Design of Vehicle Detection System based on Magnetic Sensor

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Abstract

In order to solve the problems of traditional vehicle detection technology, such as complicated installation and wiring, maintenance difficulties and high cost, the thesis design a vehicle detection system based on geomagnetic sensor that can detect the vehicles speed and implement traffic flow statistic. The system consists of vehicle detection nodes, the master node, and upper computer, the vehicle detection nodes mainly uses STM8L SCM with the geomagnetic sensor and the 433MHz wireless transceiver module. Test results show that the system possesses small size, low cost and high performance, and can actually be applied to outdoor parking spaces detection.

Keywords

Vehicle detection, Magnetic sensor, Wireless.

1. Introduction

With the increasing demand for cars, the demand for intelligent traffic is becoming more apparent, the intelligent traffic can solve the problem of transportation efficiency and other aspects, vehicle detection system is particularly important as to be able to access to the most fundamental and most effective traffic parameters, traditional vehicle detection method contain loop vehicle detector, ultrasonic detection, infrared detection technology and etc., but these detection systems are very complex installation, wiring difficult and against the maintenance, so the key problem of the intelligent transportation that need to be implemented is how to implement an easy installation, low cost, high efficiency of vehicle detection.

In the thesis, a new type of geomagnetic sensor (AMR) is selected to design a wireless vehicle detection system, the main implementation is vehicle speed detection and traffic flow statistic, compared with the traditional detection method, there is a higher performance of installation, cost, dimension, energy consumption and efficiency.

2. Vehicle detection principle

The earth's magnetic field intensity is from 0.4 to 0.6 gauss, and it is uniform and stable in a certain range, when a ferromagnetic object such as a car into the magnetic field, the magnetic field will be distorted or stretched by object. The geomagnetic sensor can determine the presence of the vehicle in the field based on the change detected magnetic strength. Magnetic field interference by vehicle diagram is shown in Fig 1.

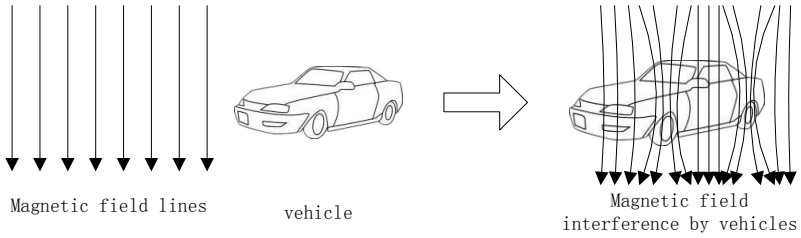

Fig.1 Magnetic field interference by vehicles diagram

3. System design scheme

Two vehicle detection nodes are installed in the middle of the lane, determine if there were any cars by detecting the change of the geomagnetic information, the vehicle transmit the current time information by 433MHz wireless network to the master node for data processing and analysis, and display statistical data in upper computer. Network architecture of the system is shown in Fig 2.

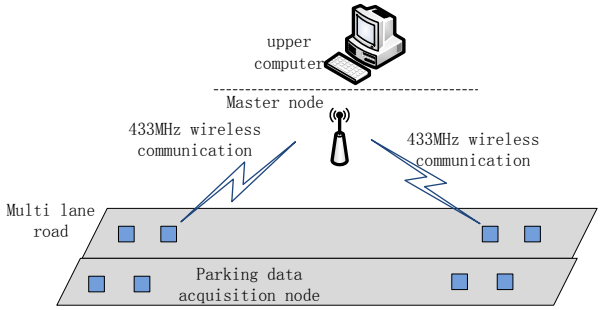

Fig.2 Network architecture of the system

3.1 Nodes hardware design

The detection node overall hardware design is shown in Fig 3.

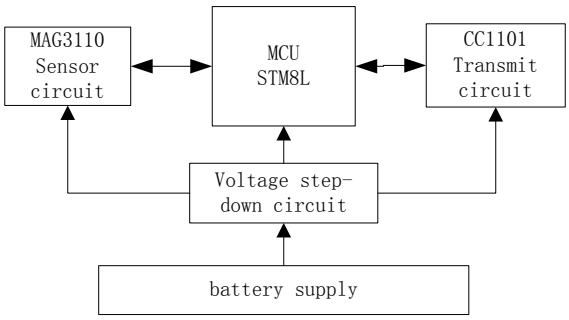

Fig.3 Detection node hardware design architecture

The whole system mainly includes MCU microcontrollers, using low-power STM8L151L single-chip microcomputer, which is responsible for controlling the work of coordinating the nodes of the whole node. The MAG3110 geomagnetic sensor is responsible for detecting the geomagnetic data. The 433MHz transceiver circuit adopts CC1101 RF module, which is responsible for wireless data transmission between nodes. Power supply part adopts the 18650 battery, and the TPS79333 buck regulator circuit for the entire node power supply.

3.2 Nodes Software Design

3.2.1 Data calibration

Due to the different geomagnetic information at different locations, it is necessary to adapt the geometrical calibration of the nodes at different locations, and the obtained calibration value is the basic value of the subsequent node threshold judgment. In order to avoid some possible pulse interference, the median average filtering method is used to calibrate the data. The detection node collecting 100 sets of data as the original data after power on, remove the maximum and the minimum value, get average value of the rest data, then can get the three-axis geomagnetic data calibration value.

After the data calibration is complete, the normal data acquisition status is entered. Data calibration algorithm process is shown in Fig 4.

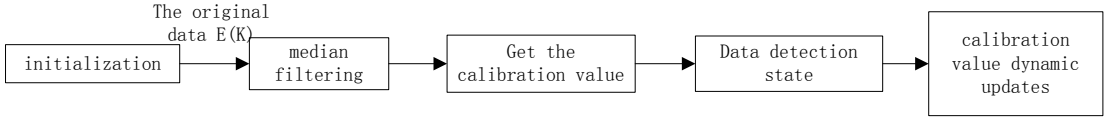

Fig. 4 Data calibration algorithm process

Data calibration was done after the sensor initialization, however, there may be some inevitable errors, if the calibration value was always been used as the judgment base when the sensor work too long. Therefore, there adopts the method of dynamic update calibration value, the number of the sensor acquisition times can be set after the long-term work to get a new calibration value, use the recent collection of multiple sets of data for smooth calculation, and then compare to the old calibration values, if the difference between the two is higher than the normal level (usually only a slight change), it may be affected by the noise pulse, and discard the value. If the difference between the two is within the normal range, then update the calibration value. And combined with the sensor network, through the upper node and send a reset command to the detection node, the node sensor is initialized to regain the calibration value after long-term work.

The calibration value dynamic update process is shown in Fig 5.

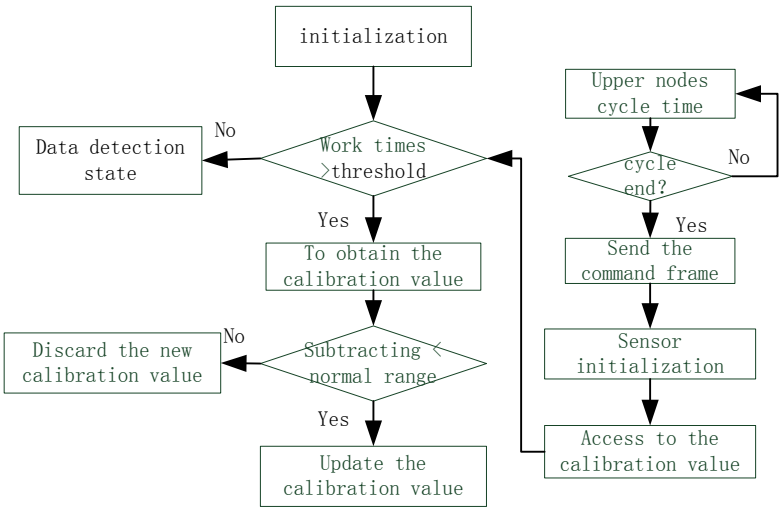

Fig.5 The calibration value dynamic update process

3.2.2 Vehicle magnetic detection

After complete initialization configuration, the vehicle detection nodes began to enter detection work status. Because the node is placed in the middle of the road lane, so the vehicle can basically cover the top of the node, thus, The node can detect the amount of change of the magnetic field in the detection range caused by the vehicle, by setting the threshold value to judge whether there are vehicles through the node, if not, the node will continue to acquisition data. On the contrary, the current time information will be sent to the master node. The master node will complete the vehicle detection through data processing. The vehicle detection software process is shown in Fig 6.

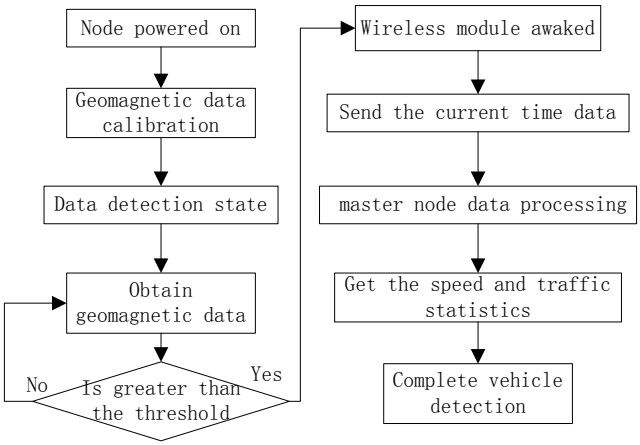

Fig.6 Vehicle detection software process

3.3 Vehicle Speed Detection

For detecting speed, time synchronization should be carried out first of all need to two nodes. the node initialization after power on, obtain measurement calibration value, and set judgment threshold, send the time synchronization request command to the master node after finish the initialization step, the master node sends the time synchronization frame to the detection nodes respectively, completes the time synchronization, and the vehicle detection node enters the normal working state. Vehicle speed detection principle diagram is shown in Fig 7.

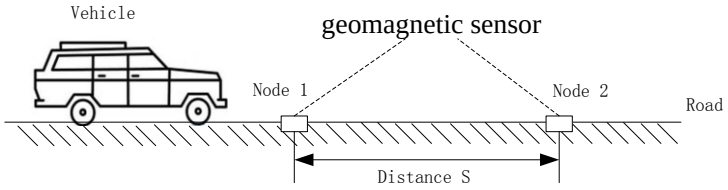

Fig.7 Vehicle speed detection principle diagram

From figure 7, the location distance of the two magnetic sensor node is S, the time that two nodes data detection wave is t1 and t2, so the instantaneous speed of the vehicle can be calculated by formula (1).

$$v = S \div (t2 - t1) \tag{1}$$

The whole process of speed detection is shown in Fig 8.

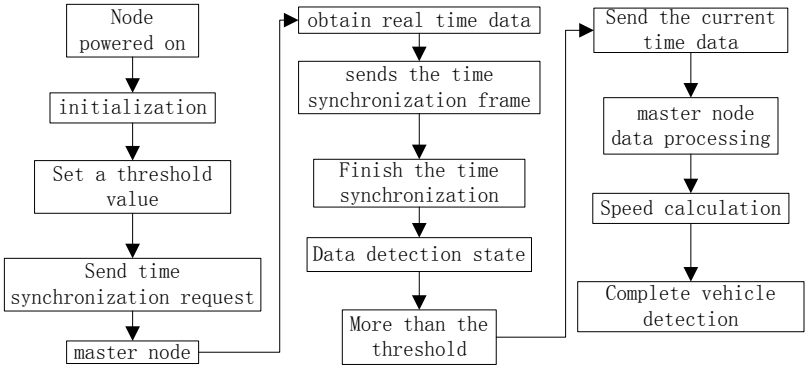

Fig.8 Vehicle speed detection process

3.4 traffic flow detection

The traffic flow statistics is base on the speed detection, with a fixed time period T as the acquisition interval, when the node 1 and node 2 data synchronization changes, then upload the time data to the master node. The traffic statistics Num on the master node added, when the fixed time period is over, then the traffic flow statistics can be obtained by formula (2).

$$c = Num \div T \tag{2}$$

For multi-lane application environment, the traffic flow can be obtained by formula (3).

$$c = \sum_{i=1}^{n} (Num \div T) \tag{3}$$

4. The system test

4.1 detection node test

There are many different types of vehicles, according to the actual situation, in the field test, select three different types for vehicle testing, test each of these three types of vehicle impact on the geomagnetic data.

Different type vehicle impact on the magnetic field variation is shown in Table 1.

Table 1. Different type vehicle impact on the magnetic

Test vehicle	variation minimum (nT)	variation maximum (nT)
Electric vehicles	105	190
Cars	130	220
Suvs	280	430

In the case of multi-lane road, whether the vehicle detection node will be affected by the adjacent lane vehicle. So, in the outdoor, choose Suvs vehicles as the test object, test nodes at different distance, after repeatedly tests, the relationship between geomagnetic strength and distance is shown in Fig 9.

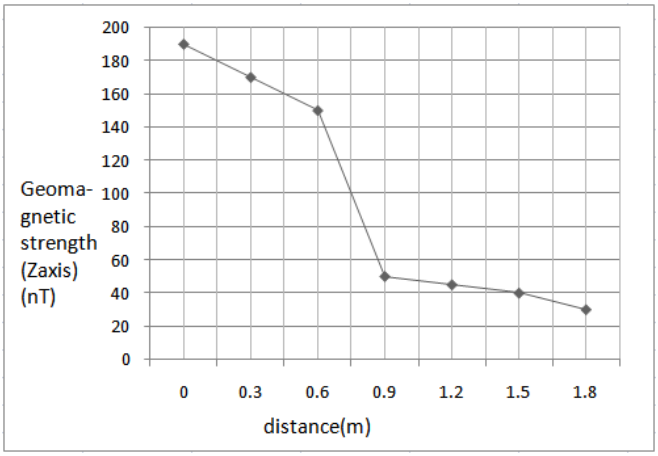

Fig.9 The relationship between geomagnetic strength and distance

According to the test results, when the distance> 1.1 m, the geomagnetic data fluctuation is less than 50nT, when the distance <1.1m, the data fluctuation amplitude gradually increases, when the distance equals to 0.1 meters, basic consistent with the normal data changes. The city road lane width is generally 3.5 meters, the node placed in the middle of the lane, the detection range is 1.8 meters, thus, the adjacent lane have not big influence on vehicle detection, just only cause a small fluctuation, through set the threshold , it can eliminate the interference.

4.2 System function test

After many tests, optimize system performance, and gradually improve the detection accuracy. Test on a variety of vehicle types, test results of traffic flow statistics is shown in Table 2.

Table 2. Traffic flow test results

test vehicle	actually passed vehicle	Test passed the vehicle	Accuracy
Electric vehicles	116	112	96.5%
Cars	82	80	97.5%
Suvs	78	79	98.7%

Choose the Suvs as the test vehicle, the speed test test results shown in Table 3.

Table 3. Speed test results

Number of tests	Actual vehicle speed	Detection vehicle speed	Accuracy
1	31.8	29.92	94.09%
2	35.2	33.61	95.48%
3	40.2	38.05	94.7%
4	50.4	52.32	96.33%
5	60.9	62.57	97.3%

5. Conclusion

The Vehicle detection system chooses the STM8L single-chip microcomputer as MCU , and combining with the 433MHz wireless module CC1101 and MAG3110 geomagnetic sensors, achieve road traffic in the vehicle speed detection and traffic flow statistics, after field testing, the system performance is verified.

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