Fall 12

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, the team will design a device to be attached to 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 FM transmitter and field strength meter, a microcontroller, and a speedometer, in addition to a relevant circuit board, alarm, 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 an elderly person into the hospital then 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 walks around without their aid. 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 falls due to forgetting a walking aid is increased 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:

Our 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. Both pieces will be integrated into the walker system using a microcontroller. First we will consider how to sense the proximity of the user to the walker and secondly cadence measurement systems will be discussed.

Proximity Sensor

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].

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

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].

Infrared Sensor:

The infrared sensor is often seen in many areas of 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 lighting. 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].

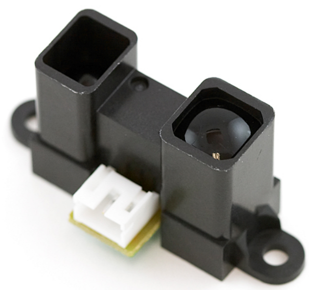
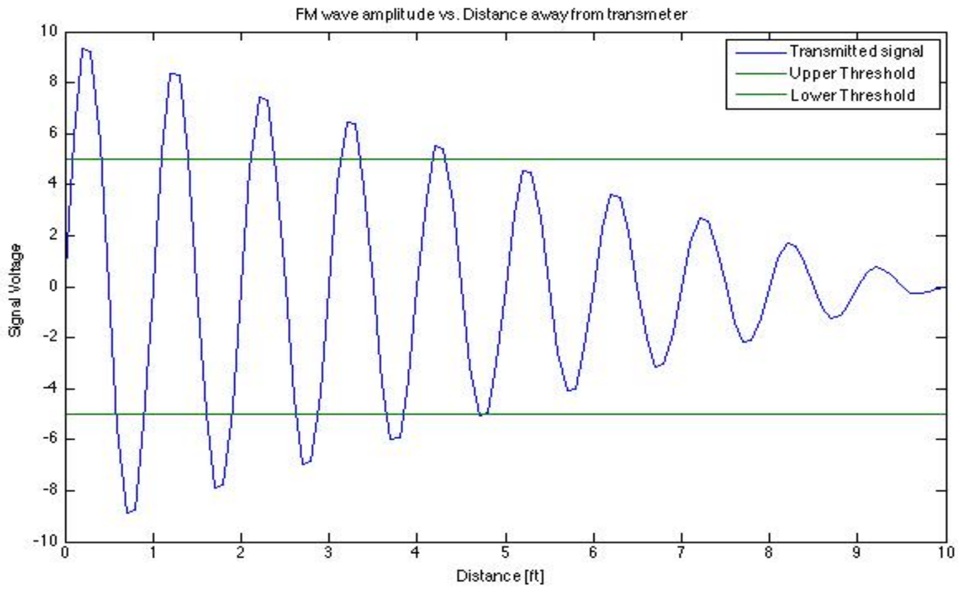


Figure 3: Infrared sensor that exemplifies its limited directionality. From http://www.sparkfun.com/products/8958

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 4]. 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.



Proximity Sensor Design Matrix:

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
Acurracy	35%	4	1	2
Interference	25%	3	1	2
Feasability	15%	4	3	2
Size/Weight	15%	3	4	3
Cost	10%	4	2	4
Total	5	3.6	1.85	2.35

A design matrix was created to evaluate our three 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. 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.

Cadence Measurement

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 5]. 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 5: Screen-based pedometer that allows connection to a computer for daily tracking. From http://www.dimensionengineering.com/images/products/DE-ACCM3Dbig.jpg

Accelerometer:

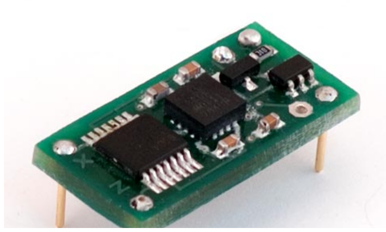


Figure 6: The typical circuitry of chip embedded

An accelerometer implements 3-axis MEMS inertial sensors to detect local accelerations [Figure 6]. 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: Bike speedometer with the equipment to count revolutions of a wheel. From http://image.made-in-china.com/2f0j00FeOEKtJhrRpj/Bicycle-Cycle-Computer.jpg

Speedometer:

Simple and inexpensive speedometers designed for bicycles calculate speed by tracking wheel rotation [Figure 7]. 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 wheel 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:

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

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. 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 FM transmitter and the speedometer.

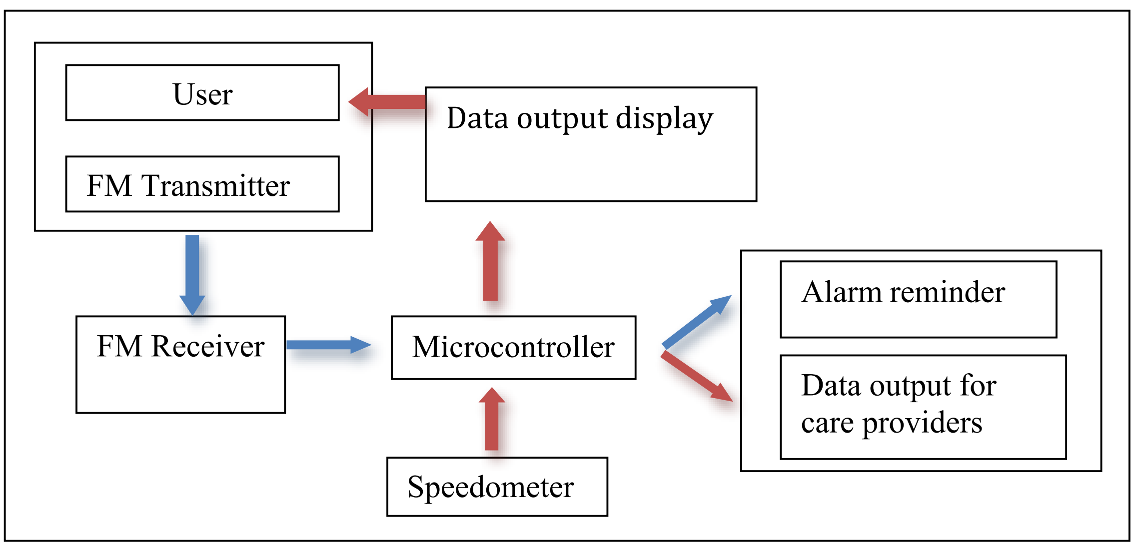


Figure 8: Block diagram of the alarm and cadence process on the two-wheel walker. A microcontroller will process and store data and output data to display or as a data file for use by care provider.

An Arduino microcontroller will serve as a central hub which in charge of activating the alarm when the FM receiver signal falls below threshold and tracking and output data gathered by the speedometer unit. Data can be accessed on the controller via USB. A circuit must be designed to allow communication between; the controller, FM receiver, Speedometer, Alarm speaker, and Output Display. A block diagram has been made to illustrate these connections (Figure 3).

Distance measurement for alarm triggering will include a receiver mounted on the walker and a small, low power, lightweight FM 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 necklace. Data transmitted to the receiver will be processed using methods previously described.

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. Our 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 9. The sensor hardware consists of a magnet 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 pule data into distance and speed we added code to a template found on Instructibles.com(13).

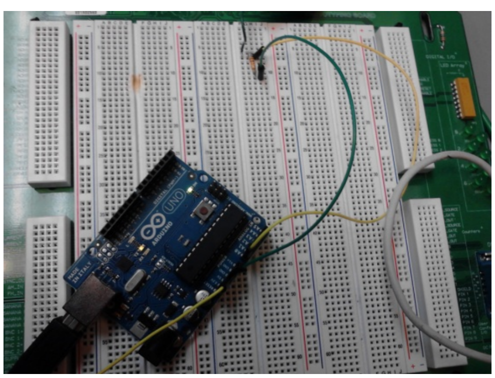


Figure 9: Speedometer hardware connected to Arduino microcontroller through a simple circuit.

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 ten 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.

Transmitter/Receiver Circuitry:

As the semester progressed the team moved away from the sinusoidal signal of the transmitter to a system which utilized field strength meter instead. A field strength meter circuit is used to detect and receive different types of radio frequencies and magnetic fields. Focusing in on what will be used for proximity sensing, the radio frequency (RF) field strength meter has a simple design, consisting mostly of resistors, capacitors and diodes. The measurement of certain frequencies can be accomplished by strategically changing the value of the resistors. This makes it useful to detect many different types of signals such as, low power transmitters and adjusting antennas (13).

For purposes of this project, a field strength meter that detects FM band RF frequencies of a specific frequency range is necessary. To accomplish such a task the field strength meter circuit must be constructed that has the appropriate resistor and capacitor values to dial in the band desired.

The transmitter used is a battery powered FM transmitter intended for using an .mp3 player in a car stereo, and can be picked up at any local department store or online at places like Amazon.com. The wireless FM transmitter used is able to pick out and use any FM RF frequency. One benefit of this device is that it is quite small and easily placed around the ankle.

The receiver in the design is a field strength circuit that can measure the strength of frequencies ranging from 30 MHz to 2 GHz. This design uses an antenna to pick up the RF frequency waves given off by the transmitter as seen in Figure 10. This signal runs passively through the circuit and amplified at the end before being passed into the device reading the output data. At this point our prototype uses an oscilloscope, but the final device will use the Arduino's analog input. Since there is amplification involved, a 9V battery source must be applied to power the amplifiers.

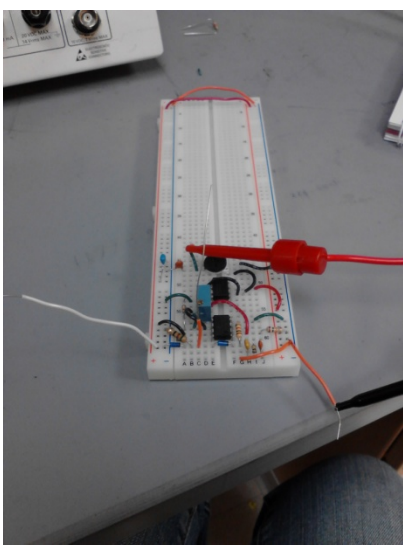
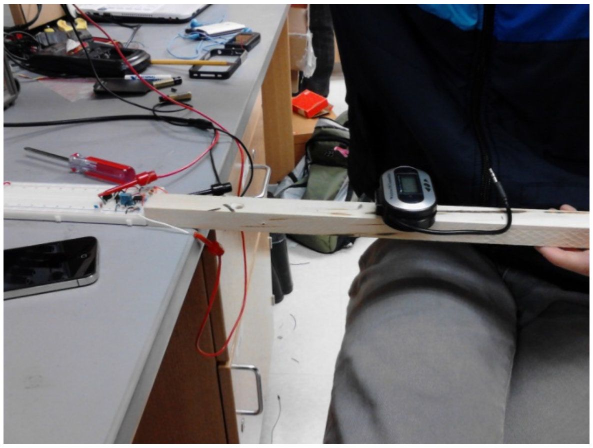


Figure 10: Receiver circuit with antenna and oscilloscope connections for receiving transmitter signal.

There are two potentiometers incorporated into the circuit. The 5 kΩ one placed just before the output is used to tune the field strength meter to the desired frequency range. The second, 10 kΩ is located in the amplification area of the circuit. Its job is to increase or decrease the gain of the output signal making the wanted frequency to become more defined.

The actual output signal is a series of sinusoidal elements in the mV range. These values increase in RMS value when the transmitter gets closer and decrease as the transmitter moves away. It was found that when the antenna is coiled, rather than straight, the detection value increases due to increases on the FFT plot.

Testing:



Upon completion of the prototype circuits, testing occurred to prove that the concept would work over all. This kind of proof of concept testing was done on both circuits separately. One such test was done to verify the signal change over distance from the antenna on the receiver circuit as seen in Figure 11. The transmitter was progressively moved away from the antenna in 3 in. increments and the decibel signal was recorded in Table 3.

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

Distance (ft)	Average dB
0.25	-39.492
0.50	-45.2767
0.75	-49.9667
1.00	-53.736
1.25	-58.2733
1.50	-58.684
1.75	-59.396
2.00	-59.8627
2.25	-59.8627

The accuracy of the speedometer was also tested. The magnet was attached to a wheel with the same 5 in. diameter as the two-wheel walker and able to rotate freely off a counter. The magnetic sensor was placed at a close distance to make measurements as seen in Figure 12. 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 results shown in Figures 13 and 14 display that the circuitry is accurate at lower revolution speeds and for greater amounts of total rotations. To help the circuitry compensate for the slow speed of normal walker usage, a total of four magnets will

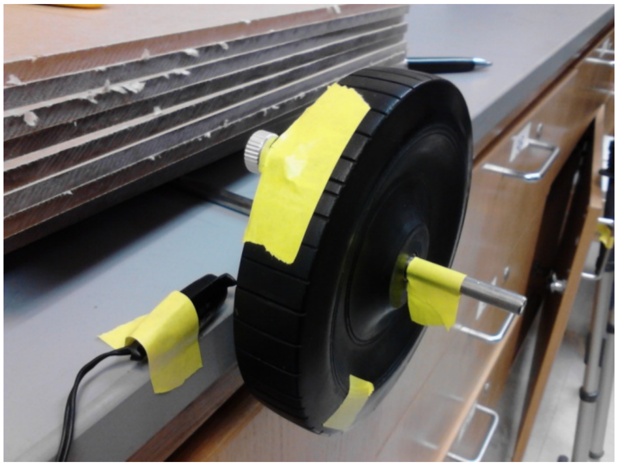
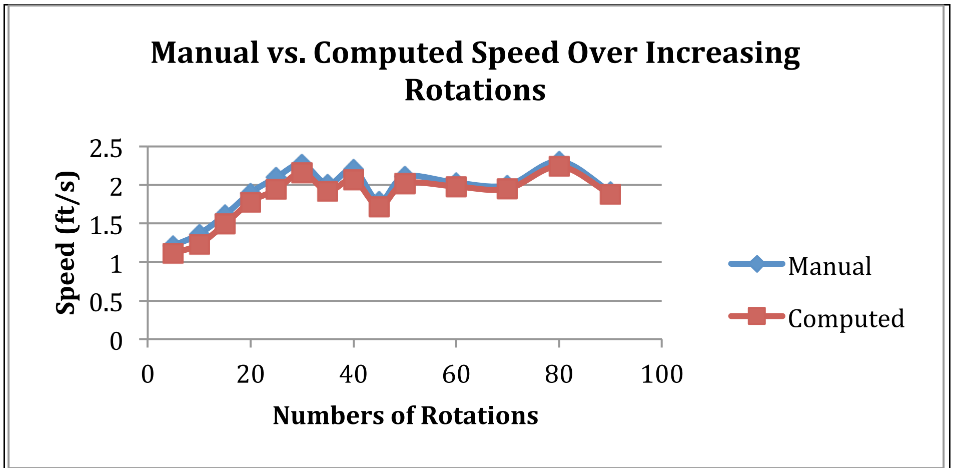


Figure 12. Setup of accuracy testing for the time and cadence recordings of the speedometer equipment and program.

be placed on the final walker wheel. This will allow the program to continuously count and a simple change in the code calculations will still give accurate speeds and cadence.



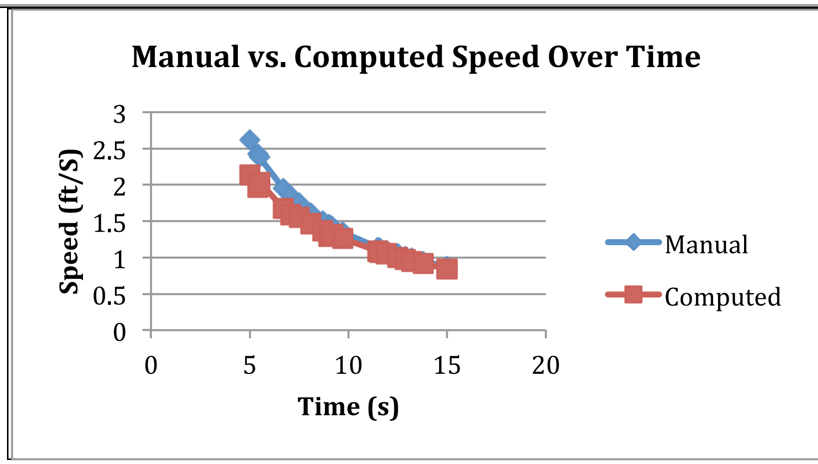


Figure 13 & 14. Comparison of the manual versus computed speed of the speedometer rotations over increasing rotations (top) and time (bottom).

Cost:

Throughout the semester 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 semester 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

Total	**$151.43**

Future Work:

Moving forward, next semester will focus on integrating the individual distance alarm and speedometer components into a unified final prototype. As the prototype is finalized, testing will be done with human subjects to provide performance feedback and suggest further improvements.

Final Device Testing:

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. The software will need to be more robust as well. Methods need to be developed for triggering the alarm, silencing the alarm, and outputting the usage data to another device.

Once the circuitry has been neatly packaged and modified for walker attachment, we will test the new prototype walker for accuracy and patient reaction. The walker must keep an accurate array of distance and speed measurements. These values should be within 5% of actual values 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. We will also test how far one is able to move away from the walker while wearing the transmitter bracelet or clip on before the alarm sounds. The alarm should not be too sensitive that it goes off too often and becomes obtrusive, but also must sound before the patient is at risk of a fall. Testing will be done to find this “sweet spot” for the distance sensor. Ideally this distance can be modified for each individual case.

Once the device has been proven properly accurate, the client would like to have the device tested on elderly subjects. This will require us to individually acquire Collaborative Institutional Training Initiative (CITI) training in order to work with human test subjects under IRB approval. 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. 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.

Conclusion:

The goal of this project is to improve two-wheel walkers to help prevent injuries from falls. The device will do by alerting the user when they have begun to walk away without their walker via low power FM transmitter and receiver 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. The next semester will be spent creating a finely packaged prototype

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Appendix A:

Project Design Specifications
October 20, 2012
Rachel O'Connell, Jared Ness, Alpha Liu, Billy Zuleger

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 foot 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;
long totTime = 0;
float avgSpeed = 0;
float storageAr [2] [100];
int k = 0; // make sure fps is only calculated once everytime magnet gets close
int n = 0; // make sure avg is only calculated once everytime timer > 2000
String dist = " Feet";
String rate = " Feet per 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
if (k == 0){
n=0;
fps = ((56.8*float(circumference))/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){
if( n ==0){
```

```
if (totTime != 0){
// newTotTime = (float)totTime;
avgSpeed = ((totDistance )/ (float) totTime)* 1000 ; //feet / sec
}
else {
avgSpeed = 0;
}
n =1;
storageAr [0] [count] = totDistance;
storageAr [1] [count] = avgSpeed;
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);
}
void loop(){
//print fps once a second
//displayFPS();
//delay(10);
}
```

Appendix C:

Receiver Circuit Schematic