# 고속도로 CCTV카메라의 효율적 운영을 위한 반구상의 영상 저장 및 복원 알고리즘

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# An Algorithm of Storing and Restoration Images in Hemisphere for Efficient Operation of CCTV Cameras on the Highway

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요 약

일반적으로 영상검지기에서 교통량, 속도, 점유율 등의 교통정보를 자동으로 얻기 위해서는 각 차로 사이에 검지영역을 정확히 설정해 주어야만 한다. 그러나 CCTV0 상지영서대학 전자상거래과(joonym@youngseo.ac.kr)카메라와 영상검지기를 통합하려는 시스템에서 수학적으로 정확한 좌표를 계산하여 검지영역을 설정하였다 하더라도 CCTV카메라의 기계적인 오차와 바람 등 외부적인 환경에 의해서 검지영역이 정확히 차로 사이에 설정되지 않는 경우가 많이 발생한다.

본 논문은 반구 상에 영상 데이터베이스를 저장하고 이를 다시 복원하여 검지영역의 좌표값을 보정하는 알고리즘을 제안한다. 반구 상에 저장되는 이미지는 CCTV카메라의 pan, tilt, zoom 요소에 의하여 캡쳐되며, CCTV카메라에서 현재 캡쳐된 영상에 검지영역이 잘못 설정되었을 경우, 검지영역의 좌표 보정은 반구 상의 저장된 이미지를 복원 한 후 이 두 개의 이미지와 비교하여 검지영역 좌표값의 오차를 계산하여 보정한다.

본 연구의 실험은 경부고속도로 상행 기흥IC에 15m높이의 CCTV카메라를 설치하여 고속도로 통행 영상을 얻어 실험을 하였고, 영상은 640×480 해상도에 256 명암값(gray-levels)으로 영상처리를 하였다.



ABSTRACT

Generally using video detector, for obtaining traffic information, such as volume count, average speed and occupancy rate automatically, detection zone have to be installed inter each lane correctly. But even though coordinates transformation are calculated by mathematical approaches exactly in integration of CCTV camera and video detector system, the calculated coordinate of detection zones are not placed inter each lane of the road because of the mechanical error of CCTV camera system and external environment such as winds.

In this paper, we propose the revision algorithm in this case using for constructing image database in hemisphere. This hemisphere image is constructed on the surface of a certain hemisphere corresponding to pan, tilt, zoom factors of CCTV camera. For revising of coordinates of detection zone in captured image in case of incorrecting detection area, we can compare the extracted image from hemisphere by panning, tilting factors with captured image in real situation, and correct the difference errors of detection zones in two images.

Experiments have been conducted on image data captured at CCTV camera installed 15 meters high on Kiheung Interchange(IC) upstream place on the highway and the images is used 640×480 resolution and 256 gray-levels.


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## Ⅰ. Introduction

In Korea, highway construction plan is that 19 new lines, total 1,848.3km 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), Video 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 only traffic controllers eyes. Thus, to help view of controllers, panning, tilting functions are provided in CCTV camera, that is controllers can obtain an information of traffic situation by rotating and zooming CCTV cameras manually to considerable direction of road, such as incident or congestion area. But this method should not be exact and rapid information because of non-automatic operations.

Therefore, recently the researches are going on to obtain traffic information automatically using panning, tilting and zooming factors of CCTV camera. For automatic operations, 3-dimensional coordinate transformation is used with transmitted factors of pan, tilt, zoom through the line of fiber cables from local CCTV camera[4,5,6,7].

For obtaining traffic information, such as volume count, average speed and occupancy rate automatically, detection zone have to be installed inter each lane correctly. But even though coordinates transformation are calculated by mathematical approaches exactly, the calculated coordinate of detection zones are not placed inter each lane of the road because of the mechanical error of CCTV camera system and external environment such as winds. In this case, the initial installed directions of CCTV camera are changed and then coordinates value of detection zone have an error, it cannot be installed inter each lane exactly after panning, tilting and zooming operation.

In this paper, we propose the revision algorithm for constructing image database in hemisphere, assuming that CCTV cameras have an unavoidable errors with pan, tilt driver caused by own mechanical error and external environments. This hemisphere image is constructed on the surface of a certain hemisphere corresponding to pan, tilt factors. For the reason of storing on the surface of a certain hemisphere, because it is possible for the images to be extracted by panning, tilting factors from this hemisphere image.

For revising of coordinates of detection zone in captured image, we can compare the extracted image from hemisphere by panning, tilting factors with captured image in real situation, and correct the difference errors of detection zones in two images

In this research, a new CCTV camera and pan, tilt driver are installed about 15 meters high on Kiheung IC upstream on the Kyongbu highway. The image data are transmitted to the Highway Traffic Information Center via optical fiber. 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 image data captured at CCTV camera installed 15 meters high on Kiheung Interchange(IC) upstream place on the highway and the images is used 640×480 resolution and 256 gray-levels.

## Ⅱ. Automatic Installation of Detection zone

We have denoted P(x,y) is project point of CCTV camera and Z denotes depth which has parallel XY plane. Let $\theta, \varphi, \phi$ denote $x$, $y$, $z$ axis angle of CCTV camera and displacements are **T**$x$, **T**$y$, **T**$z$ respectively, and s is zooming factor, f is focal length. When $\theta, \varphi, \phi$ are assumed small values sufficiently, the transformation point **P**$(x,y)$ is calculated as following equation[8].

$$x' = s \times \frac{x - \phi \times y + \varphi \times f + f \times \frac{T_x}{Z}}{1 - \frac{\varphi}{f} x + \frac{\theta}{f} y + \frac{T_z}{Z}}$$

$$y' = s \times \frac{\phi \times x + y + \phi \times f + f \times \frac{T_y}{Z}}{1 - \frac{\varphi}{f} x + \frac{\theta}{f} y + \frac{T_z}{Z}} \qquad (1)$$

In Eq. (1), the **Z** value is larger than **T**$x$, **T**$y$, **T**$z$, and $\varphi$ is smaller than $x$, and $\theta$ is also smaller than $y$, $\phi$ is almost constant. Thus Eq. (2) is shown as simplified from expression of Eq. (1).

$$x' = s \times (x + \varphi \times f)$$

$$y' = s \times (y - \theta \times f) \qquad (2)$$

In Eq. (2), $\varphi, \theta$ are related panning and tilting angles, $f$ is related position of CCTV camera.

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 1.

In this case, the image plane is a 2-dimensional projective space, we have to apply it to projective geometry[9], the influence occurred by moving angle $\theta$ as shown in figure 2.

Because the CCTV camera is located at roadside ordinarily, the difference between angle of $j^{th}$ lane and $(j+1)^{th}$ lane have a proper

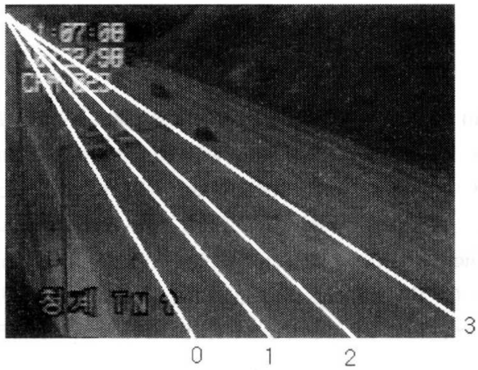



Fig. 1 Connected line of each traffic lane

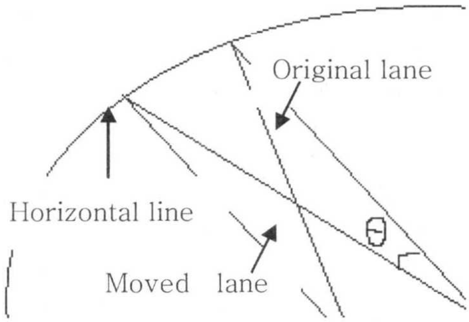



Fig. 2 Viewpoint of changed Image

deviation $\eta$, a deviation ratio of each lane is calculated as following Eq. 3.

$$\theta_{diff_i} = \eta \times [\tan^{-1}((i+j+1) \times \frac{L_w}{C_h}) - \tan^{-1}(i+j \times \frac{L_w}{C_h})] \qquad (3)$$

*where*, $j$ is lane number (0,1,2,3,... from the left side)

$L_w$ is lane width, $C_h$ denotes camera height

When $\theta_x$ denotes the panning angle, changed angle of each lane can be represented as Eq. (4) and Eq. (5) respectively.

· changed angle of $0^{th}$ lane

$$\theta_{changed,0} = \theta_x \qquad (4)$$

· changed angle of $i^{th}$ lane

$$\theta_{changed,i} = \theta_{changed,i-1} \times \frac{\theta_{diff_{i+1}}}{\theta_{diff_i}} \qquad (5)$$

If **P**$(\xi, \zeta)$ denotes an intersection 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 zone, a new transformation point $\mathbf{P}(x', y')$ after panning is expressed as Eq. (6).

$$x' = (x_1 - \xi)\cos(\theta_{diff_i}) + (y_1 - \zeta)\sin(\theta_{diff_i}) + \xi$$
$$y' = (x_1 - \xi)\sin(\theta_{diff_i}) + (y_1 - \zeta)\cos(\theta_{diff_i}) + \zeta \quad (6)$$

When a tilting is occurred, we have to calculate the depth of image which depends on camera height and distance from camera. Let $\theta_y$ is real distance from camera position to image center, the vertical moving distance $d$ after tilting is expressed as Eq. (7).

$$d = C_h \tan[\theta_y + \tan^{-1}(\frac{\delta}{C_h})] - \delta \quad (7)$$

In case of panning and tilting are occurred concurrently, ie, panning is occurred as $\sin(\theta_x)$, the detection zone is moved with distance $d$.

In zooming, 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 the **XY** direction, while **z** is positive but is less than 1, there is contraction in that direction.

$\mathbf{P}(x_c, y_c)$ is central point of image, and arbitrary point of image before zooming is $\mathbf{P}(x_i, y_i)$ after zooming, a transformed point $\mathbf{P}(x_k, y_k)$ is calculated as Eq. (8).[10,11,12]

$$x_k = z \times (x' - x_c) + x_c$$
$$y_k = z \times (y' - y_c) + y_c \quad (8)$$

## Ⅲ. Storing and Restoring Images in Hemisphere

Without mechanical errors and external environments, the detection zone installed inter lane exactly by mathematical methods as we discussed in section 2. But, these errors always occur in real world, so that it have to be applied revision algorithm to higher accuracy of setting detection zone.

We proposed an algorithm for storing and restoring images on hemisphere in order to apply revision to higher accuracy of installing detection zone.

The conceptual diagram of hemisphere image is illustrated in figure 3.

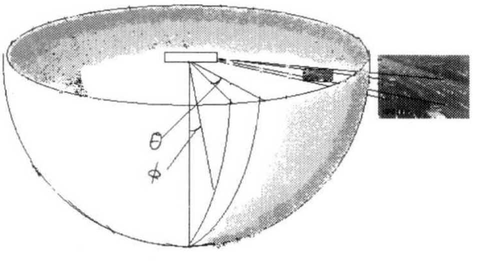



Fig. 3 Conceptual diagram of storing images in hemisphere

Since the hemisphere is most adaptive with panning and tilting as shown in figure 3, suppose that the CCTV camera can be rotated from 0 degree to 90 degree vertically and from 0 degree to 180 degree horizontally, the image data is saved from 25 to 85 degree vertically every 10 degree and from 0 to 180 degree at horizontally every 18 degree.

Then algorithm of storing and restoring images in hemisphere is as followings.

***Storing algorithm in hemisphere.***

1. Let H and V is number of horizontal and vertical pixels respectively,

2. Storing image buffer is

$$G = \begin{bmatrix} P_{00} & \cdot & \cdot\ P_{0H} \\ \cdot & \cdot & \cdot \\ \cdot & P_{ij} & \cdot \\ P_{V0} & \cdot & \cdot\ P_{VH} \end{bmatrix}$$

3. When tilting is occurred,

$$1\ pixel = \frac{2\pi}{H}\ radian$$

4. If $\phi$ denoted tilting angle from origin, the pixels of horizontal circle is $H \times \sin\phi$

5. At this time, if panning is occurred $\theta$ from origin,

the number of moving pixel is calculated by $\frac{\theta}{2\pi} H \times \sin\phi$

6. Storing $P_{ij}$ in buffer

$$for\ \ \phi_{step} = 0 \text{ to } \frac{H}{2\pi} \times \frac{10\pi}{180}$$

$$\phi_{set} = [(25 + (i-1) \times 10) - 5] \times \frac{\pi}{180} + \frac{2\pi}{H} \times \phi_{step}$$

$$\theta_{low} = [((j-1) \times 18 - 9)/360] \times H \times \sin\phi_{set}$$

$$\theta_{high} = [((j-1) \times 18 + 9)/360] \times H \times \sin\phi_{set}$$

$$for\ \ \theta_{step} = \theta_{Low}\ to\ \theta_{High}$$

$$x = \theta_{step}$$

$$y = \frac{H}{2\pi} \times \frac{10\pi}{180} \times (i-1) + \phi_{step}$$

$$\text{average} = \frac{(\theta_{Low} + \theta_{High})}{2}$$

Store to G buffer, ie,

G[x][y]=

$$(x_c - (average - \theta_{step}),\ y_c + \frac{H}{2\pi} \times \frac{10\pi}{180} - \phi_{step})$$

of (*i,j*)th image.

*where*, $x_c, y_c$ is central point of image

Next $\theta_{step}$

Next $\phi_{step}$

***Restoring algorithm from hemisphere.***

1. Suppose that the CCTV camera angle is $(\theta, \phi)$

$$y_{set} = [\frac{\phi\pi}{180} - \frac{20\pi}{180}] \times \frac{H}{2\pi}$$

2. Restoring images from buffer

$$for\ y = y_{set} - 120\ \ to\ \ y_{set} + 120$$

$$x_{set} = \frac{\theta\pi}{180} \times \frac{H}{2\pi} \times \sin(\frac{H}{2\pi} \times \frac{10\pi}{180} \times 2 + y) \times \frac{2\pi}{H}$$

$$for\ x = x_{set} - x_c\ \ to\ \ x_{set} + x_c$$

$$X = x - (x_{set} - x_c)$$

$$Y = y - (x_{set} - y_c) + 320$$

$$P(X, Y) = G[x][y]$$

$$Next\ x$$

$$Next\ y$$

Actually, we capture the images which is projected in the tangent plain on a hemisphere from the real plain.

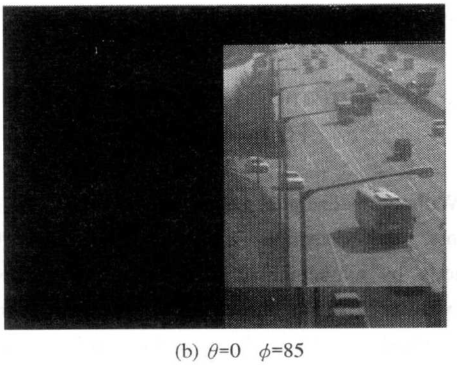
## Ⅳ. Experimental Results

In this research, a new CCTV camera and pan, tilt driver are installed about 15 meters high on Kiheung IC upstream on the Kyongbu highway. We give a value of panning angle $\theta$ from 0 to 36 degree and tilting angle $\phi$ from 65 to 85 degree, and the result of storing images in hemisphere is shown as figure 4.

Fig. 4 Storing images in hemisphere( $\theta$ is 65~85 and $\phi$ is 0~36)

For restoring images can be extracted from hemisphere $\theta$ and $\phi$ correspondingly, as shown in figure 5.

(a) $\theta$=27 $\phi$=70



(b) $\theta$=0 $\phi$=85

(c) $\theta$=9 $\phi$=75

(d) $\theta$=18 $\phi$=70

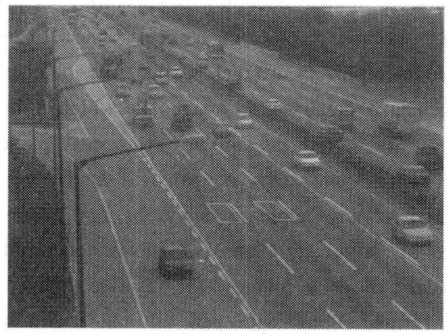
Fig. 5 Restoring images from hemisphere $\theta$ and $\phi$ corresponding

As shown in figure 5, we are able to compare the image with pan and tilt angle of CCTV camera to restored image from hemisphere $\theta$ and $\phi$ correspondingly, and then calculate the difference of two images with image matching, present image can be revised if CCTV camera is influenced by mechanical errors and external environments. When panning angle is 18 degree and tilting angle is 70 degree in this hemisphere database system the restoring image is in figure 5 (d).

In figure 6, (a) is an image in which detection zones are installed initially, and (b) is extract the restored image from the hemisphere database and the marked detection zones which are calculated with changing pan, tilt angle and (c) is the image marked with detection zones transferred by panning, tilting factors from the original image (a).

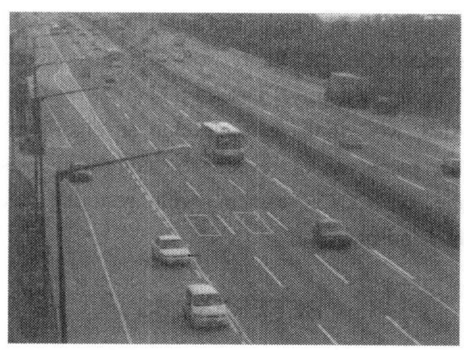
For revising of coordinates of detection zone in real captured image, suppose that pan, tilt angles are changed, then the changed image and detection zones are showed as in figure6 (c).

In this case, the changed detection zones are transformed by mathematical formulation as with pan, tilt angle and they should be corrected practically, using figure 6 (b) we can calculate some pixels which are corrected by compare the location of detection zones in figure 6 (c) with the location in (b).



(a) An image in which detection zone is installed initially

(b) Extract the restored image from the hemisphere database and marked detection zone which calculated with changing pan, tilt angle.



(c) The image marked with detection zones transferred by pan, tilt angle from the image (a).

Fig. 6 For revising the detection zone in real situation

## V. Conclusions

In this research, algorithms are suggested to install the detection zones automatically with panning, tilting, zooming of CCTV camera on the highway, and an algorithm for storing and restoring images in hemisphere in order to apply revision to higher accuracy of installing detection zone, because of mechanical and external environment errors in real world. The hemisphere images is a database of images in which a lot of images are stored tangentially from real plane as along with some steps of pan, tilt angle and are restored at any angle as same as real plane. In spite of some problem which is occurred at boundary of each images, the restored images are well formed along with pan, tilt angle and using this images we can correct the detection zone when an, tilt angle is moved in the system of CCTV camera.

A characteristic of our algorithm is the detection zones can be installed inter each lane automatically according to the panning, tilting and zooming factors of CCTV cameras and the coordinates of detection zones of captured image also can be revised automatically using pre-saved hemisphere image, if CCTV cameras are influenced by mechanical errors or external environments

However, as this algorithm was experimented with a limited the number of images, the applicability in real traffic situation is not guaranteed. 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 revision by comparing present image of CCTV camera with restoring image from hemisphere.

## 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] N. Seong, I. J. Lee, J. Y. Min, B. J. Yun, Y. H. Kim, An Algorithm for Automatic Installation of Detection Area by Analyzing the Panning, Tilting and Zooming Factors of CCTV Camera, *Proceeding of 8th World Congress on Intelligent Transport Systems*, Sydney, Sep.,30-Oct. 4, Sydney, Au., 2001

[5] 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.

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

[7] In J. Lee, S. Namkoong, Joon Y. Min, Byeong J. Yun, 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, *the Korean Institute of Communication Sciences,* Vol. 26, No.10B, 2001.

[8] 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.

[9] B.E.Meserve, Joseph A. Izzo, Fundamentals of Geometry, 2nd Ed. Addison-Wesley, 1972.

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

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

[12] D.F.Rogers, J.A. Adams, Elements for Computer Graphics, 2nd Ed., McGRAW-HILL.
[13] 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.
[14] R.Wang,T.Huang, Fast Camera Motion Analysis in MPEG Domain, *Proceedings of IEEE Intl Conf. Image Processing*, Vol.3, Kobe, Japan, pp.691-694, Oct.1999.

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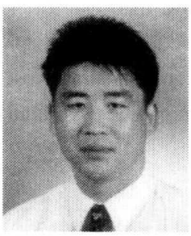

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