StrideSmart: Design Brief

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STRIDESMART

Problem Statement:
By the year 2040, it is expected that over 21.7% of the U.S. population will be over the age of 65 [1]. In 2015, one in three people over this age experienced a fall [2]. For the elderly population that is over the age of 80, the frequency of falling increases from 33% to 40%. Of the falls that occur within the 65 years or older population, 40% lead to a hospital visit for treatment of fall-related injuries. Additionally, 15% of recorded falling cases include fractures, bruises, soft tissue injuries and a loss of independence [3]. The overall direct cost to society as a result of the injuries incurred from falls has surpassed 34 billion dollars annually [2]. These statistics help to reiterate the prevalence of falls within the elderly population and the toll that these falls have on their financial status due to sustained injuries. Mobility device usage statistics have increased from 16 percent elderly usage to 24 percent usage between 2004 and 2012. This serves as further indication of increasing age within the U.S. population. It can be concluded that an estimated 8.5 million seniors currently utilize one or more mobility devices [4].

In order to promote balance and mobility in their daily lives, many elderly citizens use a mobility assistive device such as a cane or a walker. Popular assistive devices include: single tip straight or offset canes, quadruped canes, pick-up walkers, walkers with two front wheels, and rollators. These mobility assistive devices help to alleviate some of the weight that one or both legs must bear during normal ambulation. This in turn helps to decrease the pain from an affected limb and helps to compensate for weakness or impaired motor control. Canes are usually the assistive device of choice when there is a moderate level of impairment being experienced. Walkers are necessary in cases where there is a higher level of overall weakness of the body or the limitation of putting weight on lower limbs. Mobility assistive devices help to increase independence within the elderly population and to prevent osteoporosis and other health declining conditions that can result from sedentary behaviors. However, even though the use of an assistive device can help to increase everyday mobility, there is a high level of abandonment and misuse of mobility devices within the elderly population. Statistics in 2004 stated that 30-50% of users stopped using their device soon after receiving it due to not having the appropriate device prescribed for their needs, receiving improper training on the device, or obtaining the wrong device on their own, some of which actually emphasized the mobility issue that they were trying to compensate for [5]. When the proper mobility assistive device is used, it can improve the user's balance by helping to make sure the body's center of mass is supported within the limits of their base of support. Loss of balance occurs when the center of mass of a person is displaced in relation to the base of support due to an incorrect movement or an external factor such as slipping or tripping. Using an assistive mobility device increases the user's base of support and in turn provides a greater range in which the center of mass of the person can be moved around without losing balance [5].

Method and Approach:
The major causes of unintentional falls that occur with the use of a mobility assistive device stem from incorrect cane height and improper forward and lateral leaning, which can be a result of improper training or device selection [6]. There is a need for fall prevention in the elderly population due to its widespread occurrence and detrimental effects to patients.

Figure 1: StrideSmart Prototype

Currently, feedback systems that provide alerts based on poor walking quality and gait patterns are not readily available, meaning that the elderly and their caregivers often have no informative means to adapt walking practices to avoid falls. It is essential that caregivers, families and physicians have access to performance reports and data that quantifies the patient's activities and walking quality to allow their treatments to be tailored to their current progress. Motivated by this issue and need, our team of three driven undergraduate Purdue Biomedical Engineering students is dedicated to the development of StrideSmart, a smart mobility assistive device solution. This device consists of attachments for regular, single-tip canes that quantify the user's gait patterns and activity levels as well as provide haptic feedback in the handle of the cane for immediate gait correction. Our solution is aimed to successfully train users to walk with proper gait mechanics, provide invaluable information to healthcare providers, and promote a healthy, active, and confident lifestyle of the geriatric patient.

Most importantly, the solution must be able to quantitatively identify the activity and use of the device by the patient, such as leaning angles, weight applied, usage time, number of steps taken during use, and cadence of their gait. Features employed for collecting and measuring this data must consist of accurate and sensitive sensors such as a pressure sensor and an accelerometer. The pressure sensor must be able to register and record weight applied to the device ranging from 10-100 pounds. The accelerometer should calculate angular velocity and acceleration which can be used to calculate 3 axes of orientation and +/- 180º of detection. These sensors should be used to collect quantitative data that will be transferred by Bluetooth technology to an iOS application. Detection must also be extended with a feedback system which will provide alerts to users when potential triggers for falling such as too much weight on the cane or improper leaning angles are identified. The information collected by the sensors should then collaborate with smart backend algorithms to discern information of the patient to interpret results in terms of usage time, the leaning angles in which the device was used, and the amount of weight of the user applied on the cane. Further, these results must then be transferred to a smartphone application which will process data, provide feedback to the user, and give notifications. The app will display descriptive reviews of use in the form of tips, trends, and interactive graphs in multiple modules depicting quantitative data. Information such as tutorials and options to customize and control the feedback of the device will also be available. Additionally, in order to avoid precarious direct contact of the user and mechanical/electrical components, the components must be safely housed and insulated, and have the ability to get securely attached to the cane.

Moreover, it is essential for the solution to be easy to use and convenient for the elderly. It must be very user-friendly with a simple interface comprised of adaptive and customizable functionalities. Considering the needs of the elderly, the overall solution must take less than 60 minutes to learn and have less than 3 operable buttons to reduce confusion. An important aspect of our product is that it should be compatible with any type of single tip cane; however, the overall cost of the solution must be under $150. The housing containing all of the sensors and processor and the cane tip also must not weigh more than 1 pound so that an excessive amount of weight is not added to the current weight of a regular device.

Final Design

The current StrideSmart prototype accesses four key design features: tracking the position and angle of the cane in space, monitoring the force applied to the cane, providing vibratory feedback to the user when using the cane unsafely, and presenting trends and walking habits to a user after long-term cane use. The main features of StrideSmart are organized within two major subcomponents: physical attachments and integrated software.

The first design feature, tracking the position and angle of the cane in space, uses data processing on an Adafruit Feather microcontroller while an MPU-6050 sensor combines the functionality of a MEMS accelerometer and a MEMS gyroscope. The accelerometer and gyroscope combination aids in the quantification of gait through the measurement of the cane angle when it makes contact with the ground, while also calculating walking speed, number of steps, and fall detection.

To measure the force applied to the cane, an attachable cane tip component is utilized. The tip attachment is comprised of a pressure sensor integrated inside of a cane tip end cap. The attachable tip cap is designed such that it harbors the pressure sensor and enables it to remain securely centered so that it can continuously obtain readings in all directions. The tip cap enclosure enables the sensor to avoid direct contact with the ground in order to prevent wear and tear of the sensor.

A key feature that differentiates this solution from other existing or emerging ones is immediate feedback alerts in the form of vibrations that inform the user when they are either placing too much weight on the cane or using it at an unsafe angle. For this, two vibratory motor disks secured within the back of the enclosure are utilized. Vibrations propagate up the shaft of the cane to be felt in the grip by the user. When the haptic feedback is triggered, one vibrating motor disk will fire if data is outside of the acceptable threshold. Both disks will fire if data is more than 5° or 10 pounds outside of the threshold. The user continues to receive haptic feedback in the handle of the cane until they adjust the position of the cane or the weight being applied to it within acceptable limits.

Processed data from the microcontroller is sent to mobile software via low energy Bluetooth technology. Algorithms have been developed to analyze and convert the data into viewable performance trends corresponding to exhibited gait patterns and device use. The software also highlights times when data appeared too far outside of an acceptable range, such as when too much force is applied on the pressure sensor. The software consists of several modules. The home screen allows the user to choose between trends, training, and settings. The training module allows the user to access information pertaining to proper cane set-up, instructions for using the app and interpreting data, and videos that show proper technique for walking. The trends module allows the user to view activity graphs for various cane activities, forces applied, and cane angles exhibited. Finally, the settings module allows the user to enter information such as their height, weight, or to specify if they want to follow the default settings for when an alerts and emergency contacts. In addition to patient use, physicians, caregivers, physical therapists, and family members can use this information to effectively take care of their elderly patients and loved ones. Future software design considerations include monthly status reports, multi- user trend database storage, and server access to data for multiple patients.

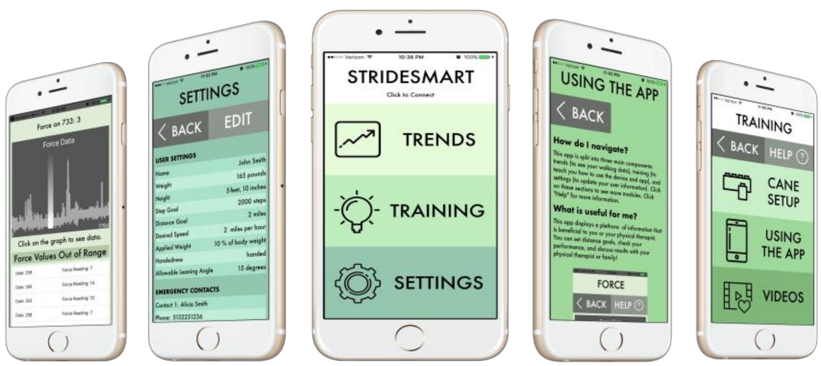
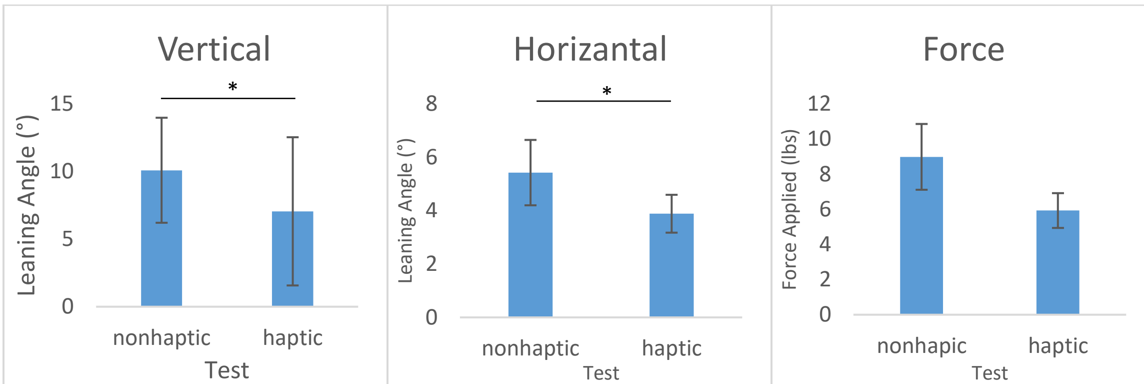


Figure 2: StrideSmart App

Outcomes:
The verification testing of the sensors on StrideSmart have been done. The results for the accelerometer testing on two axes had a correlation of .9997 with all values within one degree of the actual value, showing accelerometer can accurately determine the leaning angle of the cane. The pressure sensor also had a correlation of .9997 with all values within 2 pounds of the amount applied. This allows the StrideSmart to accurately measure the weight the user applies onto the cane. These two sensors, alone, show StrideSmart can be used as a recording tool for gait analysis which can bridge the gap between physical therapists and users.

Initial validation testing has been completed without experienced cane users. The users were trained for 10 minutes on how to walk with a cane, and then the user would walk around a rectangle that was 80 feet twice. The first time is without haptic feedback, and the second time is with haptic feedback. The force, vertical lean, and horizontal lean of the cane were measured, and compared using a student's t-test. The results show haptic feedback reduced all the outcomes. The mean vertical lean of the cane was decreased by 3.04 degrees ($p = .003$). The mean horizontal lean of the cane decreased by 1.54 degrees ($p = .0085$). Lastly, the mean force applied on the cane decreased by 3.05 pounds (p = .075). These decreases in mean show that the users followed correct walking patterns by staying in the correct range of motion along with the t-test showing significant difference between haptic and nonhaptic feedback. At the end of the test, users' response to the haptic feedback was positive. They said the feedback made them aware of their bad gait patterns which in turn corrected their gait.



Graph 1: The graphs display the mean with the standard deviation bars from the t-test. The asterisk shows a significant difference defined by a p value less than .05. The graphs from left to right are vertical lean (a), horizontal lean (b), and force (c).

In the next few months, tests will be performed with patients in the geriatric population to increase the sample size and better determine the effect of haptic feedback on the user gait. The phone application will undergo human factor studies to test if it is easy for elderly patients, their caregivers, and physical therapists to navigate.

Cost:

The total cost of creating our current prototype is ninety-one dollars. The budget is shown in Table 1 on the right. This price can be decreased from creating a printed circuit instead of using the various development boards. An estimated price for a commercially viable product is 30 to 40 dollars. As an early projection, the selling price of a finalized, commercially viable product would be in the range from 100 to 150 dollars.

Materials	Cost
MPU-9250	$15.00
Flexiforce Sensor	$20.00
Microcontroller	$20.00
Bluetooth LE Mini	$18.00
Enclosure	$6.00
Polymer Lithium Battery	$12.00
Total ($)	**$91.00**

Table 2: Itemized cost of StrideSmart Components

Significance:

Our solution is unique because there are no other products on the market that offer cane attachments or are mobility devices themselves that provide continuous immediate feedback to users during use. Our attachments can be attached to any regular single-tip cane. There are several products that claim to have redesigned the cane in ways that allow users to personalize their support currently on the market. For example, there are canes with different handles, various material constructions, foldable options, offsets, mechanical design, etc. In terms of fall prevention, solutions such as traditional walkers, quadripod canes, and Active Protective's inflatable airbag are available.

Solutions that are more comparable to our design include the UCLA produced cane and Isowalk cane that is currently under development. The UCLA cane utilizes a pressure sensor as well as an accelerometer and gyroscope which are integrated into a cane as permanent attachments. Their device can send data to clinicians with the MEDIC Telehealth System [7]. Similarly, Isowalk is a smart mobility assistive device and an emerging solution with the ability to measure vitals for proper gait usage with their cane and software. This cane is also totally redesigned in terms of the handle and cane tip used on the bottom compared to current devices that are out on the market.

In contrast with these products, our solution allows the user to use their own single tip cane that they already own instead of having to go out and purchase a separate assistive mobility device. With the attachments that make up StrideSmart, the user can make any single tip cane access "smart" features. This provides our patient autonomy and customizability. The key innovative feature that differentiates us from others is the ability to utilize an immediate haptic feedback system. The haptic feedback system serves as a notification system to provide vibratory feedback to users in real time to alert them when they are using the cane incorrectly. The vibrations can be felt in the handle of the cane when the user either uses the cane at an improper angle or places too much weight on the cane. This allows the user to recognize when they are using improper mechanics, and then they can work to reinforce good habits by being conscious of reducing the amount of vibrations they trigger while walking. The vibrational alert system is an important innovative aspect to our solution that no other product offers. Other competing systems, including the UCLA cane and Isowalk cane do not have any effective feedback mechanisms to prevent falls or help with gait correction.

Another unique aspect of our design is the target audience of users. For example, the Isowalk cane is meant for nursing homes and hospitals so that the data and results will be viewed by the nurse or physical therapist, who would then give feedback to the patient. Our team is attempting to make the data accessible to both parties. This gives us the ability to send notifications to improve the gait of the user to help prevent any escalation in improper use habits that could lead to a fall. StrideSmart allows the user to record their walking data when the cane is used, and their physical therapist can later look through their data trends to see if they need to tailor their treatments any particular way or to pinpoint particular struggles that the user can continue to work through. StrideSmart keeps the physician in the loop so that they can be completely informed of the gait habits of the user while they are away from the rehab center. This is crucial information that helps keep the user accountable for their mobility. This solution allows the physical therapist to be brought to the user in terms of reinforcing good walking habits, and the data can then be brought to the physical therapist to allow for the best care possible. Further, the innovative system integration and communication with a user-friendly mobile iOS application is what gives this solution a unique edge. Finally, with StrideSmart, we hope to gain early access to the growing market of persistent health monitoring and preventative medicine. We hope to promote a market that detects health problems before they arise in order to allow for safer and more efficient healthcare.

REFERENCES

[1] Aoa.acl.gov, "Aging Statistics", 2016. [Online]. Available: http://www.aoa.acl.gov/aging_statistics/index.aspx.

[2] Cdc.gov, "Important Facts about Falls | Home and Recreational Safety | CDC Injury Center", 2016. [Online]. Available: http://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html.

[3] Mozes, A. “More Aging Americans Using Canes, Walkers,” Health Daily, 2015. [Online]. Available: http://consumer.healthday.com/senior-citizen-information-31/misc-aging-news-10/more-aging-americans-using-canes-walkers-study-finds-699143.html

[4] Lajoie, Y, Gallagher, S.P. “ Predicting falls within the elderly community: comparison of postural sway, reaction time, the Berg balance scale and the Activities –specific Balance Confidence (ABC) scale for comparing fallers and non-fallers”, Archives of Gerontology and Geriatrics, vol.38, no. 1, pp. 11-26m 2004.

[5] H. Bateni, B. E. Maki. “Assistive devices for balance and mobility: benefits, demands, and adverse consequences”, Archives of Physical Medicine and Rehabilitation, vol. 86, no. 1, pp. 134-145, 2005.

[6] H. Liu, J. Eaves, W. Wang, J. Womack and P. Bullock, "Assessment of canes used by older adults in senior living communities", Archives of Gerontology and Geriatrics, vol. 52, no. 3, pp. 299-303, 2011.

[7] L. Orlov, Technology for Aging in Place, 1st ed. Aging In Place Technology Watch, 2014.