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Alert System and Cadence Walker

BME 400

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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 receiver, 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 prjects in all areas of the prgram 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].

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 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

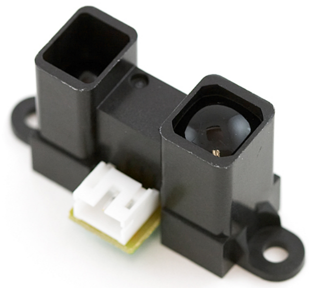

Figure 3: Infrared sensor that exemplifies its limited directionality. From http://www.sparkfun.com/products/8958

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].

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.

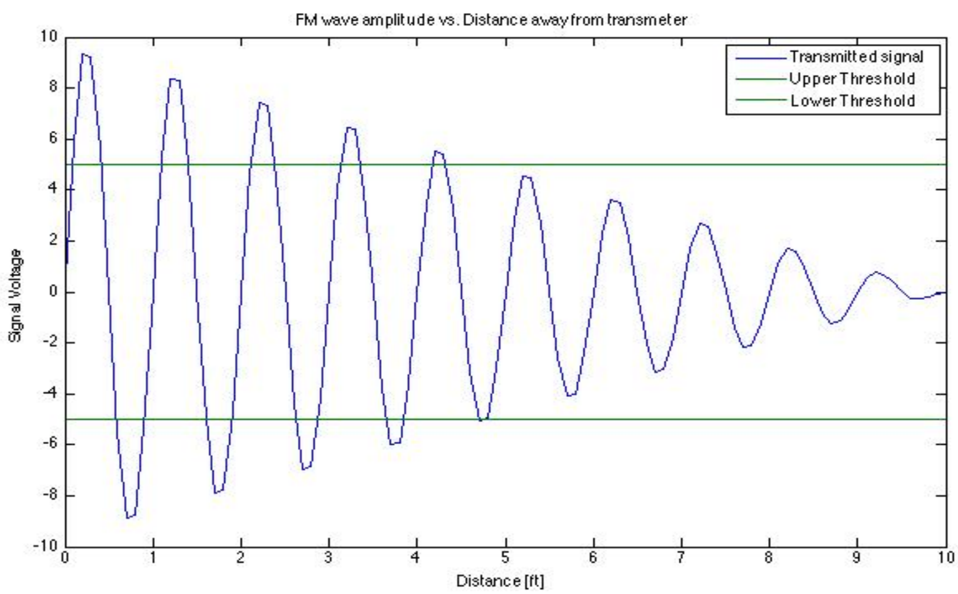

Figure 4: This graph shows the FM wave amplitude vs. distance away from the transmitter. As distance increases so does the decay in the amplitude of the sinusoid, triggering an alarm once it falls below threshold.

Proximity Sensor Design Matrix:

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

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

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:

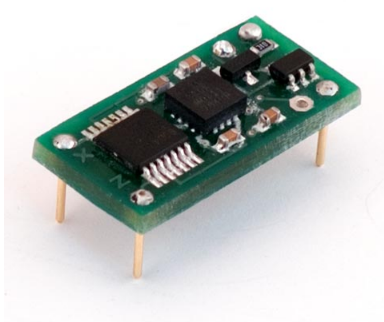

Figure 6: The typical circuitry of chip embedded accelerometer. From http://gatorade2008.republika.pl/itrip2/itrip-both.jpg

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.

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

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

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:

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

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

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.

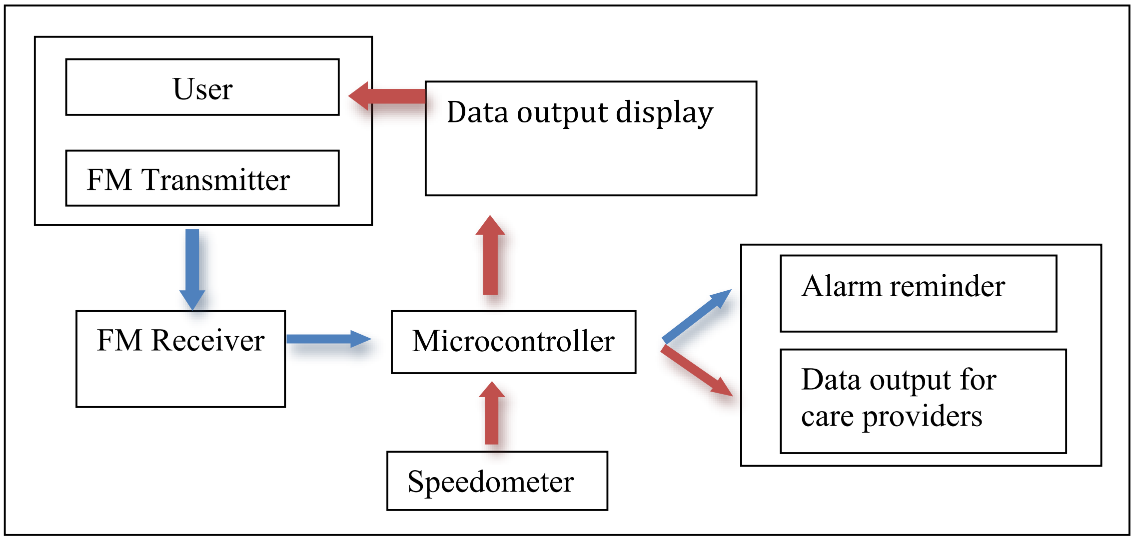

Figure 8: Block diagram of the alarm and cadence process on the two-wheel walker. A microcontroller will process and store data and output data to display or as a data file for use by care provider.

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.

Future Work:

Moving forward, we plan on visiting an assisted living facility to evaluate the types of circumstances that cause a patient to begin walking away without their necessary walking aid. This will give us a better idea of the alarm distances that would be most appropriate for patients that require walkers and help further define the parameters for the device prototype.

Prototype Fabrication:

Most of the remaining time will be spent purchasing the FM transmitter, a corresponding receiver, a microcontroller with audio capabilities, and a bike speedometer and adapting all the pieces for use on the walker. The transmitter will have to be tested for its sine wave amplitude in relation to distance from the receiver. The amplitude of 1 meter will be used to set the alarm via the microcontroller. This test can be done using available lab equipment such as an oscilloscope. The FM transmitter will be incorporated into a bracelet or clip on device that will attach directly to the patient. The speedometer that we have chosen to use will be manufactured for use on a bike. The attachments for the magnet on the wheel will have to be modified to attach on the smaller walker wheels.

For the working prototype the FM receiver, microcontroller and subsequent alarm equipment will be built in a simple circuit that connects to the speedometer and the walker. Once proof of concept is established by this prototype, these three components will have to be incorporated into one small and attachable unit. Research will have to be done on companies that offer this type of circuitry services. When the product is packaged, a USB port should be incorporated to gain the ability for the stored information from the speedometer to be sent to the primary care provider.

Device Testing:

Once the circuitry has been neatly packaged and modified for walker attachment, we will test the prototype walker for accuracy and patient reaction and use. Accuracy testing can be done individually. The walker should keep an accurate count within one minute of the total time of use throughout each day. The walker should have an accurate count of steps taken within 5% of the total steps taken. These one minute and 5% markers are 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 based on this data. We will also test how far away one is able to move away from the walker while wearing the transmitter bracelet or clip on before the alarm sounds. These measurements will help to test the distance accuracy of the transmitter and see whether the alarm sounds before the patient has a chance to put him or herself as risk for a fall.

Once the device has been proven properly accurate, the client would like to have the device tested on elderly test 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 remainder of the semester will be spent purchasing and adapting these materials for walker attachment and use.

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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 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.