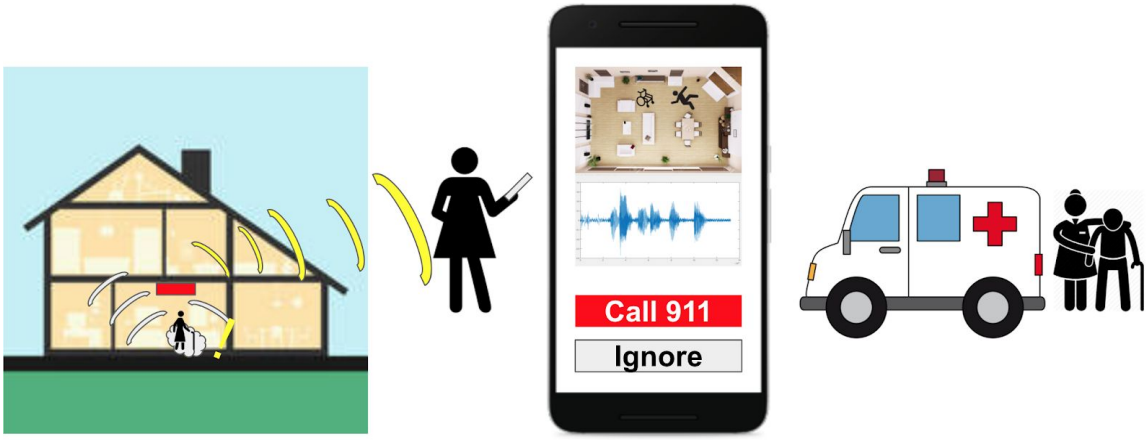
LandingCall: A Proposal for Elderly Fall Detection

by Deepak Kyasaralli Thimmappa, Rashmi Shetty and Sarah Aguasvivas Manzano

Project Goals :

Elders are likely to experience moments of disorientation and lack of stability [2], this may result in a fall that can cause major physiological problems. Most of the existing efforts to detect falls from elderly people include surveillance cameras or wearables [1]. In the past few years, researchers have been moving towards wireless sensor networks (WSN) [2]. However, most of the suggested solutions in this realm require expensive sensors. The goal in this effort is to perform said monitoring in a non-wearable, non-intrusive manner that does not require constant online surveillance or complex installations by making a careful choice in the sensors chosen. When a fall occurs inside a home, it is possible that this disturbance is heard all around the home, from all rooms, unless it happens in a crowded place or in a large open space. For this project, a method to detect a fall in a small to medium indoor space will be evaluated and tested. Once this hypothetical detection is realized, a message to the caretaker will be sent with an optional snapshot of the space where the apparatus is (permission to take such images would be taken prior to installation of set up) and the window of sound recorded that made the algorithm trigger the alert in order to have the caretaker make the final decision about whether or not to call an ambulance. Preliminarily, the sensor used will be a microphone attached to a microcontroller RPi that performs the data processing without connecting to the Internet so this system is not hackable through the Internet. When an event happens, the microcontroller sends the data to a module with internet (virtually a RPi) that contacts the caretaker.



Potential Customers :

The end user of our solution will be the caretaker of the elders, who will receive a message (snapshot, window or the recording) containing information on the state of their patient, they will be the ones who decide whether or not the system should call 911. The reason we set it up that way is because we would not like to trust an autonomous system to make 911 calls in case false positives happen. Therefore, we wanted to have a human intelligence making that final decision. This is based on the assumption that a person who buys a fall detection system for their elders cares enough about them to commit to take

action when the system alerts them of a disturbance or hire a caretaker. If this system is successful, it can also be used for IoT-based baby monitoring, which was the original inspiration for this approach.

Existing solutions :

There are many existing technologies to aid the detection of fall among elderly.

1) First type of technology focuses on wearable devices that make use of accelerometer or gyroscopes. The main issue with this approach, however, is that it requires seniors to carry devices around which is inconvenient.
2) Second type focuses on vision based technologies like installing webcams to monitor falls. The main issue with this approach is the privacy violation[7].
3) Recently, the use of sensor networks has been explored, such as the idea of using smart tiles [4], IR signal-based sensor networks [6][3], and so forth. Although the WSN idea is promising, the cost associated with some of the sensors makes them unfeasible and unscalable.

Proposed Solution:

The solution proposed in this effort is to use a sound monitoring system similar to the newborn microphones. These microphones will keep a window of the data that will be passed through an algorithm that determines whether a fall or an event is happening in a closed space. This solution will be relatively inexpensive compared to the existing WSN solutions tested in research work. The reasoning behind this concept is that the system will act as a caretaker who is always listening to the patient through a microphone. The only difference is that this time the system will be announcing an event instead of having a person listen to a monitor at all time.

Alternative Approach:

As an alternative solution, we had an idea of using UWB sensors to generate a high-resolution pattern of the resident movement to detect falls among other types of movements. The approach would require usage of two UWB sensors, one as transmitter and another as receiver. The two are placed at two ends of the room. The signal from transmitter is sent. It is scattered in the room along with other signals from TV, WIFI, Cell phone, etc. The receiver will be recording the signals sent from transmitter. The idea behind this approach is upon receiving the signals a classification is made to determine if there was blockage (a person standing) or not(fall of the person). We did not emphasize on this approach as the UWB sensors are expensive.

Technical Challenges:

Among the technical challenges that we can foresee at this moment is the fact that the signal coming from a microphone varies in amplitude and frequency. This makes it harder for a classifier algorithm to define a decision boundary that is clear and with high accuracy. We would need a system that does not require filling out the home with microphones, because that will be invasive, so a single microphone that is sensitive and with high algorithmic signal processing, we expect to get around that issue. Another technical challenge that may arise is deciding which components of the system will use the Internet and when. It is safe in terms of privacy to not be sending data packages wirelessly at all times. However, we would need a way to connect with the computer that will be sending the message.

Another major technical challenge is filtering out noise coming from a TV versus real-life noise. The signal that a microphone is getting is a collection of noise and real-life signals at different frequencies coming from different places, so we need to find a reliable way to filter out the noise from the real-life signals.

Another technical challenge is differentiating between the capacity of the human body to detect and classify disturbances from mixed signals and the capacity of a computer to do it in such a sophisticated way.

Proposed Workarounds:

For the first challenge about the strength of the signal, the solution proposed is to select a good placement for the sensor accompanied by a good amount of signal processing and a sensor that is sensitive enough to small differences in frequencies. We are hoping that when a fall occurs in an elderly person's place, the sound is strong enough to be detected.

Another solution to this is to agree with the patient in order to purposely send a signal when an event happens by agreeing upon a keyword that the patient uses to call the attention of the caretaker. For the problem about someone else using the Internet to hack the microphone, our may be encrypting the signals sent by the microphone so in case they get hacked, it is impossible to read.

Regarding the noise filtering process, our preliminary choice is to make use of a convolutional neural network that can do that noise filtering on its own by using convolutions. Something in our favor about the noise filtering process is the amount of available libraries and resources that we can use as black boxes to filter out the noise from the actual signal.

Tentative Timeline:

The main deliverable in this work would be the system with a camera and a microphone possibly enclosed in a casing and an Android app for the caretaker. The work will be done starting at the upcoming week and the tasks will be managed using Asana. March 12th is the beginning of WEEK1.

WEEK 0:

- Everyone: Keep looking into the possible solutions to this problem that are affordable
- Everyone: Finish the proposal and submit it
- Rashmi: Create github repository to share it with team

WEEK 1 and 2:

- Sarah: Record sound signals from a microphone and figure out how the noise can be filtered
- Rashmi: Start working on sending a signal from the raspberry pi to the Android app coming from the microphone
- Deepak: Start developing the Android app that will interface with the caretaker and the patient
- Everyone: Investigate about methods to detect events from filtered sound signals

WEEK 3 and 4:

- Sarah: Work on sampling of audio signals to appropriate workable size
- Rashmi: Test raspberry pi to send recorded signals from microphone over long duration of time
- Deepak: Test basic android app to check if it receives the signal from pi and performs basic functionality like display a successful reception message
- Everyone: Work towards improving signal processing to isolate sound of interest (fall vs no fall)

WEEK 5 and 6:

- Sarah: Work on implementing the signal processing methodologies
- Rashmi: Add optional camera functional capability to the system such that it does not affect the existing system
- Deepak: Implement the machine learning model to classify fall vs no fall
- Everyone: Work towards improving signal processing to isolate sound of interest (fall vs no fall)

WEEK 7 and 8: Wrapping up

- Everyone: Integrate the individual parts(signal processing, raspberry pi communication, android application, machine learning model) into the system
- Everyone: Perform both unit tests and system tests to provide meaningful outcome of the system

Performance Metrics:

Cost: The most important metric is the cost of this solution compared to the existing products in the market.

Accuracy: Another valid metric to evaluate performance is the number of true positive cases, ie, the number of valid alerts.

Response Time: Establishing connection with the caretaker within minimum time upon detection of a fall would best determine the efficiency of this solution.

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