Design and Implementation of Warning Signs for Vehicles Based on Automatic Navigation Algorithms

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Abstract. Traditional warning signs use human retrograde placement; there are problems such as short warning distances, imprecise placement positions, and difficult positioning of accident points. According to statistics, the user's reaction time after facing a car accident is generally 1.05–1.28 s, and the reaction time to light is 0.225 s. The reaction time for the user to deal with a car accident independently is completely insufficient, and these reasons are the main reasons for secondary traffic accidents. In order to solve this social pain point, we designed a new intelligent triangle warning sign. The intelligent warning sign is installed with an intelligent base at the bottom, and it gets the traffic accident point precisely located when the intelligent warning sign is working, and the system gets the vehicle accident point and reminds the vehicles behind to pay attention to avoid, realizing the three-way interconnection of drivers and passengers, traffic control departments, and the personnel of the vehicles behind, and using the automatic navigation algorithm to realize the automatic navigation of the warning sign to protect the safety of drivers and passengers.

Keywords: Warning signs · Remote control · Precise positioning · Three-way alert · Automatic navigation

1 Introduction

With the rapid development of the transportation industry, the incidence of traffic accidents has increased. Traffic accidents not only cause a large number of casualties but also seriously affect economic development and social stability. In recent years, the rise in traffic accidents has become a serious problem faced by the traffic control department. When the vehicle breaks down or encounters an emergency, secondary accidents caused by the failure to place warning signs as required are common. At the same time, secondary accidents [1] have a high probability of being ignored by people due to the traditional warning signs artificially estimated distance error, incorrect placement, poor nighttime, rain, and other bad weather warning effects, the highway's artificially reversed

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walk-to-place warning signs, and other problems caused by the highway's proneness to road traffic accidents.

Due to the limitations of traditional warning signs and potential road traffic hazards, in order to avoid the occurrence of secondary accidents, this paper designs a car warning sign based on an automatic navigation algorithm.

2 Domestic and International Overview

With the number of motor vehicles increasing year by year, when traffic accidents and vehicle failures occur, it is necessary to use warning signs to alert the vehicles behind. It is understood that in Beijing, where the largest number of cars are kept in China, various auto parts markets are selling triangular warning signs almost everywhere, which are cheap and confusing in style; drivers have poor safety awareness of warning signs [2], and warning signs have poor warning effect in fog, darkness, and other weather; and the application of intelligent warning signs is small and simple in function.

Europe is a major region for the development and application of smart triangle warning signs. The EU started a regulation in 2014 that required all new cars to carry triangular warning signs, and in 2018, the EU issued another regulation that required all new cars to carry smart triangular warning signs. Smart warning signs are also starting to be used in the market with some simple alarm or location functions [3]. In Australia, the development of smart warning signs is more mature; for example, after the launch of a pilot project of smart warning signs in 2019 [4], it is evident that road traffic accidents are significantly reduced due to the use of smart warning signs [5].

3 Overall Solution Design

The intelligent car warning sign is mainly composed of three parts: the hardware circuit, the client, and the management system. The intelligent warning sign is installed with an intelligent base at the bottom, and an intelligent cart and hardware module are set in the base for controlling the warning sign as well as realizing the related functions. The working principle is as follows:

(1) A Beidou + GPS module is installed in the base of the intelligent warning sign to collect positioning data; the control of the intelligent warning sign is realized through an automatic navigation algorithm; A Bluetooth module and SIM card are used to realize multiple ways to connect the intelligent warning sign; a NBIOT wireless communication module is used to transmit data; and LED light strings are added to expand the warning range of the warning sign to avoid secondary accidents.
(2) The Beidou + GPS module collects positioning data and transmits it to the server, which is used to manage system statistics and analyze data, as well as mark the accident point and accident danger range.
(3) The management system acquires data from the server to make statistics on the accident points, which facilitates the traffic control department to deal with the accident, and uses SMS to ask the vehicle owner whether he needs help as well as to remind the rear vehicle personnel according to the danger range classified, so as to realize the three-way interconnection between the driver and passenger, the traffic control department, and the rear vehicle personnel.

(4) When placing the warning sign, the driver and passenger can choose two placement methods—automatic navigation and remote control—instead of human placement to protect the safety of drivers and passengers.

To sum up, the intelligent triangle warning sign mainly realizes: precise positioning, accurate rescue, three-party interconnection, expanding the warning distance, and replacing the artificial placement of warning signs so that users can quickly and conveniently deal with road traffic problems.

4 Intelligent Triangle Warning Sign Function Design

4.1 Microcontroller

Traditional warning signs have simple functions and poor practicality, so considering the functionality and application scenarios of warning signs, the STM32 F103RET6 [6] is selected as the main control board, which effectively ensures real-time control and monitoring of the intelligent warning signs during their movement. Due to the high integration and low power consumption of the microcontroller, the warning sign works for a long time, which is convenient for users to deal with unexpected situations encountered during the journey.

4.2 Intelligent Warning Sign Automatic Navigation Algorithm

The Beidou + GPS module on the smart warning sign is positioned in real time, the Beidou satellite gets the data back to the server, and the management system gets the data from the server for parsing and processing, which is displayed in the map interface and analyzes and counts the specific location of the warning sign and vehicle information.

When drivers and passengers are using warning signs, they need to place them according to the requirements of different highways on the distance of warning sign placement. We use a search algorithm to plan the route. The algorithm ensures that the path found in the map is the shortest path and decides the direction of the search by evaluating the valuation function of each node to avoid useless routes as much as possible. The situation varies from road to road, so the warning signs are needed to ensure accuracy during the movement, so we plan an optimal path for the user based on the location of the start and end points.

The valuation function consists of two components: the heuristic function and the cost function.

$$f(n) = g(n) + h(n) \tag{1}$$

The above algorithm is used to implement the route planning of the warning signs, using the Beidou + GPS module to obtain the current position and update the data in real time to return it to the server. According to the positioning technology, to obtain the current information and route planning results, use the route tracking algorithm to calculate the current direction and speed that the warning sign needs to travel. Here, we use the PID control algorithm [7] to realize the route tracking of the warning sign. This algorithm is a common feedback control algorithm that can minimize the error between the actual output and the desired output of the system by constantly adjusting the output so as to The PID algorithm has three main components: proportional control (P control), integral control (I control), and differential control (D control), which are implemented as follows:

P control, according to the current error, according to a certain proportion to adjust the output; the greater the error, the greater the output; the smaller the error, the smaller the output; The formula is as follows:

$$P = Kp * e(t) \tag{2}$$

P: proportional control output Kp: proportional coefficient e(t): current error.

The control adjusts the output proportionally according to the accumulated value of the error. Similarly, the larger the error, the larger the output, and the smaller the error, the smaller the output; the formula is as follows:

$$I = Ki * \int \mathrm{e}(t)dt \tag{3}$$

I: integral control output; Ki: integration coefficient; $\int$e(t)dt: the cumulative value of the error.

D control adjusts the output according to the rate of error change in a certain proportion. The formula is as follows:

$$D = Kd * de(t)/dt \tag{4}$$

D: differential control output; Kd: differential coefficient; de(t)/dt: the rate of error change.

The final output control is the weighted sum of the three components:

$$Ut = P + I + D \tag{5}$$

U(t): the control output.

The above algorithm can realize the route planning, current moving position, and running speed of the warning sign, ensure the stability and accuracy of the system, and finally realize the automatic navigation function of the warning sign.

4.3 Communication Protocols

MQTT Protocol

Considering the diversity and wide use of smart warning signs and the reliability of positioning data, we use the MQTT message transmission protocol [8] in order to guarantee that smart warning signs can work properly and obtain precise positioning in remote areas or areas with weak signal coverage. The transmitted information is divided into topics and payloads. Topic requires both the client and the ONE NET server to subscribe to the same topic. After subscribing to the topic, the client uploads data from various sensors, and the server sends commands to control the smart warning signs. The payload is the content of the message sent by both parties, i.e., various data and commands. The data from various sensors of the smart warning sign is uploaded to the client, and the server issues commands to control the smart warning sign.

By obtaining the data from the sensors, the server side obtains the latitude and longitude to display the information of the accident vehicle and the place where the accident occurred to achieve the function of three-end interconnection.

BLE V4.0 Protocol

The difference with the MQTT protocol is that it can realize direct communication between devices and is mainly used for remote control of smart warning signs by cell phone apps [10]. When dealing with traffic accidents or vehicle accidents on highways, placing warning signs on foot by humans is dangerous and prone to secondary accidents; therefore, we designed two methods of placing warning signs remotely to protect the safety of drivers and passengers.

First, when a traffic accident or malfunction occurs, the accident vehicle personnel can remotely control the intelligent warning sign through the cell phone terminal APP. After the cell phone end APP sends the control command, the Bluetooth layer by-layer analysis of data controls the warning sign forward and backward and other functions, without human placement, to ensure the safety of personnel.

The second, the client APP, sets up the function of automatic navigation on different highways. By clicking the button, the accident vehicle personnel use the automatic navigation algorithm to calculate the warning sign placement distance, running speed, and running direction and automatically run to the designated position without manual operation by personnel to achieve the effect of avoiding secondary accidents.

4.4 Wireless Remote Control

Two ways are used for wireless remote control: the first is the NBIOT wireless communication module [11], which contains the SIM card and is characterized by low power consumption, long standby time, long connection distance, and wide coverage. The MQTT communication protocol was chosen; the main features of MQTT enable the use of a very small amount of writing and enough bandwidth to allow a fast and accurate transfer of the smart warning sign's positioning signal from the local device to the remote device and an efficient data exchange with the server.

The second way is the Bluetooth module, which uses the HC-08 Bluetooth serial communication module, which is a digital transmission module based on Bluetooth Specification V4.0 BLE Bluetooth protocol with GFSK modulation technology. It is able to reach ultra-long distance communication and can better link cell phone applications with data. Its working process: when the smart triangle warning sign is unfolded, the cell phone app connects to the smart cart to receive data or control the smart cart. The control process is shown in Fig. 1.

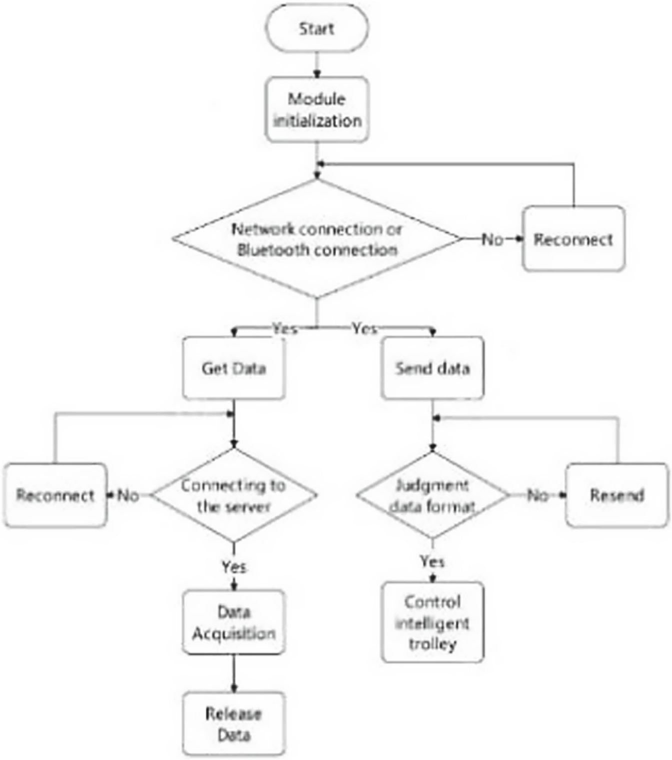

Fig. 1. Control process

4.5 Motor Drive Module

The motor drive module of the smart warning sign is used to control the motor's operation; mainly, the control signal is converted into the voltage required by the motor through the motor drive chip, which has two start-up control terminals and an external detection resistor for high-precision logic control. It realizes real-time monitoring of the working condition of the motor and provides timely feedback to the control circuit to drive the intelligent warning sign and provide good power support for the intelligent warning sign.

PWM speed control technology uses a switching circuit to realize the switching operation of the circuit, in which the switching circuit generates pulses with different amplitudes, and the width of these pulses varies with the switching of the switching circuit, thus realizing the voltage change of the circuit and its frequency change and changing the driving speed of the intelligent warning sign. The signal frequency and duty cycle of the PWM output are determined by the values of the automatic reload register (ARR) and the comparison register (CCR). The resolutions are:

$$F = CK\_PSC/(PSC + 1)/(ADD + 1) \tag{6}$$

$$DC = CCR/(ADD + 1) \tag{7}$$

$$RES = 1/(ADD + 1) \tag{8}$$

F: PWM frequency, DC: duty cycle.

Set two parameters, ENA and ENB, on L298N to adjust the PWM on it. When the enable signal is 0, the motor stops automatically. If the enable signal is 1, ENA, and ENB are 00 or 11, the motor will stop rotating.

4.6 Beidou + GPS Module

Beidou + GPS module [12] realizes double-precision positioning. The Beidou module mainly transmits signals through satellites, and the Beidou module on the intelligent warning sign receives the signals transmitted by satellites, measures the signal propagation time and the latitude and longitude positions of satellites, and can calculate the current position of the warning sign itself using the algorithm of triangulation, which covers a wide range.

4.7 LED Light-Emitting Module

LED light strings usually use LED chips, PVC material, and other components. LED lights are set on the front of the intelligent warning sign, and the warning distance grows, effectively reminding drivers to pay attention to safety and providing an effective reminder in case of traffic congestion to prevent secondary traffic incidents.

5 System Design

5.1 System Architecture Model

The vehicle backend management system uses the MVC model [13], which helps developers achieve separation of concerns. MVC is a three-tier structure consisting of a model, a view, and a controller. The model layer includes the business logic it executes with the state of the website; the view layer is responsible for interacting with the user, which presents the information in the database to the front-end through the server; the controller is the component that implements the core code of the website functionality, and the interaction with the user is handled and responded to by it.

5.2 Functional Design

Its function module is divided into four parts: vehicle distribution, user management, failure dangerous vehicle rescue SMS sending, and data analysis. The vehicle location information in vehicle distribution is obtained from the API provided by the ONE NET platform [14], extracted using regular expressions, and finally presented through the map API, with the faulty vehicle as the center and the danger range divided by a radius of 500 m. User management can add, delete, and check the owner's information; adding users to the database through the add method and deleting, changing, and checking all need to get the ID by clicking the event first and then calling different methods to operate on them. The SMS sent to the vehicle in danger of failure is realized by calling the API interface provided by SMS.com.

6 Mobile Software Design

6.1 Android Client Main Structure

The client is mainly divided into three major parts: the connection module, the control module, and the communication module, as shown in Fig. 2. The connection part can be divided into Bluetooth connection and Wi-Fi connection [15], which are used to remotely control the connection method of the smart warning sign; the control module is divided into automatic navigation placement of the smart warning sign and human remote control placement, which is used to place the warning sign at a specified distance when dealing with traffic accidents, replacing human walking. The reverse placement communication module uses a Bluetooth communication module [16], and the user sends commands to the smart warning sign to control the steering of the warning sign.

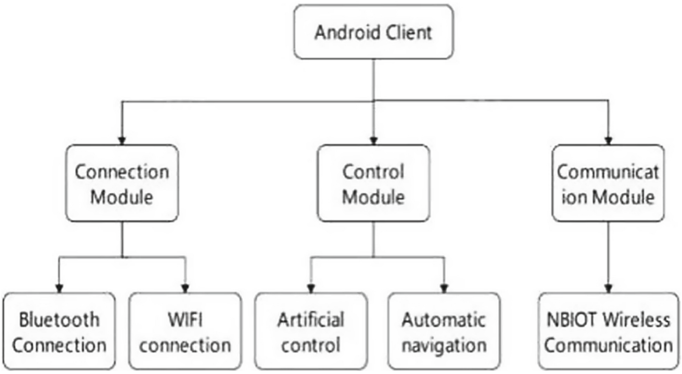

Fig. 2. Client general structure diagram

6.2 Main Interface Framework Design

The main page of the client contains connection setting and selection, an intelligent warning sign mobile control interface, automatic navigation, setting buttons, a power display, system information, etc.

7 Experimental Records

7.1 Experimental Method

(1) Test the effective range of remote control; place the intelligent warning sign on the highway; remote control by the client APP; control its forward, backward, left turn, right turn, pause; test the delay time (the time from the client pressing the button to the intelligent warning sign giving a response); and the connection situation (the percentage of successful connection and failure).

(2) Test the warning range of the intelligent warning sign, divided into daytime warning distance and night warning distance, i.e., how many meters the testers can still see the intelligent warning sign clearly in different environments.
(3) Test the accuracy of the background management system in acquiring data and marking accident points, as well as the speed of data refresh and the completeness of information display.

7.2 Experimental Data

The following four distances were selected: 0–40 m, 40–80 m, 80–120 m, 120–160 m, and the delay time when the client APP controlled the intelligent warning sign, which was recorded as T. Through the data statistics, it was found that within the range of 40 m, T1s were negligible. With increasing distance, T increases proportionally, and the average delay time is close to 1.6 s when the distance reaches 160 m. The test results of accepting command T at different distances are shown in Fig. 3.

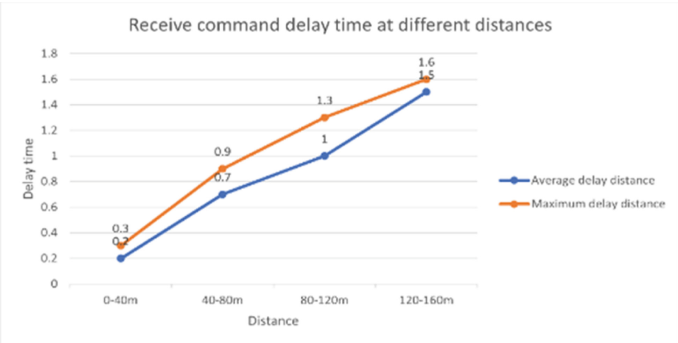

Fig. 3. Receive command delay time at different distances

According to the information, the user's reaction time after facing a car accident is generally 1.05 s to 1.28 s, while the reaction time to light is 0.225 s. When the user is exercising on the highway at 100 km/h, the reaction distance in the face of an emergency is 35.56 m, while the reaction distance to light is 6.25 m, which is a shorter reaction distance.

Through a number of testers to test the warning sign, according to the testers' feedback, during the driving process, the LED light of the warning sign can be clearly seen flashing at a distance of two hundred meters from the warning sign, and the warning distance grows compared with the ordinary warning sign, and the effect is more obvious, especially in the dark night fog and other bad weather effects.

Through the above test, the intelligent triangle warning sign designed in this paper can meet the needs of the vehicle in actual operation and cope with the unexpected situation, has achieved the design goal and the original intention, and will further improve its function in the future and continuously improve it to maximize its function and protect the safety of drivers and passengers.

8 Conclusion

Through continuous testing and debugging of the system, the design requirements can be completed. The innovative points and features of this design are reflected in: (1) real-time monitoring of accident point latitude and longitude through Beidou positioning and statistical accident points through the backend management system to achieve three-party interconnection, which is convenient for traffic control departments to deal with traffic accidents. (2) Through remote-controlled warning signs to protect the safety of drivers and passengers (3) Comparison of traditional warning signs to increase the LED light string: the warning effect is obvious, and the warning distance is extended. (4) Through an automatic navigation algorithm to achieve smooth operation and automatic navigation of intelligent warning signs placed without human personal placement to protect the safety of personnel.

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References

1. Zhang, B., Xu, W., Liu, G., Muhammad, A.: The early warning efficiency analysis of secondary accidents in expressway tunnels. Adv. Mech. Eng. **11**(4) (2019)
2. Anonymous: Warning light for night safety. Commer. Motor **231**(5821) (2019)
3. Sodikin: Mobile traffic warning signs, can it be applied?. J. Phys. Conf. Ser. **1376** (2019)
4. Frances, A.: A warning sign on the road to DSM-V: Beware of its unintended consequences. Psychiatr. Times **26**(8) (2009)
5. Zaw, K.P., Kyu, Z.M.: Character segmentation and recognition for Myanmar warning signboard images. Int. J. Netw. Distrib. Comput. (IJNDC) **7**(2) (2019)
6. Long, T.: Design of sweeping robot based on STM32 single chip microcomputer. J. Phys. Conf. Ser. **2456**(1) (2023)
7. Zhang, W., Lei, J., Lin, Z.: Research on improved PID control algorithm of a kind of high speed vehicle. In: Proceedings of the 2nd International Conference on Electronics, Network and Computer Engineering (ICENCE 2016) (2016)
8. Longo, E., Redondi, A.E.: Design and implementation of an advanced MQTT broker for distributed pub/sub scenarios. Comput. Netw. **224** (2023)
9. Held, G.: Moving IoT data with MQTT. InfoWorld.com (2022)
10. Wei, S., Zhang, Y., Li, J., et al.: Bluetooth remote control car based on app inventor. Information Engineering Research Institute (USA),Singapore Management and Sports Science Institute (Singapore). In: Proceedings of 2018 7th ICEA International Conference on Information, Education and Social Sciences (ICEA-IESS 2018).Information Engineering Research Institute, pp. 134–138 (2018)
11. Guo, Z., Liu, Y. and Lu, F.: Embedded remote monitoring system based on NBIOT. J. Phys. Conf. Ser. **2384**(1) (2022)
12. Zhimin, S., Zhengjia, W., Zhijun, Z.: Research of ETC with GPS/BDS high-speed charging and navigation system. Autom. Control Intell. Syst. **9**(4) (2022)

13. Kanjilal, J.: How to Redirect a Request in ASP.NET Core MVC. InfoWorld.com (2020)
14. Jackson, L.: The Complete ASP.NET Core 3 API Tutorial. Apress, Berkeley, CA
15. Liu, J., Liu, J.: Design of embedded intelligent car control system based on android. J. Phys. Conf. Ser. **1651**(1) (2020)