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Research on the Development Status of Highway Electronic Toll Collection System

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Abstract: Highway Electronic toll collection system(ETC) is the most important part of intelligent transport system. Research and analysis on the development status of ETC can provide a research basis for its future development. In this paper, three subsystems of the highway Electronic toll collection system (ETC): automatic vehicle identification, automatic vehicle classification, and audit system are studied, and by comparing the research methods of scholars in different periods of time on automatic vehicle identification, automatic vehicle model classification, and audit system, it is found that with the application of new technologies such as big data, edge computing, AI algorithms, and laser radar, the highway Electronic toll collection system (ETC) development level is increasing.

Keywords: Auditing system; automatic vehicle identification; automatic vehicle typing; Highway Electronic toll collection system.

1. Introduction

With the continuous progress of science and technology and the rapid development of society and economy, the problem of traffic congestion is becoming more and more serious, especially on the Highway. In order to solve this problem, countries have introduced efficient and convenient toll collection methods, among which, the Electronic toll collection system (ETC) has become a research hotspot around the world.ETC system realises fast vehicle access and automatic toll collection by adopting advanced RFID technology, which greatly improves the access efficiency of the road network, and reduces the cost and risk brought by manual toll collection. In this paper, the development status and trend of ETC system will be studied and analysed in depth.

2. Concept, Function and Operation of Highway Electronic Toll Collection System (ETC)

2.1. The Concept of Highway Electronic Toll Collection System (ETC)

Highway Electronic toll collection system (ETC) is an electronic toll collection system, also known as electronic road pricing or automatic road pricing. This type of system allows vehicles to pay tolls automatically without stopping when passing through a toll booth.

ETC system mainly relies on two core components: installs in the vehicle the ETC electron label and installs in the toll station passage the microwave antenna. When the vehicle approaches the toll station, the ETC electron label and the microwave antenna will carry on the wireless communication between, completes the expense settlement automatically.

The following is the ETC system operation process:

The vehicles prepare: The vehicle owner needs to install the ETC electron label in the vehicles, and in the association bank account or the IC card deposits the sufficient charge in advance.

Travelling to the toll station: when the vehicle travels to the toll station which has the ETC channel, does not need to stop, only needs to keep the normal travelling speed.

Automatic diagnosis and fee deduction: when the vehicles pass through the ETC channel, the microwave antenna will read the ETC electronic label information on the vehicles, and automatically deduct the corresponding fee from the associated bank account or IC card.

Completes passes: After deducts the charge successfully, the vehicles may continue to move forward, need not to wait or the stop.

It should be noted that, in order to ensure the normal operation of the ETC system, the vehicle owner needs to make sure that the ETC electronic label works normally, and the associated bank account or IC card has enough balance. Also, vehicle owners need to regularly check and update their deduction records to ensure that the fees are accurate and transparent.

Overall, the ETC system provides vehicle owners with a more convenient and faster way of charging, which greatly improves the efficiency of passage and reduces traffic congestion caused by parking charges.

2.2. Basic Functions

Highway Electronic toll collection management system (ETC) is an advanced road and bridge toll collection technology, using the computer installed in the car for car identification, information input, and automatically deduct a certain amount of money on the pre-bound IC card or bank account. The following are the characteristics of ETC management system: Motor vehicles at high speed through: motor vehicles in the toll booths, no need to stop, you can carry out automatic toll collection.

The automatic deduction: The ETC system through reads in the vehicles installs the electronic equipment (the electronic label) inside the information, automatically from in advance binds the smart card or the bank account to deduct the corresponding amount.

The data statistics and the management: The background management system is responsible for the vehicles charge information to carry on the statistics and the management, including the vehicles passes the record, the charge amount statistics and so on the function.

2.3. Operation

Installation of ETC equipment: The owner needs to install ETC equipment on the vehicle and ensure that the equipment works normally.

Pre-deposit fees: The vehicle owner needs to pre-deposit enough fees in the bound IC card or bank account to ensure that the fees can be automatically deducted when passing through the toll booth.

Activate ETC device: Vehicle owners need to follow the relevant steps to activate the ETC device, including inserting and removing the ETC card twice consecutively to turn on the Bluetooth function, turning on the Bluetooth of the mobile phone and downloading the corresponding ETC mobile phone APP, and then follow the prompts to activate and verify the device.

Using the ETC device: When the vehicle drives into the toll station, the ETC device will automatically communicate wirelessly with the card reader at the toll station to achieve vehicle identification and automatic deduction. Vehicle owners do not need to stop, just keep the vehicle speed under 20km/h through the ETC toll lanes.

It should be noted that the ETC vehicle-mounted equipment has an internal battery, and the outside of the equipment is charged using solar energy. For infrequent use of solar ETC equipment, it is recommended to charge every 3 months to avoid the natural discharge of the battery inside the equipment. In addition, if the ETC equipment malfunctions or fails to work properly, vehicle owners can contact the relevant organisations for overhaul or replacement.

Highway Electronic toll collection system (ETC) provides vehicle owners with a more convenient and efficient passage experience. By understanding the functions and operation of the ETC system, vehicle owners can use the system better and enjoy a smoother travelling experience.

3. Three Sub-systems of Highway Electronic Toll Collection System (ETC)

After years of research and practice, the technology of ETC system has been quite mature. At present, ETC system has been widely used in toll booths on Highways, bridges and tunnels, and has become a mainstream toll collection method.

With the promotion of national policies and the growing concern for environmental protection and efficiency, the number of ETC users has shown explosive growth. According to statistics, as of 2023, the number of ETC users in China has exceeded 200 million, and it is expected that by 2025, the number of users will exceed 400 million.

Highway Electronic toll collection system ((ETC) is a system system composed of several subsystems, including automatic vehicle identification, automatic vehicle typing, audit system and other subsystems.

3.1. Vehicle automatic diagnosis

Vehicle automatic diagnosis technology is the foundation of Electronic charging system. Vehicle automatic diagnosis system mainly consists of the equipment loaded on the vehicle and the equipment installed on the roadside, and these two kinds of equipments complete the technology of vehicle type recognition through short-range communication by reading and writing the information of the equipment loaded on the vehicle by the equipment installed on the roadside at one time. The information of the vehicle-mounted equipment includes the model, brand, vehicle number, owner and other information, but these information are variable and not unique. So for artificial, the licence plate number can be the best identification of the vehicle, but for the machine is really difficult, so the vehicle equipment information should be obtained through professional identification technology.

Vehicle automatic identification system is generally by the vehicle unit, roadside unit and data processing unit composed of three main components.

(1) Vehicle unit. On-Board Unit (OBU) is a kind of equipment placed in the car, used for microwave communication with road side RSU (Road Side Unit). Its main function is to identify the vehicle information, calculate the rate and deduct the toll when passing through the toll booth, so as to achieve automatic control of passage.

(2) Road Side Unit. Road-Side Unit (RSU)

Road-Side Unit (RSU) is a device installed on both sides of the road in the Electronic charging system, which adopts microwave communication technology and communicates with the vehicle-mounted unit to realise the identification of vehicle identity and electronic toll deduction. In the management of highways and car parks, roadside units (RSU) are installed on the side of the road to establish fast and special car lanes without human guards.

(3) Data Processing Unit The Data Processing Unit (DPU) compares the textual or numerical data sent by the RSU with the account data stored in the database for identity verification, and processes data such as the calculation of the passage fee, the transaction location, the transaction time, and the flow number. The basic operation process of the automatic vehicle identification system is as follows: receiving the electromagnetic wave signal from the vehicle; converting the electromagnetic wave signal into data information; and processing the data information.

3.2. Automatic Classification of Vehicle Types

Vehicle model automatic classification system is a very important part of the Electronic toll collection system (ETC), and its main function is to detect and check the vehicle model information.

Gao Wenjuan et al [1] car model automatic classification system is set in the car's lane through the sensor equipment to detect the car's external information, and then, the above vehicle information using computer software to identify and confirm the type of vehicle. The data related to the vehicle whose type has been clarified is sent to the toll collection management system of the vehicle, and the toll collection system is able to link the information related to the type of the vehicle with the information related to the road toll collection of the vehicle. In the old manual toll collection system, the type of car was first confirmed by the appropriate staff, and then the automatic car classification technology was used. And in the Electronic toll collection system (ETC), the automatic car type classification system main role is to come to calculate the passage fee amount, as well as examines the car type of the car that passes through and stores in the car on the vehicle electronic label on the data whether is consistent, so as to determine whether the user exchanges using the phenomenon of the car electronic label.

Cai Qiang [2] the automobile automatic diagnosis technology system is by can detect each kind of automobile's model characteristic as well as the physical characteristic electronic sensor composition. By using this kind of system,

can to the vehicle volume size, the whole vehicle mass, the whole vehicle wheelbase, as well as each kind of tyre characteristic and so on makes the evaluation and the determination. The design according to our country each place's vehicle classification specification, therefore needs for the driver to handle the vehicle electronic label. In the process, the system collects the vehicle position information, the specification size, the automobile model and so on the vehicle information after, records it in the OBU, and installs the OBU to the proper place. In this way, the system can determine the charging rate through the OBU in the area of automatic charging.

There are four main categories of automatic vehicle classification systems. One is based on video and image processing methods. Chen Leixing[3] optimized the vehicle detection algorithm of YOLO model of deep learning network to improve the accuracy and real-time performance of multi-scene vehicle video recognition; optimized the network model of RA-CNN, so as to improve the processing speed of fine recognition of car model brand and the recognition rate of car model classification; proposed a comprehensive algorithm of the YOLO algorithm and the two optimization algorithms of RA-CNN to realize a complete car model The YOLO algorithm and the RA-CNN optimisation algorithm are proposed to achieve a complete video recognition system for car models, which completes the functions of car model classification and brand fine recognition. Lv Lei[4] uses visible light images to classify car models; the performance of the car model classification method based on deep convolutional neural network is better than other machine learning methods. Luo Jing[5] classifies the vehicle models and relative attitudes of the vehicles in the target frame while detecting and framing the target vehicles through commonly used computer vision techniques, combining the YOLO algorithm, the B-CNN algorithm, the improved HOG+LBP feature extraction, and the support vector machine SVM. The second is based on the principle of induction coil processing method. Wu Yi[6] provides real- time and accurate road traffic information based on the induction coil principle, and the system is mainly used for high-accuracy automatic vehicle detection and classification. The third is based on acoustic features and acoustic signal processing methods. Zhao Shifeng et al.[7] used the vehicle acoustic signal characteristics for automatic vehicle model identification. Liu Fang[8] analyses and researches the vehicle model classification and recognition method based on convolutional neural network based on vehicle acoustic signal processing and deep learning technology. The fourth is the principle processing method of LiDAR. Wang Hanning[9] uses laser ranging as the basis to realize the automatic identification system of car models, which is based on the characteristics of high accuracy of laser ranging, together with the speed information of the car, can accurately obtain the side-view contour of the car, and carry out accurate identification and classification; feature extraction is relatively simple, and the algorithm computation is relatively small; it can be used in different environments, and realize the work in various climatic conditions, and provide the traffic management department with the management of the car scientific basis.

3.3. Audit system

Audit system, as the basis for violation, is a system that uses video, LIDAR and other identification technologies to automatically audit vehicles on highways. It usually combines the ETC toll collection system, high-definition cameras, image processing technology, LiDAR technology and database management system in order to realise real-time monitoring and after-the-fact auditing of information such as vehicle driving status, ETC transaction records, etc., which can be used as the evidence of illegal behaviours such as failing to pay the tolls in accordance with the regulations.

Xie Pengyuan[10] based on big data, edge computing, artificial intelligence (AI) algorithms, etc., conducted a study on the construction of artificial intelligence (AI) audit system platform, put forward the edge computing real-time auditing, multi-dimensional artificial intelligence (AI) audit engine, multi-stream fusion path reduction and other methods, and established a variety of fee evasion auditing model. The results show that the AI audit system can effectively verify many kinds of fee evasion behaviours, and the accuracy of the model is very high, which can meet the auditing requirements. Yang Li et al[11] proposed an artificial intelligence (AI) toll auditing system for highways, relying on the gantry Electronic toll collection system, roadside unit, video bayonet and other multiple equipment data, real-time monitoring and tracking of toll evasion and leakage behaviours, and scientific prediction of high-speed operating income and benefits under different circumstances, which can effectively improve the accuracy and operational efficiency of highway toll auditing. Fan Huali et al.[12] proposed the application of LiDAR technology in ETC gantry data auditing system, so as to improve the efficiency, accuracy and fairness of auditing, and provide effective data support for high-speed charging.

Through the search of CNKI and the summary of the above literature, it is found that in the past two years, there are more researches on the audit system, and the researches mainly focus on the application of big data, edge computing, AI algorithms, and LiDAR technology in the construction of audit system.

4. Conclusion

At the early stage of construction, the Highway Electronic toll collection system (ETC), limited by the basic support technology, was supported by traditional intelligent traffic energy technology means to achieve preliminary automatic vehicle identification, automatic vehicle typing, auditing and other functions. At that time, the amount of information collection was limited, the communication speed was restricted, and the control mode was simple. However, it played an important role in the highway Electronic charging system (ETC). In recent years, technologies such as big data, edge computing, AI algorithms, and LiDAR technology have gradually been introduced into the highway Electronic toll collection system (ETC) and are gradually playing an increasing role in some scenarios. Big data analysis algorithms, AI algorithms, deep learning, etc. improve the data analysis capability, which can promote the maximisation of the value of the highway Electronic toll collection system (ETC), provide more scientific and reliable support for the management decision of the highway Electronic toll collection system (ETC), and strive to provide better services for people while improving management efficiency.ETC system, as an efficient, safe and convenient As an efficient, safe and convenient way of toll collection, ETC system has a broad application prospect in the field of Highway. In the future, we expect that ETC system can play a greater role in enhancing the road network efficiency, reducing the logistics cost, improving the traffic

environment, etc., and contribute to the sustainable development of the society.

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