Rapid Response Fall Detection System

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***Abstract*– This paper presents an application titled "Rapid Response Fall Detection System" - RRFD. This application aims to detect when a cyclist has suffer an accident, and alerts the emergency contacts about the accident. "RRFD" uses the cellphone built-in accelerometer for fall detection, and the GPS to provide an accurate location. When a fall is detected, the application sends an alert via text message to previously selected contacts. Any sudden fall will activate the application and send the text with information of whether the rider requires assistance and / or immediate medical help. In the event that the cyclist is unable to request assistance or help, it provides the route and location of the cyclist using various tools of high accuracy.**

***Keywords*—Fall detection, cyclist, accelerometer, GPS, emergency.**

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I. INTRODUCTION

Bicycles have become one of the most popular transport methods due to its recreational, low-cost and health attributes. In U.S., this type of hobby has become a popular sport thought its dangers have also raised. According to [1], in 2014, 726 people lost their lives in bicycle/motor vehicle crashes in the U.S. In addition, 50,000 cyclist where injured in motor vehicle traffic crashes. The National Safety Council (NSC) estimates that the comprehensive cost of each person killed in a traffic crash to be $4,538,000 (2012 dollars) [2].Therefore, 726 bicyclists killed in 2012 totals nearly $3.3 billion. In addition the NSC estimated that bicyclist injuries in 2012 total more than $2.8 billion. However, other accident causes result in injured cyclists as shown in table one.

TABLE I
CAUSES OF CYCLISTS ACCIDENTS IN U.S.

Six most Frequent Sources of Injury	**Percent**
Hit by car	29
Fell	17
Roadway/walkway not in good repair	13
Rider error/not paying attention	13
Crashed/collision	7
Dog ran out	4

According to the Puerto Rico Traffic Safety Commission Problem, in 2015 cyclist deaths on the road have represented a three percent (3%) of deaths caused by reckless and runaway drivers, becoming "Hit and Run" cases. Meaning that after the cyclist is hit by a car and the driver flees the scene, abandoning the injured cyclist on the road. Figure 1 shows that the first cause of cyclist accidents is that the person does not see the object [3].

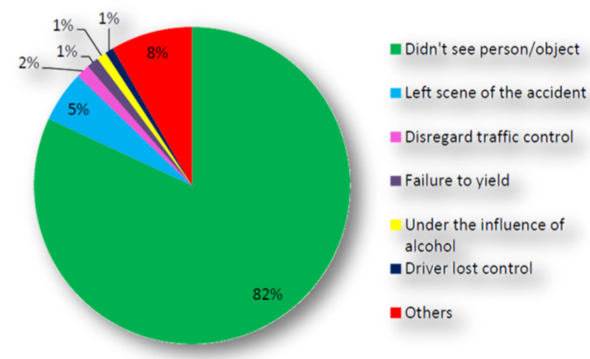

Fig. 1 Cyclist Crashes by Contributing Causes years 2007-2009, 2012 [3]

In the case of accidents, the response time is one determinant of patient survival [4]. This paper presents an application called "Rapid Response Fall Detector-RRFDS" to detect and report a fall a person is biking. Regardless of all the safety measures taken by cyclists, they are at high risk of being victims of an accident. The application aims to help cyclists when they suffer an accident.

The user only needs to set up RRFDS prior to starting their ride. The system requires the cyclist to select the contacts desired to be alerted in case of emergency. Then, the cyclist starts the service and wares the cellphone. Since the application runs as a service, it runs on background meaning the cyclist may hear music, answer calls, and other activities. In the event of an accident, the application will notify the selected contacts via text message with the location where the accident happened using a google maps pin. This improves the application efficiency given other applications only notify the emergency but do not supply the exact location which hinders the speed of the help response.

The first prototype has been developed for Android, given that is the most use mobile operating system. In this environment, applications consist of two building blocks: "activities" and "services". RRFDS are built based on both. The user interface is built as an activity. On the other hand, the fall detection algorithm, and the location module are implemented as services. The cyclist is able to turn on or off these services through a button in the user interface. In the

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case of an accident the app will send an automatic text with the location and the cyclist will only have to wait for the contact and medical attention.

The rest of the paper presents the related work followed by the system design in section III. In section IV the actual implementation is presented followed by the results of this work in section V. Finally, section VI presents the conclusions and future work.

II. RELATED WORK

Apps are basically micro software that can be installed in computers, cell phones, tablets and other devices, used to simplify an existing function and make it more simple and friendly. Modern smart phones boast a wide array of available applications that the user can choose to extend the functionality of their device. There are huge advantages in the help these apps bring, such as web browsing, making word documents, sending and reading emails, webcam calls and money transfers to other people and all those type of things you normally do either personally or in a computer.

A. Activities and services

An activity refers to a single screen with a user interface. For example, an email app might have one activity that shows a list of new emails, another activity to compose an email, and another activity for reading emails. Although the activities work together to form a cohesive user experience in the email app, each one is independent of the others. On the other hand, a service is a component that runs in the background to perform long-running operations or to perform work for remote processes. A service does not provide a user interface. For example, a service might play music in the background while the user is in a different app, or it might fetch data over the network without blocking user interaction with an activity.

B. Fall detection algorithms

Available fall detection systems in the literature are based on accelerometers as the primary sensor. Measuring the acceleration the human activity recognition systems determine what activity a person is performing [5]–[9]. For fall detection mechanisms, one of the most used technique are based a threshold approach. Here, a fall is reported when the acceleration goes beyond a pre-defined thresholds. In [10], authors use the smartphones built-in accelerometer and the gyroscope in order to identify the location of the cellphone on the body (chest, pocket, holster, etc).Using this information, the system determine when a fall occurs. Another example is presented in Kangas et al. [11]. This system used specific locations in the user's body to compute different thresholds with data collected from a three-axis accelerometer, and gyroscope. On the other hand, Chen et al. [12] presents a fall detection system based on accelerometry. Here, the sensor is located in the user's pelvis. Usually, the acceleration-based fall detection systems sum vector magnitude of acceleration, acceleration on the horizontal plane and reference velocity. By using these features, the systems are able to infer spatial changes of the acceleration while falling [13].

Recently, machine learning approaches have been used in order to improve accuracy in fall detection systems.
A different category of wearable sensor approaches for fall detection includes the systems based on machine learning techniques. These systems include a data collection module for gathering motion data; a feature extraction module that selects the most relevant characteristics from the motion that are useful for fall prediction; and an inference learning module that finds relationships from the extracted features to come up with a descriptive model for fall detection. Vallejo et al. [14] proposes a method based on artificial neural networks. The system uses an accelerometer on the user's waist, a microcontroller, and ZigBee module. The neural network is able learn falling events. In a similar work, but this time using decision trees Bianchi et al. [15] used a method that combines acceleration and air pressure. The air pressure data was collected from a wearable sensor located in the user's waist, these two input signals, namely acceleration, and air pressure were used to build a decision tree for fall detection.

III. SYSTEM DESIGN

This application is designed for the safety of the cyclist when they are in the road, we notice that many of them use all the safety features, but even with that some of them got hurt badly. Developing this app makes us think about them by implementing the Accelerometer sensor, where if it notices an abrupt change like a fall when the cyclist is on his running route they will activate in combination with the Global Position System also known as GPS to give the coordinates of latitude and longitude. Using the exact location where the cyclist has fallen, the application automatically sends an SMS to the contacts that the cyclist selected in the app before going into his running route.

A. System overview

Figure 2 presents the system overview. In the design of the app, we have the implemented the services for fall detection, location, and emergency alert. Accelerometer, GPS, contact selection and SMS services.

1) Fall detection service: the application uses the built-in accelerometer available in smartphones. The accelerometer measures the rate of change of the speed in all axes of 3-dimentional space. This sensor is used by the phone's native screen rotation, which makes the sensor available in a wide range of mobile phones; this availability is one of the reasons that the accelerometer was the chosen sensor for fall detection. The accelerometer will read the rate of change in velocity (acceleration) for each axis in its standard SI unit of meters per second squared [m/s2].

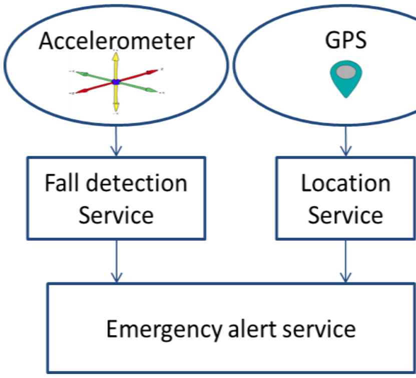

Fig. 2 System architecture.

2) Location service: The Global Positioning System - GPS service on a mobile device provides the user's current location. Just like the accelerometer, the GPS is widely available in phones. In "RRFD" every time the positioning sensor detects a change, it will update the cyclist's current latitude and longitude, and it will edit a message. The message contains a hyperlink to Google Maps utilizing the user's current coordinates.

3) Emergency alert service: Once a fall is detected, the application sends a text message to the selected contacts with the accident location. The SMS technology was selected in order to guarantee the compatibility with any cell phone available. Therefore, the emergency contacts are not required to install any application.

B. Alert data flow

The mobile app will monitor movement trough the cellphone's accelerometer. If a change in acceleration is detected, the application will evaluate if an accident alert must be activated. If positive, the app will automatically search for the contacts list and send it with the GPS location through a text message. If negative, the flow goes back to the initial state as shown in figure 3.

C. Fall Detection Service

To detect the fall itself, the accelerometer's values will be recursively stored and compared to previous values. Using a simple algorithm, the program will compare the current accelerometer readings with the previous reading and will accordingly determine if the change in acceleration is high enough to be deemed a fall or an impact as shown in equation (1).

The algorithm is executed every 100 milliseconds, this is achieved by reading the system's current time, storing it and comparing it to the previously saved time: if the difference between these times is larger than "100" (the value in milliseconds), then the program will execute the algorithm. The algorithm itself consists of adding up every current value of the accelerometer, subtracting every previously read value of the accelerometer, we take that result's absolute value and divide by the time that has passed between the current and the previous reading. This result is multiplied by 1000 because our times are read in milliseconds; this will leave us with a final result with measurement unit m/s3 which can be read as the change in acceleration per second.

$$\frac{|Ax_i + Ay_i + Az_i - Ax_{i-1} - Ay_{i-1} - Az_{i-1}|\,[m/s^2]}{\Delta t[ms]} x1000[ms/s]$$

$$. = \frac{\Delta A}{\Delta t} x1000[m/s^3] \quad (1)$$

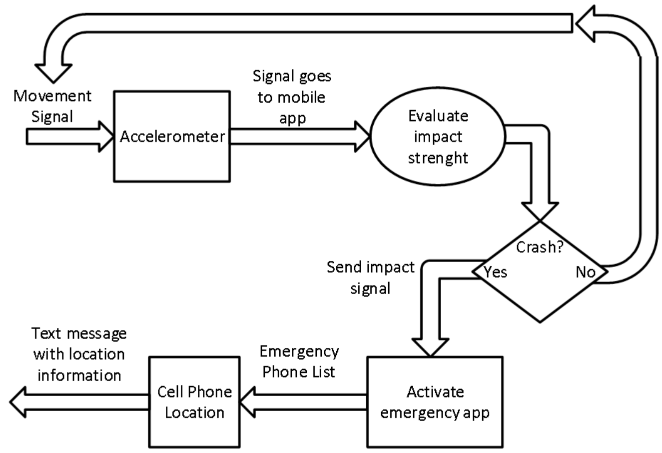

Fig. 3 Warning data flow diagram.

Figure 4 shows an example of variation on acceleration when a fall occurs. The reader can notice that the acceleration changes abruptly when a fall occurs.

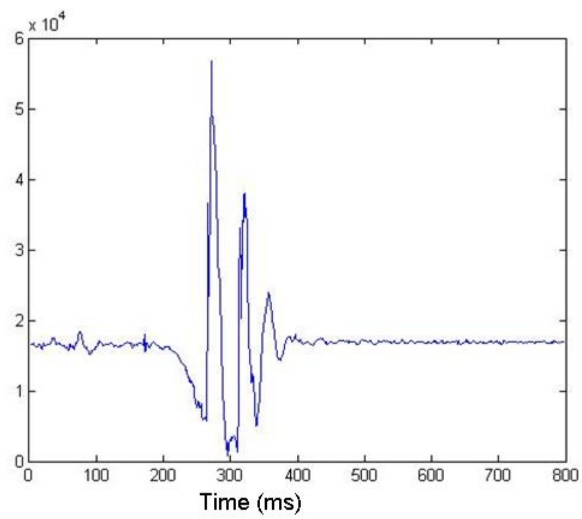

Fig. 4 Example of variation of acceleration when a fall occurs [13].

IV. ACTUAL IMPLEMENTATION

The algorithm 1 defines the application flow depending on the events. The first step is to start the application. Once the application is started, the cyclist selects the emergency contacts. Next step, the cyclist starts the fall detection service. If a fall is detected, the application sends a text message with the last location registered by it.

Algorithm 1. Application flow

```
1.  Start the application
2.  Select the emergency contacts
3.  Start the fall detection service
4.  While is not stopped
5.          Sense the accelerometer
6.          Register the location via GPS
7.          If (detected fall) or (Emergency button)
8.                  Send the alert
9.          end if
10. End  While
```

A. Starting the application

The first step is the selection of emergency contacts. The application allows the user to select up to three contacts. Figure 5(a) shows the list of emergency contacts selected for the testing phase. Once the contacts are selected, the cyclist starts the service pressing the "Start" button on the bottom of the screen. Figure 5(b) shows the message when the service has been started.

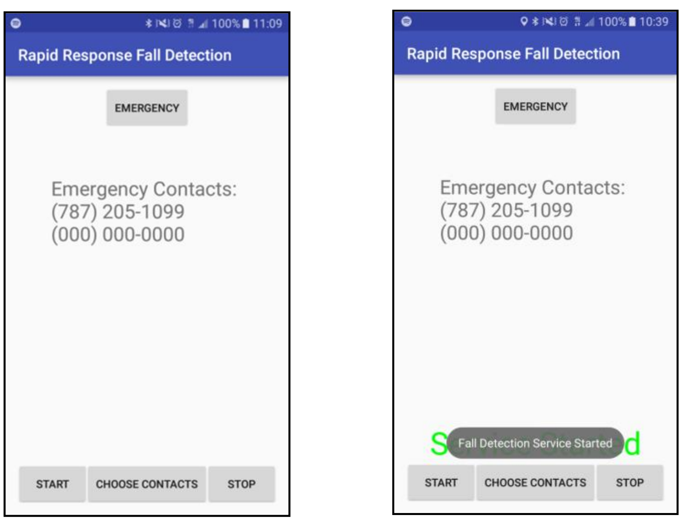

Fig. 5 (a) Contact selection screen. (b) Fall detection service started.

B. Fall detection phase and emergency alert

Once the service has been started, the cyclist wares the cellphone on body. If a fall occurs, the application sends a text message to the contacts selected by the user on the first step. Figure 6(a) shows the screen when a fall has been detected and figure 6(b) shows the screen when the message has been sent.

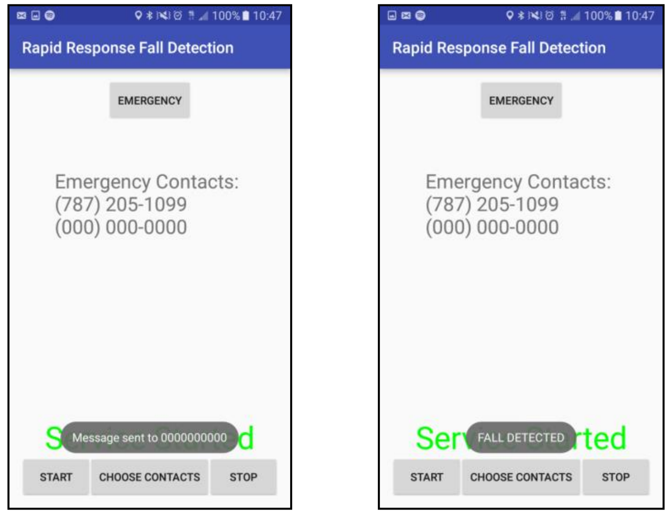

Fig. 6 (a) Fall detected by the application. (b) The alert has been sent.

When a fall is detected, the application sends a text message with the location where the accident had happened. Figure 7 shows the alert received by one of the selected contacts on the first step.

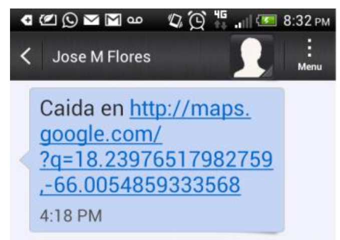

Fig. 7 Alert message.

Figure 8 shows the location reported on the text message shown on figure 7.

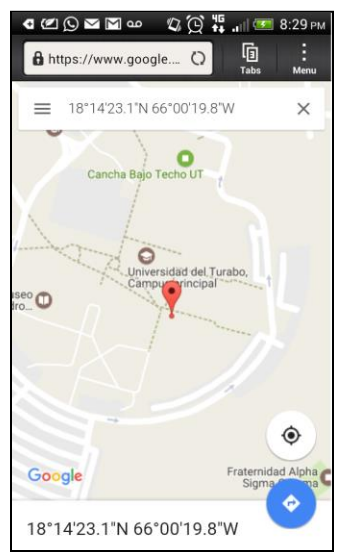

Fig. 7 Location.

C. Stopping the service

The application has the capability of stopping the fall detection service on demand. This aims to avoid false alerts once the cyclist has finished her route. Figure 9 shows the stopping screen activated by the cyclist.

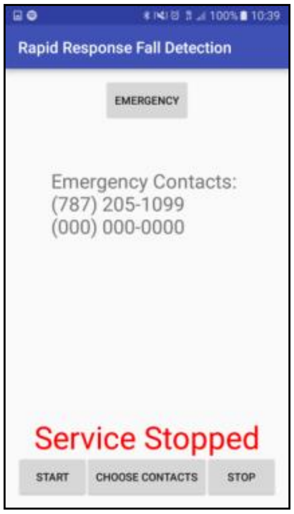

Fig. 9 Stopping the service

D. The emergency button

The application has an Emergency button which can be pressed by the cyclist in any time. This button is a backup system that allows the cyclist to request assistance in the case of a fault on the fall detection service. For instance, the cyclist suffers an accident, and the application does not detect the fall because the variation of the acceleration did not achieve the threshold. In that case, the cyclist may press the emergency button, and the application sends an alert to the selected contacts.

V. Results

The application was built using Android Studio 2.1.2, and Java Development Kit 1.8. The application was tested on a Samsung J7 running Android. 6.0.1 Marshmallow. The testing phase included the validation of each service such as the GPS, Accelerometer, and the SMS communication.

Finally, the application was tested to avoid false positive. Table II presents the results when the person carries the phone in pocket and in an arm brace.

Table II shows the testing results depending on the sensibility parameter for the accelerometer. A low threshold produces false positives. That is, other activities are recognized as a fall, which means false alerts. A very high value represents that the system could not detect a fall.

For the Samsung J7 the correct threshold is 200m/s^3. Other experiments on different devices show that the correct threshold depends on the phone. Therefore, the challenge is to determine the correct value in order to avoid false positives and true negatives.

VI Conclusions

This paper presented the Rapid Response Fall Detection System. This system is designed to assistance a cyclist that has suffered an accident. When a fall is detected, the system alerts the emergency contacts about the accident. The system uses the cellphone built-in accelerometer for fall detection, and the GPS to provide an accurate location. In addition, the application has an emergency button which may be pressed any time alerting the emergency contacts with the cyclist's location. Any sudden fall will activate the application and send the text with information of whether the rider requires assistance and / or immediate medical help. In the event that the cyclist is unable to request assistance or help, it provides the route and location of the cyclist.

The testing results show the accuracy of the system avoiding false positives. Future work includes the self-calibration of the application depending on mobile device. Currently, the accelerometer sensibility depends on the mobile device.

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TABLE II

Testing results

Samsung J7 (Android 6.0.1)

Sensitivity (m/s^3)	20		50		100		150		200		250	
Walking	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Running	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Jumping	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Impact	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE

On pocket | On arm brace

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