Requirements, $V2.0$

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1 Introduction

As information technology becomes more ubiquitous in our lives, researchers hope to find new and more complete sources of data. The question for the researcher quickly goes from how do I collect this data to how do I collect, manage and analyze an extremely large data.

This project hopes to answer these question by providing a framework for the current and future research needs of the project sponsor, Dr. Kyle Winfree. His research is focused on the analysis of human movement, specifically the issues associated with Parkinson's Disease.

While many devices are capable of tracking the count of steps an individual takes, this project aims to provide a framework for collecting data at a much higher frequency with hundreds of samples collected every time a subject takes a step. This requirement places a significant burden on the hardware and software of the layered system that has been proposed. The sheer amount of data presents a great challenge to the team.

The most resource constrained layer of the system is the microcontroller and associated sensors placed on the subject, hereafter referred to as the wearable device. The wearable device must be able to perform a number of functions at full-capacity and any inaccurate or poorly synchronized data will lead to failure. Fortunately the risks identified in the other layers are more easily mitigated.

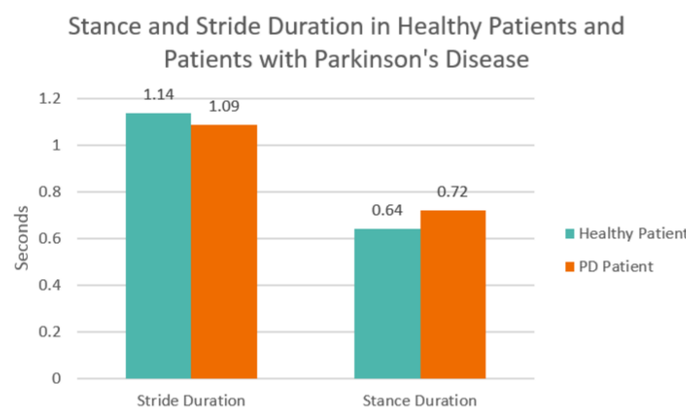
This document lists many of the key requirements of the project, the risks associated and a proposed project work plan. The analysis of these topics will help to reduce complexity and to exceed the requirements of the sponsor in a efficient and timely manner.

2 Problem and Solution Statement

Today there are many different kinds of wearable devices that track human activity and movement. However, these devices are general and only really track distance, speed or steps. The purpose of this project is to build a system that can measure and analyze gait, the person's manner of walking.

Outside of clinical settings, there is not much information available on gait. Having more information about an individual's gait could allow health practitioners to be able to identify diseases, muscle failure, or other conditions before major symptoms arise. The information can also help physical therapists better target their patients with certain exercises or simply monitor how they are progressing.

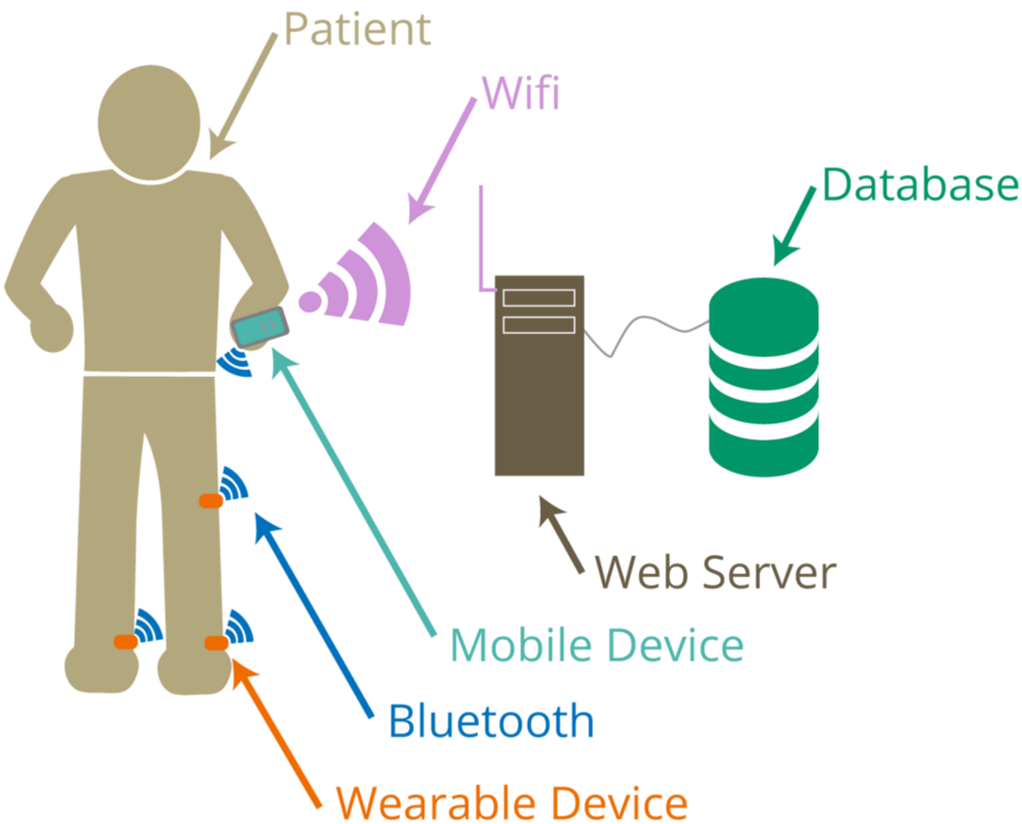
	Healthy	PD
μ Stride Duration (s)	1.14 (0.11)	1.09 (0.19)
σ Stride Duration (s)	0.05 (0.02)	0.07 (0.03)
μ Stance Duration (s)	0.64 (0.12)	0.72 (0.14)
σ Stance Duration (s)	0.08 (0.06)	0.10 (0.06)
μ Stance Duration (%GC)	56.00 (7.51)	66.22 (6.11)
σ Stance Duration (%GC)	5.54 (5.00)	8.16 (6.64)
μ Heel Max (%GC)	10.19 (4.73)	16.72 (7.00)
σ Heel Max (%GC)	3.65 (1.48)	8.37 (6.61)
μ Ball Max (%GC)	42.15 (8.60)	44.17 (6.38)
σ Ball Max (%GC)	6.45 (5.81)	7.38 (6.97)
μ Toe Max (%GC)	53.12 (2.30)	52.44 (6.44)
σ Toe Max (%GC)	3.06 (1.99)	6.60 (6.79)



Topics in this area are the primary focus of Dr. Kyle Winfree, an associate professor at Northern Arizona University's Department of Informatics and Computing. His research primarily focuses around robotic interventions for therapy, remote assessment focused outside of the lab, brain-computer interfaces and the data analysis and algorithms associated with processing these systems.

The problem of the project simplifies to getting data from a variety of sensors into a structured form within a database through an automated process. Dr. Winfree has demonstrated the use of a wearable device for his prior research, but was limited to a manual, time consuming process. The success of this project will be measured by how quickly and reliably the framework collects, manages and analyzes the data.

To meet these goals, an individual would wear a device on their feet that would record data, such as their stride length, pressure on the heel, pressure on the toes, and pressure on the sides of their feet. That data, will be than sent to a mobile device via Bluetooth. Once the phone has that data, it will be sent to a server over WiFi where it is than analyzed. From there, the end user can log on to a website, in any server browser and access the analyzed data.



The outcome of this project is invaluable. Providing a system that can easily allow researchers to gather their data, and make it easily accessible will only speed up their research. Rather than spending time trying to gather their results, they can analyze their results and come up with solutions. This system is the way to do it. Not only does it provide an accurate way to gather data, it is so simple that virtually anyone, with any level of electronic experience can operate.

3 Functional Requirements

3.1 Wearable Device

3.1.1 The Teensy microcontroller will be used to collect data.

3.1.2 The microcontroller will be able to connect to force and six-axis motion sensors.

3.1.3 The microcontroller must be able to accept various types of force resistor sensors.

3.1.4 The microcontroller will be able to connect to additional sensors using the I2C bus and/or SPI.

3.1.5 The microcontroller will maintain an accurate timestamp to the millisecond that is synchronized with other nearby devices.

3.1.6 The microcontroller will upload data through a Bluetooth module .

3.1.7 The microcontroller should store historical data in a structured format on a SD card until uploaded.

3.1.8 The data should be structured so that the type of sensor does not matter for storage and upload.

3.1.9 The microcontroller must be able to run on a battery.

3.1.10 The microcontroller must be able to be recharged.

3.1.11 The microcontroller should be extensible with different pluggable sensors.

3.1.12 The microcontroller will have a power-down method that activates on a specified voltage.

3.1.13 The microcontroller should react to commands issued over Bluetooth including power-down, activate/deactivate sensors, status queries and data queries.

3.2 Mobile Application

3.2.1 The Android application will communicate with the microcrontroller using bluetooth.

3.2.2 The Android application will communicate with the server using JSON and HTTP.

3.2.3 The Android application should be able to connect to multiple devices.

3.2.4 The Android application must be able to pair with up to 20 devices containing sensors.

3.2.5 The Android application should be able to provide basic instructions to the subject. These instructions should be dynamic and specified through the web application and database.

3.2.6 The Android application should have a command to identify specific devices by blinking an led.

3.2.7 The Android application should be able to synchronize time with the devices.

3.2.8 The Android application should be able request data from the devices.

3.2.9 The Android application should be able to query the status of devices including battery life, sensor values and time.

3.2.10 The Android application should be able to activate sensors on the device.

3.2.11 The Android application should be able to deactivate sensors on the device.

3.3 Web Server and Database

3.3.1 The database will allow analysis by patient, device or date and time captured.

3.3.2 Data will be stored in its raw form indefinitely in the database.

3.3.3 Patients will be associated with a device in a database table using the web application.

3.3.4 Devices ids will be associated with specific sensor values.

3.3.5 The web server will accept data from the mobile application using JSON and HTTP.

3.3.6 The database and server will be run locally at NAU.

3.3.7 Data will be presented to project investigators through a web application.

3.3.8 The web user will be able to filter data across patient, device and timestamp.

3.3.9 Data will be visible to the web user through graphs and tables.

3.3.10 A basic web authentication system should be in place to protect the data.

3.3.11 The web application should be accessible on the most modern browsers.

3.3.12 The project investigators should be able to share data to others with links to the web application.

3.3.13 A subset of the data should be downloadable through the server in csv format.

3.3.14 The server must send error notices to administrator.

4 Environmental Requirements

4.1 Wearable Device

4.1.1 The wearable devices must be able to operate on AVR or ARM architecture microcontrollers.

4.2 Mobile Application

4.2.1 Mobile device application must be able to operate on Android platform.

4.3 Web Server and Database

4.3.1 The web application and analysis tools must be able to work on any modern browser.

4.3.2 The database can be connected to by Matlab and/or Octave.

5 Non-functional Requirements

5.1 Wearable Device

5.1.1 The wearable device must be able to capture data at a rate greater than 70hz.

5.1.2 The subject should have no interaction with the device other than putting it on.

5.1.3 The wearable device battery must be able to last at least 24 hours, ideally lasting 72 hours.

5.1.4 The wearable device needs be easily repairable.

5.1.5 The wearable device must not impede a person's natural gait.

5.1.6 The wearable device must be reusable and work on varying subjects.

5.1.7 The wearable device must be able to absorb various levels of shock.

5.1.8 The wearable device must be able to operate in a moist environment.

5.1.9 The wearable device must be able to operate in a dusty environment.

5.2 Mobile Application

5.2.1 Aside from initial setup, the subject should not need any interact with the mobile application in order to collect data.

5.3 Web Server

5.3.1 The server must be available 24 hours a day with 95% reliability.

5.3.2 The server and database must be able to accept data from over 50 different subjects, each with many devices and sensors.

6 Potential Risks

The primary risks of the project are the loss of captured data and excessive granularity of time-sensitive data captured. It should be noted that in the most extreme failure cases, the system will not cause death or any harm to the individual themselves, only loss of data.

6.1 Loss of Data

The potential for loss of data is a direct consequence of the requirement that a layered architecture be used. This risk stems from having to cache data at each layer and effectively synchronize across potentially unreliable protocols and interfaces.

Specific design decisions relating to data structures and application layer protocols may effectively minimize much of the risk relating to data loss. A realistic testing environment will help to identify many of the challenges that the design will face.

6.2 Poor Data Granularity

The second potential risk is that the data will not be of sufficient detail due to inefficient hardware or software design. One of the key requirements of the project is that the data be collected at a minimum rate. Below this rate, the data has little value to the project.

Focusing on software efficiency will be essential in allowing the hardware to meet the data granularity needs of the project.

6.3 Lag in Data Availability

Another potential risk is that the data is not transferred in a timely manner. More specifically, the cost of the delay in transmitting data across the layers of the architecture outweigh the benefits of an automated system. If a researcher goes to analyze the data just collected and cannot do so, the system is a critical failure as the researcher would likely bypass the system by physically remove the storage device on the wearable device.

To mitigate this risk, the sponsor has suggested the use of a a 32-bit microcontroller at a higher operating frequency. Other design decisions regarding data storage structure and network application layer protocols can provide increased transmission efficiencies and speed.

6.4 Data Inaccuracy

Many sources of inaccuracy exist in the data collection including unsynchronized devices and poorly calibrated sensors. Time synchronization prevents wearable devices from being used in tandem. Sensors can be poorly calibrated at the physical, hardware and software levels resulting in excessively noisy data.

6.5 Other Risks

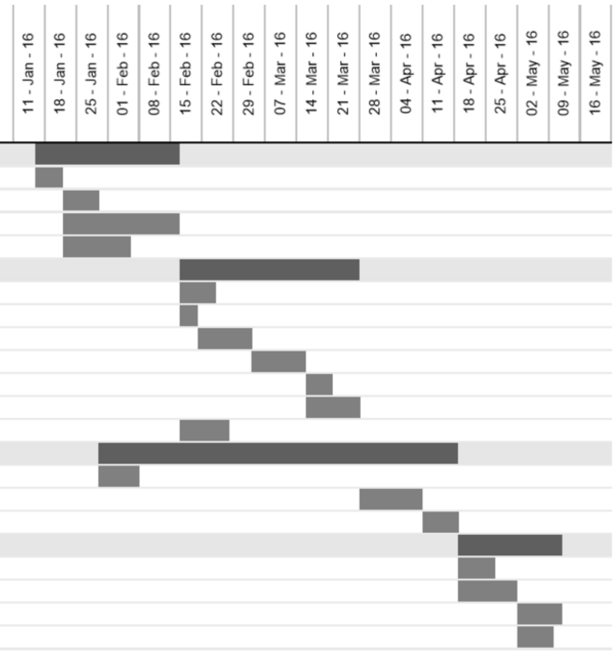
Many other risks exist that have not been identified here including the ability of the database to handle billions of rows of data, the ability to effectively distribute the mobile application to different devices and poor hardware design choices.

7 Project Plan

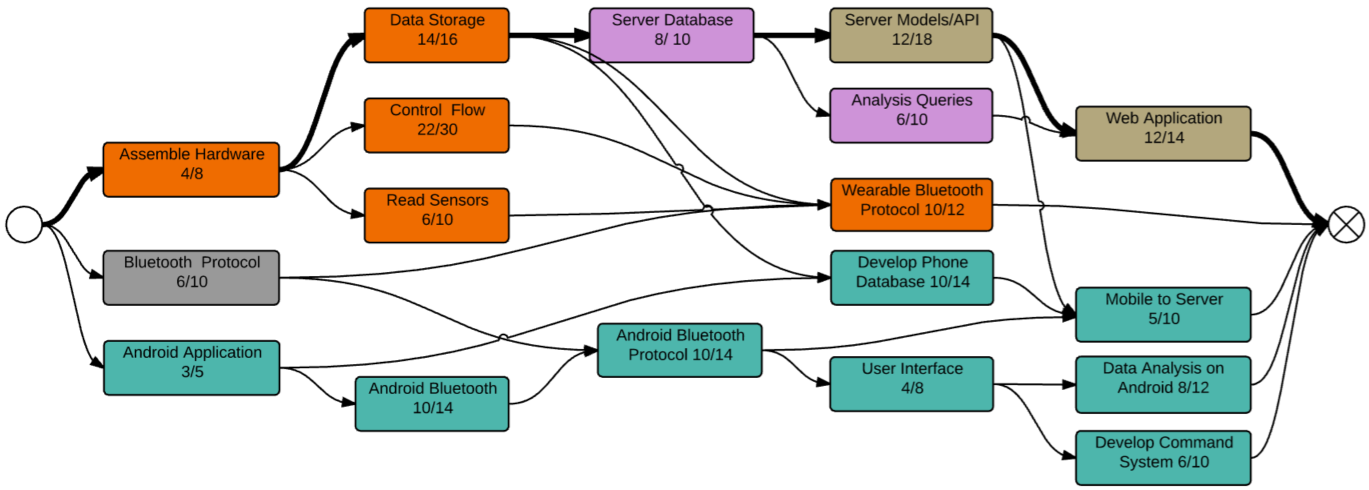
The basic outline of the projects development plan follows along with the system itself. Development of the project will start at the wearable device. Without the ability collect data to be able to send it through the system, there is no way to develop the other pieces of the system, and address problems or concerns that will arise. Therefore, development of the wearable device and android application will start concurrently at the beginning of next semester. Once either the wearable device, or android application are nearing completion, team members will transition to the web server and database to begin allowing data to be transferred from the application to the database. Once the entire system is developed (from the wearable device to the web server), the entire team will begin working on the analysis tools. Only once the system can retrieve data, and it is confirmed to be reliable, can proper work on the analysis tools begin.

The schedule laid out below has the crucial pieces of the system organized in the manner of when they will be worked on, and completed. Each section tries to blend into the next, in order to allow the team to move on to the next piece while leaving behind a working part of the system. It also allows pieces of the system to be very cohesive. It is also important to allow ample time for testing and any necessary re-factoring. Lastly, each piece is designed around the idea of having a two week sprint cycle, while bigger and more challenging pieces have a three week sprint.

WBS	Tasks	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	**Milestone 1 (Hardware Level)**	1/16/16	2/16/16	32	0%	22	0	32
1.1	Assemble Hardware	1/16/16	1/21/16	6	0%	4	0	6
1.2	Develop Sensor Reading Capability	1/22/16	1/29/16	8	0%	6	0	8
1.3	Develop Control of Workflow	1/22/16	2/16/16	26	0%	18	0	26
1.4	Develop Hardware Data Strucutre/SD	1/22/16	2/5/16	15	0%	11	0	15
2	**Milestone 2 (Mobile Application Level)**	2/17/16	3/27/16	40	0%	28	0	40
2.1	Design Application Protocol for Bluetooth	2/17/16	2/24/16	8	0%	6	0	8
2.2	Develop Android Application Frame	2/17/16	2/20/16	4	0%	3	0	4
2.3	Develop Android Bluetooth Compatability	2/21/16	3/3/16	12	0%	9	0	12
2.4	Implement Application Protocol into Android Application	3/4/16	3/15/16	12	0%	8	0	12
2.5	Develop User Interface	3/16/16	3/21/16	6	0%	4	0	6
2.6	Develop Phone Database	3/16/16	3/27/16	12	0%	8	0	12
2.7	Implement Hardware Into Wearable Device	2/17/16	2/27/16	11	0%	8	0	11
3	**Milestone 3 (Web Server Level)**	1/30/16	4/18/16	80	0%	56	0	80
3.1	Develop Server Database	1/30/16	2/7/16	9	0%	5	0	9
3.2	Develop Server API	3/28/16	4/10/16	14	0%	10	0	14
3.3	Develop HTTP Format	4/11/16	4/18/16	8	0%	6	0	8
4	**Milestone 4 (Data Analysis Level)**	4/19/16	5/11/16	23	0%	17	0	23
4.1	Develop Anlysis Queries/Tasks	4/19/16	4/26/16	8	0%	6	0	8
4.2	Integrate into Web Application	4/19/16	5/1/16	13	0%	9	0	13
4.3	Develop Analysis on Android	5/2/16	5/11/16	10	0%	8	0	10
4.4	Develop Command System	5/2/16	5/9/16	8	0%	6	0	8



		Start Day		
	Days	Earliest	Latest	Slack
Wearable Device				
Assemble Hardware	6	0	0	0
Data Storage	15	6	6	0
Control Flow	26	6	21	15
Read Sensors	8	6	39	33
Bluetooth Protocol	11	32	47	15
Design				
Bluetooth Protocol	7	0	23	23
Mobile Device				
Android Application	4	0	14	14
Android Bluetooth	12	4	18	14
Android Bluetooth Protocol	12	16	30	14
Mobile Database	12	21	38	17
Mobile to Server	8	45	50	5
User Interface	6	28	42	14
Data Analysis on Mobile	10	34	48	14
Command System on Mobile	8	34	50	16
Server and Database				
Server Database	9	21	21	0
Analysis Queries	8	30	37	7
Server Models/API	15	30	30	0
Web Application	13	45	45	0



Data Storage 14/16
Server Database 8/ 10
Server Models/API 12/18
Control Flow 22/30
Analysis Queries 6/10
Web Application 12/14
Assemble Hardware 4/8
Read Sensors 6/10
Wearable Bluetooth Protocol 10/12
Bluetooth Protocol 6/10
Develop Phone Database 10/14
Mobile to Server 5/10
Android Application 3/5
Android Bluetooth Protocol 10/14
User Interface 4/8
Data Analysis on Android 8/12
Android Bluetooth 10/14
Develop Command System 6/10