Development of Algorithm for Automatic Installation of Detection Area for Obtaining Traffic Information by Analyzing the Panning, Tilting Factors of CCTV Cameras on the Highway

In Jung Lee*, Seong Namkoong**, Joon Young Min***, Byeong Ju Yun**** *Regular Members*

요 약

본 연구는 고소도로에 설치된 CCTV카메라에서 교통량, 속도, 점유율 등의 교통정보를 수집하기 위하여 검지영역을 자동으로 설치하는 알고리즘을 제안한다. 이를 위하여 교통정보센터에 설치된 콘트롤러에서 CCTV카메라의 Pan, Tilt, Zoom 요소값을 보내면 이 값만큼 CCTV카메라가 panning, tilting이 되고, 이에 따른 변화된 영상이 교통정보센터로 전송이 된다.

기존의 연구로는 영상 내에서 도로를 추출하기 위하여 차 영상(difference image)에 의한 도로추출방법과 윤곽선추출 방법에 의한 도로추출 방법이 있으나, 전자는 도로를 추출하는 데 있어서 시간이 많이 소요된다는 문제점이 있으며, 후자는 정확한 도로를 추출하지 못한다는 문제점이 있다.

이러한 문제를 해결하기 위하여 본 연구에서는 우선 각 차로 상의 직선의 방정식을 구하고, 이 직선의 방정식에서 CCTV카메라가 Panning, Tilting하는 중심점을 찾은 다음 CCTV카메라의 Pan, Tilt 값에 의하여 3차원상의 원근비율에 따라 각 차로 별 좌표변환방법을 이용한다.

본 연구를 위한 실험은 고속도로 기흥IC에 15m 높이로 설치된 CCTV카메라에서 영상을 캡처하였으며, 차후 교통량, 속도, 점유율 등 교통정보를 산출하는 데 처리 속도를 고려하여 영상의 해상도는 640480픽셀과 256명암값에서 계산되었다.

ABSTRACT

In this paper, an algorithm for automatic installation of detection areas in each traffic lane are proposed using CCTV camera systems which are installed on highway for obtaining traffic information. For automatic installing detection area, suppose that panning, tilting and zooming factors of CCTV system is transmitted from controller installed in Highway Traffic Information Center to CCTV camera systems, and CCTV cameras is rotated according to pan, tilt factors, and then the changed images are transmitted to Highway Traffic Information Center.

In previous researches, there are two methods, difference image method and edge detection method, are used in order to extract the road in images. However the difference image method is needed much more processing time in order to extract the road and edge of road cannot be obtained exactly using edge detection method.

For solving these problems in this research, equation of lines of each traffic lane is calculated in basic image firstly and find the central point of panning, tilting rotation, and coordinates transformation is conducted for each lane according to ratio of near and far in 3-D spatial domain using panning, tilting factors of CCTV system.

Experiments have been conducted on image data captured at CCTV camera installed 15 meters high on Kiheung Interchange(IC) upstream place on the highway. The images are processed by 640480 resolution and 256 gray-levels with consideration of processing time for calculating traffic information such as volume count, speed, and occupancy rate etc.

* 호서대학교 컴퓨터공학과(leeij@dogsuri.hoseo.ac.kr)
** 한국도로공사 도로연구소(namkoong@freeway.co.kr)
*** 상지영서대학 전자계산과(joonym@youngseo.ac.kr)
**** ㈜ 비츠로시스 연구소(bjyun@vitzrosys.com)

논문번호 : K01115-0410, 접수일자 : 2001년 4월 10일
※ 본 논문은 건설교통부 2000년 ITS연구개발 사업(2000 ITS-R&D A2000-03) 연구비지원에 의하여 연구되었음.

I. Introduction

In Korea, highway construction plan is that 19 new lines, total 1,848.3 km will be constructed and that 21 lines, total 2040.5 km will be extended [1]. A new highway lines are constructed, Inductive Loop Detectors (ILD), Image Detectors and CCTV cameras are installed to provide traffic information as part of FTMS (Freeway Traffic Management System) project. ILD are the most common traffic information collectors in many countries, because of its reliability and cheap installation cost. However, as it should be installed on the road, installation and repairing require road blocking that is causing complaints and inconvenience. Image detectors can be provided information on queue length, vehicle type classification and spot speed, in addition to the information such as traffic volume, speed, and occupancy rate[2,3]. But it cannot collect the traffic information in wide area because of limited measured area and fixed direction of CCD camera. Currently, the CCTV cameras are used to monitor traffic situation on the roads with traffic controller's eyes. To help view of controllers, panning/tilting and zooming function are provided in CCTV cameras.

In this paper, to utilize existing facility and enhance productivity of the CCTV cameras, automatic installation method of detection area is proposed using panning/tilting and zooming factors of CCTV cameras. In this case, without spending extra financial resources, the traffic controllers can extend capability of traffic information collection using the existing CCTV cameras.

In previous researches, difference image method is needed much more processing time in order to extract the road and edge of road cannot be obtained exactly using edge detection method [4,5].

For automatic installation of detection area in this research, equation of lines of each traffic lane is calculated in basic image firstly and coordinates transformation is conducted for each lane according to ratio of near and far in 3-D spatial domain using panning, tilting and zooming data of CCTV system.

For this research, a new CCTV camera and pan/tilt driver are installed about 15 meters high on Kiheung IC upstream on the highway. The image data are transmitted to the Highway Traffic Information Center via optical fibre. Pan, tilt and zoom factors are sent out via separate line connected on RS232C port of control system and pan/tilt driver of CCTV camera is operated panning, tilting or zooming and return response signal to the control system.

Experiments have been conducted on initial detection area installed in two lanes manually and after panning, tilting rotation of CCTV camera, we verified that detection area is reinstalled inter each lane automatically.

II. Previous Researches

Recently, installed image detectors which is used to obtain the traffic information, for example, volume, speed and occupancy rate measurement, are fixed CCD camera's focus angle. For that reason, detection areas were installed once its first stage and need not changed. On the other hand, CCTV cameras installed on the highway have a panning, tilting and zooming function, therefore the coordinates of detection areas were changed each time the panning, tilting and zooming operation.

In case of CCTV camera, the road of each lane is needed to extract in the captured image exactly. In previous research, the methods of extracting each lane are difference image method and edge detection method.

In difference image method[4], to discriminate traffic lane in the roads, road part in the image should be extracted. A single frame of the image was grabbed at every 0.2 second and 600 frames (about 2 minutes) of difference images were obtained. Figure 1 shows road extracted from the difference image.

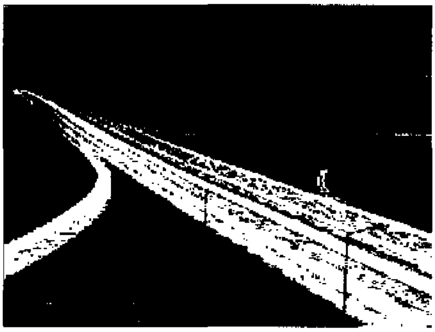


Fig. 1 Difference Image in Cheongju IC (600 frames grabbing per 0.2 second)

However, this algorithm had a problem to spend a lot of time on obtaining the difference image. Also, the road was not extracted exactly because of occlusion especially in case of passing bigger vehicles such as buses or trucks.

In edge detection method[5], extracting the edge of all objects using Sobel or Laplacian methods and only road part of these objects can be extracted to apply the equation of line or neural network algorithm. But, because of variety of edge description in the image, it is very difficult to extract the edge of road part exactly, and especially in night time, is not able to extract the edge of road part as shown in figure 2.

Fig. 2 Edge of Road Part in Night time (Cheongju IC)

Ⅲ. Automatic Installation of Detection Area

3.1 System Configuration

The procedure of this system is shown in figure 2. First, the CCTV camera is received pan/tilt/zoom factors from controller, and second, CCTV camera is rotated according to these 3 factors, and the rotated image is transmitted to controller.

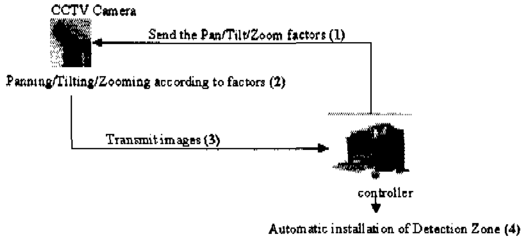


Fig. 3 System Configuration

And then in controller, the detection areas have to be reinstalled automatically according to rotated new image.

And detection area is transformed with 3-dimeasional spatial transformation by these pan/tilt/zoom factors.

3.2 Basic Idea

To solve these problems as we discussed in Section 2, for automatic installation of detection area exactly even though direction of CCTV camera is changed in the cause of panning, tilting and zooming, we propose a method of 3D coordinates transformation according to the panning, tilting and zooming factors of CCTV camera.

We have denoted **P**(x,y) is project point of CCTV camera and **Z** denotes depth which has parallel **XY** plane. Let θ , φ , ϕ denote x, y, z axis angle of CCTV camera and displacements are $\mathbf{T}_x$, $\mathbf{T}_y$, $\mathbf{T}_z$ respectively, and s is zooming factor, f is focal length. When θ , φ , ϕ are assumed small values sufficiently, the transformation point **P**(x',y') is calculated as following equation[6].

$$x' = s \times \frac{x - \phi \times y + \varphi \times f + f \times \frac{\mathbf{T}_x}{\mathbf{Z}}}{1 - \frac{\varphi}{f}x + \frac{\theta}{f}y + \frac{\mathbf{T}_z}{\mathbf{Z}}}$$

$$y' = s \times \frac{\phi \times x + y + \phi \times f + f \times \frac{\mathbf{T}_y}{\mathbf{Z}}}{1 - \frac{\varphi}{f}x + \frac{\theta}{f}y + \frac{\mathbf{T}_z}{\mathbf{Z}}} \qquad \text{Eq. 1}$$

In Eq. 1, the **Z** value is larger than $\mathbf{T}_x$, $\mathbf{T}_y$, $\mathbf{T}_z$, φ is smaller than x and θ is also smaller than y relatively, ψ is almost constant. Thus Eq. 2 is shown as simplified expression of Eq.1.

$$x' = s \times (x + \varphi \times f)$$
$$y' = s \times (y - \theta \times f) \qquad \text{Eq. 2}$$

Where φ, θ are related panning and tilting angles, f is related position of CCTV camera.

3.3 Automatic Installation of Detection Area using Panning Factor

Due to near and far, the width of each traffic lane is not displayed constantly if CCTV cameras are installed on roadside. In this paper, in order to obtain the exact coordinate value of each lane after panning rotation, the equation of line of each traffic lane can be derived from horizontal and vertical angle of line which is connected with each lane as shown figure 3.

In this case, the equation of line is calculated by Eq. 4.

$$y_j - y_{1,j} = \frac{y_{2,j} - y_{1,j}}{x_{2,j} - x_{1,j}} \times x_j - x_{1,j} \qquad \text{Eq. 3}$$

where, j : lane number

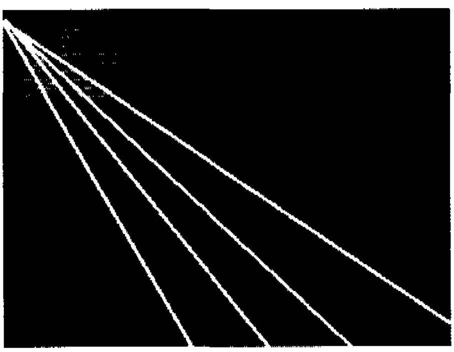


Fig. 4 Connected line of each traffic lane

When CCTV camera is located i times of width of traffic lane from left roadside and the difference between angle of j^{th} lane and $(j+1)^{th}$ lane has a proper deviation η, a deviation ratio of each lane is calculated as following Eq. 4.

$$\theta_{diff_i} = \eta \times [\tan^{-1}((i + j + 1) \times \frac{L_w}{C_h}) - \tan^{-1}(i + j \times \frac{L_w}{C_h})] \qquad \text{Eq. 4}$$

where, j is number of lane(0,1,2, from left),
L_w is lane width and C_h denotes camera height.
i is constant, deciding heuristically because the location of CCTV camera is different each site

When θ_x denotes the panning rotation angle, changed angle of each lane, $\theta_{changed}$, can be represented as Eq. 5 and Eq.6 respectively.

- changed angle of 0^{th} lane

$$\theta_{changed,0} = \theta_x \qquad \text{Eq. 5}$$

- changed angle of i^{th} lane

$$\theta_{changed,i} = \theta_{changed,i-1} \times \frac{\theta_{diff_{i+1}}}{\theta_{diff_i}} \quad (i=1,2,3) \qquad \text{Eq. 6}$$

If $\mathbf{P}(\xi, \zeta)$ denotes an intersecting point which is made by extension of connected line in each lane and $\mathbf{P}(x_1, y_1)$ is predetermined coordinate of initial detection area, a new transformation point $\mathbf{P}(x', y')$ after panning operation is expressed as Eq. 7.

$$x' = (x_1 - \xi)\cos(\theta_{diff_i}) + (y_1 - \zeta)\sin(\theta_{diff_i}) + \xi$$
$$y' = (x_1 - \xi)\sin(\theta_{diff_i}) + (y_1 - \zeta)\cos(\theta_{diff_i}) + \zeta \qquad \text{Eq. 7}$$

3.4 Automatic Installation of Detection Area using Tilting Factor

When a tilting operation is happened, depth of image has to be computed and this depth depends on camera height and distance from camera. Let θ_y denotes tilting angle of CCTV camera and δ is real distance from camera location to image center, the vertical moving distance d after tilting is expressed as Eq. 8.

$$d = C_h \tan[\theta_y + \tan^{-1}(\frac{\delta}{C_h})] - \delta \qquad \text{Eq. 8}$$

Moreover, at the same time, the panning factor that must be considered to occur as sin, for this factor we should apply the Eq. 7 with sin θ_y

In case of zooming generally, uniform scaling is used that maintains relative object proportions. Let **z** is magnification after zooming operation, all of image locations can be enlarged and contracted on the basis of central point of image. If **z** is greater than 1, the image is expended in **XY** direction, while **z** is positive but is less than 1, there is contraction along that direction.

In case of zooming operation, if central point of image is $\mathbf{P}(x_c, y_c)$ and arbitrary point of image before zooming operation denotes $\mathbf{P}(x_i, y_i)$, after zooming transformation a transformed point $\mathbf{P}(x_k, y_k)$ is computed as Eq. 9 [7,8,11].

$$x_k = \mathbf{z} \times (x' - x_c) + x_c$$
$$y_k = \mathbf{z} \times (y' - y_c) + y_c \qquad \text{Eq. 9}$$

Ⅳ. Experimental Results

This research is experimented the algorithms to verify installation of detection area in spaces of each lane. The images are collected at Kiheung IC upstream that is located near Seoul.

A maximum panning angle is 40° and factors are divided into 256 values of this angle equivalently. Also a maximum tilting angle is 60° and factors are divided into 256 values, namely, the panning rotation of CCTV camera is 0.15625° (=40°/256) on each panning factor and tilting rotation is 0.23438° (=60°/256) on each tilting factor.

Experiments have been conducted on daytime and nighttime and initial detection area installed in two lanes manually and after panning, tilting rotation of CCTV camera, we verified that detection area is reinstalled inter each lane automatically.

Then images are 640480 pixels and 256 grey-level were grabbed through IV4 grabber board.

In daytime, figure 5 shows the initial installation of detection area on Kiheung IC when panning factor is 45, tilting and zooming factor is 130 and 246 respectively. After panning rotation is 65, reinstallation of detection area is shown as figure 6 and figure 7 shows the reinstalled detection area after tilting factor is changed to 120.

Figure 8 is illustrated after the zooming when zooming factor is changed to 200.

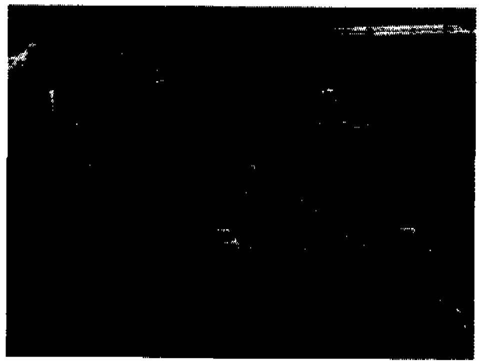


Fig. 5 Initial installation of detection area (panning=45, tilting=130, zooming=246)

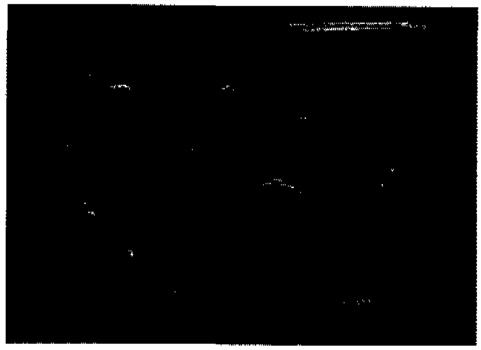


Fig. 6 Reinstallation of detection area automatically after the panning rotation (panning=65, tilting=130,zooming=246)

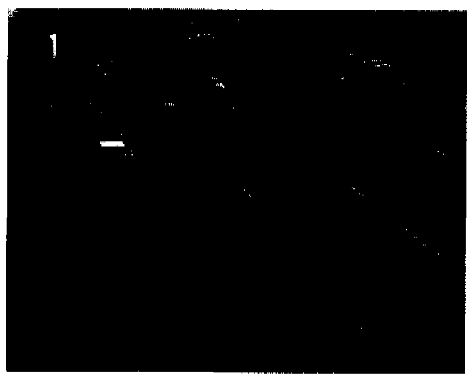


Fig. 7 Reinstallation of detection area automatically after the tilting (panning=65, tilting=120,zooming=246)

Fig. 8 Reinstallation of detection area automatically after the zooming (panning=65, tilting=130,zooming=200)

Experiments in night time were conducted in daytime process identically only different changed panning, tilting and zooming values as shown in figure 9 to figure 12.

In this experiment, the detection area is almost installed in spaces of each lane, thus traffic

Fig. 9 Initial installation of detection area in night time (panning=35, tilting=150, zooming=246)

Fig. 10 Reinstallation of detection area automatically after the panning rotation (panning=60, tilting=150,zooming=246)

Fig. 11 Reinstallation of detection area automatically after the tilting rotation (panning=35, tilting=135,zooming=246)

Fig. 12 Reinstallation of detection area automatically after the zooming (panning=35, tilting=150,zooming=220)

volume, speed, occupancy rate, and vehicle type classification could be measured in this detection area even though panning, tilting and zooming of CCTV systems are transformed.

V. Conclusions

In this research, an algorithm is suggested for automatic installation of detection areas in CCTV cameras for utilizing the existing facilities without installing image detectors at the highway or vehicle-exclusive roads, by extending function of the CCTV camera and providing function of image detectors. In the image detectors the angle is fixed, while the angle of CCTV camera is flexibly rotating, horizontally and vertically moving with pan/tilt and zooming.

The algorithm makes possible to collect the traffic information with panning, tilting and zooming of CCTV camera. A characteristic of our algorithm is coordinate transformation can be applied in real time because equation of lines of each traffic lane is calculated in basic image and coordinates transformation is conducted for each lane according to ratio of near and far in 3-D spatial domain when a panning, tilting and zooming operation of CCTV system is happened.

However, as the algorithm was experimented with a limited the number of images, the applicability in real traffic situation is not guaranteed. Thus we have plan to install another CCTV camera on Suwon IC upstream.

In the future research, this algorithm will be applied to all cases of highway situations. Also, we will have to develop an algorithm for higher precisions of measuring traffic volume, speed, occupancy rate, and vehicle type classification under CCTV system environment.

REFERENCES

[1] http://www.freeway.co.kr

[2] Y. T. Oh, H. K. Cho, E. H. Jung, "The Development for Vision-Based Realtime Speed Measuring Algorithm," *Journal of Transportation Research Society*, Vol. 14, No. 4, pp.107-129, 1996.

[3] H. K. Cho, E. H. Jung, S. H. Lee, "A Development of Traffic Queue Length Measuring Algorithm using an Image Processing based Voting Technique," *Journal of Transportation Research Society*, Vol. 16, No. 3, pp.113-121, 1996.

[4] In J. Lee, Joon Y. Min, Jong U. Choi, S. Namkoong, Jae K. Song, "An Algorithm for Automatic Installation of Detection Area in CCTV Image," *Proceedings of 7th World Congress on Intelligent Transport Systems*, Turin, Italy, Nov. 6-9, 2000.

[5] In J. Lee, Joon Y. Min, "Development of an Algorithm Automatic Installation of Detection Area in CCTV Image on Highways," *Proceedings of the CISST*, Las Vegas, USA, pp.381-386, Jun., 26-29, 2000.

[6] Dae S. Jeoune, Zi Y. Song, "Global Motion Estimation by Analyzing the Panning/Tilting Angles of Camera Rotation and Zooming Factor," *Proceedings of the CISST*, Las Vegas, USA, pp.163-169, Jun., 26-29, 2000.

[7] D. Hearn, M. P. Baker, Computer Graphics 2nd Ed., Prentice Hall, Inc., 1994.

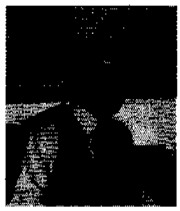
[8] E. Angel, Computer Graphics, Addison-Wesley Publishing Co., Inc., 1990.

[9] J.M.Menedez, L.Salgado, E.Rendon, N.Garcia, "Motion Parametric Modeling for Low Bit-Rate Video Coding," *Proceedings of SPIE*, Vol. 3309, pp.564-575.

[10] R.Wang,T.Huang, "Fast Camera Motion Analysis in MPEG Domain," *Proc. of IEEE Int'l Conf. Image Processing*, Vol.3, Kobe, Japan, pp 691-694, Oct.1999.

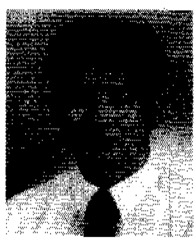
[11] D.F.Rogers,J.A. Adams, "Elements for Computer Graphics," 2nd Ed., McGRAW-HILL.

이 인 정(In Jung Lee)



1980년 : 전남대학교 수학과(학사)
1983년 : 중앙대학교 수학과(석사)
1990년 : 중앙대학교 수학전공 (박사)
1991년 4월~1992년 3월 : 한국과학기술원 Post Doc.
1992년 3월~현재 : 호서대학교 컴퓨터공학부 조교수
<주관심 분야> 영상처리, 인공지능, 계산이론

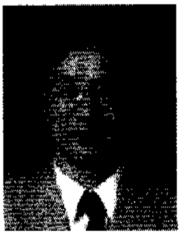
남 궁 성(Namkoong, Seong)



1988년 : 한양대학교 도시공학과 (학사)
1990년 : 한양대학교 대학원 도시공학과(석사)
1996년 : 한양대학교 대학원 교통계획 전공 (박사)
1991년 3월~1996년 8월 : 한양대학교 산업과학연구소 연구원
1999년 10월~2001년 현재 : 국가 ITS 연구개발기획 위원

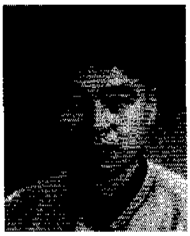
1996년 8월~현재 : 한국도로공사 도로연구소 교통연구그룹 그룹장
<주관심 분야> 첨단 교통관리 및 정보기술, 첨단차량 및 도로기술, 인공지능,

민 준 영(Joon Young Min)



1982년 : 아주대학교 산업공학과 (학사)
1989년 : 성균관대학교 정보처리 전공 (석사)
1995년 : 성균관대학교 전산통계 전공(박사)
현재 : 상지영서대학 전자계산과 부교수
<주관심 분야> 영상처리, 패턴인식, 인공신경망, ITS

윤 병 주(Byeong Ju Yun)



1986년 : 경북대학교 전자공학과 (학사)
1988년 : 경북대학교 전자공학과 (석사)
1988년 2월~현재 : ㈜비츠로시스 연구소장
2001년 8월~현재 : 건국대학교 전자정보통신 박사과정
<주관심 분야> 정보통신, 최적제어, 영상처리