

MIMS FINAL PROJECT
PROF. JOHN CHUANG

TEAL ALERT

FALL AND CONSCIOUSNESS DETECTION

By Jeanie Oh, Divya Garg, Lynell Amanna

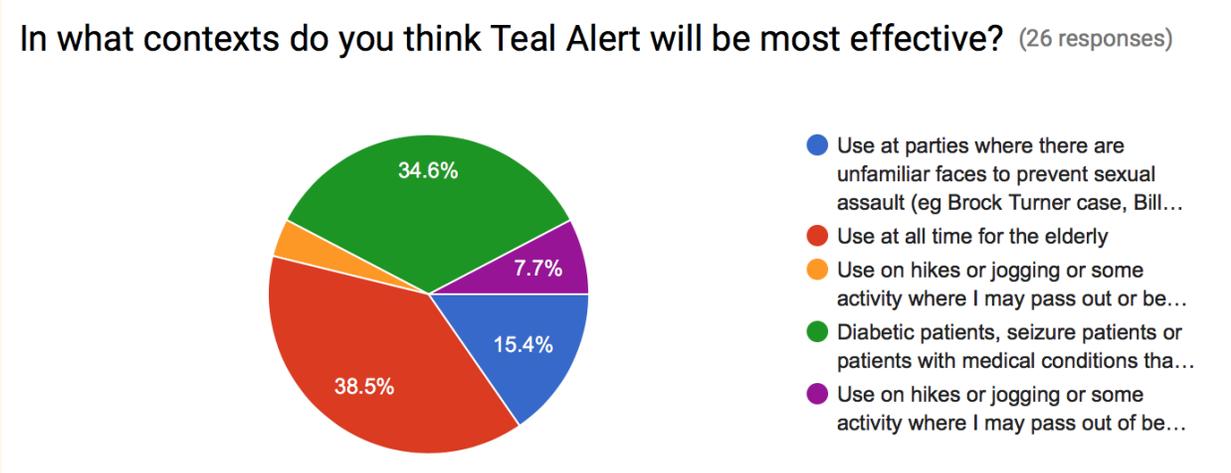


INTRODUCTION

Teal Alert is an app compatible with any device that contains an accelerometer with the purpose of alerting a designated loved one or caretaker in the event of losing consciousness due to a fall. Losing consciousness can be due to alcohol abuse, drug abuse, diabetic shock, falling or other hazards. The alert sends a text to your designated partner/parent with your location on Google Maps so that you can be reached and be rescued from harms way if need be.

User research

According to the National Council on Aging in America, “One-fourth of Americans aged 65+ falls each year. Every 11 seconds, an older adult is treated in the emergency room for a fall; every 19 minutes, an older adult dies from a fall. Falls are the leading cause of fatal injury and the most common cause of nonfatal trauma-related hospital admissions among older adults.” Incidentally, according to our survey research, the most appropriate application of our device appears to be for the elderly population as shown by the below results.

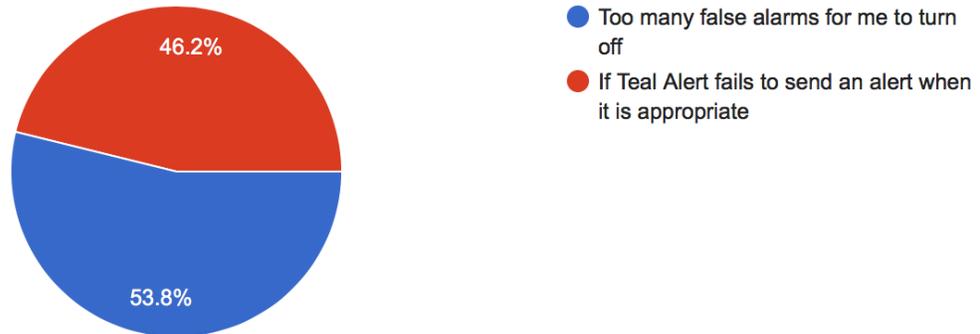


As a consequence, the usage of our product by the rest of the survey was related to the conceived usage of our app as a device that primarily assists the elderly. For example, the simple design decision for the usage of our device as an app that is constantly running in the background versus an app that is only used for specific periods of time unanimously leaned in favor of using our app as one that is constantly running in the background. Because there was such a wide range of possible use cases for an app that can detect unconsciousness, responses to our survey helped greatly in terms of narrowing down the most effective prospective use for our product.

One of the most significant insights we received in terms of user behavior for our product was with regard to false positives versus false negatives. In terms of practicality, false negatives are far more pernicious to the user, however in terms of usability and the likelihood of adoption, our gut hunch that false positives are more influential was confirmed by the below result.

Before broadcasting an alert to your friends, Teal Alert allows you 10 seconds or more to intervene and turn off the alert if it is a false alarm. Given this feature, which would make you more likely to STOP using Teal Alert

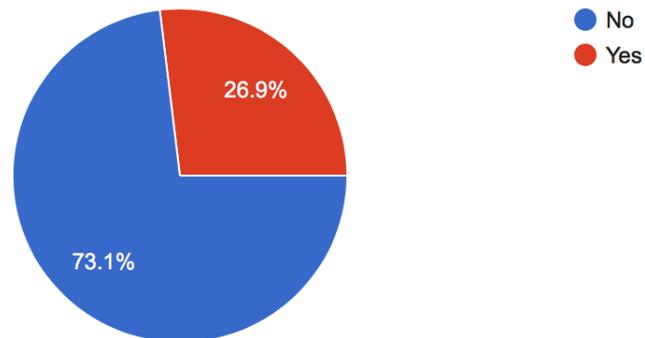
(26 responses)



The last question was positive in that over a quarter of all respondents expressed a need for our product if offered on the market.

Have you ever been in a situation where you might have appreciated an app like Teal Alert?

(26 responses)



User Segments

Based on the user research that we conducted, we found that our **target** user segment is the **Elderly people** who are above 65 years old.

Elderly care - There are risks associated with daily activities such as climbing stairs or taking showers that may end up in a bad fall but there are also other risks such as stroke or heart attacks.

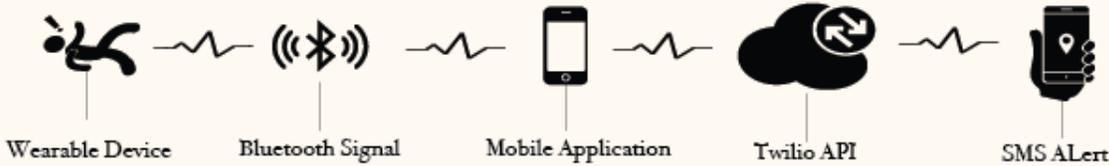
For every hour that a stroke victim is not given medical attention, the risk of losing imperative functions such as speech and hearing increase exponentially. Teal alert addresses this fear by giving an alert to a designated loved one in such an event.

However, we understand that the applications of this device are numerous and possibly life-saving in every case. We have identified two more target segments, who we can address in the **future** as our product continues to grow.

Protection for Women - in the case of the famous Brock Turner rape and many others like it, the opportunity for violence happens when women have lost consciousness and are not able to be located by friends or family. Drugs that induce unconsciousness have been reportedly used by fraternities and at parties in general on the college campuses across the nation. Teal Alert can offer women an option when worn to parties to alert their loved ones if, for some reason, they fall become unconscious.

Protection while hiking or jogging- Our product can be used on-demand in situations where people go for jogging or hiking where there is a threat of accidental fall or unconsciousness. Teal Alert would send the alert with the location details to the designated partner who in turn can reach out to emergency centers and take other appropriate actions.

System Design



The above flow depicts the sequence of events that the system is made up of. The method used for detection is threshold based.

1. Wearable Device

For the purpose of this project we have decided on using the Metawear Ambient sensor. The sensor, being approximately the size of a quarter allows for easy placement of the sensor on the body or strapped on to the wrist to be worn as a watch-like device. We decided on using accelerometer data to detect falls and

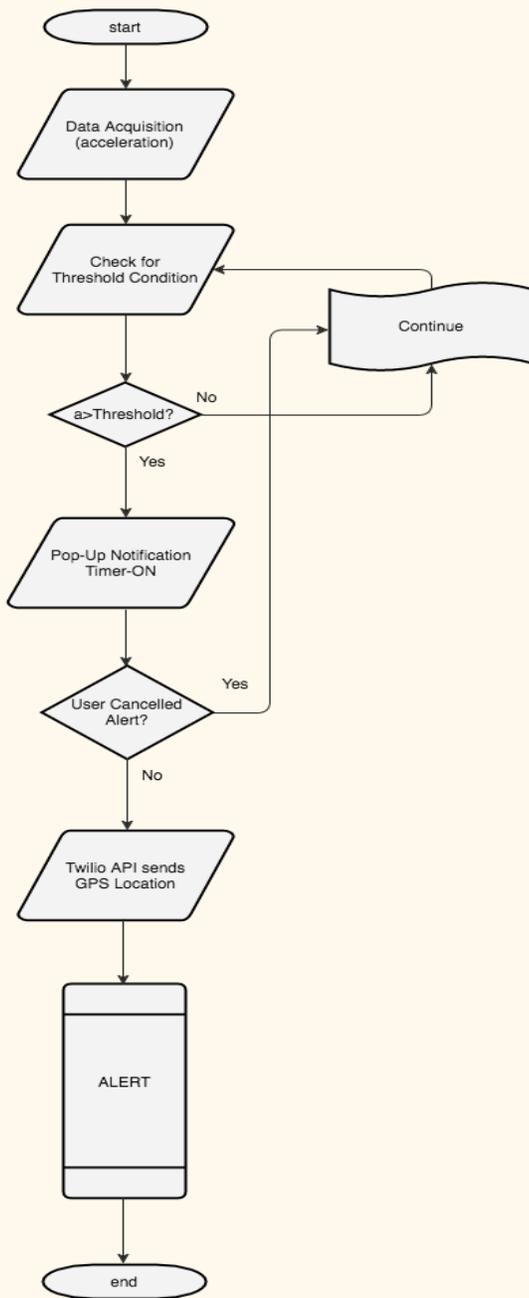
eventually consciousness. We use a Triaxial Accelerometer which records the acceleration of the object in 3 directions viz. X, Y, Z positions with the influence of gravity. The data on the sensor is sampled at 50Hz.

2. Bluetooth Data Transfer

The sensor device used for this project is fitted with bluetooth capability used to transmit data from the accelerometer readings of the user to an external device where computations can be performed. The sensor also has its own data storage capability which is limited.

3. Mobile Application : Teal Alert

The application 'Teal Alert' is built for IOS devices using Swift. The data is received using bluetooth for each of the three axes. Once the computation is complete, the value is compared against a threshold condition, if the condition satisfies the condition for a fall, the latitude and longitude of the recorded user is sent to a second file that contains code that uses the Twilio API to send out a the alert.



4. Twilio API

A second file (coded in Python) is used to send out the SMS alert. Once the latitude and longitude data is received, the code uses Google API to accurately determine the address of the individual under distress.

5. SMS Alert

The API uses a mobile network to send a text alert to the designated partner.

State Diagram

The diagram on the left displays the flow of the system.

When the sensor is in the ON mode accelerometer data is gathered for the user.

This data is then transmitted to the cell phone connected to the sensor to check for the threshold condition.

If the vector sum of the data recorded at each instance of time is less than the threshold set for fall detection, the data acquisition continues.

If the vector sum of the data recorded is greater than the threshold set, an instant notification is sent to the user on the mobile device.

The notification includes the a check for whether the fall was detected accurately or not. This condition was included to avoid false positives or reduce its occurrence.

The notification consists of a cancel button, which rejects the alert. If the user cancels the alert, no message is sent and the state of the system goes back to data acquisition.

If no action is taken by the end of the timeout, the application sends the latitude and longitude data to the secondary code file which uses the Twilio API to send out an SMS alert along with the GPS location of the user wearing the sensor, to the designated partner.

Application Design

The motivation for this project started with the detection of unconsciousness and intoxication. In keeping with the initial motivation for the project we decided to address a more specific problem. The application now supports fall detection followed by no movement.

Application Walkthrough

On starting the application, the home page includes the project icon, the design for the icon directly ties into the goal for the project which is a life ring, allowing users to send an SOS or a distress signal to a designated partner.

Before connecting to the sensor (Metawear) the bluetooth on the device needs to be turned ON. The user must enter the information required for the designated partner. Once the available sensors show up on the screen, the user can click on the respective one. A button to start the application data transfer will be seen. On clicking the button, the data begins to stream from the sensor to the application on the phone.

The bluetooth on the phone must be ON at all times during the data streaming and the sensor must be within the required bluetooth range for smooth functioning.

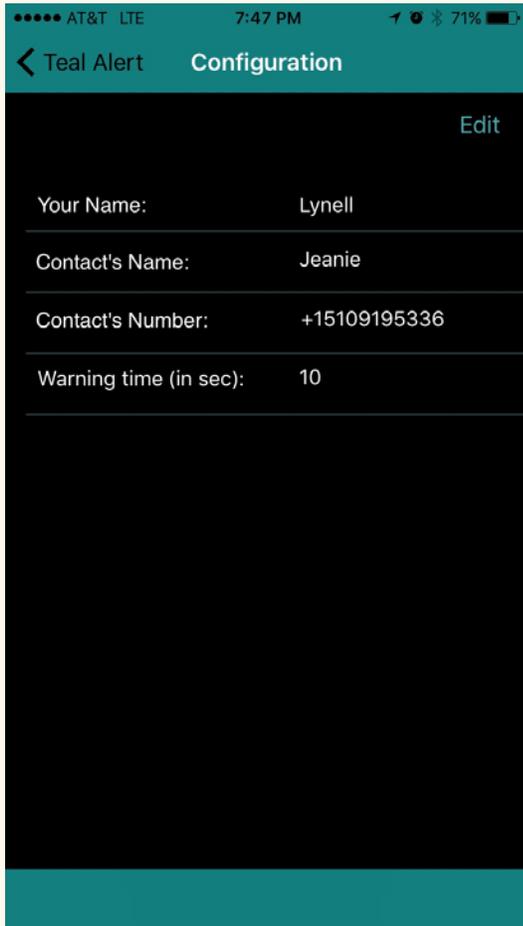
If the user experiences a fall, the algorithm on the application will trigger a set of tasks (will be discussed in detail in coming sections). If all conditions are triggered, the application triggers a pop up notification the user's phone. Allowing the user to dismiss a false alarm. The application is set to begin a countdown when the notification is displayed. The user must choose to cancel a false alarm before the timer times out. If no action is performed, the application sends an SOS signal to the designated partner.

Saved Devices +



MetaWear >

Add a MetaWear device to get started! >

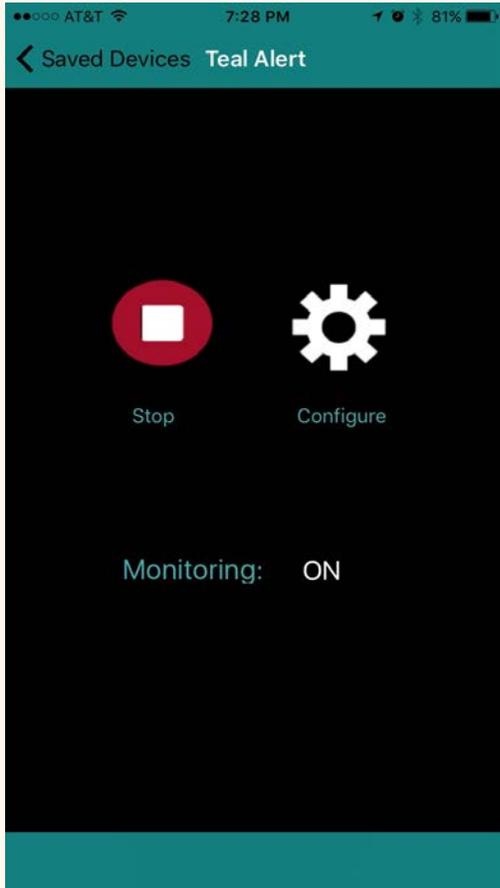


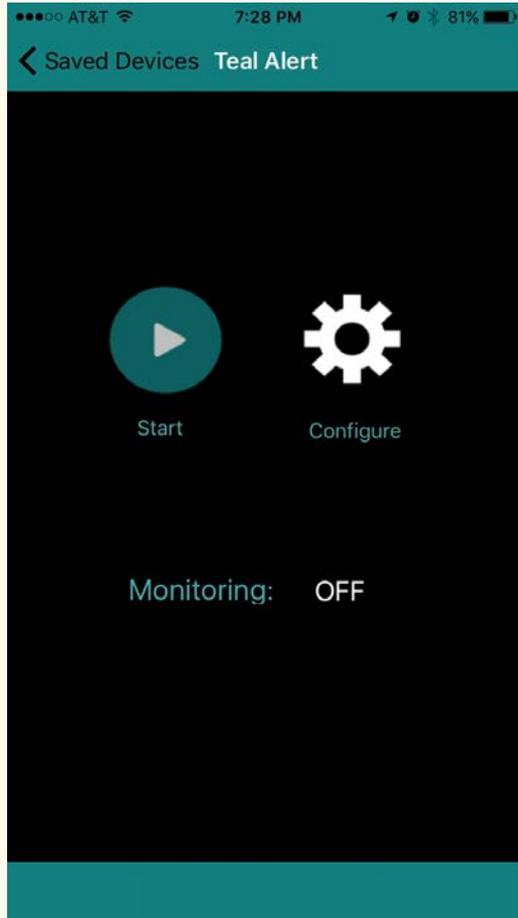
●●●● AT&T 7:28 PM 81%

< Teal Alert Configuration

Your Name:	Lynell
Contact's Name:	Jeanie
Contact's Number:	+15109195336
Warning time (in sec):	10

Save Cancel





Concept Design

Fall Detection

Two possible approaches were considered for the fall detection.

The First Approach - Machine Learning.

While machine learning was an interesting path to consider, the data received from the sensor consisted of purely accelerometer data for each axis orientation (X, Y and Z) depending on how the sensor was worn and which direction it was placed. Although machine learning as a concept is a robust approach, the accuracy for this methodology is relatively low. Considering the purpose and goal of the project, a lenient model was would not suffice.

Another issue we faced with this approach was data collection specific to a user. In order for the model to be robust, the detection must take place after the device has recorded data for a given individual considering all possible external factors. This means that the first few detections would have to be conducted on a previously collected generic dataset before user specific data is drawn.

The computational power required for the machine learning approach increases drastically as the dataset increases. The accelerometer reads 50 data points for each second, making the data set for even an hour extremely heavy. The data storage requirements add up as well, since the training set data needs to be maintained consistently. Since the detection and the distress signal need to be sent without large delays, this approach did not seem appropriate for this project.

For the above reasons we decided to switch to a technique that would result in a higher accuracy.

The Second Approach - Threshold Trigger

This method resulted in not only a much higher accuracy but addressed the second issue discussed for the machine learning approach. However, in order to achieve a higher accuracy, a large number of tests considering various external variables had to be taken into consideration.

The accelerometer data is read as raw values, and the vector sum for each value is calculated. This computation must be made for each of the 50 data points received in a second. If a value computed exceeds the decided threshold value the unconsciousness detection actions are triggered.

In order to arrive at the decided threshold value a series of tests with various positions had to be conducted. The tests in total exceeded 150 different simulated falls (More details in the tests section).

Unconsciousness Detection

While the initial goal of the app was to be able to detect when a fall as occurred, we decided to incorporate an unconsciousness detection algorithm as well. The basic logic of this algorithm is given that an individual has experienced fall there exists a certain buffer period that the accelerometer takes to come back to a still position. After the buffer is complete, we store the values for a given period of time. If the stored values fall within a given range (unconsciousness) then the second condition is true resulting in the signal being sent to the designated partner.

We determined the buffer period by testing out various fall scenarios to establish that it takes about a third of a second for the vector sum of the accelerometer values to return from the “Fall” range to the “Still” range.

Metric Improvement - Minimizing False Alarms

Some of the biggest issues we faced was minimizing false alarms. In order to reduce these errors we tested extensively on the various positions and their corresponding threshold levels. On testing for people for different weights and heights we concluded that the impact on the threshold was not significant and the fall was independent of the weight of the person. This is consistent with theories in physics which state that the speed of a body falling under the influence of gravity does not depend on the weight of the body unless that body is affected by the influence of air resistance.

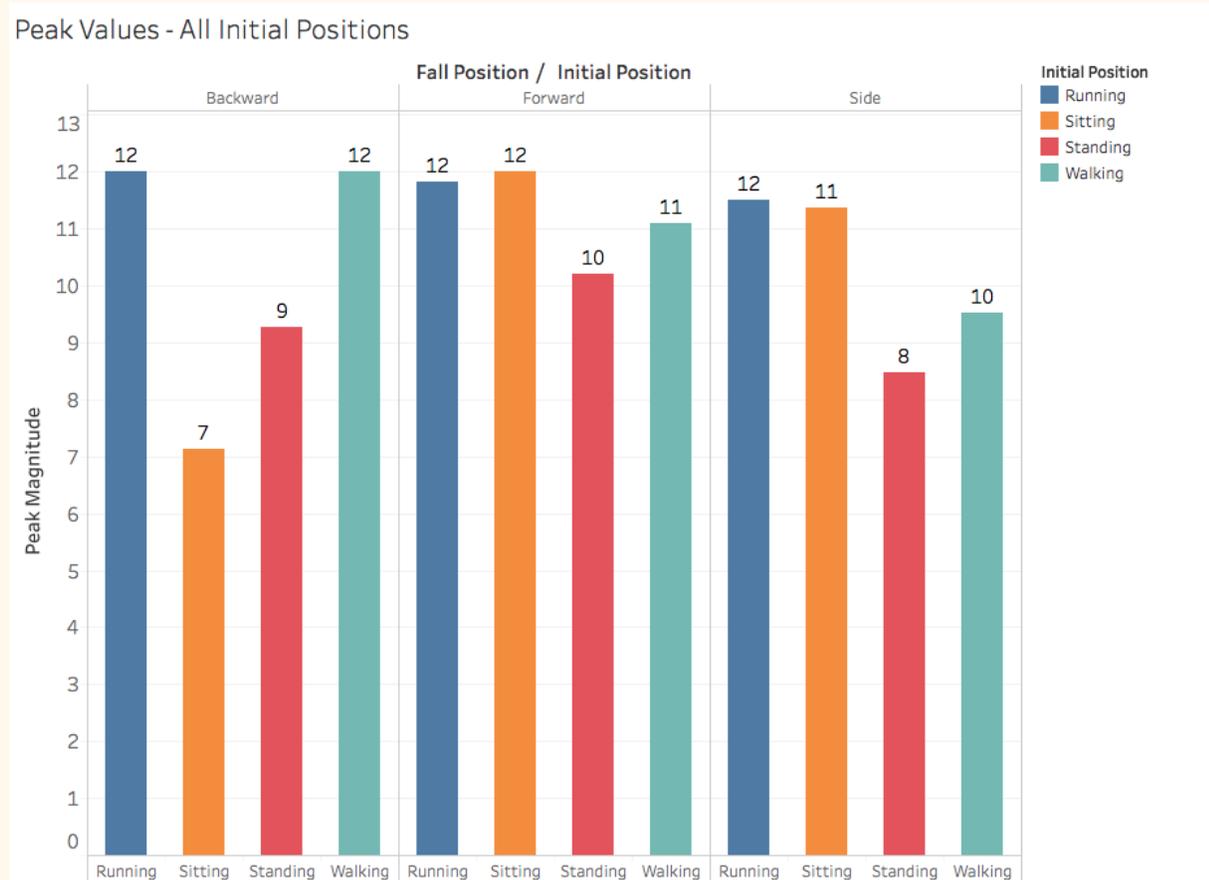
In order to include a second layer of checks on the app and to improve the accuracy, we decided to implement a false alarm timer. When the conditions for a fall are satisfied, the application sends a pop up notification on the screen of the user with a timer counting down. If this was a false alarm the user must cancel this popup before the timer times out. If no action is taken by the user, and the timer times out, the twilio api sends a notification via text to the designated care-taker.

In order to improve the detection of the fall itself, we decided to add an upper limit to the vector sum calculated. The vector sum should not exceed a value of 9.8m/s^2 unless an external force was applied on the body.

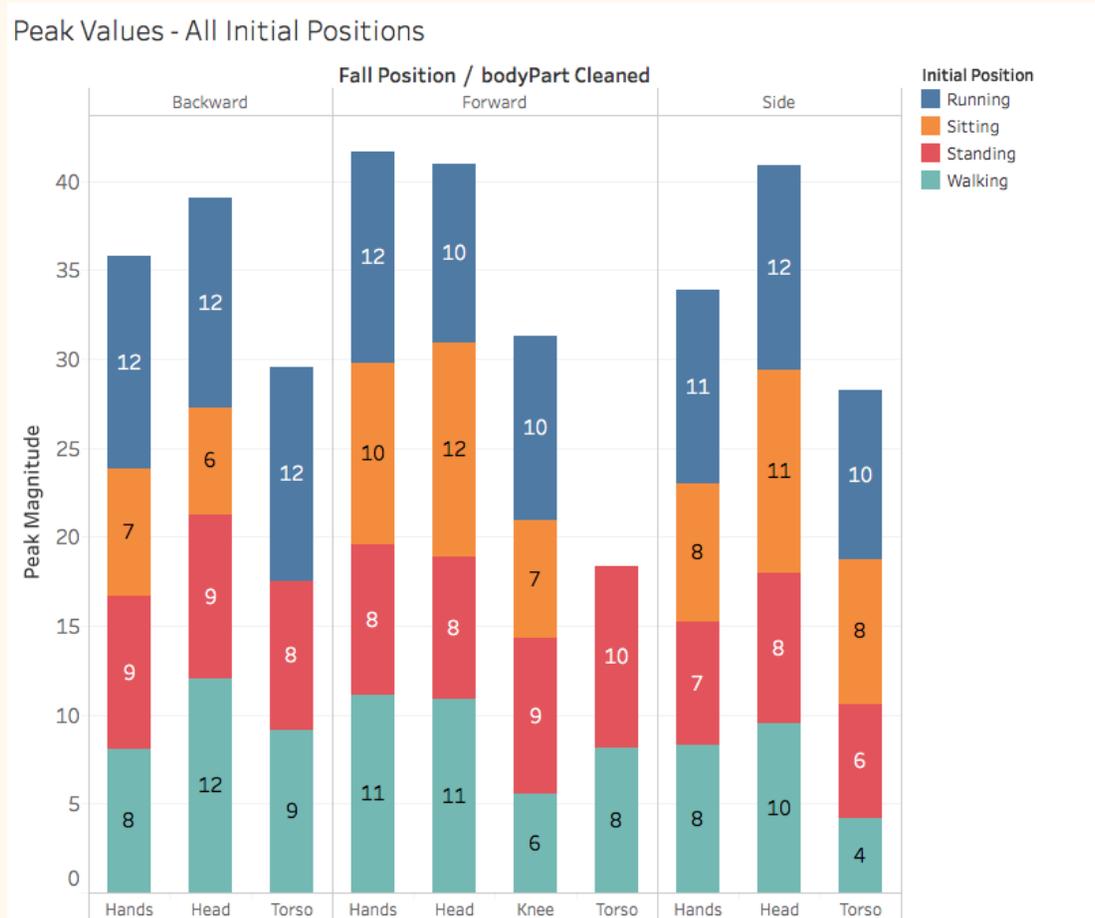
Testing

Teal Alert works based on accelerometer data we gathered on various fall scenarios across different genders, age, weight and other factors that may influence fall behavior. The resulting thresholds from our data are set in the device and when the readings from the accelerometer exceeds the established thresholds. These established thresholds are the product of multiple tests (over 120 falls) that were run on many iterations.

On the first iteration of our testing, we identified 39 different kinds of fall scenarios such as falling sideways versus falling backward. Among the different scenarios, we also tested for different parts of the body hitting the ground first. For example, we wondered if a fall that happened where the knee was the first body part to hit the ground was significantly different from falls where the torso was the first body part to hit the ground. The results showed that there was not much variation across most of the different scenarios but the most significant differences seemed to emerge in terms of falling backwards versus falling forwards.

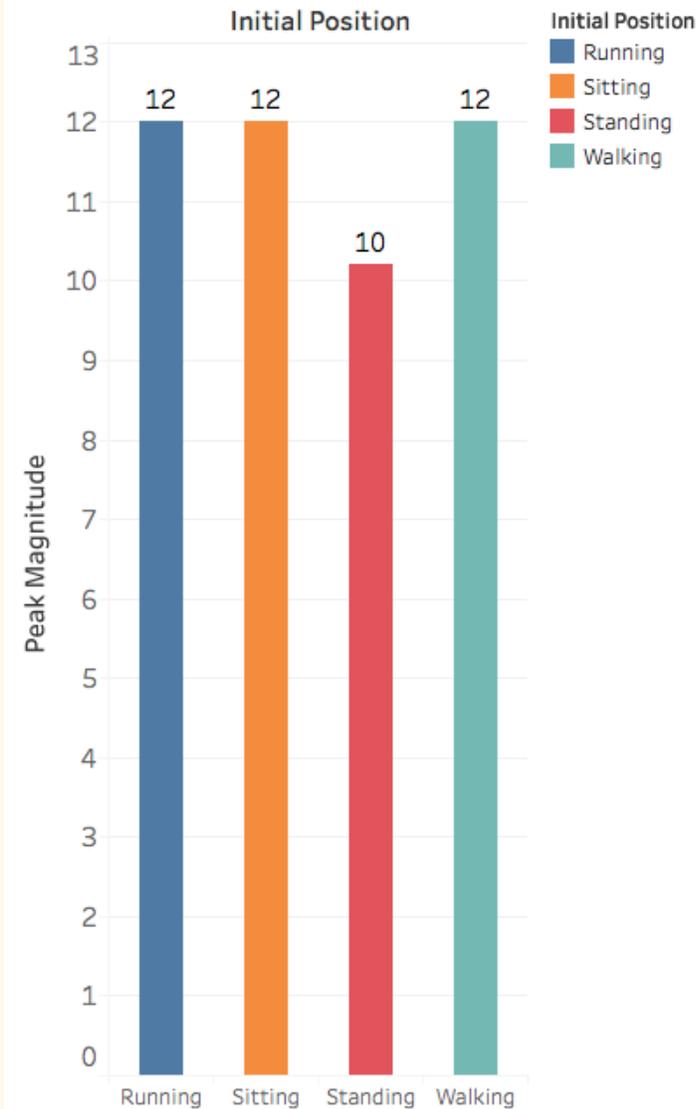


The graph below depicts the threshold values obtained for the different body parts touching the surface first.

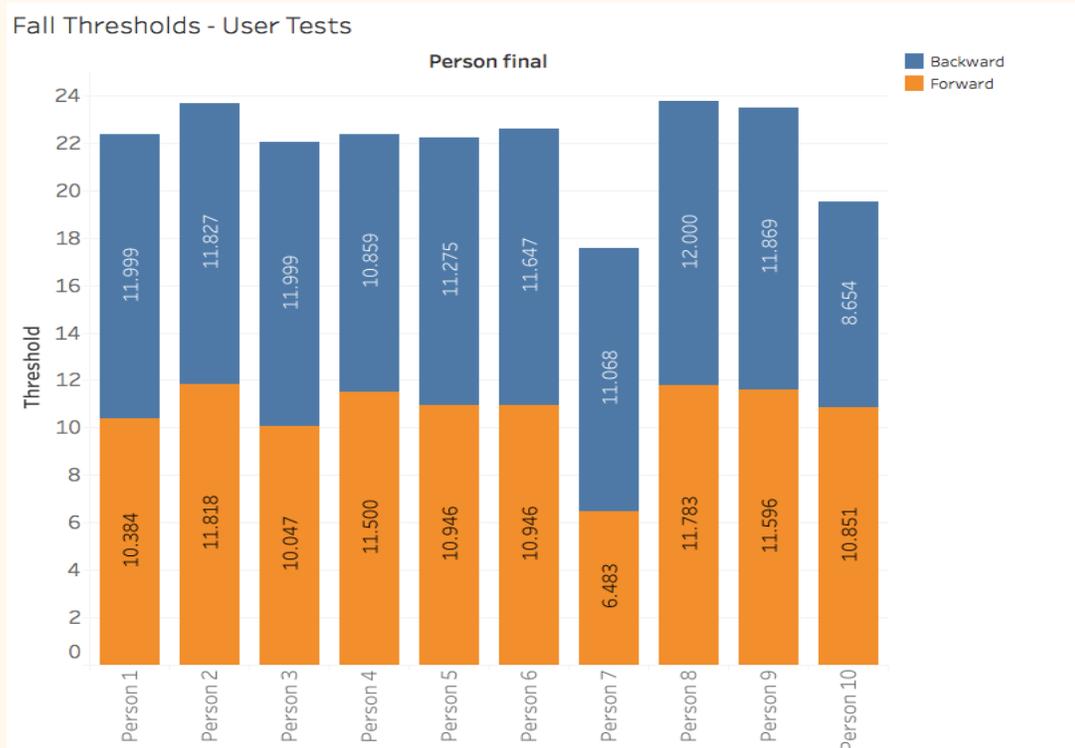


This graph takes a closer look at the initial positions and the average value obtained for the falls.

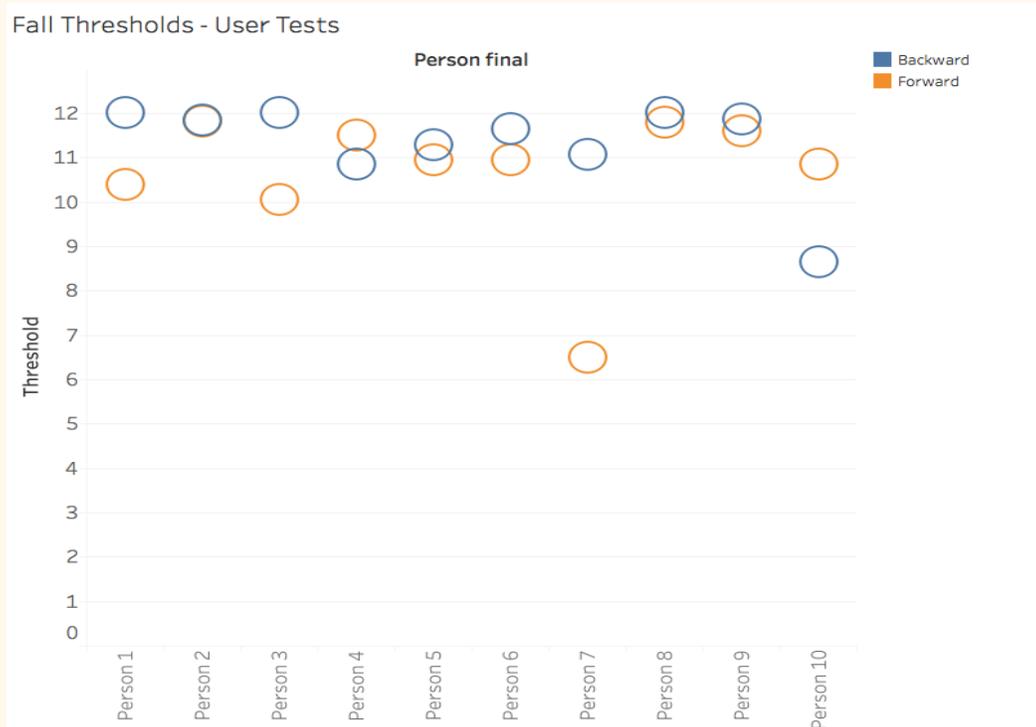
Peak Values - All Initial Positions



The next iteration of the testing we aimed to isolate the two distinct falling scenarios (ie - falling forwards versus falling backwards) and test for variances across different gender, age and weight that may influence thresholds. The below results showed trends that were robust and invariable enough to establish reliable thresholds for falls. The below results show variances across 10 different individuals varying in age, gender and weight:

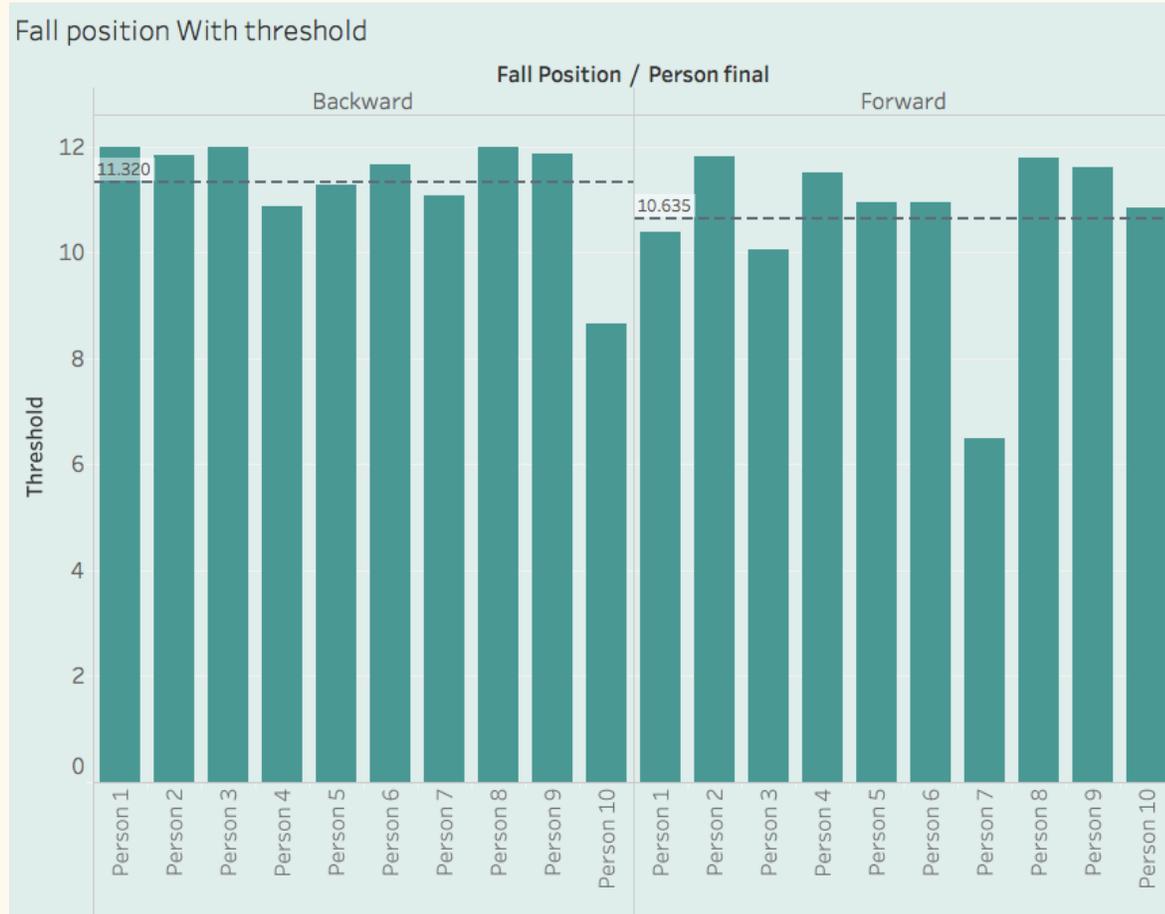


As with any sample, there are outliers like Person 7 and Person 10, but the vast majority (80%) shows a trend that shows little variance and gives a sufficiently narrow range with which we can set our algorithm to detect. An added positive result better depicted in the below visualization shows that there is not that much variation between the two main kinds of falls that can take place (ie - falling backwards and falling forwards):



As illustrated in the above results, the variations in thresholds between the two main kinds of falls we've identified shows little variation in range minus Person 7 and Person 10. The fact that the Person 7 and Person 10 are outliers not only in terms of how wide the range is between the different falls but also in terms of how their thresholds are overall lower than the rest of the sample gives us further reason to believe that these are truly anomalous and consequently a trivial consideration in setting the thresholds for our algorithm for detecting falls.

The final visualization shows us again that the standard deviation of the average of each kinds of fall is pretty low. The dotted line running horizontal across all 10 subjects reveals an average of 11.32 for backward falls and an average of 10.635 for forward falls. What will be rather noticeable in this visualization is that all subject fall within a very tight range of this average minus Person 10 for backward falls and Person 7 for forward falls.



The conclusion of our testing reinforced our hypothesis that it is indeed possible and even effective to set thresholds to detect falls as most falls fall within a very tight range around the average that the algorithm will set. The encouraging extrapolation from this study is that Teal Alert can serve as an effective tool in detecting falls followed by unconsciousness by our algorithms methodology of setting thresholds based on real fall data. Giving alerts if plus or minus 80% accuracy, we believe, is better than any existing technology in the status quo today.

Future Work

We would like to continue improving our algorithm to reduce false alarms but also not miss out on actual incidents. As of now, Teal Alert uses the accelerometer to monitor positioning, fall, and inactivity. We would like to explore other kinds of sensors to come up with an even more robust algorithm.

Currently, the Teal Alert sends the alert to a single designated partner. We would like the provision to add multiple emergency contacts. In the future, we would also like to integrate the app with nearby taxi drivers and medical hospitals so that the help could be provided as soon as possible.

As mentioned in the user segments section, the application of Teal Alert can be expanded to many scenarios and use cases including protection of women, on-demand use during hiking or jogging and so on. We would like to address each problem by adding features relevant to the specific scenario. For example, eliminating the need of Internet for sending alerts so that the alert could be sent if the user has gone for hiking in the wild where there is low or no internet connectivity.