Accident Detection System using Image Processing and MDR

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Summary
In this research, we suggested a vision-based traffic accident detection system for automatically detecting, recording, and reporting traffic accidents at intersections. This model first extracts the vehicles from the video image of CCD camera, tracks the moving vehicles, and extracts features such as the variation rate of the velocity, position, area, and direction of moving vehicles. The model then makes decisions on the traffic accident based on the extracted features. And we suggested and designed the metadata registry for the system to improve the interoperability. In the field test, 4 traffic accidents were detected and recorded by the system. The video clips are invaluable for intersection safety analysis.

Key words:
Accident, image processing, moving picture, metadata registry.

1. Introduction

Intersections also tend to experience severe crashes due to the fact that several types of injurious crashes, such as angle and left turn collisions, commonly occur there. Therefore, accurate and prompt detection of accidents at intersections offers tremendous benefits of saving properties and lives and minimizing congestion and delay.
Traffic accident detection employing computer vision and image processing on freeways has attracted much attention recently [1]. Kimachi *et al*. [2] focus on abnormal vehicle behaviors causing incidents (e.g., a traffic accident), traffic jams, fallen-down obstacles, etc. They propose a method that employs image-processing techniques and fuzzy theory to predict an incident before it happens. The judgment of whether an incident has happened or not is made using the "behavioral abnormality" of some continuous images. Michalopoulos *et al*. [3] carried out an autoscope video-detection system to detect incidents. This system is able to detect incidents almost 2 miles away.
Unfortunately, however, these methods have rather limited capability to detect accidents at an intersection because the intersection is a very complicated place. Hence, we suggested a new traffic accident detection algorithm using the features of moving vehicles at intersections and developed a system for automatically detecting and recording the before/after Accident Moving Picture (AMP) and reporting it to Traffic Monitoring Center (TMC). The AMP is a more reliable surrogate of crash data than the conflict data, and it provides a time efficient method of analyzing intersection collisions compared to a conflict analysis or a continuous videotaping. A system with these properties would assist in determining the cause of accidents.
Data processing and electronic data interchange rely heavily on accurate, reliable, controllable and verifiable data recorded in databases. A prerequisite for correct and proper use and interpretation of data is that both users and owners of data have a common understanding of the meaning and representation of the data. To facilitate this common understanding, a number of characteristics, or attributes, of the data have to be defined. These characteristics of data are known as "metadata", that is, "data that describes data". This part of ISO/IEC 11179 provides for the attributes of data elements and associated metadata to be specified and registered as metadata items in a metadata registry [4].
The metadata registry is not simply a database; it also has a formal registration process with an organizational structure to support it. It is important to note that a metadata registry holds only the definition of structure and semantics of data; it does not hold the actual data. To improve the interoperability of the system, we designed and suggesteded the metadata registry for the system.

2. Background

2.1 Related works

A number of conventional expressway incident detection algorithms have been developed in the past several decades. Techniques based on decision trees for pattern recognition, time series analysis, Kalman filters have been attempted, but met with varying degrees of successes in their detection performance [5 – 10]. On the other hand, only a few researchers have investigated the detection of traffic crashes at intersections.

Manuscript received March 5, 2007
Manuscript revised March 25, 2007

2.2 System configuration

The traffic Accident Recording and Reporting System (ARRS) is an image-actuated moving picture recording and reporting system used to analyze and evaluate the occurrence of traffic crashes at intersections. The system consists of a charge coupled device (CCD) camera located on the corner of the intersection to obtain a view of incidents, an image processing unit that detects images which could be related to a traffic crash, a digital video recorder (DVR) that has recorded all the situations of the intersection for the previous two weeks, and a communication unit that send the AMPs to the TMC.
When the ARRS detects an event that could be a collision and captures the AMPs (which include five seconds before the event and five seconds after the event) from the DVR, the system sends the AMPs to TMC by Virtual Private Network (VPN). This AMP consists of pictures taken five seconds before and after the event that activated the system. The signal phase is then encoded onto the recorded AMP.

Fig. 1 Configuration of ARRS.

3. Accident detection algorithm via image processing

Accident detection algorithm generally includes three steps: vehicle extraction, feature extraction of a moving vehicle (MV), and accident detection. Based on vehicle tracking results, we analyzed traffic images and detected the traffic accidents [11].

3.1 Vehicle extraction and tracking

Vehicles are extracted by detecting moving parts in each frame based on a difference equation. This process consists of taking the difference of two continuous frames, binarization, and horizontal and vertical projection, and then extracting parts which exceed the threshold value. For the extraction of moving regions in a video sequence, an input image, a pair of gray-level images, $I_{k-1}(x, y)$ and $I_k(x, y)$ acquired at successive time instants τ_{k-1} and τ_k, respectively. The output is the moving regions in which significant changes have been detected. For the extraction of moving regions, the difference image, $D(x, y)$ is computed: $D(x, y) = I_k(x, y) - I_{k-1}(x, y)$.

3.2 Feature extraction

Depending on the tracking result, the ARRS extracts features for accident detection. Features such as the acceleration, position, area (size), direction of the MV are used for accident detection [11] [12].

Acceleration and retardation

Rapid velocity variation is a useful descriptor of a traffic accident. In general, a traffic accident causes rapid change to vehicle speeds. Hence, we used the variation rate of vehicle speed (acceleration and retardation) for accident detection. In the tracking process, we extracted the speeds of the MVs, calculated the positive or negative accelerations of the vehicles, and used them for accident detection [12].

Variation rate of the position

Positions are useful descriptors of objects within images. An image that represents an object consists of positive-valued pixels that is set against a background of 0-valued pixels. Position refers to the location of the object in the plane. The objects's centroid (or center of mass) is the point that is used to specify its position [12].

Variation rate of the area

Area is a commonly used descriptor for regions in the plane. Let R denote the region whose points have pixel value 1. One way to calculate the area (S) is simply to count the number of points in R. This can be accomplished with the image algebra statement $S = \Sigma s$. When the vehicle moves away from the camera, the size of the MV decreases, and as it moves towards the camera, the size of the MV increases; however, its variation rate is small. On the other hand, the accidents cause rapid change to the size of the MV. Therefore, we used the variation rate of area as a factor for traffic accident detection [12].

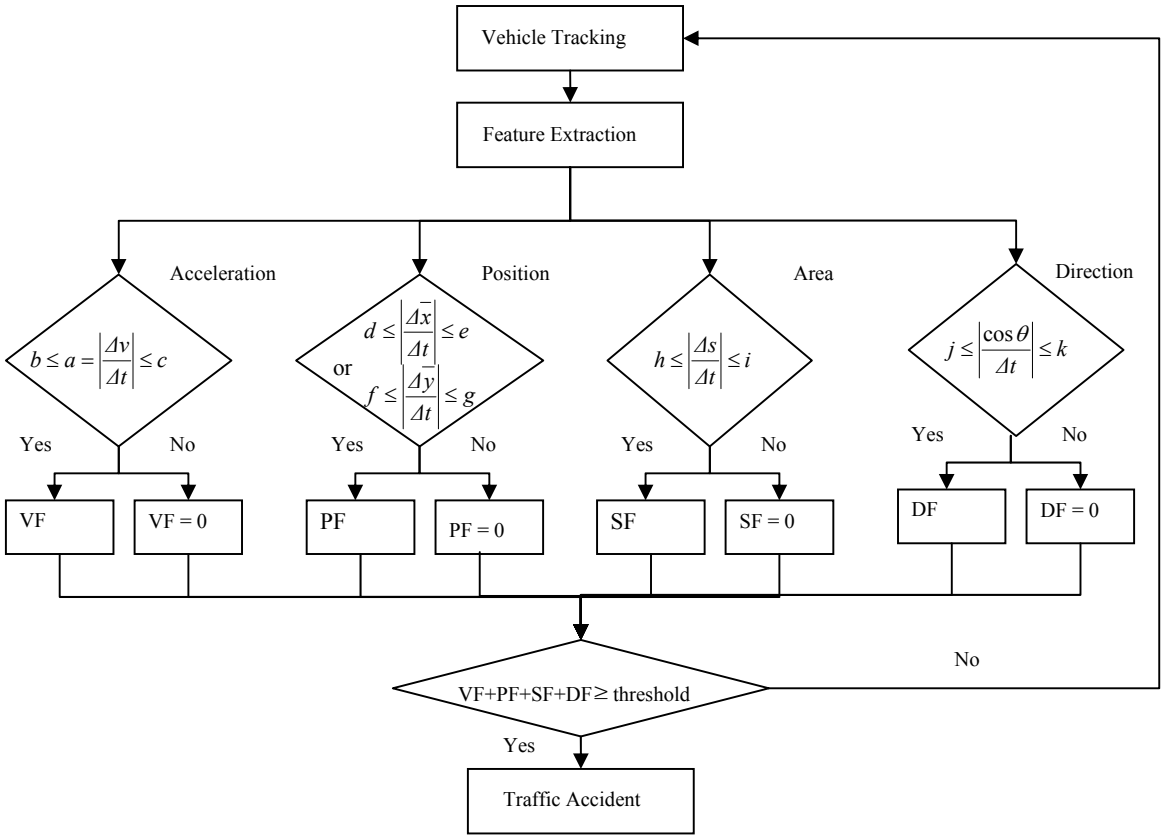

Fig. 2 Flowchart of the accident detection algorithm [12].

Variation rate of the direction

With reference to the extracted part in one frame, the corresponding part in the subsequent frame is searched by cross correlation. The motion vector spanning the two corresponding points in each image is defined as optical flow. The mean optical flow obtained by averaging the normal optical flow of each pixel in the extracted part is represented by V_n,, and the motion vector obtained by cross correlation is represented by V_i. The angle θ formed between the two motion vectors can be expressed as follows [12].

$$\cos\theta = \frac{V_n \cdot V_i}{|V_n||V_i|} \quad (1)$$

3.3 Accident detection algorithm

The traffic accident detection algorithm was established following a flowchart. The accident features in each image were calculated in the steps mentioned above. Finally, considering the "Feature indexes" in the sequence, it was determined whether or not the traffic accident had occurred. An outline of this process is shown in figure 2, and the accident detection algorithm is summarized as follows [12]:

step 1: extract the vehicle objects from the video frame
step 2: track the MVs by the tracking algorithm
step 3: extract features such as variation rates of velocity, position, area, direction of the MV as the accident index
step 4: estimate the sum of the accident index flags (VF+PF+SF+DF) and identify the accident.

4. Metadata registry for ARRS

To improve the interoperability, we designed a metadata registry that manages the accident data from ARRS. As shown in Table 1, the proposed registry consists of five categories; identification, definition, relation, presentation, and management attribute.

Table 1: Definition of the metadata attribute

Attribute Category	Attribute name of the data element
Identification Attirbute	(1) Name
	(2) Identifier
	(3) Version
	(4) Registration Authority
	(5) Synonymous Name
	(6) Context
Definition Attribute	(7) Definition
Relation Attribute	(8) Classification Scheme
	(9) Keyword
	(10) Conceptual domain
	(11) Conceptual domain definition
	(12) Conceptual domain name
	(13) Object class
Presentation Attribute	(14) Data type of data element values
	(15) Maximum size of data element values
	(16) Minimum size of data element values
	(17) Permissible data element values
	(18) Unit of measure
	(19) Value meaning name
	(20) Value meaning definition
Management Attribute	(21) Responsible Organization
	(22) Registration Status
	(23) Submitting Organization
	(24) Comments
	(24) Change Date
	(25) Change Description Text
	(26) Create by User Name
	(27) Create Date
	(28) Data Steward organization Name

We designed a database for ARRS by entity-relation (E/R) model. As shown in figure 3, the proposed model consists of seven categories; traffic accident, accident information, cause of the accident, driver, vehicle, site condition, and driving pattern at accident time.

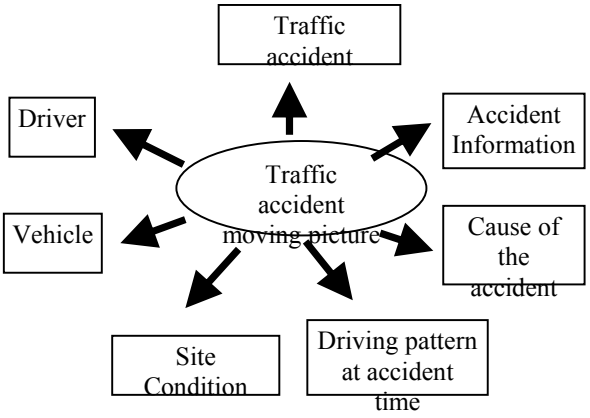

Fig. 3 Database model for ARRS.

5. Test result

In this paper, we suggested a vision-activated accident detection system. To evaluate the performance of the proposed model in a real world environment, we developed the ARRS. The ARRSs were installed at two intersections in Seoul, South Korea. The data from the DVRs were used to match each crash report to an AMP of ARRS. Information such as the description of the crash, colors of the vehicles involved, and type of crash was used. During the test period, a total of 4 traffic accidents were detected and recorded by the AARSs.

(a)

(b)

Fig. 4 Accident image detected by ARRS (a) before an accident during the day, and (b) an accident during the day

6. Conclusion

We have demonstrated a promising approach for an image processing system for automatically detection, recording, and reporting traffic accidents at an intersection. And we suggested and designed the metadata registry for the system to improve the interoperability.

To evaluate the performance of the new model, we developed and placed the ARRS, which is a vision-based accident detection system, at two intersections in Seoul, Korea. During the test period, 4 traffic accidents were detected and recorded by the AARSs. This accident detection and video-verification mechanism will be able to provide real-time crash warnings to the operators and drivers. The video clips are invaluable for intersection safety analysis.

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