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Monitoring Algorithm for Speed Information of Autonomous Vehicles Based on Magnetoresistive Sensor

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Abstract

Based on a magnetoresistive sensor, an algorithm for speed information monitoring of autonomous vehicles suitable for fewer target feature points is proposed. When using a magnetoresistive sensor on the road, the monitoring principle of the magnetoresistive sensor is that the magnetoresistive sensor generates a voltage signal and sends it to a signal processing module. In the signal processing module, the vehicles signal is compared with a threshold value to determine whether the vehicle is present. In the signal processing module, the vehicle signal is compared in the presence of the vehicle, and the node time synchronization technology is used to select the two-node autonomous vehicle speed information monitoring method. Then, the speed information of the autonomous vehicles in motion is monitored in real time. The vehicle speed information is sent to the upper node by using the single chip microcomputer. It is then sent to the coordinator module using ZigBee technology in the wireless sensor network. Finally, it is sent to the intelligent traffic monitoring center to achieve speed information monitoring of autonomous vehicles. The experimental results show that the accuracy rate of the autonomous vehicles' speed information monitored by the algorithm is above 97%, and the monitored energy consumption is only 13.5 J. This shows that the algorithm's monitoring accuracy and energy consumption have an advantage.

Keywords: magnetoresistive sensor; autonomous; vehicles; speed; information; monitoring algorithm.

1. Introduction

Transportation is the urban arterial system, the link between the various social and economic activities of the city, and the fundamental condition for the economic development of the city and even the country. Properly solving the traffic problems will directly affect the development of the national economy and the living standards of the people. Throughout the history of global economic development, reasonable transportation layout and planning can promote the economic development of the entire society, and vice versa, which seriously restricts the pace of social and economic progress [1].Intelligent transportation system, as the most direct and effective measure to alleviate urban traffic congestion and improve transportation efficiency, has become a hot spot in the field of transportation. Autonomous vehicles are a type of smart car, also known as a wheeled mobile robot, which relies mainly on the smart pilot (mainly computer system) in the car to achieve autonomous. Monitoring speed information is a prerequisite for obtaining traffic parameters [2], which provides real-time and reliable parameter basis for scientific dispatching and management of intelligent transportation system, and is the most basic and important part of the system.At present, the most widely used monitoring and research methods for speed information of autonomous vehicles are toroidal coil monitoring, video monitoring, microwave monitoring and infrared monitoring. Among these monitoring technologies, there are generally disadvantages such as high installation and maintenance costs, environmental conditions affected by use conditions, and low monitoring accuracy. In order to make up for the shortage of the monitoring algorithm for the speed information of traditional vehicles, the focus of research has shifted to the magnetoresistive sensor monitoring technology (AMR) with characteristics of low cost, low power consumption, easy networking and micro-volume [3].

At present, the mainstream monitoring algorithms for vehicles based on magnetoresistive sensors include fixed threshold algorithm, adaptive threshold algorithm, state machine monitoring algorithm, artificial neural network algorithm and support vector machine algorithm. These algorithms generally have problems such as baseline drift, fixed thresholds leading to reduced accuracy, and inability to accurately discriminate the departure of vehicles [4].The monitoring principle of magnetoresistive sensor: The distribution of the Earth's magnetic field is very limited in a very wide area (about several kilometers). A ferromagnetic object such as a car, whether it is moving or stationary, changes in the earth's magnetic field caused by

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its interference can be monitored by the magnetoresistive sensor.

There are two ways to monitor vehicles speed information. The first is a single-axis sensor that can be used to monitor the presence of vehicles. The other is to monitor the passage of vehicles [5]. Since different types of vehicles have different effects on the Earth's magnetic field when passing through, the output waveforms of the data acquisition system based on magnetoresistive sensors are also diverse.Accurate magnetic field information (intensity and direction of the magnetic field) can be obtained by using the appropriate magnetoresistive sensor and amplifier. The output waveform pattern of the data acquisition system is recognized by the single-chip microcomputer, which not only can judge the existence of the vehicles, but also can identify the vehicle type. That is, the presence of the vehicles, the direction and speed of the vehicles are determined by the two-axis sensor to obtain sufficient information.

The Earth's magnetic field strength is 500 to 600 m Gauss. When there is no large magnet object, the geomagnetic field in this area remains basically constant; when there is the large magnet object, the geomagnetic field of the area will change, and the magnetoresistive sensor can express the magnetic field changes before and after the disturbance in the form of voltage [6].The autonomous vehicle is a large magnet object. Therefore, when the magnetoresistive sensor is placed in the lane, the output signal of the magnetoresistive sensor can be analyzed to obtain traffic parameters such as traffic volume and vehicle speed of the current section. The monitoring algorithm for speed information of the existing autonomous vehicles has various drawbacks [7]. Therefore, designing a monitoring algorithm for speed information of autonomous vehicles with high reliability, low cost, high precision and low power consumption has become the primary task of developing the intelligent transportation system.

In recent years, intelligent transportation has been a research hotspot at home and abroad, especially autonomous vehicles. At present, scholars at home and abroad have made some progress in the monitoring of vehicles speed information [8].In 2012, AdiNurhadiyatna et al. proposed a new method for monitoring the speed of vehicles in real time from video. First, the principal components analysis method is used to identify the vehicles. The Kalman filter is used to track the past vehicles, and then the Euclidean distance method is used to estimate the speed of the vehicles. In 2012, Hou Liang et al. proposedan adaptive weighted average vehicle speed monitoring method based on a laser monitoring algorithm, which is processed according to the determined best performance monitor data to obtain the fusion value with the smallest error. The method has strong real-time performance and saves a large amount of data storage space, and has high practicability. In view of the target tracking algorithm based on SIFT and SURF features has the problems of poor real-time performance and large computational complexity, Meng Fanqing proposed an ORB-based moving target tracking method in 2015.The target is extracted from the ORB feature and matched between the frames, and then the extracted feature points are combined to complete the update and localization of the target feature. However, when there are fewer matching features or fewer target feature points, the accuracy of the algorithm is significantly reduced.Aiming at the defects of the above algorithm, the monitoring algorithm for speed information of autonomous vehicles based on magnetoresistive sensor is proposed.The magnetoresistive sensor is applied to the speed monitoring of autonomous vehicles, and the algorithm is applied to the intelligent transportation system. The system is used to monitor the autonomous vehicles' speed information, which is helpful for the further development of autonomous vehicles and the improvement of transportation efficiency.

2. Materials and methods

2.1. Monitoring principle of magnetoresistive sensor

In the magnetoresistance effect, when the magnetization direction inside the nickel-iron magnetic alloy is parallel to the external magnetic field direction, the resistance value of the nickel-iron magnetic alloy reaches the maximum, which is independent of the applied magnetic field strength [9].When there is a certain angle between the direction of the external magnetic field and the magnetization direction in the alloy, the resistance value of the nickel-iron magnetic alloy will decrease. When the direction of the external magnetic field is perpendicular to the magnetization direction in the alloy, the resistance value is the smallest, which is the well-known AMR anisotropic magnetoresistance effect. After a large number of experiments, the resistance value of the nickel-iron magnetic alloy is the angle function between the internal magnetization direction and the bias current direction [10], as shown in Figure 1 and formula (1).

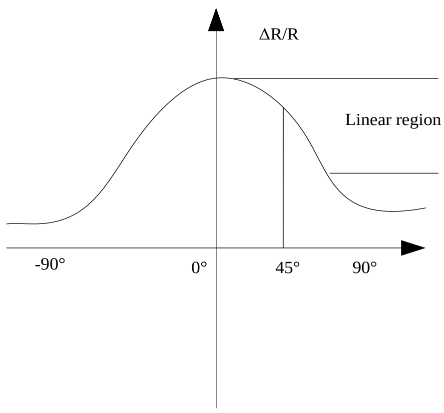

Figure 1. Principle of anisotropic magnetoresistance

It can be clearly seen from Fig. 1 that when the direction of the applied current is the same as the magnetization direction in the alloy ($\theta = 0°$), the resistance change rate of the alloy strip is maximized; when $\theta = 45°$, the resistance change rate of the alloy strip has a very good linear characteristic. Therefore, usually an internal bias magnetic field is applied so that the magnetoresistive sensor operates in the linear region.

$$R(\theta) = R_{(\perp)} \sin^2(\theta) + R_{II} \cos^2(\theta) = R_{\min} \sin^2(\theta) + R_{\max} \cos^2(\theta) \quad (1)$$

Where, $R_{(\perp)}$ is the resistance value when the bias current is perpendicular to the magnetization direction in the alloy, R_{II} is the resistance value when the bias current is parallel to the magnetization direction in the alloy, and θ is the angle between the direction of the bias current and the magnetization direction in the alloy.

The nickel-iron alloy film is deposited on a silicon wafer using a modern semiconductor process to form a resistor strip, and then four such resistors are spliced into a Wheatstone bridge. When the applied magnetic field changes, the Wheatstone bridge can convert it to a differential voltage and output it [11]. After the output signal of the Wheatstone bridge is amplified, filtered, and digital-analog converted, the magnetic field strength in the direction of the sensitive axis of the sensor can be measured. The wheat stone bridge magnetoresistive sensor working diagram is shown in Figure 2 .

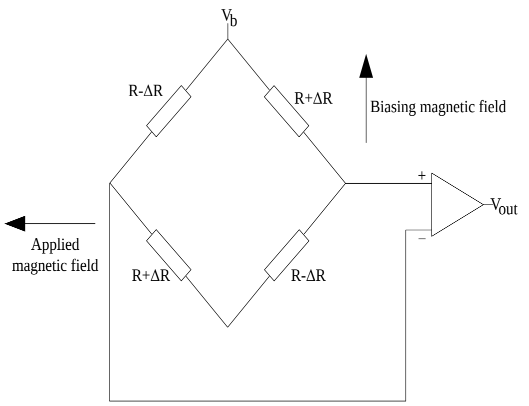

Figure 2. Wheatstone bridge magnetoresistive sensor works

In Figure 2, V_b is the power supply for the bridge. The magnetoresistive sensor is placed in a magnetic field. According to the anisotropic magnetoresistance effect, the resistance of the two resistors placed oppositely increases, while the resistance of the other two resistors decreases [12]. The differential voltage of the Wheatstone bridge is thus obtained.The Wheatstone bridge magnetoresistive sensor is shown in equation (2).

$$V_{out} = \frac{\Delta R}{R} g V_b \quad (2)$$

The output curve of the magnetoresistive sensor with the change of the external magnetic field is shown in Figure 3.

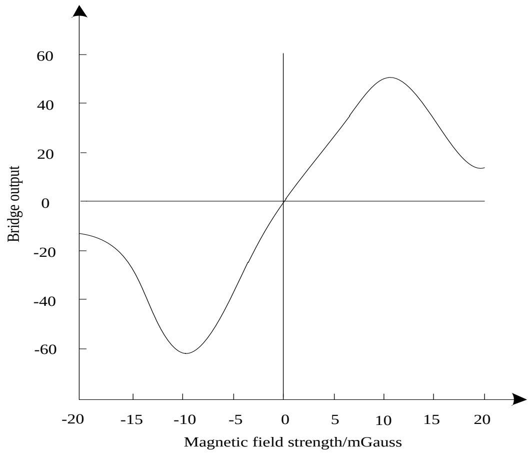

Figure 3. AMR magnetoresistive sensor changes with the change of the magnetic field

In a particular magnetic field, the bridge output is positively linearly related to the change in external magnetic field strength, and the Earth's magnetic field is just within this linearly correlated range. Therefore, the AMR magnetoresistive sensor is used to monitor changes in the local earth's magnetic field to obtain autonomous vehicles' speed information. This is very effective, and it is also an important basis for the use of magnetoresistive sensor.

The Earth is a natural magnet with a very weak magnetic field, about 0.5-0.6 Gauss. When a large magnet object enters the area covered by the Earth's magnetic field, the originally relatively stable geomagnetic field will be disturbed in a local range. These disturbances distort the magnetic field lines of the earth's magnetic field, and the disturbed earth's magnetic field is equivalent to the applied magnetic field that affects the resistance of the Wheatstone bridge [13].The Wheatstone bridge can convert this change of magnetic field into the differential voltage. Autonomous vehicles are large magnet materials. During driving, it will locally disturb the stable earth's magnetic field and distort its magnetic lines of force. At this time, if the magnetoresistive sensor is buried below the road surface where the magnetic field lines are distorted, the influence caused by the autonomous vehicles (the strength, direction, time, and the like of the earth's magnetic field) can be expressed in the form of voltage. After the voltage signal is conditioned and analyzed, the speed information of the autonomous vehicles can be extracted. Finally, the traffic parameters such as the speed information of the autonomous vehicles are transmitted to the collection center of the traffic information in real time by using the wireless network. This is the basic principle of the magnetoresistive sensor to monitor the speed information of autonomous vehicles.

The flow chart for monitoring the speed of autonomous vehicles using the magnetoresistive sensor is shown in Figure 4.

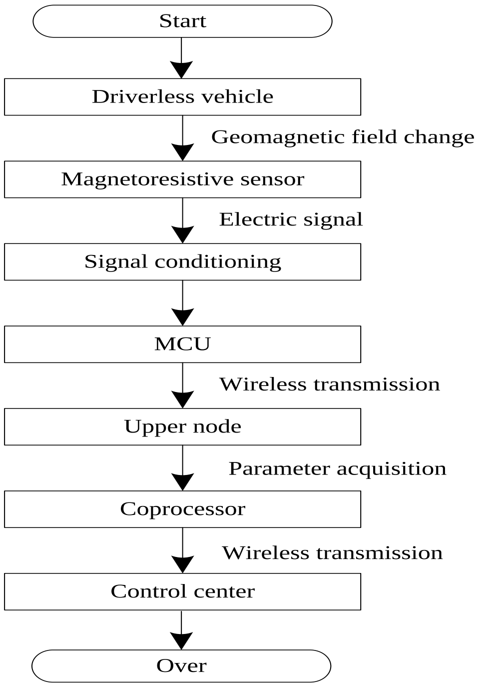

Figure 4. Magnetoresistive sensor monitoring speed information of driverless vehicles

As can be seen from Figure 4, when autonomous vehicles are driven on the road surface with the magnetoresistive sensors, the magnetoresistive sensor generates the voltage signal and sends it to the signal processing module. The vehicle speed information is sent to the upper node by using the single chip microcomputer. It is then sent to the coordinator module. Finally, it is sent to the intelligent traffic monitoring center to achieve speed information monitoring of autonomous vehicles.

When autonomous vehicles pass the road surface with the magnetoresistive sensor, the disturbance curve of the earth's magnetic field collected by the magnetoresistive sensor is shown in Figure 5.It can be seen from Figure 5 that autonomous vehicles have obvious regularity and variation characteristics on the earth's magnetic field during driving [14], so various parameters of road traffic can be obtained by analyzing the collected magnetic field curves.

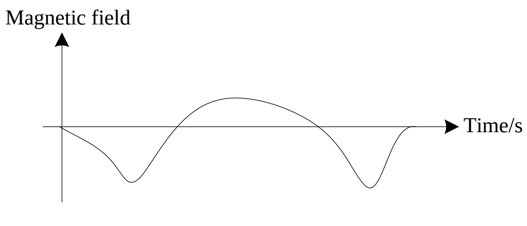

Figure 5. Earth's magnetic field curve disturbed by driverless vehicles

2.2. Monitoring algorithm for speed information

Currently, two intelligentoresistive sensor nodes are generally used in intelligent transportation systems to estimate the speed information of autonomous vehicles. Assuming that the distance between two magnetoresistive sensors is s, and the times of autonomous vehicles passing through two magnetoresistive sensors are t_1 and t_2, then the speed formula of autonomous vehicles can be obtained as follows:

$$v = s / \left(t_2 - t_1\right) \tag{3}$$

However, because the distance between the two magnetoresistive sensors is very close, and the autonomous vehicles are very fast when passing through two magnetoresistive sensors, the estimated speed is far from the actual situation which inclued friction, inertia, acceleration and deceleration [15]. Therefore, a series of measures to improve the accuracy of the algorithm are implemented, such as further analysis of signals.

This article uses two nodes to obtain the speed information of autonomous vehicles. Assuming that the signal frequency is the same in the detection range of the magnetoresistive sensor, the vehicle runs at a constant speed between the two magnetoresistive sensor nodes. Through the hardware setting [16], the access point performs time synchronization to nodes A and B at intervals, which can offset the clock skew. The monitoring model of the speed information of autonomous vehicles is shown as Figure 6.

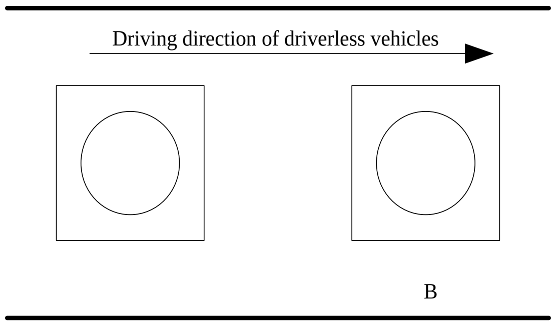

Figure 6. Unmanned vehicle speed information monitoring model

Assume that the length between the nodes of the magnetoresistive sensor is L_{AB}, the time of autonomous vehicles reaching the sensor nodes A and B is $t_{A,up}$ and $t_{B,up}$ respectively, and the time of autonomous vehicles leaving the nodes A and B respectively is $t_{A,\mathrm{down}}$ and $t_{B,\mathrm{down}}$, then the monitoring formula of the vehicle speed information v is as follows: :

$$\Delta t_{up} = t_{B,up} - t_{A,up} \tag{4}$$

$$\Delta t_{down} = t_{B,down} - t_{A,down} \tag{5}$$

$$v_{up} = L_{AB} / \Delta t_{up} \tag{6}$$

$$v_{down} = L_{AB} / \Delta t_{down} \tag{7}$$

$$v = \left(v_{up} + v_{down}\right) / 2 \tag{8}$$

The accuracy of the vehicle speed information obtained by the above method is poor. Different magnetoresistive sensors have different sensitivities, and it is determined that the time of arrival or departure of autonomous vehicles may be delayed and varied [17]. Digital filtering can also cause delays in time monitoring, so the sensitivity of the magnetoresistive sensor is introduced. Assume that the correction parameter of the autonomous vehicles arrival time is α, and the correction parameter of the departure time is β, then

$$\Delta t'_{up} = \Delta t_{up} - \alpha \quad (9)$$

$$\Delta t'_{down} = \Delta t_{down} - \beta \quad (10)$$

$$\begin{aligned} v'_{up} + v'_{down} &= L_{AB} / \Delta t'_{up} + L_{AB} / \Delta t'_{down} \\ &= \left[(\beta - \alpha) L_{AB} + \left(\Delta t_{up} - \Delta t_{down}\right) L_{AB}\right] / \left(\Delta t_{up} \Delta t_{down} + \beta \Delta t_{up} - \alpha \Delta t_{down} - \alpha\beta\right) \quad (11) \\ &\approx v_{up} + v_{down} \end{aligned}$$

The magnetoresistive sensor is different, and the correction parameters introduced should also be different. Here, the same correction parameters are used for the convenience of calculation, and α and β are extremely small. In order to reduce the complexity of the algorithm, an approximation method can be used, but the accuracy of the algorithm is also reduced. This algorithm is performed under the premise that the sensor nodes A and B receive signals at the same time. The introduction of node time synchronization technology makes the monitoring algorithm for speed information of autonomous vehicles more accurate.

The ZigBee technology is introduced into a wireless sensor network, which consists of the access points and nodes of themagnetoresistive sensor.All control commands can be communicated directly to each sensor node by the access point [18]. Time synchronization means that the access point adjusts the time of the sensor node to the standard time at intervals. Only two sensor nodes are time synchronized, and the collected signals of the sensors can be analyzed and calculated. During the process of sending a message to each sensor node by the access point, if the current time of the access point is t_{AP}, the time of each node can be synchronized to $t_{AP} + \Delta$. (Transmission distance and network transmission delay can be ignored). Δ is the sum of the time that the message is transmitted at the access point and the time that the node receives the message. The time synchronization model of the wireless sensor is shown in Figure 7.

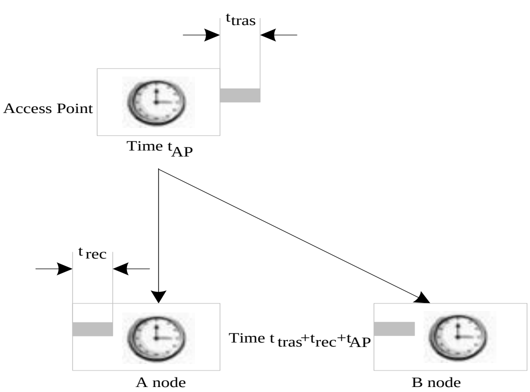

Figure 7. Wireless sensor time synchronization model

The vehicles signal is compared to a threshold to determine the presence of vehicles. The two-node monitoring method is selected to monitor the speed information of the autonomous vehicles [19], and the flowchart of the monitoring algorithm for speed information of autonomous vehicles based on magnetoresistive sensors is shown in Figure 8 and Figure 9.Figure 8 can determine the presence of autonomous vehicles and then monitor the speed information of autonomous vehicles by Figure 9.

As can be seen from Figure 8, the specific process for determining the existence of autonomous vehicles is as follows: After receiving the monitoring signal of the autonomous vehicles, the magnetoresistive sensor processes the signal through the moving average filtering process. Then, the threshold is updated and the threshold is initialized, and the signal to be monitored is divided into a vehicle state and a carless state by using a threshold. After the state is distinguished, the new threshold is calculated, and the new threshold is determined to be different from the current threshold. When the threshold difference is too large, the step of updating the threshold is returned; when the difference between the new threshold and the original threshold is sufficiently small, the state of the autonomous vehicles is judged by the state machine. When the current state is that there is a car, the result of the discrimination is output [20], and whether to continue monitoring is required. If it is necessary to continue monitoring, the new autonomous vehicles signal is read again, and if it is not necessary to continue monitoring, the process ends.

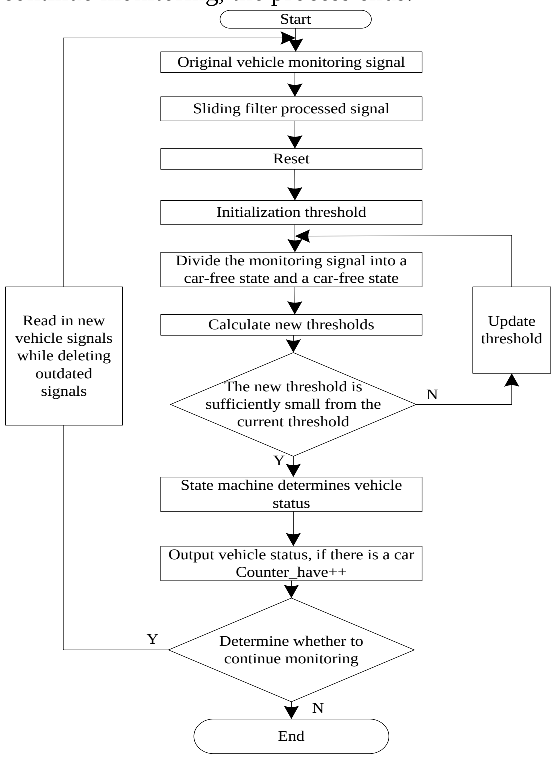

Figure 8. Unmanned vehicle presence algorithm

After determining the existence of autonomous vehicles, the vehicle speed information of the autonomous vehicles is monitored by Figure 9.

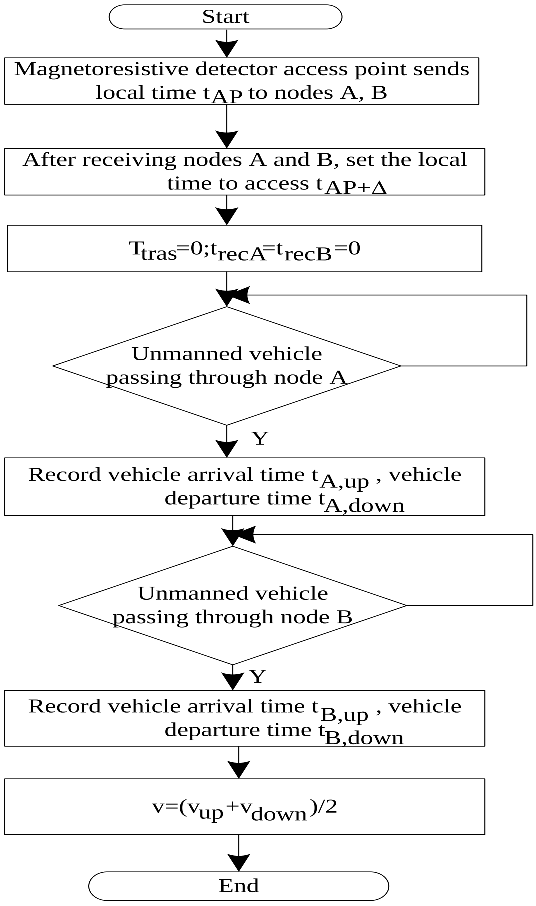

Figure 9. Sensor information monitoring algorithm for unmanned vehicles based on magnetoresistive sensor

As shown in Figure 9, after determining that autonomous vehicles exist, the access point sends the local time to the monitoring nodes A and B. After the nodes A and B receive the local time, the local time is set to access $t_{AP+\Delta}$. Let $T_{tras}=0; t_{recA}=t_{recB}=0$, when the vehicles pass the node A, record the arrival time and the departure time of the vehicles. When the autonomous vehicles pass the node B, the arrival time and the departure time of the vehicles are recorded. The speed information of the autonomous vehicles is obtained by the formula $v=\left(v_{up}+v_{down}\right)/2$.

3. Results

In order to verify the effectiveness of the monitoring algorithm for speed information of autonomous vehicles based on magnetoresistive sensor, experiments were conducted on a two-way lane in a city. The algorithm is applied to the intelligent traffic monitoring system. The monitoring system includes two monitoring nodes, one upper node, one coordinator, one PC, and one 4G router.

In order to make the monitoring results more accurate, the buried depth, monitoring radius (sensitivity) and node spacing of the monitoring nodes are tested before the formal testing. When the parameters meet the best standards for system testing, the vehicle speed information monitoring of autonomous vehicles begins. The monitoring node sends the monitored speed information to the upper node of the roadside by wireless, and the data processed by the upper node is packaged by the coordinator and transmitted to the PC through the RS232 MCU.

The width of the city lane is generally 3.5-3.75 meters, and the monitoring node consisting of magnetoresistive sensors is buried in the center line position of the single lane. The monitoring node has a monitoring radius of 1.8 meters, which can just detect the geomagnetic signal after monitoring the vehicle’s interference in the lane. The optimal buried depth and separation distance of the monitoring node are determined by monitoring the presence and the speed information of the autonomous vehicles.

100 autonomous vehicles will be monitored by two monitoring nodes on the road surface. When the monitoring nodes are buried at different depths, the monitoring results of autonomous vehicles are shown in Table 1.

Table 1. Statistics of buried depth monitoring results of monitoring nodes

Node burying depth/cm	Monitor vehicle passing quantity/n	Actual number of vehicles passing/n	Accuracy/%
0	105	100	95
10	103	100	97
20	100	100	100
30	98	100	98
40	94	100	94
50	92	100	92

The experimental data in Table 1 shows that when the buried depth of the monitoring node is 0 cm and 10 cm, the number of autonomous vehicles monitored by the algorithm is higher than the number of autonomous vehicles actually passed, and the traffic flow monitoring accuracy is low. The reason may be that the monitoring nodes are too exposed to the road surface under the sensitivity set before the experiment, and the passing vehicles of the adjacent lanes are also monitored. When the buried depth of the monitoring node is 40 cm and 50 cm, the number of autonomous vehicles monitored by the algorithm is lower than the number of autonomous vehicles actually passed, and the traffic flow monitoring accuracy is also low. The reason may be that the monitoring node is buried too deeply under the sensitivity set beforehand, and eventually the autonomous vehicles in the monitoring lane are missed.When the buried depth of the monitoring node is 20 cm and 30 cm, the autonomous traffic flow rate monitored by the algorithm is relatively high. It can be seen that the buried depth of the magnetoresistive monitoring node has the great relationship with the setting of its sensitivity. In order to make the monitoring node anti-theft function and easy to install, when the monitoring radius is set to 1.8 m, the optimal installation depth is 20 cm-30 cm.

Autonomous vehicles will pass at a speed of 60 km/h at different distances of the monitoring nodes. In this case, the speed information of autonomous vehicles is shown in Table 2.

Table 2. Monitoring results of distances of different monitoring nodes

Monitoring node spacing/m	Monitoring speed information results/km/h	Actual speed information result/km/h	Accuracy/%
2.5	55.18	60	91.96
3	56.05	60	93.42
3.5	57.18	60	95.3
4	58.31	60	97.18
4.5	57.35	60	95.58
5	56.81	60	94.68
5.5	55.04	60	91.73
6	54.18	60	90.3

It can be seen from Table 2 that when the distance between two monitoring nodes is 4 meters, the accuracy of the speed information monitored by the algorithm is the highest.Therefore, when using the algorithm of this paper to monitor the speed information of autonomous vehicles, the monitoring node is set to have the monitoring radius of 1.8 m, the buried depth of 20 cm, and the distance of 4 m between the two monitoring nodes.

The algorithm of this paper is used to monitor the speed information of autonomous vehicles. The test installation diagram is shown in Figure 10.

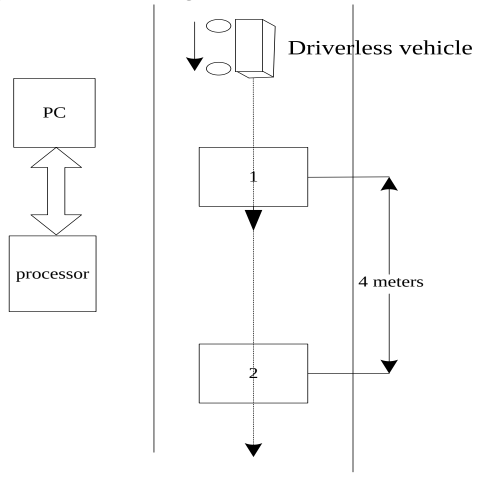

Figure 10. Experimental installation diagram

When the monitoring radius of the node is 1.8 m, the buried depth is 20 cm, and the distance between the two monitoring nodes is 4 m, the traffic parameters such as traffic flow, speed and time occupancy rate are counted, and the monitoring result is uploaded to the PC through the RS232 single-chip (once every minute).

In order to make the monitoring results accurate and reliable, the algorithm is used to carry out 5 tests in a number of time periods of the road. The monitored traffic flow is shown in Table 3.

Table 3. Traffic flow monitoring results

Number of experiments	Actual traffic flow/n	Monitor traffic/n	Accuracy/%
1	105	107	98.13
2	55	56	98.21
3	75	78	98.34
4	34	35	97.14
5	21	21	100

The time occupancy rate, also known as the lane occupancy rate, is an important parameter reflecting the traffic situation. The time occupancy rate refers to the ratio of the time taken by the vehicles through the cross section of the monitoring node to the statistical time during the statistical time (the experimental set time is 60 s).Traffic flow can reflect traffic conditions. The time occupancy rate reflects the intensity of the vehicles on the road from a microscopic perspective. It is the most direct response indicator of congestion. The time occupancy rate measured by the algorithm of this paper is shown in Table 4.

Table 4. Time occupancy monitoring results

Number of experiments	Actual time share/%	Monitoring time share results /%	Accuracy/%
1	73.5	74.8	98.26
2	52.1	53.4	97.57
3	66.8	64.5	96.43
4	25.9	26.7	97
5	32.4	31.5	97.14

Table 3 and Table 4 show that the accuracy of the algorithm can be as high as 97% when monitoring the traffic volume of autonomous vehicles. The algorithm of this paper is used to monitor the time occupation rate of autonomous vehicles, and the accuracy rate can be as high as 96% or more. It has very good dynamic monitoring effect, which shows that the algorithm can effectively reduce the complexity of the algorithm and improve the monitoring accuracy. It can be widely used in intelligent traffic monitoring systems.

In the traffic flow passed above, an autonomous vehicle is randomly selected. In the five experiments, the algorithm is used to monitor the speed information of the autonomous vehicles. The results are shown in Table 5.

Table 5. Vehicle speed monitoring results

Number of experiments	Actual speed of the vehicle/km/h	This algorithm monitors the speed/km/h	Accuracy/%
1	51.84	52.04	99.62
2	31.58	32.11	98.35
3	42.61	42.23	99.11
4	59.54	60.47	98.46
5	36.54	36.34	99.45

In the five experiments, the accuracy of the speed information of autonomous vehicles monitored by the algorithm is as high as 98%, which indicates that the speed information of the autonomous vehicles collected by the algorithm is more accurate.

If autonomous vehicles travel at a constant speed in the range of 0-80 km/h, the algorithm is used to monitor the situation of autonomous vehicles at different speeds. The monitoring results are shown in Table 6.The algorithm is compared to the video monitoring algorithm and the laser monitoring algorithm, and the results are listed in table 7 and table 8.

Table 6. Algorithm monitoring results

Serial number	Actual speed/km/h	Monitoring speed information/km/h	Accuracy /%
1	10	9.7	97
2	20	19.6	98
3	30	30.8	98.34
4	40	39.1	97.75
5	50	51.1	97.8
6	60	60.4	99.34
7	70	71.3	98.81
8	80	78.8	98.5

Table 7. the video monitoring algorithm monitoring results

Serial number	Actual speed/km/h	Monitoring speed information/km/h	Accuracy /%
1	10	9.15	88.25
2	20	16.25	92.35
3	30	21.96	91.25
4	40	27.96	92.46
5	50	35.97	89.34
6	60	48.36	91.20
7	70	57.26	92.37
8	80	61.87	91.58

Table 8. the laser monitoring algorithm monitoring results

Serial number	Actual speed/km/h	Monitoring speed information/km/h	Accuracy /%
1	10	8.9	80.05
2	20	18.5	89.58
3	30	24.6	87.69
4	40	30.9	89.25
5	50	41.8	82.48
6	60	53.8	91.20
7	70	60.8	89.25
8	80	71.6	90.25

It can be seen from Table 6,7and 8 that when the driving speed of autonomous vehicles is 0-80 km/h, the accuracy of monitoring the speed information of autonomous vehicles is above 97%, and the accuracy of the video monitoring algorithm is above 88%, and the accuracy of the laser monitoring algorithm is above 80%, which indicates that the algorithm can meet the speed information monitoring of autonomous vehicles.

When the vehicle speed is 0-80 km/h, the energy consumption of the autonomous vehicles monitored by this algorithm,and the algorithm is compared to the video monitoring algorithm and the laser monitoring algorithm, and the result wereshown in Figure 11.

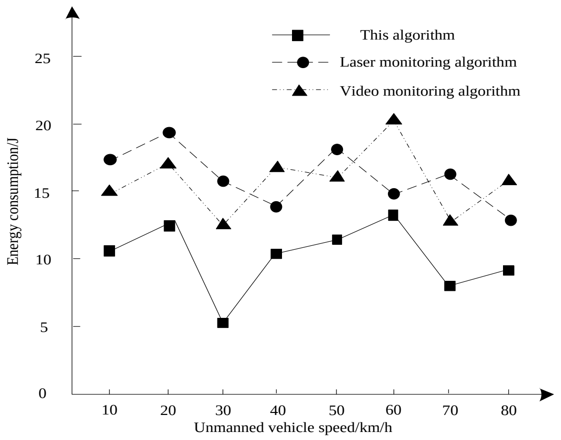

Figure 11. Comparison of energy consumption of three algorithms

It can be seen from Fig. 11 that when the vehicle speed is 0-80km/h, the energy consumption of the autonomous vehicles using the algorithm of this paper is only 13.5 J. The energy consumption of the video monitoring algorithm can reach up to 20.8 J, and the energy consumption of the laser monitoring algorithm can reach up to 19.7 J.It can be seen that the monitoring energy consumption using the algorithm of this paper is significantly lower than the energy consumption of the video monitoring algorithm and the laser monitoring algorithm. This verifies that the algorithm proposed in this paper has the advantage of low energy consumption when monitoring the speed information of autonomous vehicles.

Through the performance test of the monitoring algorithm for speed information of autonomous vehicles based on the magnetoresistive sensor, the algorithm can effectively monitor the traffic volume, time occupancy rate and speed information of autonomous vehicles. It can achieve accurate acquisition and transmission of speed information.

4. Discussion

There are widespread problems, such as urban traffic congestion, frequent traffic accidents, and exhaust pollution at home and abroad. Intelligent transportation systems can solve traffic problems such as traffic congestion, inconvenient traffic management, traffic accidents, and transportation. The intelligent traffic monitoring system can accurately provide traffic flow information to the traffic control department in real time, which provides a basis for the traffic control department to carry out work. The monitoring of speed information of autonomous vehicles is a core component of the intelligent traffic monitoring system. Through the intelligent traffic monitoring system, the vehicle information is collected and further processed, such as calculating autonomous vehicles density, judging the direction of vehicles, and monitoring vehicle speed information. In the end, the monitoring system for road restrictions and the road toll system are intelligent. Starting from China's basic national conditions with large traffic volume and complicated roads, the intelligent traffic monitoring system should have the advantages of energy saving, simple, practical, low cost and high monitoring accuracy. The AMR magnetoresistive sensor is small in size, low in cost, high in sensitivity, and long in use. Zigbee technology is a low-cost, simple, short-distance, low-energy wireless communication technology that can be applied to network data transmission. Therefore, this paper combines AMR magnetoresistive sensor monitoring technology and Zigbee technology to achieve speed information monitoring of autonomous vehicles. In the large environment of intelligent traffic monitoring system, the monitoring of speed information of autonomous vehicles is the front end of traffic parameter acquisition. Its stability and precision directly determine whether the intelligent traffic monitoring system can play the role of scientific management. The experiment proves that the algorithm has the advantages of high precision, low power consumption and low cost, and it has a good application prospect. The specific research contents and innovations of this paper are as follows:

1. By analyzing the advantages and disadvantages of the existing monitoring algorithm for the speed information of autonomous vehicles, the advantages of the monitoring algorithm for speed information of autonomous vehicles based on the magnetoresistive sensor are clarified, and the monitoring principle of the magnetoresistive sensor is elaborated.
2. The two-node monitoring algorithm for speed information of autonomous vehicles is proposed, which successfully solves the problem that the monitoring time is difficult to synchronize and the accuracy of the vehicle speed monitoring is low, and the high-precision monitoring of autonomous vehicles' speed information is realized.
3. When autonomous vehicles pass, the geomagnetic field is disturbed and produces a strong disturbance signal, which is completely different from the background signal. So set a threshold to monitor the presence of vehicles. Because the background signal drifts as a whole, the dynamic threshold algorithm is employed. The state machine algorithm is used in the specific judgment to improve the robustness of the algorithm and record the autonomous vehicles' arrival and departure time to estimate the vehicle speed. The clock synchronization two-node speed estimation algorithm is proposed to improve the accuracy of the algorithm and verify the feasibility of the algorithm.
4. The autonomous vehicles' speed monitoring algorithm is applied to the actual road section, and the monitoring performance and accuracy of the algorithm are tested repeatedly.Through a large number of experiments and data analysis, the optimal working environment of the monitoring algorithm for speed information of autonomous vehicles based on magnetoresistive sensors was determined. The experimental results also show that the algorithm has higher monitoring accuracy and lower power consumption, and achieves the expected goal.

During the monitoring of the AMR magnetoresistive sensor, the influence of the aging of the AMR magnetoresistive sensor on the monitoring accuracy was not considered. In the design of the monitoring algorithm for the autonomous vehicles' speed information, the signal characteristics are not used to obtain more traffic flow information, but the multi-node data is used to improve the monitoring accuracy of the algorithm. Further research work is as follows:

1. In the autonomous vehicles' monitoring algorithm, the autonomous vehicles have little disturbance to the earth's magnetic field when the slow speed passes, and the output signal of the magnetoresistive sensor does not fluctuate significantly. However, the algorithm designed now is based on the comparison between the strong fluctuation signal and the threshold signal, so it is likely to cause the leakage monitoring phenomenon. Autonomous vehicles have been passing the sensor for too long, and signal interruption may occur. It is easy to monitor into two cars, so further improvements to the algorithm are needed.
2. In the algorithm of autonomous vehicles' speed, it is difficult to achieve sensor node time synchronization. Because of various factors, such as filtering processing, sensor sensitivity, etc., it is also difficult to accurately determine the arrival and departure time of autonomous vehicles, so the algorithm needs to be improved. The magnet material inside the autonomous vehicles determines the peak distribution. During the magnetoresistive sensor performance test, the vehicles pass the sensor from directly above. The time of the vehicles passing through the magnetoresistive sensor can be judged according to the position of the peak, and the speed of the autonomous vehicles can be further estimated. This algorithm can be implemented with a single node, and the signal processing requirements are improved.
3. Conduct large-scale, multi-lane monitoring research. The research in this paper is limited to a certain cross section of the road, and the intelligent traffic monitoring system collects traffic parameters from a wide range and grasps the traffic conditions. Therefore, the next step should be to arrange the monitoring nodes to multiple sections and intersections to realize networked information collection and processing.
4. Study a variety of monitoring techniques. Each monitoring technology of vehicles has its advantages and disadvantages. The development trend of intelligent traffic monitoring system is that multiple monitoring technologies are connected in parallel to realize the integration of monitoring data, in order to achieve all-weather, high-precision monitoring. In particular, the combination of video surveillance technology and magnetoresistive sensor enhances the monitoring efficiency of intelligent traffic monitoring systems.
5. Networking research on subsystems of intelligent transportation. The monitoring of autonomous vehicles speed information is only a subsystem of data acquisition in the intelligent traffic monitoring system. Its function is to provide the parameter basis for the intelligent traffic monitoring system, so that the control center of the intelligent traffic monitoring system issues corresponding instructions. Therefore, it needs to be networked with other subsystems of the intelligent traffic monitoring system to form the coordinated network, so as to truly reflect the value and advantages of the intelligent traffic monitoring system.

5. Conclusions

Monitoring algorithm for speed information of autonomous vehicles based on magnetoresistive sensor is proposed in this paper.The AMR magnetoresistive sensor is applied to the monitoring algorithm for the speed information of the autonomous vehicles. The algorithm is not affected by the weather, and has high monitoring accuracy, stable reliability and good scalability, which greatly prolongs the service life of the magnetoresistive sensor. The magnetoresistive sensor has the advantages of small size, convenient installation, small damage to the road surface, and easy maintenance. If the magnetoresistive sensor is installed on a large scale in practical applications, a large number of accurate autonomous vehicles speed information can be collected when monitoring by the algorithm proposed in this paper. This provides basic data support for the analysis of micro and macro aspects of road traffic, the study of traffic flow characteristics, and the prevention of road traffic accidents.

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