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ROAD MONITORING METHODOLOGY USING IMAGE REGISTRATION TECHNOLOGY

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ABSTRACT

Real-time monitoring using CCTV is performed 24 hours a day at the major points of roads, tunnels and bridges. In particular, tunnels and bridges are subject to regulations regarding regular monitoring, traffic flow and facility management for all sections. Even in the case of roads, CCTV monitoring is conducted around the intersection, and the CCTV monitoring system is constructed and operated to monitor the entire sections in urban roads and expressways.

However, since the same background is displayed on the screen of the CCTV installed at different positions in tunnels and bridges, it is difficult to quickly and accurately detect specific position by the CCTV screen alone. This in turn makes it impossible for the beginner of the system operation to respond quickly to the unexpected situation on the CCTV screen.

To overcome this problem, this study proposed a methodology for road monitoring utilizing image registration with the use of overlapping part of the CCTV image. In this case, since the image seen from the side of the road was collected due to the CCTV installed on the side of the road, the collected image was corrected to that taken from the top to conduct image registration. In addition, the optimum application methodology was derived by analyzing the error rate of the image registration according to the installation height of CCTV.

Key Words: Image Registration Technology, CCTV, Image Rectification, Image Stitching

Introduction

In Korea, the government has actively promoted the revision of laws and regulations related to traffic safety and projects to prevent traffic accidents since the National Assembly passed the ‘Traffic Accident Zero Resolution’ in 2013. As a result, the number of deaths due to traffic accidents in 2014 was reduced to less than 5,000 in 37 years after 1976. However, the death toll from tunnel traffic accidents increased by 170% in 2012 compared to that in 2008. and the number of injured increased by 190%(Press release from Lim Nae-hyun, a member of the

national assembly, February 2014). If a quick response to the traffic accident in the tunnel is not done, it leads to a high risk of secondary accident, and the scale of the accident is also larger than that of the accident that occurs on the general road. In addition, the extension of tunnels has continuously been increasing due to the geographical characteristics of the country. Therefore, it is urgent to seek measures to increase traffic safety in tunnel sections. According to the results of reviewing the current tunnel section management systems and conducting interviews with working-level personnel, accurate site monitoring and rapid response to the situation are difficult due to the monitoring system, which is not intuitive.

Therefore, there is a need not only for rapid and accurate monitoring systems for tunnel sections, but also for smart control systems to allow tunnel managers to take quick response measures. In this regard, this study proposed a method to correct multiple CCTV images to those seen from the top of the road and conduct image registration with the focus on the overlapping part of the corrected image. It is expected that the registered image will help to quickly identify the exact locations of unexpected situations that occur on the road, as compared to the existing monitoring method, and thus to promptly respond to the situations.

Image registration technology trends

Image registration refers to a process of aligning two or more images obtained with different time intervals, those obtained at different points in time or those obtained from different sensors into one coordinate system. Depending on the registration process, the image registration is largely classified into area-based registration technique, shape-based registration technique, relational registration technique and comparison technique of feature point operators. The characteristics of each technique are shown in the following table.

Table 1 Image registration methods and registration elements

Registration methods	*Conjugate entities*	*Registration elements*	*Similarity observations*
Area-based registration - Brightness correlation method	Point	Brightness value	Correlation coefficient, standard deviation
Shape-based registration	Point, line, face	Extracted image	Cost function
Relational registration	Point, line, face, area and etc.	Symbolic relationship, semiotic characteristics	Cost function
Feature point registration	Point	Extracted image	Cost function

The most active use of image registration technologies is made in medical and control fields. In the case of the medical field, medical images obtained by different types of medical image acquisition devices, those between other patients obtained by the same medical image acquisition device or those from the same patient obtained at a different time zone are converted into the same coordinate system and then utilized in a comparative analysis.

In the control field, the image registration technologies have been applied and utilized in panorama vision. Panorama images can be made by creating a whole image with a number of small images of external areas with a focus on the subject or by creating a single image with several images of the subject taken from external areas, as in QuickTime VR^{TM} developed by Apple. These image registration technologies have already been applied in the realities of life such as virtual tour to art galleries and museums.

In the case of the image registration algorithm, the biggest problem lies in the fact that while the subject is three-dimensional, the photographed image is located in the plane. Because of this, the photographed image is simply registered, distortion occurs, which may result in serious errors in object recognition and tracking. Therefore, the main point of technology implementation is how to process the points where the two images meet, while performing image registration using only the region that can minimize the distortion. In the case of moving vehicles, it is possible to obtain a smoother registration image by using the technologies of extracting feature points of the background or foreground for image registration and tracking the moving objects after the background segmentation or foreground/background segmentation with the use of an algorithm that distinguishes the object(vehicle)area and fixed background area.

Image Registration Algorithm

The image registration technique used in this study is to extract the feature points of the image and use the feature points to perform fast registration. The detailed descriptions of the image registration technique structure and each procedure are as follows.

① When images acquired from one or more cameras are entered, the images are formed for each frame and image, when each image is subjected to image rectification (3D→2D) to extract feature points for each image.
② At this time, the process of adjusting the number of feature points is performed for the efficiency of the algorithm.
③ The normalized mutual information with a focus on the maker points of each image is calculated to select the feature points with the highest level of correlation.
④ The feature points of these images are used for corresponding pair matching, and each image is sequentially registered.
⑤ The optimal matching image is registered by identifying the convergence of the feature points for each image.
⑥

The image registration algorithm created based on the above process is shown in Figure 1.

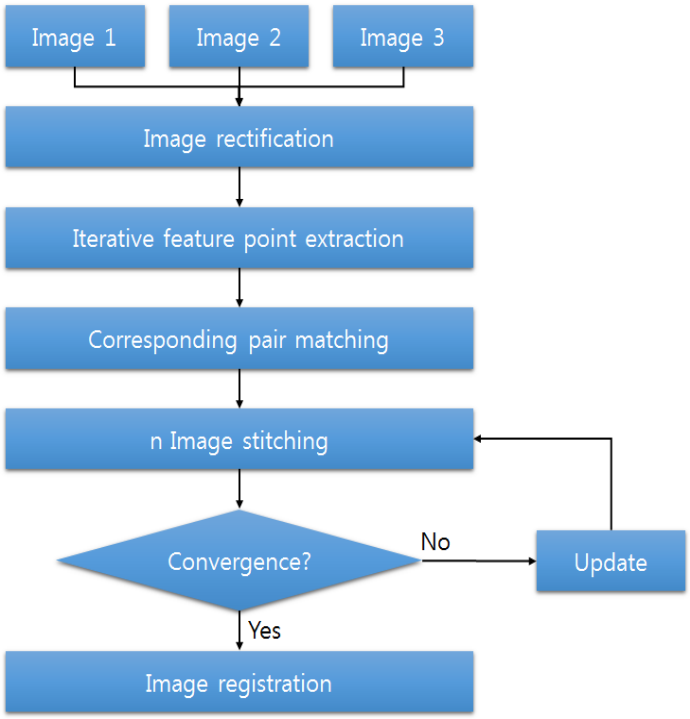


Figure 1 Image registration algorithm

Image Rectification

The process of changing the CCTV image taken from the side of the road to the image seen from the top of the road is referred to as image rectification. The detailed method of image rectification is performed in three steps.

The first step is to set the installed angle and height of the CCTV camera as the camera parameter setting step.

The second step is to set the region of interest(ROI) for each CCTV camera image as the ROI setting step.

In the last step, image rectification for the registered image is completed. At this time, the change rate of the image is determined depending on the installed angle and height of the CCTV camera, and thus the corrected image that minimizes the distortion is derived.

The results are shown in Figure 2.

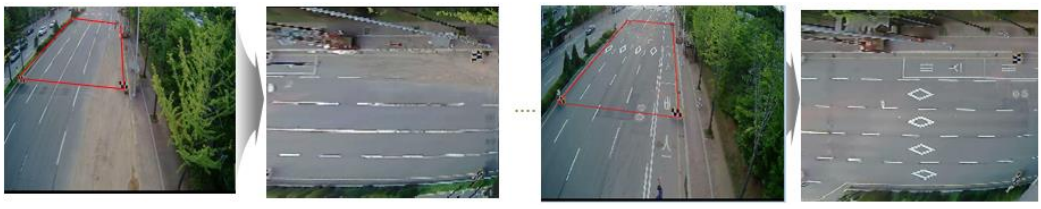


Figure 2 Image Rectification

Feature Point Detection Using Maker Point

In general, if positions of the feature points such as edge and corner, or the geometric characteristics of the images have similar distributions, assuming that multiple images are obtained from similar scenes, and the corresponding pairs can be found from the detected feature points, the image registration can be performed effectively. In this study, a Harris detector was used to extract the feature points.

The Harris method applied in this study has its advantages in that the operation amount is small, and the number of feature points is determined through the threshold value in the Harris response. The equation is as follows.

$$T_{target} = \arg\, min_T \left| N(R;T) - N_{target} \right|$$

Where, R is the Harris response, and N(R;T) is the function that obtains the number of feature points detected from R according to the threshold value T, when T detects the results within the ratio of T with respect to the local maximum feature point, and $N_{target}$is the number of feature points to be detected. Since N(R;T) is a decreasing function for T, desired feature points are extracted while changing the T value. The subsequent procedures are as follows.

- Contrast feature detection through gray level image processing
- Detection of geometric features such as shape and corner point
- Selection of optimal feature points through correlation between contrast feature and geometric feature

Image Stitching

Since the feature points obtained in the previous step represent the characteristic information of each image, they can be used to infer the relative relation of multiple images to be registered. In order to select the pairs of feature points corresponding to each other among the detected feature points. A method of using normalized mutual information around the feature points was used for design. Under the assumption that two or more images are acquired from similar scenes, two images represent similar scenes, and therefore the feature points are characterized by localization. In this case, if the feature points that are far from each other are excluded from the process of selecting the corresponding feature points, the erroneous corresponding pairs can be removed by increasing the level of statistical correlation, and the operation amount can be reduced by eliminating the unnecessary operation, thereby contributing to the derivation of fast results. The results are shown in Figure 3.

Figure 3 Image stitching using maker point

Image Registration after Extraction of Highly Reliable Corresponding Maker Points

Even if the corresponding maker points are selected using the localization characteristics, it is hard to say that the selected maker points are accurately corresponded. In addition, it is true that the mutually well corresponding points have higher degrees of normalized mutual information, but the higher normalized mutual information does not ensure that the points are well corresponded.

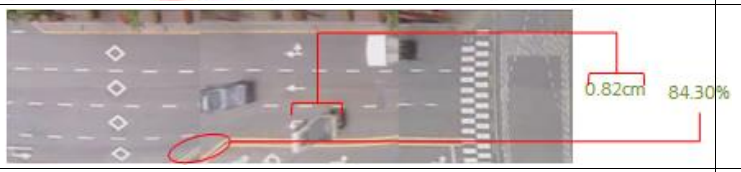
Therefore, although the normalized mutual information is used in the tunnel environment, it is not easy to distinguish images from other neighboring images. Therefore, if the corresponding maker points are selected only from one image, a wrong result is obtained. For this reason, the use of mutual comparison technique using maker points applied in this study makes it possible to reduce the erroneous correspondence that occurs in the feature point selection even in the case of repeated images of similar patterns and reduce the matrix error of the registration by extracting only the corresponding points with a higher degree of reliability.

Derivation of CCTV Installation Specifications That Can Minimize Distortion

The optimal camera position specifications were derived through the registered images for each camera position (height, angle, interval). The image collected with the best camera installation specifications (camera angle 70°, height 9m, distance 50m) was found to exhibit the size of subject, which is 0.45cm smaller, and more improved image malocclusion rate by 42.98%, compared to the image collected from the camera installation specifications with the greatest distortion as Table 2(angle 70°, height 9m, distance 50m).

Table 2 Analysis of image registration results for each specification

Angle	*Installation height*	*Installation interval*	*Multiple registration image*	*Distortion range*	*Malocclusion rate*	*Location result*
70°	5m	50m				

Angle	*Installation height*	*Installation interval*	*Multiple registration image*	*Distortion range*	*Malocclusion rate*	*Location result*
70°	7m	50m				
70°	9m	50m				○
75°	5m	50m				
75°	7m	50m				
75°	9m	50m				

Conclusion

This study is concerned with road monitoring technologies that can be applied to tunnels and bridge sections with difficulties in reducing accidents despite the introduction of technologies and implementation of policies for a reduction in the number of accidents. Especially in the case of tunnels, the risk of the secondary accidents is very high if a prompt judgment regarding the location of the accidents is not made. Therefore, there is an urgent need for the countermeasures. In this regard, the registration of continuous CCTV images into a single imageis advantageous in that the location of the accident can be easily recognized. In this study, a multiple image registration technology using the Harris detector and maker points was developed to implement such a technology.

It is expected that the application of the technology can help to perform more intuitive and easier monitoring of road sections, especially tunnels and bridge sections where the same structures are repeated. In addition, if the technology is combined with the existing accident reduction technologies and policies, it is expected to contribute to a reduction in the number of the secondary accidents.

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