Design study of detachable car accident alarm

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Abstract. The current market alarm has limitations such as non-removable, high cost, and many restrictions on the alarm. The removable, embedded installation structure of this design makes the car accident alarm have the advantage of high applicability, and the combination of cell phone APP terminal and embedded hardware design achieves effective reduction of waste of public resources, lower cost and resistance to product popularity. In terms of reliability, the design can detect whether the sensor is damaged, and ensure that the sensor can still correctly determine that the vehicle has been in a car accident when it is damaged, which is more reliable than most alarms. When receiving information about a car accident from the embedded hardware, an alert will be sent through the user's mobile device in time to remind the user. Through the cell phone's built-in GPS positioning technology, the application will automatically obtain information such as the vehicle's current location and send that information to emergency contacts.

Keywords: Detachable, Car accident alarm, Sensing technology, Software and hardware combination.

1. Introduction

In 2020, 244,700 road traffic accidents occurred in China, with more than 61,000 fatalities [1], about 40% of the injured died on the spot, the remaining 60% died in the hospital or on the way to the hospital, and 30% of the injured died because of untimely resuscitation. The probability of survival would be greatly enhanced if the seriously injured were rescued in time, which is the value of this design to study car accident alarms.

Although there are already smart enough car accident alarms on the market, their popularity is relatively low because car manufacturers only install them on expensive high-end vehicles. And, throughout the world, there are only a handful of teams that can make car accident alarms application-level. There are three main reasons for this. First, the car accident alarm to determine the occurrence of a vehicle accident requires a sufficient number and real car accident data; second, the real environment has a variety of environmental factors and various vehicle equipment, which can generate a certain amount of electromagnetic interference, or a car accident resulting in damage to the sensor, which cannot guarantee the accuracy of vehicle information, such as Huang Yuejin's invention of a remote automatic car accident alarm system [2], and Hou Juntao's invention of a microcontroller-based intelligent alarm system for car accidents [3], Third, the manual service platform only contacts the vehicle owner through the reserved call number, and the staff cannot determine in time whether the vehicle has actually been in a car accident, thus limiting the popularity and application value of the car accident alarm, such as the STm32-based automatic car accident alarm system invented by Xiaohong Wang [4]. Therefore, it becomes one of the key considerations in this field to avoid the multiple limitations caused by using human-assisted alarms without sending data to a human service platform and to propose a new alarm method.

Compared with these alarms, this design is divided into two parts: embedded hardware and cell phone APP software, and ensures that the accuracy of car accident judgment under the detachable structure is the same as that under the non-detachable structure. The design is applicable to common car accidents such as high-speed impact, rollover, water entry, fire, etc. The hardware alarm part can

alarm normally in case of sensor damage after a car accident, and automatically disengage the vehicle according to the alarm needs, and send SMS to inform friends and relatives of the exact location, time, and type of car accident through the cell phone APP in the software part when no one responds, and send a distress signal to the surrounding environment. The software can also send a distress signal to the surrounding environment.

2. Main content

2.1. Overall system design and working principl

2.1.1 Overall system design of detachable car accident alarm

The design consists of two parts, namely hardware part and software part. The hardware part uses STM32F1 as the main control chip, with sensors and modules to form a detachable structure. When the hardware part determines that a crash has occurred, it sends the crash information to the cell phone APP via Bluetooth communication module.

The design uses a thin-film pressure sensor as a means to detect the vehicle suffered from high-speed impact, by installing the thin-film pressure sensor at the airbag, detecting whether the airbag pops out and causes a certain force to squeeze the pressure sensor, so as to determine whether the vehicle suffers from high-speed impact; using the attitude sensor as a means to detect the vehicle rollover, backward rollover, forward rollover and other non-normal driving attitude, through the attitude The sensor obtains the Euler angle of the car, constructs a three-dimensional vehicle posture model, and then judges the current posture of the vehicle, so as to determine whether the vehicle is in a normal driving state; using the flame probe as a means of detecting vehicle fire, by installing the flame probe in the vicinity of the three-way catalytic converter of the car and other places prone to fire, detecting the wavelength of light and light intensity near the probe, so as to determine whether the vehicle In the fire state; using the water level sensor as a means of detecting the vehicle into the water, by installing the water level sensor above the door drainage hole, to detect whether there is no water level above the alarm line, so as to determine whether the need to alarm. The hardware alarm part consists of an electronic lock and an audible and visual alarm, which can be unlocked in accordance with the alarm requirements, so that the audible and visual alarm can be detached from the vehicle body to carry out the alarm action and prevent the alarm action from being carried out due to environmental factors, such as hardware damage caused by the vehicle entering water.

The design sets the Bluetooth module to transmit mode to connect wirelessly with the cell phone, and the effective communication distance is ten to thirty meters, and the transmitted data is checked and encrypted to ensure the reliability of communication. The design determines whether the sensor is damaged by detecting the analog signal on the sensor signal line to ensure that the vehicle can still be correctly judged to have been in a crash when the sensor is damaged. The design of the hardware alarm part can effectively prevent the influence of environmental factors and sensor damage, and improve the accuracy and timeliness of the alarm.

The mobile terminal is developed based on Android Studio as the IDE, calling Baidu map API and using various positioning technologies and transmission protocols, which increases the reliability of the software alarm, improves the coverage of the alarm and ensures the timeliness of the alarm. The designed APP has the function of browsing headlines, local and other news by calling the API of NetEase News, and by uploading the accident information to the server, it can synchronize the crash news on each user's cell phone in real time [5]. After receiving the car accident information from the hardware part, a pop-up notification is sent to the user, who can click on OK or cancel, clicking on cancel can avoid false alarms, clicking on OK sends an SMS to the emergency contact, and if no answer is made within 40 seconds an alarm message is automatically sent.

The overall workflow of this design is shown in Figure 1.

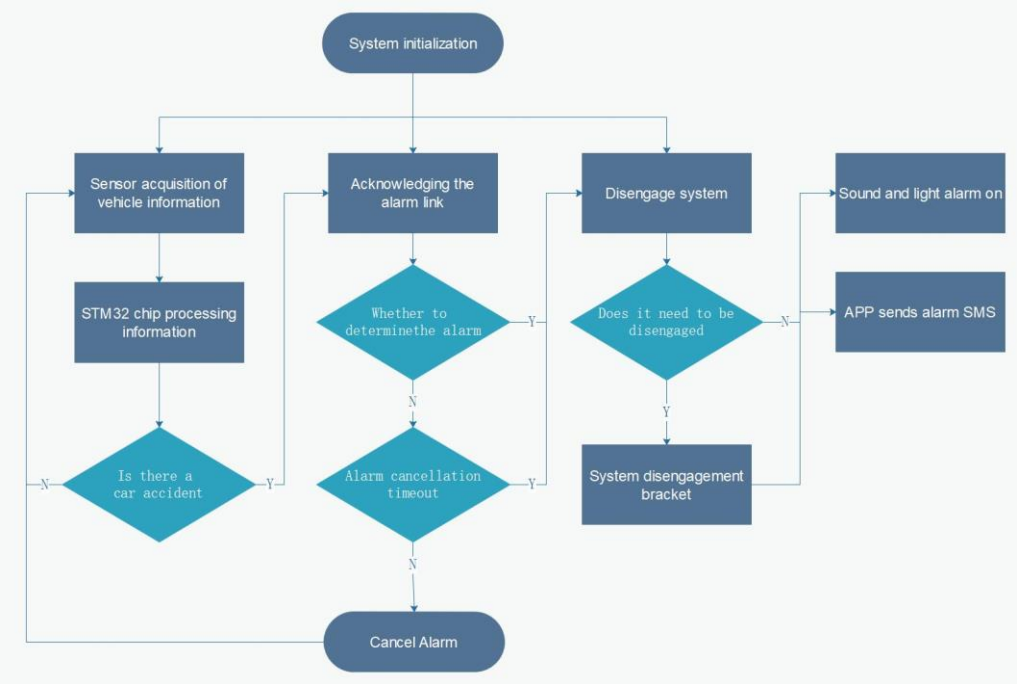

Figure 1. The overall workflow

After the initialization of the system, each sensor gets the vehicle information and sends it to the main control chip for processing and decision making of the alarm mode. For example, the vehicle washed into deep water, water from the drainage hole of the door to fill in, after reaching a certain water level, the main control chip judge that the vehicle has been in the water to a certain depth, start the alarm program, and confirm to the personnel in the vehicle whether the alarm. If the alarm is confirmed or no one cancels the alarm within the waiting time, the embedded alarm part will automatically detach from the vehicle after the water level exceeds the roof and float on the water surface relying on the lightweight and high buoyancy design structure, and turn on the sound and light alarm to draw the attention of the surrounding vehicles that may pass, at the same time, the mobile APP sends to the emergency contact set in advance containing the type of crash, the location of the crash, the time of the crash Alarm information.

2.1.2 Main technologies and their principles

(1) Acquisition and judgment of vehicle information;

For this design, the key to correctly judging whether a car accident has occurred is whether the acquired vehicle information can be completely transmitted to the code model for judging the type of car accident, and the code model for judging the type of car accident can reliably judge the occurrence and type of car accident.

Crash judgment model: It consists of flame judgment part, water level judgment part, impact judgment part, and attitude judgment part.

Flame judgment part: When the analog voltage read from the ADC voltage acquisition pin connected between the flame probe and the embedded microcontroller exceeds 1.0 V, the main control chip judges that the vehicle has started to catch fire and sends the corresponding crash information to the mobile APP.

Water level judgment part: when the analog voltage read from the ADC voltage acquisition pin connected to the water level sensor and the embedded MCU exceeds 1.0 V, the main control chip judges that the vehicle has entered the water to a certain depth and sends the corresponding crash information to the mobile APP.

Impact judgment part: when the analog voltage read from the ADC voltage acquisition pin connected between the thin-film pressure sensor and the embedded MCU exceeds 1.0 V, the main control chip judges that the vehicle has suffered a high-speed impact and sends the corresponding crash information to the mobile APP.

For the above model using ADC for voltage acquisition [6], the detailed judgment model is as follows:

$$U = ADC_X*(U_C/U_X) \quad (1)$$

where.

U is the analog voltage read from the ADC voltage acquisition pin.

ADC_X is the input voltage signal converted by ADC.

U_C is the reference voltage.

U_X is the maximum input voltage signal converted by ADC.

Attitude judgment part: the attitude of the vehicle is described by Euler angle construction, where the tilt angle (Roll), pitch angle (Pitch) and yaw angle (Yaw) correspond to the angle of vehicle rotation around the X-axis, Y-axis and Z-axis, respectively [7]. When a vehicle rolls on its side or backwards, its tilt and pitch angles will significantly deviate from its attitude during normal driving. Therefore, by monitoring the change of the vehicle's Euler angle, it is possible to detect whether the vehicle is in an abnormal driving posture. For example, when the tilt angle of a vehicle exceeds a certain threshold, it is possible to know that the vehicle is in a rollover situation, and when the pitch angle of a vehicle exceeds a certain threshold, it is possible to know that the vehicle is in a backward rollover situation [8].

The detailed model is constructed as follows:

Measure the angle βx, βy, βz between the vehicle and the standard state (standard state: the space right-angle coordinate system with the vehicle straight direction as the X-axis and the vertical direction as the Z-axis) to calculate the body offset angle α. As shown in the figure below, the unit vector vector M (1,0,0) is the standard direction, and the vector N is the current vehicle orientation.

$$\cos\alpha = \frac{cos\beta_x}{\sqrt{cos\beta_x^2+cos\beta_y^2+cos\beta_z^2}} \quad (2)$$

$\cos\alpha$—The angle between the vector N and the x-axis.

$\cos\beta_x$—The angle between the vector N and the xy plane.

$\cos\beta_y$—The angle between the vector N and the yz-plane.

$\cos\beta_z$—The angle between the vector N and the xz-plane.

According to the cosine theorem, the magnitude of the angle between vector N and M is the tilt angle of the vehicle, as shown in Figure 2.

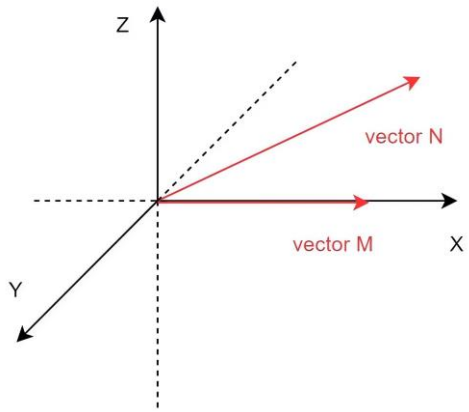

Figure 2. Vector diagram

(2) Transmission and sending of alarm information;

For this project, the flow of alarm information has the following three main points: embedded hardware and APP, cloud server and APP, APP and other mobile terminals, the key is whether APP can connect to the Bluetooth module of the embedded hardware part, connect with the cloud server and send crash information through cell phones.

For this design, the key to perform the action of canceling the alarm and normal alarm properly is that the APP can connect to the Bluetooth module in the embedded hardware part through the cell phone and can correctly obtain the geographic location information in order to send traffic accident related information based on a common protocol. In fact, this process involves the synergy of several technical aspects, which include the design and development of the embedded hardware, the configuration and debugging of the Bluetooth module, and the writing and testing of the mobile application.

The hardware part discriminates the type of car accident and transmits it to the cell phone via Bluetooth, and the cell phone Bluetooth receives the type of car accident and obtains the location information through Baidu map [9]. If the person chooses to alarm or does not respond, the time, location, and type of the crash is sent to the emergency contact by SMS, and the crash news is sent automatically so that other users can see it.

The embedded hardware part needs to communicate with the Bluetooth module through a certain hardware interface, and secondly, to perform the debugging of the Bluetooth module configuration and software APP interaction [10]. Finally, the normal interaction between APP and server is carried out: APP connects to the server using the network protocol and sends a request; the server receives the request, processes it, and returns the response data to the client; the client receives the response data and parses and displays it.

For the part of the embedded hardware communicating with the mobile app:

Based on the BLE protocol, the hardware part sends information about traffic accidents to the cell phone via Bluetooth. By configuring the physical layer, link layer and host controller interface of the BLE protocol stack as a way to receive the packets sent by Bluetooth and finally to unpacketize them.

For the part where the APP communicates with the server:

APP connects to the server using the network protocol and sends the request; the server receives the request, processes it, and returns the response data to the client; the client receives the response data and parses and displays it. For Baidu Map API call, you need to register Baidu Map Open Platform, create an application to get AK, and launch HTTP request to Baidu Map server to pass parameters and AK, and finally parse the server response data and process it.

For the part of APP communication with other mobile terminals:

According to the information of the corresponding traffic accident, call the corresponding SMS template, use the SMSManager class library provided by the system, and realize sending the SMS to the emergency contact set in advance by calling the relevant methods, whose information, including name, phone number and other information is stored and backed up in the local SD card.

2.2. Overall scientific and advanced system

2.2.1 Overall Science

The hardware part of this design uses embedded microcontrollers, sensors, and embedded peripheral modules to complete the pre-defined functions, and the mobile APP part uses custom Volley, retrofit, http and other frameworks to complete the pre-defined functions. Therefore, the project team members are required to master the programming knowledge of programming languages such as C, Java, Xml language, and the corresponding integrated development environment of microcontroller C software development system and Android development.

The technical route of this design is from knowledge reserve, to hardware and software construction, to joint debugging, and finally to complete reliability experiments, crash simulation, and design improvement, carrying out the design ideas of scientificity, rigor, and objectivity to ensure the overall scientific nature of the project.

The technical route of this design is shown in Figure 3.

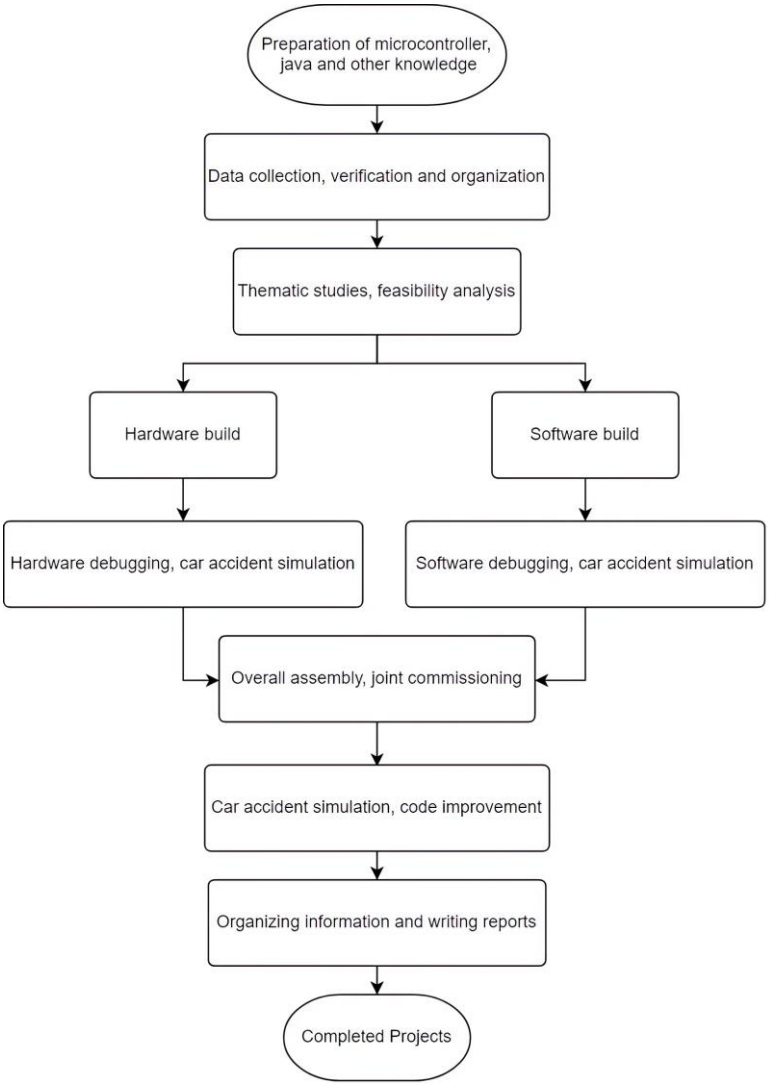

Figure 3. Technology Line

The project team conducted a variety of test experiments for this design, and the types of experiments and experimental results are shown in Table 1:

Table 1. Experimental records

Number of experiments	Type of experiment	Experimental results	
100	Frontal Impact	Success:99	Failure:1
100	Rollover after impact	Success:100	Failure:0
100	catch fire	Success:100	Failure:0
100	Into the water	Success:98	Failure:2
100	Normal Alarm	Success:100	Failure:0
100	Cancel Alarm	Success:99	Failure:1

Specific experimental methods as well as parameters are as follows:

Frontal impact: take three experimental car models of different sizes and weights (corresponding models are tricycles, cars and trucks), make them travel at a speed of 1.6m/s, and also travel at 1.6m/s, carrying the standard car model of this design (the experimental car), and impact them head-on on a flat or pothole-ridden road to verify whether they can correctly judge the type of car accident.

Vehicle rollover: Take three experimental car models of different sizes and weights (corresponding models are tricycle, car and truck), make them travel at a speed of 1.6m/s and crash sideways on a flat or pothole-ridden road to the standard car model with this design rolls over (the experimental car) to verify whether it can correctly judge the type of car accident.

Vehicle on fire: The standard car model (the experimental car) with this design is placed on the road in sunny, cloudy or rainy days, and a lighter is used near the flame sensor (installed to the place where the vehicle is prone to catch fire) to verify whether it can correctly determine the type of crash.

Vehicle in water: Place the standard car model (experimental car) equipped with this design in a container with the water depth not exceeding the roof of the experimental car to verify whether it can correctly determine the type of car accident.

Normal alarm: Trigger the alarm function of the project, and then wait for fifty seconds to verify whether it can be alarmed normally.

Cancel the alarm: trigger the alarm function of the project, and then select cancel the alarm on the APP to verify whether it can cancel the alarm.

Note: Because the size and weight ratio of the experimental car model and the actual vehicle is 1:10 (450mm*180mm*160mm, 150kg), the driving speed of 1.6m/s in the experiment is about 60km/h in reality.

2.2.2 Advanced Features

For car accident alarms, the situation in China and other countries is basically the same, with the bulk being monopolized by car manufacturers and configured only for high-end vehicles. Most of the car accident alarms of other studios and companies are pure hardware, the number of hardware used may mistakenly occupy social resources (lack of effective means of revoking the alarm), the rescue party needs to be equipped with a special information receiving end, and the reliability of the embedded hardware is relatively high, the probability of damage and high production costs.

The design is a detachable structure, with strong environmental adaptability, and the combination of cell phone APP terminal and embedded hardware design, to effectively reduce the waste of public resources, reduce costs and product popularity resistance, and enhance the ubiquity. The design can also detect whether the sensor is damaged, to ensure that the sensor is damaged can still correctly determine that the vehicle has been in a car accident, than most of the domestic alarm has a higher reliability.

Compared with the same type of cell phone software, most other APPs only support a single function, i.e., only support news viewing or alarm function, but the APP developed in this design combines the two functions into one, so that users can use the APP normally even in a safe situation, and at the same time, when in danger, they can also use the "Anxing IOT" APP can also be used to call for help in case of danger.

2.2.3 Substantial technical characteristics

(1) Sensing technology, which is characterized by:

①Many varieties and wide application areas. It can measure including many physical and chemical quantities, convert analog signals into digital signals, give microprocessor processing, and realize the processing of data operations. In the project embodied in the analog signal of water level, flame, car attitude into a digital signal, and then transmitted to the microprocessor.

②The response speed is very fast and the sensitivity is very high with high accuracy. It is reflected in the project as the fast acquisition of analog signals, and the total acquisition time is less than 50ms.

③Small size, with its own processing chip, can be filtered for jittering unstable data. The sensor used in the project is small in size and comes with a processing chip that can automatically filter out part of the invalid data.

(2) Satellite positioning technology, which is characterized by:

①Continuous global coverage, with at least four satellites observed at any location on Earth at any time. This is reflected in the project as continuous 3D positioning on a global scale and in all weather.

②The GPS positioning system can determine the 3D coordinates and velocity loss of the moving carrier in real time. This is reflected in the project as real-time monitoring and correction of the carrier's movement direction.

③High positioning accuracy. The GPS system can obtain the high-precision coordinate, velocity and time information of the dynamic target. This is reflected in the project as a relatively high positioning accuracy can be obtained for static targets on a larger spatial scale.

④High static positioning observation efficiency, depending on the accuracy requirements, the GPS static observation time ranges from several minutes to tens of days. It is reflected in the project that the process from data acquisition to data processing is done automatically.

(3) Communication technology, which is characterized by

① Fast data information transfer. Communication technology is based on binary digital signaling, capable of delivering 480,000 characters per minute, and the response time of data is kept below 1s, and only the response time of data from ultra-long distance is extended. In the project is reflected in the embedded hardware and APP interaction information time of no more than 10ms.

② Data is more secure. For binary digital signals, if the message is encrypted at the sending end, then these binary codes in the transmission process, even if intercepted by hackers, it is difficult to decipher. In the project is reflected in the data transmitted by the Bluetooth module and cell phone, APP and APP will be checked and encrypted processing, to ensure the reliability of communication.

③ Strong anti-interference ability. Through the binary signal transmission, in principle, as long as the electrical signal is not interfered with, its transmission is very stable. The design is most likely to suffer from electromagnetic interference, except for the embedded hardware Bluetooth module and APP is wireless communication, other parts are wired communication, no fear of electromagnetic interference, and the wireless communication part is far from the car's electromagnetic interference sources, under normal circumstances can ensure its reliability.

2.2.4 Significant progress

(1) The design reduces the dependence on hardware and manual service platform compared with similar products, the hardware structure of the project is detachable, and the project consists of embedded hardware and APP, which reduces the production cost and product popularity resistance.

(2) It can detect whether the sensor is damaged by itself, which improves the overall reliability.

(3) The alarm can be cancelled artificially and the alarm SMS can be sent automatically.

(4) It can determine the type of car accident and promptly notify emergency contacts and send help signals to the surrounding environment, so that users who are in danger can get appropriate and timely assistance.

3. Conclusions

This design is a detachable car accident alarm, which aims to provide users with intelligent security alarm means that can cope with common types of car accidents. The design consists of two parts, namely the embedded hardware part and the mobile APP part. The hardware part uses STM32F1 as the main control chip, with sensors and modules to form a miniaturized, reliable and anti-interference detachable structure. It is suitable for high-speed collision, rollover, backflip and other non-normal driving posture, vehicle fire, vehicle into the water and other common types of car accidents. When the embedded hardware part judges that a crash has occurred, it will send the crash information through Bluetooth communication module to the cell phone that has completed Bluetooth pairing, and the APP will store the crash information. The hardware alarm part can choose whether to detach from the vehicle body for alarm action according to the alarm demand. The design can determine whether the sensor is damaged or not, and ensure that the sensor can still correctly determine the corresponding crash type and alarm when it is damaged.

The mobile APP uses a variety of positioning technologies and transmission protocols to ensure real-time positioning information, accuracy and automation of positioning, increase the reliability and safety of data transmission, and improve the reliability and coverage of the alarm. The designed mobile APP has the function of browsing headlines, local and other news. By uploading accident information to the server, it can synchronize the news of car accidents on each user's cell phone in

real time. In case of false alarm, the user can choose to cancel the alarm on the mobile terminal. And after a crash, if no response is made within 40 seconds, the mobile app automatically sends an alarm message containing the type of crash, the location of the crash, and the time of the crash.

Acknowledgment

Project number: 202210742016

Note: 2022 Northwest Minzu University for Nationalities Student Innovation and Entrepreneurship Training Program Project Grant.

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