Projects I Final Report

Fall Prevention

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Abstract
Falls are the leading cause of injury for older adults. [5] The need for something to combat this epidemic is huge due to the healthcare costs as well as the outcomes of a fall such as an injury. The objective of this project is to design a system capable of analyzing electromyography and accelerometer data in real-time and alert the patient when they are at increased risk of falling while walking. We will test three parameters on individuals to assess the gait profiles. Once analyzed, we will set threshold parameters that, if reached, will alert the patient.

Background
As people age and the body gets older, many health problems may arise due to a decrease in function of the various systems. These can include problems with the heart, lungs, muscles, bone density, as well as diabetes, heart disease, stroke and decreased muscle strength. [2] When these problems are combined with medications used to treat conditions, changes in a person’s mental status or their gait may result. [5] Biomedical engineering has come a long way in treating many conditions, working hand in hand with doctors to try to solve some of the problems associated with aging. However, there is somewhat of an epidemic within the elderly that results in millions of dollars of healthcare costs and many deaths. [5] One out of every three adults falls each year. Many who fall cannot get up on their own which can result in being left on the floor for hours causing dehydration, pressure ulcers, and bleeding. Even if they are able to get up on their own before the fall, falling down and hitting their head or any part of their body could result in a concussion or a fracture. To young people, a fracture may not seem like a big deal; but to the elderly whom already have decreased bone density, decreased nutrition and immune system, a fracture could result in death. [5]

Any time a fall occurs there is a potential danger for repercussion. For these reasons, our goal as biomedical engineers is to come up with a device which can be worn and can alert the person whether their gait is deviating from normal; this being a huge indication of a possible fall. When the device senses this change, it will alert the person so that they can stop, slow down or sit down. This type of ‘training’ is called biofeedback and it has been shown to help in many areas. A device such as this can be used as a tool to teach patients good walking patterns, or allow someone to be a little more independent with the safety feature that their caregiver can be alerted before the fall actually happens.

Our hypothesis is that when someone is walking, they have a certain pattern which is maintained; the pattern may change slightly but certain aspects remain the same. If these aspects change however, they may be at an increased fall risk which can be detected and thus alert the patient and the doctor. Gait has been studied extensively, and there has been many studies involving gait patterns related to falls. However, there are not many devices capable of easily measuring gait in any setting, such as in the home.
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Currently, a patient can go to the doctor for an extensive gait measurement study; but this requires an extensive network of sensors and it only acquires a small amount of data. [7]

**Research Plan**

To produce a device capable of detecting irregular gait patterns, a few considerations must be made. To execute this project correctly we must first acquire data from subjects as they are walking. For this project we will be using the DELSYS system. The DELSYS system is a set of small sensors which can track EMG signals as well as acceleration. The small sensors are wirelessly connected to the computer which uses a software development kit (SDK) to analyze and display the resulting data which we can use to explore capabilities for programming the device to automatically trigger the alarm. It is important to use a microprocessor for a system such as this, due to the large amount and complexity of the data as well as having the capabilities to trigger an alarm automatically.

When we acquire enough data to determine which parameters will be best for detecting a change in a person’s walking pattern, we will be able to decide where to set the threshold values for these parameters. This will be based on the experiments we conduct, as well as literature. As we set the parameters, we can then begin to write the program which will be used to trigger an alarm. The end result will be a design for a system which can possibly prevent a fall from occurring and thus preventing injury to the person.

**Methods and Tasks**

In order to properly develop this system, various aspects have to be taken into account. Running trial experiments with sensors placed in different areas of the body will be important to identify the best location that maximizes sensitivity while reducing false positives. Once key aspects have been identified and a pattern is established, we can then develop software that is capable of responding to specific walking patterns. For this type of data analysis, typically a microprocessor should be used; this must be designed to be capable of processing inputs related to acceleration, velocity, and orientation and comparing this to stored data. If a deviation from normal is detected, it will send an alert (alarm, vibration, etc.) to the user. The type of alarm used will be evaluated to see which would be best fit whether it is a vibration, or a loud beep/buzzer.

The development of a system this complex will rely on a microprocessor capable of quickly measuring active movements. To power such a system, a rechargeable battery must be implemented within the device. The key aspects of the device design will include: sensors, microprocessor with software developed for our goal, battery, and alarm. The whole system will be encased in a protective covering which will also include attachment to the user.
For our project we will be conducting research using the DELSYS system to measure acceleration and EMG at various points in the body. Each DELSYS sensor is less than 2cm by 2cm in size; each sensor contains a 3-axis accelerometer and an EMG sensor with 4 electrodes protruding from the core. The sensors are light-weight and can be attached to most muscles of the skeletal system. Raw data will be collected from these sensors for various points of the body, i.e. the upper and lower legs and the torso. The sensors are wirelessly connected to the charging station which is connected to a PC. Software installed on the PC enables the data to be analyzed and manipulated; it also includes a software development kit with various examples for different code. The data can also be exported to Microsoft Excel which it can then be further analyzed and manipulated, or exported to MATLAB for other types of data processing.

We have also submitted a proposal to Nike to possibly incorporate the Nike+ system with our project. The specific Nike+ system we are interested in using is comprised of two insoles that each have four pressure sensors and two accelerometers. We believe that if we can include data regarding pressure, we can analyze balance issues along with muscle contraction and acceleration to create a more robust walking profile.

Standard protocol for human subject testing shall be followed in accordance with the Lawrence Technological University Institutional Review Board. The protocol regarding the instrumentation follows a standard based on the function of the DELSYS software. A PC with the Trigno Control Utility installed must be used which allows the data collection. EMGworks data acquisition and analysis packages will be used for our studies. The software development kit which comes with the DELSYS software will also be used, and as a part of the project protocols will be developed based on the data collected. A new test is configured for each study participant and the sensors are set up according to the location on the body. Each test is performed and data is collected; at the end, the data is saved and exported to Excel for further analysis. Protocols shall be developed which detail how each variable of interest is extracted, as well as how to determine thresholds for these variables based on the data collected in the study.

The target group of our study is individuals over the age of 60. Most injuries associated with falls are a result of people over the age of 60. Age is not the only factor in our target approach. The target group should have no gait related issues, and they must have the ability to ambulate without an assistive device. These criteria make testing more refined. We can ensure we are getting readings that are not attributed to other factors. By standardizing our target, we can get accurately replicate the data gathering.

While our targets are individuals over 60 year, we want to compare how those individuals walk to other age groups. We would like to test three age categories: 18-30, 30-60, 60+) We chose those three age categories because it would be beneficial to explore how those at a younger age compared to elderly. It would also be essential to understand if walking patterns change gradually or quickly. We would need at
least two individuals for each age group. To test how gait patterns differ, we would like to conduct three trials on each individual: walking for five minutes, walking up a flight of stairs, and walking after sitting in a chair for ten minutes. These three trials would help determine the walking profile for various individuals, at various age groups. The profile will include the acceleration versus time for each of the 3-axis (x,y,z) as well as the EMG versus time; this profile contains this information for each sensor.

For our study, walking profiles will be quantified for various age groups. Literature will aid in producing values for our experimental group, the group which are at increased risk of falling based on aspects of their gait. The control group will be all the participants in the study, based on the fact that we are collecting data for “normal” “safe” walking/activity patterns. From this data, we will compare the values to literature based on statistical analysis. A study done by Caby, B. et al, measured accelerometer values for two different groups: people who have fallen and people who have not fallen. Many variables were extracted from this study which showed significance based on which group they were in. [7] There have been many studies similar to this which have extracted different thresholds for the border between “safe” walking and “risky” walking.

**Deliverables**

The outcome we expect from our project is a design for a system in which a device can be placed on the body and can sense a change in gait. When this change is sensed by the system, some sort of an alarm will alert the patient; the type of alarm used is to be determined. The device will be easy to use; the only requirement from the user is that the battery is charged and the device be placed on the body. We expect that the device will always be on when attached, to ensure that someone will not forget to turn it on. This will ensure that there are no false alarms when the user takes off the device and places it on their nightstand to go to sleep. Within the device will be a standard template for the software which will analyze the gait and activate the alarm. The data will also be processed and stored which will then be available for others to view, such as the doctor.

**Anticipated Challenges**

Setting up the device to accurately sense abnormal gait with minimal false positive is our first goal. To achieve this, it is important to test our device in different situations for many trials. This is why we include an intermediate age group for our study; we can run many tests on ourselves to develop a pattern but we must determine how this data will compare to older adults. Gait analysis also involves a lot of data, thus we must be able to sift through the data and determine which aspects are most important. This issue can be resolved by comparing literature to the data we collect in the study. Our minimal
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background in coding and microprocessors will be a hindrance but with the help of an SDK, our technical
advisors, and extensive research into these types of systems, we will develop this system to fit our goals.

**Implications and Impact**

Designing a device capable of detecting a fall before it occurs would have an enormous impact on
individuals who suffer from an increased risk of falling. The cost associated with falls continues to
increase and more importantly, individuals who fall face a diminished quality of life. Creating a device
that can detect abnormal walking can ultimately prevent people from falling. A device such as this, in the
future, will be easier to use than a smartphone and be able to track a person’s walking patterns and
activity level and in turn use it to train themselves into good walking patterns. These methods are already
used for athletes and children, so we believe that the extension of this technology onto the older adult
population will be huge. On another level, you can be safe knowing that a device is helping Mom or Dad,
while sending you and the doctor activity reports to make sure your loved one is doing well.

**Future Directions**

Future work on our device could be tailor the sensitivity by making the program more complex
regarding analyzing gait. For our device, we simply want to look at patterns which deviate from normal as
well as periods of time not active; future devices could actually categorize different walking patterns and
possibly diagnose different conditions or even predict falls sooner. We can also add on to the device an
automatic fall detection system which, in case the device fails to prevent the fall can call the authorities to
get help for someone who has fallen down. Other things that could be worked on in the future may
involve instructions given by the device to the user of how exactly to correct their walking patterns; sort
of like a pocket physical therapist.

**Team members and Responsibilities**

Akram Alsamarae and Lindsay Petku will work the together on running the experiments and
analyzing the data. It is important that we both master the data collection process and the DELSYS
software so that in case one person is not available for a test, other can be. It is important to have two
people, one person working with the test subject, such as helping with the sensors and instructing, while
the other person runs the computer software.

When the data is collected, it may be necessary to divide the analysis work into EMG-based
analysis and accelerometer-based analysis. Also, it can be broken down further by analyzing each sensor,
or set of sensors (if they are located symmetrically) separately. It is also important to categorize each trial
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into the three different activities, and to see how they compare. A table for the tentative breakdown of the work is displayed below.

<table>
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<th>Task</th>
<th>Experiment</th>
<th>Walking</th>
<th>Sit-then-walk</th>
<th>Walking up stairs</th>
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<td>Lindsay</td>
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</tbody>
</table>

References

[10] “Preventing Falls Among Older Americans”. CDC. http://www.cdc.gov/Features/OlderAmericans/
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Figures

Figure 1: A DELSYS sensor, capable of measuring acceleration and EMG

Figure 2: NIKE plus system; (left) set up system including USB connection, (right) two sole inserts including 4 pressure sensors and 2 accelerometers

Figure 3: Data collected using DELSYS showing the EMG and acceleration of the rectus femoris (anterior thigh muscle)
Cost

Costs for this project are offset by systems generously provided by Lawrence Technological University. The DELSYS system and the software that comes with it are at no cost to this project. There are many analysis tools which come with this software, but it can also be exported to Microsoft Excel and MATLAB, which are both programs provided on the Lawrence Tech. laptops.

Outside of the scope for the project would be to build a prototype of this device which is not one of the goals; however it would be the next step in the future for a commercial product such as this one so it may be noteworthy to mention. EMG sensors cost around $50, accelerometers are $20, a microprocessor would be around $80-100, and any other straps, housing, or circuitry would be another $30-50.