Athlete Motion Tracking

Project Plan

Team Number
sdmay19-01

Client: Precision Performance Cycling (Nathan Johnson)
Adviser: Craig Rupp

Team Members
Software Engineer: Monte Friestad
Hardware Engineer: Ryan Hansen
Software Engineer: Nathan Mazarelo
Hardware Engineer: Madeline Rogers

Email: sdmay19-01@iastate.edu
Website: http://sdmay19-01.sd.ece.iastate.edu/

Table of Contents

List of Figures

List of Tables

1 Introductory Material

1.1 Acknowledgement

The Athlete Tracking Team would like to thank Nathan Johnson of Precision Performance Cycling for his time, financial aid, technical experience, and equipment. As the sole proprietor and employee of Performance Cycling we worked closely with Nathan through the project. He provided us great examples and a clear direction for our project.

1.2 Problem Statement

Elite cycling athletes depend strongly on a good fitting bike fit. The bike fit encompasses the saddle height, three separate angles of the saddle, handlebar stem length, and handlebar angle. Each variable translates into athlete body position. The fitting is currently done by eye with no angle analysis and only exists on a trainer.

The project will encompass two different systems: a video system and hardware system of sensors. These two systems will operate both in a lab and during real life training and races. The data will be saved for coaches and athletes to analyze at a later time - not live feed. The client requested this so the athlete will not change their performance during the race according to the data collected.

In addition, the different angles will be presented on the screen but not analyzed. Each athlete is different depending on their body. Thus, the data will be presented as calculated and not compared to a preferred ratio. Instead, the coach and athlete will make the next steps to better the performance independently.

The future outlook for this project will be to use this system for running as well. This expansion into running will also allow for the expansion of the company. The requirements will translate over and only require a few software implementations.

1.3 Operating Environment

The two systems will be held to two different locations while maintaining the common underlying fact that it cannot interfere with the athlete. The video analysis is to be done indoors. The stickers for the tracking must be easily visible for the camera and ergonomical for the athlete.

The hardware system is comprised of accelerometers and pressure sensors. The hardware system will be used outside during races and training. The locations for the sensors will be dynamic, needing them to be wireless. In addition, the sensors will need to be waterproof and durable for multiple hour races or training sessions outdoors.

1.4 Intended Users and Intended Uses

The end consumer will be the athlete. The athlete has a strong background in cycling and understands their comfort level. This system is used to collect data from a real life scenario and turn it into data that they can read and understand. Therefore, collecting the data must not interfere with the athlete. Then on the final product, the data must be presented in a way that is easy for both the athlete and coach to read. The coach and athlete will take the data and analyze it on their own, only needing the angles and pressure values reported.

The raw data will also need to be looked at in an outside format. The client would like the data reported for the athlete and coach but also accessible to be pulled out for further analysis.

1.5 Assumptions and Limitations

The first assumption is that the sensors and camera will collect data fast enough to account for the biking and running rpms at 107 and 170, respectively. This is important to create the proper amount of points to avoid skewing the data. The other assumption is that the system can be used for multiple athletes. The client uses their system on multiple different athletes. Therefore, the next assumption is that the systems can put on multiple different athletes and not have the analysis skewed.

The limitations we are facing vary. The first limitation comes from the rider comfort. The stickers for the camera and the sensors for the system need to not interfere with the athlete. The other limitation needs to be that the sensors are wireless. Sensors when not fitted properly will affect how the rider is positioned on bike making the data not representative of when the sensors or stickers are not on the rider. The next limitation is price on the camera. While the price of camera was not specifically laid out, many cameras that are used for athlete body position are in the tens of thousands of dollars. In addition, the area used for these camera is quite large. The space specified for the system we are producing is not as large as these cameras require.

1.6 Expected End Product and Other Deliverables

There are two deliverables that are expected: the image capturing system and the hardware sensor system. The project is split into two very intense sections based on the two systems. The first system is due by the end of the first semester. The system encompasses everything from choosing the camera, collecting the data, analyzing it, and presenting the data in a user friendly manner. While keeping this on track, testing needs to be implemented along the way, different software and sources need to be used to get the data into a format that will be usable, and then presented into an interface for the coach and athlete. The deliverable is working system that includes a camera and a web app for the consumers to use.

The second portion of our project was listed to begin after the first part is complete. The hardware system is currently scheduled to be completed by the end of the second semester. The deliverable is the hardware system and the app that will relay the info from the system. The hardware will include the sensors and a transmitting device that will allow for the data to be transmitted from the wireless sensors.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The goal of the project is to create a system to measure, compile, and display the motion of an athlete, specifically a bicyclist. The project will measure the motion of an athlete through video and sensors. This motion includes the motion of a rider on a bicycle, a person running, and even an motion an athlete may perform. Once the measurements about the athlete has been taken, the data is compiled into a database to be displayed for the coach, trainer, or athlete. This data will be displayed in a web application and will show the measurements and change over time to the user. The user should also be able to see the results graphically and view the sensor readings and video at different times. This interface will be available in real time in lab scenarios and will always be available after training.

2.2 Functional Requirements

- Able to capture and analyse video of an athlete riding a bicycle in the lab setting.
- Able to capture sensor data of an athlete riding a bicycle in any setting.
- Logging data captured outside of the lab.
- Able to compare data and readings over multiple training sessions.
- Data is shown in the raw form and little analysis is done to the data.
- Should be able to view the data as it is collected in the lab setting.
- Should be able to view previous runs from any setting.

2.3 Constraints Considerations

- Measurements should be consistent per athlete and within 2.5%.
- The is not a precise requirement for price, it should be as low as possible.
- Be able to handle 150 rpm for cycling and 170 rpm for running.

2.3.1 Standards

Engineering standards are very important to the work we accomplish as engineers. Standards allow us to have minimum performance, meet safety requirements, make sure that the product/system/process is consistent and repeatable, and provide for interfacing with other standard-compliant equipment. For this project we will usings standards from IEEE that deal with the development cycle and measurements.

IEEE 12207 - 2017 sets a framework for the how the processes, activities, and tasks will be used during the supply, development, operation, maintenance, and disposal of software product. This standard is relevant to our project because we are making a web application for our client. The web application will need to go through development, operation, and maintenance which are all activities mentioned in the this standard.

EEE 15939 -2017 is standard for system and software engineering disciplines. It sets a model for what measurements are to be required, how the analysis of the measurements are to be applied, and how to tell if the analysis results are valid. This standard is relevant to our project because we will be measuring different motions of an athlete. This will include the angles of their body as well as their pressure data using sensors. In this standard they talk about how the analysis of measurements are to be applied and how to tell if the analysis results are valid. This is very necessary to us as we need to make sure that we are interpreting the measurements in the correct way and then verifying that our interpretations are valid.

2.4 Previous Work And Literature

The Dartfish software gives the angles of various parts of the body for athletes on camera. This software takes a video and shows the angles of the athlete's back, legs, and arms over top of the athlete [6]. The Dartfish software is the closest to the goal of our project, however, there are a few main differences [6]. The most notable difference is that our software wants to include readings and measurements as data to accompany the video. The Dartfish software does not allow the user to analyze the data any farther than the video overlay.

Other software requires the user to wear a specific suit inside of a highly calibrated room. While this software is very precise, it is expensive and inhibits the user by requiring many sensors to be placed on the body. The goal of our project would be to create a less precise version which is cheaper and less inhibitive.

2.5 Proposed Design

For the video capture, there are a few alternatives, mostly revolving around the placement and quantity of the cameras in the lab. For the number of cameras used, there are many options however, of the likely possibilities, there will be between 3 or 4 cameras. Having 1 camera comes with a high cost of accuracy [5]. More than 4 cameras increases the cost of the project greatly while each extra camera does little to improve quality. Now the placement of the cameras is important as well. For 2 cameras, there are three possibilities: front and back, one on each side, or one side and one in front. The main issue with any of these configurations is that some data about the location can be lost. To recover this data we need to add in the third camera. After considering these possibilities, the design needed either 3 or 4 cameras [1].

For three cameras, there are 2 configurations that will be tested. The first has two cameras to the side of the athlete and one in front. From these three angles, measurements can be taken which measure the movement of the hips, knees, shoulders, and other important parts of the body that we need to measure. Similarly, the two side cameras could be placed at an angle behind the athlete so that each camera is 120 degrees apart. Testing will decide which configuration produces better results. Now, for four cameras, the cameras would be placed so that they are equally spaced around the athlete, 90 degrees between neighboring cameras. This could be done by placing cameras in front, behind, and either side or rotating that configuration. Testing will determine whether the fourth camera is worth the cost and which configuration provides the highest accuracy.

2.6 Technology Considerations

For the camera, there are many options on the market and in general, an increase in price produces a higher quality image. Therefore, most of the trade off is cost versus quality. The lowest price product that will likely have accurate enough readings is the Microsoft Kinect.

This device costs $110 per camera and does not require any specific software [2]. The other main camera that we have considered is the OptiTrack, which starts at $300 per camera,but also has an installation fee and requirement for their software, which is $500 per year. The last possibility would be the ipiSoftware. This uses $60 cameras and uses software which costs $1000 [5].

The next consideration is software for processing the video. For two of the cameras, they come with their own software. However, other software is available including Dartfish, which has a $70 monthly fee and works with any camera. This software is highly recommended by people in the industry and would likely be the software used if the camera system does not come with its own software.

The last factor would be hosting the web application and database. The price for the hosting would be determined once the size of the database and web server is known. However, Microsoft hosting starts at $0.05 per GB. For the web application, there are many possibilities, however the project will be made in python using popular, free, open source libraries like Django and Numpy.

2.7 Safety Considerations

The first and only safety consideration is that our sensors and cameras do not inhibit the athlete in a way that will cause injury.

2.8 Task Approach

We intend to approach the tasks at hand using the design thinking model which is included below (Figure 1). Our methods to approach the project will be discussed in our weekly meetings and directly with the client.

Process Flow

1-2: Successfully understand the needs to define the problem

4-3: new ideas made from prototypes created

5-3: Testing reveals new ideas to solve the problem

5-2: Testing provides further insight that can solve the defined problem

5-1: Users/client learn from testing and want further functionality or greater understanding

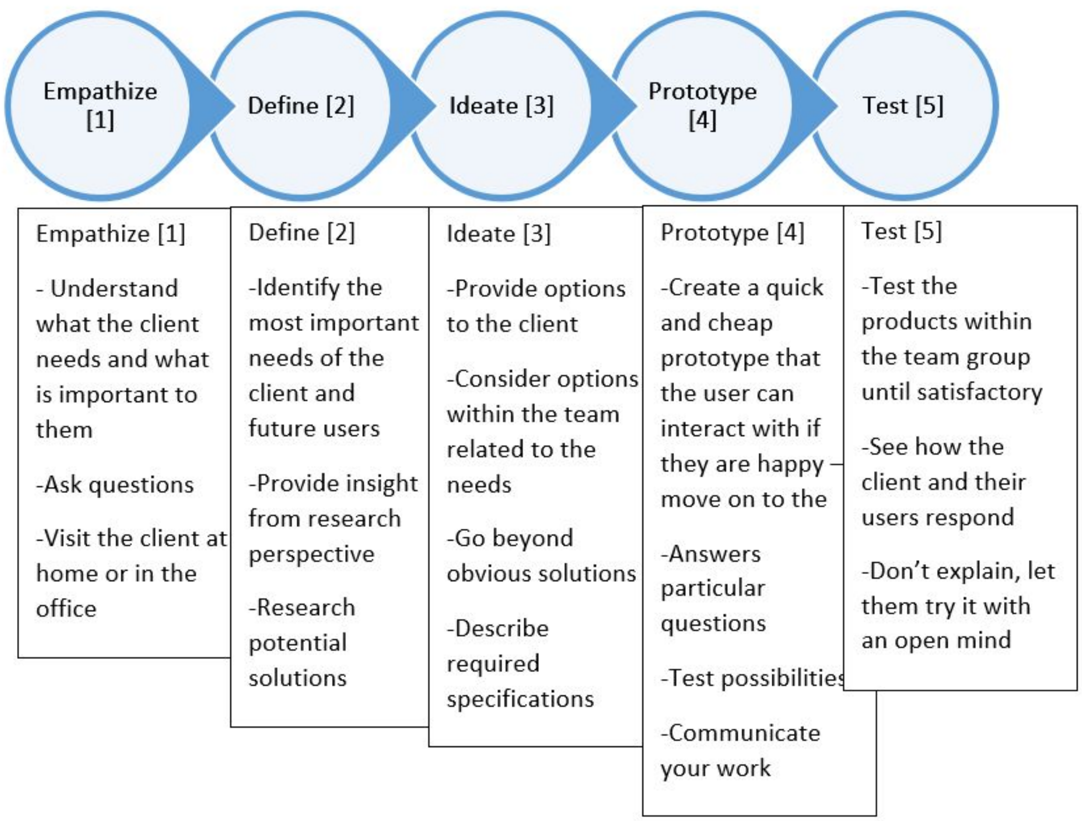


Figure 1: Design Thinking Model

2.9 Possible Risks And Risk Management

Budget: not explicitly stated, depends on equipment. We have a few different approaches to producing a product that works for both of us.

Materials: We have been using free trial software and we reserved a Microsoft Kinect for testing with Microsoft's developer toolkit. The materials we need can be relatively cheap all the way up to camera systems that can cost anywhere between 2k-20k.

Equipment: Cameras for motion tracking. We are thinking a minimum of 4 cameras to cover every position for the athlete up to a maximum of 8.

Knowledge of Area: We aren't professional cyclists, so most of our information will be coming directly from Nathan.

Accuracy Issues: Our client didn't seem concerned with accuracy issues, he wants to focus on precision.

2.10 Project Proposed Milestones and Evaluation Criteria

Key milestones: Video tracking, interpreting tracking data, web application to show data that can easily be interpreted by athletes and coaches.

Testing: We will create a testing video and move all of the target areas on the body to evaluate and confirm that our tracking software is recording movements correctly. We will also have to test to see if our program is interpreting the data sent from the cameras properly and that all the angles are updated frame by frame. The web app needs to show the data in an easy to understand way and we will need to test and confirm that the data is uploaded correctly.

2.11 Project Tracking Procedures

Weekly Reports, weekly agenda presentations during meetings, gitlab and trello.

2.12 Expected Results and Validation

Tracking: Robust tracking of anchor and dynamic portions, rotation in hip, ankles and knee. Tracking these angles needs to be within 2.5% of the expected values received from the baseline athlete image tracking.

Efficiency: Not just cycling but also running applications. The system should be easy to use for our client and easy to set up in other locations as needed. The results produced from the system need to be efficient at identifying problem areas before an injury may occur.

Expected Overall Results: Focus mainly on precision not accuracy. Lower back is the central point, ankle, knee, and hip are other tracking areas of concern. Determine average angles and deviations. Also wanted to have pressure sensors for the athletes feet and possibly for the handlebars in the future after motion tracking is solid. Power outputs for agility. Devices that we use need to be able to sync with one another. Most of his clients use a Garmin module on their bikes for speedometer readings, could use the sensors on the Garmin device to aid in data collection. Need to track the athlete's foot, it should be going in a uniform circular motion since the pedals follow this motion. Need to detect when its going out of motion. Cadence requirements of 150 rpm for cycling 170 rpm for running. Doing the video capture for the first deliverable isn't the main issue, its how we interpret the data and present it in an easy to understand form. Focus on storing the data, doesn't necessarily need to be real time. Need to be able to compare data over time not actively.

Not comparing the athletes, personalized data between different sessions during different days of the week. Does the athlete data change between sessions? Identify if its due to injuries or injuries that could potentially happen or if it's just due to them being fatigued. We need to be able to catch abnormalities before an injury occurs.

Any device needed that the athlete will wear needs to be non intrusive, stay in position, and be able to handle all weather conditions.

Parts of the bike we need to be aware of in tracking: saddle, handlebars, stem, petals and foot cleats.

Validation: We will test and confirm each part that we need to track is being recorded correctly before moving onto additional tracking points. The most important areas Nathan has identified are the lower back, hip, legs, and shins. We will validate that the angles we record from the tracking are within the designated angles and deviations that Nathan has given us.

2.13 Test Plan

Test the cameras and their functionalities. We have determined that we need cameras with a higher video quality and frame rate than the Microsoft Kinects that we have been using. The best option would be acquiring cameras that can record 1080p video at a minimum of 60fps. We will also need to make sure that the devices we use are reliable and easy to calibrate. Once acquiring the new cameras, we will have to test different locations and heights of the cameras for the optimal recording area. Record position and sensitivity settings.

For our testing, we will need to record where the cameras on the tripods are located and their relative distances from one another so they are consistent throughout all of our testing. We will also need to perform baseline testing that we can use to compare with other data that we acquire. This can be done using athlete data provided to us by our client Nathan. Data should be easy to understand so after the data collected looks good.

The user also should have the capability of viewing data gathered from previous runs. This will require the creation of a web application with different ways to display the data, and we will decide on one format to use eventually based on what the client prefers. Currently, the graphs derived from the data overlap which is difficult to interpret, we will have to test different ways of displaying this data and find a way to pull individual data and highlight the important areas. Some image tracking testing photos a jumping jacks exercise are included below to show the trackable anchor points.

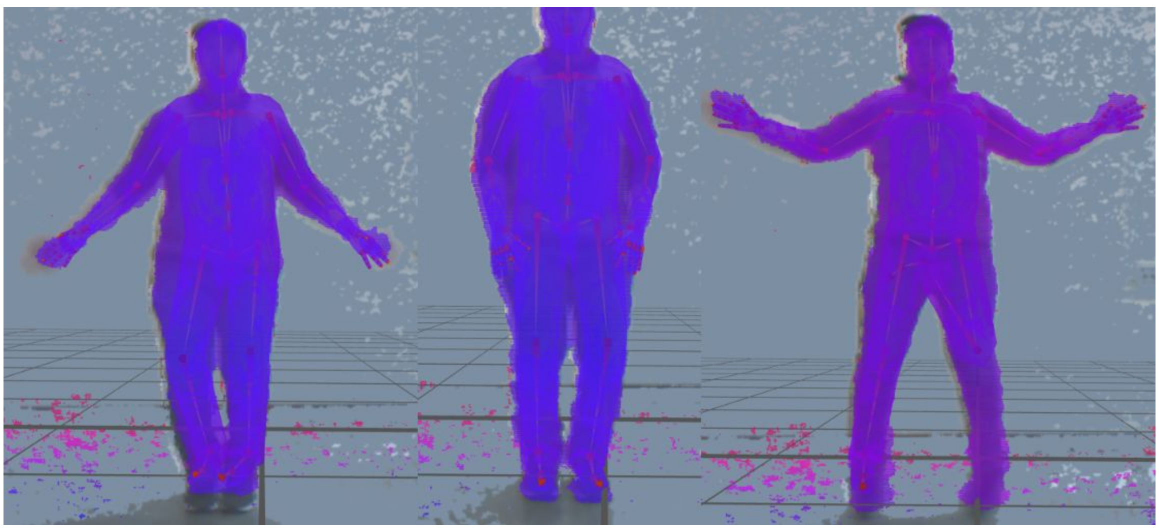


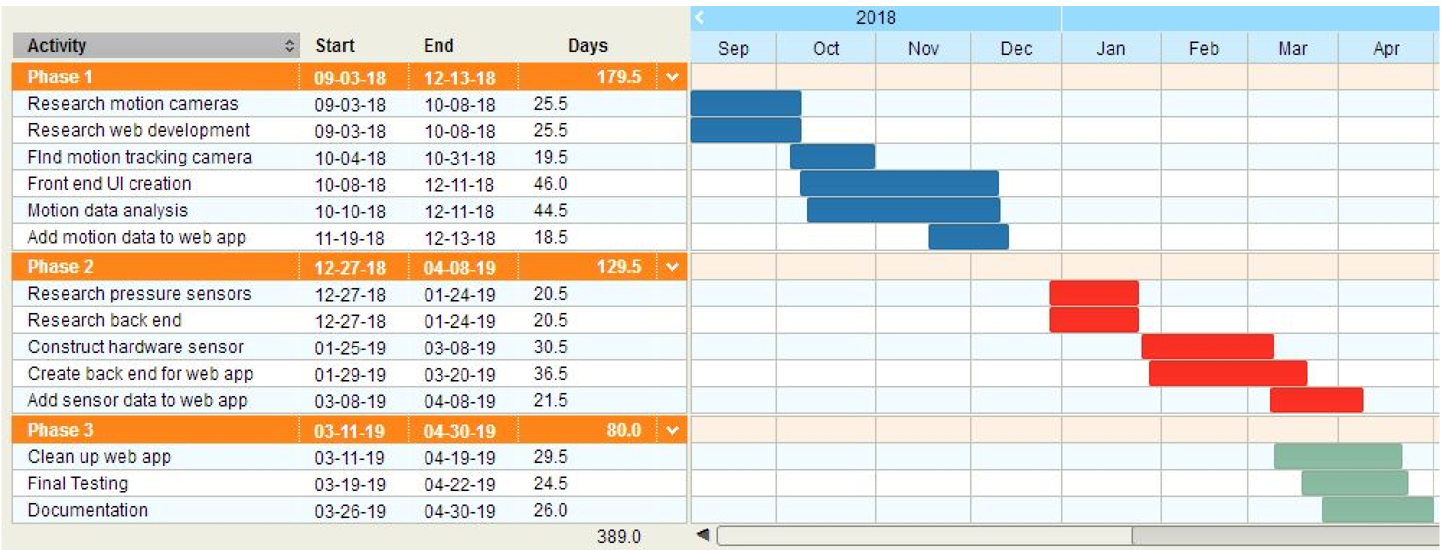
Figure 2: Kinect Motion Tracking

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

Project development will be divided into 3 distinct phases, each corresponding to a set of deliverables expected at the end of each phase. Phase 1 will be the start of the first semester and Phase 2 will be the start of the second semester.

Phase 1 will consist of implementing an image capturing system to collect data to monitor the athlete's motion. A program will be developed to analyze the angles of the data collected by the cameras. A web application will then be created to display the motion analysis program and raw data captured by the camera. Phase 2 will consist of creating the hardware to detect the athlete pressure readings using sensors, displaying that data onto the web application, and creating the back end. Phase 3 will have the final rounds of testing for the image capturing system and hardware sensors to make sure they meet the constraints of the project. Phase 3 will also include the final documentation and presentation of the project to our client. The timeline can be seen below in Figure 3: Project Gantt Chart.



Activity	Start	End	Days
Phase 1	09-03-18	12-13-18	179.5
Research motion cameras	09-03-18	10-08-18	25.5
Research web development	09-03-18	10-08-18	25.5
FInd motion tracking camera	10-04-18	10-31-18	19.5
Front end UI creation	10-08-18	12-11-18	46.0
Motion data analysis	10-10-18	12-11-18	44.5
Add motion data to web app	11-19-18	12-13-18	18.5
Phase 2	12-27-18	04-08-19	129.5
Research pressure sensors	12-27-18	01-24-19	20.5
Research back end	12-27-18	01-24-19	20.5
Construct hardware sensor	01-25-19	03-08-19	30.5
Create back end for web app	01-29-19	03-20-19	36.5
Add sensor data to web app	03-08-19	04-08-19	21.5
Phase 3	03-11-19	04-30-19	80.0
Clean up web app	03-11-19	04-19-19	29.5
Final Testing	03-19-19	04-22-19	24.5
Documentation	03-26-19	04-30-19	26.0
			389.0

Figure 3: Project Gantt Chart

3.2 Feasibility Assessment

This project will deal with extracting data, processing data, and storing data, and then displaying it to the user on a web application. This project may be difficult due to the precision required for the data that is being collected.. The manner in which the data is being recorded for each athlete has to have minimal variation from week to week to ensure that coach and athlete can effectively compare such data. Other concerns that arise are from the lack of experience in web development. Since the data is to be presented in way that both the coach and athlete can easily interpret the data. It is integral that we make the presentation of data as user friendly as possible.

3.3 Personnel Effort Requirements

We have been able to setup the project in a way that splits the focus of the project into two main ideas. These ideas include data collection and data presentation. The data collection will be hardware based while data presentation will be software based. Two members will be tasked with doing the hardware aspect while the other two will be doing the software aspect. For each phase we have come up with tasks that will guide us to completing the main objective for that phase. Each task is listed below in Table 1: Major Tasks.

Task	**Description**	**Estimated Days**
Phase 1 (Semester 1)	Implementing the image capturing system and web application interface with basic motion analysis	179.5
Hardware		
Research motion cameras	Research different options for motion tracking cameras and software that is compatible with said camera	25.5
Find motion tracking cameras	Retrieve cameras we chose through research to begin testing with	19.5
Software		
Research web development	Research web development and and other software that can used to show data extracted from the cameras on the website	25.5
Front End UI creation		46.0
Motion data analysis	Develop a way to find angles between specific points of motion	44.5
Add motion data to web app	Move the motion data analysis program to the web app	18.5
Phase 2 (Semester 2)	Implementing the hardware sensor and backend and updating the frond end with the sensor data	129.5
Hardware		
Research pressure sensors	Research different kinds of sensors to find one that is suitable for our price range and specifications	20.5

Construct pressure sensors	Hardware is to be constructed to have sensors that will wirelessly transmit the information to a database so it can used on the web page	30.5
Software		
Research back end	Research different types of web hosting platforms and databases in order to run our web application and keep the data stored in a secure environment	20.5
Create backend for web app	Create a database to store data and register a domain for web hosting	36.5
Add sensor data to web app	The front end interface is modified to see display the data retrieved from the hardware sensor	21.5
Phase 3 (Semester 2)	Testing, polish work, and final documentation	80
Clean up web app	Make final changes to the web app improving performance, looks, and efficiency	29.5
Final testing	Final stages of testing to make sure all requirements of the project have been satisfied	24.5
Documentation	Start writing the final documentation for the report and the presentation	26.0

Table 1: Major Tasks

3.4 Other Resource Requirements

A few other resources will be needed to complete the software and hardware sides of the project. To develop The code required to develop the web application, an IDE like PyDev will be needed. Using an IDE for the code development part of the project will help with overall efficiency because we can use integrated features like auto import, code analysis, debugger, and much more to support us when writing code. In addition to the IDE, the software side of the project will also require a database to store the data retrieved by motion tracking cameras.

3.5 Financial Requirements

The financial requirements are split are into hardware and software cost. The hardware cost will cost cameras, sensors, and prototyping materials. The software costs will include camera software and website hosting. Some costs are still being determined as we move along in the project timeline. The costs can be seen down below in Table 2: Financial Requirements.

Items	**Description**	**Price**
Hardware		
Motion Tracking Cameras	Cameras needed to track points of motion on athletes bodys for further analysis	$65 each x 4 $260 total
Pressure Sensors	Sensors will track the amount of pressure the athlete is using	TBD
Prototype Design materials	A makeshift bike axle will be constructed to test the accuracy of the software created to track points of motion	TBD
Software		
Camera Software	Software the will help track motion through the camera and give back data in format that can be used for other analysis	$1200
Website Server	Data recorded by the cameras will need to stored onto a database so records can be accessed at anytime needed	$0.075 per hour

Table 2: Financial Requirements

4 Closure Materials

4.1 Conclusion

For our senior design project, we have been given to opportunity to design a system for tracking the motion of various athletes. Our client Nathan Johnson, owner of Precision Performance Cycling, has given us this task as a way to further the performance of his own clients. To fulfil this task, we will be implementing motion tracking cameras and pressure sensors to be positioned around the athlete to give us optimal readings of motion for further analysis.

All data will be be readily available through the interactive web application being built for the users of the motion tracking system. The web application will create an easy and organized means for the athletes and their coaches to analyze the data as they see fit and create optimal changes to their movement based on the information that they are seeing through our web application. This project is intended as a way to give athletes a means of optimizing their performance through analysis of their own motion. Our team is excited to help Nathan and rest of Precision Performance Cycling in their goal of improving and developing their clients.

4.2 References

Technology:

[1] ipioft.com. 2008. About ipi Software. Retrieved November 11 2018 from http://ipisoft.com

[2] Shiffman. 2015. Getting Started with Kinect and Processing. (May 2016). Retrieved October 1, 2018 from https://shiffman.net/p5/kinect/

[3] John Hunter, Darren Dale, Eric Firing, Michael Droettboom. 2002. Matplotlib: Python plotting. (March 2012). Retrieved September 20, 2018 from https://matplotlib.org

[4] Ruth Chabay, David Scherer, and Bruce Sherwood. 2017. VPython Help GlowScript Python and Python 7. (January 2018). Retrieved September 20, 2018 from http://www.glowscript.org/docs/VPythonDocs/index.html

[6] Dartfish. 2017. Take Efficient Decision Making to the Next Level. (November 2018). Retrieved November 1, 2028 from https://www.dartfish.com/

Pricing:

[5] Amazon Azure. 2018. Pricing - App Service. (July 2018) Retrieved September 20, 2018

from https://azure.microsoft.com/en-us/pricing/details/app-service/windows/

4.3 Appendices

1. Class Workshop Client Process Flow