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Alert System and Cadence Walker

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Abstract

Older adults who are dependent upon walking aids may harm themselves from falling when they forget to use their aid. In order to achieve fall prevention through increased walking aid usage, the team will design a device to be attached on a two wheeled walker with the ability to alert users when they move an unsafe distance away from the walker. The walker will also be capable of recording information about user use regarding time usage, distance traveled, and cadence. This data will be reported to care providers for clinical observations and evaluations. The key components to achieve these features include using a coupled proximity transmitter and receiver, a microcontroller, and a speedometer, in addition to a relevant circuit board, power source, storage device and display screen. Once this prototype is finished, proper testing regarding accuracy will be conducted. Finally, older adults will be participating as human test subjects to evaluate the overall quality of the walker performance and how well it reminds the user to use their walking aid.

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Background:

Falls are the leading cause of injury and death among older adults. In fact, falls are five times more likely to bring elderly people to the hospital than any other condition. These falls can occur in a number of ways, but one of the leading causes is when an older adult who requires a walking aid, forgets his or her aid when walking. These falls can cause serious injury to the elderly. One out of three adults over 65 years old experiences a fall annually, with 25% of the incidents resulting in moderate to severe injuries. The risk of a fall due to forgetting walking aids increases in elderly who also suffer from some form of dementia, which affects more than 60% of the elderly population over the age of 85 [1]. Economic impact of these falls is estimated at $237 million annually in Wisconsin, and near $20 billion annually in the United States [2].

Motivated by these facts Dr. Jane Mahoney, one client for this project, coordinates a 7 week community based workshop called "Stepping On" which develops specific knowledge and skills to prevent falls. Adults who participate in the Stepping On program experience a 31% reduction in falls [3]. This project also works with the University of Wisconsin Center for Health Enhancement Systems Studies (CHESS). The mission of the center is "To lead in research and development of innovative health systems, in order to optimize individuals' health behaviors, quality of life, and access to services." Their research focuses on integrating cutting edge informative technologies with healthcare systems to better understand patient concerns and deliver custom care treatment strategies. CHESS works on issues such as substance addiction, improving communication between oncologists and patients and enhancing quality of life for the elderly. One of the project clients is Dr. David Gustafson who is member of the CHESS research team and has worked projects in all areas of the program center.

Problem Statement:

Older adults who require the use of assistive walking devices for daily motility can harm themselves due to falling when forgetting to use their aid. This issue is further complicated in adults diagnosed with any type of dementia, who are more likely to forget their walking devices. The goal of this project is to design a system to be mounted on a two wheel walker that notifies the user when they begin to walk away without their walker. In addition to the alert mechanism the walker should provide usage feedback such as time usage, distance traveled, and cadence. This data should then be transferrable to care providers on a daily basis to help evaluate the health and habits of the patient and improve patient care. The technology would ideally be transferable to use with other assistive walking devices such as canes and four-wheel walkers.

Design Criteria:

This device must meet a number of expectations and criteria in order to adequately improve the safety of walker use and prevent falls. The most important aspect of the design is to alert the user when they begin to get up and walk away without their walker. This feature is the main way to help prevent falls resultant from the user walking without the necessary walking aid. In order for this alarm to prevent falls, it must alert the user before they begin to walk away without the walker by sounding an alarm when the user is more than one meter away from their walking aid. The alarm sound should be gentle so as to not startle the user and subsequently cause them potential harm. Ideally, a voice recording capability would be best for the alarm sound.

The design should be able to record and report daily usage of the cane such as total time used, total distance covered, and cadence. These values can be displayed on a screen attached to the walker for simple reference by the user. These data should be able to electronically transfer daily to the care provider. This information will help the care provider evaluate the health of the user.

Lastly, this device will be designed for the use of elderly, particularly those that exhibit cognitive impairment. The user interface should be simply navigable for those who are not familiar or comfortable with technology. There should be no small buttons or features that are difficult to manipulate. The alarm should also have an adjustable volume so that those with hearing impairments will still be able to use it effectively. The alarm system and screen based device should not add a weight over two pounds and should not hinder normal use of the walking aid.

Competition:

The idea of a talking wheeled walker that measures cadence is a relatively novel idea. There is one close competitor that may be discussed, which is the TrekCane adjustable walking cane from Sky Med [Figure 1]. This cane allows for the measurement of cadence giving the user data on steps, time walked, and estimated calories burned [4]. The price for a device such as this costs around $35 based on a google shopping search. What this assisted walking device does not have and what this project aims to implement is a alert system for when the user forgets their walker when getting up to move. It also does not have the ability to easily send this data to the care provider for patient health analysis.

Figure 1: Sky Med TrekCane that counts steps taken and estimates distance. From http://www.soymedical.com/coms1602.html#.UH9Y2W_MjQQ

Ethical Considerations:

Ethics behind the two-wheel walker include balancing cost and function. As mentioned earlier this device will act as an assistive medical device, which requires a certain level of accuracy. Accurate data collection for clinical observation and analysis are highly important to help improve in home patient care as well as help prevent injury due to falls. As a result when selecting proper components for the device, performance should be considered a relative priority over cost. The device should find a medium that allows very accurate function and data collection with a minimally expensive cost.

Further ethical concerns are when this device is complete, human subjects will be needed to test its performance. Procedures required for testing on human subjects include each project member's completion of the Collaborative Institutional Training Initiative (CITI) training for Institutional Review Board (IRB) approval. Any additional applications and legal documents will be prepared and submitted to the IRB before testing can begin.

Design Alternatives:

In order to effectively design a device for the client, the design was split into two pieces, the alert system and cadence. Each category has several design alternatives discussed below and a matrix of the options that helped the team choose the most effective design.

Alert System:

The first set of designs considered deal with the walker sensing when it is being forgotten. These alternatives are sensors that in some way can detect the distance between the user and the walker once they have been integrated.

Bluetooth Sensor:

The Bluetooth sensor can be found in a multitude of electronic devices including computers, cell phones, and headsets. Information is exchanged wirelessly between two devices by transmission of a radio signal on a 2.45 GHz band [5]. To avoid interference with other signals the Bluetooth device frequency hops 79 channels that are spaced 1 MHz apart [6].

To incorporate the Bluetooth sensor [Figure 2] into our device we wish to attach a lightweight Bluetooth transmitter on the wrist of the user and the receiver on the walker. The receiver would be constantly receiving signals until the transmitter was out of range and the receiver stopped receiving signals, at which point the alarm sequence would be triggered. Bluetooth signals come out of range at 10 meters, but may carry up to 40 meters in open spaces [7].

Figure 2: Circuitry of a typical Bluetooth sensor. From http://electronicsbus.com/bluetooth-wireless-sensor-network-system

Infrared Sensor:

The infrared sensor is often seen in many areas daily for motion sensing of light or in gaming systems such as the Wii. This sensor operates by using a photosensor detects elements of thermal variation emitted as infrared light [8]. This would allow the device to sense motion of a user around the device. In this design, the infrared sensor would be placed on the walker and constantly track the movements of the user. If the user started to move too far from the walker, the alarm would then be triggered. Infrared sensors are vulnerable to interference from other infrared sources, such as candle light and fluorescent light. This may give a false reading and cause the alarm to sound when it should not, or fail to sound when it should. These sensors are also one directional and the device would require several of them to get full 360° coverage of motion around the walker [Figure 3].

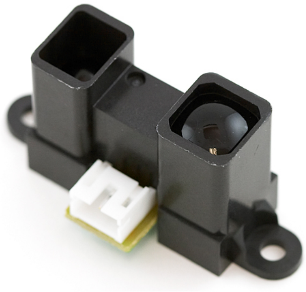

Figure 3: Infrared sensor that exemplifies its limited directionality. From http://www.sparkfun.com/products/895

Proximity Sensor:

This alternative was added after the first semester of the design process. The reason for this change is discussed in the Final Design section later. There are several devices known as proximity sensors commercially available that can detect how far away a user is from a specific device. This is done through a Bluetooth based transmitter and receiver. The receiver is worn or carried by the user and detects the signal output of the transmitter which is attached to the device in question. When the user has gone out of range of the transmitter signal, which is usually adjustable for desired distance, the receiver will beep to inform the user they are out of range [Figure 4]. This type of proximity sensor would need minimal adaption, if any, to be integrated into the walker. Depending on the devices available, the transmitter may have to be altered to be wearable around the wrist or ankle [15].

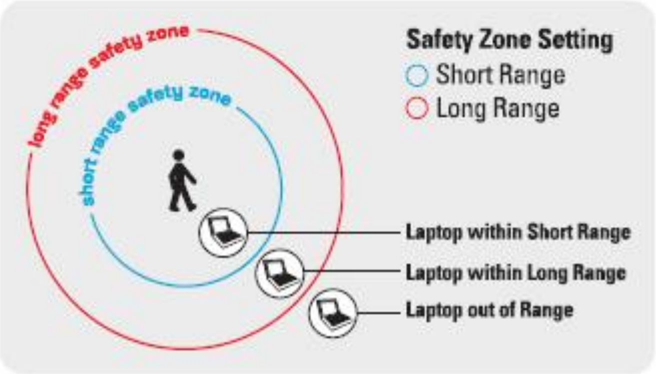

Figure 4: Proximity sensor design to alert user when they have walked unsafe distance from their laptop. From http://www.remoteplay.com/support_laptop.asp

FM Transmitter:

The final alternative for sensing the distance between the user and the walker is the use of an FM transmitter. Common uses of FM transmission include long range radio station transmitters all the way down to low power transmitters which may connect an .mp3 player with a car radio. FM radio transmitters work by emitting a sinusoidal carrier signal of a given frequency, which is modulated, by higher frequency data signals [9]. The carrier signal amplitude decays as distance between transmitter and receiver increases. Cutoff amplitude can be then processed to estimate distance between transmitter and receiver [Figure 5]. With this device, the user will carry a small FM transmitter, and the receiver will be mounted on the walker. A microcontroller will process the signal strength and trigger the alarm when the amplitude falls below threshold.

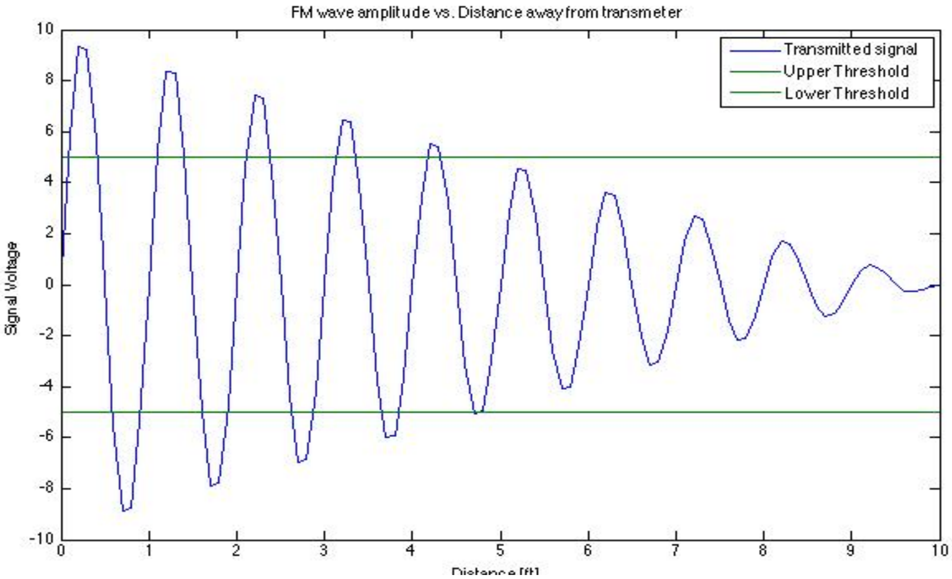

Figure 5: This graph shows the FM wave amplitude vs. distance away from the transmitter. As distance increases so does the decay in the amplitude of the sinusoid, triggering an alarm once it falls below threshold.

Proximity Sensor Design Matrix:

A design matrix was created to evaluate our four alternatives to choose which one will continue into our prototyping phase. Criteria include accuracy, interference, feasibility, size/weight and cost. Accuracy and interference were the most important criteria and were weighted as such.

Table 1: Alarm sensor design matrix with three alternative designs scored against a set of weighted criteria.

Alarm Sensor					
Criteria	Weight	FM Transmitter	Bluetooth Sensor	Infrared Sensor	Proximity Sensor
Accuracy	35%	4	1	2	5
Interference	25%	3	1	2	4
Feasibility	15%	4	3	2	4
Size/Weight	15%	3	4	3	3
Cost	10%	4	2	4	2
Total	5	3.60	1.85	2.35	4.00

Accuracy is the ability to appropriately measure a distance of 1 meter as defined in the design requirements. With this in mind the FM transmitter scored the highest because of its ability to tune distance measurement by altering the transmission signal strength.

Bluetooth scored low because its cutoff range is at least 10 meters, which is too far for the design needs. Interference is defined as the ability of the data input to the receiver to be free of artifacts, which may skew the accuracy measurement. Both Bluetooth and FM transmitters rate high here as a clear transmitter-receiver connection is needed. FM transmitters score a little lower because of the possible errors it could run into with other various radio waves. Infrared scored the least because of misreads when under candle light and fluorescent light. Feasibility is the ability to incorporate the sensor with the governing microcontroller. Here FM transmitter and Bluetooth scored the highest because the transmission and receiving components already have established literature, and signal processing is minimal. Infrared got low marks due to extensive signal processing and programing needed for distance calculations. With the given weights and scores determined, the matrix helped to conclude that the FM transmitter was the best way to incorporate proximity sensing into the device.

The proximity sensor was an alternative that was added after the FM transmitter, the previous design with the highest score on the matrix, was proven to be too problematic for the team to use (discussed in Final Design). The addition of this alternative in the matrix resulted in it being the best option overall for the alarm system portion of the design. It scored top marks in accuracy due to its ability to directly alarm based on distance between the walker and the user with minimal or no changes by the team. Many of these proximity sensors are designed for use in areas with a high population, and therefore a high tolerance for potential electronic interferences. This makes it unlikely to be susceptible to any kind of electronic interference in normal settings and gives it a high score in that category. While the feasibility category previously referred to the ability to integrate with the microcontroller, the proximity sensor would not have to be integrated unless voice modifications were made later on. In this respect it scored high in feasibility as well. The size and weight of the device depends on the specific one purchased but should be reasonable small and light, putting it at an average score for that category. Finally some proximity sensors can range near $70 for the setup, making it one of the pricier options on the matrix. However its excellent scores in the higher weighted categories makes it the best way to proceed with in the final design.

Cadence Measurement

Cadence is another area of the design that deserved consideration of alternative designs. Because there is no direct way to measure cadence on a walker, the team considered alternatives that could be incorporated into a microcontroller to convert the data collected into the cadence data desired by the client.

Pedometer:

A pedometer is a small, inexpensive, electromechanical device that tracks the user's steps by detecting hip motion. This is accomplished by counting the oscillations of lead ball or a pendulum within the device. Pedometers, which use these systems are vulnerable to false positives caused by uneven terrain or an unsteady gait. Most often a pedometer is calibrated by the user for step distance to provide an estimate of distance [10]. A pedometer could be incorporated into the device to count the lifts of the non-wheeled legs of the walker, counting it as two steps. There are screen-based pedometers that also track time and allow the user to connect them to a computer via USB to track their daily usage [Figure 6]. This feature would allow an elderly user to easily send their caregiver daily updates on their walker usage. However, this measurement would be near to impossible for those individuals who put tennis balls on the non-wheeled legs to prevent them from having to lift the device at all.

Figure 6: Screen-based pedometer that allows connection to a computer for daily tracking. From http://www.dimensionengineering.com/images/products/DE-ACCM3Dbig.jpg

Accelerometer:

An accelerometer implements 3-axis MEMS inertial sensors to detect local accelerations [Figure 7]. This raw data is then processed with software designed to filter out false positives and detect true steps. Accelerometer based step detection is often found in smart phones and similar devices. When the step counter is in a smart phone distance measurements can be taken from existing connections to the GPS, otherwise total distance is estimated from the users calibrated individual step distance [11]. This technology could be implemented into the walker device to count the steps of the use. This kind of cadence counting would be significantly more complicated however and require a lot more circuitry, data processing, and programming.

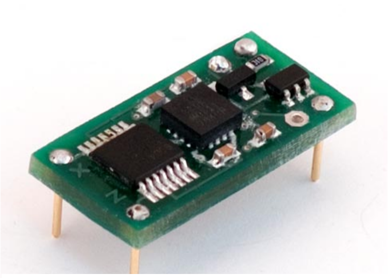

Figure 7: The typical circuitry of chip embedded accelerometer. From http://gatorade2008.republika.pl/itrip2/itrip-both.jpg

Speedometer:

Figure 8: Bike speedometer with the equipment to count revolutions of a wheel. From http://image.made-in-china.com/2f0j00FeOEKtJhrRpj/Bicycle-Cycle-Computer.jpg

Simple and inexpensive speedometers designed for bicycles calculate speed by tracking wheel rotation [Figure 8]. By mounting a magnet to the spokes of the wheel and an electric sensor mounted on the forks tracks wheel revolutions by the magnetic induction as it passes by the current [12]. By calibrating the device for the radius of the wheel, distance and speed can easily be calculated from the pulse rate count. A device such as this could easily be modified to work with the wheel of a two wheeled walker. Bike speedometer are also able to record the relevant data needed for this design such as time used and distance traveled in addition to counting wheel revolutions, which with some simple programming of the microcontroller could give cadence data. Like the pedometer, some more expensive speedometers have the ability to connect via USB to the computer. This would eliminate modifications to the device in order to send usage data to the care provider.

Cadence Design Matrix:

A design matrix was constructed to evaluate the three designs and choose which design will continue on to prototyping. Evaluation categories include accuracy, attachment, feasibility, and cost.

Table 2: Cadence measurement design matrix with three alternative designs scored against a set of weighted criteria.

Cadence				
Criteria	Weight	Accelerometer	Speedometer	Pedometer
Accuracy	45%	3	4	2
Attachment	25%	3	4	1
Feasibility	20%	1	5	3
Cost	10%	3	3	5
Total	5	2.6	4.1	2.25

These categories were then given a weight based on importance. The highest weight was given to accuracy because the cadence information will be sent to the care provider for analysis on patient health and care. The other substantial category was attachment because the device has to attach in a manner that will not impede normal use of the walker. The speedometer scored well in both categories, because of the simplicity of the sensing wheel revolutions of the walker. The pedometer and accelerometer received poor marks in these categories because they must be kept on the user's person, and ideally the device should be centralized to the walker. The accelerometer also scored poor marks in feasibility because of the complex software analysis needed compared to the low program requirements of the speedometer and pedometer.

Final Design:

Based on the results of the two matrices, the key components on the two-wheel walker in terms of the sensor and cadence measurements will be the proximity sensor and the speedometer. An Arduino microcontroller will serve as a central hub which will power the device and store the output data gathered by the speedometer unit. Data can be accessed on the controller via USB modification that will be added. A circuit must be designed to allow communication between the controller, speedometer, storage device, and output display. A block diagram has been made to illustrate these connections [Figure 9].

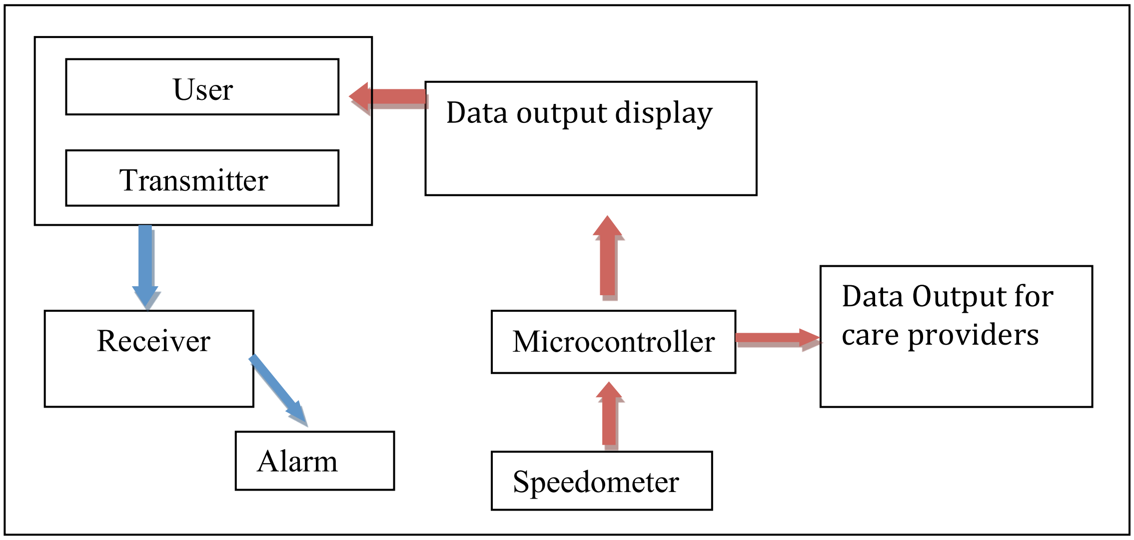

Figure 9: Block diagram of the alarm and cadence process on the two-wheel walker. A microcontroller will process and store data and output data to display or as a data file for use by care provider.

Originally, the alert system was created with the FM transmitter and receiver through implementation with the microcontroller. A circuit was connected to connect a simple receiver with an Arduino microcontroller and the decibel signal attenuated around one foot from the transmitter, ideal for the distance the clients wanted. While the distance testing data, seen in Appendix C, seemed promising for this setup, there was a lot of signal interference when the device was removed from a controlled lab setting. The signal would frequently be lost entirely of diminish to allow only a couple inches distance between the transmitter and receiver. This prompted the change to the proximity sensor for measuring patient distance from the walker.

Distance will be monitored by a receiver mounted on the walker and a small, low power, lightweight proximity transmitter to be kept on the user's person. The transmitter will have to be designed into a wearable device such as a bracelet or anklet. When the distance between the receiver and the transmitter exceeds a meter, an alarm on the transmitter will sound.

As for cadence measurement, a modified bike speedometer will be placed on the walker to measure wheel revolutions per unit time. This digital data will pass through the same microcontroller mentioned previously for further processing, such as time usage and velocity. The microcontroller will also be programmed so that the data collected can be sent to other databases for care provider's analysis.

Prototype:

Speedometer Circuitry:

To augment the functionality of the alarm system we have included a method of recording some information about how the walker is used. Data such as walking speed and distance are potentially important metrics for a study of an elderly patient's behavior, and our client has expressed interest in adding this functionality. The design uses hardware components from a bicycle computer to sense the wheel revolutions and the Arduino microcontroller to interpret the data as seen in Figure 10. The sensor hardware consists of four magnets attached to a spoke of the wheel and a reed switch attached to the frame. A reed switch is a circuit component, which is normally open but closes in the presence of a magnetic field. As the wheel rotates the magnet passes by the reed switch, completing the circuit and outputting a pulse of current into the analog input of the microcontroller. To integrate the pulse data into distance and speed, code was added to a template available online (13).

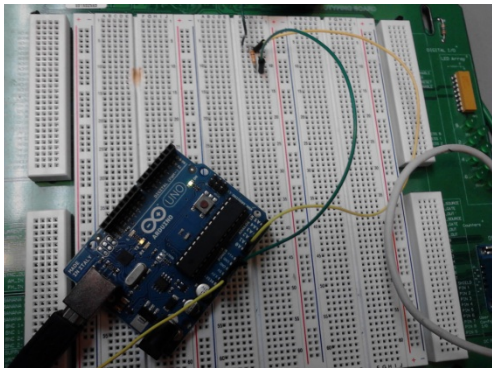

Figure 10: Speedometer hardware connected to Arduino microcontroller through a simple circuit.

The first bit of code tells the computer to run each loop at a rate of 1000 Hz. At the beginning of the loop the computer detects if the reed switch is open or closed. Once the switch is found to be closed a series of tasks are executed. First a 300 ms counter is started to prevent duplicate readings of a single switch close. Next the time elapsed between pulses is stored and summed to provide the total time the walker was in use. Given the time between pulses and the constant wheel circumference (equivalent to the distance traveled in one revolution) an instantaneous speed is calculated. This speed can then be sent to a display in a future model of the device. If more than twelve seconds has elapsed after a pulse detection the walker is assumed to have stopped. Once the walker has stopped the total distance and average speed are calculated and stored in an array. This usage array could be output to a care provider via USB connection with the Arduino and a device such as a smartphone. The simplified flowchart of how the above codes work is shown in figure 11.

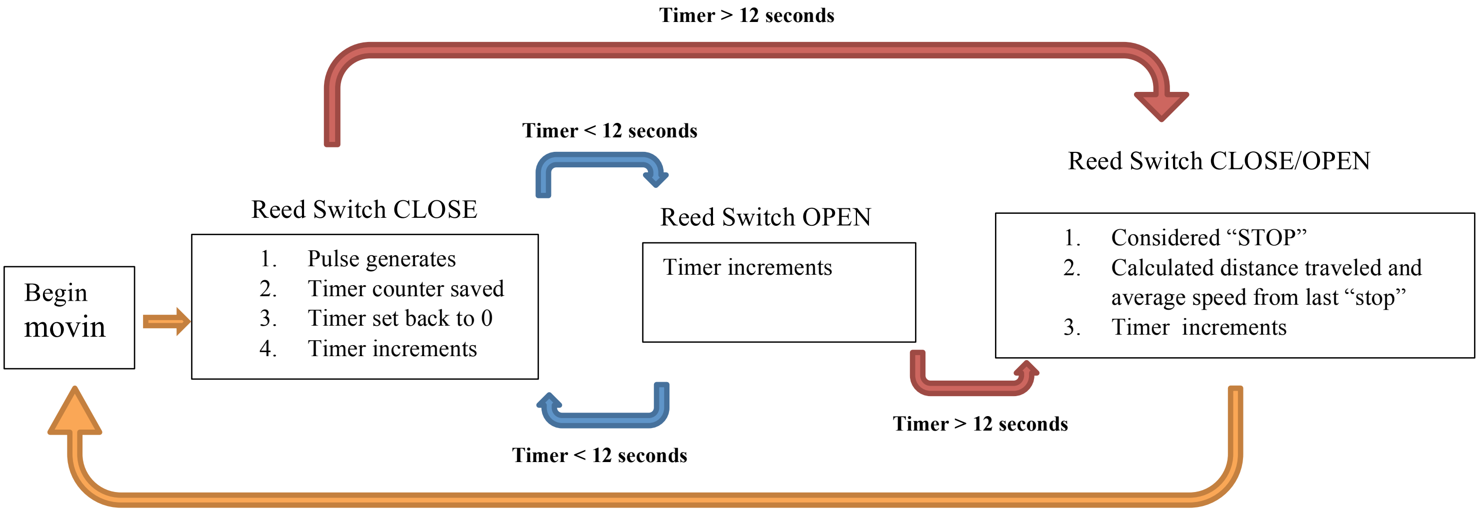

Figure 11: Arduino Flowchart of the Speedometer. Timer counter increments constantly

Child Proximity Sensor:

The team chose a proximity sensor that is designed to alert a parent when their child has wandered an unsafe distance in busy and highly populated areas. The transmitter is inside the panda bracelet, which is normally worn by the child [Figure 12]. The parent then holds, pockets, or clips on the receiver. The side of the receiver has an adjustable dial that controls the distance of alarm, which is a loud beeping. Both pieces operate through battery power [16].

Figure 12. Proximity sensor that alarms when the panda bracelet is too far from the receiver. Taken from http://www.specialtyalarms.com/site/1313932/product/30-210

For the walker the panda is strapped onto the lower bar of the walker and the receiver is clipped onto the user. The exact inner working of the transmitter and receiver are currently unknown, but the team believes that they run off Bluetooth sensors similar to other proximity sensors that were considered.

Accuracy Testing:

The first stage of testing for the prototype aims to confirm the devices are accuracy to our desired specifications, seen in Appendix A. This is to ensure that the device is both reliable for the walker user and that the data being sent to the care provider is representative of user usage.

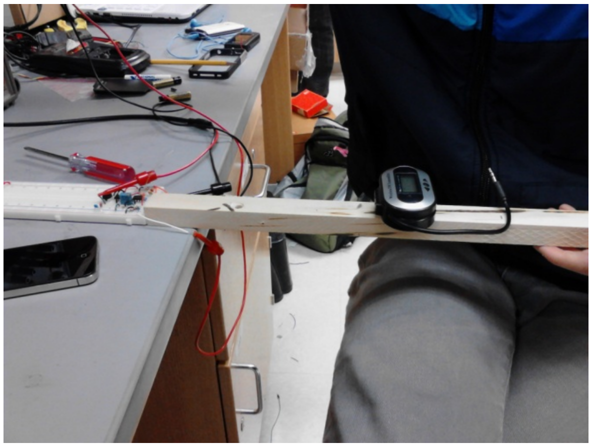

Figure 13. Distance testing of the transmitter signal as it moved away from the antenna in 3 in. increments.

The team replicated the FM transmitter test plan for testing the alarm distance for the new proximity sensor [Figure 13]. The panda transmitter was attached to the lower bar of the walker at 19.81 in. above the floor. The receiver was then incrementally moved away until the alarm sounded and this horizontal distance was recorded. To measure for some sense of reliability, this process was repeated for a total of ten trials [Table 3]. Simple geometry and Pythagoreans theorem were then used to find the total (taking into account both horizontal and vertical components) alarm distance between the transmitter and receiver.

Table 3. Recoded decibel levels of the transmitter signal as it moved away from the antenna in 3 in. increments.

Trial	Horizontal Distance (in)	Alarm Distance (in)
1	28.50	34.71
2	27.25	33.69
3	56.50	59.87
4	28.75	34.92
5	27.63	34.00
6	27.88	34.20
7	56.25	59.64
8	28.13	34.40
9	28.13	34.40
10	28.75	34.92
Average	33.78	39.47
Standard deviation	11.92	10.70

Trials 3 and 7 gave significantly higher alarm distances than the other eight trials. This directly resulted in the high standard deviation for the data set. The team will be conducting further testing and analysis, discussed in Future Work, to determine if these two trials are anomalies or if they are significant and could potentially deter from the reliability of the device.

The accuracy of the speedometer was also tested. The magnets were attached to one of the walker wheels at approximately equal distances from the center. The magnetic sensor was taped to the walker leg to create a similar set up to the one seen in Figure 14. The time and distance data was recorded on the computer using the microcontroller and corresponding computer program. Manual recording of the revolutions and time were recorded by the team members and then compared to the data from the speedometer. The difference between the two values are shown in Figures 15 and 16. These figures display that the circuitry increases in accuracy over greater distance (rotations) and potentially over time, although additional trials will be need to confirm that trend.

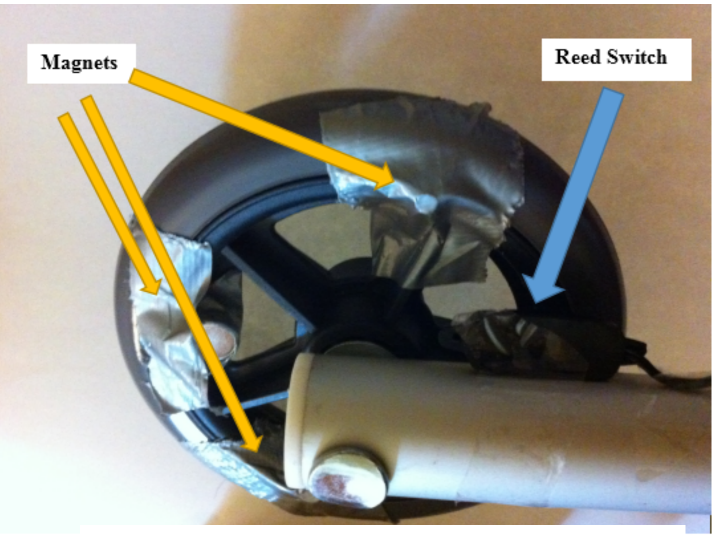

Figure 14. Setup of accuracy testing for the time and cadence recordings of the speedometer equipment and program.

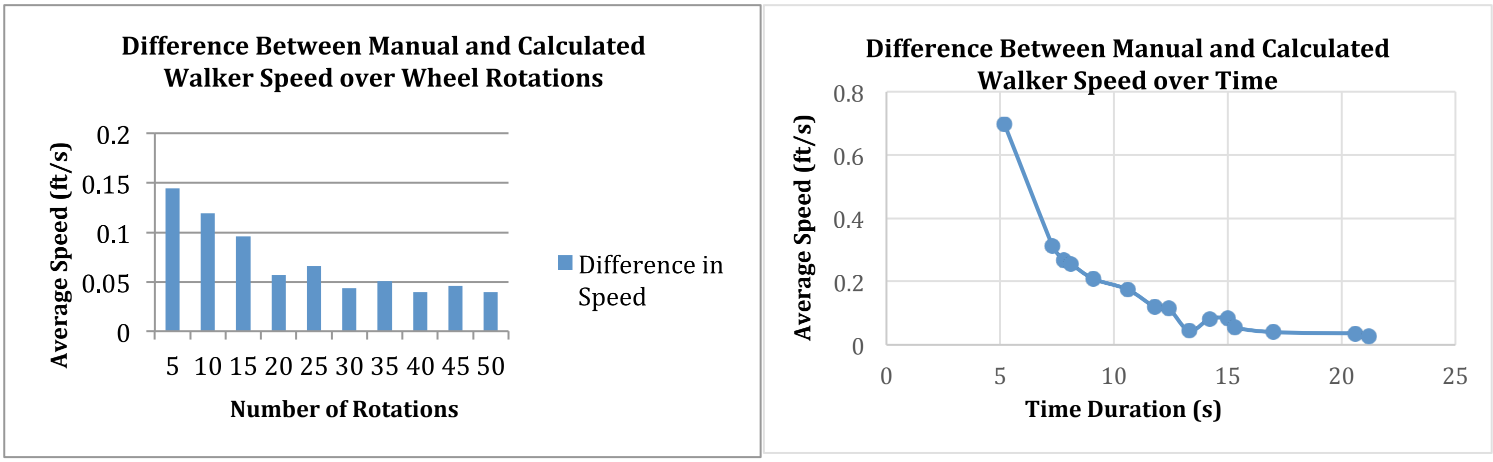

Figure 15 & 16. Speed differences of speedometer computed speed subtracted from the manual speed recordings over increasing rotations (top) and time (bottom).

Cost:

Throughout the year the team bought a variety of parts to build circuits, a speedometer kit, and several transmitter and receivers while the prototype developed and changed. The total cost for the year so far is listed below in Table 4.

Table 4: Total costs for the project over the course of the semester. Prices for individual purchases and pieces included.

Item Purchased	**Cost**
RD100 Speedometer Parts Kit	$20.05
Receiver/Transmitter Kit	$54.97
FM Receiver	$9.88
FM Transmitter	$10.31
Diodes	$56.22
Proximity Sensor	$27.98
Arduino modifications	$20.01
Total	**$199.42**

Future Work:

Moving forward, the rest of the semester will focus finishing the integration of the device onto the walker. This includes increasing the number of magnets to five to fit the orientation of the wheel. In addition, adding the Arduino modifications that the team newly purchased. These pieces will allow the microcontroller to run off of battery power rather than the computer and will allow the usage data to be stored on a simple SD card that can then be transferred and sent to the care provider. As the prototype is finalized, accuracy testing will continue to ensure there are no major design flaws. This will lead to human subjects testing of the device.

Final Device Testing:

The walker should be able to record cadence and time usage data accurately within 5% of the values. The client suggesting this daily 5% limit to ensure that the data sent to the care provider gives an accurate measure of patient use so that the care provider can monitor for subsequent health changes. This testing will continue and be repeated as the prototype develops and changes. Once it has been completed, the team would like to see standard deviation within an inch for the alarm to display that the proximity sensor is reliable. Additionally the standard deviation of the speed recordings for both time and distance should be within the 5% daily totals previously mentioned and yet to be determined by the team. Meaning that we will look up the average daily walker usage for the elderly population for both time and distance and would then like the standard deviations for speed difference to be equal or less than those values.

Once the device has been proven properly accurate, the client would like to have the device tested on elderly subjects. This will require the creation of an informed consent from based on IRB rules to allow research to be conducted with human test subjects. When the device is used by this group of subjects, we will look to see how well it is received both for ease of use and ability to remind the subject not to get up and walk without their walker along with other design aspects that the client could want. A questionnaire will be used to help evaluate overall test subject perception of the device. This data will be used to evaluate the need for subsequent changes to the prototype for finalization and manufacturing. The device will also be used over a two week period with several tests subjects. During the first week only the speedometer and data collection equipment will be recorded to get a baseline for daily use for each patient. At the start of the second week the proximity sensor will be added to the walker. The team will use a t-test to see if the addition of the proximity sensor significantly increases the use of the walker in the users.

The receiver circuit, speedometer, microcontroller and alarm components will have to be incorporated into one small discrete unit that is simple to attach to any wheeled walker. Research will have to be done on companies that offer this type of circuitry services. Additionally an LCD display and interface navigation buttons will be added to display relevant data and make any adjustments, such as adapting the device to walkers with varied wheel diameters. Finally, a simple pamphlet with mounting, battery, and data instructions will be constructed, including any possible warnings that are later deemed necessary.

Conclusion:

The goal of this project is to ultimately help prevent injuries from falls by increasing patient use of a walker and decreasing movement without the walker. The device will do this by alerting the user when they have begun to walk away without their walker via proximity sensor attached to the patient. It will also provide useful information on the walker user to the primary care provider via a screen based speedometer that will be modified to attach to the computer.

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Appendix A:

Project Design Specifications
October 20, 2012
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Problem Statement:
Older adults that require the use of a walker for daily motility can cause serious harm to themselves by forgetting to use their walker. The goal of this project is to design a walker that can notify the user when the user begins to walk away without it. In addition, the walker should provide useful feedback about the walker usage such as time, total steps taken and cadence. The technology would ideally be transferable to use with a walker.

Client Requirements:

- Walker must have a sensor that notifies the user when they walk away without it
- Walker needs to be able to measure time used, steps taken, and cadence
- Data from the walker must be transferable to care provider

Design Restraints:

1. **Physical and Operational Requirements**
    a. *Performance requirements:* The walker should be able to support user weight and should not inhibit normal mobility.
    b. *Safety:* The alarm on the walker should not startle the user causing unsafe behavior.
    c. *Accuracy and Reliability:* The walker should notify the user when they are approximately one-three feet away from the walker. Step count, cadence and time of use data should be accurate within 5% of the total steps taken and the total time used.
    d. *Life in Service:* The device should last for lifetime of the patient with appropriate power supply.
    e. *Shelf life:* Shelf life is not an applicable restraint for the device.
    f. *Operating Environment:* The device will be used in a clinical study by a clinical research assistant. The device should be able to function in the home as well as outside.
    g. *Ergonomics:* The device should be comfortable for the user and not inhibit their normal. The device should be easy to read for low vision

users, should have no small buttons, and should be easy to use for users with limited technological knowledge.

   h. *Weight:* The device weight should not add more than 2 lbs to the functional walker weight.
   i. *Materials:* The walker should be made out of standard materials such as aluminum, that can incorporate the appropriate electronic equipment.
   j. *Aesthetics, Appearance, and Finish:* The user sensor should be small and attachable to clothing or wrist. The incorporated electronics should be neatly packaged.

2. **Product Characteristics**
   a. *Quantity:* The client requires one working prototype to be tested by human subjects.
   b. *Target Product Cost:* $20-500, could be increased with client approval

3. **Miscellaneous**
   a. *Standards and Specifications:* The device should hold patient weight and be user friendly.
   b. *Customer:* The device will be tested on human subjects
   c. *Patient concerns:* The device should be user friendly for those with audio, visual, and precise movement impairments. The alarm should not cause additional agitation or unhealthy patient behavior.
   d. *Competition:* There are no walkers that are able to sense when the user walks away or that are able to quantify usage.

Appendix B:

Speedometer Code (C++)

```
//calculations
//tire radius ~ 2.5 inches
//circumference = pi*2*r =~15.708 inches
#define reed A0//pin connected to read switch
//storage variables
int reedVal;

long timer;// time between one full rotation (in ms)

float fps; //feet per second

float radius = 2.5;// tire radius (in inches)

float circumference;

int maxReedCounter = 100;//Time after first detection of switch
closed (in ms)
```

```
int count = 0; // counter for data storage array.

int reedCounter; // decrements by one every 1/1000s

float totDistance = 0;

float newDistance = 0;

float totTime = 0;

float totTimeUsage = 0;

float totTimeSecond = 0;
float avgSpeed = 0;

float storageAr [3] [100];

int i = 0; //after 10 secs without pulse response, output 0
avgSpeed.

int n = 0; // make sure avg is only calculated once everytime
timer > 2000

String dist = " Feet";
String rate = " Feet per Second";
String time = " Second";

void setup(){

  reedCounter = maxReedCounter;

  circumference = 2*3.14*radius;

  pinMode(reed, INPUT);

  // TIMER SETUP- the timer interrupt allows precise timed
measurements of the reed switch

  cli();//stop interrupts

  //set timer1 interrupt at 1kHz

  TCCR1A = 0;// set entire TCCR1A register to 0
  TCCR1B = 0;// same for TCCR1B
  TCNT1 = 0;
  // set timer count for 1khz increments
  OCR1A = 1999;// = (1/1000) / ((1/(16*10^6))*8) - 1
  // turn on CTC mode
  TCCR1B |= (1 << WGM12);
  // Set CS11 bit for 8 prescaler
  TCCR1B |= (1 << CS11);
  // enable timer compare interrupt
```

```
  TIMSK1 |= (1 << OCIE1A);
  sei();//allow interrupts
  //END TIMER SETUP
  Serial.begin(9600);
}
ISR(TIMER1_COMPA_vect) {//Interrupt at freq of 1kHz to measure
reed switch

  reedVal = digitalRead(reed);//get val of A0

  if (reedVal){//if reed switch is closed
    if (reedCounter == 0){//min time between pulses has passed
      i = 0;
      n=0;
      fps =
((56.8*float(circumference/3))/float(timer))*5280/3600;
//calculate feet per second
      newDistance = fps * float(timer)/1000;
      totDistance = totDistance + newDistance;
      totTime = totTime + timer;
      timer = 0;//reset timer
      reedCounter = maxReedCounter;//reset reedCounter

    }

    //else{
    //if (reedCounter > 0){//don't let reedCounter go negative
    //reedCounter -= 1;//decrement reedCounter
    //}
    //}
  }

  else{//if reed switch is open

    if (reedCounter > 0){//don't let reedCounter go negative
      //k = 0;
      reedCounter -= 1;//decrement reedCounter
    }

  }

  // walker is stopped. average speed calculated. total distance
and average speed stored in array. array count updated, mph
reset.
  if (timer > 2000){
    i +=1;
    if (i > 10000 && n ==1){
      avgSpeed = 0;
      storageAr [0] [count] = totDistance;
      storageAr [1] [count] = avgSpeed;
      storageAr [2] [count] = totTimeSecond;
      displayFPS();
```

```
      i = 0;
      n = 2;
    }

    if( n ==0){
      if (totDistance != 0){

        avgSpeed = ((totDistance )/ (float) totTime)* 1000 ;
//feet / sec
      }
      else {
        avgSpeed = 0;
      }
      n =1;
      totTimeUsage = totTimeUsage + totTime;
      totTimeSecond =totTimeUsage /1000;
      storageAr [0] [count] = totDistance;
      storageAr [1] [count] = avgSpeed;
      storageAr [2] [count] = totTimeSecond;
      displayFPS();
      count +=1;

    }
    fps = 0;//if no new pulses from reed switch- tire is still,
set mph to 0

      totDistance = 0;
    totTime = 0;
  }
  else{

    timer += 1;//increment timer

  }

}

void displayFPS(){

  //Serial.print(storageAr [0][count]);
  //Serial.println(dist);
  //Serial.print(storageAr [1][count]);
  //Serial.println(rate);
  Serial.print(totDistance);
  Serial.println(dist);
  Serial.print(avgSpeed);
  Serial.println(rate);
  Serial.print(totTimeSecond);
  Serial.println(time);
}
```

```
void loop(){

}
```

Appendix C:

FM Transmitter Testing

Distance (ft)	Trial 1 (dB)	Trial 2 (dB)	Trial 3 (dB)	ave (dB)	stdev (dB)
0.25	-39.156	-39.62	-39.7	-39.49	0.29
0.50	-44.14	-45.39	-46.3	-45.28	1.08
0.75	-46.8	-49.5	-53.6	-49.97	3.42
1.00	-49.608	-53.9	-57.7	-53.74	4.05
1.25	-56.62	-58.8	-59.4	-58.27	1.46
1.50	-57.252	-59.4	-59.4	-58.68	1.24
1.75	-58.188	-59.7	-60.3	-59.40	1.09
2.00	-58.188	-60.8	-60.6	-59.86	1.45
2.25	-58.188	-60.8	-60.6	-59.86	1.45