SafeStride

10.20.2017

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Abstract

In the United States alone, approximately 6.5 million citizens are using either a cane, crutches, or walker for assistance with their mobility. In many cases, people are using the wrong device, or using it incorrectly without knowing it. A cane is meant to bear only twenty percent of the user's weight and has a specific height and angle of incidence when it is most effective. SafeStride wants to tackle this problem by designing a cane that constantly measures the cane's state of motion and the user's grip strength.

Project Description

Our goal at SafeStride is to design a cane that can record and collect data to determine if the cane is being used safely and efficiently. This data will be easily accessible through a Bluetooth application, allowing for real time evaluation by a medical professional. Additionally, SafeStride seeks to collect long-term data that is tailored to medical researchers. The measurements of force, velocity, angle, and a pressure map of the grip will be used to analyze if a person is holding the cane correctly, putting too much pressure, too little pressure, and even pressure in the wrong area. In addition, we want the cane to resemble a typical cane as closely as possible; this means that our design must be low-maintenance and require minimum effort from the user.

<u>The Handle</u>

The handle will contain several printed circuit boards (PCBs) designed to measure the varying resistance of a conductive fabric that is proportional to pressure applied in various locations along the board. These voltages detected at various points around the handle will be multiplexed and sent to the microcontroller in the center of the cane. The handle will also be monitored for the purpose of waking the system from sleep mode.

The Center

The center of the cane will contain a PCB that is the processing and communication hub, which includes the microcontroller (uC), Bluetooth Low Energy (BLE) module, inertial measurement unit (IMU), and power monitoring system. The battery and charging peripherals will also be located in the center of the cane.

Microcontroller - A PIC32MM will be the microcontroller used for the project. It provides an optimal combination of computation ability and low power consumption. The microcontroller is responsible for collecting all data and sending it to the BLE module in addition to detecting conditions for entering or exiting sleep mode.

Power System - An 18650 Lithium Ion battery that combines low form factor and large capacity will be used to power the cane. A coulomb counter will be used to monitor the charge entering the battery as well as the charge consumed by the system. A combination of coulomb counting and monitoring battery voltage will be utilized to determine the state of charge. When the charge is dangerously low, the system will enter a deep sleep state and consume virtually no power, ensuring the battery cannot be damaged.

Inertial Measurement Unit - The IMU provides nine degrees of freedom, allowing for precise monitoring of the cane's state of motion. The measurements obtained from the IMU are angular acceleration, angular velocity, and angular position - each with respect to three axes.

The Base

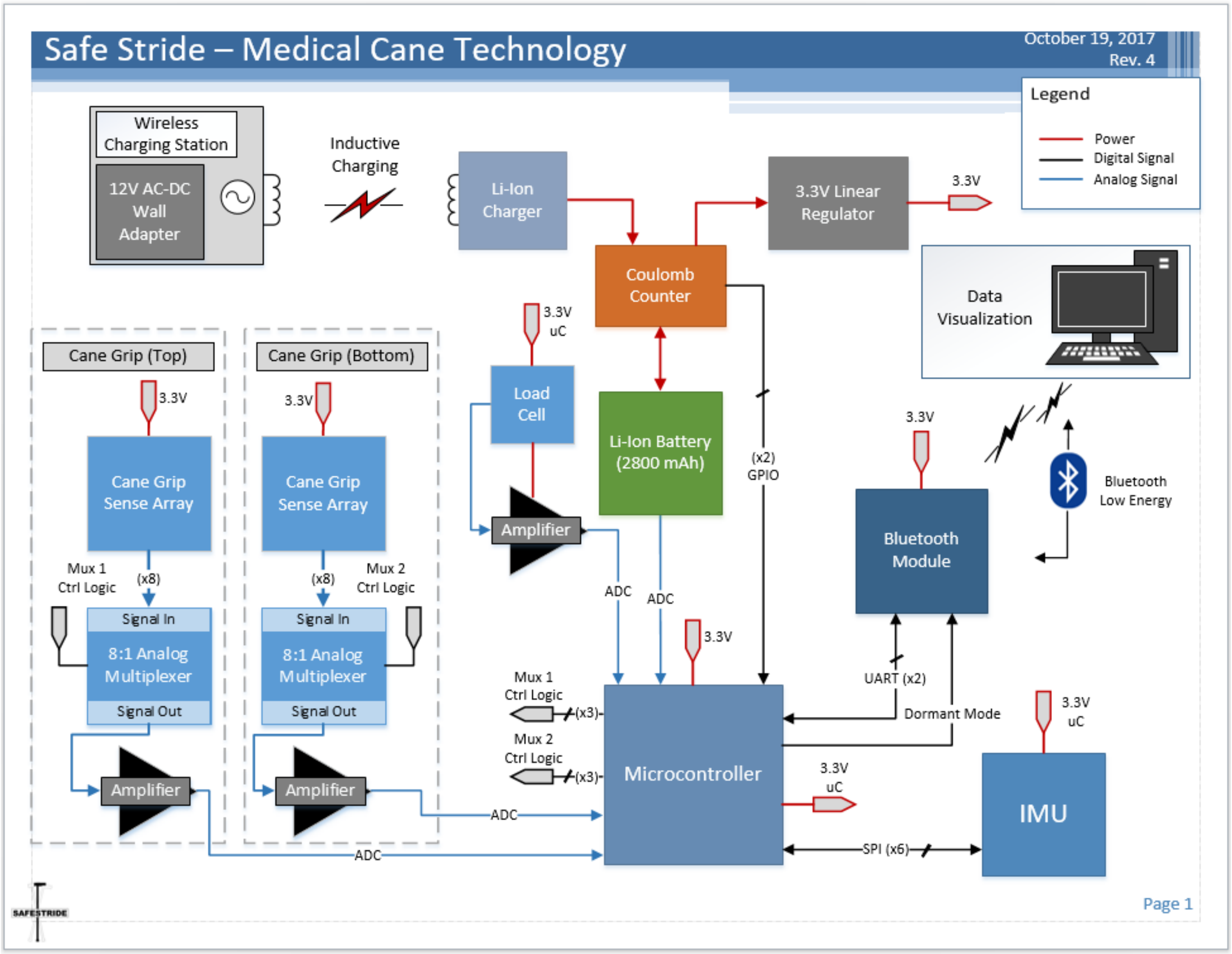
The base of the cane will contain the wireless charging unit for ease of use along with the load cell for downward force measurements. The load cell is another important component that indicates whether the user is applying the appropriate amount of weight on the cane. The load cell will be routed to the central PCB for processing and the inductive charging coil will be routed to the battery charging system.

Visualization

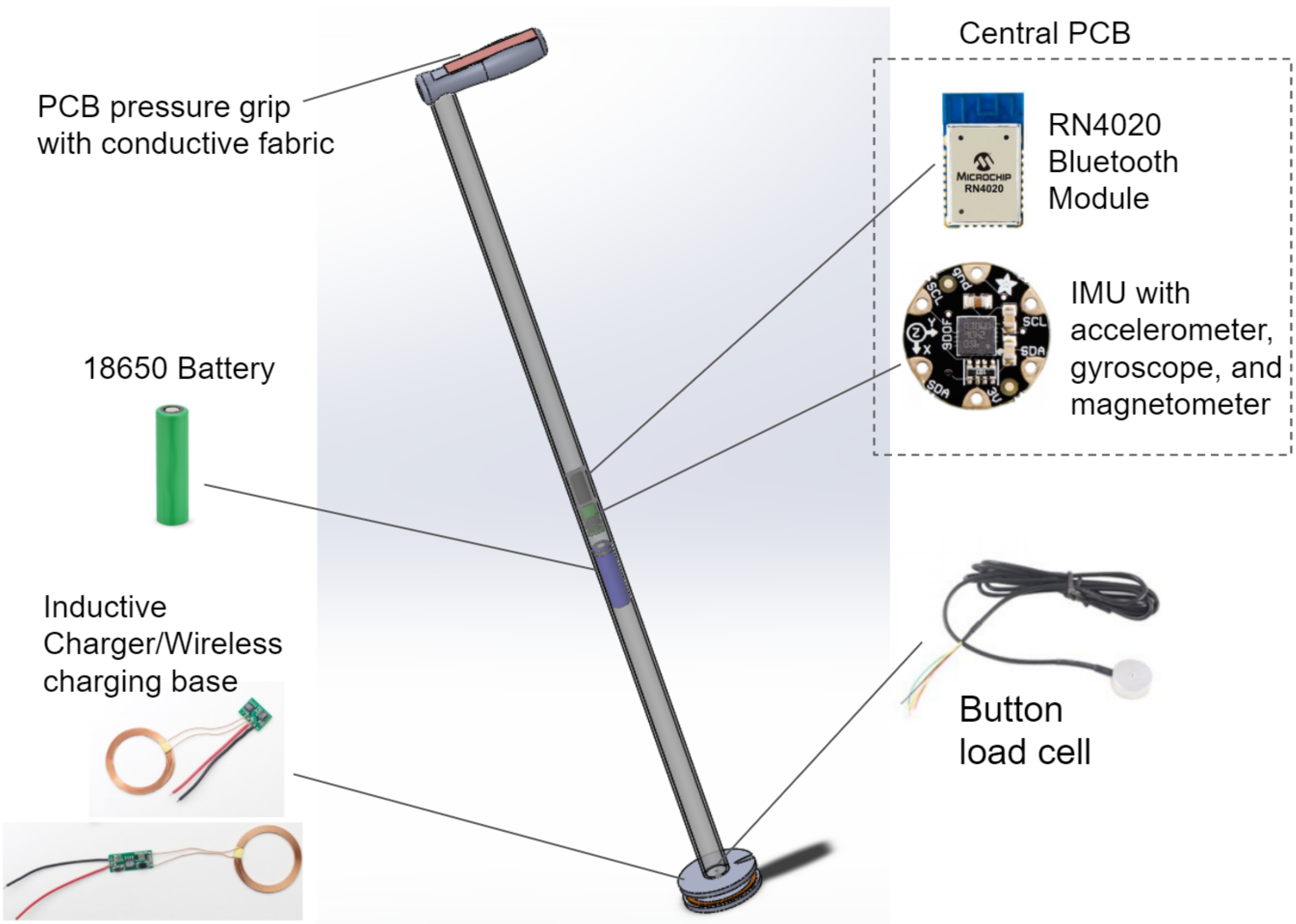
Data visualization is another important component of the SafeStride project. Force measurements, IMU data, and handle force sensing will all be displayed in an intuitive graphical display. The display application will also be configured to allow the user to playback data that has been logged to a file, allowing for detailed analysis of certain events or time periods.

The display will feature gauges for force, a moving 3D representation of the cane to represent IMU data, and displays for the bottom and top grip that use color to represent grip intensity with respect to position.

Block Diagram



Mock-Up Illustrations



Performance Requirements

1. Load Cell Accuracy Requirement
    a. The load cell should meet the accuracy requirement of 1 pound.
2. Data Rate Requirements
    a. Grip position and intensity, IMU readings (9 degrees of freedom), battery voltage, and the force applied to the load cell should be updated at a constant rate, and a minimum of 50 Hz.
3. Grip Requirements
    a. Grip should be able to map position of all fingers on the handle and the respective relative pressure applied.
    b. Grip should be able to map the force distribution of the user's palm on the cane's handle.
    c. Data should not show any signs of noise. All irregularities or erratic measurements should be handled by hardware of software.
    d. All readings should be proportional to grip applied by user.
        i. Since this is not easily measurable, it will be dictated by an outside user's satisfaction with the device's response according to requirement 3-d.
4. Data Visualization Requirements
    a. A Bluetooth Low Energy connection should be established between the cane and display computer such that the information mentioned in requirement 2 is consistently updated at a minimum rate of 50 Hz.
    b. The visualization should include gauges and numerical displays of all parameters mentioned in requirement 2.
        i. IMU data should be displayed by means of rotating 3d model.
        ii. Grip data should be displayed by means of color on relative handle position varying with intensity and position.
5. Fall Detection Requirements
    a. Cane should create an alert and indicate on the display if the user has fallen while using the cane.
    b. Cane should not create an alert if it has merely been dropped.

Testing Procedures and Benchmarks

1) **Grip Interface**

   To test the grip we will need to walk with the cane and apply various amounts of pressure. Assuring that we test all the different pressure pads across the top of the handle.

   Benchmark: The data is shown on our visualization tool with the correct amount of pressure applied at the right locations.

2) **Load Cell**

   Testing the load cell will be done by walking with the cane and applying different amounts of weight to the cane. Also applying different weighted objects on top of the cane. First weighing the object then putting it on top of the cane.

   Benchmark: The amount of weight applied is correctly represented on our visualization tool with a +/- 1 pound difference.

3) **IMU**

   Can be tested by simply walking with the cane. We will also just tilt and move the cane around every direction to test it can read every direction.

   Benchmark: The cane is properly displayed as a 3D model on the PC and is moving with the same orientation as the cane.

4) **Charging & Power Consumption**

   Tested by draining the battery in the cane and then placing it on the charging pad**.** Let the cane constantly send data as long as the battery is at a safe level.

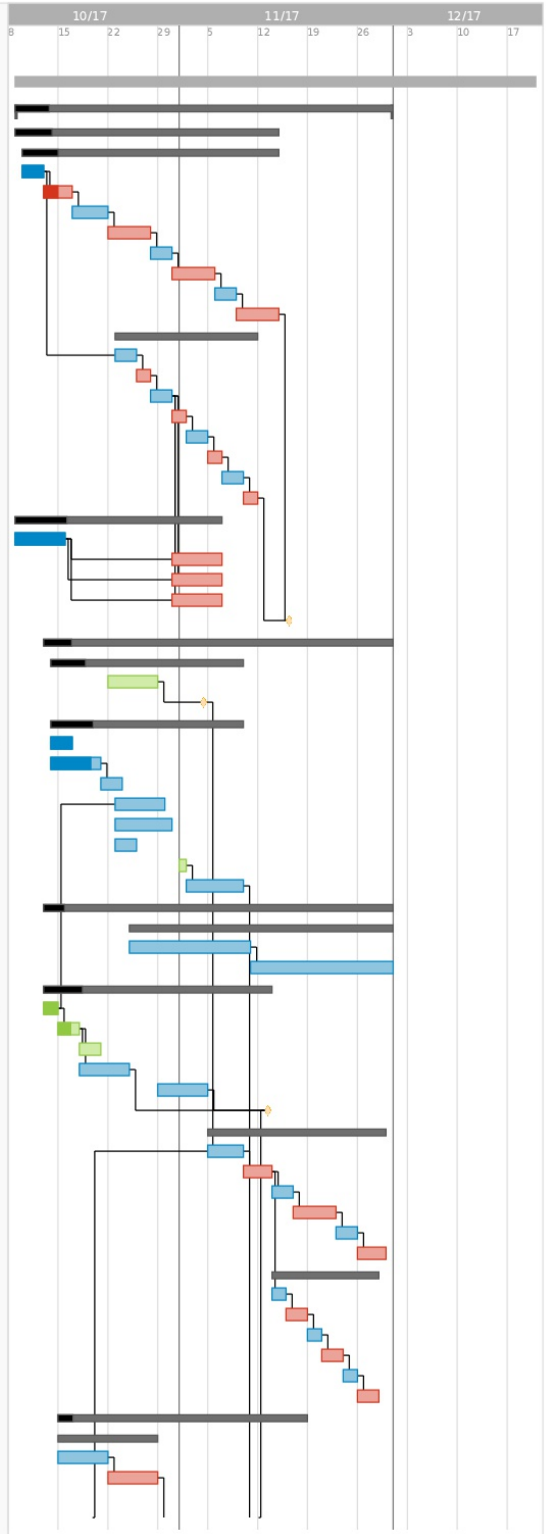
   Benchmark: Check to make sure battery is fully charged. The fully charged cane should be able to remain active for a minimum of 96 consecutive hours.

5) **Sleep Mode**

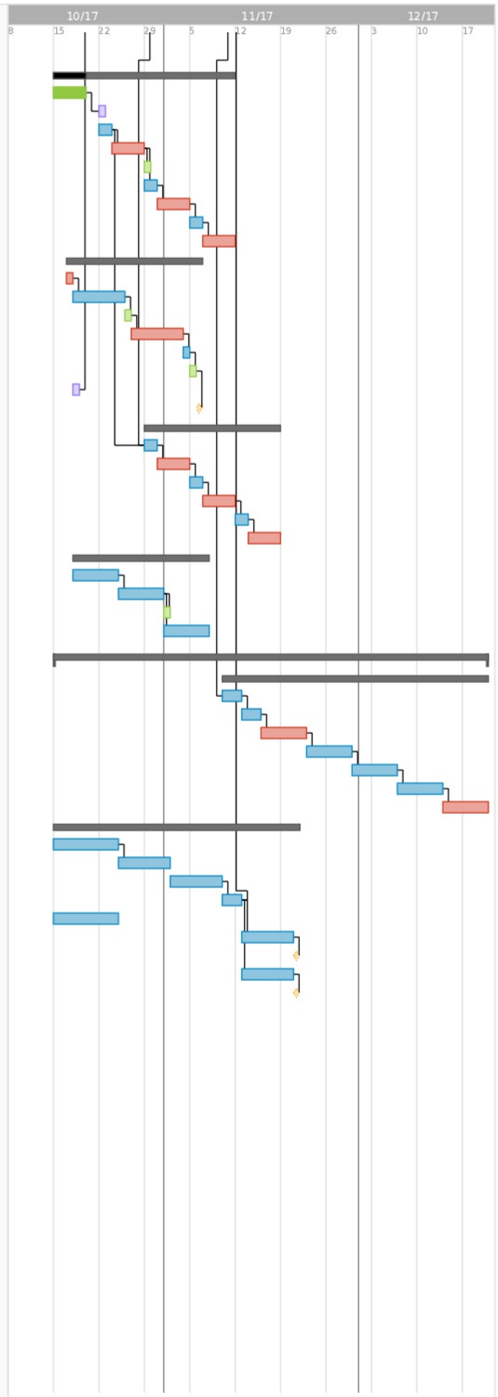
   Tested by simply picking up and applying pressure to the grip.

   Benchmark: Should wake up after applying pressure to the grip. Should fall asleep after no data is read after 30 seconds.

Safe Stride	start	end	0h	7%
CANE	10/09/17	11/30/17	0h	9%
HANDLE	10/09/17	11/14/17	0h	14%
Test Handle Types (3D Prints)	10/10/17	11/14/17	0h	14%
Revision 1	10/10	10/12	0	100%
Force test	10/13	10/16	0	50%
Revision 2	10/17	10/21	0	0%
Force test 2	10/22	10/27	0	0%
Revision 3	10/28	10/30	0	0%
Force test 3	10/31	11/05	0	0%
Revision 4	11/06	11/08	0	0%
Force test 4	11/09	11/14	0	0%
Test Grip Methods PCB	10/23/17	11/11/17	0h	0%
Print Grip Type 1	10/23	10/25	0	0%
Test Grip Type 1	10/26	10/27	0	0%
Print Grip Type 2	10/28	10/30	0	0%
Test Grip Type 2	10/31	11/01	0	0%
Print Grip Type 3	11/02	11/04	0	0%
Test Grip Type 3	11/05	11/06	0	0%
Print Grip Type 4	11/07	11/09	0	0%
Test Grip Type 4	11/10	11/11	0	0%
Test Grip Materials	10/09/17	11/06/17	0h	25%
Order grip materials	10/09	10/15	0	100%
Test material 1	10/31	11/06	0	0%
Test material 2	10/31	11/06	0	0%
Test material 3	10/31	11/06	0	0%
Final Handle Working	11/16	11/16	0	0%
MIDDLE	10/13/17	11/30/17	0h	8%
Microcontroller Development	10/14/17	11/09/17	0h	18%
Write and verify code for ADC mu...	10/22	10/28	0	0%
Print all sensor inputs via serial p...	11/04	11/04	0	0%
Interface IMU Module	10/14/17	11/09/17	0h	22%
Write and verify SPI exchange ...	10/14	10/16	0	100%
Setup all struct messages for r...	10/14	10/20	0	80%
Create circular buffer for IMU d...	10/21	10/23	0	0%
Read all relevant IMU data and...	10/23	10/29	0	0%
Design packet format(in ASCII ...	10/23	10/30	0	0%
Create circular buffer for ADC ...	10/23	10/25	0	0%
Verify packet format and accur...	11/01	11/01	0	0%
Implement sleep mode state m...	11/02	11/09	0	0%
Bluetooth	10/13/17	11/30/17	0h	6%
Bluetooth Software	10/25/17	11/30/17	0h	0%
Pair computer to BLE module u...	10/25	11/10	0	0%
Modify example UWP App to re...	11/11	11/30	0	0%
Interfacing with BLE Module	10/13/17	11/13/17	0h	17%
Verify code for UART transmit ...	10/13	10/14	0	100%
Verify UART communication wi...	10/15	10/17	0	60%
Verify wire replacement functi...	10/18	10/20	0	0%
Write functions to configure all...	10/18	10/24	0	0%
Write function to load IMU & A...	10/29	11/04	0	0%
Receive sent Bluetooth data on...	11/13	11/13	0	0%
PCB Prototyping	11/05/17	11/29/17	0h	0%
PCB Proto Circuit 1	11/05	11/09	0	0%
Test Circuit 1	11/10	11/13	0	0%
PCB Proto Circuit 2	11/14	11/16	0	0%
Test Circuit 2	11/17	11/22	0	0%
PCB Proto Circuit 3	11/23	11/25	0	0%
Test Circuit 3	11/26	11/29	0	0%
Print Middle Container Section	11/14/17	11/28/17	0h	0%
Print Middle Container Section 1	11/14	11/15	0	0%
Test Middle Container Section 1	11/16	11/18	0	0%
Print Middle Container Section R...	11/19	11/20	0	0%
Test Middle Container Section 2	11/21	11/23	0	0%
Middle Container Section Rev 3	11/24	11/25	0	0%
Test Middle Container Section 3	11/26	11/28	0	0%
BASE	10/15/17	11/18/17	0h	6%
Rubber Foot	10/15/17	10/28/17	0h	0%
Order 3 Variations of Rubber Feet	10/15	10/21	0	0%
Test and Select Foot	10/22	10/28	0	0%



Task	Start	End	Hours	Complete
Loadcell	**10/15/17**	**11/11/17**	**0h**	**18%**
Verify load cell circuit performan...	10/15	10/19	0	100%
Create load cell schematic sheet	10/22	10/22	0	0%
Create Loadcell Housing 1	10/22	10/23	0	0%
Test Loadcell Housing 1	10/24	10/28	0	0%
Choose loadcell location (base or...	10/29	10/29	0	0%
Create Loadcell Housing 2	10/29	10/30	0	0%
Test Loadcell Housing 2	10/31	11/04	0	0%
Create Loadcell Housing 3	11/05	11/06	0	0%
Test Loadcell Housing 3	11/07	11/11	0	0%
Power	**10/17/17**	**11/06/17**	**0h**	**0%**
Test inductive charging perform...	10/17	10/17	0	0%
Modify inductive charging setup	10/18	10/25	0	0%
Verify inductive charging perfor...	10/26	10/26	0	0%
Test 2 of inductive charging perf...	10/27	11/03	0	0%
Modify inductive charging setup	11/04	11/04	0	0%
Verify inductive charging perfor...	11/05	11/05	0	0%
Create power schematic sheet	10/18	10/18	0	0%
Power System Working	11/06	11/06	0	0%
3D Printed Parts	**10/29/17**	**11/18/17**	**0h**	**0%**
Print Base Version 1	10/29	10/30	0	0%
Test Base Version1	10/31	11/04	0	0%
Print Base Version 2	11/05	11/06	0	0%
Test Base Version 2	11/07	11/11	0	0%
Print Base Version 3	11/12	11/13	0	0%
Test Base Version3	11/14	11/18	0	0%
Medical Outreach	**10/18/17**	**11/07/17**	**0h**	**0%**
Research medical applications and...	10/18	10/24	0	0%
Talk to medical professionals	10/25	10/31	0	0%
Revise list of potential medical solu...	11/01	11/01	0	0%
Get an endorsement from medical ...	11/01	11/07	0	0%
VISUALIZATION	**10/15/17**	**12/20/17**	**0h**	**0%**
Fall Detection	**11/10/17**	**12/20/17**	**0h**	**0%**
Create list of expected fall conditio...	11/10	11/12	0	0%
Create an algorithm based on expe...	11/13	11/15	0	0%
Test algorithm, fall detection indica...	11/16	11/22	0	0%
Record data output from all concei...	11/23	11/29	0	0%
Examine loadcell, IMU, grip combin...	11/30	12/06	0	0%
Program findings	12/07	12/13	0	0%
Test algorithm, fall detection outpu...	12/14	12/20	0	0%
Data Output	**10/15/17**	**11/21/17**	**0h**	**0%**
Read serial data into Labview	10/15	10/24	0	0%
Create a Labworks Data Display	10/25	11/01	0	0%
Determine how software can read b...	11/02	11/09	0	0%
Integrate Bluetooth data into displ...	11/10	11/12	0	0%
Select software for data display an...	10/15	10/24	0	0%
Create Data display Rev 1	11/13	11/20	0	0%
Finish Data Display	11/21	11/21	0	0%
Create 3D cane Rev 1	11/13	11/20	0	0%
Finish Cane Display	11/21	11/21	0	0%



Safe Stride

CANE	9%	Start	Due	Assigned
HANDLE	**14%**			
Test Handle Types (3D Prints)	**14%**			
Revision 1	100%	Oct 10, 2017	Oct 12, 2017	
Force test	50%	Oct 13, 2017	Oct 16, 2017	
Revision 2	0%	Oct 17, 2017	Tomorrow	
Force test 2	0%	Sunday	Oct 27, 2017	
Revision 3	0%	Oct 28, 2017	Oct 30, 2017	
Force test 3	0%	Oct 31, 2017	Nov 5, 2017	
Revision 4	0%	Nov 6, 2017	Nov 8, 2017	
Force test 4	0%	Nov 9, 2017	Nov 14, 2017	
Test Grip Methods PCB	**0%**			
Print Grip Type 1	0%	Monday	Wednesday	
Test Grip Type 1	0%	Thursday	Oct 27, 2017	
Print Grip Type 2	0%	Oct 28, 2017	Oct 30, 2017	
Test Grip Type 2	0%	Oct 31, 2017	Nov 1, 2017	
Print Grip Type 3	0%	Nov 2, 2017	Nov 4, 2017	
Test Grip Type 3	0%	Nov 5, 2017	Nov 6, 2017	
Print Grip Type 4	0%	Nov 7, 2017	Nov 9, 2017	
Test Grip Type 4	0%	Nov 10, 2017	Nov 11, 2017	
Test Grip Materials	**25%**			
Order grip materials	100%	Oct 9, 2017	Oct 15, 2017	
Test material 1	0%	Oct 31, 2017	Nov 6, 2017	
Test material 2	0%	Oct 31, 2017	Nov 6, 2017	
Test material 3	0%	Oct 31, 2017	Nov 6, 2017	
Final Handle Working		Nov 16, 2017	Nov 16, 2017	
MIDDLE	**8%**			
Microcontroller Development	**18%**			
Write and verify code for ADC multi-chann	0%	Sunday	Oct 28, 2017	
Print all sensor inputs via serial port using		Nov 4, 2017	Nov 4, 2017	
Interface IMU Module	**22%**			
Write and verify SPI exchange function	100%	Oct 14, 2017	Oct 16, 2017	
Setup all struct messages for	80%	Oct 14, 2017	Today	
Create circular buffer for IMU data (only	0%	Tomorrow	Monday	
Read all relevant IMU data and display i	0%	Monday	Oct 29, 2017	

Design packet format(in ASCII or bit leve	0%	Monday	Oct 30, 2017
Create circular buffer for ADC data (fall	0%	Monday	Wednesday
Verify packet format and accuracy throu	0%	Nov 1, 2017	Nov 1, 2017
Implement sleep mode state machine u	0%	Nov 2, 2017	Nov 9, 2017
Bluetooth	6%		
Bluetooth Software	0%		
Pair computer to BLE module using	0%	Wednesday	Nov 10, 2017
Modify example UWP App to read all ca	0%	Nov 11, 2017	Nov 30, 2017
Interfacing with BLE Module	17%		
Verify code for UART transmit and recei	100%	Oct 13, 2017	Oct 14, 2017
Verify UART communication with BLE	60%	Oct 15, 2017	Oct 17, 2017
Verify wire replacement functionality in	0%	Oct 18, 2017	Today
Write functions to configure all BLE mod	0%	Oct 18, 2017	Tuesday
Write function to load IMU & ADC circula	0%	Oct 29, 2017	Nov 4, 2017
Receive sent Bluetooth data on comput		Nov 13, 2017	Nov 13, 2017
PCB Prototyping	0%		
PCB Proto Circuit 1	0%	Nov 5, 2017	Nov 9, 2017
Test Circuit 1	0%	Nov 10, 2017	Nov 13, 2017
PCB Proto Circuit 2	0%	Nov 14, 2017	Nov 16, 2017
Test Circuit 2	0%	Nov 17, 2017	Nov 22, 2017
PCB Proto Circuit 3	0%	Nov 23, 2017	Nov 25, 2017
Test Circuit 3	0%	Nov 26, 2017	Nov 29, 2017
Print Middle Container Section	0%		
Print Middle Container Section 1	0%	Nov 14, 2017	Nov 15, 2017
Test Middle Container Section 1	0%	Nov 16, 2017	Nov 18, 2017
Print Middle Container Section Rev 2	0%	Nov 19, 2017	Nov 20, 2017
Test Middle Container Section 2	0%	Nov 21, 2017	Nov 23, 2017
Middle Container Section Rev 3	0%	Nov 24, 2017	Nov 25, 2017
Test Middle Container Section 3	0%	Nov 26, 2017	Nov 28, 2017
BASE	6%		
Rubber Foot	0%		
Order 3 Variations of Rubber Feet	0%	Oct 15, 2017	Tomorrow
Test and Select Foot	0%	Sunday	Oct 28, 2017
Loadcell	18%		
Verify load cell circuit performance to	100%	Oct 15, 2017	Yesterday
Create load cell schematic sheet	0%	Sunday	Sunday
Create Loadcell Housing 1	0%	Sunday	Monday
Test Loadcell Housing 1	0%	Tuesday	Oct 28, 2017
Choose loadcell location (base or center)	0%	Oct 29, 2017	Oct 29, 2017
Create Loadcell Housing 2	0%	Oct 29, 2017	Oct 30, 2017

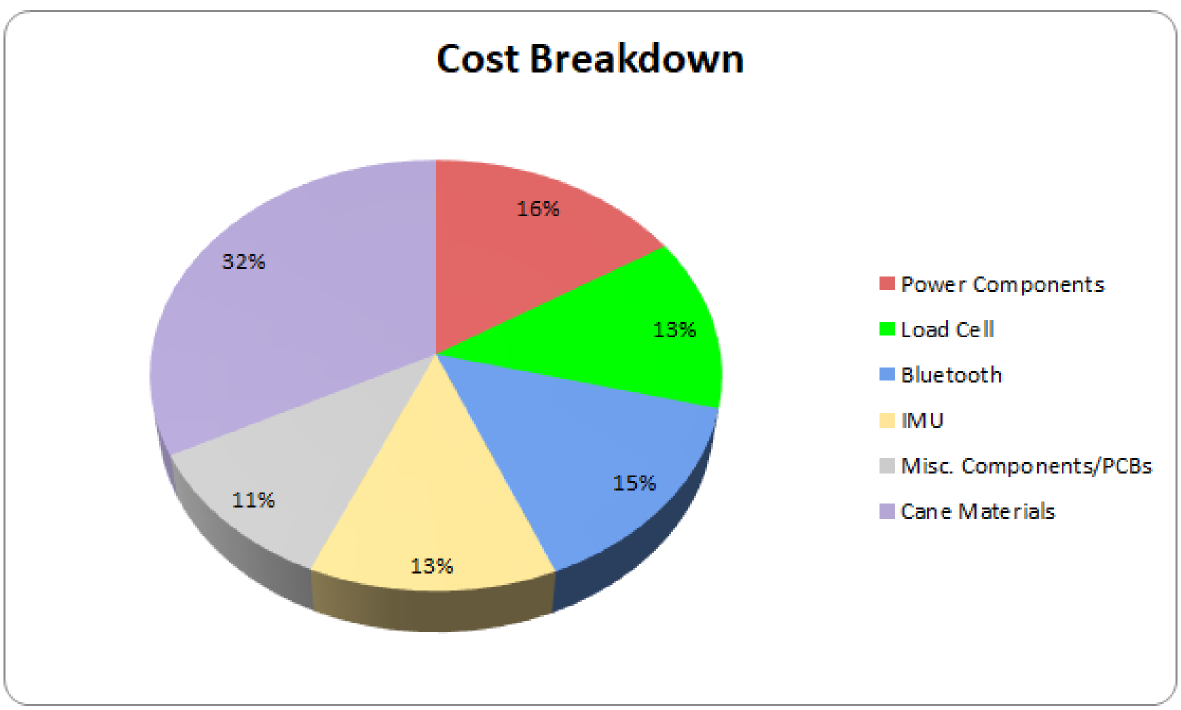
Test Loadcell Housing 2	0%		Oct 31, 2017	Nov 4, 2017	
Create Loadcell Housing 3	0%		Nov 5, 2017	Nov 6, 2017	
Test Loadcell Housing 3	0%		Nov 7, 2017	Nov 11, 2017	
Power	0%				
Test inductive charging performance	0%		Oct 17, 2017	Oct 17, 2017	
Modify inductive charging setup	0%		Oct 18, 2017	Wednesday	
Verify inductive charging performance	0%		Thursday	Thursday	
Test 2 of inductive charging performance	0%		Oct 27, 2017	Nov 3, 2017	
Modify inductive charging setup	0%		Nov 4, 2017	Nov 4, 2017	
Verify inductive charging performance	0%		Nov 5, 2017	Nov 5, 2017	
Create power schematic sheet	0%		Oct 18, 2017	Oct 18, 2017	
Power System Working			Nov 6, 2017	Nov 6, 2017	
3D Printed Parts	0%				
Print Base Version 1	0%		Oct 29, 2017	Oct 30, 2017	
Test Base Version1	0%		Oct 31, 2017	Nov 4, 2017	
Print Base Version 2	0%		Nov 5, 2017	Nov 6, 2017	
Test Base Version 2	0%		Nov 7, 2017	Nov 11, 2017	
Print Base Version 3	0%		Nov 12, 2017	Nov 13, 2017	
Test Base Version3	0%		Nov 14, 2017	Nov 18, 2017	
Medical Outreach	0%				
Research medical applications and create	0%		Oct 18, 2017	Tuesday	
Talk to medical professionals	0%		Wednesday	Oct 31, 2017	
Revise list of potential medical solutions	0%		Nov 1, 2017	Nov 1, 2017	
Get an endorsement from medical	0%		Nov 1, 2017	Nov 7, 2017	
VISUALIZATION	0%		**Start**	**Due**	**Assigned**
Fall Detection	0%				
Create list of expected fall conditions	0%		Nov 10, 2017	Nov 12, 2017	
Create an algorithm based on expected	0%		Nov 13, 2017	Nov 15, 2017	
Test algorithm, fall detection indicated via	0%		Nov 16, 2017	Nov 22, 2017	
Record data output from all conceivable fall	0%		Nov 23, 2017	Nov 29, 2017	
Examine loadcell, IMU, grip combinations	0%		Nov 30, 2017	Dec 6, 2017	
Program findings	0%		Dec 7, 2017	Dec 13, 2017	
Test algorithm, fall detection output in serial	0%		Dec 14, 2017	Dec 20, 2017	
Data Output	0%				
Read serial data into Labview	0%		Oct 15, 2017	Tuesday	
Create a Labworks Data Display	0%		Wednesday	Nov 1, 2017	
Determine how software can read bluetooth	0%		Nov 2, 2017	Nov 9, 2017	
Integrate Bluetooth data into display	0%		Nov 10, 2017	Nov 12, 2017	

Select software for data display and 3D	0%		Oct 15, 2017	Tuesday
Create Data display Rev 1	0%		Nov 13, 2017	Nov 20, 2017
Finish Data Display			Nov 21, 2017	Nov 21, 2017
Create 3D cane Rev 1	0%		Nov 13, 2017	Nov 20, 2017
Finish Cane Display			Nov 21, 2017	Nov 21, 2017

View in Gantt

Cost Analysis

Category	Item	Unit Cost	Qty	Ext. Cost
Power Components	Batteries	$5.00	2	$10.00
	Battery Chargers	$7.95	1	$7.95
	Inductive Charging	$10.00	3	$30.00
	Coulomb Counter IC	$3.64	2	$7.28
	Coulomb Counter Breakout	$12.95	1	$12.95
	3.3V Regulator	$2.32	3	$6.96
Load Cell	Load Cell	$45.00	1	$45.00
	Instrumentation Amp	$5.12	3	$15.36
BLE	Bluetooth Module	$10.60	2	$21.20
	Bluetooth Dongle	$10.45	2	$20.90
	Alternative Bluetooth Module	$13.49	2	$26.98
IMU	Inertial Measurement Unit	$19.95	3	$59.85
Components / PCBs	DIP Microcontrollers	$1.68	5	$8.40
	Surface Mount Microcontrollers	$1.63	10	$16.30
	Multiplexers	$0.47	5	$2.35
	ADC Amplifiers	$1.04	4	$4.16
	Professional PCB (set of 3)	$20.00	1	$20.00
Cane Materials	Force Fabric	$12.95	3	$38.85
	3d Printed Material	$18.00	1	$18.00
	Aluminum Pipe	$20.00	1	$20.00
	Various End Cap Options	$5.00	3	$15.00
	Various Silicone Materials (Grip)	$10.00	2	$20.00
	Various Neoprene Materials (Grip)	$10.00	2	$20.00
	Various Foam Materials (Grip)	$10.00	2	$20.00
				$467.49



FALL DETECTION/ALERT
CANE MOVEMENT ANALYSIS
GRIP/WEIGHT SENSORS
WIRELESS CHARGER
TEAM ENGINEERS:
Ali AlShatti
Scott Szafranski
Yousef Alsharef
Jared Thomas
Kirk Anderson
Chris Nolan Alagar
Richard Sioson
A cane with fall detection, wireless data analysis of cane usage, and wireless charging. Never walk alone.
SAFESTRIDE
SPONSORED BY:
John Kennedy