Fake Plate Vehicle Auditing Based on Composite Constraints in Internet of Things Environment

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Abstract. According to the real application demands, this paper proposes a fake plate vehicle auditing method based on composite constraints strategy, a corresponding simulated IOT (internet of things) environment was created and uses liner matrix, Base64 encryption and grid monitoring technology and puts forward a real-time detecting algorithm for fake plate vehicles. The developed real system not only shows the superiority on its speed, detection accuracy and visualization, it also be good at realizing the vehicle’s real-time position and predicting the possible traveling trajectory.

1. Introduction

The accelerated socialization process increased the average household vehicle holdings dramatically, also yielded to appear the associated phenomenon like that fake plate vehicles. It is often occurred case that some people steal someone else's license plate number in order to facilitate driving and avoid from fining for regulation violation and vehicle management costs. This behavior seriously damaged the benefits of ordinary citizens and increased the difficulty of traffic management departments to investigate and deal with illegal vehicles. Thus, it is gradually falling into the white-hot stage for many scholars and researchers to develop algorithms and systems for automatically detecting the fake plate vehicles.

Lu Xiaochun et al. [1] proposed the "time difference" strategy which based on the investigation principle that a vehicle cannot appear at two different places ‘at the same time’. But the constraint of this strategy is not good enough, because it will fail while the fake palate vehicle and legal vehicle appearing at different times in different places, and this will definitely cause poor detection accuracy. Zhu Ping et al. [2] proposed a strategy for fake plate vehicles auditing based on big data technology. This strategy uses big data related technologies to greatly improved the speed of detecting and analyzing process. Although, new items such as vehicle color was introduced in the detection analyzing process, too much focusing on detection speed and the old “time difference” based strategy and still no obviously upgrade on detection accuracy. Wang Ziran et al. [3] put forward the idea of restricting the vehicle information in many ways. This approach mainly uses the information of vehicle archive and traffic-bayonet consistency to detect fake plate vehicles. Although this strategy has greatly improved the accuracy of the fake plate vehicle detection, but there are some disadvantages like that needing too much more data, to get the matching information is difficult, the speed of information retrieval is slow and so on, result in the consequence that this algorithm has not been recommended and applied at all. Wang Feng et al. [4] proposed an algorithm to combine the “time
difference” strategy and the “weighted speed” strategy to detect fake plate vehicles. Using dual constraints on time and speed was proved helpful to get better results than single “time difference” strategy, but it still couldn’t achieve desired detection accuracy.

In view of some of the above problems, this paper uses gridized monitoring technology to propose a fake plate vehicle auditing approach based on composite constraints in internet of things environment [5][6], the proposed algorithm uses multiple constraints including "traffic-bayonet number" strategy, "traffic-bayonet continuity" strategy, and "time difference" strategy and so on.

Vehicle related information such as traffic-bayonet, camera time, and license plate number which collected through gridized information collection technology is analyzed and organized using fast processing algorithm [7]. The processed vehicle information is filtered by the proposed algorithm to detect the suspicious vehicles [8]. Then, locate the suspicious vehicle and predict the next traffic-bayonet that suspicious vehicle may be pass through using linear matrix algorithm [9]. So, the traffic police can intercept the suspicious vehicle at the next traffic-bayonet. The effectiveness of the algorithm has been verified by the experiments during developing the fake plate vehicle detection system.

2. Conditional assumption and scene simulation

Internet of Things wants to integrate the relationships between things and things, things and person, person and person. In the particular case of this study, it is needed to achieve the link about the traffic-bayonet and camera, camera and vehicle, vehicle and people. scene simulation is one of the fundamental tasks to develop and test the proposed algorithm. The data need to be simulated include traffic-bayonet distribution on city roads, gridized city traffic monitoring points and the camera distribution around the monitoring point, the regulated vehicle speed range and regions, possible driving directions, position and time of passing traffic-bayonet, specific position of camera etc. By storing the simulated vehicle-related information into the initialized database to carry out further analysis of the data.

In our work, we have created a simulated environment, and there are following assumptions and parameter settings. It was assumed that the periphery of the city road is a 25km long square, there are 2000 traffic-bayonets(ports) in this range, five cameras are deployed in each port, and they can capture the license plate of each vehicle which passed through this port. On this basis, it was further assumed that there are 200,000 vehicles running on the city road, and 50 of them are fake plate vehicles, all the vehicles are running on the road and the maximum speed is 60 km/h and the minimum speed is 20km/h. And then, it is also required that the license plate information captured by each camera will be real-time storing in the database and statistics and analysis will be conduct every 5 minutes, if there are any fake plate vehicles are detected, then the analyzing results will be shows the vehicles details of license plate number, location, and tested time and so on. In addition, it is also should be able to check all the ports that a particular license plate vehicle was passed by.

Data preprocessing is also the basis for data modeling and analysis [10]. Since the collected raw data is out of order and neatness, preprocessing including cleaning and denoising are necessary for convenient extraction of position and distribution information of traffic-bayonet, camera and the belonging region of vehicle plate number and other related information which is needed for the study. All extracted information is loaded to the database created and initialized using SQLServer2008 platform. Various tables of database and storage structure are automatically constructed during building database and loading data procedures. Finally, the database is encrypted using Base64 encryption algorithm [11].

3. Algorithm design

The fake plate detection algorithm which proposed in this paper is combined uses three kinds of detection techniques including "Time Difference", "Traffic-bayonet Continuity" and “Traffic-bayonet Number” strategy. The combination of these three strategy strengthens the detection constraints and greatly narrows the scope of the checking, so fake plate vehicles can be find out quickly and accurately.
3.1. "Traffic-bayonet Number" Strategy

Under normal circumstances, when a vehicle is driving on the road and if its speed is up to the limit of maximum, then the total distance traveled by the vehicle in a period of time also must be a maximum, so this vehicle would pass through the maximum numbers of traffic-bayonets in this distance. That is to say, for any period of time $v_T$, the upper limit of traffic-bayonet number which a vehicle would pass through in this period of time can be expressed as follows:

$$\Delta n = \lfloor \sum_{i=1}^{n} S_{max}/V_{max} \rfloor \times \lfloor S_{min}/V_{max} \rfloor + 1 \quad (1)$$

Where $\sum_{i=1}^{n} S_{max}$ stands for the sum of distance traveled by the vehicle in $v_T$, $V_{max}$ is the fastest speed of the vehicle traveled in $v_T$, $S_{min}$ is the shortest distance between the traffic-bayonets which the vehicle passed through in $v_T$. If the real number of traffic-bayonets passed through by this vehicle is $n$ and $n$ exceeded the maximum theoretical value $\Delta n$, that is $n > \Delta n$, then it shows that this vehicle is either speeding or is a fake plate vehicle, both cases indicates that the vehicle violated the traffic regulation and traffic police can be informed to intercept and punish them in its upcoming traffic-bayonet. So, this strategy can not only help us to detect the fake plate vehicles, but also helps us to detect the legal vehicles for speeding.

3.2. "Traffic-bayonet Continuity" Strategy

For a vehicle on the road, normally it will pass through continuous traffic-bayonets on its movement [12][13]. Specifically, when a running vehicle pass through a traffic-bayonet $a \sim b$, its next direction must be adjacent to the traffic-bayonet $a \sim b$. or $a \sim h$, or $a \sim b \sim h$. or $a \sim b \sim h$. In other words, the vehicles can only move between the neighbor traffic-bayonets, there should be no jump between the traffic-bayonets and a vehicle cannot skip the current adjacent traffic-bayonet over and move to the next non-adjacent traffic-bayonet directly.

3.3. "Time Difference" Strategy

Normally, for a running vehicle on the road, if the vehicle’s maximum speed and the distance between the two traffic-bayonets are fixed, then the vehicle’s used time for its movement between two certain traffic-bayonets also can be determined. That is to say, the minimum time $\Delta T$ it takes for a normal running vehicle to leave from one traffic-bayonet and to the next can be calculated using the formula below:

$$\Delta T = \lfloor S_{1} \div S_{2} \cdots S_{n} \rfloor + \lfloor V_{1} \div V_{2} \cdots V_{n} \rfloor \quad (2)$$

Where $[S_{1} \sim S_{n}]$ stands for the shortest distance the vehicle may travel between two traffic-bayonets, $[V_{1} \sim V_{n}]$ is represents the fastest speed of the vehicle on this distance of travel. Then it is not difficult to judge using this formula whether the real traveling time $\tau$ is within the specified period of time $\Delta T$, and it is very helpful to judge is it a fake plate vehicle or not [14]. In other words, the real traveling time $\tau$ must be equal or greater than $\Delta T$, if $\tau < \Delta T$, then the vehicle can be judged as a fake plate vehicle, because a vehicle cannot appear in two places simultaneously within a period of time it cannot be reached at all.

3.4. vehicle trajectory identification

After using the above three strategies for all collected vehicle information to conduct a comprehensive analysis and calculation, we can do effective identification and give all of information of identified fake plate vehicles timely, including license plate number, which traffic-bayonets it passed through, where and when it was found, and related analyzing and calculation results that proves it is a fake plate vehicle. In addition, for further rigorous verification or other special purposes, we also need to track the trajectory of a particular vehicle. So, we introduced the liner matrix calculation approach to identify the vehicle's trajectory and visualize it to the user [15].

When the target vehicle being tracked has been identified, all its data will be transferred from the database to the linear matrix, then calculate and get the moving track of the target vehicle in a period of time and draw it out on a two-dimensional plane that mimics the city traffic map.

The main process of linear matrix localization algorithm can be described as follows.

\[ \text{null} \]
(1) Extract the coordinate information of all the traffic-bayonets which the target vehicle passed through, and project these coordinates into the liner matrix and prepare to matrix calculation, that is to import the gridding traffic-bayonet distribution coordinates into a corresponding matrix $D$, shown in Fig. 1.

$$D = \begin{bmatrix}
    a_1 b_1 & \ldots & a_n b_n \\
    \vdots & \ddots & \vdots \\
    a_m b_1 & \ldots & a_m b_m
\end{bmatrix} \rightarrow \begin{bmatrix}
    1 & 2 & 3 & \ldots & m \\
    m+1 & m+2 & m+3 & \ldots & 2m \\
    2m+1 & 2m+2 & 2m+3 & \ldots & 3m \\
    (n-1)m+1 & (n-1)m+2 & (n-1)m+3 & \ldots & n^2m
\end{bmatrix}$$

**Figure 1.** Linear matrix filled with traffic-bayonet distributions.

(2) For a target vehicle, there is a traffic-bayonet set filled with the serial number of traffic-bayonets which the target vehicle passed through in a period of time $\tau$, then using the following formula find the corresponding position coordinates of each traffic-bayonet and locate them in the matrix $D$. There is a one to one correspondence between the serial number of each bayonet and its subscript in the matrix.

$$\begin{align*}
    a_i &= n \div m \\
    b_i &= n \mod m + 1
\end{align*}$$

In the formula, $n$ stands for the serial number of the traffic-bayonet, $a_i$ and $b_i$ represent its coordinates in the matrix $D$, $m$ is the number of columns in the matrix. For a serial number set of traffic-bayonets which passed through by a specific vehicle, it is be able to find their position coordinates in the liner matrix uses above formula. For example, a car passes through Nos. 27, 37, 47, 46 and 45, then the liner matrix after localization is shown in Fig. 2.

**Figure 2.** Vehicle trajectories in linear matrix.

(3) Finally, the identified driving trajectory of a target vehicle will soon be drawn and displaying by visual programming method for reference and further verification.

4. **Experimental Results and Analysis**

4.1. Development and Experimental Environment

In order to verify the proposed method and its effectiveness, this paper developed a Windows 64OS based fake plate vehicle detection system using c# language on Microsoft .NET Framework 4.0 environment, Microsoft Visual Studio2016 and SQL Server2008 development tools.

The Base64 encryption algorithm and T-SQL statements are applied to create and initialize the database. In the process of data simulation, created a grid-like traffic monitoring simulation environment that is exactly the same with the actual environment and has all data of traffic-bayonet coordinates distribution, camera location distribution, and vehicles information, etc. Then, a new algorithm based on composite constraint is developed which can be used to analyse and calculate the
real-time captured data quickly and identifying fake plate vehicles accurately. Finally, a linear matrix method is also used to identify and draw the vehicle's trajectory.

4.2. Results and Analysis
The system simulates such an application scenario: assumed that the periphery of the city road is a 25km long square, there are 2000 traffic-bayonets (ports) in this range, five cameras are deployed in each port, and they can capture the license plate of each vehicle which passed through this port. On this basis, it was further assumed that there are 200,000 vehicles running on the city road, and 50 of them are fake plate vehicles, all the vehicles are running on the road and the maximum speed is 60 km/h and the minimum speed is 20km/h. And then, it is also required that the license plate information captured by each camera will be real-time storing in the database and statistics and analysis will be conduct every 5 minutes, if there are any fake plate vehicles are detected, then the analyzing results will be shows the vehicles details of license plate number, location, tested time, and another related data and calculation and analyzing results that prove this is a fake plate vehicle, and so on.

The implemented system consists of four functional modules, including database initialization module, data simulation module, fake plate vehicle detection module, and analysis and visualization model. The first two models are mainly responsible for providing data for the following modules. The system UI of data loading and simulation shown in Fig. 3.

![Figure 3. Data loading and simulation UI.](image)

The fake plate vehicle detection module periodically computes the data in the database and outputs the results to the next model and being analyze and visualize. Corresponding system UI shown in Fig. 4.

![Figure 4. Data analysis visualization UI.](image)
For the legal traveling vehicles, this system also provides tracking service and be able to view a target vehicle’s driving trajectory in a special period of time, shown in Fig.5.

The composite constraint strategy for fake plate vehicle detection which proposed in this paper combines the advantages of "time difference" strategy, "traffic-bayonet continuity" strategy and "traffic-bayonet number" strategy, then reached above 99% and much higher detection accuracy than single using above mentioned strategy. The comparison of experimental results of each single strategy and proposed strategy shown in Fig.6.

Experimental results showed that the algorithm proposed in this paper has greatly improved the accuracy of the fake plate detection system, the detection accuracy is close to 100% and much higher than using single strategy based approach. Obviously, there are different shortcomings in the methods of a single strategy, that could not identify a fake plate vehicle when it appears in different locations and different time with same plate legal vehicle, too sensitive to the amount of data, lower speed of retrieval, and poor detection accuracy, and so on.

However, the composite constraint algorithm proposed in this paper combines the advantages of a variety of single strategy, using fast data loading and updating techniques. Therefore, it shows superior performance over existing methods in recognition accuracy, detection speed and so on.

5. Conclusion
This paper uses T-SQL statement and Base64 encryption technique to manage large-scale traffic data well and capture, store, update, and quickly exchange vehicle information among each model, this is the premise and basis for the rapid calculation and analysis of vehicle information to accurately identify the fake plate vehicle. On this basis, the combination of “traffic-bayonet number” strategy, “traffic-bayonet continuity” strategy and “time difference” strategy as a composite constraint to conduct calculation and analyzing the vehicle information and significantly improved the overall efficiency of the fake plate vehicle audit system. Introduced the liner matrix method to calculate the
vehicle trajectory and visualization, and this is also another highlight of this work. Finally, a large number of experiments were done based on the traffic-bayonet and camera layout and 200,000 vehicle information provided by authoritative departments and the validity of the work in this paper was verified.

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