Smart Foot Device for Women Safety

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Abstract— **In this paper, an attempt has been made to develop a smart device that can assist women when they feel unsafe. This smart device will be clipped to the footwear of the user and can be triggered discreetly. On tapping one foot behind the other four times, an alert is sent via Bluetooth Low Energy communication to an application on the victim's phone, programmed to generate a message seeking help with the location of the device attached. The results obtained were analysed using Naïve Bayes classifier and this low cost device showed an overall accuracy of 97.5%.**

Keywords – women safety; Internet of Things; Bluetooth Low Energy; acceleration sensor; wearable device;

I. INTRODUCTION

In today's world, women come across many situations that make them feel unsafe. Women from various walks of life face situations that make them feel threatened in different environments. Sixty six percent of women have reported sexual harassment in the year 2010 in New Delhi [1]. It has also been proven that in urban environments, women are more prone to experience harassment especially in developing countries [2]. In such situations, the aid of a safety device that will inform the victim's family members or the authorities (in severe situations) may help women feel safer, confident and reduce the chances of harassment. Though there are a few Smartphone based solutions for the same, it might not be possible for the victim to reach for her phone in some situations without the knowledge of the perpetuator. Thus, there is a need to introduce a discrete safety device that can be triggered discursively without any explicit action.

The idea 'Internet of things' has seen a rapid development in the last few years. Emergence of IoT devices can significantly improve the quality of living and provide assistance and aid to those in need [3].Current technological advances in wireless communications and wireless sensors have facilitated the design of smart, low cost, small and lightweight sensors. The practical applications of the IoT are made possible through enabling technologies such as Bluetooth Low Energy (BLE) which is required to embed intelligence in footwear.

By coalescing the concept of IoT, wireless sensors and BLE, numerous simple yet effective smart devices can be developed. The sequence of actions performed by the devices connected are as follows: (1) the devices use wireless sensors to detect any change in the environment. (2) If a valid change is observed, the appropriate message is sent to the other device(s) in the network. (3) Based on the information received, the device can be programmed to behave in a certain manner.

In this paper, section II discusses the literature review and section III describes the block diagram. The working methodology of the proposed solution is explained in section IV and the results obtained have been discussed in the fifth. The last section summarizes the results and concludes the paper.

II. LITERATURE REVIEW

The recently developed solutions for the safety of women include Smartphone Applications, Intelligent Security Systems and Wearable devices. Suraksha is a security device that can be activated in three ways; a voice command, click of a button and when it is thrown with a force. Upon activation, this system sends the location of the device to preselected contacts via an inbuilt GSM module. But during times of distress, it might not always be possible for the user to carry this device in her hand. Also, the attacker might notice the device that the victim is holding [4]. Another such solution is a one touch alarm system designed to look like a watch. The GSM and GPS module within the device is used to send the user's location to preset SOS contacts when triggered by pressing a button. This device may be aesthetically unappealing to the user and might be noticed by the attacker [5].

Channel V developed an application that is triggered by holding the power button down two times in a row. On receiving the trigger, the application sends an alert message to the victim's family with the location of her mobile phone every two minutes. B'safe & B'secure is an android application that can be installed in the user's smartphone which sends an alert message to preset contacts with the location of the device when the 'send SOS' button on the screen is tapped twice [6].

Another solution suggested installing an Intelligent Security System in public places that would detect the facial expressions of women. If the expression was suggestive of anger or fear, a message would be sent to the control room. But in situations where a woman is angry or upset over any other issue, a false alarm will be triggered. Also, it is not possible to install such surveillance cameras in all areas [7].

The smartphone based solutions that exist require the user to have access to her phone as all of them are triggered by some action performed on the phone. In dangerous situations, the user might not always have the opportunity to reach for her Smartphone. Some solutions use smart jewelry such as necklaces and so on to trigger an application on the user's phone. However, these devices are distinctly noticeable and can easily be removed from the victim.

Hence, there is a need to introduce a solution that can be triggered externally but in a discreet manner without the knowledge of the perpetuator. The proposed solution does not require the user to press a button, it only requires the victim to tap her left foot behind her right foot. This smart device will be clipped on to the user's footwear in a manner in which it is not easily visible to the attacker's eye. Thus, an alert can be triggered in a simple and subtle way.

III. DESIGN OF THE SMART-FOOT DEVICE

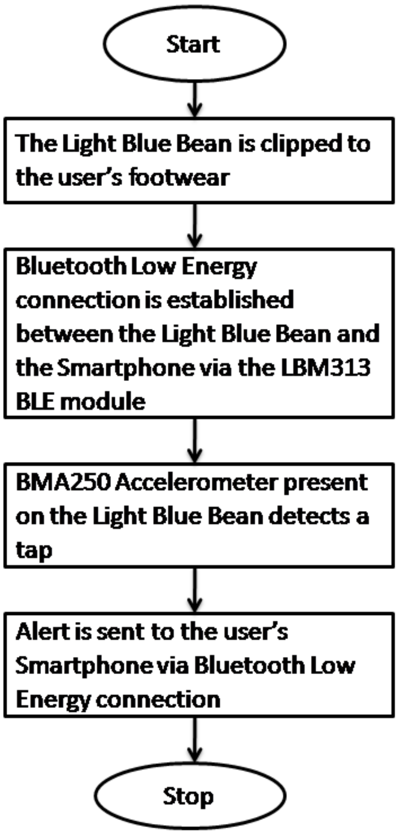

Figure 1. Block diagram of the proposed system

Figure 1 is a diagrammatic representation of the successive actions performed by the proposed system. The first step is the clipping of the device to the footwear of the user. The next step is the establishment of Bluetooth connection between the device and the user's Smartphone. The device must be paired with the user's Smartphone to work in conjunction with the application. Hence, no unauthorized user can connect to the device. Since BLE (Bluetooth Low Energy) is being used, the phone can be connected to the device without much loss in the battery life [8]. The acceleration sensor present on the device will record the acceleration reading in x, y and z axes once every second. When the user taps her left foot from the back using the right foot, the accelerometer senses a change in the reading in the z axis and an alert is sent to trigger the user's phone via BLE connection. When consecutive taps are detected, an alert is sent to the user's smartphone via the established BLE Connection. On receiving the alert from the device, an application on the smartphone is programmed to send its location to four contacts that the user can preset on the application. The application can further be programmed to inform authorities.

IV. WORKING METHODOLOGY

Data Acquisition

In order to implement the proposed idea, a Light Blue Bean is used. The Light Blue Bean is a Bluetooth Arduino microcontroller with an embedded tri-axial acceleration sensor. The user's smartphone and the device are connected by a Bluetooth Low Energy (BLE) connection.

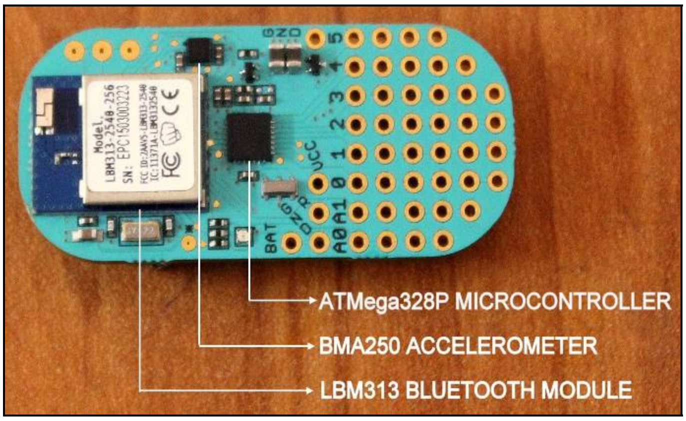

Figure 2. Hardware configuration

Bluetooth Low energy connection is achieved using the LBM313 Bluetooth Module. The LBM313 BLE module can support data rates between 250 kbps and 1 Mbps and operates at a voltage range of 2- 3.6 V. The Bluetooth Low Energy connection is used as it consumes a very small fraction of the power consumed by Classic Bluetooth radio [9]. It imparts intelligence to the controller such that the host is asleep till an action has to be performed. In addition, Bluetooth Low Energy provides an enhanced range of over 100 meters.

The accelerometer used is the BMA250, which is a digital, tri-axial acceleration sensor. The sensor allows measurement of accelerations in 3 perpendicular axes and is used to sense tilt, taps and motion. The acceleration sensor data depends on the orientation of the foot of the user. Upon tapping the other foot from behind as shown in Figure 3, the acceleration sensor reading with respect to the z axis undergoes a distinct change. This property is used to detect and trigger an alert when a woman is in danger.

Figure 3. Left foot tapped from behind

By programming the Arduino appropriately, after the detection of the tap, a trigger can be sent with the aid of the Bluetooth module via the established Bluetooth connection to the user's smartphone. The user's smartphone, upon receipt of the trigger, alerts an application on it. The application is programmed to send a message for help with the location attached via Short Message Service (SMS) to four contacts that the user will be prompted to select after downloading the application. Thus, the user can call for help even if the smartphone is not within reach.

In order to analyze the performance of the device, Naïve Bayes classifier, which is a supervised learning method, is used. Forty data points are considered in each case for training as well as testing purposes where the first twenty data points represent the walking phase and the next twenty data points represent the tapping phase. The average value for the walking and tapping scenarios are recorded each time the protocol is performed by each subject. To ensure that there is no bias, cross validation is performed [10]. The Naïve Bayes Classifier is simple to comprehend and can be implemented with ease. It is suitable in cases where the number of observations is not very high. Also, the Naïve Bayes Classifier shows better Accuracy, F Measure and AUC in comparison to a Decision Tree [11]. As this device will be triggered in dangerous situations, an algorithm achieving a high accuracy is essential. In the confusion matrix, the True Positive (TP) condition is satisfied when the classifier correctly identifies the tapping action, the True Negative (TN) is satisfied when the classifier identifies a walking scenario correctly, the False Positive (FP) condition exists when the classifier incorrectly identifies walking as a tapping scenario, and lastly, the False Negative (FN) condition exists when the classifier falsely identifies the tapping scenario as walking. These four parameters are used for evaluating the performance of the classifier with respect to criterions such as accuracy (ARY), specificity (SPY), sensitivity (SEY) and F-measure (FMR) [12]. Using the receiver operating characteristics, the AUC can be computed. The AUC is an important performance metric as it is independent of the existence of a bias. [13]. These performance metrics are computed as follows

Metric		**Formula**	
Accuracy (ARY)	=	$\frac{TP+TN}{TP+FP+FN+TN}$	(1)
Specificity (SPY)	=	$\frac{TN}{FP+TN}$	(2)
Sensitivity (SEY)	=	$\frac{TP}{TP+FN}$	(3)
F-measure	=	$\frac{2.TP}{2.TP+FP+FN}$	(4)

Experimental Protocol

For this experiment, five subjects (Age: 25 years (±10.59), Height: 167.8 centimeters (±4.96), Weight: 59 kilograms (±9.96), Footwear size: 7 inches (±1)) were considered. The safety device was clipped on to the footwear of the user. Each subject was requested to walk in a free lab environment for around ten seconds and requested to tap the left foot from behind with the right foot as shown in Figure 3, for about ten seconds. This protocol was repeated four times for each subject.

V. RESULTS AND DISCUSSION

The walking and tapping scenarios are represented graphically in Figure 4. The x-axis indicates the time in seconds and the y axis represents the acceleration sensor reading in the z axis in raw format. One unit in the raw format corresponds to $3.91*10^{-3}$ g. The walking phase is marked as the red line region and tapping phase is represented as the green line region. The average z axis acceleration values for walking and tapping across all subjects is represented as a scatter plot in Figure 5. A clear demarcation of the readings in each region is observed.

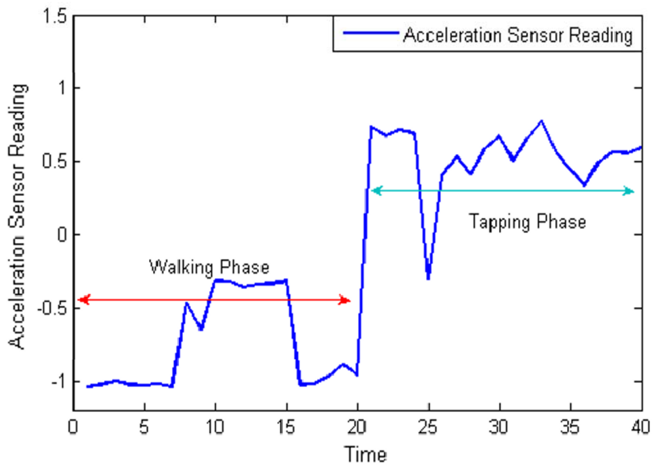

Figure 4. Analysis of the accelerometer data for walking and tapping phase

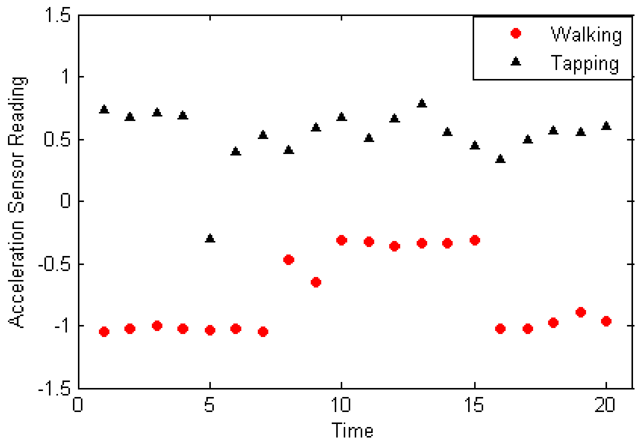

Figure 5. Scatterplot for walking (red circles) and tapping (Black triangles) phases

The acceleration sensor readings in the walking phase is observed to be in the negative region and that in the tapping phase is observed to be in the positive region. The average value of the acceleration sensor reading with respect to the z axis for the walking phase was found to be -0.7583 and in the tapping phase, it was found to be 0.5309.

The statistical values with minimum and maximum acceleration values for the two phases, namely, walking and tapping are represented in Table 1. The results of the NB classifier performance measures are represented in Table 2. The device showed a success rate of 97.5%. The best performance was achieved in the tapping scenario with 100% accuracy, sensitivity and specificity. The accuracy of the walking scenario is observed to be 95%.

Table 1: Statistical metrics of readings in different scenarios

Action	**Min**	**Max**	**Mean**	**Std**
Walking	-1.0429	-0.3125	-0.75833	0.320865
Tapping	-0.30245	0.7382	0.530956	0.230025

Table 2: NB Classifier performance metrics

Performance Metrics	**Results**
Accuracy	97.5%
Specificity	95%
Sensitivity	97.5%
F-Measure	0.975
AUC	0.978

VI. CONCLUSION

This work was aimed at developing a smart low-cost device to help women feel safer and prevent the occurrence of rape, harassment and other dangerous situations. The design is developed using an Arduino microcontroller with a tri-axial accelerometer and a Bluetooth Low Energy module embedded in it. This device is clipped to the footwear of the user. The automated system gave a high accuracy of 100% in the tapping scenario and 95% in the walking scenario. This low cost system does not require the user to have physical access to her smartphone and the device is well hidden. To trigger the device, the user is not required to press any buttons or carry any object in her hand. The user has to simply tap her left foot from the back using her right foot and a trigger will be sent to her smartphone which will send an alert via SMS to five pre-set numbers containing the location details of the device. The size and form of the device make it easy to incorporate in daily life. Due to its small size, it is discrete and difficult to notice. In the future, an appropriate case can be designed for the device to improve its durability and prevent any hardware damage. This study has a few limitations such as the trigger of a false alarm if the user taps her foot from the back involuntarily. The device works well only in scenarios where the user's feet are at ground level. By working on more number of scenarios and with sufficient collection of data (subjects with different age group, gender, and height), the reliability and robustness of the system can be improved.

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