A Web-based Surveillance System for Traffic Behavior and its Application for Practical Recommendation of Crosswalk Installation

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ABSTRACT: *A Web-based surveillance system has been developed to observe some intrusion into dangerous and security area. It is designed based on a Linux PC with Web services, Open CV engine, remote monitoring camera, remote controlling sub-server and other facilities. It supports users of mobile phones. Its image understanding facility by Open CV engine gives us information about intruders' tracks at the monitored places. As the result, it is beneficial that we can exactly know moving direction of intruders. Traffic security is one of the most important problems to be improved for our daily environment. In order to monitor traffic behavior, the surveillance system has been customized and applied to monitor traffic behavior about a specific area. It can acquire data about intruders' tracks when they go across relatively narrow streets. Such data provide information about suitable place to realize a necessary crosswalk which will comply with silent but real intruder's requests. Its monitoring function and image processing one are not so excellent but there are significant results for surveillance by means of limited adoption and adjustment. And we can recommend installation of Crosswalk based on intruders' tracks with image processing function of the surveillance system. It is concluded that our surveillance system is efficient enough to observe a specific place, compute image understanding about it and mine some kind of useful information of intruder's periodical behaviors.*

Categories and Subject Descriptors: H.3.4 [Information Systems]; Systems and Software - Information Networks: **K.4 [Computers and Society];** Privacy*:* **H.5.2 [User Interfaces];** Graphical user interfaces (GUI): **H.3 [Information Storage and Retrieval];** H.3.4. Systems and Software -- Performance evaluation (efficiency and effectiveness):

General Terms: Surveillance system, Image understanding

Keywords: Surveillance system, Mobile computing, Image understanding, Evidence-based recommendation

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1. Introduction

As a social background, an increase of criminal behavior is one of the major factors that have been pushing up the demand for remote surveillance system. Security cameras play very much important roles of many surveillance systems, and several companies have designed and produced many kinds of such cameras. Some surveillance systems have been developed even in our laboratory for the sake of their applications to continuous monitoring of working system, protection of intruders, and so on [1][2][5][7][10].

Security is one of the most important keywords to utilize a surveillance system in the real world. A surveillance system with monitoring facilities will become useful and necessary for improvement of our security and daily lives, because, even in Japan, they are directly related to the matter for consideration of ways to ensure our safety. Some surveillance systems have been introduced at companies, elementary schools and other social organization in order to keep our lives from facing crimes and accidents [4]. Not only surveillance but also security cameras are widely employed and working in the several area and public environment. Managers, teachers, parents and other users want to utilize surveillance systems or security cameras and obtain useful image-based information, because they need such information for their appropriate determination as well as risk aversion [7].

So surveillance systems should not be restricted to narrow and limited usage for prevention of criminals. For example, we can compute image processing and get information about intruders' tracks in the monitored places, after application of our surveillance system into detection of intrusion. In such a case, the surveillance system will be very useful to understand trace of intruders' tracks exactly. It may provide knowledge about correct direction of intruders. We have applied our system to acquire data about tracks of intruders who go across a not-so-large street. Consequently, it helps us obtain appropriate information about the monitored place to realize a necessary crosswalk based on real evidence.

This paper introduces our surveillance system with monitoring facilities, explains its GUI for mobile computing devices, and illustrates its image-processing facilities and e-mail services for emergency contact. And then it describes detail and evaluation of our surveillance system and its application to traffic assessment. Namely, it presents graphically that our system provides useful information about intruders' tracks in the monitored places. Finally, our system is very beneficial to perform evidence-based demonstration in order to prepare application proposal of crosswalk installation.

2. Monitoring Facilities of Surveillance System

Our Web-based surveillance system is introduced in this section. It is organized with an integrated information server called JSW(Java Web Server), network cameras, control subserver for peripheral appliance devices, and so on. JSW periodically obtains images each the network camera through its private network. The images are transmitted from a camera

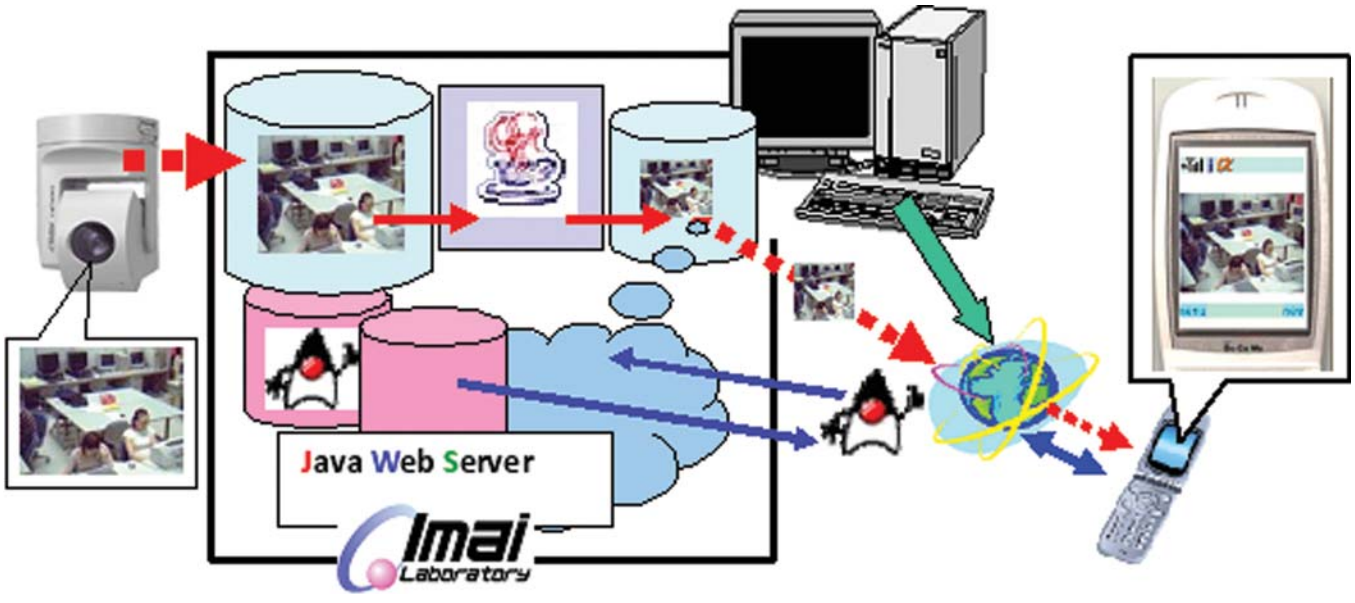

Figure 1. A Scheme of Remote Monitoring Procedure and GUI of the Surveillance System

to JSW through HTTP-based communication procedure. They are accumulated as JPEG images temporally into an internal buffer of JSW, reduced into a fourth or a ninth resized image data, and finally stored into JSW's image database.

Such images are used for remote monitoring services of our system. For flexible availability of surveillance, image reduction is necessary because some mobile computing devices can only allow data transmission with a limited amount of packet size between server and themselves [8][9]. Our system can only deal with continuously stationary images still now, although moving pictures would be much more effective to make a suitable decision for the target situation than static ones. Figure 1 shows a scheme of remote monitoring procedure and GUI of our system.

Our system prepares Java Applets on specific homepage of JSW and distributes them through its Web service. JSW is not a freeware such as Apache but our original software for flexible customization. It begins to run the process of an HTTP daemon service, waits for client's access from global network and then delivers its Applet to an according target client. At a client side, the above Java Applet downloaded from our system provides a GUI service, which can communicate the surveillance system to request transmission of JPEG image by means of HTTP connection, output received JPEG data file on the browser of client PC, and display it in the stationary mode or continuously alternating one like as slide show.

In the case of later mode, the Applet can perform continuous prefetch of JPEG data from the server, store and preload in the double-buffering style, and then realize quasi-moving pictures on the display of client's browser. If communication band is available enough, our users can get dynamically altering pictures and enjoy an ever-changing scene about the target.

It may be more effective and convenient for clients to browse specific monitoring images with their mobile phones, because almost all people (in the Japanese case) always carry their mobile phones together with them. One of various Java technologies such as, for example CLDC (Connected Limited Device Configuration) of Java 2 Micro Edition [6], allows us to utilize relatively small sizes of Java application program working on the specific mobile phones. Such a Java program can be downloaded from a certain Web server and perform a mobile communication based on HTTP-connection between our system and mobile phones, and then perform display control of the mobile phone. Each monitoring image is obtained by camera as JPEG data and transmitted into JSW of our surveillance system periodically.

As explained in the former part, such an image data has been resized suitably for displaying on mobile phone. Figure 1 also illustrates a sample display of Java application emulator for a certain mobile phone [9][13]. As there are some constraints on the image data size, which mobile phones can accept at the one time, for both of transmission and display of it, then our surveillance system must reduce JPEG images from network camera into a suitable size for mobile phones and accumulate these images in its storage for request of image delivery from mobile phones [3][6].

3. Image Understanding and Emergent e-Mail Services of our Surveillance System

Our surveillance system can provide image understanding facilities based on Open CV and some kinds of their applications. And an emergency contact with e-Mail service will be illustrated

Figure 2. Detection of Intrusion at the Specific Place: it is judged as intruders

Figure 3. Detection of Intrusion at the Specific Place: it is judged that there is no intruder

as one of applications in this section.

3.1. Detection of Intrusion

At first, in this section, it is necessary to explain a procedure for intruder judgment method and intrusion tracks acquisition with our surveillance system. Its image-understanding facilities for monitored image are provided based on a background difference method and Open CV libraries.

In order to judge whether such an image includes an intruder or not, our system can perform the following procedures:

1) Extracts a candidate area which is recognized as difference of basic frame,
2) Compares the according area with the pre-defined threshold size described below,
3) Determine the area including intruder, and
4) Specify explicitly the according area with a mark, namely surrounding the intrusion object acquired from the image with a red circumscription rectangle.

The conditional expression for comparison procedure is shown below,

$$S_{min} < S < S_{max,}$$

where S is the area of target object to be an intruder. S_{min} and S_{max} are lower limit and upper one of thresholds of the area of the intrusion object. These thresholds decide the circumscription rectangle for intrusion object shown in Figure 2 and 3. Figure 2 shows two red circumscription rectangles to judge intruders, while Figure 3 shows no circumscription rectangle, so that it does judge that there is no intruder at the according place.

3.2. An e-mail service for emergency contact

Users whose e-mail addresses have been registered in our surveillance system can receive e-mails about some kinds of message from JWS of the system, when monitoring and image-understanding facilities recognize a remarkable change at the specified target and decide to send message to such users. An e-mail service for emergency contact will be done in the above procedure. Figure 4 shows a scheme of our e-mail service for emergency contact with cooperation of image-understanding facilities.

Such a mail has the image of intruder as an attached image file. Therefore, the users can investigate received images by means of their viewer to perform practical determination whether intruder enters at the specific place really or not.
Our message mailing service covers the following two cases; namely,

1) A normal e-mail transmission service, which includes sending message to such personal computers connected to wired/wireless LAN.

2) A mobile e-mail transmission service, which deals with mobile phones and/or PDAs through global communication network.

In the former case, generally speaking, an e-mail service is one of the most usual and daily message transmission methods between computer's users of LAN and the Internet [11]. And the message to be sent may contain a description of the special URL, which shows users to get information about image,

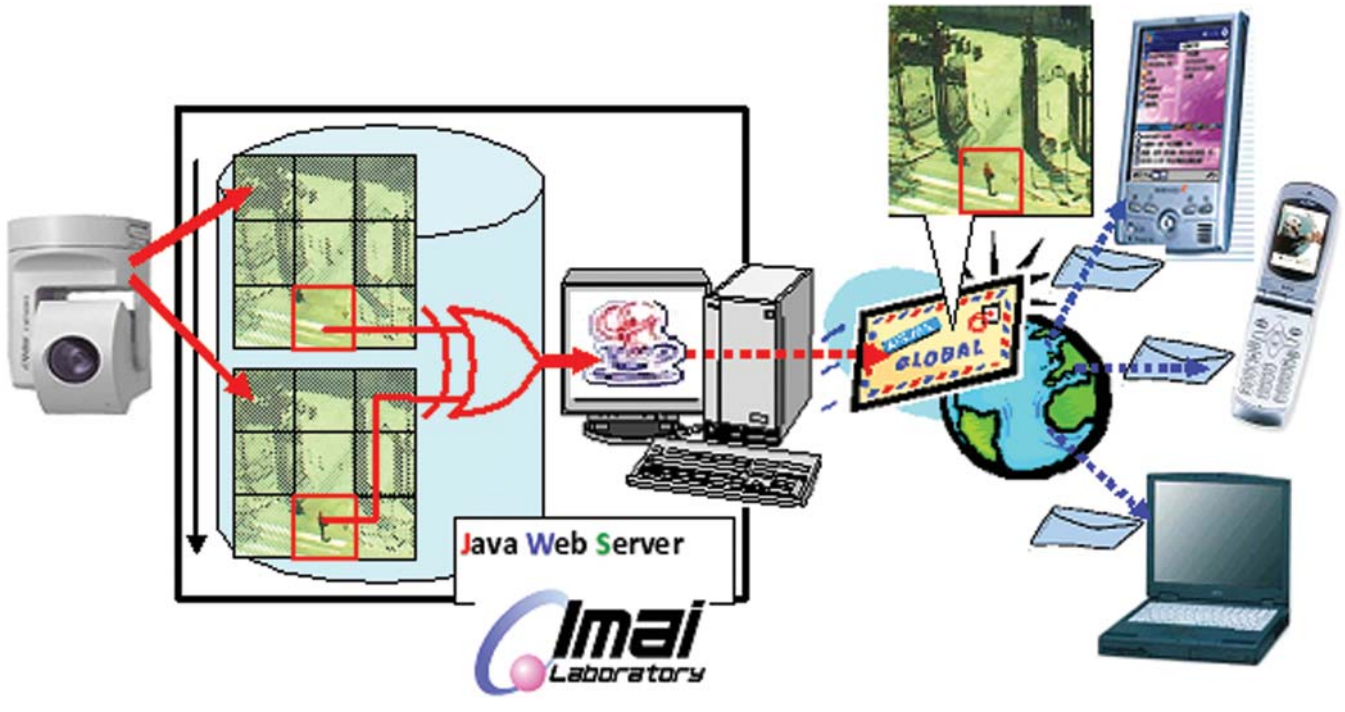

Figure 4. Schema of Image Understanding with Database and E-mail Service for Emergency Contact

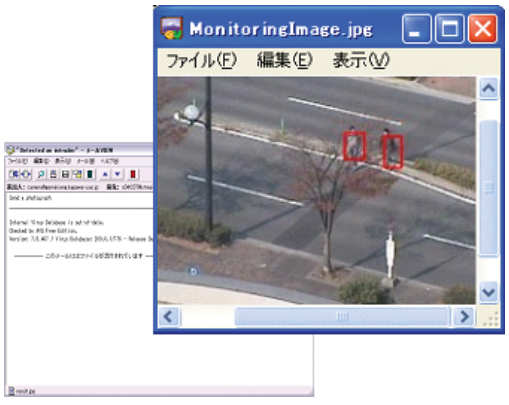

Figure 5. e-Mail from the Surveillance system for Emergency Contact (on PC)

control scheme or Java applet, shown in Figure 5. With such information, each client of the system can access the suitable resource to steer his/her monitoring device efficiently.

On the other hand, users of our system sometimes leave their seats where they sit down and work with computers. They will carry mobile phones or PDAs with them, however, even at such a situation. In the later case, a mobile phone and/or PDA provide wide area of e-mail service to our clients, shown in Figure 6, so that message from the system can be delivered to the according clients no matter where they are [3][12]. It is very much useful for emergency message to be sent to the specific clients when the system get their permission before the fact and decide to utilize e-mail service through global communication with mobile phone network.

An emergency contact can be performed with the above e-mail service as follows:

1) JWS of our system periodically obtains a series of images from network cameras.
2) It invokes image-understanding facilities in advance.
3) It performs the according recognition when a new image is partially different from the previous one.
4) It investigates whether the target image has a certain difference in comparison with base image on a ninth of whole image or not.
5) It detects that some change of images happens at the monitoring place if such a procedure proves some difference between two images.
6) It decides to send a suitable style of e-mail by means of the above e-mail service.

Our surveillance system has been customized to deal with function of a mail server directly. When image recognition procedure points out the difference between target images, the system has sent e-mail to the previously registered clients with e-mail sending facilities. Especially, sending e-mail to mobile phone is convenient and effective because such users almost always carry mobile phones with themselves [13].

4. Application to Recommendation for Crosswalk Installation

This section illustrates an application of our system to traffic assessment in order to reduce traffic accident. The first half of this section describes performance evaluation for image processing facilities of our surveillance system. And then the second half shows an application of the system to practical recommendation for crosswalk installation.

4.1. Performance evaluation for image processing facilities

As shown in our previous report of performance evaluation for our surveillance system [13], we had measured 10 times of response time of an image, from pushing a button of phone to getting image on the display of mobile phone as transmission time of an image. The average of transmission time of an image is 5,089 milliseconds (about 5 seconds). Amount of image is 2.2-kilo bytes in that case. Due to global communication of mobile phone network, transmission times range from 2,060 to 7,100 milliseconds. In almost case, however, clients of our surveillance system will be able to obtain the monitoring image and take a look at the display of mobile phone about under 10 seconds of response time. In almost case, however, clients of our surveillance system will be able to obtain the monitoring image and take a look at the display of mobile phone about under 10 seconds of response time.

In order to show another performance evaluation of our system, we illustrate two graphs to explain image- understanding facili-

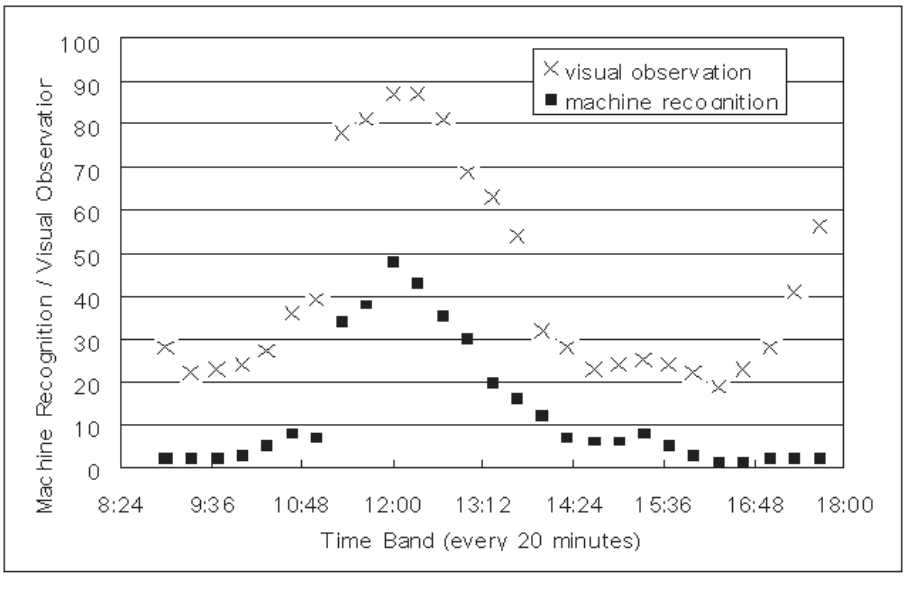

Figure 6. e-Mail from the Surveillance system for Emergency (on Mobile Phone)

ties. Graph 1 shows time-series analysis of comparison between visual observation and machine recognition for intruder's track for image received from the surveillance system.

Graph 2 shows another time-series analysis of cognition rate based on the above comparison. Measurement has been carried out from 9:00 O'clock (morning in Autumn) to 18:00 O'clock. And sample rate of comparison is every 20 minutes during 9:00 and 18:00.

Graph 1. Comparison between visual observation and machine recognition for intruder's track.

Graph 2. Recognition rate based on comparison between visual observation and machine recognition.

Numbers of real intruders at the target place increase from Morning to 12:00 and decrease to Evening. It is confirmed by visual observation for image received from monitoring camera. Numbers of intruder detected by the surveillance system (= numbers of machine-recognized intruder) vary just like ones of visually observed intruder. In fact, recognition rate based on image-understanding facilities of our system is not constant but changing because of influence of sun angle, shadows and other conditions of the target place.

Graph 2 tells us change of recognition rate of image- understanding facilities. It is changing from 0.036 (at 18:00 evening) to 0.552 (at 12:00 high noon). The average of recognition rate is 0.304 (about 30%). This is not so good score on image processing performance itself. But it can be available for detection of intruders at the target place under the condition that about 40% mounts of intruders used to enter into the place during 11:00 and 13:00.

4.2. Evidence-based recommendation for crosswalk installation

As mentioned above, it is judged that an appearing object must be an intruder when the size of the according object satisfies the range of the conditional expression in the previous section. After this appearing object is recognized through image processing, it is enclosed with the redline circumscription rectangle. And the intruder's track is simultaneously recorded and cumulated into the database of the surveillance system with its position and the according time stamp. In such a case, position is calculated as the center of gravity of the circumscription rectangle. After that, this image is used for evidence-based demonstration as follows.

In order to achieve fast response, employed algorithm is not complicated. Consequently, recognition rate of intrusion is not so excellent as described before. If we wanted to improve precision of our fast recognition of intrusion, we would have to invest more computing power and more excellent algorithm into this judgment of intrusion. So we think our surveillance system is suitable for problem solving for human matters, because such an application is expected that our system is available based on human check (or support) for compensate its low recognition capability.

We have applied our system to traffic monitoring and find that there is relatively huge numbers of intruders are concentrated at some specific place during specific period of time. Figure 6 shows huge numbers of intruders concentrated at the specific place. This is special case that many people get across a relatively narrow street during lunch hours (from 11:00 to 13:00), because they want to go to noodle shop to have their lunch. And there is a trend towards increasing traffic mount during the above period of time.

As a computational result based on recognition of intrusion, it is confirmed that people who go across the street are recognized and judged to be intruders at a heavy traffic place during specific period of time. Our surveillance system can illustrate evidence-based demonstration for many intruders at such a heavy traffic place. Namely, people who want to have lunch go across a dangerous place periodically. Our system can also point out that some traffic assessment will be necessary for people who intrude into such a dangerous place to receive more safe condition.

In order to reduce traffic accidents, an application proposal of crosswalk installation can be realized as follows.

1) Our surveillance system is set to monitor the specific place and to analyze what time and how many people enter into such a place.
2) Information about tracks and time stamps of intruders are cumulated into database of our system.
3) Intruders' tracks are illustrated as little red circles at the monitored place during specified interval as described

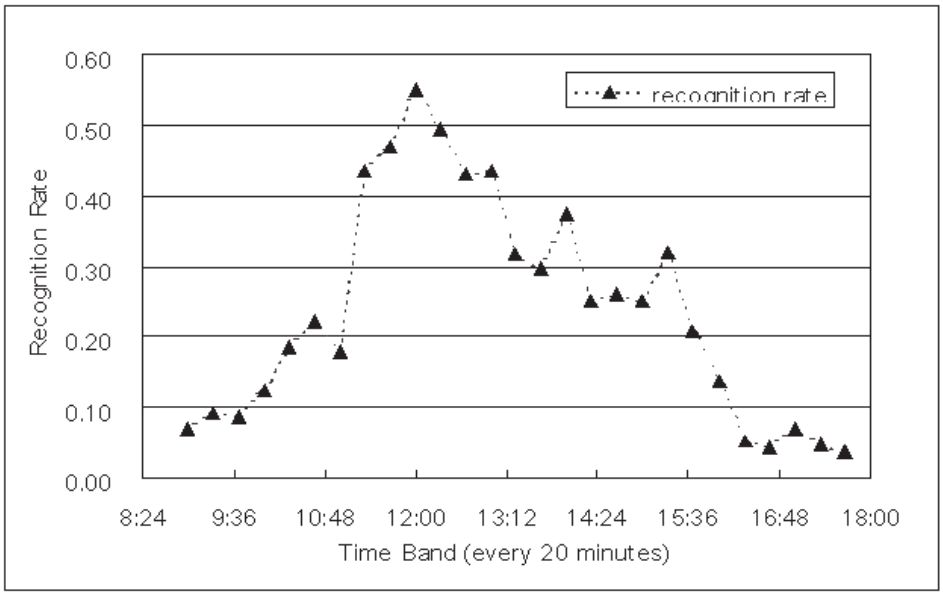

Figure 7. Accumulated Tracks of the Intruders at the Specific Place.

Figure 8. Imaging of Crosswalk Installation

in the previous explanation. Information about intruders' tracks can teach us how many numbers of intruders enter into this dangerous place during specific period of time.

4) It is proposed that if a crosswalk is installed, many people can go across the street more safely during specific period of time. It is demonstrated based on evidence which can be derived from computation of intruder recognition, shown in Figure 7.

This application seems to be another performance evaluation of our surveillance system. In conclusion, it is useful to show evidence-based demonstration of application proposal of crosswalk installation shown in Figure 8.

5. Conclusion

This paper introduces our Web-based surveillance system. The system provides image understanding and e-mail services as well as remote monitoring one. Some characteristic properties are illustrated to be useful in the applications. And its performance evaluation is explained in relation to the response speed for remote monitoring and to recognition rate for image understanding. The second part of this paper describes an application of the surveillance system to reduction approach of traffic accidents. In concrete term, it explains how to apply the system into evidence-based practical recommendation of crosswalk installation.

It is confirmed that image understanding facilities and e-mail service are available for detection of intruder and accumulation of intruder's tracks. And it is also demonstrated that our Web-based surveillance system is significant to perform practical recommendation of crosswalk installation In the future, we must tune up our system in order to be more available and applicable:

1) Adjustment of the threshold for suitable (more precise) comparison.
2) Increase of detection function against several kinds of disturbance.
3) Improvement of adaptive control for camera homing.
4) Performance of automatic recognition of Intruder's tracks.

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