Crowd Sensing Based Semantic Annotation of Surveillance Videos

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Today, video surveillance technology is playing a more and more important role in traffic detection. Vehicle's static properties are crucial information in examining criminal and traffic violations. With the development of video surveillance technology, it has been wildly used in the traffic monitoring. Image and video resources play an important role in traffic events analysis. With the rapid growth of the video surveillance devices, a large number of image and video resources are increasingly being created. It is crucial to explore, share, reuse, and link these multimedia resources for better organizing traffic events. Most of the video resources are currently annotated in an isolated way, which means that they lack semantic connections. Thus, providing the facilities for annotating these video resources is highly demanded. These facilities create the semantic connections among video resources and allow their metadata to be understood globally. Adopting semantic technologies, this paper introduces a video annotation platform. The platform enables user to semantically annotate video resources using vocabularies defined by traffic events ontologies. Moreover, the platform provides the search interface of annotated video resources. The result of initial development demonstrates the benefits of applying semantic technologies in the aspects of reusability, scalability, and extensibility.

1. Introduction

With the development of video surveillance technology, it has been wildly used in the traffic monitoring. Therefore, there is a trend to use video surveillance to do intelligent analysis on vehicles. Now, using software and tools to analyze vehicles in videos has already been used in smart cards and electronic eye, which helps police to extract useful information like plate, speed, and so forth. Nowadays, traffic events have become more important in the emergency events field. Traffic jam, crash, and other traffic events influence daily life of almost all persons. Crowd sensing is a process of acquisition, integration, and analysis of big and heterogeneous data generated by a diversity of sources in urban spaces, such as sensors, devices, vehicles, buildings, and human. Crowd sensing connects unobtrusive and ubiquitous sensing technologies, advanced data management and analytics models, and novel visualization methods, to create solutions that improve urban environment, human life quality, and city operation systems. With the rapid growth of the video surveillance devices such as cameras (some statistics suggest that the number of linking cameras for traffic is 630 thousand in China), a large number of image and video resources are increasingly being created. With the help of cloud computing [1–4], internet of things [5–7], and Big Data [8, 9], the data volume of all video surveillance devices in Shanghai is up to 1 TB every day. Thus, it is important to accurately describe the video content and enable the organizing and searching potential videos in order to detect and analyze traffic events.

The Ministry of Public Security is the management department of traffic events in China. Different provinces or cities of the Ministry of Public Security manage their own resources separately because the resources, especially video resources, are provided by different cameras under different spatial and times. However, some resources are related to one another and can serve multiple traffic events. Therefore, it is crucial to annotate these video resources with useful content. The appropriate annotations...
can create the semantic connections among video resources and allow their metadata to be understood globally. To this end, this paper has identified the following primary challenges.

1. Video resources which should be annotated precisely: it is important to use the appropriate concepts to annotate the video resources. Particularly in the traffic events case, the standard concepts should be provided to the users to annotate video resources. Moreover, it is difficult to use only one general description to tell the whole story of a video resource because one section of the video stream may have plenty of information but some may not be related to the main points of the video when it was created. Therefore, besides the standard concepts, a more accurate annotation mechanism, based on the timeline of the video stream should be required. For example, given a car in an image, different users may give different annotation of this car such as “car,” “vehicle,” and “SUV.”

2. The annotations of the video resources which should be accurate and machine-understandable, to support related organizing and searching functionality: though the standard and supervised terminology can provide accurate and machine-understandable vocabularies, it is impossible to build such a unified terminology to satisfy different description requirement for different traffic events. For example, the annotation of a red traffic light in an image may be helpful for detecting cross red lights.

3. Linking video resources using the annotations: of course, the web resources are not separate. It is crucial to explore, share, reuse, and link these multimedia resources for better organizing traffic events. For example, a video resource about a crash event can be linked to a video resource about a traffic jam at the close timestamp.

This paper adopts Semantic Web [2, 10–13] technology to address the above challenges. The following lists the major contributions of the proposed method.

1. A video annotation ontology [14] is designed by following the traffic law of China. The ontology provides the foundation for annotation videos based on both timestamp in the video streams. The ontology can provide not only the precise description details but also the standard machine-understandable data.

2. A semantic video annotation tool is implemented for annotating and organizing video resources based on the video annotation ontology. The annotation tool allows annotators to use domain specific vocabularies from traffic field to describe the video resources. These annotated video resources are managed based on the semantic relations between annotations.

3. A semantic-based video organizing platform [15, 16] is provided for searching videos. It supports reasoning operation of the annotations of video resources.

The remainder of the paper covers background and related work discussions (Section 2), the overall platform architecture (Section 3), the detailed illustration about the annotation process (Section 4), and the conclusions and future work (Section 5).

2. Related Work

In this section, we give the related work of the proposed method including the background of Semantic Web and semantic annotations.

2.1. On Semantic Web. The Semantic Web [25] is an evolving development of the World Wide Web, in which the meaning of information on the web is defined; therefore, it is possible for machines to process it. The basic idea of Semantic Web is to use ontological concepts and vocabularies to accurately describe contents in a machine readable way [26]. These concepts and vocabularies can then be shared and retrieved on the web. In the Semantic Web [27], each fragment of the description is a triple, based on Description Logic. Thus, the implicit connections and semantics within the description fragments can be reasoned using Description Logic theory and ontological definitions. Earlier research on the Semantic Web focused on defining domain specific ontologies and reasoning technologies. Therefore, data are only meaningful in certain domains and are not connected to each other from the World Wide Web point of view, which certainly limits the contributions of Semantic Web for sharing and retrieving contents within a distributed environment.

In this paper, the technologies from Semantic Web are used for annotation and organizing video resources. The following summarizes some important advantages of using Semantic Web to create video annotations for the educational domain.

1. The video resources of traffic events are unique and explicitly identified. Each video resource is identified by a URI and the RDF based content presents explicit semantics of the data.

2. The video resources of traffic events are annotated with a unified ontology. The unified ontology resolves the language ambiguities and allows machines to accurately process the meanings of video annotations.

The video resources are linked to each other. By using the semantic technologies such as RDF [28] and OWL [29], the relations among videos are created dynamically and explicitly. These relations improve the sharing, searching, and reusing mechanism.

2.2. On Semantic Annotation. The concept of annotation can be defined as “the practice of adding interpretative linguistic [17], information to a corpus” [18]. More concretely, annotation or tagging is a process that permits mapping attributes, comments, or descriptions to a document or to a fragment in a text. In general, annotations can be seen as extra information associated with a particular point in a document or another piece of information. Annotation systems can be classified into three different categories: manual (performed by one or more people), semiautomatic (based on automatic suggestions) [19], or simply automatic (based on computer annotations processes).

Semantic annotations help bridge the ambiguity of natural language and its computational representation in a formal
Table 1: The summary of the related semantic annotation approaches.

| Method      | Standard format | Ontology support       | Annotation storage       | Automation       |
|-------------|-----------------|------------------------|--------------------------|------------------|
| Armadillo [17] | RDF             | Multiple ontologies    | Semantic model           | Automatic        |
| CERNO [18]   | RDF OWL         | No multiple ontologies | Semantic model           | Semiautomatic    |
| CREAM [19]   | RDF             | Multiple ontologies    | Semantic model           | Automatic        |
| S-CREAM [20] | RDF             | No multiple ontologies | Semantic model           | Semiautomatic    |
| KIM [21]     | RDF extensible to OWL | Multiple ontologies     | Semantic model           | Automatic        |
| EVONTO [22]  | RDF OWL         | No multiple ontologies | Semantic model           | Automatic        |
| GoNTogle [23]| RDF OWL         | Multiple ontologies    | Semantic model           | Manual           |
| MnM [24]     | RDF             | No multiple ontologies | Semantic model           | Semiautomatic    |

language through ontologies. The process basically consists of inserting tags in a document. These tags represent links between text fragments and ontological elements (attributes, concepts, relationships, and instances). As a result of this process, documents are created that can be processed not only by humans but also by automated agents [20]. According to [15], these systems can be classified based on the kind of annotation method used. There are two primary categories, namely, pattern-based annotation and machine learning-based annotation. The former is based on discovery rules, and the latter relies on probabilistic and induction techniques. Although in the last decade several systems for ontology-based annotation have been proposed, there is no standard approach for semantic annotation [21–23]. The following table (see Table 1) shows some of the most well-known semantic annotation systems as compared against our approach, which is presented in the last row. The classification is based on the one presented in [24]. The parameters selected for their representation in Table 1 are the following: standard format, ontology support, heterogeneous document formats support, annotation storage, and automation.

3. The Overall Architecture

The proposed method adopts the principles of Semantic Web to annotate the existing video resources of traffic events. The video resources are also linked to each other based on the semantic relations.

The annotation tool has the following modules.

(1) Annotation ontologies module: this module provides the unified ontologies for users to annotate the video resources. Users can only use the provided concepts to annotate the video resources.

(2) Semantic mining module: different from the annotation ontologies module, this module provides the semantic rules for mining manually annotation data.

(3) Video resources annotation module: this module is the core module of the annotation tool. It provides a friendly interface to the users to annotate the video resources.

(4) Semantic searching module: this module provides the searching function of users. Users can search the related video resources according to their providing semantic annotations [30–32].

(5) Semantic analysis module: this module receives the searching result from the searching module. It analyzes the searching results and generates the semantic relations between the video resources.

In the next section, the detailed analyses of these five modules are given.

4. Semantic Annotation Tool

In this section, we give the detailed description of the proposed semantic annotation tool. The five modules listed in the Section 3 are introduced separately.

4.1. Video Annotation Ontology. The video annotation ontology and annotation instance are stored in a RDF scheme, and the ontologies reuse a number of RDF vocabularies. These ontology vocabularies are extracted from the following knowledge repository.

(1) The traffic law of China: we analyze the traffic law of China and extract the basic concepts from it, for example, the traffic light, car, people, and road line. These basic concepts are provided to users when they annotate the video resources. Since the video resources are all about traffic events, these ontologies are enough for users.

(2) The basic features of a car: we give the basic features of a car, such as color, shape. Figure 1 gives the car ontologies of the proposed method.

(3) The basic features of a person: we give the basic features of a person, such as cloth’s color, the hair style. Figure 2 gives the car ontologies of the proposed method.

Intelligent transportation was conducted abroad in the earlier time; many countries have been independent. License plate detection and recognition are a very important part in structured description of the video in intelligent transportation direction. Automatic Number Plate Recognition is the key technology in automated intelligent traffic management. By vehicle capture, image processing, license plate located,
character segmentation and character recognition, and a series of digital image processing and pattern recognition algorithms effectively extract the vehicle license plate information, and then it can be widely used in various applications, such as parking and district management, urban road monitoring. The process of Automatic Number Plate Recognition is as follows.

Image capture is a very important step in the whole process; the efficiency is highly dependent on the image quality. Now, there are mainly three technologies in image capture: based on car sense coil, radar, and video detection technology. The first two methods have high vehicle capture rate and can get precise vehicle speed, where both need equipment. While the last one uses the newest image technology and computer visual technology, it does not need any equipment, but it is easy to be disturbed by the environment.

The aim of image pretreatment is to improve image quality. It includes several steps, such as noise reduction, sharpening, and contrast enhancement. After the pretreatment, the image is more clear and in high quality, which is good for the following processing.

Locating the license plate is the key step in the process; it is to locate the license plate location in the image. The algorithms can be divided into two categories. First one is knowledge driven, which contains methods like those based on the color distribution of plate, based on edge detection, and so forth. The other is data driven; it uses features and classifiers to do the locating; features like histogram of oriented gradient, Haar-like, and classifiers contain neural networks, Adaboost, and SVM. This step is not necessary; if the result is not a standard rectangle, there is a need to correct it. Character segmentation is really important.
for character recognition, directly affecting the accuracy of license plate recognition. The mainstream segmentation technologies include projection, connected domain detection. The current common character recognition methods are simple template matching algorithm, genetic algorithms, KL transform and support vector machine (SVM), and artificial neural networks. The following section is to do a brief introduction of each license plate recognition algorithm and analyze their advantages and disadvantages.

4.2. Video Annotation Module. The video annotation module provides the core function for users. Users can use this module to annotate video resources. Of course, the annotation concepts should follow the ontologies. The annotation procedures of a user are as follows.

Select or upload video resources. Users can choose to annotate an existing video resource of uploading their own video resources. It is noted that the users of the proposed annotation tool are all policemen; the upload videos are also about traffic events.

(1) According to the given ontologies, users select the appropriate concepts to annotate the videos. For example, if a video contains a car, users should annotate the color, style, and other features of it.

(2) In a video, users can annotate the different frame in the different timestamp.

The annotation interface contains the following parts:

(1) Annotation part. The annotation part is in the middle of the annotation interface. Users can annotate a rectangle to her/his interested parts. For example, users annotate the person in the car.

(2) Input part. The input part is in the right of the annotation interface. Users can input the detailed features of the provided attributes. For example, users annotate the hair style, cloth color of the person.

(3) Time scroll part. Time scroll part is in the bottom of the annotation interface. Users can scroll forward or back of a video. For example, users annotate the image in the 8:02:43 of the video.

Vehicle color recognition plays an important role in monitoring road; it is also an indispensable part in vehicle static information, especially when the license plate positioning system cannot locate license plate accurately. Vehicle color recognition system mainly recognizes the vehicle body color from the segmented image and classifies the color to the color classification. Vehicle color classification can be simply divided into multicolor and achromatic. Multicolor contains eight types, like red, green, and so forth, while the achromatic is black, white, grey, and silver. The number of vehicles in achromatic is bigger than multicolor. Nowadays, research on vehicle color recognition system is mainly in two parts: how to pick the vehicle body color recognition area and identify the color.

Color recognition is based on the color characteristics. Different from the image texture and shape, color characteristics have small dependence on image size, and computational complexity is low. There are various manifestations, such as color histogram and color moment. The color characteristics often use color space to express. The most common color space is RGB, YCrCb, HSI, CIELab, and so forth. As HSI is really conforming to people’s eyes, it is the most common. Different color has different advantages and disadvantages, so before image process, we should choose proper color space first. According to this feature, many algorithms firstly choose one color space and then define the threshold of the color through a priori knowledge to identify the color. This algorithm is easy to apply, but not good in stability. Color difference is used to describe the difference between colors. The algorithm counts the feature that different vehicle color is shown in different illumination and uses it as feature vector. Next, nearest neighbor algorithm is used to identify color difference. Commonly, Euclidean distance is counted to describe similarity. The smaller the color difference, the greater the likelihood of the color.

From the perspective of machine learning, there are algorithms: Bayesian classification, Boost, random forests, decision trees, K-means, and so forth. These algorithms have to be based on the training samples features, and use appropriate classifier model to complete color recognition. The result is good, and the key point is color feature. Now, research of color recognition is in the preliminary stage; there are still many challenges. Poor image quality, color difference, noise disturbance, the illumination, and other factors will influence the result of the color recognition. So the pretreatment is essential. Besides, choosing classifier and machine learning algorithm is significant.

4.3. Video Searching Module. The video searching module provides the search function for users. Users can use this module to search video resources. Of course, the search concepts should follow the ontologies. The searching interface contains the following parts.

(1) The queries input part: the queries input part is in front of the searching module. Users can input the searching queries in this part. For example, the user searches the query “car light.”

(2) The searching results part: the searching results part is in the middle of the searching part. Users can browse the searching result in this part. For example, if users search the car light in the searching module, the returned results are all annotated image or video resources contain the concept “car light” in the annotated metadata.

(3) The video searching module is implemented on the Virtuos [36] database. Java is used to add, delete, and revise the database. Different from the Larkc [37] and SDB, the Virtusoso database contains the better performance and friendly interface.

With the rapid increase in car ownership, more and more cars are using fake license plate which requires high standard vehicle identification and detection technology, while identifying the license plate number, using the consistency of license plate number and vehicle type to test whether it is illegal vehicles. Logo as a significant feature of vehicle, it plays key role in identifying vehicle type. Logo recognition system is a crucial part of the video vehicle detection system. If the logo can be located precisely, the accuracy of logo recognition
will be highly improved. And then improve the accuracy of vehicle type identification.

Logo recognition contains two steps: logo location and logo identification. Now, the widely used methods of logo location are as follows: based on texture consistency logo location methods, the use of the car standard vertical edge energy method [17], based on PCA and moment invariants logo location method, and based on energy enhancement and morphological filtering logo location method. Logo identification methods include template matching, based on pixel distribution, based on the edge of the histogram, and based on edge moment invariants methods. Logo location and identification methods are as follows. The logo location process is divided into four steps.

Locate a coarse position of the license plate. Many methods can be chosen, for example, based on the color information of the license plate, based on the edge detection, based on the geometric characteristics of the license plate, and based on the spectrum analysis. Locate a coarse position of the logo. Locate the logo's left and right bounds. Locate the logo's upper and lower bounds. The algorithm of logo identification is as follows.

The specific method is (1) to deal with the located logo screenshot, horizontal quartered and vertical bisected. Thus the screenshot now is in eight equal portions. (2) Calculate every pixel's gradient direction and the gradient that are in the logo screenshot and classify the gradient direction to eight-direction unit, which are $0^\circ$, $45^\circ$, $90^\circ$, $135^\circ$, $180^\circ$, $225^\circ$, $270^\circ$, and $315^\circ$. (3) Count the pixels that are classified to the eight direction unit, and then a $8 \times 8$ SIFT feature vector is produced.

The main task is to classify the $8 \times 8$ SIFT feature vector. The classifier can be SVM or others. SVM algorithm can use the known efficient algorithms to find the global minimum of the objective function. However, other classifiers such as neural networks can only get the local optima.

4.4. Semantic Analysis Module. The semantic module receives the searching result from the searching module. It analyzes the searching results and generates the semantic relations between the video resources. From the annotation tool extracts the relation between images based on the annotation. Since the annotation is based on the ontology, it is easy to reason the relations by predefined relations.

Use the technology in image processing to analyze the vehicle's pattern recognition based on image processing, which means to feature in the image, and then identify the vehicle type through pattern recognition. The advantage of the method is that it can fully exploit all kinds of information in an image, and use the information to identify vehicle type. Besides, its tools are low in complexity and easy to maintain. However, it does have some shortcomings, such as the vehicle's features are hard to extract and the algorithm's complexity is high. The following part is an introduction of vehicle type recognition algorithms based on image processing.

As for the first one, the algorithm is to regard the vehicle image or a part of the vehicle image, and then use linear projection or matrix transformation to extracting algebraic features of vehicles. Vehicle type recognition system based on algebraic features has three parts: locating the interest area, extracting the regional characteristics, and vehicle type recognition and classification. And according to the different interesting region, there are three types: algorithms based on plate color, algorithms based on logo, and algorithms based on vehicle facial feature. And now this paper elaborates the three types of algorithms. Vehicle type recognition system based on plate color is very easy. As the method is depending on the standard which only distinguishes larger and small vehicles, thus, this method is always used as an aid and used in conjunction with other algorithms.

Vehicle type recognition system algorithms based on logo. It mainly uses logo to identify the vehicle. The feature extracting method is quite clear and the model is simple. However, it cannot distinguish different models of the same series. Moreover, if the logo is fuzzy or off, the method does not work anymore.

Vehicle type recognition system algorithms based on vehicle facial feature. Vehicle facial is the front flat area of the vehicle, which contains plate, logo, exhaust network, lights, and so forth. The method is to identify vehicle type on the basis of extracting feature of the vehicle face. As different vehicle has different exterior vehicle design and the uniqueness mainly reflect in the vehicle face, it contains various information of vehicle models. In theory, this method can classify the vehicle precisely. However, features the method needs are in large number and various classification, so the algorithm is complex and needs large workload.

In the vehicle type recognition system based on algebraic features, the most important part is located region of interesting; the common method is locating the plate position first and then using a priori knowledge to locate. As for extracting features module, there are many methods, such as extraction based on the characteristics of K-L transform, Gabor filter-based feature extraction, SIFT-based feature extraction, extraction based on PCA, and LDA weighting characteristics. The last step is vehicle type recognition and classification; there are many methods which can be divided into two categories; one is training-based approach, for example, BP neural network, SVM, and Adaboost. The other is method based on template matching, namely, to match the features extracted and the template model's feature to get exactly vehicle type classification.

5. System Architecture

System architecture design is divided into three levels system architecture, through effective hierarchy that can fully show the whole application system design thought, system architecture, and data flow.

The base layer is mainly composed of mysql, solr, and file systems. Mysql runs by using the single instance mode; the default listener port is 3306; set up a database. The database is composed of several tables, used to support the vehicles advanced retrieval, statistics, and statistical and monitoring alarm business models; Solr is used to support text search operations; the file system is used to store the image data layer.
The gateway program of Business Logic Layer is responsible for analyzing the results from the terminal of structural description, putting the information into a mysql database, solr, and file systems, and sending the alarm data obtained from the analytical to the message queue. The gateway program can receive the information from the front-end configuration; open API system will perform inheritance to remote invocation framework and is responsible for querying the database and statistics. Then it will put the statistical data which need to alarm in the message queue.

Presentation layer is mainly a Java web application. On the one hand, presentation layer will access API system by means of remote method invocation (RMI), obtain the results of query and statistical. On the other hand, presentation layer will get the alarm information from the message queue and show the two results to the user.

We mainly are through two servers in the central engine room to install the deployment; one is used for image information database; the main deployment is mysql relational database, solr search application and FTP, and so forth; another server is used as application management; the main deployment is message queue service, the web container. At the same time, this server needs to run the gateway program, API service, and Java web applications by third research institute of the ministry of public security research and development.

As a corresponding topology, we put the high-speed service area surveillance system in Nanchang as an example. The import and export of surveillance area, namely, Lushun service area to Yinchuan direction and the direction of Yinchuan to Fujian, have four road bayonets. There are two parts of every road bayonet which are a gun camera and a terminal of structural description. We put the service platform in center engine room of the high-speed service area and set two dell servers. The information of surveillance area is transmitted to the center engine room by the IP network. The center engine room will provide surveillance, management, query, and alarm for the staff of the service area by the IP network and mobile communication network.

The video surveillance system in the high-speed service area is based on the video, to analyse the vehicle flow, and provides alarm of parking spaces, stranded and violation. First we will install GigE Vision standard camera which is used to output the original video stream in the surveillance area, namely, in road bayonet. Usually, the camera is set up at 8 m height above in order to make ultra high vehicles through; the second one in the import and export of the high-speed service area, respectively, set up collection and analysis equipment, which is used for video capture, analysis, coding, storage, distribution, collection and release, and so forth. Collection and analysis equipment will count the number of vehicles, license plate, the speed of the vehicle, and color information of the vehicle by capturing moving objects in video and vehicles on the video structural description, according to the semantic relation of video content, using spatiotemporal segmentation, feature extraction, object recognition, organized into text information available for computers and human understanding of technology, offering illegal stay, retention service area, parking, early warning, and alarm information. In order to reduce the influence of external environment on the cabinet of the equipment, the collection and analysis equipment cabinet is equipped with lightning protection, temperature, voltage regulation equipment. Then, the collection and analysis equipment will transmit collected information to the service platform. Image information server (or streaming media server) is used to publish and play videos. Application management server (or web application server) will provide analysis report to the police, query, and management of application. Finally, application management server receives the alarm and statistical information, deposited it into the database, and shows integration of information in the form of web pages to the user.

This system provides VOD functions. The realization of the function of VOD mainly depends on SQLite. Open a new file and write a video, in the database, the content including file address, file name, video start time, and video over time. When finishing sending a file, postpone request time; repeat the above steps, until the length is zero.

6. Conclusions

Image and video resources play an important role in traffic events analysis. With the rapid growth of the video surveillance devices, a large number of image and video resources are increasingly being created. It is crucial to explore, share, reuse, and link these multimedia resources for better organizing traffic events. Most of the video resources are currently annotated in an isolated way, which means that they lack semantic connections. Thus, providing the facilities for annotating these video resources is highly demanded. These facilities create the semantic connections among video resources and allow their metadata to be understood globally. Adopting semantic technologies, this paper introduces a video annotation platform. The platform enables user to semantically annotate video resources using vocabularies defined by traffic events ontologies. Moreover, the platform provides the search interface of annotated video resources. The result of initial development demonstrates the benefits of applying semantic technologies in the aspects of reusability, scalability, and extensibility.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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