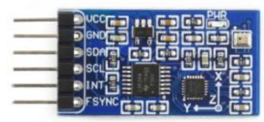
2.2 Concept Selection

2.2.1 Internal Measuring Unit

Internal Measurement Unit (IMU)			
	MetaMotion R 	10 DOF IMU Sensor 	Blue Trident 
Price	$87	$25	$1,600
Weight	0.3 oz	0.11 oz	0.21 oz
Battery Life	8 hrs	~	12 hours
Range	+-16g	+-16g	+-16g
Frequency	400 Hz	200 Hz	1125 Hz
Durability	Water resistant, protective shell	No case	Water resistant, protective shell

An Inertial Measurement Unit is a device that has a variety of sensors that collect useful data. For our project we are in need of an IMU that has an accelerometer, gyroscope, and a magnetometer. These three sensors will give us the proper data in order to determine acceleration. In addition to containing those sensors, it must also meet the other specified needs we have to ensure data processing as well as the device operation.

Internal Measurement Unit (IMU)			
Better Than: 1 Neutral: 0 Worst Than: -1	MetaMotion R	10 DOF IMU Sensor (D)	Blue Trident
Price	0	1	-1
Ease of Use	1	0	1
Weight	0	1	0
Battery Life	0	-1	1
Range	0	0	0
Frequency	0	-1	1
Durability	1	-1	1
Score	3	-1	3

The Pugh matrix was used for selecting the best Inertial Measurement Unit (IMU) sensor required for our device. This matrix shortens the choices we have to make among many complex design elements by assigning a one, zero, or negative one value based on the usefulness of how each requirement is met. As shown below, the price of the Blue trident was assigned to be negative one because it is the most expensive among the three (IMU) and the least affordable, which makes it an impossible option to choose from even though it has a good battery life, a good range of sensitivity, frequency and durability. From the Pugh matrix, we can deduce the MetaMotion R (IMU) is the next best thing after the blue trident because it's easy to use, and has a weight that's negligible to the sprinter and the price is affordable.

2.1.2 Program

Programming Software			
Better Than: 1 Neutral: 0 Worst Than: -1	Visual Studio	Matlab	Python
Familiarity	1	0	-1
Functionality	1	-1	1
Accessibility	1	1	1
Score	3	0	1

For selecting the best programming software to use a pugh matrix was appropriate. There are several different options available regarding the use of a program that has the capabilities we need. However, Visual Studio and the use of C++ coding language is the best option for us. Most of us are familiar with the use of C++ and the features it has to offer. OpenCV is a library that is compatible with C++, which will allow Visual Studios to encapture data from video files and transcribe it into C++ language. This will give us the functionality we need in order to analyze our videos. Visual studio is available on different platforms such as Windows and Mac operating systems which allows us to access our program from various devices. C++ language also enables the future development of an iOS application that would allow a very portable method of analyzing sprinter data.

In addition to OpenCV compatibility, the usage of .csv files is going to be the primary focus when it comes to accessing accelerometer data, and C++ can interpret .csv files, take the data from them, and store it into variables. Therefore, the ability to have easy access to that data through C++ proves that it is the best option. This feature will enable us to integrate the two types of data into a single main program that portrays both ends of data interpretations.

2.1.3 Camera System

The camera system is what we will use to capture the movement of the sprinter in time. It is our goal to find a camera system that is compatible with the concept we choose to use for image processing, OpenCV. With the video captured from our selected camera system, we will be able to identify the length of each stride and provide this information to our user as an output in our program. Although we are on a budget, we feel that the device we use to capture the image of the sprinter in motion should not be cheap. We are looking for a reliable camera system at a reasonable cost. We are focusing on factors such as depth sense, resolution, frame rate, adaptability to lighting changes, size and price. Below we have our top three camera choices displayed. Of the previously proposed camera systems, these three listed above provided the best combination of specifications needed to carry out our goals.

Camera System			
Categories	Intel RealSense Depth Camera D435 	iPhone Camera System 	MYNT EYE 3D Stereo Camera Depth Sensor 
Video Resolution	1920 x 1080	1920 x 1080	752 x 840
Frame Rate	90fps	60 fps	60 fps
Adaptability to light changes	Great low light sensitivity	Adaptable to brightness and exposure	Optimized performance in normal or low light
size	90mmx25mmx25mm	158.2 mm x 77.9 mm	65 mm x 31 mm x 30 mm
price	182.13	0	249.00
OpenCV compatibility	Open source	compatible	compatible

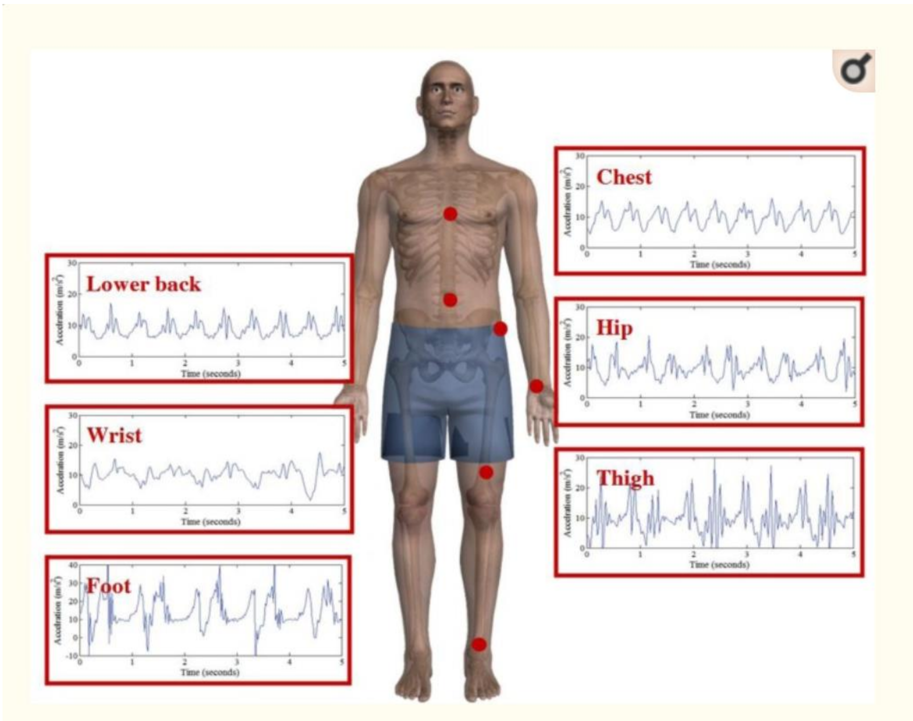
Using the pugh matrix seemed to be the best method to use for selecting our camera system. We already knew our most important components: depth sense, video resolution, frame rate, adaptability to light changes, size, price and OpenCV compatibility. Through this method we were able to conclude that the *iPhone Camera System* was the best camera system to use. Aside from not having any negative scores, the frame rate and resolution were optimal. Those two components are important to our overall system because the higher the frame rate the more images that can be captured per second providing higher data volumes. Considering we are capturing swift motion, we want to capture as many frames as possible to get the best image for measuring stride length and frequency.

Camera System			
Better Than: 1 Standard: 0 Worst Than: -1	Intel RealSense Depth Camera D435 	iPhone Camera System 	MYNT EYE 3D Stereo Camera Depth Sensor 
Video Resolution	1	1	-1
Frame Rate	1	1	1
Adaptability to light changes	1	1	1
size	0	1	0
price	0	1	-1
OpenCV compatibility	1	1	1
Score	3	5	1

2.1.4 Sensor Position

To choose the sensor placement a pugh matrix was not necessary since the acceleration signal recorded from the human will depend on the location of the sensing device and the activity being performed. Based from research we were able to decide the best location for the sensing device in the runner's body and the number of sensors we will be using. We decided to use one IMU sensor placed in the chest of the runner. The reason why we decided to use only one sensor is because its operation will be only to grab the velocity of the whole body. The stride length and stride frequency will be obtained from the camera system. Also if we take a look at the figure below, we can see that the highest signal frequency was obtained from the foot and the thigh, but this will not give us the desired velocity for the whole body. If we placed the sensor in the chest the signal frequency is more clear and we can obtain the whole body velocity. In order to decide how the sensor will be mounted to the body, we did research on the different mountings available, and the best option was an elastic chest belt strap.

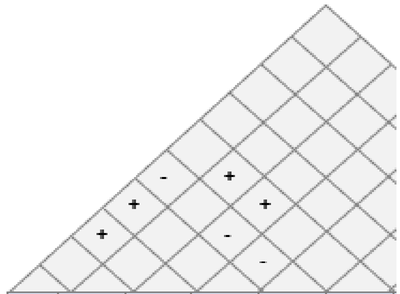
- Sensor Recognition Data



- User Comfort

  Sensors should be worn in a comfortable and unobtrusive location in the runner's body. They need to be attached firmly to the body in order to detect motion and collect data. Based on research and surveys, we found that placing the sensor on the wrist, foot, thigh, chest, and lower back will not affect the collection of data and it will not cause any discomfort to the user. This further supports the chest as the best placement for the sensor.

House of Quality



		Lightweight	User Interface	Data Measurement	Water Resistance	Affordable	Customization
Pricing	2	-1	0	-2	-1	+1	0
Given data	3	+1	+1	+2	-1	0	+1
Ease of use	1	0	+1	-1	0	0	+1
Wearability	2	+1	0	+1	+1	+1	-1
Weight	2	+2	0	+1	-1	-1	-1

Key	
+2	Very strong relationship
+1	Strong relationship
0	Neutral
-1	Poor relationship
-2	Negative relationship

Based on the House of Quality created above, correlations were determined between the customer needs and targets, showing the interaction with one another. It exhibits the relation between each of these criteria, therefore depicting a clearer picture as to what the differences are of each need and target. On the top section of the chart, it is clear that affordability downplays a lot of the other variables such as lightweight. In order to make the item inexpensive, some sacrifices must be made in the other areas. When looking at the center of the chart, values are shown by what is considered a strong or weak relationship between targets and customer needs. Data measurement plays a significant role in each of the customers needs, as a lot of factors determine the importance of data measurements.

I. Cleland, B. Kikhia, C. Nugent, A. Boytsov, J. Hallberg, K. Synnes, S. McClean, and D. Finlay, “Optimal placement of accelerometers for the detection of everyday activities,” Sensors (Basel, Switzerland), 17-Jul-2013. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3758644/. [Accessed: 17-Oct-2019].