Design of Traffic Monitoring System Based on Video Detection

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Abstract: Traffic monitoring system is an important means to ensure the safe operation of traffic. According to the characteristics of road traffic monitoring environment, a real-time traffic monitoring system is designed by using image processing, computer vision, pattern recognition and other technologies. Experiments show that the system can effectively detect various typical traffic incidents and traffic operation parameters, and provide a favorable guarantee for traffic safety.

1. Introduction
With the continuous growth of the national economy and the rapid improvement of people's material living standards, the number of vehicles in cities shows a trend of rapid growth. Traffic conditions are paid more and more attention. How to effectively manage traffic has gradually become the focus of attention of the government and relevant departments[1]. To solve this problem, various intelligent transportation systems have been produced or studied, and monitoring the vehicle violations is a very important segment.

Intelligent traffic monitoring system based on communication technology and computer image processing technology emerged as the times require, and has become the development direction of current traffic management. Nowadays, all countries in the world are building and improving their own traffic monitoring (electronic police) system. Traffic monitoring system is an important part of Intelligent Transport System (ITS).

The function of traffic monitoring system is not only to capture illegal vehicles, but also to control the traffic timing at intersections, traffic flow connection at adjacent intersections, to help to plan new roads in the whole city, the transformation of old roads and even the re-layout of urban intersections. In view of the above background, a traffic monitoring system based on video detection is designed in this paper, which aims to solve the practical application requirements. The experimental results show it has higher practical value.

2. Framework of Traffic Monitoring System
The traffic monitoring system based on computer vision is a comprehensive system which integrates image acquisition and processing, traffic incident detection and analysis, and information management system. It includes mainly the following modules: video capture module, video image processing module, video storage and playback module, and information management module. As shown in Figure 1.
2.1. **Video Acquisition and Transmission Module**

Video acquisition and transmission module is the first module of traffic monitoring system \[2\]. The module captures video images of road and intersection by acquisition equipment and transmits them to a video processor. The whole process of video image acquisition and transmission is: CCD camera + Optical Fiber Transceiver - Optical Fiber + Optical Fiber Transceiver + Image Acquisition Card + Video Processor.

The video capture module is composed of a camera and a video capturing card. Video is captured by the camera. Video capturing card is used for compression and coding to get high compression rate and better performance.

Video transmission: The camera outputs analog signals, enters the optical fiber transceiver, converts them into optical signals, and transmits them through optical cables. Optical cable transmission can ensure real-time image transmission, and ensure that there is no distortion in the transmission process.

2.2. **Video Image Processing Module**

Video image processing module is the core module of the whole system. This module uses computer vision technology and digital image processing technology to process real-time video image information about the road traffic conditions. Its’ purpose is to detect the moving vehicles, to predict the moving state and tracking of vehicles, so as to detect abnormal traffic events, and to provide supports for traffic parameter measurement and statistics.

2.3. **Video Storage and Playback Module**

The task of this module is to search, locate and play back the video of the current situation of vehicle violation after inquiring the violation record. Among them, the main content of traffic information fusion is that: According to the specific time information of traffic violation stored in the database, the corresponding conversion is carried out, and then the specific time period of the occurrence of the violation event is obtained. Based on this, the video data is located and intercepted. Then the information of vehicle recognition, vehicle tracking, license plate recognition and rule judgment is integrated.

2.4. **Traffic Abnormality Detection Module**

Using the results of multi-target tracking in video image processing module, the traffic state of intersection is effectively detected. Our basic assumption is to set up a region of interest (ROI) in the video image sequence to simulate zebra crossings of road in the actual scene, and to simulate stopping lines with detection lines. Then, six kinds of traffic abnormal behaviors are analyzed based on detection line and ROI intrusion detection technology(as Table 1). Storing the tracking results in the video image processing module of the detection system, then comparing them with the early warning rules in the knowledge base, we can make a judgment and output the early warning results.
Table 1. Typical Early Warning Logic Table

| Traffic Abnormal Behavior                              | Limitations                          | early warning                        |
|--------------------------------------------------------|--------------------------------------|--------------------------------------|
| Pedestrians Running Red Light                          | Crossing the detection line          | Alarm prompt and do records          |
| Pedestrians crossing the road encounter vehicles turning right | In ROI                               | Alarm prompt and do records          |
| Pedestrians cross the road in the area outside the zebra crossing | Beyond ROI                           | Alarm prompt and do records          |
| Wrong Steering of Vehicles                            | Crossing the detection line          | Alarm prompt and do records          |
| Vehicles Running Red Light                            | Crossing the detection line          | Alarm prompt and do records          |
| Reverse driving of vehicles                           | Reverse crossing detection line      | Alarm prompt and do records          |

2.5. Information Management Module

This module acts as the main function of the intelligent traffic monitoring information management platform. It can provide users with structured traffic information, such as single or multiple traffic violation records, various traffic macro-statistical information, etc. In order to ensure the correctness, completeness and rationality of the system, users can not only query the relevant information, but also modify and delete the traffic information according to the actual situation.

3. Relative Technologies

3.1. Obstacle Detection and Road Segmentation

Obstacle detection and road recognition based on monocular system have been paid more and more attention by researchers at home and abroad because of its low cost and high efficiency. In order to achieve true monocular vision, a single still image is used to detect obstacles and segment roads effectively in the image.

Given an image, using spatial layout and depth of field to describe the three-dimensional spatial model of the image scene[3]. For the former, a method for annotating image scene based on spatial layout information to obtain road and potential obstacle areas is proposed. Firstly, the depth of field of each object in the image is predicted. Then, based on the combination of spatial layout information and field information, we use a support vector machine to get the obstacle area in the image.

3.1.1. Algorithm of Predicting Depth of Objects

First, an image is segmented into some smaller blocks and each small block is described with the absolute depth feature and relative depth feature. The absolute depth feature describes the depth of a specific small image block and the relative depth feature is expressed as depth difference of two adjacent small image blocks[4].

The absolute depth feature is computed as follow: Given an image block i in the image \( I(x, y) \), compute the 9-D Laws mask texture, 2-D color channel and 6-D texture gradient to form a 17-D filter \( E_n(x, y) \), \( n = 1,2,\ldots,17 \)

\[
E_n(x, y) = \sum_{(x,y)\text{search}(i)} |I(x, y)\times F_n(x, y)|^k, k = \{1, 2\}
\]

, indicates accumulative absolute value and square sum outputted by the filter, so a 34-D initial feature vector is obtained.

The relative depth feature is expressed as follow: for each image block i, one 10-bin full histogram is used to describe output of each dimension of the filter \( |I(x, y)\times F_n(x, y)| \), then a 170-D (17×10) feature \( y_i \) is produced. Finally, relative depth feature of the adjacent image blocks i and j can be expressed as the histogram difference

\[
y_{ij} = y_i - y_j
\]
After the absolute depth feature of each block and relative depth feature of each adjacent block group in the image are obtained, the local image feature is fused with the space relation via the Markov random field (MRF).

### 3.1.2. Algorithm of Labeling Space Layout

Each image block is described with the following features: color feature, shape feature, texture feature, position feature, 3-D geometric feature. The features about color, shape and texture are adopted frequently in different image system. The position feature can better distinguish them in our task, because most images collected by the camera are horizontal. 3-D geometric feature is used to determine the orientation of the middle scene.

Labeling space layout is regarded as multi-label problem[5]. Assuming \( C = \{c_1, \ldots, c_T\} \) is the label set, \( S' \subseteq S \) is the segmentation assumption and \( H' = \{h'_1, \ldots, h'_n\} \) is the image block set in \( S' \). For one image block \( h'_i \) in the segmentation assumption \( S' \), its label vector \( I'_u \) is a 7D vector. \( i^{th} \) dimension indicates probability of this image block with label \( C_i \) and is represented with \([0, 1]\). One pixel \( p \) of the image belongs to different images in each segmentation assumption. We indicate the image block set covering the pixel \( p \) in \( S \) by using \( H_p = \{h'_p, \ldots, h'_n\} \). \( L_p = \{l'_p, \ldots, l'_n\} \) is the corresponding label vector set, we can represent label vector of the pixel \( p \) with \( L_p \), namely:

\[
L_p = \sum_{i=1}^{n} \pi_i l'_p
\]

\( \pi_i \) is the weight factor and is used to represent weight relation between the pixel label vector and the label vectors of different image blocks with this pixel.

### 3.2. Algorithms of Moving Target Tracking

#### 3.2.1. Particle Filter Algorithm

The core idea of applying particle filter algorithm to track moving object is to describe probability distribution with random samples. These samples are regarded as particles. Then, on the basis of measurement, the distribution of actual probability is approximated by adjusting the weight of each particle and the position of the sample, and the mean of the sample is taken as the estimated value of the system. The algorithm is divided into two stages, as follows:

1. **prediction stage:**
   \[
p(x_t | y_{1:t-1}) = \int p(x_t | x_{t-1}) p(x_{t-1} | y_{1:t-1}) dx_{t-1}
\]

2. **filtering stage:**
   \[
p(x_t | y_{1:t}) \propto p(y_t | x_t) p(x_t | y_{1:t-1})
\]

Here, \( p(x_t | y_{1:t-1}) \) is called posterior probability density.

#### 3.2.2. Mean-Shift Algorithm

Mean-Shift Algorithm is widely used in target detection and tracking, it is a fast pattern matching algorithm without parameters based on kernel density estimation. For a finite data set \( A \) in \( N \)-dimension Euclidean space \( X \), the sample mean near point \( x (x < X) \) can be defined as:

\[
sm(x) = \frac{\sum_{a} K(a - x)w(a)u}{\sum_{a} K(a - x)w(a)}, a \in A
\]
Here, $K$ is kernel function, $w$ is weighting function, the difference value $sm(x) - x$ is called Mean-shift vector.

Mean-shift algorithm is to move data points to Mean-shift vector repeatedly and eventually converge. At this time, the position of the core corresponds to the extreme value of a probability density, i.e. the position of target mode.

4. Experiments and results

In this system framework, video processing and client system are integrated and run on workstations with Pentium dual-core CPU, 3.0GHz main frequency, 1GB independent display memory, 500G hard disk and 4GB memory. Using Windows 2003 Server operating system and VC++ 2008 development tools, vehicle detection and tracking algorithm, data network transmission, data dynamic display and human-machine interface are realized. The detected data and traffic video information are dynamically displayed on the client side.

The system captures real-time road video images by camera, and monitors the road environment by video image processing and recognition technology. It mainly aims at pedestrians running red lights, pedestrians crossing roads encountering right-turn vehicles, pedestrians crossing roads outside zebra crossing areas, vehicles running red lights, vehicles driving backwards and vehicles. Six common traffic abnormal behaviors, such as wrong turn. The information obtained by the system in the test is more reliable than that obtained by manual statistics.

The system can process the traffic video information in real time and acquire the abnormal situation of the current road effectively. Taking a vehicle running a red light as an example, when a pedestrian is passing a green light, the system will give an alarm message and record the content of the early warning information when the vehicle forcibly crosses the crosswalk, as shown in Figure 2.

Figure 2. Real-time Processing Screen of Vehicle Running Red Light

The system is tested on the road site. The results show that the system has good real-time performance and reliability. The test results are shown in Table 2.
Table 2. Results of Detection of Traffic Abnormal Accidents

| Description of Test Video | Detection Result |
|--------------------------|------------------|
|                          | Number of Testing Video | Number of Abnormal Events | Number of Detected Events | Detection Rate | Number of False Alarms | Misdetection Ratio |
|                          | 10                | 52                         | 50                      | 96.15%         | 3                      | 5.76%              |

5. Conclusion
A traffic monitoring system based on video detection technology is designed in this paper, which analyses the principle framework of the system, and gives the technical implementation points of each functional module. The system can process real-time traffic video information, effectively detect typical traffic violations, and obtain some basic traffic information. The experimental results show that the system has good real-time performance and reliability.

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