고속도로 CCTV카메라 영상에서 차량 추적에 의한 교통정보 수집 알고리즘

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요 약

본 논문은 고속도로에 설치되어 있는 CCTV카메라 영상을 이용하여 자동으로 교통정보를 수집할 수 있도록 영상검지기 기능을 부가하는 방법을 제안한다. 현행 고속도로 영상검지기에서 수집되는 교통정보는 차로별로 교통정보를 검지하여 수집할 수 있으나 이 방법은 대형차량이 지나가는 경우 Occlusion에 의한 오 검지 빈도가 빈번히 발생하고 있다. 또한 이 Occlusion의 영향으로 고속도로 8차로 중 최고 6차로까지만 검지가 가능하고 그 이상의 차로를 검지한다는 것은 불가능하다. 따라서 본 논문에서는 교통정보를 차로별 검지를 하지 않고 전체 차로를 포함하는 검지영역을 설정한 다음 다음 이 검지영역 안에서 차량이 통과할 때까지 개별차량을 추적하여 교통정보를 수집함으로써 고속도로 8차로까지 검지가 가능한 알고리즘을 제안한다.
본 연구는 실제 경부고속도로 상행선 기흥IC에 실험용 CCTV카메라를 설치하여 획득한 영상과, 청계터널 앞 도로에서 녹화한 영상을 대상으로 실험을 하였으며, 영상처리는 frame-grabber보드에서 초당 30프레임으로 캡쳐를 한 다음 640×480 해상도와 빠른 데이터 처리를 위해서 256 gray-level로 영상처리를 하였다.

An Algorithm for Traffic Information by Vehicle Tracking from CCTV Camera Images on the Highway

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ABSTRACT

This paper is proposed to algorithm for measuring traffic information automatically, for example, volume count, speed and occupancy rate, from CCTV camera images installed on highway, add to function of image detectors which can be collected the traffic information. Recently the method of traffic informations are counted in lane one by one, but this manner is occurred critical errors by occlusion frequently in case of passing larger vehicles(bus, truck etc.) and is impossible to measure in the 8 lanes of highway.
In this paper, installed the detection area include with all lanes, traffic informations are collected using tracking algorithm with passing vehicles individually in this detection area, thus possible to detect all of 8 lanes.
The experiment have been conducted two different real road scenes for 20 minutes. For the experiments, the images are provided with CCTV camera which was installed at Kiheung Interchange upstream of Kyongbu highway, and video recording images at Chungkye Tunnel. For image processing, images captured by frame-grabber board 30 frames per second, 640×480 pixels resolution and 256 gray-levels to reduce the total amount of data to be interpreted.

Ⅰ. Introduction

In Korea, highway construction plan is that 19 new lines, total 1,848.3km will be constructed and that 21 lines, total 2040.5km will be extended[1]. When a new highway lines are constructed, ILD(Inductive Loop Detectors), 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]. However, 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 controllers eyes.

To help view of controllers, panning/tilting and zooming function are provided in CCTV cameras.

The difference between image detectors and CCTV cameras, first, the traffic image should be provided in the limit area, 200~300m forward, through the image detectors, whereas CCTV camera system has pan/tilt and zoom driver, therefore, it should provided traffic information in wide area, at over 2km. And second, image detectors is able to cover maximum 4 lanes, so that it cannot detect the incident vehicles on the shoulder, however, it is possible to cover as far as 8 lanes and shoulders through the CCTV camera, incident vehicles on the shoulder can be detected.

The most popular applications of tracking algorithm is used to autonomous vehicles system and image detectors. Several vision systems for autonomous vehicles have been focused on the road following and obstacle avoidance problems[4]. Dickmanns *et. al.*[4,5] proposed a Kalman-based integrated spatio-temporal approach for autonomous vehicles driving. This system, which performs recursive state estimation by implemented on a multiple instructions multiple data. Results concern road-vehicle guidance at high speed, including obstacle detection, however, road scene recognition is not performed. The CMU-Navlab system[4,6], was developed at the Carnegie-Mellon Univ., includes road-following and recognition capabilities by using color classification and neural nets. 3-D perception using difference types of terrain representation, obstacle maps, terrain feature maps, etc., is examined. Foresti *et. al.*[4,7] developed a distributed 3-D road scene

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recognition system based on multi-level representation of object models and signals. Results include recognition of static object such as road and stopped vehicles on it, and their location.

And the other method, the snake methods[8] was calculated the energy of counter, the clustering methods and optical flow[8,9] method using vector quantization for estimation of moving direction of vehicles.

In this research, for measuring traffic information automatically such as volume count, speed and occupancy rate, from CCTV camera images installed on highway, and then being added function of image detectors which can be collected the traffic information. Recently, the most algorithms of traffic informations using image surveillance system have a critical errors by occlusion[10] in case of passing larger vehicles such as bus, truck etc., because these methods are counted in lane one by one, especially, far off lanes from CCTV camera position, the occlusion is occurred extremely. Thus it is impossible to measure the traffic information over the 8 lanes of highway. To solve these problems, we propose an algorithm for traffic information by vehicle tracking from CCTV camera images on the highway.

For the experiments, the images are provided with CCTV camera which was installed at Kiheung Interchange upstream of Kyongbu highway, and video recording images at Chungkye Tunnel. For image processing, images captured by frame-grabber board 30 frames per second, 640×480 pixels resolution and 256 gray-levels to reduce the total amount of data to be interpreted.

Ⅱ. Tracking Algorithm for Collecting the Traffic Information

2.1 Setting up the Detection Area

In preceding work, detection areas which were set up in each lane[11], have an fatal error to be caused by occlusion, especially when larger vehicles are passed. Therefore, it is not possible to measure all over the 8 lanes(including upstream and downstream). In this research to solve the problem of occlusion, one detection area block is set up including all of 8 lanes, and tracking should be applied that the vehicles pass through a detection block.

Figure 1 shows the result of setting up detection area in proposed method.

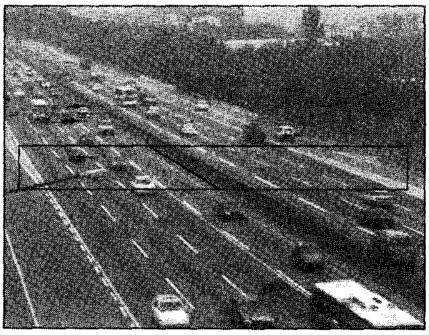


Figure 1. Setting up Detection Area (Kiheung IC, Upstream of Kyongbu Highway)

2.2 Detect the Vehicles

In measuring volume count of passing through the detection area as shown in figure 1, the difference image from background is obtained and generate the binary pattern as Eq. 1.

$$I_t : R^{+} \rightarrow \{0, 1\} \text{ by}$$

$$I_t(X) = \begin{cases} 1 & \text{if } X > \theta \\ 0 & otherwise \end{cases} \quad \text{(Eq. 1)}$$

Where, R^{+} denotes 0 and positive real number, θ is threshold,

$X = |P_t(x, y) - Bg(x, y)|$,

$P_t(x, y)$ is current frame image, and $Bg(x, y)$ is background image.

The binarized image of passing vehicles in detection area from Eq. 1 is shown in figure 2.

Figure 2. Binarized image of passing vehicles in detection area (at Chungkye Tunnel)

2.3 Detection of VAR(Vehicle Area Rectangle)

In this research, the detection area is divided into $n \times n$ sub-blocks in order to decide the VAR(Vehicle Area Rectangle). If white colors in each sub-block are distributed more than λ% after binarization, occupancy flag should be TRUE. Then from Eq. 2, the sub-blocks which have TRUE of occupancy flag, are extracted from detection area.

Binary function $OccFlags(x) : R \rightarrow \{0, 1\}$ by

$$OccFlags(x) = \begin{cases} 1\ (TRUE) & \text{if } x > \lambda \\ 0(FALSE) & otherwise \end{cases}$$

(Eq. 2)

where, $x = \frac{1}{N} \sum_{i,j=0}^{N-1} p_{i,j}$ and

$p_{i,j}$ has 0 or 1; λ is threshold.

In Eq. 2, the VAR is drawn as much as vehicle size when the influx of a vehicle into detection area, and then tracking process for vehicles in each frame is performed according to direction of vehicles until the vehicles pass through the detection area. At this time, the VAR is drawn in each frame continuously.

For deciding on VAR, the left line of VAR is decided by tracing from left-side of detection area and counting the TRUE occupancy flag of sub-blocks, they are over 20% between M sub-blocks. Also, the right line of VAR is decided by tracing from right-side of detection area, and then the width of VAR is decided.

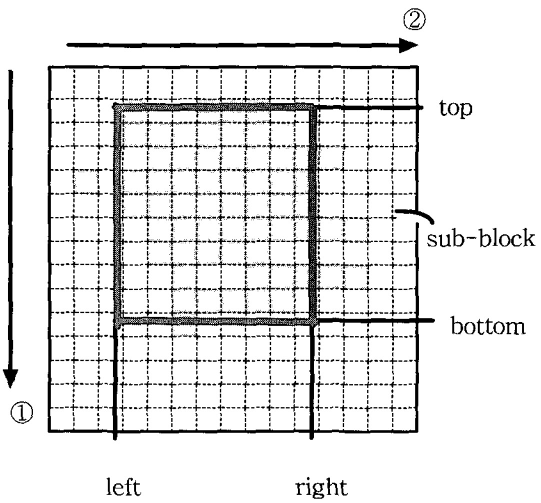


Figure 3 shows the result of making VAR.

In figure 3, searching to direction ①, the left and right line of VAR can be drawn by counting the TRUE sub-blocks(for example, 4 and 5 blocks as figure 3) which are over 20% of occupancy rate between M sub-blocks(15 blocks in figure 3) in detection area. And searching to direction of ②, the top and bottom line of VAR also can be decided by projection between left and right line, and counting the TRUE sub-blocks, over 20%.

By this method, the VAR should be drawn all vehicles within detection area as shown in figure 2.

Ⅲ. Collecting the Traffic Information

3.1 Volume Count

For collecting the traffic information using by tracking, the direction ingredients of vehicles have to be extracted in each frame image. That is made a comparison the central point of VAR between *t-1* frame and *t* frame image, we can consider the same vehicle when the nearest point of VAR between two frames can be found as Eq. 3.

$$D_j = \min_{1 \le k, j \le n} \left(\sqrt{(x_{k,t} - x_{j,t-1})^2 + (y_{k,t} - y_{j,t-1})^2} \right) \qquad \text{(Eq. 3)}$$

n : the total number of VAR within detection area.
k : a number of VAR within t frame image.
j : a number of VAR within $t-1$ frame image.

As Eq. 3, if the nearest VAR between two frames is found, assign a volume number to VAR. This procedure is performed repeatedly to next frame, and the assigned volume number is maintained until the vehicle is passing through the detection area. At this time, the assigned number indicates volume information. If several vehicles are existed in detection area, the volume number is assigned sequentially to each vehicle.

3.2 Measuring Velocity

The moving distance of vehicle is different from each lane according to ratio of near and far because CCTV camera is installed on road-side of highway. Therefore, in order to measure the speed passing from P_1 through P_2 of detection area, the real distance of lanes $L_1, L_2, \cdots L_n$, as shown figure 4, have to be obtained on the basis of L_1 from Eq. 4

$$R=\frac{L_i}{L_1} \quad , \quad 2 \leq i \leq n \qquad \text{(Eq. 4)}$$

The real distance of each lane within detection area is calculated from Eq. 4, if the central point of VAR is existed between L_k and L_{k+1}, $(1 \leq k \leq n-1)$, the velocity can be calculated by moving distance and passing time.

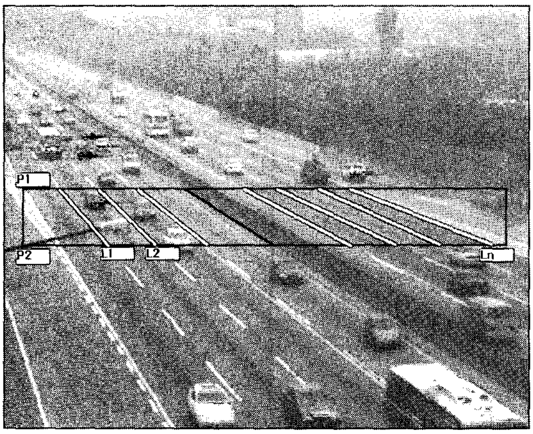


figure 4. real distance of each lane within detection area for measuring velocity

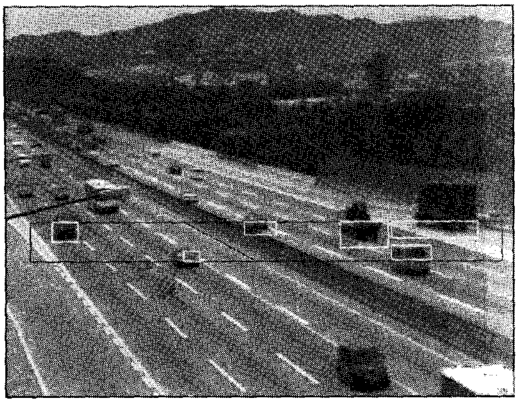
Ⅳ. Experimental Results and Analysis

Experiments have been conducted on image data captured at CCTV camera installed 15 meters high at Kiheung Interchange(IC) upstream place on the highway and video recorded image from image detector system at Chungkye tunnel. The images of Kiheung IC was collected on July 5, 2001, from 2:00pm for 20 minutes and images at the front of Chungkye tunnel was recorded on October 22, 1998, from 11:15am for 20 minutes.

For image processing, images captured by frame-grabber board 30 frames per second, 640×480 pixels resolution and 256 gray-levels to reduce the total amount of data to be interpreted.

The detection area is divided into $M \times N$ sub-blocks, the resolution of each sub-block has 4×4 pixels. The occupancy flag should be TRUE, if the white colors have been distributed over 30% in sub-block after binalization. Figure 5 shows the result of measuring volume count.

(a) the front of Chungkye Tunnel



(b) Kiheung Interchange
Figure 5. The result of measuring volume count

The accuracy rate is calculated by comparing between measured volumes from system and observed ones. And speed accuracy is calculated by average of accumulated speed for 5 minutes. The observed velocity data was obtained by ILD(Inductive Loop Detectors), and compared with measured data.

Such a measurement precision method is carried out actually by the certification test of official organization.

The table 1 shows the result of our experiment.

<Table 1> Experimental Results

Place	Time	Volume Count			Velocity(Km/h) (average accumulated speed for 5 min.)		
		measured	observed	error rate (%)	measured	observed	error rate (%)
Chungkye Tunnel	Oct. 22, 1998 11:15am ~ 11:35am	171	185	92.5	121 132 123 119	112 122 105 108	92.0 91.8 82.9 89.8
Kiheung IC	July 5, 2001 2:00pm ~ 2:20pm	825	989	83.4	85 91 88 90	105 103 102 105	80.9 88.3 86.2 85.7

In this table, the accuracy is shown on the decline at Kiheung IC, because this section is located near by metropolitan area, so that too many vehicles passed in this area, the volume cannot be counted exactly in some cases, especially very crowded situations. Also, the measurement of velocity is affected by those cases.

In existing image detector system on the highway, the accuracy rate of volume is ordinally a little bit over 80% in fine weathers and lower 75% in rainy or snowy days.

V. Conclusions

We have developed a measurement of traffic information automatically, for example, volume count, speed and occupancy rate, from CCTV camera images installed on highway, and then being added function of image detectors which can be collected the traffic information. In preceding work, detection areas which were set up in each lane, have an fatal error to be caused by occlusion, especially when larger vehicles are passed. Therefore, it is impossible to measure all over the 6 lanes including upstream and down-stream. In this research to solve this problem, one detection area block is set up including all of 8 lanes, and tracking should be applied that the vehicles pass through a detection block.

The characteristics of this algorithm are as followings.

First, the volume error which is caused by occlusion, is reduced because the detection area is installed without dividing lanes. And second, it is possible to measure the traffic information in over 8 lanes.

But, this method have some problems. In this research, the experiment is only conducted in daytime, however in nighttime, it is difficult to measure the volume and speed because taillight of vehicles is shown dimly in a contrary direction of CCTV camera. And this method have to be spent more time to process because of the broad detection area. Also, the accuracy rate is not satisfied and guaranteed in very crowded situation.

In the future research, we will have to improve an algorithm for higher precision of measuring various traffic information under any situations, nighttime, rainy and snowy day.

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