SensorFall – An Accelerometer Based Mobile Application

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Abstract— **In recent years, the use of sensors in mobile devices is extremely desirable. In particular, an accelerometer can be used for numerous applications such as tracking objects or monitoring elderly people. This paper presents an application tool based on an accelerometer, called SensorFall, to detect and notify the acceleration caused by a fall. We have implemented and verified the SensorFall in several environments, such as in a hospital or in a regular daily life, for older people. The obtained results show that it performs well.**

Keywords- **mobile devices, sensors, accelerometer, fall detection**

I. Introduction

Every day new technologies appear and can be used in several applications. In recent days, incorporating sensors in the mobile devices such as mobile phones and portable digital displays (PDAs) is considered necessary. The sensor used is an accelerometer that can be applied for different uses and purposes, such as games, screen rotation, changing the music track, monitoring movements of the human body [1, 2], among others.

Accelerometers are more and more being incorporated into personal electronic devices, like Smartphone, Digital Audio Players and PDAs have accelerometers for user interface control.

There are several problems, which come with the falls, such as in hospitals and with elderly people. Falls and fall-induced injuries among older people are major public health concerns worldwide, accounting for over 80% of all injury-related admissions to hospital of people over 65 years [3, 4]. Falls are also the leading causes of unintentional injury death in these individuals and responsible for appreciable morbidity, including bone fracture, head injury, joint disruption, and soft tissue contusion and laceration resulting in pain, functional impairment, disability, fear of falling, depression, loss of independence and confidence, and admission to residential care [3, 5, 6].

This paper proposes a system that uses a regular mobile phone or PDA with an accelerometer to detect the acceleration caused by a fall and corresponding report. This application is named as SensorFall. As we know, a fall is a very serious and frequent problem in older people and hospitalized patients. The aim of this project is to construct an application for mobile devices that allows the detection of falls and corresponding notification. It pretends to give speed and quality of response, in assisting the patient or user.

The mobile application monitors the acceleration in different axes *X*, *Y* and *Z*, in real time [7]. It can detect the change of the sensor and can decide if it is acceleration that is worthy of a fall or just a natural movement of labor of a day-to-day human being. When a fall happens, it will send a message notifying the user. After a few seconds, if a reply is not given, it will be issued a warning via shortest message service (SMS) to a predefined mobile phone number. Its aim is to provide higher security to the user and to be an efficient mean of warning, such that hospital professionals can offer a prompt and efficient response and quick assistance.

The rest of the paper is organized as follows. Section II reviews the related literature while Section III presents the system architecture, focusing on the application architecture, the system requirements, application development and technologies used to deploy the solution. In Section IV, the system is tested and its validation is performed. Section V concludes the paper and point directions for further research works.

II. Related Work

This section deals with some of the existing works related to the proposed mobile solution, mainly, using sensors for measuring and identifying different human behaviors. In [8], authors use acceleration signatures from everyday activities for on-body device location. They present a solution to favor the recognition of everyday life activities, through the changing positions that are detected using a set of sensors that are incorporated in phones, PDAs, and watches. These systems must identify the devices position in the body.

Using a three-axis accelerometer, the authors describe two methods for measuring the time spent in vertical jumps [9]. These algorithms are based on the morphology of the signal. The first uses the maximum curve during the stage of landing, while the later uses the time interval between the minimum and maximum acceleration values during the flight (up) and landing (down), respectively.

An approach based on wearable accelerometer sensors is presented in [10] for an ambulatory monitoring of human posture and walking speed. Authors propose a classification system for monitoring real-time physical activity, which will be able to detect body postures (lying, sitting and standing) and race. The system acquires data from a set of two-axis accelerometer implemented in a wireless body sensor network (BSN). A sensor is mounted on the waist, while other two are attached to their thighs.

An implementation of an accelerometer sensor module and fall detection monitoring system, based on wireless sensor networks, was proposed in [11]. The authors implement a wireless accelerometer to determine the posture of a person, activity, and fall. The system uses a two-axis accelerometer (the ADXL202), and a wireless radio-frequency (RF) module. This module measures the signals from the accelerometer and shows them in a personal computer. Standing, sitting, lying down, walking and running are the activities detected by the accelerometer.

Another approach for health monitoring using electrocardiogram (ECG) and three-axis accelerometers for elderly persons at home is presented in [12]. Authors present a prototype of "wellness" and surveillance system with capacity to record and analyze data from the ECG and the accelerometer. The resources of the electrocardiogram are used to detect risk of arrhythmias and so on. The system includes a base station, to collect the data from wireless sensors placed on the patient body. Walking and other body functions are activities detected and recorded by accelerometers. It uses the standard IEEE 802.15.4 protocol for communication between the sensors and the base station. If any abnormality occurs the system sends an alarm condition for a predefined PDA.

Authors of [13] propose a solution that tries to detect, in real time, the basic living activity at home using a wearable sensor and smart home sensors. This approach aims to locate people and detect their movements. Already in [14], a proposal based on a wearable accelerometer sensor was proposed for gait authentication and identification. In [15] and [16], different proposed methods but with a similar use of accelerometers, with different objectives, are presented. In [15], an accelerometer on the trunk of a person is used to recognized activities, such as lying, running, walking and standing. In [16], an accelerometer placed on the trunk of a person tries to detect vibration noise caused by heartbeats and thus measure the heart.

As it may be seen in the above-mentioned systems, most of them provide dedicate solutions using sensors to monitor different human behaviors. Our proposal is designed for a regular mobile phone or PDA that incorporates an accelerometer. We have gathered suggestions of approaches in order to build the system described in the given sections. The proposed solution can furnish better functionalities and is very easy to deploy in a regular mobile phone or PDA with an accelerometer. This application was designed to notify and monitor falls, thus providing an instant help not only in hospital but also on daily life environments. Outside the hospital, this system may be very useful for old people that live alone or people with physical diseases, for example.

III. System Architecture

This sector discusses the requirements of the SensorFall tool, the application architecture, application development and the technologies necessary for its deployment. Our emphasis will be on obtainable as well as emerging architectures that foster its practical deployment.

A. Application Architecture

The application SensorFall is constantly monitoring the patient, using the accelerometer to measure acceleration, process the information obtained by them and provides in the display of the PDA.

Data from the menus and options are saved in the XML file, and contacts use the Microsoft Outlook from the PDA to store them, and can also save a contact on the PDA and are automatically obtained by SensorFall.

When application is started, the data is loaded from the XML file and will apply it to behave according to these parameters.

B. System Requirements

A mobile application has specific requirements that SensorFall must also cope with. The user interface must be as easy to use as possible, with minimal input from the user. Screen size and orientation are a big concern in this system. Stylus input minimization dictate an interface with large buttons and appropriate font size, to enable on-the-move application use.

SensorFall is not just another mobile application. It must offer constant monitoring and deal with several variants of accelerations.

To better explain the main steps of SensorFall, the corresponding activity diagram is shown in Figure 1. The activity diagram is used to describe operational activity (step-by-step) of system components, following the global flow of control. In SensorFall, when a drop is detected, the flow begins whether it is a fall or just a false positive. If it is a not fall, it goes back to monitoring, otherwise, because it said *YES* or because there was no response in last few seconds, it goes to the next stage in which verifies what parameters will be used, also verifying if everything was send correctly. If user selects *NO*, it tries again; if *YES*, it comes back to the monitoring.

C. Technologies

The mobile application targets Pocket PCs running Windows Mobile 6 and 6.1 (WM). Two major solutions for application development exist: .NET Compact Framework and J2ME. The Microsoft solution was chosen, mainly due to the following two features: immediate availability of version 2.0 on every WM 6.0 device without the need for further installations, and tight interaction with a suitable database engine.

The development software used to create the mobile application was the Microsoft Visual Studio 2008 PRO IDE that offers the Microsoft Windows SDK V6.0. Both versions offer emulation debug for simple initial debugging of applications. The IDE also offers a database system management, the Microsoft SQL Server 2005 Compact Edition that we used to generate and manage the database. The C# is a language oriented to objects, which was very powerful fusion of Java with C++, also because it tries to resemble Visual Basic, and was specially made from base for the Visual Studio platform, which is dedicated to the Framework. NET.

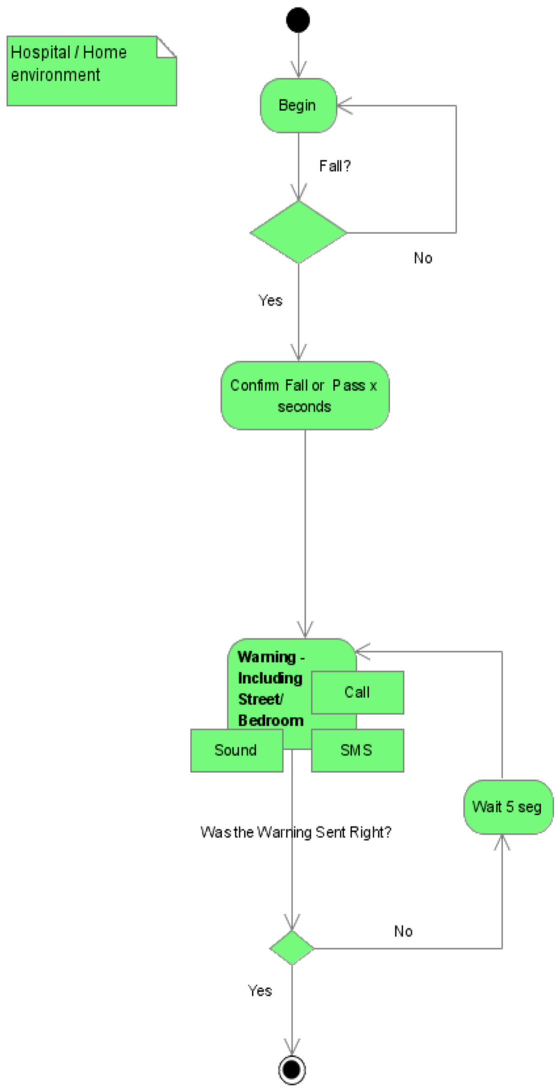

Figure 1. The activity diagram of SensorFall.

The Microsoft. NET Compact Framework is a framework that currently can only be installed on computers having a Windows operating system (OS). It includes large programming libraries, solutions for common problems, and a virtual machine that manages the programs execution written specifically for the framework. We have chosen the .NET Framework 2.0 instead of the latest 3.5, so it can be combined with another framework, the Smart Device Framework, which provides a complete scope of the core. The smart Device Framework allows developers to concentrate on the core functionality of the application. Advantages are the visual power level, thus being more attractive, with more custom buttons and flashier, and also a provided tool to manage the battery.

D. *Application Development*

The interface of the mobile application is simple, with large buttons for the user, and also with standard size of Visual Studio, but with appropriated size for finger use. The information provided by the user application is concise and with an appropriate size for easy reading.

When the application is running, even in the background, it will always be monitoring the values of the accelerations in several areas. It will consider the values of accelerations and whenever there is a peak acceleration that exceeds the predefined threshold value of the drop, the application launches an alert, sound, bright and vibrant (depending on the choices that are selected). The application will wait a certain period of time that user may respond to this alert. The user can confirm a fall or a false alarm. After this predefined period of time, if the application does not get response or if the *YES* button is not pressed, the application will send a short message service (SMS) or will make a phone call (depending on the system customization).

To determine the detection of falls, it has to circumvent the so-called false positives, which can range from a jump, going down/up stairs or even sitting in a chair, such as in the case of an elderly person. This is a difficult situation to evaluate because one can literally fall on the chair and thus have a significant acceleration. In order to circumvent these obstacles, the system was tested and evaluated under several situations of gender. Based on the collected results, several graphics were built in order to understand better the collected values, and thus reaching a threshold value which shall be deemed to be exceeded fall.

IV. System Evaluation and Validation

This section presents the performance evaluation and validation of SensorFall tool.

A. *User experience and the SensorFall interface*

This subsection presents a general idea of the mobile application and its use in practical deployment. The SensorFall shows a simple user interface, which is easy to use by its adopters. The main window is very intuitive. Figure 2 presents the main application interface where we can see how the screen of SensorFall is presented poorly at the start of the application. The figure is numbered so it may be easier understanding the environment of the user. In (1) is displayed the threshold value of warning. If this threshold value is passed by any of the axes, it will trigger the warning of a fall. The area identified by (2) include the information collected by each one of the three axis *X*, *Y* and *Z* and the PDA Orientation, with colored bars. Below the three-axis information, a bar with the percentage of available battery is shown. When the values reach the available percentage of 20%, 15%, 10% and 5% it prompts the user to charge the PDA. The *Menu* Button is identified by (3).

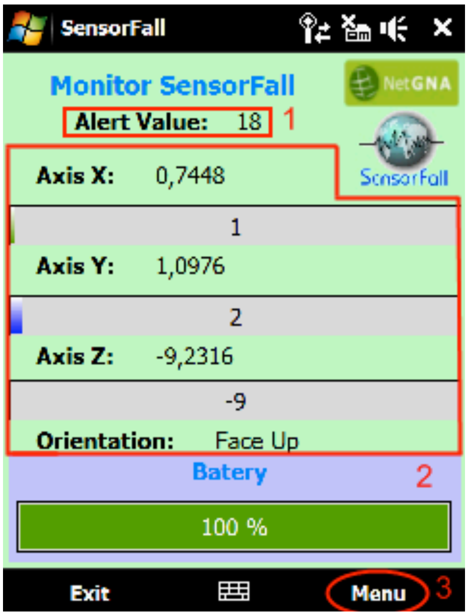

Figure 2. Main Application Interface.

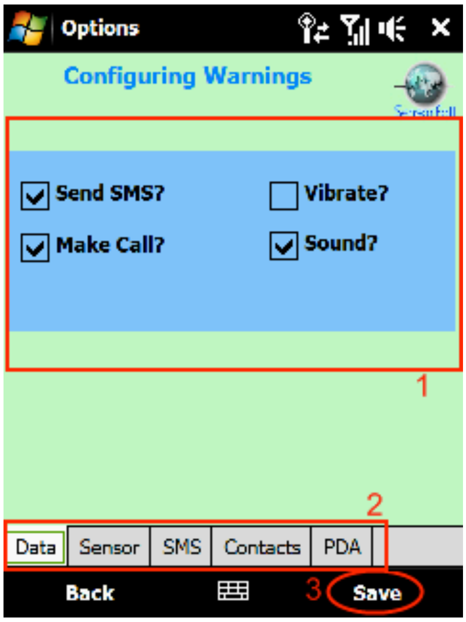

Figure 3. Options Menu.

Depending on the PDA position in relation to land, the orientation differs, as the value of acceleration is in different axes to an acceleration almost nil. When the PDA is with the guidance Face Down, in perfect conditions, one can see the axis values $X = 0$, $Y = 0$ and $Z =- 9.8$ m/s^2. The sensor is very sensitive and it can be a fairly accurate reading of the values.

If the PDA is Face Down, the *X* and *Y* axis will present the same values close to zero, but the *Z* axis will be positive and close to 9.8 m/s^2. With Portrait orientation of the PDA, the axis that has the value of gravity is the *Y* with a positive value. If the PDA is in Landscape, the *X*-axis measures gravity with a positive value. In case of Reverse Portrait, the *Y*-axis shows the negative gravity value, and in Reverse Landscape the *Z*-axis is also negative.

After clicking Menu, it will appear the Login window where user can show it is authentic with his Login and corresponding Password. If any data is incorrect the user is not allowed to go to the Options and the status of a message Login Failed will appear.

After making the successful login, the application shown in the screen represented by Figure 3 will appear. This user (meaning that the user is here, which contains the permission to enter the options) is facing a window, divided by TABs in order to make it more fluid to browse. The figures are numbered so it can be easier to understand the environment of the user. In (1) appears the desktop where the user chooses the options that best suit his/her use of the apparatus. Horizontal bar is pointed by (2) and it contains several TABs, in which each presents a different desktop, with different options. Thus, it enables the separation of content areas and a greater storage of application. After concluding the application customization, the *Save* Button (3) can be pressed for recording data in a file.

The first TAB, classified *Data*, where the user decides whether the operation, after detection of a drop, will be to send SMS, a phone call, vibration, or if it beeps. The second TAB, allows the user to configure the parameters of the sensor, which set the value of warning and also choose the tone of the application.

In the third TAB, the SMS configuration, the contact parameters user name and address or room number can be set (if the application is customized for hospital environment).

In the fourth TAB is the area of contact, where the user adds, modifies and removes his/her contacts. The contacts will receive alerts, in case of fall. If it contains only one contact, only this contact will receive alerts. If there are more registered contacts, all of them will receive notifications. The last TAB contains the about.

When a fall is detected a window will appear, when the PDA is dropped or there is a false positive, containing bars that surround flash to draw more attention. In the center of the screen two large buttons appear, with different colors, green for *YES* and red for *NO*. If none of these two options are selected, after 10 seconds, *YES* option is accepted by default.

B. Application validation

This subsection discusses the tests and experiments performed by the system and corresponding results obtained. Authors simulated both real situations of falls and other movements to identify false positives. Note that the values of acceleration can be negative due to the position of the accelerometer, which corresponds to the orientation of the screen. For falls detection, it is valid the threshold value of 17 and -17 (as it is not possible to have a fall up).

Figure 4 shows the results collected in the first test. As it may be seen, at the time 31 the simulation of a fall is presented in bed with the PDA Facing Down. After, at the time 46 the simulation of someone raising from the ground up to 52 and starting to walk, with the PDA in Portrait orientation. Finally, at the time 91 it is registered a fall in forward motion. After detailed analysis of these and other sets of results, the threshold value of 17 was defined.

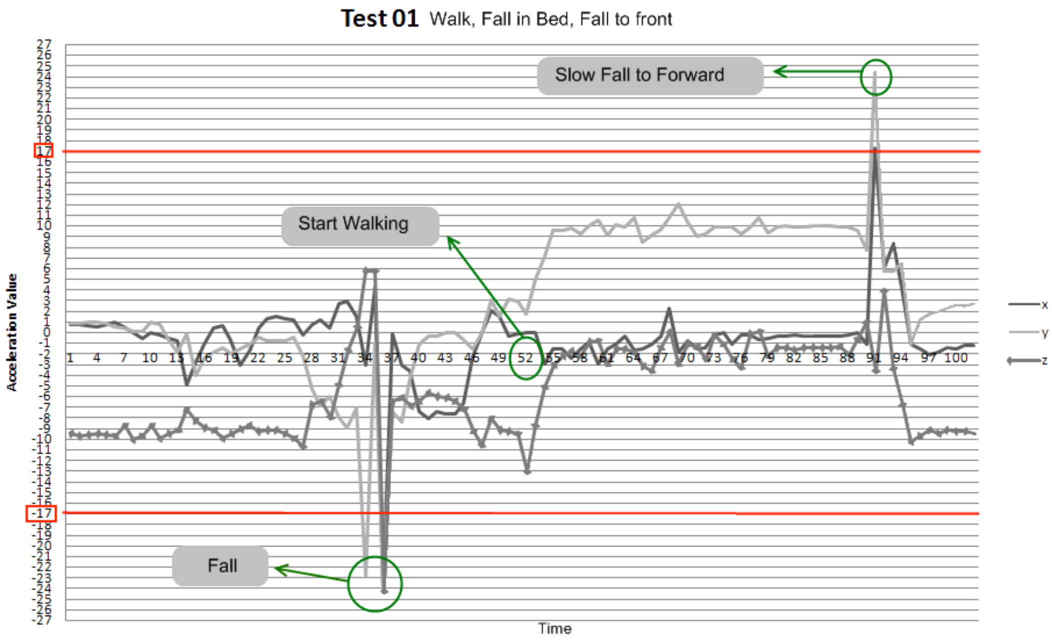

Figure 4. First Experiment.

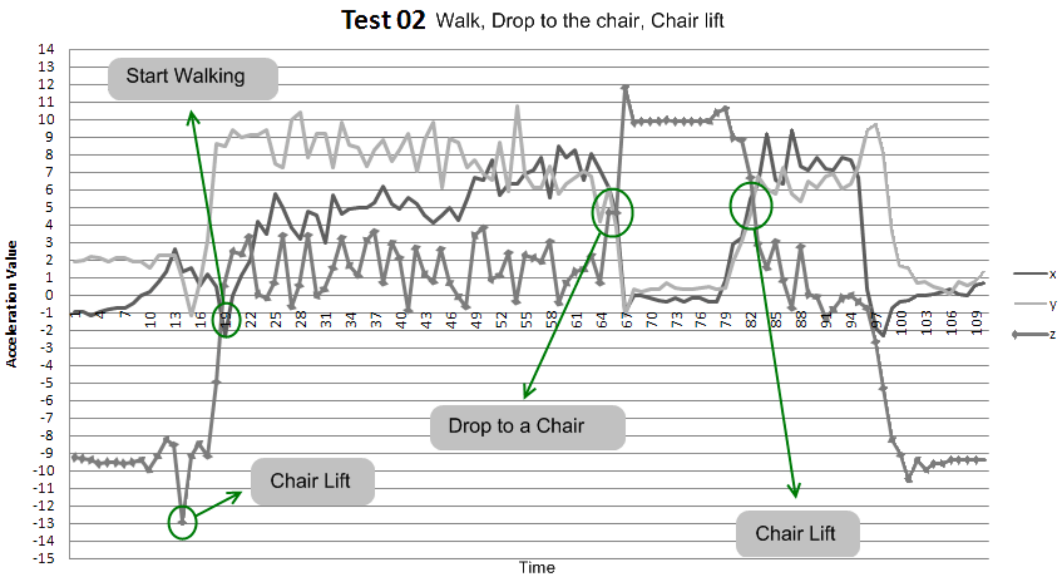

Figure 5. Second Experiment.

Another important experiment is presented in Figure 5. At the time 13 the chair lift is presented (Face Up). From the time 19, the user is walking until the time 64, when he/she performs a drop on chair. After that, he/she lifts from the chair, time 82. Finally, at the time 97 the PDA was taken from the pocket.

As it may be seen through the performed tests, when simulating a fall, the acceleration value of 17 in one of the three axes, was confirmed as the right threshold value for the system. The day-to-day activities do not pass this threshold value, so it was defined as the threshold value of alert 17.

V. CONCLUSIONS AND FUTURE WORKS

This paper presents a mobile application tool for PDAs with an accelerometer called SensorFall. The main objective of this system is to detect and notify a fall and it has been fully achieved. It includes several features, such as sound and visual alarms, the total capacity for system customization, and with an advantage of being able to adapt to different individuals, from a senior to a sportsman.

Taking into account the results presented and analyzed in this paper, we can conclude that the mobile application is able to detect with sufficient accuracy the values of acceleration, thereby enabling to create a line between an invisible fall, a true and a false positive.

SensorFall is easy to handle, providing a very simple user interface. The mobile application also allows a low consumption of battery, even if the application is running in the background of the OS.

For future work, it is proposed the incorporation and use of global positioning system (GPS), so in case of a fall outside the hospital environment, we can obtain the coordinates of the user and that will be send by SMS asking for support, providing a more effective way to a faster and a more accurate intervention.

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