2GB of data produced by al the sensors incorporated in the shoe. The sampling rate of sensors should be at least 10 Hz when the system is active. Another of the shoe will be to detect pronation and supination. Use at minimum two flex sensors to determine the state of the foot. There are three states considered over-pronation, neutral and over-supination. At minimum one flex sensors will be used per each side of the foot for a total of two flex sensors. A microcontroller will collect data. Flex sensors must withstand a minimum of 10 trial cases. One trial case is one over-pronation and one over-supination. A third feature we are planning to implement is to notify user at least once of a low battery if the level is reached. The level at which users should be notified is 20%. Additionally, the battery detection must safely and preemptively power off the microcontroller. The levels will be sampled at least every 30 min to ensure the battery is still good. A fourth feature we are focusing on is automated deployment of software. This feature will require that at least 2 microcontrollers on the same network to be configurable at once or in rapid succession. The process of deployment must take place in under 30 minutes and must not require user interaction after the process has begun. This part will not be completed until second semester due to dependency on other features of the project. Automated deployment of software should provide an easy way for shoes to be configured. This means that it should be almost as easy to configure one shoe as it would be to configure 10 or 20 shoes. This would make it easier to update shoe feature, and would also make it possible for the manufacturer to easily produce these therapeutic shoes. This featured will be considered complete when it can be demonstrated that more than multiple microcontrollers on the same network can be either configured simultaneously or in rapid succession. An important aspect of the project is the visualization of data since it has to be user friendly. The visualization could be a web based solution. Data for the visualization should be stored in a database and should be accessible through queries. The visualization must display each set of data per each sensor. This includes a minimum of six pressure metrics and two flex metrics. Visualization must be easy to access and user friendly. This means no coding whatsoever should be required for the user. Table V shows the different task levels that form the system. There are five main subsystems that are represented in level 1. Each subsystem is divided into separate task that consist of multiple subtasks. The system is partitioned into many levels of tasks so the team can divide and conquer. It also allows for multiple tasks to be developed concurrently.

TABLE V.
TASK LEVELS

Level 1	Level 2	Level 3	Owner	Hours
Plantar Pressure				
	Create Circuit for Sensors			
		Create initial circuit to determine functionality of sensors	Eduardo	15
		Adjust circuit to correct force values	Eduardo	20
	Collecting and storing data in local database			
		Collect initial metrics	Eduardo	10
		Write a program to collect pressure metrics	Eduardo	5
		Transfer metrics to a local database or remote database	Jose	50
		Testing robustness of metric collectors	Jose	5
	Fit pressure sensors and circuit into therapeutic shoe			
		Wire sensors into the sole of mock shoe	Eduardo	10
		Wire the sensors into the sole of the shoe	Eduardo	12
		Design PCB for acquisition circuit	Eduardo	15
		Readjust sampling rate based on the data from a test case	Eduardo	5

Pronation and supination detection				
	Create circuit for flex sensors			
		Customize resistors in circuit to optimize range of values of output	Phillip	7
		Amplify signal if necessary with op-amp circuit	Phillip	2
	Determine proper orientation of flex sensors			
		Orientation must differentiate between pronation and supination	Phillip	4
	Determine how sensors fit in the shoe			
		Location and method of holding sensors in place	Phillip	2
	Collecting and storing database			
		Microcontroller code to operate sensors	Phillip	20
		Write a program to collect and store flex metrics	Jose	1
		Determine flex values that indicate pronation and supination for text case	Phillip	5
Data visualization				
	Get data from microcontroller			

	to remote server			
		Configure remote server	Jose	5
		Configure database on the server	Jose	5
		Transfer data from microcontroller to remote database	Jose	10
		Set up authentication to database	Jose	5
	Link database to graphing application			
		Create or use existing graphing application	Jose	15
		Configure graphing application to use our database as its data source	Jose	2
	Create graphs			
		Create graphs for pressure sensors	Jose	5
		Create graphs for flex sensors	Jose	1
Low battery detection				
	Low battery detection circuit			
		Create test circuit to test functionality of notification hardware: LED	Ahriben	2
		Create test circuit to indicate low voltage	Ahriben	30
		Add notification components to the low battery detection circuit	Ahriben	5
	Preemptive power off			

		Create script to sample battery voltage	Ahriben	8
		Create script to test preemptive power off	Ahriben	2
		Add preemptive power off to the voltage sampling script	Ahriben	2
Automated Deployment				
	Create initial setup for single microcontroller			
		Install dependencies for microcontroller	Jose	20
		Configure microcontroller settings	Jose	20
		Ensure that programs is robust and repeatable	Jose	10
	Create setup that will run on multiple hosts			
		Configure connection over Wi-Fi	Ahriben	15
		Run existing program on multiple hosts	Jose	3

This chart shows the work breakdown structure of the project. Level one is the main features of the project. Level two is the sub-tasks of each of the main features. Level 3 is the activities required to complete each of the subtasks. The chart was created by Eduardo Anaya. [12].

1. *Plantar Pressure Using Pressure Sensors*

Monitoring plantar pressure is essential for Sunrise Shoes since they want to be able to determine if the shoe is relieving the offload on the proper areas of the shoe. We want to incorporate at least six pressure sensors into the shoe to track the pressure distribution of at least three of the major parts of the foot. During the sampling time the shoe shall calculate the pressure for each of the six sensors sequentially. The sensors need to be able to make measurements for an average person of about 100 – 160 lbs. This system is meant to track information of the pressure the shoe is experiencing as the patient wears the shoe. Pedorthic shoes are meant to relieve pressure from the heel and the inner and outer ball of the foot. At times, shoes are modified and personalized for a single individual to correct specific plantar conditions. Plantar pressure wants to be monitor in this cases to track the effectiveness of the pressure offload of the shoe design. This allows for modifications to be made as they are need it to achieve the patient's needs. The pressure is meant to be placed in the center of the foot to place the pressure in the entire leg so the wounds heal quicker and more efficiently. "Current healing devices in the market, such as Darco Surgical Shoes, or the CAM Walker Bledsoe Brace System, either have no control of your musculoskeletal system, or they completely lock it up, resulting muscle atrophy, deformity, and subsequent ulcers," stated the National Institute of Health- NIH [4]. Since Sunrise Shoes, success is partially due to efficient offloading its essential for us to monitor if the shoe is serving its purpose.

a) Creating circuit for sensors and power distribution through sensors

This section is one of the first activities done. This section will be done from October 15 to October 31. It will be attempted to be completed before that to modify any mistakes or problems with the circuit. This part involves distributing the power though all the pressure sensors.

i. Create initial circuit to determine functionality of sensors

To test the functionality of the circuit we will begin by making a simple circuit. The circuit will consist of using a simple voltage divider circuit with the force/pressure sensitive resistor sensor and another resistor. This will create a variable voltage output which then will be read by a microcontroller's (probably a simple Arduino board for the simple testing) ADC input. The trickiest part of the voltage-dividing is an FSR (force sensitive resistor) is selecting a static resistor value to pair with it. An example of the schematic and diagram of the testing circuit is shown below in figure 18. This is because we don't want to overpower the maximum resistance of the maximum resistance of the FSR but at the same time we also don't want the FSR's minimum resistance to be completely overshadowed either. It is helpful to know what ranges of forces we will be reading that way we can pick a suitable resistance value to start with. If the project's force/pressure sensing covers the broad range of the FSR sensor (for this cause is 0-100 pounds), we need to pick a static resistor in the middle-range of the FSR's resistive output. For testing we will start with a resistor of about 3.3 KΩ as a starting point for simply testing the functionality of the sensor.

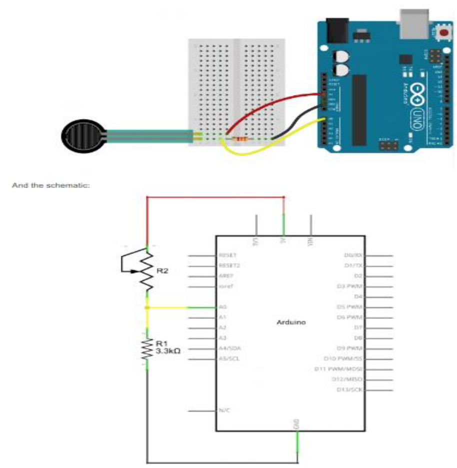
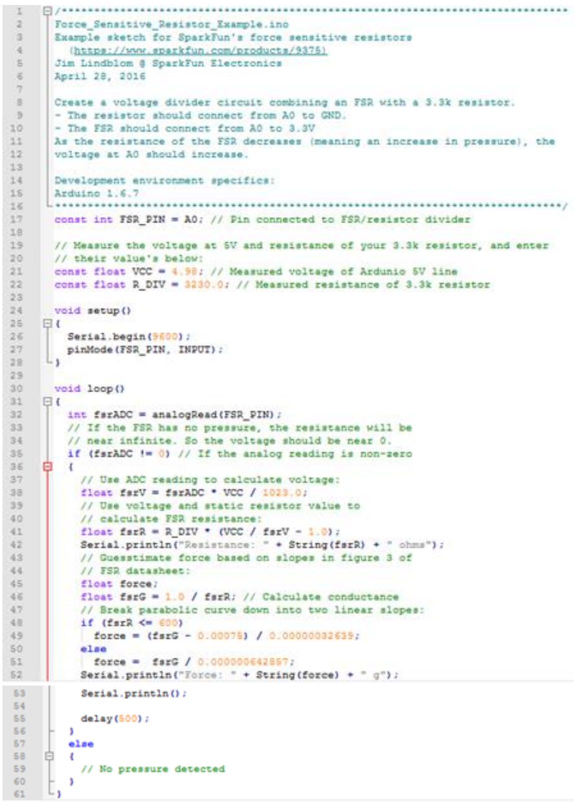


FIG. 18. SCHEMATIC AND DIAGRAM TEST CIRCUIT
The schematic and diagram of the testing circuit for determining the basic functionality of the pressure sensor. This circuit won't be the actual circuit ambitioned for the pressure sensor system [6].

Later in the future, we will use a potentiometer to range the resistance without having to switch resistors. Ranging the potentiometer will allow us to find the desired resistance for the pressure values the project will be engaging on. Using the sample code provided by Sparkfun Inc, we will test the circuit. The code provided is shown in figure 19.



```
/*****************************************************************************
Force_Sensitive_Resistor_Example.ino
Example sketch for SparkFun's force sensitive resistors
  (https://www.sparkfun.com/products/9375)
Jim Lindblom @ SparkFun Electronics
April 28, 2016

Create a voltage divider circuit combining an FSR with a 3.3k resistor.
- The resistor should connect from A0 to GND.
- The FSR should connect from A0 to 3.3V
As the resistance of the FSR decreases (meaning an increase in pressure), the
voltage at A0 should increase.

Development environment specifics:
Arduino 1.6.7
*****************************************************************************/
const int FSR_PIN = A0; // Pin connected to FSR/resistor divider

// Measure the voltage at 5V and resistance of your 3.3k resistor, and enter
// their value's below:
const float VCC = 4.98; // Measured voltage of Ardunio 5V line
const float R_DIV = 3230.0; // Measured resistance of 3.3k resistor

void setup()
{
  Serial.begin(9600);
  pinMode(FSR_PIN, INPUT);
}

void loop()
{
  int fsrADC = analogRead(FSR_PIN);
  // If the FSR has no pressure, the resistance will be
  // near infinite. So the voltage should be near 0.
  if (fsrADC != 0) // If the analog reading is non-zero
  {
    // Use ADC reading to calculate voltage:
    float fsrV = fsrADC * VCC / 1023.0;
    // Use voltage and static resistor value to
    // calculate FSR resistance:
    float fsrR = R_DIV * (VCC / fsrV - 1.0);
    Serial.println("Resistance: " + String(fsrR) + " ohms");
    // Guesstimate force based on slopes in figure 3 of
    // FSR datasheet:
    float force;
    float fsrG = 1.0 / fsrR; // Calculate conductance
    // Break parabolic curve down into two linear slopes:
    if (fsrR <= 600)
      force = (fsrG - 0.00075) / 0.00000032639;
    else
      force =  fsrG / 0.000000642857;
    Serial.println("Force: " + String(force) + " g");
    Serial.println();

    delay(500);
  }
  else
  {
    // No pressure detected
  }
}
```

FIG. 19. TEST CODE FOR PRESSURE SENSORS
This figure shows the sample code provided by Sparkfun to test the Pressure/Force sensors using the Arduino board. The code is in Arduino C and will be modified later to create the actual code later in the month [6].

ii. *Adjust circuit to correct force values*

The pressure sensor we will be using for our project is the FlexiForce Standard Model A301. We chose this sensor because the small size is ideal for prototyping and integration to the actual system. The Sensor is thin and flexible which is what we were looking for when we were looking for the ideal sensor. The sensor is also easy to use since it can be integrated into the system and calibrated very quickly. The FlexiForce A301 is the smallest standard piezoresistive force sensor we could find that had the properties we were looking for. The A301 sensor is ideal for embedding into products and applications [7]. Each sensor can read up to 445 Newtons which is about 0 to 100 pounds, which should be enough for the areas of the foot we are trying to monitor since the pressure is distributed and not centered in a specific area to exceed the pressure being able to measure.

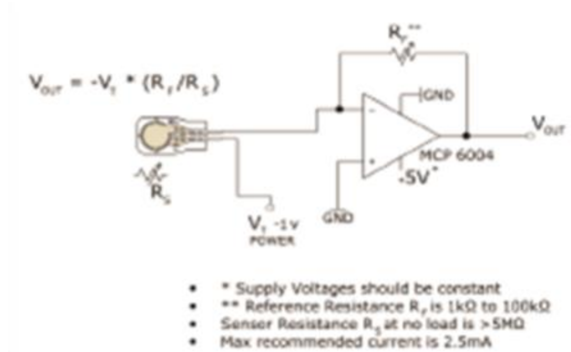


FIG. 20. SCHEMATIC OF FINAL PRESSURE CIRCUIT
4 The figure shows a more advance circuit that will allow us to test and adjust the force sensor much more efficiently. The schematic of the circuit is shown in the figure [7].

The actual circuit we are planning to implement to adjust the correct force values desired is shown in figure 20. To measure higher forces, we will need to apply a lower drive voltage (-0.5V, -0.10V, etc.) and reduce the resistance of the feedback resistor (1KΩ min.) [6]. To measure lower forces, we need to do the opposite, which is to apply higher drive voltage and increase the resistance if the feedback resistor. The sensor output is a function of many variables and interface materials. Therefore, we need to calibrate each sensor for the application. The FlexiForce sensor are resistors that vary linearly in terms of conductance vs. force under an applied load. With no force applied to the sensor the resistance is on the order of megaohms which is essentially an open circuit. As the applied force rises the output resistance drops eventually reaching about 10KΩ or lower depending on the application [8]. External circuitry to convert the output into a linear analog voltage can be relatively simple. The chart in figure 21 shows the conductance and resistance of the pressure sensor as the force varies.

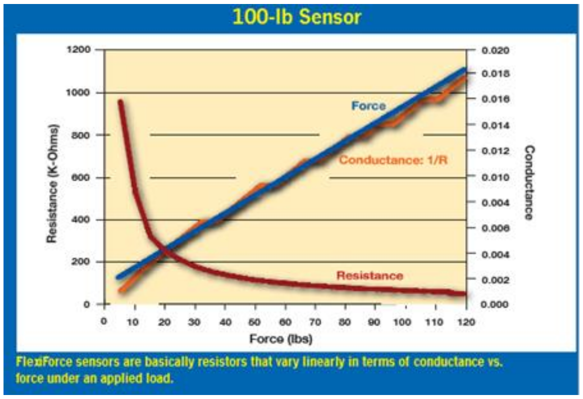


FIG. 21. CONDUCTANCE AND RESISTANCE OF FORCE SENSOR 5. It shoes the conductance and resistance of the 100-pound pressure sensor as the force applied in pounds' changes [8].

To adjust the pressure sensors, we will use a simple op-amp circuit shown in figure 20. We will calibrate the sensor by adjusting the feedback resistor or the drive voltage. These adjustments will allow us to fine-tune the force ranges of the system to the desired values.

b) Collecting and storing data in local database

To use the metrics, we collect, we need to have them in a local database and then transfer them to a remote database. The initial part of getting and storing metrics should be started in October 16th and be completed before November 16th. The latter half, that ensures the stability and robustness of the system, should be completed in the time between February 24th and March 1st

i. Collect initial metrics

This task only requires that we collect metrics from our force sensor. These should be analog signals from our sensors. For this step the format of the metrics does not matter. We will likely do this section in the C programming language and the microcontroller used for this activity is not necessarily the one used in our final prototype. The goal of this subtask is to ensure the functionality of our sensors and microcontroller. This task should be completed by October 22nd.

ii. Write program to collect pressure metrics

Pressure metrics coming from our sensors will be an analog signal. To make this information valuable, we must write a program that sets our sample rate and converts our data into Newtons. It must then make the data available in a readable format. This means that the data would be available to be read and stored into a database. Most likely, the data in this step will just be stored in a file. We expect this task to be completed by October 31st.

iii. Transfer metrics into a local database or remote database

The metrics that we collect must be sent to a database for easy access in future tasks. To do this, a program must be written to parse the metrics and add them to the local database on our microcontroller. The local database that we plan to use for this storage is InfluxDB, a time series database. Because the goal is to make the destination where the metrics are sent easy to change, in case we have problems with our current database or decide to publish data to a remote database, we may also want to rewrite the collector for this step. This will likely be a collector for Snap, an open-source telemetry framework. Since our goal is to write a Snap collector, there will need some extra time assigned to learning for this task. Therefore, we don't expect this task to be completed until November 16th.

iv. Testing robustness of metric collectors

This tasks involves accounting for situations outside of our test case. Mostly this includes adding error handling to the metric collector. This activity is not very high priority since we will be controlling the test case for our prototype. On the other hand, this is a very important task for a completed product. Thus, we aim to complete this task in the second semester in the time between February 24th and March 1st.

c) Fit pressure sensors and circuit into therapeutic shoes

One of the last tasks for implementing pressure metrics is fitting the sensors and circuit into the therapeutic shoe. Fitting the sensors into the shoe will be done next semester while producing the final product. This semester we are only going to be producing a prototype of our system to check how the system is going to be function. The prototype of the shoe for the pressure sensors will be completed before October 31 since it's the most important feature of the shoe. Setting up the pressure sensors into the actual shoe will be from January 30 – May 1 of the year 2017.

i. Wire sensors into the sole of mock shoe

For the prototype, we will likely be fitting our design into a mock shoe, which will be a regular shoe or something shaped like a shoe. In this case, it is not necessary for the circuit to be entirely inside the shoe. The expected time during which this task will be completed is between November 21st and December 2nd. This section will be done this semester since it will be the prototype of the shoe we will be implementing next semester. Reading data from the sensors in the mock shoe will be completed before October 31, since it's the most important feature of the shoe so we need to make sure its functioning by December 2. A mock shoe will be implemented with similar dimensions to the actual shoe. The mock shoe will function as the base of the for the prototype. The sensors will be set up into the mock shoe to simulate the actual system. This will allow us to get an idea of what the final product is going to look like next semester.

ii. Wire sensors into the sole of the shoe

For the final design, more thought will need to be put into the layout of the shoe. In this case, we anticipate that the design will fit inside of the shoe, but are willing to make sacrifices to maintain the functionality of the therapeutic shoe. We also expect to manufacture our circuits during this step since we do not want to have breadboards in our final design. Overall, this is a task that will be done during the second semester. We expect to work on this task from the time of February 1st to April 21st. Setting up the final pressure sensing circuit inside the therapeutic shoe will be done next semester. Our goal is to set up the circuit before March 1st, since we want to be able to fix any problems since it's the base for many of our other features. Although we have until May 1 to complete the entire project, we want to complete this feature as soon as possible. We are aiming to finish this feature by February 15 and the latest being March 1. We want to finish this feature as soon as possible so we can get the rest of the features functioning like data transfer and data storage. Many other features depend on this activity which is why it has a high priority.

iii. Create PCB for acquisition circuit

The printed circuit board (PCB) was developed to reduce the size of the acquisition circuit. The acquisition circuit needs to be reduce to fit inside the sole of the shoe. The PCB contains the voltage inverter and the two op-amps that are reading the resistance change of the sensors. The PCB also contains the inputs for all the sensors and the outputs of the op-amps. The board also has a VDD and VCC input to power all the components without having to power the board with separate wires. This process was complete by February 24.

iv. Readjust sampling rate based on the data from a test case

This task is another task for refining the final product. With this activity, we would like to adjust the sample rate based on the measurements we have been receiving during our tests. Our expected sample rate is at least 10 Hz, but we would like to adjust the sample rate based on the walking speed of our test person. This might seem like a very small task to change, but if we decided to collect a significantly larger amount of data, we will need to adjust other activities. This task may include increasing the size of our local storage on the microcontroller. The expected time during which this task will be completed in February 15th to March 1st. This activity will allow us to modify the rate at which we sample data based on the need portrayed by the system as we test it. This will not be done until the spring semester since it depends on the system being complete. This modification will be done to make the system much more efficient based on the need. Although this activity as a lower priority, we still want to complete it before March 1. The sooner the pressure sensing system is completed the better since it will allow us to complete the rest of the features. We also want to finish this activity soon so we can start calculating the power consumption of the system as soon as possible so we can modify anything in need to reach the goal for our system running time. The pressure sensor system has the highest priority since it is the feature acquiring most of the data.

2. Pronation and Supination Detection

Pronation and Supination detection is an important part of the design. They indicate that the patient is not using the shoe properly. This feature will be handled primarily by Phillip Dye.

a) Create circuit for test sensors

i. Customize resistors in circuit to optimize range of the output values

This is the first part of this section. The flex sensors need to be set up and working to proceed with the other parts of this section. The sensors need to be giving data. Initially the sensors will be giving constant data to help with design process. A more basic initial setup may be used to proceed with the other parts of this section. This basic setup will be done between October 18 and 30th.

The sensor circuit will be revisited when combining this section with the other workings of the shoe. The circuit may need to be modified to meet the low power needs of the project. Two flex sensors will be used in the circuit. The flex sensors give a variable resistance based on the amount of flex that is read through a voltage division circuit and outputs a voltage result.

ii. Amplify signal in necessary with op-amp circuit

During this section, we will be tweaking the flex sensor signal and possibly add an op-amp if the signal needs to be amplified. Depending on the system and the sensor we will be probably adding an op-amp to calibrate the sensor to the desire setting. This section will probably be done from November 1st to November 15th since it has a high priority and we want to get it functioning as soon as possible.

b) Determine proper orientation of flex sensors

To begin this section, a circuit for the flex sensors must be working. A series of experiments will need to be designed and implemented to determine how the flex sensors should be orientated.

There are several key factors that need to be considered when determining the orientation of the flex sensors. First, the sensors must bend when pronation and supination occur in the foot. Second, the amount of bend that occurs in the sensors must be large enough to be repeatedly measured. Third, the sensors should not bend measurably less significantly when pronation and supination are not occurring. This section will be started by October 30.

i. Orientation must differentiate between pronation and supination

The sensors must be reactive to determine pronation, supination or a neutral position. The sensors should be configured to allow for this detection. This will be tested by moving the foot in different position and checking if it detects positions of the foot. Detection of foot orientation will likely be done as a post process, using the sensor values as the base for a data processing script. The prototype will be completed from October 30 to December 2.

c) Determine how sensors fit in the shoe

There are two phases of this step. The first phase is setting up the flex sensors in the shoe to test for the proper orientation of the shoe. the requirements for this part of the design is that the flex sensor is stable enough for testing purposes, but can be adjusted and is not permanent. This first phase needs to be done simultaneously with determining the proper orientation of the flex sensors. The second phase is setting up how the flex sensors will be held in place in the actual shoe design. This requires that flex sensors will not shift in position relative to the shoe over time. This section will be started by October 30.

i. Location and method of holding sensors in place

The sensors need to be placed in a way to detect changes in foot position without disturbing the foot of the patient. This will likely be a trial and error process to best determine how to position sensors to be efficient, functional and non-invasive. The designated team member will be in communication with Sunrise Shoes to assure compliance with shoe fitting and design. Sensors must be secured to shoe to prevent unnecessary wear and make sure sensors remain functional and collect data. This section will be done from October 30th to December 2nd for the prototype. For the actual shoe, it will be done in the spring semester from February 1st to March 1st since it has a high priority due to the data collection.

d) Collecting and storing data in database

This section is the flex sensors link with the rest of the project. The previous steps can be done in isolation, while this one requires interaction with other parts of the project. The flex sensors will collect data at the same rate as the pressure sensors, which is at least 10 Hz, if that data rate is determined to be sufficient. This is also the final and most complicated part of pronation and supination detection and it can't be completed until the other parts have been completed. This part is planned to be started November 15 and continue till April 30.

i. Microcontroller code to operate sensors

The code we will be using for the flex sensors needs to be created by November 15th since we need to be able to read data accurately as soon as possible so we can start storing the data. The testing code will be created before by November 1st to get familiar with the flex sensor and so the sensor can begin to get calibrated to read data from the desired ranges based on the position of the sensor inside the shoe.

ii. Write a program to collect and store flex metrics

Flex metrics coming from our sensors will be an analog signal. To make this information valuable, we must write a program that sets our sample rate and converts our data into the desired data format. It must then make the data available in a readable format. This means that the data would be available to be read and stored into a database. Most likely, the data in this step will just be stored in a file. We expect this task to be completed by November 15th.

iii. Determine flex values that indicate pronation and supination for test case

Since the flex sensors are going to be giving a value since they are going to flex as the shoe moves, we need to find what data is useful. This tasks involves accounting for situations outside of our test case. Mostly this includes adding error handling to the metric collector. This activity is not very high priority since we will be controlling the test case for our prototype. On the other hand, this is a very important task for a completed product. Thus, we aim to complete this task in the second semester in the time between February 24th and March 1st.

e) Determine if flex sensors are good indicators of pronation and supination for our test case

Once an orientation and method for holding sensors in position has been developed, a test must be performed to determine that pronation and supination are being properly detected. This test must show that the data gathered by the shoe will indicate pronation and supination when they occur. The test must also show that the data gathered by the shoe will indicate when pronation and supination do not occur. The test will involve someone not knowing the position of the foot and determining its position from the data. If the setup being used cannot pass this test, the setup needs to be redesigned. The redesigns will initially be focused on different orientation methods for the flex sensors. If after multiple attempts it is learned that flex sensors will not be able to properly measure pronation and supination in any orientation and alternate method for detection must be created. One alternative is to see if the pronation and supination can be gathered through the data being gathered by the pressure sensors. This will be worked on November 1 through the 15.

3. Data Visualization

Another feature that we felt was necessary to implement was the visualization of our data. Visualization is important for making sense of the numbers we collect. Metrics can be taken but if not visualized well it can be meaningless. Data in a database can be difficult to decipher and manage for a non-technical user. Given sponsorship from a non-technical company, data should be presented in a way that is easy to access and visually appealing. To meet and implement this feature we would like to create a graph for each of the sensors we use.

a) Get data from microcontroller to remote database

The first step in the process of implementing data visualization is getting the data from our microcontroller to an external database.

i. Configure remote server

This activity requires that a remote server be configured for the collected data to be sent to. This will likely require setting up a server with a cloud provider or it could just be another microcontroller, such as a Raspberry Pi, to serve as a mock server. The best way to identify if this task is completed is to test the connection to the server. If we can ping the server from our microcontroller, then we know the initial configuration of the server was done correctly. The server should also have a capacity of thirty gigabytes. This task should be completed in the time between October 16th and November 8th.

ii. Configure database on the server

The requirements for this activity will be setting up a database on our remote server. The setup of this database needs to be reproducible in case something happens to our remote server. Doing this will require the creation of a setup script for the database. To call this task completed, the setup script would need to be tested. Testing that this setup script works without potentially damaging our current setup would require some sort of testing space. One way this could be implemented is through a second server for testing. The more likely solution to this problem is to use a Docker container to test. The structure of the Docker is shown in figure 22.

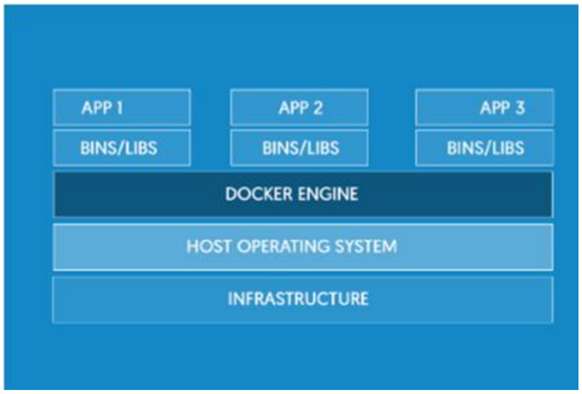


FIG. 22. STRUCTURE OF SERVER:
The diagram shows the structure of server using Docker containers [9].

Docker containers, as defined by the developers, is “wrap a piece of software in a complete filesystem that contains everything needed to run: code, runtime, system tools, system libraries – anything that can be installed on a server. This guarantees that the software will always run the same, regardless of its environment” (Docker). Basically, Docker containers will allow us to test our server configuration without using a server. This will hopefully save the cost of having a second mock server for testing. Since we want to use Docker for this part, we can start even before setting up our first server. Thus, the task will be worked on between the time of October 9th and November 10th.

iii. Transfer data from microcontroller to remote database

For this activity, we need to find a way to transfer data from our microcontroller's local storage to our database. This will likely just be a data dump where all the data is taken from the database and sent over WIFI or Bluetooth to another machine. Another possibility, is to take advantage of backup features that most databases have. This means that we use the backup feature to, rather than just create a backup, send the data to the correct location on our external database. We will know that this feature is working when the data from our remote database can be accessed and shows values from our sensors. This task should be completed within the time of November 16th to November 23rd.

iv. Set up authentication to database

This activity addresses the issue of security for our data. We would like the database to be secure enough so that not just anyone on the same network can corrupt our data. For the prototype, this is not a large concern since we will be testing in a confined network, but in preparation for a finished product, security becomes a big concern. Because this activity will not be required for the prototype, its priority is not as high as the other tasks. We expected it will be worked on between the time of February 1st to February 8th.

b) Link database to graphing application

Once we have a database on a server with the data that we need. The only step left for data visualization is linking the database to a graphing application.

i. Create or use existing graphing application

This activity requires that a web application for graphing be set up. The graphing application can either be created by one of our members, or we can use an existing graphing application. The web application will be hosted on the same remote server as our database. To consider this activity complete, we must have a web application for graphing, but it does not require that the application already have graphs for our sensors. The time period we must work on implementing the graphing application is from October 9th to November 8th.

ii. Configure graphing application to use our database as its data source

This tasks requires that our web application can retrieve data from our database. To accomplish this, our web application must make requests to the database as needed for any graphs that are created. Any visual representation of data from our database will confirm the completion of this activity. We expect to have this task completed within around a week of completing the graphing application. This puts the expected date of completion at November 14th.

c) Create graphs

Once we can create graphs, we can create graphs for each of the sensors that we are using.

i. Create graphs for pressure sensors

Creating graphs for pressure sensors is an activity that requires the graphing application to be completed. The graphs for the pressure sensors should contain at least one graph for each of the pressure sensors. This means that there will be at least 6 graphs for the pressure sensors. Each of the graphs should plot time versus force. Force will be plotted using Newtons and time will either be in time of day or represented as the sample number. With the sample number and the time in between each sample, we will be able to determine the total amount of time that has passed. We expect this activity to be completed within a couple of days of having the graphing application linked to our database. This puts the expected date of completion at November 11th.

ii. Create graphs for flex sensors

Creating graphs for flex sensors is an activity that is very like creating graphs for pressure sensors. The graphs for the flex sensors should contain at least one graph for each of the flex sensors. This means that there will be at least 2 graphs for the flex sensors. Each of the graphs should plot time versus an analog value. The analog value will just be an integer and time will either be in time of day or represented as the sample number, like the pressure sensors. We expect this task to be completed around the same time as the other graphs or within a day of the pressure graphs. This puts the date for completion at November 12th.

4. Low battery detection

The low batter detection circuit is meant to notify the user that the system is no longer going to be taking data due to the lack of battery power. Most importantly the system will prevent data corruption by properly shutting down the system when the battery starts to run low. This feature is mostly being develop to protect the systems integrity and data protection.

a) Low battery detection circuit

i. Create test circuit to test functionality of notification hardware

This is a validation step to ensure a clean start for the construction of the feature. By ensuring the functionality of certain hardware components, debugging future complications will be simpler given that the functionality of said components are already established. This step tells us if we need to use a different component. This should be completed by October 20th.

ii. Create test circuit to indicate low voltage

This step is critical for the feature. The circuit must be able identify a low voltage with respect to the operating voltage of the system. Analog signal associated with a battery will be converted to a digital signal. This should be completed by November 1st.

iii. Add notification component to the low battery detection circuit

This step is dependent on the previous steps. It cannot be completed without the other steps. Once a battery level is detected the notification components must be triggered. As an example, once indication of a low battery is conceived the led should alert the user via a visual response. The components will not be permanently set to notify the user. Once the battery hits a low level the component will be initially on and then be signaled on intervals which vary as the levels decrease. The priority for this aspect of the feature is high with respect to the feature but low in respect to the overall project because no metrics are actual collected. Real time data is used to create a system response. This should be completed by November 3rd.

b) Preemptively power off system

i. Create script to sample battery voltage

This step entails creating a script to read battery voltage levels. This step is important for preemptively powering off the system. This script will be run at a minimum every 30 min. This step coincides with the notification hardware of type piezo buzzer and led. This should be completed by November 7th.

ii. Create script to test preemptive power off

Test functionality of power off by sending signal to microcontroller. Also, measure time it takes to shut off. This measurement is important to get as much as we can from the battery without hurting the battery or corrupting the microcontroller. This should be completed by October 26th.

iii. Add preemptive power off to the voltage sampling script

Combine the above steps to sample voltage and then respond by either powering off or continuing. This task also entails running a full test on the system with other sensors in place. This is dependent on completion of sensor integration for the system. This should be completed by November 9th.

iv. Test power off system

Once the sensors are integrated a full test can be conducted. If adjustment is needed it will be done. We concluded that that the power of the system was about This should be completed by December 1st.

5. Automated Deployment System

The idea behind the feature of automated deployment is can configure many devices for minor changes or updates. In our case, we will be using an automated deployment program to configure the microcontrollers in our shoes. This task is dependent on the completion of all other features. Thus, this feature will need to be added in the second semester if possible. The time during which this feature would be implemented would be from February 1st to April 21st. We have not allocated any budget for this section since it only requires the use of hardware that we already need for other tasks.

a) Create initial setup for single microcontroller

To simplify the steps, it makes sense to first test the deployment program on one microcontroller.

i. Install dependencies for microcontroller

Installing dependencies for the microcontroller include installing all the requirements for collecting metrics from our sensors, all the requirements for our database, and all our requirements for low battery detection. This includes copying in any necessary programs and scripts as well as installing any dependent libraries and drivers for using our sensors. We can verify that this task is completed by testing on a second microcontroller. As much as we would like to be safe and use Docker containers, in a similar way to testing our remote server configuration, Docker will not support our anticipated microcontroller operating system. This means that testing using a second microcontroller will be necessary.

ii. Configure microcontroller settings

Configuring microcontroller settings includes disabling any unnecessary services that the microcontroller will not be using. For example, maintaining a Wi-Fi connection is very costly. If the team decides to move away from this approach and use Bluetooth, it would be wise to disable Wi-Fi and save on battery life of the device. As with the previous activity, any configurations to the microcontroller settings would need to be tested on a second microcontroller.

iii. *Ensure that program is robust and repeatable*

Normally, when a program does a setup, it is only meant to be used once. In the case that a specific part of the setup failed, we would not be able to run the setup again without receiving errors or doubling steps.

b) *Create setup that will work in multiple hosts*

Once we have the setup working for one microcontroller, we can turn our attention to configuring more than one.

i. *Configure connection over Wi-Fi*

It is very possible that we will already have a connection configured over Wi-Fi for another task, but this is a necessary task for running the program on multiple microcontrollers. To consider this task complete, we must be able to ping at least two microcontrollers from one of our machines running the program. In the case of Bluetooth, we need to established pairing with the other devices.

ii. *Run existing program on multiple hosts*

Before completing this task, the setup must work for a single microcontroller. This activity requires that we can use the setup on at least two microcontrollers in rapid succession or at the same time. To accomplish this, we expect to write Ansible playbooks. Ansible playbooks will run on any of defined machines prior to starting Ansible [10]. This will save us the time of creating a program that will iterate through the microcontrollers on our network. To determine the completion of this task, we should be able to configure two microcontrollers within 30 minutes without user interaction once the program has started. A diagram of ansible is shown below in figure 23.

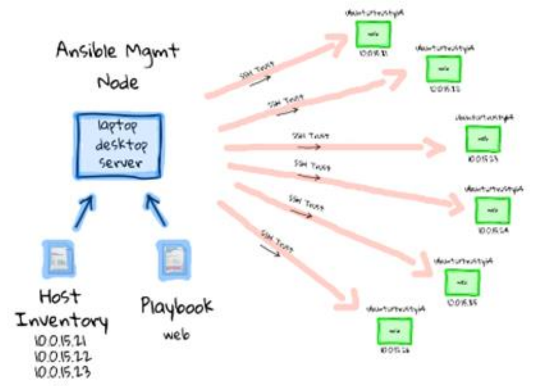


FIG. 23. ANSIBLE PLAYBOOK DIAGRAM;
This figures shows how Ansible can run an Ansible playbook on all of machines in its host inventory. Ansible will likely be run from one of our personal computers [11].

B. *Final Product Results*

The results of the entire system were positive since all the subsystems passed testing and functioned correctly. All the subsystems were integrated with successes achieving correct synchronization. All the components communicated with each other without any issues. The system was completed without any major issues or modifications. There were only two major modifications that were made to the system during the development phase. The first major modification that was made to the system was to add stability to the sole of the shoe due to the carving. We had to design an enclosure for the PCB board to cover the carving on the sole of the shoe. A solid layer was also added to the bottom of the sensor pad to add more support to the sensors. We also added a puck on top of each of the pressure sensors to make better contact on the sensors and reduce errors in the data. In table VI, we should the hours spent by each team member over the past two semester. Overall, all the issues were resolved and the system is working properly.

TABLE VI.
HOURS PER MEMBER

Member	Hours
Eduardo Anaya	250
Jose Aguirre	270
Phillip Dye	200
Ahriben Gonzalez	230

Chart created by team 9 [12].

VII. RISK ASSESSMENT AND MITIGATIONS

Having a second plan is essential during the development phase. We developed solutions for most of the situations that posed a risk to the project. One of the most important goal our team is trying to accomplish is to increase the quality while reducing the cost as much as we can. Risk assessment is crucial because during development of the system, unpredictable outcomes can be encountered that might pose some risk to certain parts or the entire project. The main goal of the risk assessment report is to steer parts of the project to reduce risks while achieving maximum results. Since no projects are risk free, we need to identify the areas of the project that could cause severe risk implications. Since our project consists of multiple features, it introduces more areas of risk to the system. Some areas and sources of failures in our system are hardware, software, and organization failures. To successfully complete the project, we need to approach the project with risk resolutions in mind. To reduce the severity of risk, we need to begin risk management at the earliest stages since problems are easier to resolve. Risk management will continue throughout the process to try to reduce the risks. We will develop risk mitigation plans to solve any risks that we might encounter throughout the project. Since the multiple features of the system increase the complexity of the system, the risks increase as well. This calls for more formal tools and methods to manage risks that might occur. During the report, we will be evaluating the risks that our project might encounter and how to manage the risk.

A. Perceived Critical Paths

Since the first moment, the team took in consideration the risks that could appear based on the design chosen. We implemented a secondary plan for each of the implementations in case something had to be redesigned. Risk management is extremely important since it allows us to identify unpredictable outcomes that we can encounter as we proceed with the project. These outcomes can pose a risk to part of the project or the entire project. We know that no project is risk free, so we need to be prepared to solve or prevent any risks we might encounter. Hardware, software, and organizational sources are prone to cause failures in the system being developed. We cannot fully prevent these risks so to have a successful project we need to shape the system with risk resolutions in mind. Risk management begins at the earliest stages of our project to reduce and prevent as many risks as possible. Risk management will be a continuous process that will be updated as needed. We will also be creating risk mitigation plans to have something to fall back if the risk ever happens. It is important to identify risks before they become serious problems. To identify these risks, we need to list the work breakdown structure since each element introduces risk. After identifying all the elements of the project, we need to determine what could go wrong with each of the elements of the project. The main structure is shown in Figure 17. Identifying the likelihood and possible impact of each element is important because we want to identify the elements with the greatest impact. Using the risk matrix shown in figure 24, allow us to identify which risks are more severe depending on their probability and impact toward the project. The information obtained by the risk assessment will be translated into decisions and actions. We will address the proper approach to solve or reduce the impact of the risks. We will specify what will be done, when it will be done, and who will do the work in our risk mitigations.

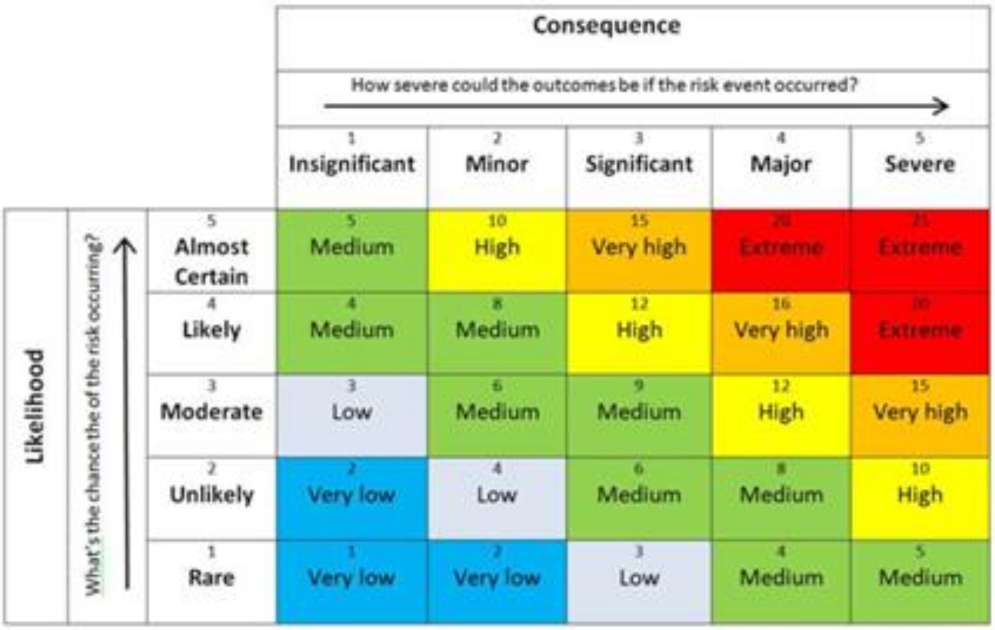


FIG. 24. RISK MATRIX DIAGRAM FOR EVALUATING RISK SEVERITY:
The risk matrix allows us to identify the risk level of each of the risks that might occur [26].

Based in the severity, the team will decide to either avoid the risk, control the cause, transfer the risk, or continue the current program plan. In the following chart, we will create a risk assessment chart where we state all the possible risks associated with each element of the system. The we will talk about the possible mitigation in the subsections. The different risks identified throughout the system are shown below in table VII. The Table shows the different risks with their impact and likelihood.

TABLE VII.
RISK RESULTS

Problem Risk	**Assessed Likelihood**	**Impact Severity**	**Risk Result**
Pressure Sensor Failure	2	2	4 – Low Risk
System fails to fit in shoe	4	4	16 – Very High Risk

Breakout Board Unsupported	3	3	9 - Medium risk
Data Outliers	4	1	4 - Low Risk
Automation Dependent on other tasks	4	4	16 - Very High Risk
Ansible is not supported	1	4	4 - Low Risk
Battery size	3	2	6 - Medium Risk
Flex Sensor Reliability	3	3	9 - Medium Risk

This table shows how we measured risk for each of our perceived critical paths. [3]

1. *Plantar Pressure using Pressure Sensors*

Monitoring plantar pressure is essential for Sunrise Shoes since they want to be able to determine if the shoe is relieving the offload on the proper areas of the shoe. We want to incorporate at least six pressure sensors into the shoe to track the pressure distribution of at least three of the major parts of the foot. During the sampling time the shoe shall calculate the pressure for each of the six sensors sequentially. The sensors need to be able to make measurements for an average person of about 100 – 160 lbs. This system is meant to track information of the pressure the shoe is experiencing as the patient wears the shoe. Pedorthic shoes are meant to relieve pressure from the heel and the inner and outer ball of the foot. Many issues can occur as we develop the feature.

i. Pressure sensor failure mitigation

One possibility when testing and designing the system is that the sensors break or burns by improper installations. The sensor can be easily replaced so the impact of the problem is low. The probability that it happens is also low since it is not likely that the sensors break or destroy. To solve this possible risk, we will order more sensors to have as replacements in case we need to replace any of the sensors.

ii. System fails to fit in shoe

Since we are working with a defined area, we need to design the system to fit properly into the shoe. It is easy go above the dimensions specified, so it has a high probability that this might happened. This will mean relocating the system or even redesigning the system which will cause a severe impact to the system. To prevent these from happening, we have chosen the small components available to achieve size specifications. If this is not enough, we have planned in positioning the system outside the show by incorporating a new compartment to the shoe. This compartment will be located externally so we can position the system properly as well as comfortably to the patient.

iii. Smaller breakout board is unsupported

One of our goals is to fit as much of the design into the shoe as possible. Thus, we have selected components that are small. One of those anticipated components is the Intel Edison. This is a very small microcontroller that we can most easily fit into the therapeutic shoe. Now, for our prototype, we are working with an Arduino breakout board for the Intel Edison. Unlike the microcontroller, itself, the Arduino breakout board is not small. This means that we will need to the smaller regular breakout board. A picture of the smaller board can be seen below in figure 25.

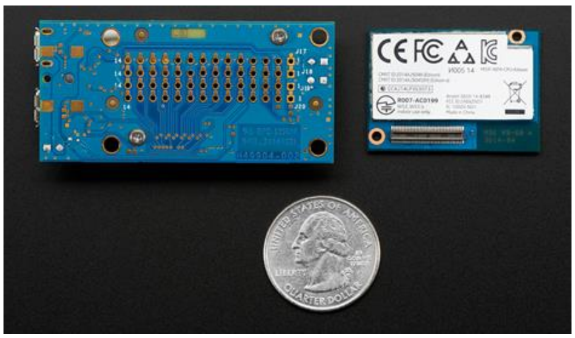


FIG. 25. REGULATOR BREAKOUT BOARD:
The above figure shows the size of the regular breakout board on the left, and the size of an Intel Edison microcontroller on the right. [28]

Relative to the regular breakout board, the Arduino breakout board that we are planning to use for our prototype is more than 4 times the size.

Normally, switching between boards is a relatively trivial, but there is some risk in switching boards for our anticipated setup. We plan to use a Golang platform for controlling microcontrollers called Gobot [27]. Gobot will allow compatibility with Snap, the telemetry framework we wanted to use for transferring our data. Gobot claims support for the Intel Edison, and we have tested the compatibility using the sample code seen below in figure 26.

```
package main

import (
    "github.com/hybridgroup/gobot/platforms/gpio"
    "github.com/hybridgroup/gobot/platforms/intel-iot/edison"
    "time"
)

func main() {
    e := edison.NewEdisonAdaptor("edison")
    e.Connect()

    led := gpio.NewLedDriver(e, "led", "13")
    led.Start()

    for {
        led.Toggle()
        time.Sleep(1000 * time.Millisecond)
    }
}
```

FIG. 26. GOLANG TEST CODE FOR ARDUINO
This shows some Golang sample code that has been tested using the Arduino breakout board. [27]

After doing some additional research and testing, we have come to the unsettling realization that Gobot does not officially support the smaller version of the Intel Edison breakout board. There is support for the smaller board, but it has not gone through any testing. Thus, in the case that the current implementation for smaller boards does not work, we may need to find an alternative.

There a few possibilities for mitigating this risk. The first option is to write the support for the smaller breakout board ourselves. The cost for this solution would be some time, but would resolve the issue without any other major changes. It also would not halt the progress of other tasks since we have an implementation using the Arduino board already. The second option is switch out our microcontroller to another one entirely, like a Raspberry Pi. This solution would provide us with more support, but it would introduce its own risks and require that changes be made in tasks that have already been completed. Thus, we will attempt to solve this risk by rewriting a small section of Gobot before resorting to a switch of microcontrollers.

2. Pronation and Supination Detection

i. Flex sensor reliability

The risk in this feature is that the flex sensors will not be able to reliably detect pronation and supination. The assumption we have begun with is that the sides of the shoe will bend enough to give data that indicates pronation and supination. This will need to be confirmed. To reduce the risk associated with this feature work to confirm this hypothesis is already being started. A backup plan if this fails is to try to use the data from the pressure sensors to detect pronation and supination.

A separate risk is the flex sensors not fitting in the shoe. This risk is extremely low because the flex sensors are very thin. They should be able to be glued to the inside of the shoe without adverse effects. If necessary, however they can be glued to the outside of the shoe and covered with some protective material to prevent damage.

3. Data Visualization

Another feature that we felt was necessary to implement was the visualization of our data. Visualization is important for making sense of the numbers we collect. Metrics can be taken but if not visualized well it can be meaningless. Data in a database can be difficult to decipher and manage for a non-technical user. Given sponsorship from a non-technical company, data should be presented in a way that is easy to access and visually appealing. To meet and implement this feature we would like to create a graph for each of the sensors we use. However, we can also introduce problems with poor data visualization.

i. Graphing application shows outlier data

One such problem would be graphing outliers that can cause unnecessary concern for the company. If we plot every data point, outliers would be become apparent and it would also be difficult to gather useful information from the data. The likelihood of having this problem is high, but luckily the solutions are various and all easy to implement using features of software we already plan to use. The first possible solution would be to use a Snap plugin. Since we are already using Snap, we can use the existing snap plugin for anomaly detection [29]. This plugin will make it easy to filter data points without any additional programs. Another solution would be to take advantages of features of our anticipated database, InfluxDB. One of these features, and a feature of many databases, includes the ability to take the average of data as it is being queried. Both solutions mitigate the risk of outliers and are extremely easy to add to our design.

4. Low Battery Detection

Another feature is energy management in terms of a low battery detection circuit is meant to notify the user that the system is no longer going to be taking data due to the lack of battery power. Most importantly the system will prevent data corruption by properly shutting down the system when the battery starts to run low. This feature is mostly being developed to protect the systems integrity and data protection.

i. Battery size

One risk is that the team has found is the size of the battery. The low battery detector must preemptively shut down the system. Inherently this will reduce active battery time, yet the system has a requirement of 2 hours of active time. Due to this a battery, must be selected to accommodate this requirement. If the battery is too big it poses threat of too much heat and additionally there will not be enough open space to place the battery.

If this situation presents itself remediations have been established by the team. In the case of the battery being too hot because of its size a temperature sensor can be used to monitor the ambient heat. If a big battery is producing too much heat, the system can be safely powered down to cool off.

If the battery is too big and there is no open space, there is a different approach. One approach is to design an external harness for the battery itself. Another approach would have to have several separate batteries connected in parallel. This would possibly allow for better space management.

The circuits could also be reviewed to make sure only necessary power is being consumed. This includes sampling rate. If less power is consumed a smaller battery can be used.

5. Automated Deployment

The idea behind the feature of automated deployment is can configure many devices for minor changes or updates. In our case, we will be using an automated deployment program to configure the microcontrollers in our shoes.

i. Dependency on other tasks

The biggest concern for implementing this feature is that it is dependent on the other tasks, aside from data visualization, being completed. This means that if one of those other tasks falls too far behind on schedule, this task will also suffer. This means this possibility has both high likelihood and high impact to our project. The best way to mitigate this problem is to work on the automated deployment gradually as we complete tasks. This will make it easier to finish on time if we do have problems.

The good news is that this task can also be used as a measure to mitigate risk in other tasks. For example, if our local database stops working on our microcontroller, we can use our automated deployment to immediately fix the problem without manual changes.

ii. Ansible not supported

Another big obstacle for this task is that we might not be able to use Ansible, a deployment software, as we originally intended. The Intel Edison that we are plan to use has on operating system called Yocto, which is a distribution of Linux. Ansible should support Linux distributions, but this does not guarantee the all same functionality across operating systems. While this is an unlikely occurrence, completing this task without ansible will be significantly more difficult. To mitigate the risk of task, we can write scripts and insert them into Ansible where Yocto is not supported. Alternatively, we can switch to another microcontroller, like a Raspberry Pi, but this introduces its own risks.

VIII. DESIGN OVERVIEW

Diabetics and wounded veterans often face foot complications that can result in the development of foot ulcers. These foot ulcers can cause major health risks and can often lead to amputation. With the help of our sponsor, Sunrise Shoes, our project will use therapeutic shoes with sensors to help diabetics, and wounded veterans, walk without fear of foot ulcers or eventual amputation. This will be accomplished through the features of our project that sense pressure and bending in the shoe, visualize the recorded data and notify the wearer. All setup will be automated for easy use.

First there is the pressure sensing and supination and pronation detection. This feature of our project will provide information to Sunrise Shoes so that they can adjust pressure distribution on an individual patient basis. Customizing footwear will help prevent otherwise harmful foot complications that a patient may face. This feature will also let wearers walk with peace of mind by knowing that their doctors have access to data about their activity and can provide them with feedback if necessary. The pressure sensing will function with the use of 6 major sensor areas at the sole of the foot. Pronation and supination detection is handled using flex sensors on the sides of the shoe. All information is relayed as voltage values to the Intel Edison.

Second is the feature of visualizing recorded information. This is a necessary task because it allows Sunrise Shoes and doctors to quickly understand the information they are receiving. Understanding a labeled graph takes much less time than reading through a long table of values. The feature is also useful because it allows understanding of pressure duration. This means doctors will know not only how much force the patient applies to their foot, but also for how long this force is being applied. It is accomplished using an InfluxDB database that receives converted voltage metrics from the Edison. These metrics tell us how much weight is being applied to a sensor and are graphed using timestamps to Grafana.

Another feature of our project includes notifying the user about necessary information for using the shoe. This includes an indicator so that the patient knows when their shoe is low on power, and a potential indicator to let the patient know when they need to readjust the position of their foot. Both of these are accomplished through email notifications. One comes from the Intel Edison itself and the other comes from the remote device where data is being stored.

Finally, there is the automatic installations. These will make all software installations in our project automatic, and will be able to install to multiple shoes. This will provide the groundwork for remote updates so that customizations for each patient will be easy and won't require the patient to visit their doctor in person. Overall, these features will work to make the lives of diabetics and wounded veterans easier.

IX. DEPLOYABLE PROTOTYPE STATUS

We were successful in fully meeting the planned feature set of our project. We have completed planar pressure detection with data visualization. This was the fundamental goal of our project. We also completed the secondary goals of low battery detection, pronation and supination detection, and automated deployment of software.

In addition to fully meeting our feature set, we were able to complete the different task either on time or ahead of our schedule set up by our project timeline.We were able to overcome different software bugs to be on schedule. We also had to troubleshoot and repair problems with our physical circuit. Through these obstacles we did complete our project on time.

Our project does a good job addressing our societal problem. By providing planar pressure metrics collection we can help diabetics detect problems in the foot before they reach further complications.

X. DEPLOYABLE PROTOTYPE MARKETABILITY FORECAST

Doing market research is an important process for any system or product lifecycle. Market research is important since it evaluates the market the product it's going to enter and it allows to estimate the product success. The market review is also important because it will allow us to answer important questions like if there is interest for the product? How much are people willing to pay for the system? Or how much can the company charge for the product? There are some similar products in the market which are used for different purposes. Our product is application innovational because we are using existing technologies for new purposes. Our system is different because we are reducing the cost and making it for continuous use. The other products are meant for single use since they are only to measure and map the pressure distribution of the patient. We want to product innovate by improving an existing product by reducing the cost and maintaining the quality of the product. The market for Pedorthic shoes is small since not a lot of companies join the industry. Although the market is not that big, the requirement and quality is very high since it involves health risks. We also want to analyze the market to predict if the product can have commercial success or if it's a risky project. There is a few fundamental rules for success that need to be followed by the product for positive achievements in the market. One rule that needs to be accomplished is to make sure the product addresses the need. In our case we have to make sure the system meets all the requirements that the sponsor requested for his product. Since Sunrise Shoes is trying to trigger a new concept of shoes in an existing market, we need to analyze that the system can make a significant difference in the quality of the shoes and the reliability. The product being developed needs to be differentiated by the rest of the products available in the market. The product also needs to provide convenience to the life of the user by making life easier. Before a new product is launched, the market needs to be understood by running market analysis and market research. To achieve the market research, the company needs to gather market information and also initialize information and data analysis. The market dimensions also need to be considered by analyzing the market size and growth rate, key success factors, and market profitability.

A. *Market Analysis of Pedorthic Shoes*

The therapeutic shoe market focuses on producing shoes that are specially designed and developed for the diabetic population. The purpose of the shoes is to minimize the risk of various skin related problems in diabetes. This market main purpose is to develop shoes that can prevent difficulties which can cause ulcers, skin conditions, or amputations for patients with diabetes. These shoes are prescribed by physicians since sometimes they are modified to meet specific needs. The utilization of prescribed diabetic shoes by patients suffering from various diabetic complications which include improper circulation of lower limbs and peripheral neuropathy has proven successful treatment in preventing and curing various foot ulcers, which can ultimately lead to foot and toe related problems [34]. These shoes need to provide diabetic patients a substantially enhanced results with their diseases and better recovery to improve their quality of life. This diabetic footwear is important to individuals since they can potentially decrease the high cost of care related with diabetic foot ulcers and amputations. The demand for diabetic shoes have observed an upliftment over the past few years which has strengthened the growth of diabetic shoes market all across the globe [34]. Since the number of diabetes increase every year, the demand for therapeutic shoes is also increasing. If more and more people suffer from diabetes, the market for therapeutic shoes will increase. The global diabetic food market is likely to grow at a stupendous CAGR over the next ten years from 2016-2026 [34]. With the growth of diabetic patients and the cost increase for diabetic care, therapeutic shoes have become an essential tool for recovery and prevention of related problems. The market segmentation for global diabetic shoes is based of consumer groups such as men and woman. The diabetic market is also divided by retail distribution that depends on store based and non-stored based. The store distribution branch is further divided department stores and chains, shoe stores, and special stores. In our case, we are working with a non-store distribution store since they are only obtained with subscription. The non-store distribution branch is further bifurcated on the online channels. The share of online channels is anticipated to grow at a significant CAGR over the next few years which will drive the overall global diabetic shoes market [34]. Since the market for therapeutic shoes is directed to a narrow population, having stored based distributors can be unproductive since they are not demanded by the entire population. Online based stores tend to be more effective since they can be reached easier by the desired population. Online distributors are more effective because they can reach the diabetic population much easier and spread their market from locally to nationally.

The global diabetic shoes market growth drivers are mostly dependent on the number of diabetic patients. Since there has been a constant increase in diabetic patients throughout the past years, the market has been constantly growing. Robust incline in number of diabetic patients all over the world is escalating the demand of diabetic shoes all over the world and thus intensify the growth of global diabetic shoes market [34]. The market has a need for new types of shoes which increases the opportunity for market growth for small companies. The expansion in demand and the awareness of healthy and energetic lifestyles has intensified the demand and the growth of the global diabetic shoes market in the near future. The growth in population as well as the growth in prosperity in some emerging countries has boost the demand for the shoe. Escalating population especially in emerging countries along with rising propensity of people to spend more is also expected to foster the demand for diabetic shoes all across the Asia and the world [34]. The market has an even greater opportunity for growth due to the emergence of the internet. Since most of the pedorthic stores are locally, the internet has allowed local markets to expand globally. The diabetic shoe market has wide opportunity with the expansion of e-commerce and expanding new brands in the market. These opportunities have the potential to strengthen the growth of the therapeutic shoe market all over the globe.

1. Market opportunity for Pedorthic shoes

In the United States alone it is estimated that 24 million people are diagnosed with diabetes. From the population that exhibits diabetes around 70 percent show signs of neuropathy [5]. Neuropathy is often caused by uneven offloading of the foot, especially in diabetic patients. Neuropathy in severe cases can eventually lead to amputation. Amputation operation are upwards of about ten thousand dollars. This surgery is not only extremely costly but it is also invasive and crippling to some. The loss of a limb can mentally disable patients as well as physical.

Pedorthic shoes are currently widely used. They have existed for some time, but it can be difficult to gauge their effectiveness or know when changes are needed without constant supervision. There is a need for an embedded design that allows for the benefits of Pedorthic shoes with the added feature of validating distributed offloading. Currently there is not much development for this system. This allows for a great opportunity. There is a need and our system has a solution. Our product would be less expensive than invasive surgery like amputation. The diabetic community would prefer a preemptive solution like our system rather than amputation. Opportunities for our system will stem from the healthcare business. Diabetic and wounded veterans alike would provide need for our system.

The global diabetic shoe market is growing each year. As the diabetic population increases the demand for therapeutic shoes has increased as well. The demand has increased since it was found that wearing proper shoes is of equal importance as diabetes interrupts the blood flow in a human body and causes sores and cuts to heal considerably slowly. With the help of physicians and footwear professionals, diabetic patients are now able to avoid several serious foot complications as it helps in relieving the areas of excessive pressure, reducing shock and shear, accommodate and stabilize deformities, and limit the motion of joints [35]. The prevalence of diabetes is undefinable which is seems to be increasing since the number if patients continues to increase annually. Consequently, the global market for diabetic shoes is estimated for a healthy CAGR of 8.1% during the forecast period of 2016 – 2024 [35]. This means that the market is increasing at a healthy rate since diabetes patients increase every year. The revenue of the diabetic shoe market will keep increasing as the patients needing the service keep increasing. Since the shoes seem to decrease the occurrence of several serious foot complications, the diabetic population have increase the demand for the shoes. The larger the demand, the more opportunity for the market to grow bringing opportunity to new innovations and emergence of companies. According to the report, the opportunities in global diabetic shoes market was valued at US$5.0 billion, which is projected to reach US$9.9billion by 2024 [35]. As the market keeps increasing, it leaves greater revenue and opportunities for the development of new technologies.

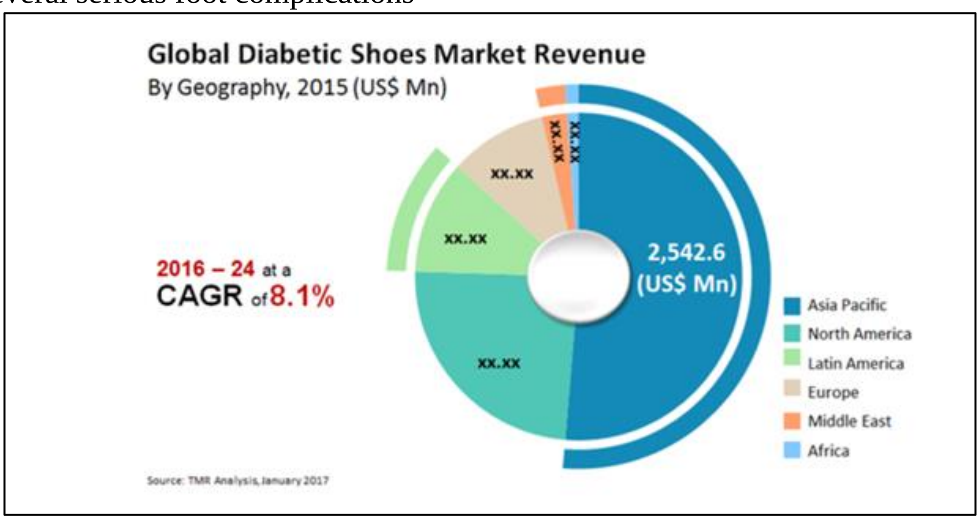


FIG. 27. A CHART FOR THE GLOBAL DIABETIC SHOE MARKET REVENUE:
The chart illustrates the global diabetes shoe market revenue for the different areas of the world. It also shoes the CAGR from the years 1016 to the year 2024 which shows an increase of about 8.1 percent [35].

The revenue of the different areas of the world for the diabetic shoe market is shown above in figure 27. This information was presented based on several factors that are expected to have an influence in market from the year 2016 to 2024.According to recent estimations by the International Diabetes Federation (IDF), there were 415 million diabetic patients across the globe, and the number will reach 642 million by 2040 [35]. This population is the one that mostly drive the therapeutic shoe market. This brings a great opportunity for the market since the patients are willing to make an investment on therapeutic shoes to reduce the risk of more expensive situations. Since diabetic expenses are already large, the diabetic patients do as much as possible to stay healthy and reduce the risk of severe conditions appearing on their lower extremities. Currently, the market is expanding steadily due rising disposable income among the urban population, who are well aware of infections caused by weak blood flow in the foot, and are willing to invest to avoid the complications such as ulcers and gangrenes [35]. The population suffering of diabetes need these shoes since they are part of their medical tools to stay healthy. These shoes offer a chance to live a more normal life without having to worry about amputation and sores.

The project we are currently working on has great opportunities since the market welcomes new technologies. The diabetic population crave new products that can help them stay healthier and feel more secured. Since the shoes we are currently developing offers a more secure shoe that can monitor itself, the population will feel much confident about the tools they are using. The shoe currently in development can monitor the effectiveness of the shoe. The feedback information produced by the sensors will allow the developer of the shoe to make any modifications if required. Introducing new products into the market, as well as research, provides great opportunities for the diabetic shoe market. Research and development for enhancement of these products is another factor that is propelling the market in positive direction, as newer products provide more comfort [35]. The market is always opened to new technologies that can improve the quality and performance of their products. Providing more efficient and trustworthy products increases the credibility of these products which in return will increase the demand of the market. These products are important because they provide hope for the diabetic population in need. The market is open to the production of innovated items that can further improve the market. Moreover, emphasis on innovation production quality on the formulation of new therapeutic shoes to improve performance is expected to impact the market for diabetic shoes globally [35]. The market welcomes research and innovation since the customers are asking for items with a greater improvement that offer better results. Since the diabetic shoes is gaining importance among the aged population, it offers even greater opportunities for market growth. The shoe we are implementing can deliver usage for a greater population. Incorporating technology into a product can provide reliability of the product since it allows collecting feedback information that can be used to improve the product.

2. *Market barriers for Pedorthic industry*

There are a couple large barriers for entry to the Pedorthic Industry. The first of these barriers is trust and reputation with customers. Luckily, we have partnered with Sunrise Shoes, who have a long history in providing footwear solutions to customers such as Kaiser Permanente Hospitals, UC Davis Medical Center, Sutter Health Medical Centers, the California Department of Corrections and Rehabilitation (CDCR) and many more [5]. Without partnering with an established pedorthic foot care group, it would be extremely difficult to market our product to any immediate customers in the area.

A second large barrier to entry for our product in particular is accumulation of data. As we finish developing our product, we will find that our thresholds are not as “smart” as one would expect from an deployable product. The reason for this is that we don’t have the time to conduct tests with many different people as test subjects. The problem with our product is that it has different requirements for every different kind of person, and we need smarter thresholds for detecting things such as pronation and supination detection. This a barrier to entry that can only be solved with time.

3. *Strengths and Weaknesses of Product*

There are a few strengths to our product. The biggest strength that our therapeutic shoe has is the cost for the system. The prices of similar products hover in the range of thousands of dollars, while the cost of production for our shoe would likely be less than a couple hundred dollars. This would make it a very attractive product for consumers. Another strength of the system is that it includes solutions for customers to view data and expand their number of patients. Normally, a system sold with more expensive products such as the Tekscan F-scan systems, only allow local viewing of data through their graphs and mapping. One must be physically present and next to the system, or must transfer the data and system to other devices. In contrast, systems used with our product allows users to view data and information without ever needing to install any software or transfer any data themselves. The database and graphing solutions will be available through any internet connection and viewable through browsers. This provides ability for doctors, and possibly patients, to see usage data without any learning curve or frustration. Our system also uses technologies that offer assistance in the case that our therapeutic shoe has more customers than a single database can handle. Our database of choice was using InfluxDB, and with InfluxDB enterprise it is possible to have multiple databases work together to handle increasing number of users and backup their data [23].

While these advantages seem nice, they also come with a set of disadvantages. The first disadvantage is directly related to our price advantage. While our system can measure pressure, the price of the sensors means that they are less accurate and robust than the sensors of our competitors. Our sensors only measure the force applied in 6 areas of the shoe, but the Tekscan F-scan solution can map the entire foot of the wearer. This leads us into the second disadvantage of our therapeutic shoe system. While our visualizations are easily accessible and can be easily scaled to a large number of users, they are not matured in the same way the visualizations of our competitors are. Tekscan can create a heatmap of the wearer’s foot with their system. Even more impressively they can do automatic analysis of the data to segment the results into stages of the gait cycle. For our product to reach this level of efficiency would require a large amount of testing and refinement which would likely be outside the constraints of a senior design course. Until this is done, our system faces huge problems in competing with existing systems.

4. Changes needed for a marketable product

There are still some major changes required to our hardware and software in order to make this from a deployable prototype to a deployable product.

The first major refinement would be coordination between two shoes. Normally, one would expect that this would involve additional hardware, but everything for the second shoe would be exactly the same in terms of hardware. The major difference would be in how the second shoe handles data. Two solutions come to mind right now, that would involve sending data points to the database with a tag indicating which foot they come from: the left or the right. The second solution would be to transfer data to one “main” shoe and it would handle all remote data transfer.

A second major refinement to the device would be patient identification. Each Intel Edison would need to be assigned to a specific patient. As the device functions right now, it would provide data, but would not have any way to determine between different patients.

Finally, as mentioned earlier in the market review. Data analysis is likely a must in order to compete with the current state of the market. This would require time and testing until our product could judgements about the meaning of the data being collected.

XI. CONCLUSION

Our goal is to provide a system that can help evaluate the performance of therapeutic shoes by incorporating sensor technologies. The information collected should provide feedback of the shoe stabilities and functionality. The system needs to go be tested before being incorporated to make sure it’s working appropriately. Testing allows us to create a more reliable system that can help diabetic patients. Diabetes is currently a huge health problem in the United States. According to the 2014 national Diabetes Statistics Report, 29.1 million people or nearly 10% of the United States population suffers from diabetes [1]. Diabetes has been highly linked with the occurrence of foot ulcers which can potentially lead to even more severe health issues. A 2009 Clinical Evidence Study stated that the annual rate of foot ulcers occurrence is as high as 2.5 – 10.7 percent of the diabetic population in wealthy countries [2]. The diabetic population tends to show higher prevalence of musculoskeletal, neuropathy, and cardiovascular diseases compared to the general population. Because of the large number of diabetics, there is many people suffering from diabetic related complications. In fact, one of the biggest groups suffering from complications with foot ulcers is the diabetic community. Not only does diabetes and its related complications affect the health of the population, it also poses an economic problem for the country. The economic cost of diabetes in the year 2007 was estimated to be around 174 billion dollars. In the year 2012, the economic cost of diabetes grew to 245 billion dollars, an alarming 42% increase in just five years [4]. Lowering the expenses for diabetic patients is an essential necessity in our present time. About 20% of healthcare spending is spent in the diabetic area, with one out of five health dollars used on someone diagnosed with diabetes [4]. Finding ways to monitor symptoms and early detection for prevention of diabetes and its resulting complications is necessary for reducing the economic cost of diabetes. The diabetic population suffers many health issues, which is why early identification of symptoms is essential to help prevent severe health conditions. In cases, preventative measures can save extremities of diabetics and decrease mortality rates. The diabetic community suffers from a range of medical problems, many of which still do not have a coherent process and solution. With increasing knowledge and technology, preventative steps and systems could help to free diabetics of future complications. Integration of sensor technology in shoes is vital development since it permits to monitor the musculoskeletal activities of patients during the foot ulceration period and the post-operation period before a need to amputate [3]. Providing the proper offloading footwear to costumer can dramatically reduce healing time while lowering extremity amputations. Sensors allow monitoring patients for musculoskeletal movement and neurological conditions by using the integrated sensors in the shoe. Since diabetic patients are more prone to foot complications, which is why it is important to monitor the status of the foot throughout the day. Providing the proper offload footwear to diabetic patients can dramatically reduce healing time and lower extremity amputations. Monitoring patients for musculoskeletal movement can help prevent future severe health issues like amputations and parlous infections. Peter Wong stated that monitoring diabetic patients could provide healing and mobility solutions to an array of patients with different medical backgrounds [3]. Incorporating sensor technology into the H-Fit Healing Shoes will potentially allow for analysis, efficiency, and prevention of health conditions in the foot. By inserting sensors into the shoe, we want to provide a dramatic reduction of healing time and reduction in lower extremity amputations by monitoring the status of the foot. It is essential and necessary to have the capability to monitor patient's feet because prevention is the key principle to minimize disabilities and health care cost. Achieving our goal to monitor patients by incorporating sensors into the therapeutic shoes will improve lives of people who have ulcers on their feet due to diabetes. Incorporation of pressure sensing technology inside the shoe is one of our goals since we want to be able to monitor the plantar pressure the shoe is exerting on the patient. We also want to integrate flex-sensing technologies into the shoe to determine patient’s use of the shoe and other stress areas that the foot employs in the surroundings of the shoe. Maintaining the functionality of sensors during the use of the shoe is essential which is why we need to monitor battery life. Providing indication of battery status is another important function we want to develop in the shoe. On top of this, displaying the data we collect graphically is necessary for people to quickly make sense of the metrics the shoe collects. Finally, since the shoes are going to be mass-produced, we want to create an automated deployment system to program multiple shoes at the same time and hopefully lay the groundwork for Sunrise to create updates. Our main goal is to provide significant aid to diabetics in need. By helping diagnose the effectiveness of their therapeutic shoes we can allow them to enjoy more effective and comfortable equipment.

Sensor information will allow for needed modifications of the shoe to provide comfort to the patient’s foot when they walk with ulcers, while also giving them the peace of mind if they fear ulcer development or recurrence. Being able to track for proper distribution of pressure throughout the shoe using sensors can decrease chances of ulcers getting worse and preventing future amputations that can sometimes lead to death. Sunrise Shoes states that "Sensor technology is a vital development for measuring the musculoskeletal activities of patients during the postoperative (amputation) of foot ulceration period, and is a significant and vital development for patient disability prevention" [3]. Our team is going to be working with the therapeutic healing shoe from Sunrise Shoes. The space we are going to be working with is very limited. Therefore, we must be able to develop effective and limited size circuits since we are working within a parameter of space. Sunrise Shoes Company provide is with a pair of deconstructed shoes to have a visual of the product we are going to be working with. The sole of the shoe is going to change since the shoe size of every patients is different. This means that we should center most of the components in an area where most of the shoes can have the space for the sensors. If the sensors are centered toward the middle of the shoe, so they can satisfy the minimum requirement for the size of the shoe. The shoe will incorporate at least six pressure sensors to track the plantar pressure. The shoe will also incorporate at least two flex sensors to detect pronation and supination of the foot to track the balance of the patient as it wears the shoe. The shoe will have at least two gigabytes of memory to save the data before transferring to a database with an anticipated storage capacity of thirty gigabytes. The shoe will be able to detect low levels of battery so it can properly shut down to prevent data corruption. Automated deployment of software is also a feature we want to focus on to program multiple shoes with no problem. We are aiming to create a system that can function for at least two hours for every battery charge. Our main goal is to incorporate useful features into the therapeutic shoe to impact the diabetic population in a positive way.

One of the main concerns in a team is keeping the team members in the same page. To achieve this, we created a system that allows us to know what we need to be do and by when. We decided to do this using a Gantt chart, PERT diagrams, and by tabulating tasks and assignments by date. The chart and the diagram will provide the team with a visual aid for deadlines and future assignments. It will also allow us to stay on track by setting all the tasks throughout the year with deadlines and starting points. The chart and diagram spread assignments and project tasks throughout a timeline so we can visually derive where we need to be. This will allow us to quickly know what is next and if we are falling behind in the project. It a useful tool for evaluating our progress and assigning tasks to the teammates as needed. The tabular chart will allow the team to mark assignments status and other important information. The tabular chart of assignments is just to keep the team synchronized on what the others are doing. This will allow the team leader to decide what areas need more attention or if members need help completing their tasks. Since we are incorporating different features into the shoe, we need to be organized to complete all the task on time and successfully. Also, since we are focusing in a low-cost system we are going to need a lot of time to produce a quality product. We want the system to produce accurate data in an efficient matter. Since the data of our system is the core of the project, its essential to produce an accurate and efficient system for the user to use as a tool. So, to successfully produce this system, the team needs to be well organized. A Grantt chart and PERT diagram will aid the team with assignments and task deadlines. While the tabular chart will keep, all members informed of what tasks and assignments have been completed and which members might need support. This will help us stay on track throughout the year. Keeping the team together is essential because teamwork makes the dream possible.

During every step of the development of the project we might encounter unpredictable outcomes that can pose certain risks to part or the entire project. Risk management is essential in a project because it allows us to identify the areas that could hinder the progress of the project. Our goal as the engineers of the system is to steer a course that reduces risks while achieving the maximum results possible. Risks can be present as multiple sources of failure. Some sources of failure that can be present in our project are hardware failures, software failures, and organizational failures. To successfully complete the project, we need to shape the system with risk resolutions in mind. To successfully assess any risk, we need to begin risk management since the earliest stages of the project. Managing the risks should be done continuously through the life of the project. It is also essential to have a risk management plan to solve any risk that occurs during development and the testing phase. Since the risk goes high when the complexity of the project goes up, adding multiple features increases the amount of risk that might occur while developing the system. Also, the risks can increase when we lack information from our sponsor since it might result in changes to the system which will cause delays. Also, since we are focusing in a low-cost system we are going to need a lot of time to produce a quality product. Reducing the cost of the hardware also increases the possibilities of risks in our project. We want the system to produce accurate data in an efficient matter but many things can go wrong increasing even more the time will need to complete the system. So much time is needed for the system since it depends on many features, but one of the most important features is data collection. Since the data of our system is the core of the project, it’s essential to produce an accurate and efficient system for the user to use as a tool. In order successfully complete all the features, we must assess the risk that we might encounter. We want to do our best to reduce the risks that can cause the most problems. By assessing the risk likelihood and probability of failure, we can decide what risk to prioritize. Reducing the risk that have a higher risk criticality are more important to solve or plan to reduce the impact of failure it might cause toward the project. Risks have two basic attributes which are probability and impact. We want to focus on the risk that have a higher impact to the project since they can cause higher damage to the project. To determine the risk that can occur, we need to list the WBS elements and decide what can go wrong with each element. Doing this risk assessment is so important because we want to identify the risks before they become serious problems.

Since the system needs to be verified, we need to develop a test plan to evaluate all the platforms of the system. The system will be tested to ensure it meets the specifications in the punch list and the engineering requirements. The main reason for the test plan is to verify the system is working properly. The test plan outlined the strategy we will be using to test the device. The outline involves different aspects of the system involving hardware and software. We developed the plan taking in consideration the different resources we used. We also want to test the system against changes in the environment. We want to test the system with changes in moister and changes in temperature since they are both present inside a shoe. We also want to test if the sensors will work appropriately with the load a shoe needs to handle. Some of these testing processes might not be fully efficient so we might have to modify a few of them in the future. Some assumptions are made considering the system which allow us to run the testing. The test plan is designed to test all the different levels in the system. This is done to ensure that all the levels are functioning properly. We want to begin testing as soon as possible to reduce the risk since it increases the closer we get to the completion of the system.

We decide to incorporate these features into the system to create a product innovation since no other Pedorthic shoe in the market has sensors integrated. There are some similar products in the market but they are not for continuous use and they are too expensive for the regular costumer. Some similar products are about $10,000 which are too costly for the purpose they are supposed to serve. The market the system is entering has space for growth but it is also demanding since the consumers require efficient and reliable products. Since the field is part of the medical industry, the systems require a higher level of reliability and trust since it relies around the health of the patients. We are trying to develop a system that can help evaluate the functionality of the shoe, while also monitoring certain aspects of the patient. Some questions we want to answer with the market review is if the there is any interest for the product, how much are the people willing to pay, and how much we can charge for the product. The goal is to determine if the product is addressing a need that attracts the attention of customers. The system developed also needs to provide convenience for the addressed costumers. The product is aimed to make the life of the user easier. In this case, the user is the diabetic patients since it will monitor their balance and evaluate the effectiveness of their Pedorthic shoes. This will permit the user to get modification to the shoes if its required without waiting until symptoms are present. In the report, we want to estimate the customer interest for the product and if has any profitability potential. The goal is to produce a product that provides innovations in the Pedorthic market to increase its demand. By introducing sensors into the shoe to check the effectiveness of the tool and to monitor the patient, we want to revolutionize the market for the shoes. If we can monitor and proof the effectiveness of the shoes, the clients will trust the product even more. A market review will allow us to determine the possibilities of the system for commercial success. Before launching a new product, we need to understand the market by gathering information and performing data analysis.

Throughout the development phase, the team did not encounter any major issues when constructing the deployable prototype. We are stayed on track by finishing most of the task early. As the systems were developed, each of the members tested the subsystems being developed to make sure they were working properly. The visualization of data and the automated deployment system were postponed until the spring semester. These two subsystems were postponed until the next semester because they depend on other subsystems. The visualization of data depended on the sensor systems and the automated deployment system depended on the software being developed. All the subsystems have been completed and fully integrated into the final system. The system has been tested and validated for proper functioning. The system has been integrated into the shoe with the least modifications done to the integrity of the shoe. The stability of the shoe has been protected by adding support to the carvings to protect the firmness of the material. The components visibility was reduced as much as possible to keep the system safe. The components visibility was also reduced to keep the view of the shoes with the least modifications as possible. Overall, the system has been successfully implemented and all the requirements were reached.

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GLOSSARY

Cloud Provider - A service provider that offers customers storage or software services available via a private or public network

Golang - is an open source programming language that makes it easy to build simple, reliable, and efficient software

Musculoskeletal – relating to the skeleton and the arrangement of muscles in the body

Neuropathic Lesions – Neuropathic lesions occur when a region in an organ or tissue has been damaged to the nerve fibers.

Parse - analyze a string or text into logical syntactic components, typically in order to test conformability to a logical grammar

Pedorthic – the science and practice of evaluating, and fabricating footwear to prevent disabling conditions

Ping - query (another computer on a network) to determine whether there is a connection to it

Plantar Pressure - The pressure measured on the plantar surface of the foot. The plantar surface is also referred to as the sole of the foot.

Pronation – the way the foot roils inward when you walk or run.

Snap - An open source telemetry framework that helps simplify the collection of data for many purposes and then publish all sources of data to a single place

Supination – the outward roll of the foot during motion. The opposite of pronation

Telemetry - an automated communications process by which measurements and other data are collected at remote or inaccessible points and transmitted to receiving equipment for monitoring

Time Series - A sequence of data points, typically consisting of successive measurements made from the same source over a time interval

APPENDIX A. USER MANUAL

Telemetric Shoes User Manual

Instructions

Wear:

Before you put on the shoe, find a place to sit. To wear the shoes, first put your foot in the shoe. Second, tie the laces the shoe. Make sure to tie shoes snug, but not extremely tight. Third, take the ankle component and place it at desired height on ankle. Make sure that wires are not tight. Fourth, strap brace to ankle with strap. Make sure to tighten strap to keep ankle component firmly in place. Repeat entire process with the other foot.

Charging:

Keeping your shoe properly charged is essential to the shoes ability to collect data. Charge the shoe when it is not in use. To charge the shoe use a micro usb charging cord and plug into the ankle component of the shoe.

If you are using the shoe and the battery runs low, the shoe will detect this and power off. The shoe will send an email indicating that it is low on charge to the account it is setup to send to. The shoe can still be used when the power is off, but it will no longer collect data.

Accessing Data:

The data can be accessed both by the user and the users doctor. To access data, visit InfluxDB website. This will normally be installed at http://localhost:8086 using automatic installation. Visualization can normally be found at http://locahost:3000 using automatic installation. To understand data consult with your doctor.

Warnings:

The shoe has not been designed to be waterproof. Do not wear in rain, or step in water. Water can cause damage to the electric components of the shoe. Water can also danger the user with shocks.

APPENDIX B. HARDWARE

The hardware of the system depended on a few different components. One of the most important components driving the calculations and collecting the data was the intel Edison microcontroller. The microcontroller depended on two ADC blocks and a Battery block. The ADC block is used to collect the voltages being produced by the acquisition circuit and to monitor the status of the battery. The battery block is used to connect the microcontroller to a LiPo battery and it functions as a single cell charger.

FIG. 28. INTEL EDISON MICROCONTROLLER BEING USED IN DEPLOYABLE PROTOTYPE:
The final deployable prototype is using the intel Edison microcontroller with the Sparkfun blocks for power and ADC inputs [36].

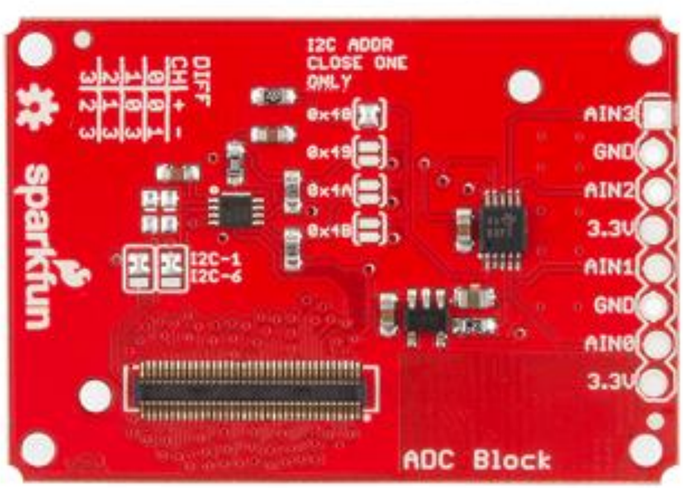


FIG. 29. ADC SPARKFUN BLOCK FOR THE INTEL EDISON USED ON THE DEPLOYABLE PROTOTYPE:
The final deployable prototype is using the Sparkfun ADC block to read the analog voltages produced by the acquisition circuit monitoring the different sensors [36].

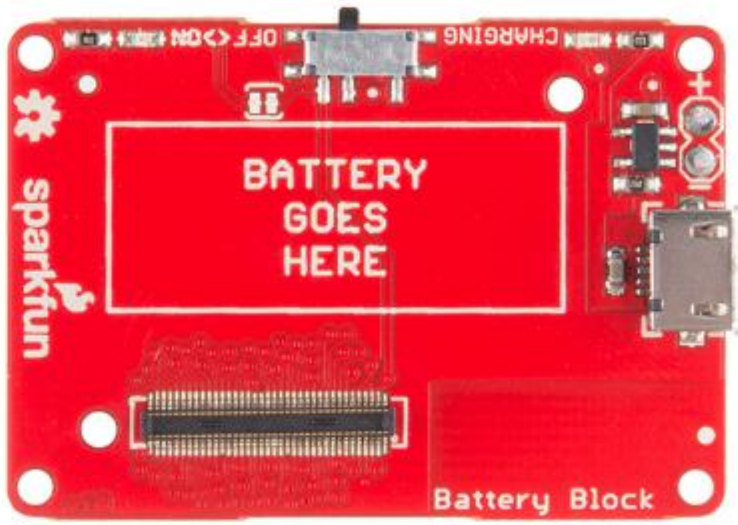


FIG. 30. BATTERY SPARKFUN BLOCK FOR THE INTEL EDISON USED IN THE DEPLOYABLE PROTOTYPE:
The deployable prototype uses the battery block to power the intel Edison and the ADC blocks. It is also used as a charger for the battery [36].

The other important part of the system was the acquisition circuit that converts the change in resistance from the sensors into a voltage change. The acquisition circuit is composed of two Op-amps and a voltage converter. These components are placed in a PCB which was designed by the team to reduce the size of the circuit. These components are located inside the shoe in a carving on the sole.

FIG. 31. MCP 6004 OP-AMP USED FOR THE ACQUISITION CIRCUIT:
This Op-amp is the chip used for monitoring the resistance change of the sensors [37].

FIG. 32. MAX660 SWITCHED CAPACITOR VOLTAGE CONVERTER:
The voltage converter was used to convert the positive 3.3 V into a negative 3.3 V. This was done to input a negative voltage into the Op-amp and get a positive voltage output [38].

The last components we used, were the two types of sensors which involve a pressure sensor and a flex sensor. The pressure sensors were used to monitor the plantar pressure in the sole of the shoe. The flex sensors were used to monitor pronation and supination.

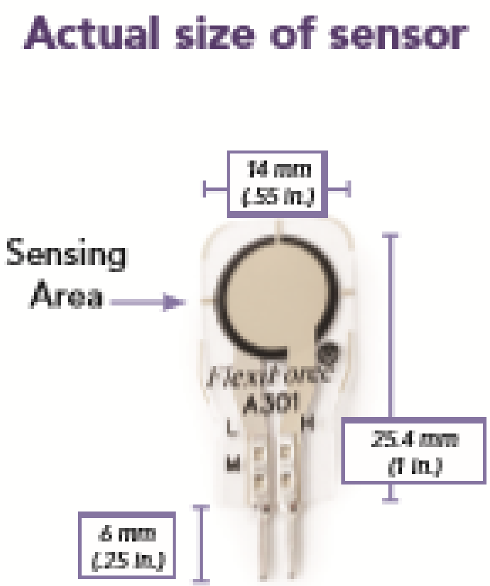


FIG. 33. TEKSCAN FLEXIFORCE STANDARD MODEL A301 PRESSURE SENSOR:
The system used six of these sensors to monitor the plantar pressure throughout the sole of the shoe. The measurements of the sensors are included in the diagram [7].

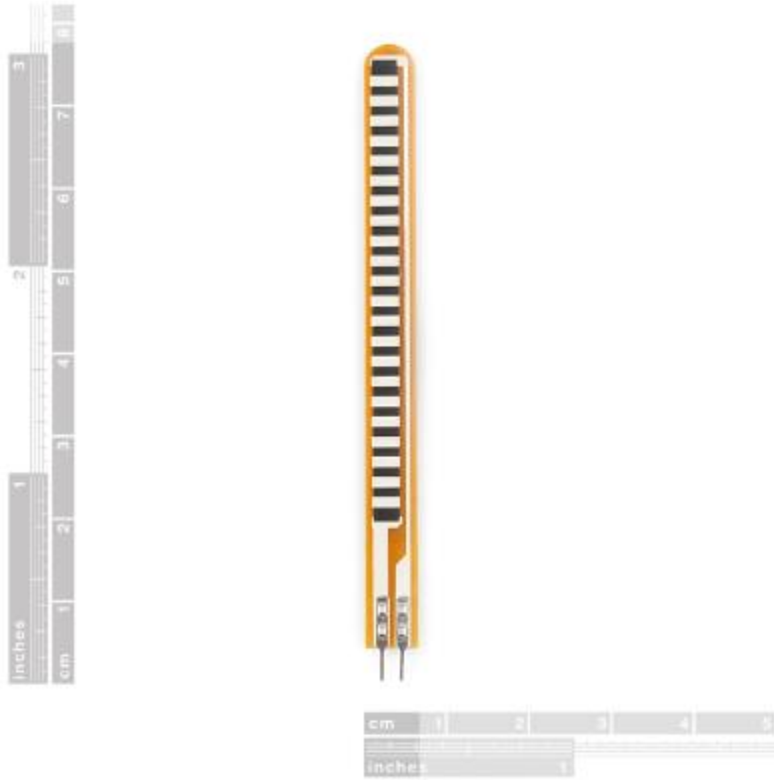


FIG. 34. FLEX SENSORS FS USED FOR THE SUPINATION AND PRONATION DETECTION SYSTEM:
One flex sensors was used on the final design since we were able to detect which way the sensor was flexing based on the resistance of the sensor [39].

Schematic of the different components:

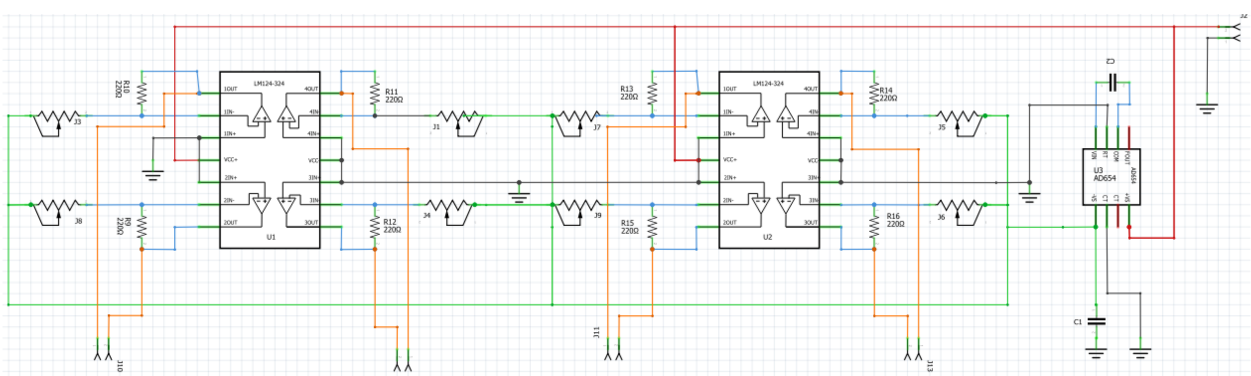


FIG. 35. SCHEMATIC OF THE ACQUISITION CIRCUIT:
The schematic of the acquisition circuit is shown in this figure. It contains the three chips and the six different sensors. It also shows the output leads for each of the sensors [12].

APPENDIX C. SOFTWARE

A. Data collection:

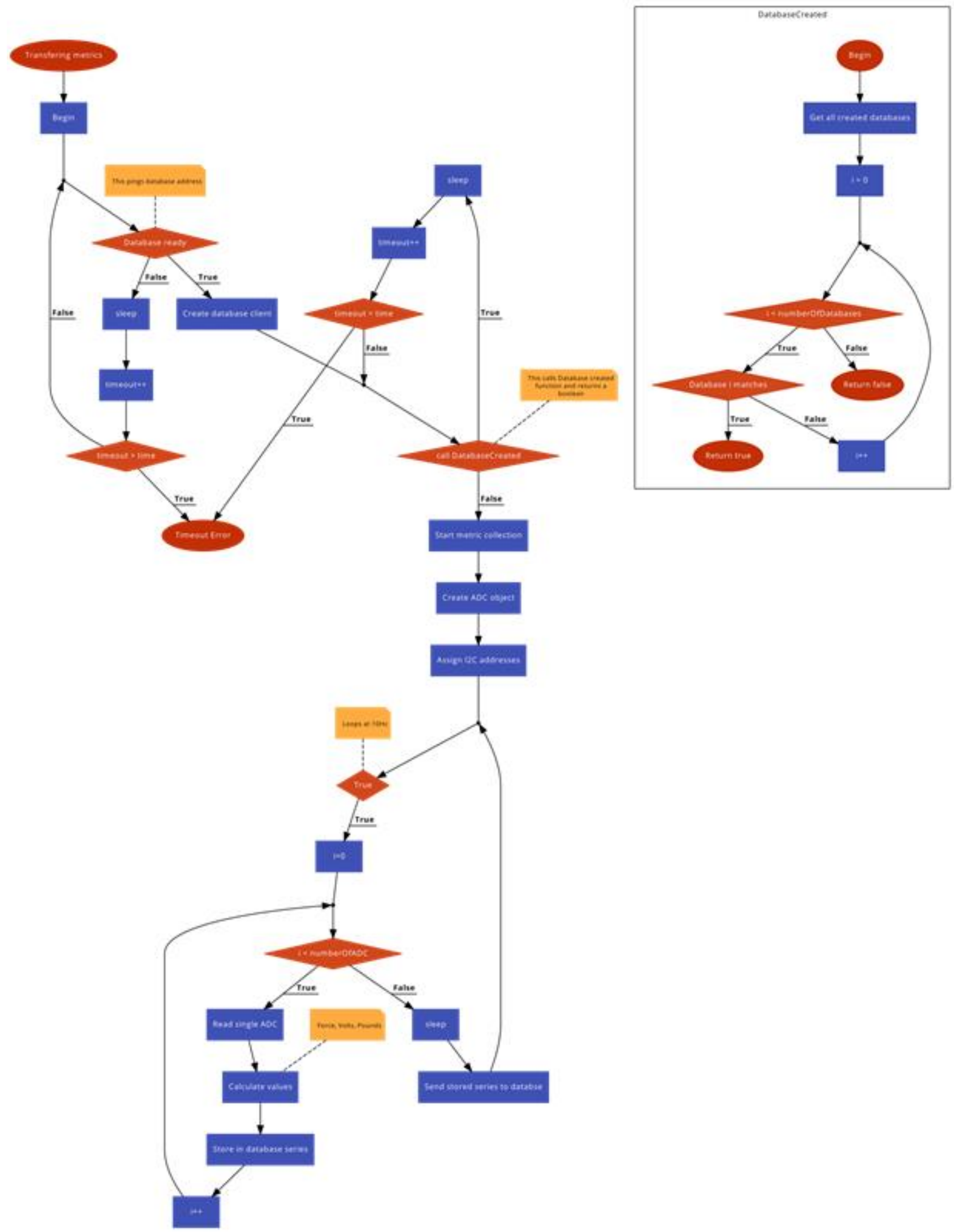


FIG. 36. DATA COLLECTION FLOW CHART OF DATA COLLECTION SOFTWARE:

The chart shows the flow of the collection software when collecting the data from the acquisition circuit [12].

The above diagram shows a flowchart for the data collection software that was used. It handles the collection of data from ADCs at 10Hz, the local storage of that data, and the remote transfer of the collected data to our database.

B. Data Visualization:

Data visualization was based off of two major components. The first major component was the database, which was InfluxDB in our case. The second major component was the visualization software used, which was Grafana. Here we will provide an overview of the testing and results done for each of these components.

1. Database testing

Database testing went well and testing with the database suggests that it will remain stable as long as there is enough memory on the machine in which is runs. As a result of the testing, we have decided that even local machines should not have too much difficulty running the software. To aid in the testing of our database, we employed our automated deployment through Ansible. Running our setup with Ansible can tell us the state of our machine and whether things need to be fixed. An example of a passing test on a Debian virtual machine can be seen in the figure below.

```
TASK [setup] *******************************************************************
ok: [127.0.0.1]

TASK [Install pip] *************************************************************
ok: [127.0.0.1]

TASK [Install docker-py for ansible docker module] *****************************
ok: [127.0.0.1]

TASK [Create Docker network] ***************************************************
skipping: [127.0.0.1]

TASK [Create InfluxDB container] ***********************************************
ok: [127.0.0.1]

TASK [Create "snap" InfluxDB database] *****************************************
ok: [127.0.0.1]

PLAY RECAP *********************************************************************
127.0.0.1                  : ok=5    changed=0    unreachable=0    failed=0
```

FIG. 37. AUTOMATED TESTING DATABASE:
This figure shows a passing test for the database installation of InfluxDB on a virtual machine. This handles both the testing and automated setup of the database [12].

2. Graph Verification:

Graph testing went well for the most part. It behaves similarly to the passing tests of the InfluxDB database, but there are occasionally timestamp issues with the graphs as a result of running Docker on a Mac computer. To clarify, this is not a bug with anything we have done incorrectly, but a bug that is possible because of Linux namespaces being used on a MacOS computer. Other than that, very unlikely possibility, testing for the graphs showed to be reliable. The resulting graphs of our software stack can be seen below.

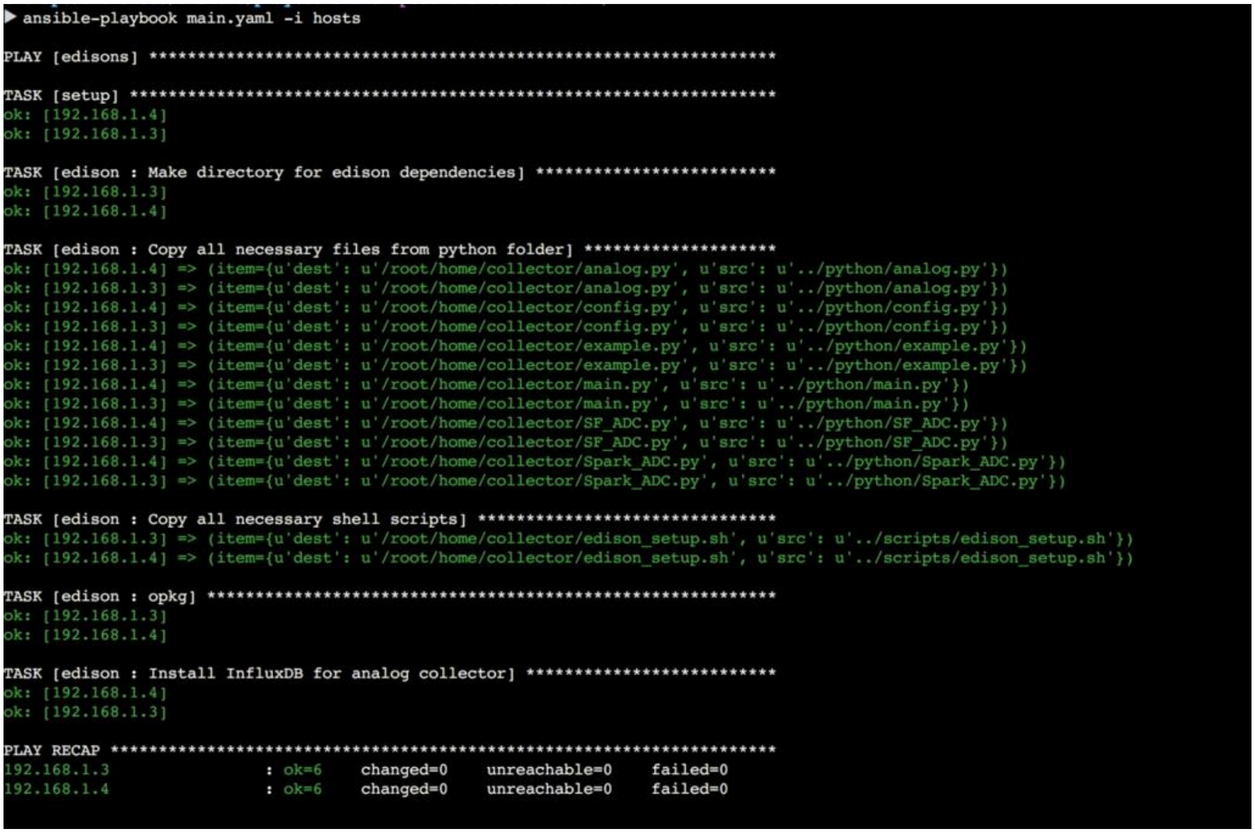
FIG. 38. EXAMPLE RESULTING GRAPHS FOR GRAFANA:
This figure shows a passing test for the database installation of InfluxDB on a virtual machine. This handles both the testing and automated setup of the database [12].

C. Automated Deployment System

The automated deployment went really well. As it turns out, there were no compatibility problems with the Intel Edison and Ansible automation. The nice thing about Ansible automation is that it is state based. This means that when it finishes a run, it knows the state of things before and after. As a result, it is easy to tell if it is completely successful by running the Ansible script twice.

1. Verify appropriate download on multiple systems

The testing for automated deployment on multiple systems was completed quickly after the setup on a single system. For this reason they were tested together. The below diagram shows that the setup of multiple devices was completed successfully with every single step showing as OK. This means that the system is configured correctly.



```
▶ ansible-playbook main.yaml -i hosts

PLAY [edisons] *****************************************************************

TASK [setup] *******************************************************************
ok: [192.168.1.4]
ok: [192.168.1.3]

TASK [edison : Make directory for edison dependencies] *************************
ok: [192.168.1.3]
ok: [192.168.1.4]

TASK [edison : Copy all necessary files from python folder] ********************
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/analog.py', u'src': u'../python/analog.py'})
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/analog.py', u'src': u'../python/analog.py'})
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/config.py', u'src': u'../python/config.py'})
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/config.py', u'src': u'../python/config.py'})
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/example.py', u'src': u'../python/example.py'})
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/example.py', u'src': u'../python/example.py'})
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/main.py', u'src': u'../python/main.py'})
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/main.py', u'src': u'../python/main.py'})
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/SF_ADC.py', u'src': u'../python/SF_ADC.py'})
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/SF_ADC.py', u'src': u'../python/SF_ADC.py'})
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/Spark_ADC.py', u'src': u'../python/Spark_ADC.py'})
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/Spark_ADC.py', u'src': u'../python/Spark_ADC.py'})

TASK [edison : Copy all necessary shell scripts] *******************************
ok: [192.168.1.3] => (item={u'dest': u'/root/home/collector/edison_setup.sh', u'src': u'../scripts/edison_setup.sh'})
ok: [192.168.1.4] => (item={u'dest': u'/root/home/collector/edison_setup.sh', u'src': u'../scripts/edison_setup.sh'})

TASK [edison : opkg] ***********************************************************
ok: [192.168.1.3]
ok: [192.168.1.4]

TASK [edison : Install InfluxDB for analog collector] **************************
ok: [192.168.1.4]
ok: [192.168.1.3]

PLAY RECAP *********************************************************************
192.168.1.3                : ok=6    changed=0    unreachable=0    failed=0
192.168.1.4                : ok=6    changed=0    unreachable=0    failed=0
```

FIG. 39. EXAMPLE RESULTING GRAPHS FOR GRAFANA:
This figure shows a passing test for the database installation of InfluxDB on a virtual machine. This handles both the testing and automated setup of the database [12].

APPENDIX D. MECHANICS

Due to the space limitations a shoe offers, we had to implement an outer enclosure of the larger components. The outer enclosure was designed as an ankle brace which is to hold the microcontroller and the ADC clocks. The battery is also placed inside the enclosure since we wanted to keep it close to the microcontroller.

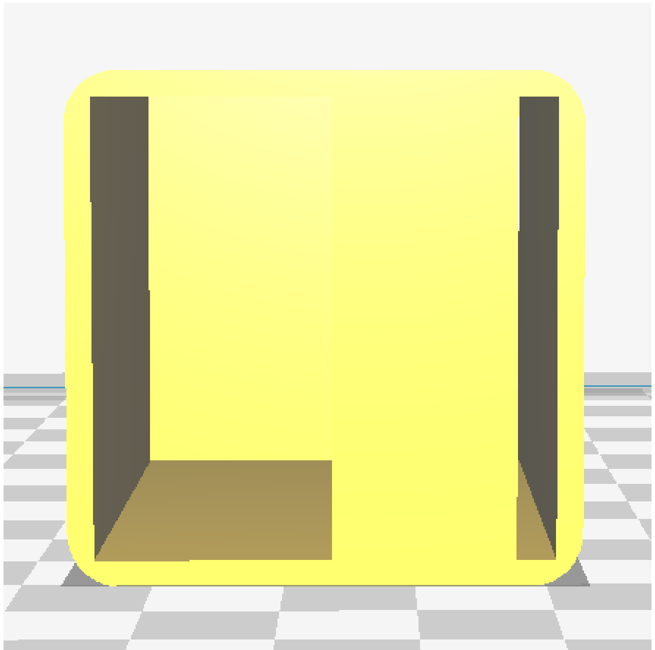


FIG. 40. FRONT VIEW OF 3D DESIGN FOR ANKLE BRACE:
The ankle brace was 3D printed to give it a more professional look since the product was for a sponsor [12].

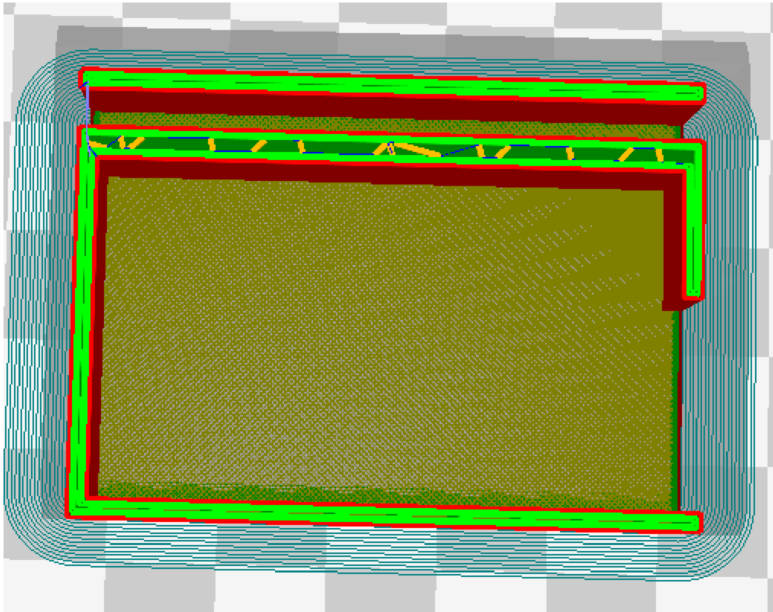


FIG. 41. TOP SLICE VIEW OF 3D DESIGNED ANKLE BRACELET:
The inside of the 3D designed enclosure for the ankle brace. It was designed to fit the battery and the microcontroller content [12].

TABLE VIII.
ANKLE ENCLOSURE BRACELET

Width	Length	Height
54.5 mm	39 mm	39 mm

Table made by Ahriben [12].

Another important design was the PCB because it allowed us to minimize the size of the acquisition circuit. Using this PCB, we could fit part of the design inside the shoe minimizing the size of the ankle brace.

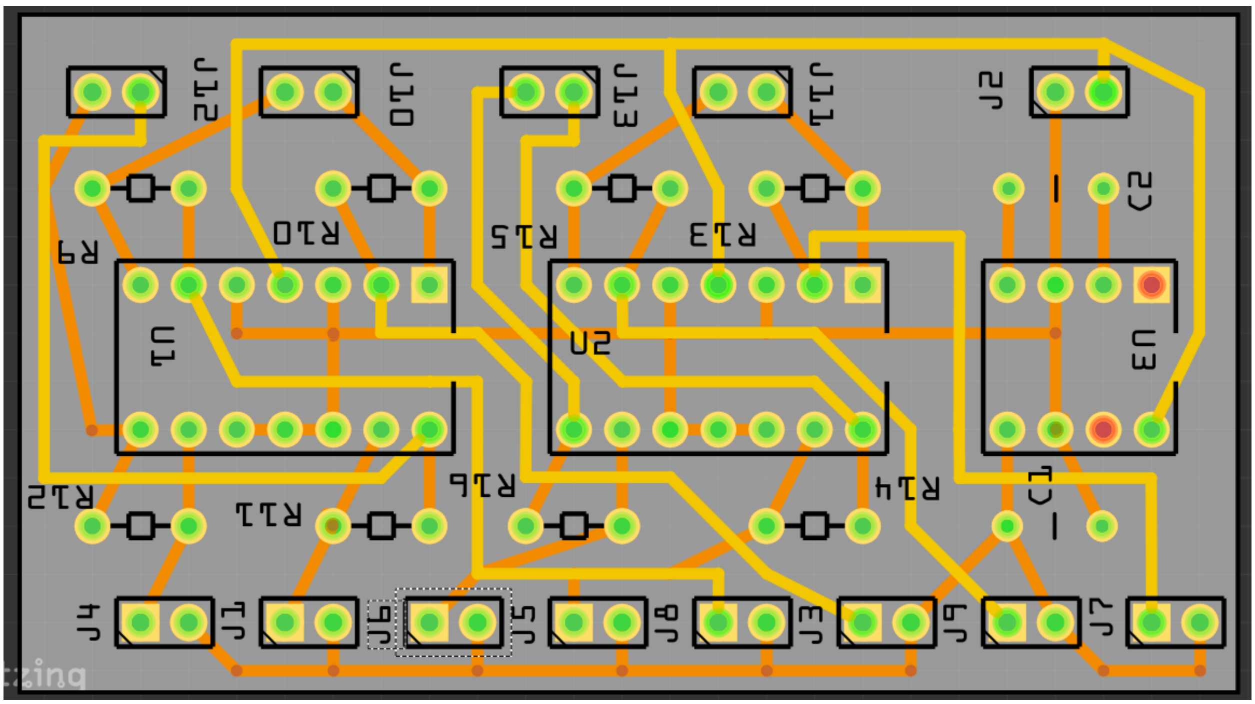


FIG. 42. THE PCB ROUTING AND DESIGN FOR THE ACQUISITION CIRCUIT:
The diagram shows the two-layer PCB that was constructed for the acquisition circuit. The diagram shows the routing of the traces and the setup of the different chips and sensors.

APPENDIX E. VENDOR CONTACTS

Special Thanks to Sunrise Shoes and Pedorthic Service,

Sunrise Shoes and Pedorthic Services has been a big help to us and have provided us with the opportunity to help those with foot complication through our senior design. They have provided us with therapeutic shoes for us to design with and have provided us with a wealth of information about the people who we are helping. They have also helped give our team direction by making requests that would benefit them in the real world.

We hope that we can continue working with Sunrise Shoes and Pedorthic Services as we work to create a deployable prototype.

Thank you,

Team Trial Through Telemetry

Special Thanks to the Software Defined Infrastructure (SDI) Team at Intel,

You have all been a great help in our software implementation and in helping us create a collector plugin for Snap. Advice from members of the Snap team was very useful in creating the collector and advice from other members of the SDI team has been very useful in helping making design decisions. There are many technologies that we may have been unaware of or overlooked without their advice.

We hope that we can continue to seek advice from the SDI team as we work to create a deployable prototype and wish success for their software projects such as Snap.

Thanks to all of you,

Team Trial Through Telemetry

APPENDIX F. RESUME

Phillip Dye

Objective

· To obtain a full time position in the field of electrical engineering

Experience

Student Engineering Assistant | CAl Public Safety Communication Office | Jan 2013-AUG 2015

· Installing programing updates on radios

· Soldering and testing of basic circuit boards, coaxial cable connectors, and diode modifications to line filters

· Cross checking radio firmware for errors and inconsistencies

· Assisting Engineers in testing of antennas using a network analyzer

· Edited rack elevation, antenna layout, and system interconnect drawings in AutoCAD

Quality and Reliability Assurance Intern RFAB | Texas Instruments | may 2016-AUG 2016

· SEM Review (Scanning Electron Microscope) of semiconductor wafers tracking progression of defects along process line. Using programs SMS, Klarity, and Trackworks

· Analysis of Customer Returns of DMOS 5 in order to determine applicability to RFAB

· Putting together CIPs (Continual Improvement Plans) from past CCB (Change Control Board) reports

Education

In Progress | BS | CSU Sacramento | Expected Date of graduation: may 2017

· Major: Electrical and Electronic Engineering

· Senior Project: Specialized shoes with pressure sensors to collect data to track diabetes related foot issues

· Related coursework completed:

Network Analysis	Intro to Circuit Analysis	Signals & Systems
Intro to Logic & Design	Computational Methods & Apps.	Calculus 1-3
Differential Equations	Chemistry	Physics: Mechanics
Physics: Electricity & Magnetism	Applied Electromagnetics	Intro to Microprocessors
Applied Electromagnetics	Intro to Microprocessors	Electromechanical Conversion
Electronics 1 and 2	Intro to Feedback Systems	Engineering probability and statistics

Cumulative GPA of 3.12 as of Fall 2016

AHRIBEN GONZALEZ

EDUCATION

- Sacramento State: Bachelor of Science, Computer Engineering
- Planned date of graduation: Spring 2017
- GPA: 3.57
- Dean's Honor List: 2013 - 2016

EXPERIENCE

NSG Validation Engineer - Intel, Folsom (2017)
+Python

Undergrad Technical Intern - Intel, Folsom (2016 - 2017)
+ Python

- Product validation (SSDs), SATA and PCIe
- Automation
- Test development, execution and debugging
- Software development: code review, bug fixes and design

Technical Analyst Intern - Chevron, San Ramon (Summer 2016)
+ PHP, SQL, HTML, JS

- Project planning
- Meet with stakeholders to identify business requirements
- Data mining and develop dashboard for business unit
- Training and documentation

IT Student Assistant-Sacramento State, Sacramento, (2013-2016)
+ JavaScript, HTML, CSS, SQL, Python

- Lead student assistant
- Develop web forms, surveys and applications
- Troubleshoot system and network problems
- Train Student Assistants

SKILLS

Platform: Windows, Linux
Languages: JavaScript, Jquery, VbScript, C, VHDL, Verilog, Python, Powershell, SQL, HTML, CSS
Tools: Microcontrollers, FPGA, APC PDU, Lecroy Analyzer, Agilent Keysight Analyzer
Bilingual: English, Spanish

EXTRA-CURRICULAR ACTIVITIES

- MESA Engineering Program (MEP) member
- Society of Hispanic Professional Engineers (SHPE)

RECENT PROJECTS

Group Meeting Finder App: +Python, Django
CRUD APP: +JS, MEAN

Jose Aguirre

OBJECTIVE: Obtain an internship or full time position within the field of computer science or engineering for summer 2017.

EDUCATION

BS, Computer Engineering, • CSU, Sacramento • GPA: 3.96 • May 2017

Related Courses:

- Programming Concepts & Methodology (Java)
- Data Structure and Algorithm Analysis (Java)
- Systems Programming in UNIX
- Logic Design (Verilog)
- Advanced Logic Design (Verilog/VHDL)
- Computer Interfacing
- Circuit Analysis
- Network Analysis (PSPICE/Oscilloscope)
- Computer Architecture (Assembly)
- Computer Hardware Design
- Advanced Computer Organization

COMPUTER SKILLS

Programming Languages: Java • Verilog • C • Golang • VBA • Bash • JavaScript • HTML & CSS • Python
Systems: Windows • UNIX • Linux
Software: Kubernetes • Ansible • OrCad PSpice • Multisim • Xilinx ISE Design Suite • Quartus Design Suite • MS Office

PROJECTS

Simplified Microprocessor Design with Video Display

Created a simplified microprocessor that made use of an ALU for calculations. The microprocessor was controlled with a finite state machine. The project was programmed in Verilog and displayed its results to a video monitor.

Custom UNIX Shell

Recreated a mini UNIX shell by writing the UNIX commands in C.

Networked Tracking Security Camera

Made a tracking security camera with a group of 2 others. I was responsible for programming the Arduino and allowing users to connect remotely to the camera. The Arduino detected movements from PIR sensors and moved the direction of the camera.

JavaScript Based Games

Created multiple JavaScript based games using the HTML 5 canvas. One of the games makes use of real gravitational equations in order to determine the movement of in-game objects.

WORK EXPERIENCE

SDI Undergrad Technical Intern | **Intel Corporation** | 06/2016 - Present

TSD Student Assistant | **California Board of Equalization** | 04/2014 – 6/2016

- Wrote a VBScript to help automate the process of pulling information from each networked switch.
- Wrote a VBA macro that automates the process of recording printer statistics through parsing HTML. Saves about 4 days worth of time per month.
- Wrote a VBA macro that automates the configuration of printers before deployment.
- Troubleshot a variety of printer related issues through assigned ticket system.
- Worked with customers in person and over the phone to resolve printer and network issues.
- Reconfigured and cleared old network switches using Tera Terminal.
- Assisted in recent network infrastructure update by organizing network closets.

ACTIVITIES AND ACCOMPLISHMENTS

Club Liaison	**Association for Computing Machinery chapter at CSUS**	2015 - Present
Member	**MESA Engineering Program (MEP)**	2013 - Present
Member	**CSUS Honors Program**	2013 - Present
Member	**SpaceX Hyperloop Competition – CSUS Team**	2015
Participant	**MESA Student Leadership Conference**	2015
Participant	**Intel Ultimate Engineering Experience**	2013
Award	**NACME Scholar**	2014 – Present
Award	**CSUS Dean's Honor Roll**	2013 - Present

Eduardo Anaya

Objective

Obtain an internship or full time position in the field of engineering or computer science for the summer of 2017.

Education

		Sixth Year
• CSU Sacramento	6000 J St.	Expected Graduation
Major: Computer Engineering	Sacramento, CA	May 2017

Related Courses

GPA: 3.60

• Physics	• Calculus I & II	• Differential Equations
• Chemistry	• Public Speaking	• Ecology

Computer Skills

• Java, HTML, Assembly, C	• Logic Design	• Circuit Analysis
• Linux, Unix	• Data Structure	• Computer and discrete structures
•Advance Logic Design	•Electronics I	•Signals and systems
•Hardware System Design	•Operating Systems	• Algorithm Analysis
• Verilog, Spin, Arduino C	•Adobe Photoshop, InDesign	•Computer Networking
• Advance Computer Organization	• CMOS and VLS	• Operating System Pragmatics
• Cadence Virtuoso & SPICE	• Software Engineering	•Probability and Statistics

Skills

Language skills:		• Spanish (fluent)	• English
Special Skills:	•Teamwork	• Problem Solving	•Leadership
	•Communication	• Creativity	•Critical Thinking

Experience and Leadership

MEP	2011 – present	6000 J St.
• Member of organization	Organization CSUS	Sacramento, CA 95819
Society of Hispanic	2011 – present	6000 J St.
Professional Engineers	Volunteer Organization CSUS	Sacramento, CA 95819
• Student volunteer (events, setting up, and organization)		2011 – present
• Professional development assistant	2012 - 2013	
Campbell Soup Supply Company Dixon	2015 – Present	8380 Pedrick Road
• SAP Clerk, shipping and receiving product	Paid Work	Dixon, CA 95620
Wendy's	2010 – 2015	146 Dorset Dr.
• All positions, Manager Assistant	Paid Work	Dixon, CA 95620

Projects

Custom UNIX Shell: Developed a simplified version of a UNIX shell by recreating UNIX commands using C.

Design Chip Using 0.18 µm CMOS Process: designed and layout of a digital decoder and error correction logic for a 5-bit pipeline analog-to-digital converter.

Simplified Microprocessor Design: designed a 5-stage pipelined microprocessor using VHDL for MIPS instructions.

Simplified Operating System: developed the structure of a simplified operating system using C, SPEDE, & FLASH

Printed Circuit Boards: Designed a PCB to reduce the size of the circuitry of our senior design project.

Software Engineering: Build a student attendance tracking system using JAVA and GOOGLE API calls.

Awards

• Dean's Honor Roll: 2012 – 2016	• Hispanic Committee scholarship
• Distinguish Scholar, Dixon High School	•NACME Scholar, CSUS: 2014 - 2017