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Ultra Alert: Safety Alert Mechanism for Pedestrian Mobile Phone Users in Crowded Area

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Abstract

Now a day's use of mobile phone is increased so that the pedestrian mobile phone users also increased. Walking by using the mobile phone may cause various accidents with pedestrians. To provide a safety to pedestrian mobile phone user there are various apps are developed to detect a vehicle, object in front and surface change. But none of these apps provide a safety in the crowded area. So we have proposed UltraAlert, which uses ultrasonic sensor and Android inbuilt sensors to detect a hazard in the crowded area. The ultrasonic sensor measures a ranging distance with the help of hardware interface unit to detect an abrupt change in the crowded area. Android inbuilt sensor and proposed algorithms provide the accuracy for detection with leveraging the sensors usability to reduce energy consumption and unnecessary alarm.

Keywords: Pedestrian mobile phone users, surface change detection, inertial and external sensors, human walk, walk speed estimation, pedestrian safety.

Introduction

Mobile device usage is increasing rapidly. Continuous usage of Smartphone causes an effect on pedestrian attention and walking. While using the mobile phone pedestrian neglect obstacle, unseen platform change, neglect upcoming vehicle may cause an accident. To avoid an accident and resolve effect by detecting visual and auditory task [13], Smartphones are equipped with various sensors to sense the mobile motion, touchstroke, holding orientation etc. Such sensors have been utilized in numerous contexts such as to detect user physical activity [14] and sensing around a mobile device [2], the position based risk awareness [10], and interactive activity recognition [3]. There are various sensors in the mobile device like accelerometer, magnetometer, gyroscope, proximity, light sensor, camera etc. Also compare the external sensors like infrared sensor [1], ultrasonic sensor [4, 16] for ranging data.

While working with the sensor, recent studies raised a question: Is it possible to augmented Mobile phone with a device to detect hazard related to surface change in the crowded area without annoying the pedestrian with unnecessary alarm alerts?

To determine this we have introduced UltraAlert, the system that is able to detect a sudden change of ground for pedestrian mobile phone users in the crowded area. We found that when a person is walking while engaged in eyes-busy mobile interaction (e.g. texting, playing games, and watching videos), their mobile phones are rarely held vertically but tilt more towards the ground. With this observation, augment the smartphone with a small ultrasonic sensor. The ultrasonic sensor keeps sending signals to measure the distance between the mobile phone and the ground. If there is an abrupt change in the distance measurement which we believe can lead to some hazards, an alarm will get generated to the mobile phone user.

In this paper, for practical solutions, deal with such challenges. To reduce the energy consumption of the system, identify some situations and turn off the ultrasonic sensor when its usage is not necessary. To provide reliable and timely results, firstly remove walking-induced noise by using a pedometer for detecting step counts. Then determine the maximum number of data points that can be collected to meet the real-time requirement, and identify hazards by providing a limit on distance detection. An alert will be issued only when the user has not noticed the hazard. All the information required is obtained from smartphone embedded sensors and the ultrasonic sensor (HC-SR04).

Related Work

Pedestrian safety apps emerged that are devoted to increasing the safety of pedestrian mobile phone users. Among these apps, some utilize the camera module. For example, X. D. Yang's Surround-see [2] uses an Omni-directional camera to detect user activity by providing field-of-view and SpareEye [17] also uses the camera to provide attention as a blind smartphone. CrashAlert [3] and Walk-Compass [5] detect the users' physical motion while walking to enhance alertness for eyes-busy mobile interaction. C. Hang's INS and PDR based tracking [7] and LookUp [20] uses shoe mounted inertial sensor module for surface change detection. X. Liu's UltraSee [4] detect abrupt changes of ground surface using ultrasonic sensor. Type N Walk [13] and WalkingText [14] display a transparent background image captured by the camera, which allows users to see the environment ahead through the mobile phone while texting. WalkSafe [8] could detect the approaching vehicles by processing the camera video frames. A system proposed in [10, 19] exploits the GPS sensor to identify whether a pedestrian is in-street rather than on the sidewalk and notifies the user when such an event occurs. Despite the promising results achieved and also these apps have some limitations. None of them is able to detect some more common and equally dangerous situations such as falling down from stairs or platforms. Though the apps [4] [13] and [14] may help tackle this problem, continuously turning on the camera module drains the battery quickly. Besides, the performance of the apps may affect the low-light environment. More importantly, even if the dangers ahead are displayed as the background image, the user who is distracted by the mobile phone apps may not be aware of them.

Problem Statement

The lack of user awareness, distraction, less accuracy from the mobile device may reduce the safety of the pedestrian mobile phone users. It causes the accident if the user is talking while walk. To avoid hazards with less energy consumption and without an unnecessary alarm on a mobile device, we have used an ultrasonic sensor, Android inbuilt sensors and various algorithms to provide accuracy to detect a hazard.

Proposed Work

The introduced UltraAlert system aims to improve the safety of a pedestrian mobile phone user while walking in the crowded area.

A. System Overview

UltraAlert, a system augments mobile device with an ultrasonic sensor (HC-SR04) which measures the distance of the ground surface from the sensor and temporal variation of distance can provide information about the change of ground surface ahead. With ultrasonic sensor for accuracy UltraAlert perform various operations as follow

- First, accelerometer and magnetometer used to sense holding orientation from the smartphone; for that Android built-in function getRotation-Matrix () is used.
- Second, for the touch stroke, we took the interrupt information from the Android phone screen layout keyListener.
- Third, to detect the pedestrian movement like walk we have used pedometer which can detect the step counts.
- Forth, walking speed and walking activities are detected through walking speed estimation algorithm with GPS-based Trilateration algorithm and Haversine formula.
- Finally, UltraAlert provides alert to pedestrian mobile phone user in a reliable and energy efficient way if the hazard is detected.

B. Ultrasonic Sensor and Hardware Interface Unit

The UltraAlert adopts ultrasonic sensor (HC-SR04) as the ranging sensor, which has the detection accuracy 3mm

Fig. 1. Ultrasonic Sensor (HC-SR04)

A Hardware Interface Unit (HIU) i.e. NodeMCU kit with Arduino IDE used to connect the Ultrasonic sensor to the mobile phone as shown in fig.2. The mobile phone is able to turn on/off the ultrasonic sensor to reduce energy consumption. Adjust its sampling frequency, and read the range data for analysis.

Fig. 2. HC-SR04 ultrasonic sensor attached with NodeMCU kit and connectivity status on device.

The ranging data detected by the ultrasonic sensor and HIU are passed to the smartphone via MQTT connection. For MQTT connection set a same secret password for HIU and smartphone. So that without any wired connection data will be transfer through remote access.

Properties	US-020	HC-SR04	SHARP GP2Y0A710
Max. frequency	20 Hz	40 Hz	100 Hz
Accuracy level	155 cm	280 cm	340cm
Detection range	7m	4.5 m	5.5 m

Table.1. The comparison between an ultrasonic sensor US-020, HC-SR04, and the infrared sensor SHARP GP2Y0A710.

US-020 [5] has detection range higher than, HC-SR04 i.e. 7m but its accuracy is inaccurate above the 106cm so, we have used HC-SR04 ultrasonic sensor. As compared to US-020 Ultrasonic sensor [5] and SHARP GP2Y0A710 infrared sensor [1] it is cheap and has better performance.

C. Android Inbuilt Sensors

Accelerometer and Magnetometer sensors are used to detect the mobile phone orientation values; for that Android function getRotationMatrix() is used. The getRotationMatrix() function used to fetch the orientation values roll, pitch, and yaw on the basis of x, y, z-axis.

Fig. 3. Pitch, roll, and yaw defined on a mobile phone for getting orientation coordinates.

Pedometer sensor is used to detect step counts. Pedometer sensor is an advanced accelerometer sensor. It fetches a human walk activity in step counts based on the roll, pitch, and yaw coordinates of the human body while walking.

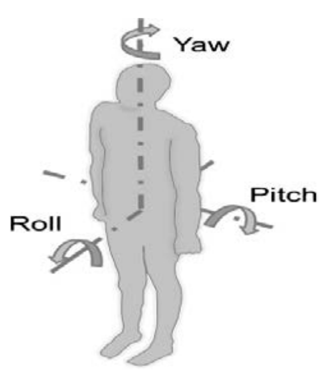

Fig. 4. Roll, pitch, and yaw coordinate for the human to detect the step counts though pedometer.

Architecture

Ultra Alert system based on three modules as follow

- Using Mobile Phone while walking and Hold Orientation Data Obtaining
- Identifying Hazard Ahead
- User Noticed the Hazard Ahead

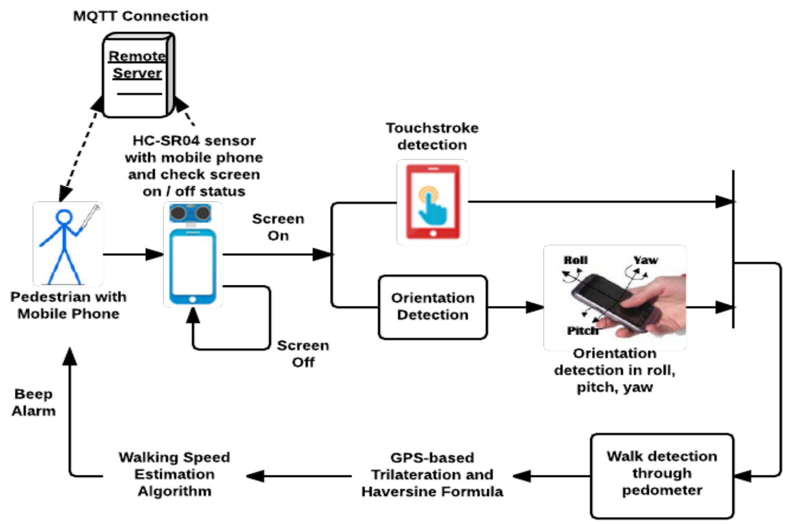

Fig. 5. The Ultra Alert System.

The three modules of the UltraAlert system are explained detail in the conditional cascading architecture which is shown below in fig 6. Three modules are nothing but three stages: status estimation, hazard detection, and user awareness detection. The details of each stage are as follows.

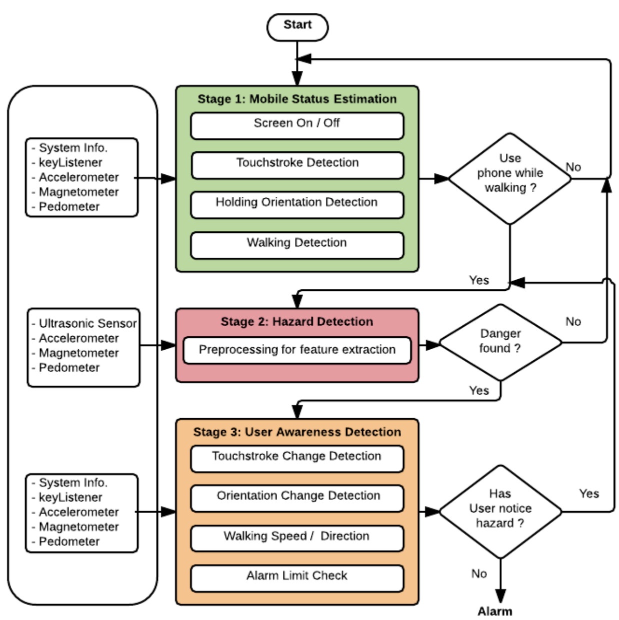

Fig. 6. The conditional cascading architecture of UltraAlert System.

Status estimation: Status estimation stage is served to answer the question: Is the person using the mobile phone while walking? The answer is obtained from the screen status (on/off), holding orientation and touchstroke. In mobile phone screen status estimation, if found the screen of a mobile phone is turned off, then safely assume that the phone is not being utilized. If found the screen is on with touchstroke being detected, then the person is using the mobile phone. When the screen is on while no touchstroke is detected, then further analyze the orientation data to draw the conclusion. Orientation data of mobile phone are pitch, roll and yaw show in fig. 3 which gets collected by using an accelerometer and magnetometer. Leverage the binary classifier which categorizes an input pair (pitch, roll) into one of the two classes: using a mobile phone and not using a mobile phone. Only when the answer is positive, proceed to the next stage.

Hazard detection: The aim of this stage is to know whether there is a possible hazard ahead. First, the range data collected from the ultrasonic sensor. Then pedometer used to get the step count to know whether a user is walking or not. If a user is not walking then a user is stable in place and doing work so consider it as a safe state. If the user is walking then walking parameter combines with first stage result. Then GPS-based Trilateration algorithm and Haversine formula applied to get user location. Furthermore, we have performed the statistical testing on the pre-processed ultrasonic data to identify the possible danger ahead and the time it is detected. Once a hazard is found, go to the next stage.

User awareness detection: The purpose of detecting users' awareness is to issue an alert only when the user is not aware of the hazards ahead. We identify some typical behaviors of mobile phone users when they notice a hazard ahead. To detect typical behaviors like putting down the cell phone, reducing walking speed, and changing directions refer to walking speed estimation algorithm [6, 9]. When UltraAlert detects an un-noticed hazard ahead, it generates a beep to alert the user.

Algorithms

Propose algorithm Walking Speed Estimation to obtain speed and direction of the walk with Trilateration algorithm and Haversine Formula to detect hazard indoor and outdoor.

A. Walking Speed Estimation Algorithm

Walking Speed Estimation algorithm take roll, pitch, and yaw parameters through pedometer sensor with respect to x, y, z-axis. Also it uses a magnetic sensor to provide unit gravity while walking to get step counts for speed and direction for indoor Process.

Data: Triaxial Accelerometer Parameters

Result: walking speed and direction.

Input:

$<x_j, y_j, z_j>$ = Triaxial Accelerometer (Pedometer) Parameters of human walk with respect to one sample within the window;

Begin

$a_j = (x_j, y_j, z_j)$; Original Acceleration vector;

$m_j = \|a_j\|$; Acceleration magnitude;

$\hat{g}$ = Unit gravity vector for a entire window (x, y, z);

$v_{j} = a_{j}.\hat{g}$; Magnitude of vertical acceleration with respect to a_j;

$v^{porj}_{j} = v_{j}.\hat{g}$; Vertical Projection;

$h^{porj}_{j} = a_{j} - v^{porj}_{j}$; Horizontal Projection;

$h_{j} = \| h^{porj}_{j} \|$; Magnitude of horizontal acceleration with respect to a_j;

return h_j; Horizontal Acceleration for walking speed and direction;

end

B. Trilateration Algorithm

It's a standard internet-based algorithm used with walking speed estimation algorithm. It gives the user location at the outdoor process for detecting user walking activity.

Data: 3D space sphere Co-ordinates.

Result: Middle Location Co-ordinates.

Input:

<P1, P2, P3> = Sphere centers;

<r1, r2, r3> = Sphere radius;

<x, y, z> = Unknown variables for planes;

Begin

$<r1^2, r2^2, r3^2>$ = Equations for the three spheres.

$r1^2 = x^2 + y^2 + z^2;$

$r2^2 = (x - d)^2 + y^2 + z^2;$

$r3^2 = (x - i)^2 + (y - j)^2 + z^2;$

<P1, P2, P3> = sphere centers are in the plane z = 0;

P1 = origin;

P2 = x-axis;

$<\hat{e}_x, \hat{e}_y, \hat{e}_z>$ = Unit Vector with respect to x, y, z planes and <P1, P2, P3> on z=0 plane.

$\hat{e}_x$ for direction P1 to P2 (x direction);

$\hat{e}_y$ for direction P1 to P3 (y direction);

$\hat{e}_z = \hat{e}_x \times \hat{e}_y$;

$\vec{P}_{1,2} = P1 + x\,\hat{e}_x + y\,\hat{e}_y \pm z\,\hat{e}_z$;

return $\vec{P}_{1,2}$; Middle Location Co-ordinate;

end

C. Haversine formula

Like Trilateration it is also a standard internet-based algorithm and used with walking speed algorithm. It gives the user location in latitude, longitude at an outdoor process for getting user walking direction and turn activity.

Data: Continuous GPS-based global values.

Result: Distance From object.

Input:

<lat1, lat2, lon1, lon2> = Latitude and longitude values selection;

R = Earth's Radius 6371 km constant;

begin

Lat = lat2 - lat1;

Lon = lon2 - lon1;

a = Distance calculation; sin (Lat / 2) + sin (Lon / 2)* cos (lat1) * cos (lat2);

c = 2 * asin (sqrt (a));

return R * c; angle based on earth's radius;

end

Result

- HC-SR04 ultrasonic sensor used to measure distance measure. It needs 5v of power that power is reduced by using NodeMCU kit into 3v and ultrasonic sensor used only when mobile screen is on for energy consumption.

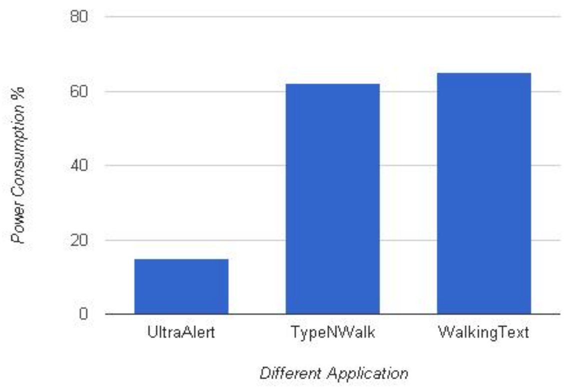

Fig.7. the Power consumption of different applications

- Set a limit for distance (110cm-200cm) based on this limit. Measure the changes of ranging data to get a variation for detecting the hazard.
- Pedometer provides a step count and walking speed estimation algorithm with the Trilateration algorithm and Haversine formula will reduce walking induce noise and provides accuracy for detection.

Conclusion

Proposed UltraAlert system detects many abrupt changes accurately in a crowded area. In UltraAlert, Ultrasonic Sensor with HIU keeps sending the signal to measure the distance between the mobile phone and the ground. The detected distance passed to the smartphone via MQTT connection. The accelerometer and magnetometer will sense the holding orientation of mobile and pedometer senses the step count for walking activity. Walking speed estimation algorithm with GPS-based Trilateration Algorithm and Haversine Formula detects walking direction and speed. Combine the values of touchstroke, orientation, step count and walking speed estimation algorithm with GPS-based Trilateration and Haversine Formula to detect a change of ranging data and change of surface. Ranging data is collected based on detection frequency and set detection limit to reduce the unnecessary alarm in the crowded area.

In the future work, our plan is to use this system completely with Google map to support various applications which based on distance and security.

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