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Research of ETC with GPS/BDS High-speed Charging and Navigation System

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Abstract: Aiming at the disadvantages of ETC electronic charging compared with traditional manual charging, a ETC charging method based on GPS/BDS combined system is proposed. In view of the vehicle in the process of driving will be due to a variety of reasons in the road through the gantry record omission and other circumstances, resulting in the exit billing failed to charge according to the actual driving path; Because ETC electronic toll collection system is implemented by network technology under the environment of information technology, in the case of network technology problems, ETC electronic toll collection system will stop working phenomenon, thus affecting the efficiency of the highway; For vehicles on business trips, the ETC channel is cumbersome to charge and reimburse. At present, manual toll channels are still used for high-speed bus trips. At present, there are still some technical loopholes in the ETC electronic charging system. Criminals steal or rub others' ETC cards. When the vehicle enters the ETC sensor area and opens the railing, they will rub others' ETC by following closely or changing lanes instantly, which will affect the interests of the owners and lead to safety accidents and other problems. The GPS/BDS chip is installed on the ETC device. According to the real-time path information and preset navigation route of the charging vehicle, the precise positioning of the charging vehicle is realized to achieve accurate charging. According to the observed vehicle density of road conditions, select the path that is not easy to jam vehicles to achieve accurate navigation; Judge whether the real-time location information of the vehicle is in the target navigation route, so that when the vehicle takes a wrong route, it can quickly return to the correct route and reduce the high-speed charge.

Keywords: GPS/BDS, ETC, Accurate Charges, Precision Navigation

1. Introduction

The ETC charging method, device, computer equipment and storage media based on GPS/BDS combined system provided in this paper, calculate the real-time path information of the vehicle to be charged in real time to achieve accurate positioning of the vehicle to be charged and accurate charging. Provide accurate navigation route information to achieve fast and accurate navigation of vehicles.

2. ETC Electronic Toll Collection System Problems

ETC electronic toll collection system has obvious advantages, but due to some factors, ETC electronic toll collection system has disadvantages, including the following main problems:

1. In the current information technology, the ETC system calculation buckle time-consuming, is based on import and export and passing the gantry rate in the process of britains, however, due to various causes in the process of vehicle road passes through the gantry records there are

omissions, ETC., leading to failed to according to the actual billing at the exit path to collect fees, Therefore, the same path accounting is different.

2. As the ETC electronic toll collection system is implemented by network technology in the information technology environment, the ETC electronic toll collection system will stop working in the case of network technology problems, thus affecting the traffic efficiency of expressways;
3. Vehicles on business trips go through ETC channel, so the charging and reimbursement process is complicated. At present, manual toll channels are still used for high-speed bus trips;
4. At present, there are some technical loopholes in the ETC electronic charging system. Criminals steal or rub others' ETC cards.

Therefore, a new ETC charging method is proposed to solve the above problems [1-5].

3. GPS/BDS Actual Dynamic Positioning Principle

The calculation of GPS/BDS dynamic absolute positioning is based on pseudo distance measurement. As shown in Equation (1)

$$t_b - t_a = \tau = \tilde{\rho} / c \tag{1}$$

When the satellite signal transmitted is δt_a, the correction coefficient of the satellite clock is δt_b; when the receiver receives the signal, formula (2) can be derived.

$$\begin{cases} t_a + \delta t_a = \tau_a \\ t_b + \delta t_b = \tau_b \end{cases} \tag{2}$$

Formula (2) can be substituted into Formula (1):

$$\frac{1}{c}\tilde{\rho} = t_b - t_a = \tau_b - \tau_a + \delta t_a - \delta t_b \tag{3}$$

Considering that the ionosphere and troposphere are separated between the satellite and the ground aircraft station, the geometric distance ρ between the Beidou satellite and the receiver can be obtained by combining the ionospheric refraction correction coefficient $\delta\rho_{ion}$ and tropospheric refraction correction $\delta\rho_{trop}$:

$$\rho = c(\tau_b - \tau_a) + \delta\rho_{ion} + \delta\rho_{trop} \tag{4}$$

Thus, from Equations (4) and (3), the relation between geometric distance ρ and pseudodistance $\tilde{\rho}$ can be obtained:

$$\rho = \tilde{\rho} + \delta\rho_{ion} + \delta\rho_{trop} - c\delta t_a + c\delta t_b \tag{5}$$

It is assumed that the ionospheric and tropospheric refraction correction coefficients can be accurately measured;

So we have the equation $\rho = \tilde{\rho}$. And the coordinates of satellite (X^j, Y^j, Z^j) and receiver (X, Y, Z) are related as follows:

$$\rho = \sqrt{(X^j - X)^2 + (Y^j - Y)^2 + (Z^j - Z)^2} \tag{6}$$

Since the satellite navigation message information contains the coordinate position of the satellite, there are three unknowns in Equation (6). If the user measures the pseudo-distance of three satellites at the same time, the receiver position (X, Y, Z) can be solved.

The mathematical model of pseudometric legal position can be expressed as:

$$\rho^j = \tilde{\rho}^j + (\delta\rho^j)_{ion} + (\delta\rho^j)_{trop} - c\delta t^j + c\delta t_b \quad (j = 1, 2, 3, 4, ...) \tag{7}$$

Where, δt^j represents the clock correction number of the J satellite at the moment of signal transmission, ρ^j which can be calculated according to the coefficient given in the satellite navigation message; ρ^j is the geometric distance between the satellite station and the J satellite, according to Equation (6):

$$\rho^j = \sqrt{(X^j - X)^2 + (Y^j - Y)^2 + (Z^j - Z)^2} \tag{8}$$

According to Equation (5), the observation equation of the pseudo-distance of the measurement code is:

$$\tilde{\rho}^j = \rho^j - (\delta\rho^j)_{ion} - (\delta\rho^j)_{trop} + c\delta t^j - c\delta t_b \tag{9}$$

If the correction provided by the navigation message and its correction model are used to correct the above pseudo-range observations $\tilde{\rho}^j$, and the following formula is obtained:

$$\tilde{\rho}^j = \tilde{\rho}^j + (\delta\rho^j)_{ion} + (\delta\rho^j)_{trop} - c\delta t^j \tag{10}$$

Substituting Equation (9) into Equation (10), we can get:

$$\tilde{\rho}^j = \rho^j - c\delta t_b \tag{11}$$

Where, ρ^j is the geometric distance between the receiver and the satellite, and the expression is:

$$\rho^j = \sqrt{(X^j - X)^2 + (Y^j - Y)^2 + (Z^j - Z)^2} \tag{12}$$

After linearization of (12), the following equation can be obtained:

$$\tilde{\rho}^j = \rho_0{}^j - l^j\delta X - m^j\delta Y - n_0^j\delta Z - c\delta t_b \tag{13}$$

If j satellites are observed synchronously by station I at epoch t (j= 1, 2, 3, 4... N), can be a pseudo-distance observation system composed of N equations:

$$\begin{cases} \tilde{\rho}_i^{1'} = \rho_{i_0}^1 - l^1\delta X - m_i^1\delta Y - n_i^1\delta Z - c\delta t_b \\ \tilde{\rho}_i^{2'} = \rho_{i_0}^2 - l^2\delta X - m_i^2\delta Y - n_i^2\delta Z - c\delta t_b \\ \vdots \\ \tilde{\rho}_i^{n'} = \rho_{i_0}^n - l^n\delta X - m_i^n\delta Y - n_i^n\delta Z - c\delta t_b \end{cases} \tag{14}$$

When the number of equations is greater than 4 (i.e. more than 4 observed satellites), the three-dimensional geocentric coordinates of point locations are solved according to the least square principle, namely:

$$\begin{bmatrix} V_i^1 \\ V_i^2 \\ \vdots \\ V_i^n \end{bmatrix} = -\begin{bmatrix} l_i^1 m_i^1 n_i^1 - c \\ l_i^2 m_i^2 n_i^2 - c \\ \vdots \\ l_i^n m_i^n n_i^n - c \end{bmatrix} \begin{bmatrix} \delta X \\ \delta Y \\ \delta Z \\ \delta t_b \end{bmatrix} + \begin{bmatrix} \rho_{i_0}^1 - \tilde{\rho}_i^{1'} \\ \rho_{i_0}^2 - \tilde{\rho}_i^{2'} \\ \vdots \\ \rho_{i_0}^n - \tilde{\rho}_i^{n'} \end{bmatrix} \tag{15}$$

The matrix notation can be expressed as follows:

$$V_i = A\delta X + L \tag{16}$$

The least square method can be used to obtain:

$$\delta X = -(A^T A)^{-1} A^T L \tag{17}$$

Thus, the three-dimensional coordinates of the fixed point can be obtained:

$$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} = \begin{bmatrix} X_{i0} \\ Y_{i0} \\ Z_{i0} \end{bmatrix} + \begin{bmatrix} \delta X_i \\ \delta Y_i \\ \delta Z_i \end{bmatrix} \tag{18}$$

i_0 is the initial coordinate value, the initial value of the coordinate point is the coordinate value of the previous moment, the exact value can be obtained by the iterative algorithm [6-9].

4. Design of GPS/BDS Combined ETC Charging System

In order to solve one or more of the above technical problems, the main technical solutions adopted in this paper are:

On the first hand, it provides a ETC charging method based on GPS/BDS combined system, which includes the following steps:

(1) Receive the start charging request sent by the terminal device, including the basic information of the vehicle to be charged;

(2) Calculate the real-time path information of vehicles to be charged based on GPS/BDS combined system;

(3) Receive the charging stop request sent by the terminal device and extract all the charging point information included in the path information;

Calculate and obtain the payment bill of the vehicle to be charged according to the charging point information, basic information and preset charging rules for bank settlement.

Based on GPS/BDS combined system, real-time acquisition of the real-time location information of the vehicle to be charged includes:

Based on GPS/BDS combined system and GNSS high-precision positioning technology, the real-time location information of the vehicle to be charged is obtained in real time, and the real-time path information of the vehicle to be charged is generated according to the real-time location information.

Further, based on GPS/BDS combined system, real-time calculation of real-time path information of vehicles to be charged includes:

When the vehicle to be charged is running, it sends the transaction information to the road-side device and receives the response information returned by the road-side device based on the transaction information, including the charging point information.

Further, according to the charging point information, basic information and preset charging rules, the payment bill of the vehicle to be charged is calculated and obtained, including:

Determine all toll roads contained in real-time path information according to charging point information;

Matching the corresponding target charging rule in the preset charging rule based on the charging section and basic information;

Calculate and obtain the payment bill of the vehicle to be charged according to the toll road section and the target charging rule.

According to the starting point information and the end point information, generate the preset navigation route of the vehicle to be charged;

Based on GPS/BDS integrated system, the road condition information on the preset navigation route can be acquired in real time.

The preset navigation route is adjusted in real time according to the road condition information, and the target navigation route is generated for navigation to the vehicle to be charged.

Obtain the real-time location information of the vehicle to be charged and judge whether the real-time location information is in the target navigation route. If not, obtain the information of the nearest underground passage, which is used for the vehicle to be charged to return.

GPS/BDS combined system includes a compact combined model of GPS and BDS-3.

Second, it provides a ETC charging device based on

GPS/BDS combined system, including:

(1) Data receiving module, which starts charging after receiving the request from the terminal device, including the basic information of the vehicle to be charged;

(2) Path generation module, used for real-time calculation of the real-time path information of the vehicle to be charged based on GPS/BDS combined system;

(3) Information extraction module, used to receive the charging stop request sent by the terminal device and extract all the charging point information included in the path information;

(4) The fee calculation module is used to calculate and obtain the fees to be paid of the vehicles to be charged according to the charging point information, basic information and preset charging rules for bank settlement.

Third, the computer equipment is provided, which is realized when the processor executes the computer program:

(1) Receive the start charging request sent by the terminal device, including the basic information of the vehicle to be charged;

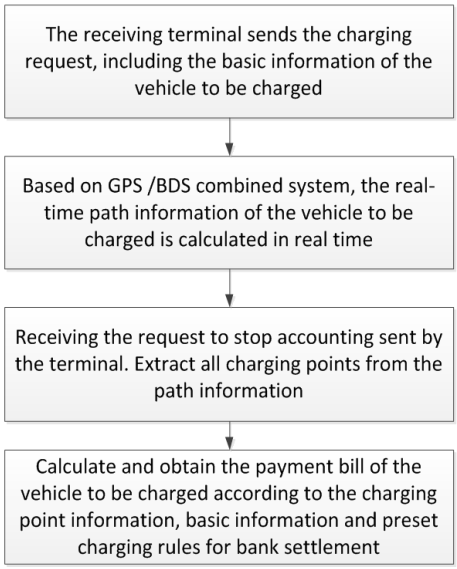

Figure 1. *Flow chart of charging method based on GPS/BDS combined system ETC.*

(2) Calculate the real-time path information of vehicles to be charged based on GPS/BDS combined system;

(3) Receive the charging stop request sent by the terminal device and extract all the charging point information included in the path information;

(4) Calculate and obtain the payment bill of the vehicle to be charged according to the charging point information, basic information and preset charging rules for bank settlement.

Figure 1 is a flow chart of ETC charging method based on GPS/BDS combined system based on an example embodiment, as shown in Figure 1. The method consists of the following steps:

1. When the vehicle to be charged enters the induction area at the entrance of the expressway, the vehicle to be charged automatically sends the start charging request to the ETC charging device on the ETC lane of the toll station through the terminal device set on the vehicle. The start charging request includes the basic information of the vehicle to be charged, such as license plate number, model and owner information. As a better example, when implemented, the initiation of billing requests could be transmitted through microwave dedicated short-range communications between an on-board electronic tag mounted on the windshield of the vehicle and a microwave antenna on the ETC lane at the toll booth.
2. Real-time path information of the vehicle to be charged is calculated based on GPS/BDS combined system.

The Beidou Dou (COMPASS) Navigation Satellite System is an independently developed and independently operated global Navigation Satellite System that China is implementing. By the end of 2018, the Beidou-3 System was basically completed and provides guidance to the whole world. Beidou satellite navigation system by the space segment, ground and users of three parts, including 5 geostationary orbit satellite space segment and 30 non stationary orbit satellite, ground segment including master station and injection station and monitoring station and so on a number of ground stations, user segments include beidou user terminal and other satellite navigation system compatible with terminal [10-12].

Satellite navigation and positioning system has entered the era of multi-system. It has become an inevitable trend of GNSS development to use different multi-system satellites for simultaneous positioning. Based on the analysis of BDS, GSP, BDS/GPS ambiguity fixed rate and relative positioning accuracy, the results show that the combined POSITIONING of BDS and GPS can effectively improve the positioning accuracy of BDS and GPS. In order to solve the problems of omission of records in ETC charging method in existing technologies, GPS/BDS combined system is used to collect relevant information when obtaining the path information of vehicles to be charged, thus improving the accuracy and reliability of acquired path information [13-15].

3. Receive the charging stop request sent by the terminal and retrieve all the charging point information contained in the path information.

When the vehicle to be charged arrives at the induction area at the exit of the high speed, the vehicle to be charged will automatically send a charging stop request to the ETC charging device on the ETC lane of the toll station through the terminal device set on the vehicle. Similarly, as a better example, stop-billing requests could be transmitted through microwave dedicated short-range communications between an on-board electronic tag mounted on the windscreen of the vehicle and a microwave antenna on the ETC lane at the toll booth.

After receiving the stop charging request of the charging vehicle, ETC charging device will extract all the charging point information included in the path information for subsequent calculation. At the same time, it can also obtain the

weight of the vehicle to be charged through the weighing device set in the induction area, so as to facilitate the subsequent calculation of the cost.

4. Calculate and obtain the payment bill of the vehicle to be charged according to the charging point information, basic information and preset charging rules for bank settlement.

As the current highway toll standards across the country are not the same, each city has its own toll standards, and the toll standards for different models are not the same. For example, small buses are mainly charged by distance, while large trucks are charged by tonnage as well as distance. The heavier the load, the more expensive it will be. Small cars with five seats or seven seats are charged the same. Therefore, in order to facilitate the subsequent cost calculation, this paper sets the charging rules in accordance with the local expressway charging standards in advance, including but not limited to the cost per unit path. Specific in the cost calculation, you can first according to the highway section, vehicle type and other information to match the corresponding charging rules, and then the corresponding calculation.

A number of charging points are set up at appropriate locations on the expressway, and all the information of charging points passed by the vehicles to be charged is recorded in the process of driving, and the charging points divide the paths into several sections. Then according to the distance between each two charging points and the corresponding charging rules can be calculated to be charged vehicles in this distance to pay the cost. Finally, the cost to be paid for each section is added up to calculate the cost to be paid for this driving of the billed vehicle.

Based on GPS/BDS combined system, the real-time location information of vehicles to be charged includes:

Based on GPS/BDS combined system, GNSS high-precision positioning technology is used to obtain real-time location information of vehicles to be charged, and real-time location information generates real-time path information of vehicles to be charged.

Because there are many branches on the highway, when there is a loop in the road network, there will be more than one reachable path from the entrance to the exit, that is, there is ambiguous path, if the vehicle cannot determine which path, it cannot determine how to charge. In order to solve this problem, when generating the real-time path information of the vehicle to be charged, this paper firstly obtains the real-time location information of the vehicle to be charged based on GPS/BDS combined system and GNSS high-precision positioning technology, and then calculates the current real-time path information of the vehicle to be charged according to the obtained real-time location information.

Usually, when a vehicle runs the wrong route on the highway, it needs to turn around and return to the next exit, which will lead to a lot more driving, which not only wastes time, but also increases fuel consumption and tolls. This paper creatively proposes to set up some underground passages on the expressway, through which vehicles can directly turn around on the expressway without driving to the next exit of the expressway. As a better implementation, underpasses can be located in service areas. Specific implementation, in pricing, in the process of vehicle time obtaining pricing real-time location information of the vehicle, judge whether the real-time location information in the target navigation path, if in, then stay billing vehicle direction is normal, don't do processing, if not, then billing vehicle driving direction appeared deviation, recent underground passage information right now, And remind the driver to drive to the underpass turn around and return.

Mentioned in real-time access to billing real-time location information of the vehicle, according to the real-time location information generated for billing real-time path information of the vehicle, and real-time access to the default navigation route traffic information, adjust the default navigation route, according to real-time traffic information to generate the target navigation path, and other functions can be encapsulated into a GPS/BDS chips to implement, the specific implementation, The GPS/BDS chip is installed on the ETC device, which not only realizes accurate navigation, but also accurate charging.

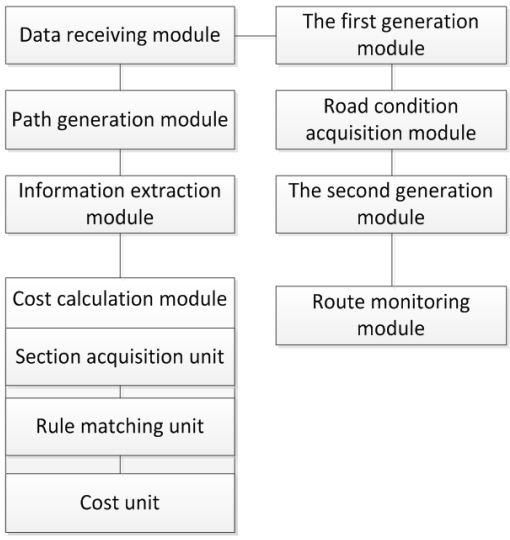

Figure 2. *Structure diagram of ETC charging device based on GPS/BDS combined system.*

Figure 2 is a schematic diagram of the structure of the ETC charging device based on a GPS/BDS combined system, as shown in an example embodiment, which includes:

(1) Data receiving module, which starts charging after receiving the request from the terminal device, including the basic information of the vehicle to be charged;

(2) Path generation module, used for real-time calculation of the real-time path information of the vehicle to be charged based on GPS/BDS combined system;

(3) The information extraction module is used to receive the stop accounting request sent by the terminal device and extract all accounting point information included in the path information;

(4) The fee calculation module is used to calculate and obtain the fees to be paid for the vehicles to be charged according to the charging point information, the basic

information and the preset charging rules for bank settlement.

As a better implementation, the device also includes:

The first generation module is used to generate the preset navigation route of the charging vehicle according to the starting point information and the end point information.

The road condition acquisition module is used to obtain the road condition information on the preset navigation route in real time based on GPS/BDS combined system;

The second generation module is used to adjust the preset navigation route in real time according to the road condition information and generate the target navigation route to navigate to the vehicle to be charged.

In an embodiment of the invention, the device also includes:

The route monitoring module is used to obtain the real-time location information of the vehicle to be charged and judge whether the real-time location information is on the target navigation route. If not, the information of the nearest underground passage is obtained, and the underground passage is used for the vehicle to be charged to return.

As a better embodiment, the GPS/BDS combined system in an embodiment of the present invention includes a tight combined model of GPS and BDS-3.

Receives the charging start request sent by the terminal, including the basic information of the vehicle to be charged.

Based on GPS/BDS combined system, the real-time path information of the vehicle to be charged is calculated in real time.

Receives the charging stop request sent by the terminal and extracts all the charging point information contained in the path information.

According to the charging point information, the basic information and preset charging rules, the payment bill of the vehicle to be charged is calculated and obtained for bank settlement.

Based on GPS/BDS combined system, GNSS high-precision positioning technology is used to obtain the real-time location information of the vehicle to be charged in real time, and generate the real-time path information of the vehicle to be charged according to the real-time location information.

When the vehicle to be charged is running, it sends the transaction information to the road-side equipment and receives the response information returned by the road-side equipment according to the transaction information, including the charging point information.

5. GPS/BDS Combination ETC Charging System Beneficial Effects and Advantages

The ETC charging method, device, computer equipment and storage medium based on GPS/BDS combined system provided in this paper receives the start charging request sent by the terminal device, and the start charging request includes the basic information of the vehicle to be charged. Based on THE GPS/BDS combined system, the real-time path information of the vehicle to be charged is calculated in real time. Receiving terminal equipment send to stop billing request, extract described path information includes all billing information, according to the above mentioned in the billing information, basic information and the default billing rules described calculation for billing vehicles paying bills, for settlement with the bank, precision positioning, to pricing of the vehicle, to achieve accurate charge;

It is proposed to generate the preset navigation route of the charging vehicle according to the starting point information and end point information, obtain the real-time road condition information of the preset navigation route based on GPS/BDS combined system, adjust the preset navigation route in real time according to the road condition information, and generate the target navigation route, so as to conduct navigation to the charging vehicle. According to the observed vehicle density of road conditions, the path that is not easy for vehicles to jam can be selected to achieve accurate navigation;

Is proposed to obtain described for billing real-time location information of the vehicle, whether real-time location information described in above target navigation route, if not, have access to the underground passage information, as described in an underground passage for described for billing the vehicle back, realize when vehicle takes the wrong course, you can quickly return to the correct route, reduce unnecessary distance and time, Thus reducing high-speed charges.

6. Conclusion

The ETC designed in this paper combined with GPS/BDS high-speed charging and navigation system, according to the real-time path information and preset navigation route of the charging vehicle, to achieve accurate positioning and navigation of the charging vehicle, accurate charging; According to the observed vehicle density of road conditions, select the path that is not easy to jam vehicles to achieve accurate navigation; Judge whether the real-time location information of the vehicle is in the target navigation route, so that when the vehicle takes a wrong route, it can quickly return to the correct route and reduce the high-speed charge.

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