SIGHT CIRCUMSTANCE ANALYSIS ON THE INTERSECTION OF CITY AREA

Guo ZIJIAN
Research Student
Regional Planning and Surveying Lab.
Civil Engineering Department
Faculty of Engineering
University of Tokyo
7-3-1, Bunkyo-ku, Tokyo,
113-8656, Japan
Fax: +81-3-5841-7453
E-mail: guo@planner.t.u-tokyo.ac.jp

Hidetatsu HAMAOKA
Research Associate
Regional Planning and Surveying Lab.
Civil Engineering Department
Faculty of Engineering
University of Tokyo
7-3-1, Bunkyo-ku, Tokyo,
113-8656, Japan
Fax: +81-3-5841-7453
E-mail: hamaoka@planner.t.u-tokyo.ac.jp

Abstract: In order to analyze the circumstances of intersections in city area, this paper defines three indices from the stereovision that are employed to obtain the spatial information of the intersection. A simple photogrammetry method to survey the sight circumstance is proposed. Also surveying cost is taken into account by avoiding the specially manufactured expensive instruments. To precisely define the sight circumstances of an intersection, in this paper not only the concept of sight distance but also other indices are introduced; and the method to calculate these data from the stereovision is proposed and the error of the method is discussed. This paper provides a basic idea of forming a database for the intersection in the city area. The result can be applied to the automatic driving system of ITS.

Key Words: sight circumstance, intersection, stereovision

1. INTRODUCTION

Many traffic accidents occur at intersections in the city. Most of them happen within sight distance of intersections. But there are few theoretical studies and practical methods on surveying sight circumstances at the intersections of city area. Hassan (2000,1998) proposed a 3D sight distance with speed model considering the interaction among the horizontal alignment, vertical alignment and cross section based on the predicted operating speed so as to evaluate the sight distance of highway in North American. But the situation in the city area is quite different as moving and stationary obstacles are the main problem of sight distance. Based on the analysis of accidents happened in the intersection, Yoshimura (2000) hypothesized the mechanism of accident and proposed an index for evaluating the dangerousness of intersections within sight distance. The research conducted by Yoshimura emphasizes accidents caused by moving obstacles, that is, the interaction between vehicles and road structure like alignment. Other researches on sight distance, including Easa (2000,1999), Okuchi (1996) and Hamaoka (1998), can be classified into two categories: geometry analysis and statistics analysis. The technique of stereovision has been developed since Marr (1982) proposed the calculation theory for 3D vision. It is applied to robotics, photogrammetry, medical examination and industry measurement, though there are lots of problems that now confront us such as the matching method, automatic calibration and so on.

This paper focuses at the sight circumstances of intersection of city area where many traffic accidents occur. The sight circumstances in the intersection of city area are different from that of highway; where the interaction of vehicles and the impact of buildings should be taken into account. Priority is given to stationary obstacles in this paper because the influence of moving obstacles has been studied using the statistics method by Yoshimura (2000) and Hamaoka (1998). The intersections are surveyed to obtain the 3D coordinates of each visible point. Based on the spatial information of the intersection, the indices of sight circumstances can be calculated given a driver's situation from the stereovision in different location. Further, the area-based matching method is used for intersection selection. The sight circumstances are described by proposed indices, sight distance, sight range and brightness. By digitizing the image data, a Geographic Information System (GIS) can be formulated, which is the main purpose of this research. The concept of sight circumstances is very important for Intelligent Transportation System (ITS) and traffic planning applications. The research is also conducted to help determine improvement priorities of intersections in the city from the view of sight circumstances.

2. THEORY OF STEREOVISION AND SURVEYING

In order to describe the spatial characteristics of an intersection in the city area, stereo image is a good form, but there are some technical difficulties to be overcome. Mainly they can be classified into matching obstacle and surveying obstacle. Matching method will be mentioned at the end of this section. First the basic theory of stereovision is introduced, then a simple photogrammetry method is proposed to obtain the spatial information of the sight circumstances of intersection in the city area.

In this research, stereovision is applied to survey the spatial information of intersection in the city area. Stereovision offers the 3D information of an object so that a 3D model can be formulated. This technique is widely used in medical examination, photogrammetry, and ITS. The basic theory of stereovision is showed in the Figure 1. In the 3D space, P is a point with absolute coordinate (x,y,z); O_L is the center of left camera lens; O_R is the center of right camera lens; d is the distance between the center of left lens and of right lens; f is the focal distance of the lenses that are parallel. Take the picture of $P(x,y,z)$. $P_L(x_L,y_L)$ is the point in the left picture, $P_R(x_R,y_R)$ is the right one. Here $P_L(x_L,y_L)$ and $P_R(x_R,y_R)$ are coordinates relative to the center of pictures as the origin. According to the principle of triangular surveying, we can obtain the relationship of $P(x,y,z)$, $P_L(x_L,y_L)$ and $P_R(x_R,y_R)$ as follows,

$$x = d \times x_L /(x_L - x_R) \tag{2.1}$$

$$z = d \times y_L /(x_L - x_R) = d \times y_R /(x_L - x_R) \tag{2.2}$$

$$y = d \times f /(x_L - x_R) \tag{2.3}$$

Next, the surveying instrument is chosen by comparing the characteristics of imagine catching instruments. To survey the sight circumstances of intersections, several instruments can be used. First laser scan instrument is the best in catching the exact three-dimensional images without any influence of climate and other factors, but it is expensive. Second the digital camera is considered but it is difficult to synthesis the stereovision when 2 pieces of pictures are not taken on the same horizon plane because it is difficult to take the pictures continually. The third is to use the video camera. This is the suggested method considering the surveying

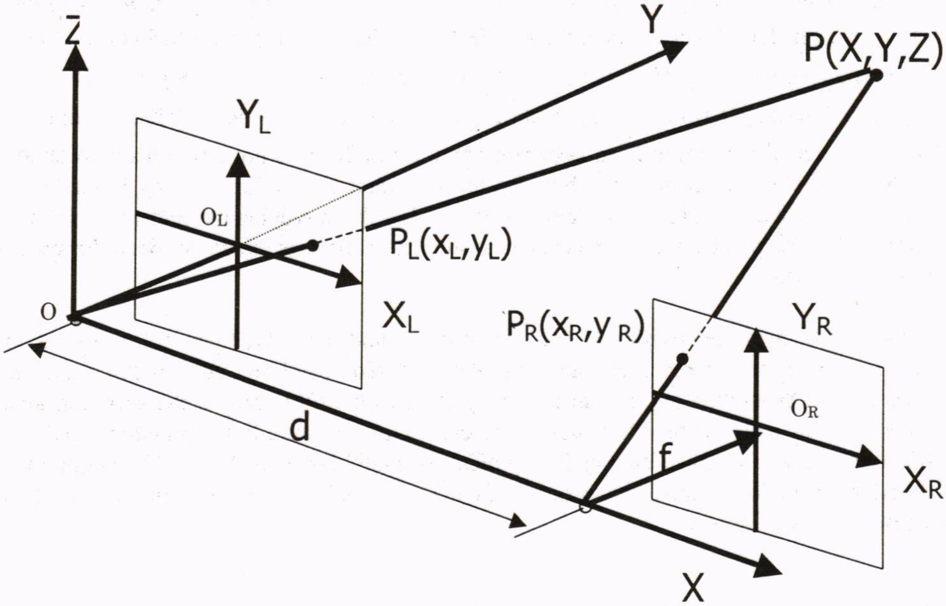

Figure 1. The Basic Theory of Stereovision

cost and synthesis cost.

In general, the instrument to catch the spatial image can be classified into two kinds, the professional surveying instrument and common imagine instrument. From the point of picture, the instrument can also be divided into continuous capture and single capture. These instruments are listed in Table 1. The difference of common camera and photogrammetry camera is the price and accuracy. Usually, the price of photogrammetry camera is 10 times as much as that of common camera, but the precision is much higher. The laser mirror scan is much expensive and much minute than photogrammetry camera. Video camera is relatively cheaper and has the near precision as the common camera. Moreover, it can obtain the continuous pictures. What kind of instrument is used depend on the purpose of the surveying and the expected expense.

Table 1. Classification of Picture-Capturing Instruments

	Single Picture	Continuous Picture
Common	Common (digital) Camera	Video Camera
Professional	Photogrammetry camera Laser Mirror Scan	Moving Laser Mirror Scan (Under Development)

This paper proposes a method that can finish the task with low expense and tolerance error instrument. Generally, the common camera has the weak point of precision. On the other hand, to study the sight circumstances of city area, usually lots of images of intersections need to be captured. So continuous pictures will be suitable for this purpose. The computational error of continuous picture capturing instrument is further analyzed. When the pictures is captured in a moving vehicle, for instance in a car, the computational error consists of two parts. One is the capturing system error σ_C; the other is the moving system error σ_M. Capturing system error σ_C changes depend on the instrument like VC (video camera) and LMS (Laser Mirror Scan). And $\sigma_C(VC) >> \sigma_C(LMS)$; but $\sigma_M(VC) = \sigma_M(LMS)$, also $\sigma_M(LMS) >> \sigma_C(VC)$, we have $\sigma_{CM}(VC) \approx \sigma_{CM}(LMS)$ if the condition $\sigma_M(VC) \approx \sigma_C(VC)$ is satisfied. From this inference, we identified that to keep system error in a low level is not only means to choose the high precision survey instrument, but also the key point to develop Moving Laser Mirror Scan is how to reduce the moving system error level. For the surveying of sight circumstances of intersections, the precision of video camera system is enough, as we do not need the system error is in millimeter unit.

The other problem of stereovision is the matching method. Usually, there are two kinds of matching method, area-based matching and feature-based matching. Area-based matching searches the corresponding point from the one picture to the other one in the surround area. The size of the area affects the efficiency of the calculation. Feature-based matching finds the relation lines, curve and other features in two pictures. Matching is the key point to combine a stereovision from two pictures. This is one of the main topics in stereovision; the results of the other researches are applied.

3. EVALUATION OF SIGHT CIRCUMSTANCES

3.1 Factors Affect Sight Circumstance

As mentioned above, the purpose of this study is to propose a method to evaluate the sight circumstances of intersections. First, the factors that affect the sight circumstances in the intersection are identified and classified as listed in Table 2.

Table 2. Factors Affecting the Sight Circumstances

		Controllable	Uncontrollable
Stationary Object	Road	Alignment	
	Structure	Profile	
Moving Object	Vehicle		Characteristics (speed etc) Interval
Others	Natural Condition		Rain; Fog
	Driver		Judgment; Response

3.2 Evaluation of Sight Circumstance

The goal of this paper is to develop a method to obtain and evaluate the spatial information of the intersection in the city. This found the basis of a database of GIS that allows for wider dissemination of the traffic and road information.

The general process to evaluate sight circumstances is showed in Figure 2. Measurement processing and image processing are based on the existing theories in stereovision and

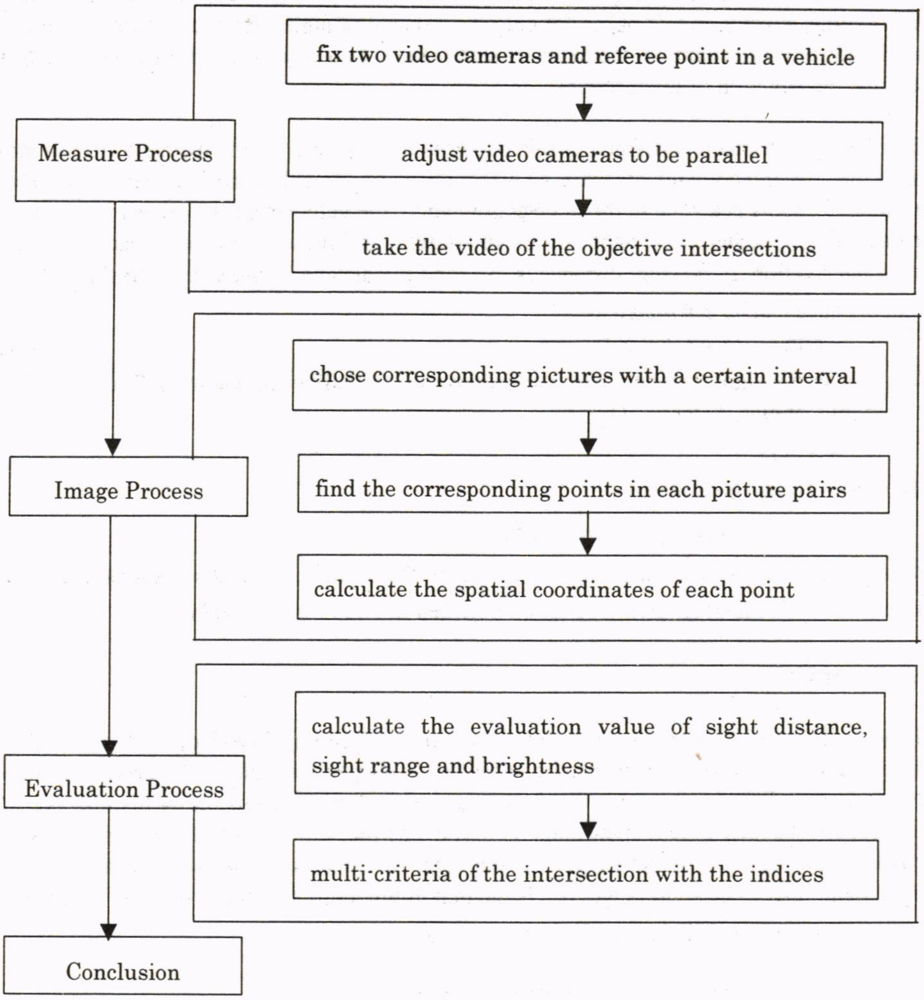

Figure 2. General Process to Evaluate the Sight Circumstances of Intersections

photogrammetry. We try to use these theories to get the spatial information of the intersection. For the distance data, there are many instruments like laser distance meter that can easy find it, but it cannot provide the enough information like the tree and other obstacle. And usually this part does not need to be real time, thus this simple photogrammetry method is proposed to obtain these information. The indices proposed in this paper can be applied to forming the GIS of intersections independently or to evaluating the sight circumstances comprehensively.

3.2.1 Sight Distance

Usually, the sight distance is considered as the only element of the sight circumstances, and the subject of most researches about the sight distance is the highway. These researches consider only the horizontal and vertical alignments, some of them using three-dimensional alignment. In city areas, most of the roads forming the intersection are straight. If the concept of sight distance defined by highway is adopted, there will be little difference no matter it is wide or narrow, or there is a pier heat near it. In order to define the sight circumstances of intersections exactly, in this paper not only the concept of sight distance but also other indices are introduced. For example, the index of sight range, as well as brightness is defined to fully describe the situation of intersections.

First the sight distance is defined in this paper as the shortest visible distance from a moving car to the crossing collision area (CCA) when a driver approaches the intersection. As showed in Figure 3., CCA is a zone in the intersection where the vehicles on the other intersection legs or oncoming vehicles make right turn or go straight, and these actions can lead to a collision in the intersection. If the sight distance is S_d, and the distance from vehicle to the CCA is L_i, sight distance can be calculated as

$$S_d = \min L_i \quad (i = 1,2,...,n) \tag{3.1}$$

To evaluate the sight distance, here we propose to normalize the value of Equation (3.1) by maximum stopping distance D_m,

$$U_d = S_d / D_m \tag{3.2}$$

The index D_m can be inferred as

$$D_m = (V_{max}/3.6)t + V_{max}^2 / \{2gf(3.6)^2\} \tag{3.3}$$

where V_{max} is the maximum permitted speed of the vehicle, t is the response time of the driver, and f is the coefficient of friction between tire and road surfacing.

3.2.2 Sight Range

Many traffic accidents are caused by delay in recognition. The index of sight distance expresses the length for the driver to be permitted to stop the vehicle. If the driver can stop the vehicle in that distance, it means that he can prevent from the collision by his mistake in the intersection. Another index, sight range is defined as the scope that a driver can find another vehicle in the intersection. In general, if the sight distance is the same, it is safer to have a larger sight range. The sight range S_r is the maximum angle that the driver can find the CCA points as Figure.3, and it is normalized by the largest angle 180°

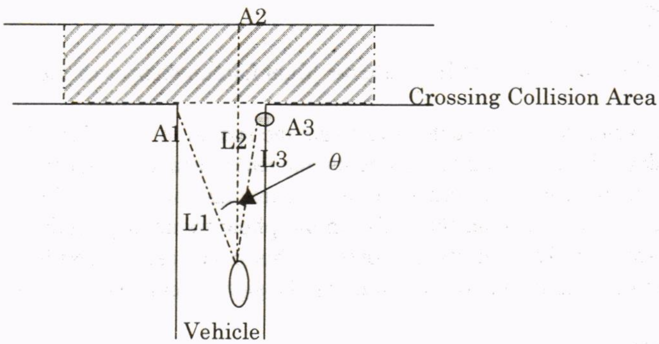

Figure 3. Definition of The Evaluation Indices For an Intersection

$$S_r = \max \theta_j \quad (j = 1,2,...,m) \tag{3.4}$$

$$U_r = S_r / 180 \tag{3.5}$$

'3.2.3 Brightness

To evaluate the brightness, the index of visual level is proposed by Ohya (1999). It is to evaluate the effect of the fusion of road lighting and automobile headlight beam. There are also some other indices to evaluate the brightness, for example the screen illumination ratio, luminance ratio and so on. In fact, these kinds of indices are used to design the road lighting. To find an oncoming vehicle for a driver, the brightness is an important index, but it is usually defined as the percent contrast. That is the ratio of difference brightness of background and the object and the brightness of background. It is also affected by the sharpness of vision. These indices are surveyed with the special instrument and not easy to find them with a video camera. On the other hand, what we want to know is the effect of buildings and other structure, for example an overpass in the intersection. The tone characteristic of a picture can help us to get this information. And it can be obtained from the video image. So in this paper we try to use a image index B_t to evaluate the brightness of the intersection. B_t is defined as the average tone value of the pixel in the CCA.

$$B_t = \sum_{k \in CCA} T_k / K \tag{3.6}$$

$$U_t = B_t / (\sum_{k' \notin CCA} T_{k'} / K') \tag{3.7}$$

3.2.3 Multi-Criteria Of The Sight Circumstance

Here we simply use the weight of each index to give a multi-criteria evaluation on the sight circumstance of intersection in the city area. The multi-criteria value U_M is obtained by the weights of each index w_d, w_r, w_t,

$$U_M = w_d U_d + w_r U_r + w_t U_t \tag{3.7}$$

where $w_d + w_r + w_t = 1$ is satisfied.

4. EXAMPLE

Here we give a simple example to show how to get the information of intersections in the city area by the proposed method. For the measure process, we took the video of a selected intersection of Setagaya Ward in Tokyo. A pair of image from the video is showed in Figure 4. Figure 4 shows some vibration when taking the video. In fact, there is always this kind of error to obtain the information from a moving vehicle. What we need to do is to reduce error to an acceptable level. So next, we should calibrate the video precision.

In order to find the error of the calculation from pictures, we measured real distance of 10 standard points by meter in advance. Then we begin to process the images. First, to calibrate the camera by one calibration point that has a distance from the video with 6m, 8m and 10m. By each calibration coefficient, we can obtain the calculation value. The error of the calculation is defined as the difference between the real distance and the calculation value.

The result is showed in Figure-5, the vertical axis is the error and horizontal axis is the real distance from the standard point to the camera. Through this graph we know that if the calibration distance is less than 9m, the error can be controlled under the 0.5m. It is acceptable

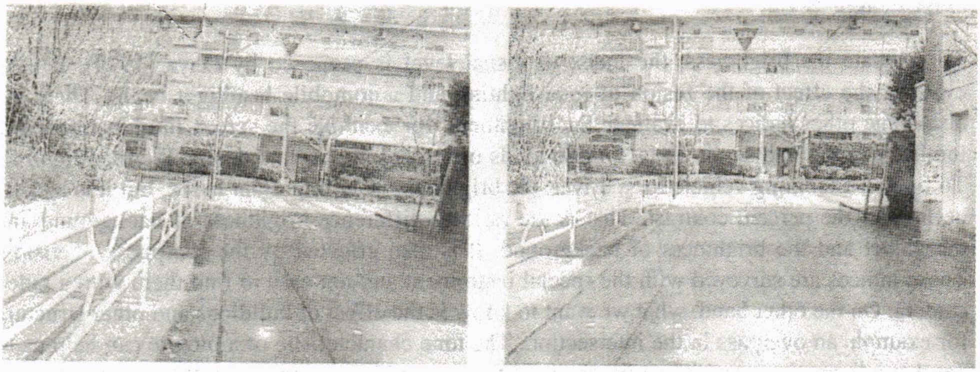

Figure 4. A Pair Of Pictures From The Intersection Of Setagaya Ward

to calculate the sight distance that will be evaluated by a relative index in Equation (3.3).

Now we calculate the corresponding point in each picture pairs and obtain the coordinate of each point. The area-based matching is used in this case.

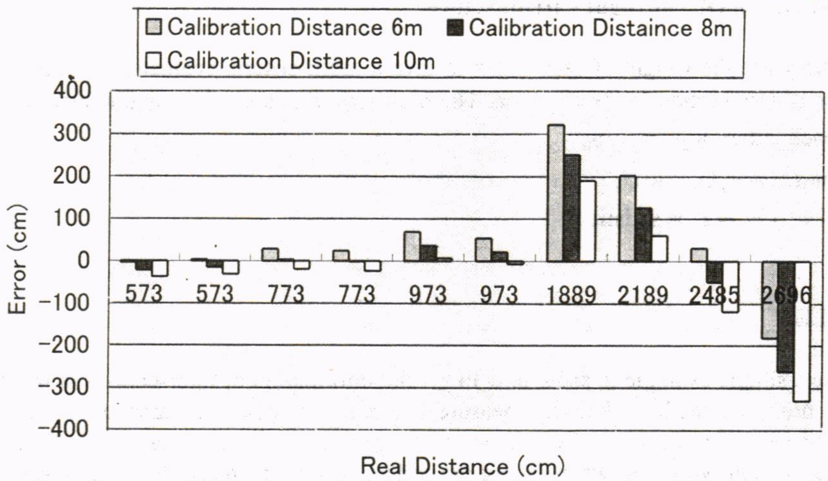

Figure 5. Error Change With Distance

Next we evaluate the sight circumstances of the intersection by proposed method. First we calculate the information of sight distance. We choice a pair of picture showed in Figure 4 as an example. The corresponding points in the pictures are decided, and find the CCA; here three key points in the CCA are chosen to show the process, which is higher than 1.20m because generally the average sitting height of a driver is 1.20m. There are CCA points A1, A2 and A3 in the left corner, right corner and right opposite of the driver, as shown in Figure 3. The index of the sight distance from the given position is

$$S_d = \min L_i = \min(14.3, 30.2, 15.2) = 14.3m \quad (4.1)$$

$$U_d = S_d / D_m = 14.3/72.2 = 0.198 \tag{4.2}$$

The index of sight range can be obtained by

$$S_r = \max\theta_j = \max(22.85, 11.74, 11.11) = 22.85° \tag{4.3}$$

$$U_r = S_r / 180 = 0.127 \tag{4.4}$$

To calculate the evaluation value of brightness, we first determined the CCA from the pictures, and then find all the pixels in the stereovision and the value of each pixel. Here we gray scale the pictures to change the value of pixel to the range of [0,255]. The average value of the CCA and that of outside are calculated as follow

$$B_t = \sum_{k \in CCA} T_k / K = 160.64 \tag{4.5}$$

$$U_t = B_t / (\sum_{k \notin CCA} T_{k'} / K') = 160.64/170.99 = 0.934 \tag{4.6}$$

If each index has the same weight, the multi-criteria value is

$$U_M = w_d U_d + w_r U_r + w_t U_t = 0.420 \tag{4.7}$$

Many methods are developed to determine the weight of multi-criteria. In this paper we recommend Tatsuta (1990)'s method to determine the weight in practice.

The data obtained in this example can be analyzed as follow. The index value of sight distance, sight range and brightness reflect the sight circumstances of a driver in a certain position. They can compare with the data of the other intersection or other distance, and form a database. The normalized value can be used to evaluate the intersection comprehensively. When we need to improve the sight circumstances, these normalized indices are combined with weight to give the multi-criteria of the intersection and they can be used to determine the priority order of improvements. The evaluation value is useful when there are all these kind of data in an area, we can simply compare them and decide the priority of improvement of intersections by selecting it with a low value.

5. CONCLUSION

In this paper, we first introduce the basic principle of the stereovision, then proposed a method to obtain the spatial information by this principle. Stereovision is employed to synthesize the intersection and indices of sight distance, sight range and brightness from the stereovision are defined to describe the circumstances of intersections. Surveying cost is also considered by avoiding the specially manufactured expensive instruments and the induced error is discussed.

The main results in this study are: (1) the definition of sight distance, sight range and brightness are reasonable to describe the circumstances of the intersection in the city area; (2) the proposed method to get the spatial information from a stereo video image is feasible considering the cost and error; and (3) the result can be used to decide the priority order of street improvement from the view of sight circumstances. It is also a basic method to construct the database of sight distance in the city area together with the GIS data. It should be noted that our method is not to improve the accuracy of the measurement of sight distance and other data; it provides an economic method to obtain the spatial information including the sight distance, sight range and brightness. The error of the method is also discussed through an example.

REFERENCES

Easa, S.M. and Hassan, Y. (2000) Development of transitioned vertical curve 1 - Properties, **Transportation Research Part A-Policy And Practice 34: (6)** 481-496

Easa, S.M. and Hassan, Y. (2000) Development of transitioned vertical curve II Sight distance, **Transportation Research Part A-Policy And Practice, 34: (7)** 565-584

Easa, S.M., Hassan, Y. and Siczkar, D. (1999) An approach for auditing highway sections for safety improvements, **Canadian Journal Of Civil Engineering** 26: (6) 724-735

Hamaoka, H., Nagashima, H. and Morichi, S. (1998) An analysis of cause of traffic accidents at the block spots, **Proceedings 8th World Conference on Transportation Research, Antwerp**

Hassan, Y., Gibreel, G. and Easa, S.M. (2000) Evaluation of highway consistency and safety: Practical application, **Journal Of Transportation Engineering-ASCE, 126:(3),** 193-201

Hassan, Y., Easa, S.M., and Abd, E.H.A. (1998), Highway alignment - Three-dimensional problem and three-dimensional solution, **Highway Geometric Design Issues (1612),** 17-25

Marr, D (1982) **Vision**. W.H, Freeman and Company

Oguchi, H., Katakura, M. and Shikara, S. (1996) A study on relationship between road alignment and sight distance, **Proceeding of Infrastructure Planning of JSCE, No.19 (2)** 585-588

Ohya, H.and Ishikura, T. (1999) Study On Visibility At The Fusion Of Road Lighting And Automobile Headlamp Beams**, Proceedings Of Annual Conference Of JSCE, Vol 54,** 380-381

Yoshimura, M., Hamaoka, H. and Morichi, S. (2000) Traffic accident analysis based on Sight distance, **Infrastructure Planning Review of JSCE, Vol. 17**, 989-994

Tatsuta K., Fujii T. (1990) Integrated evaluation method for alternative plans using standard deviation of value as weight in evaluation item, **Infrastructure Planning Review of JSCE, Vol. 8**, 265-271