APPLICATION OF IMAGE PROCESSING TECHNOLOGY TO TRAFFIC COUNTING

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ABSTRACT

We have been studying how to apply image processing technology (IPT) to traffic counting. Our particular interest is to identify optimum camera settings according to different traffic conditions. Our previous studies demonstrated that there are two types of errors in traffic counts with IPT: failing to count a vehicle due to a limited time to observe the vehicle in the image (Error type 1), and counting several vehicles as one due to the overlapping of vehicles in the image (Error type 2).

In this study, we investigated how the two types of error occur according to different traffic conditions. We videotaped running vehicles simultaneously by four cameras installed at different angles (15, 30, 45 and 60 degrees from the vertical) when traffic was “free flowing”, “moderately congested” and “heavily congested.” Through the analysis of these images, the following results were obtained:

1) When traffic is heavily congested, eliminating Error type 2 is more significant than Error type 1 because the gap between vehicles is smaller, and the optimum camera angle is 15 degrees from the vertical so as to observe a greater space between vehicles in the image.
2) When traffic is free flowing, eliminating Error type 1 is more significant than Error type 2 because vehicles travel faster, and the optimum angle is 45 degrees so as to observe a vehicle in the image for a longer time.

Keywords: vehicle, traffic survey, road transport, Markov random field model

1 INTRODUCTION

The primary method for measuring traffic volume on arterial roads in Indonesia is the combined use of an inductive loop and a piezoelectric sensor (LPS) as shown in Figure 1. However, this method lacks accuracy. Obviously, an LPS device cannot detect motorbikes that do not pass over it. Also, when several motorbikes are on the LPS device at the same time, they are counted as one vehicle or are not counted at all. In terms of durability, the LPS device often fails due to damage caused by overloaded vehicles, and the labor and cost for monitoring and maintaining the sensors are considerable. Traffic volume is a fundamental consideration when drawing up road network plans or implementing measures to address congestion issues. Therefore, there is a need to develop a robust and reliable method for measuring traffic volume.

Accordingly, the Institute of Road Engineering (IRE) in Indonesia and the National Institute for Land and Infrastructure Management (NILIM) in Japan launched in 2010 a joint study to devise an optimal method for measuring traffic volume in Indonesia by using image processing technology (IPT). This is one of the activities based on a memorandum concerning cooperative activities that was concluded between the IRE and the NILIM in 2009. The primary objective of our study is to determine the optimum camera settings for the most accurate traffic counts with IPT. This article reports some major findings of the study.

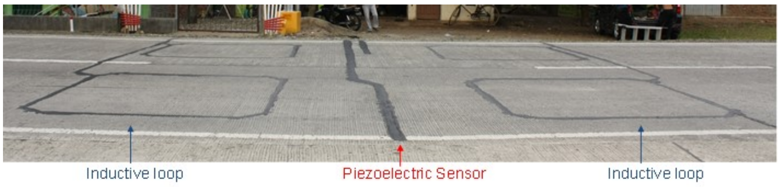

FIGURE 1 Configuration of LPS device

2 STUDY METHODS

2.1 Analysis method

Regarding the optimum camera settings, we obtained the following findings from our previous study [*1*]: a camera angle of 60 degrees from the vertical is optimum to measure traffic volume accurately, which was reported at the 14th REAAA conference in 2013. However, the analysis method we used to obtain this result might not have been ideal. As shown in Figure 2, when obtaining traffic images in the field survey, we used a single camera and installed it at several different angles during different time periods. Although the fundamental conditions used when obtaining these images were the same (in the daytime, fine weather, free flowing traffic, etc.), detailed conditions were not necessarily identical. For example, the number of cars and motorbikes, their movement, and the degree of overlapping of these vehicles differed among the images. We cannot reject the possibility that the obtained relationship between the camera angles and the error ratio might have been influenced by the difference in such detailed conditions. This motivated us to conduct the present study, where we simultaneously used multiple cameras to obtain several images from different camera angles at the same time. This enabled us to make a genuine comparison of the error ratio resulting from the difference in camera settings, and exclude the influence of the difference in detailed conditions. Also the optimum angle of 60 degrees from the vertical was derived from the comparison of images that were obtained under “free flowing” traffic; the optimum angle might differ according to traffic conditions. Therefore, in this study, we analyzed images for several traffic conditions, as shown in Figure 2.

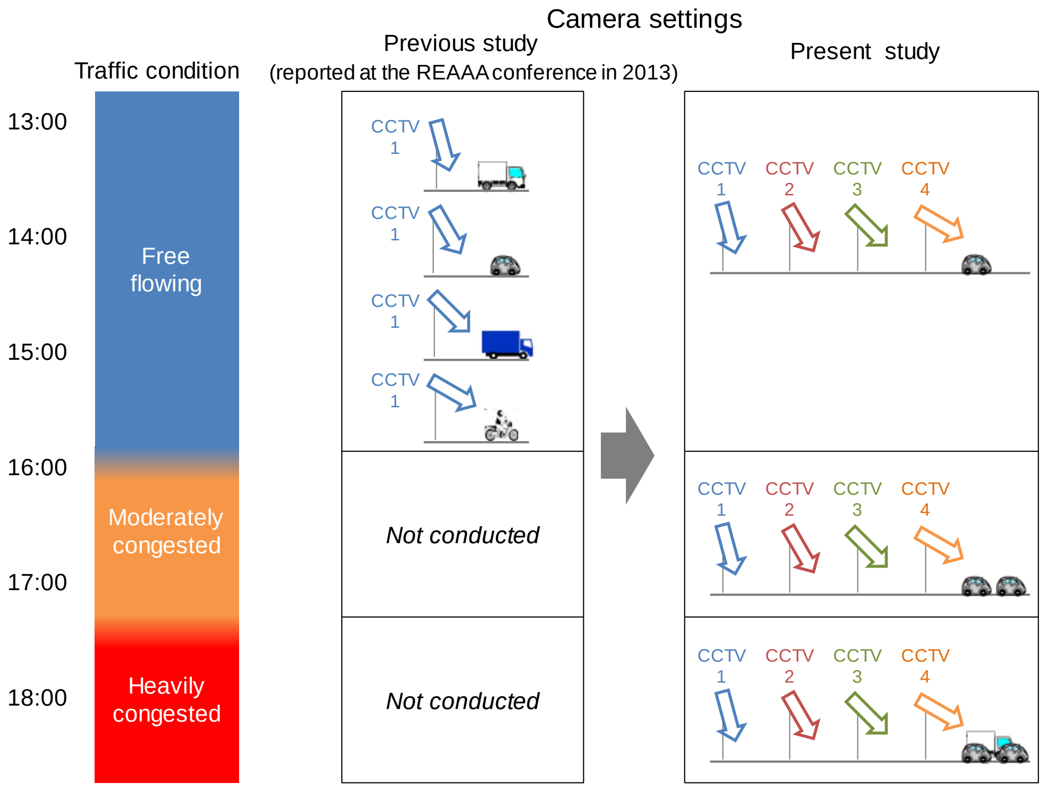

FIGURE 2 Analysis methods

2.2 Image processing technology used in study

We used an IPT device that involves the spatio-temporal Markov random field model (S-T MRF model), which was proposed by Kamijo et al. [*2*]. As shown in Figure 3, when the device detects a moving object within the analysis area in the image, the device starts following it. If the object passes the first check line and the second check line in this order, it is counted as a vehicle. The device also measures the size of the moving object when it reaches the first check line, and can thus classify vehicle types. The size is expressed by the number of pixels of the rectangle that encloses the object. We set a single threshold to distinguish cars from motorbikes. When the size of the moving object exceeds the threshold, it is counted as a car; if not, it is counted as a motorbike. The specifications of the camera used in the study are shown in Table 1.

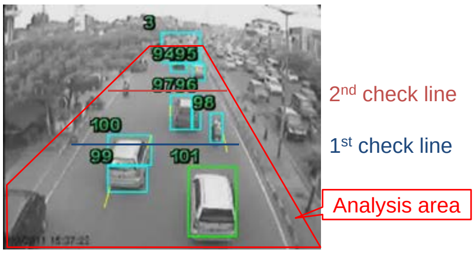

FIGURE 3 Traffic counts with IPT device

TABLE 1 Specifications of camera

Image sensor	CCD Type 1/3”
Horizontal resolution	420 TVL
Minimum illumination	0.4 lux
Electronic shutter (s)	1/50 – 1/100000
Gamma correction	0.45
Dimensions (mm)	L: 100, W: 55, H: 52

2.3 Field survey

We conducted a field survey on a national arterial road in Bandung City, Indonesia. This road lies in an urban area and functions as a feeder road for a national toll road system. The traffic volume in one direction is estimated to be 15,000 to 20,000 vehicles per day. We installed four cameras, at intervals of 0.2 meter, on a pedestrian bridge at a height of 11 meters from the ground and at different angles (15, 30, 45 and 60 degrees from the vertical). Then we videotaped running vehicles, which travel away from the cameras, under different traffic conditions (“free flowing”, “moderately congested” and “heavily congested”). Figure 4 illustrates the images obtained from the field survey.

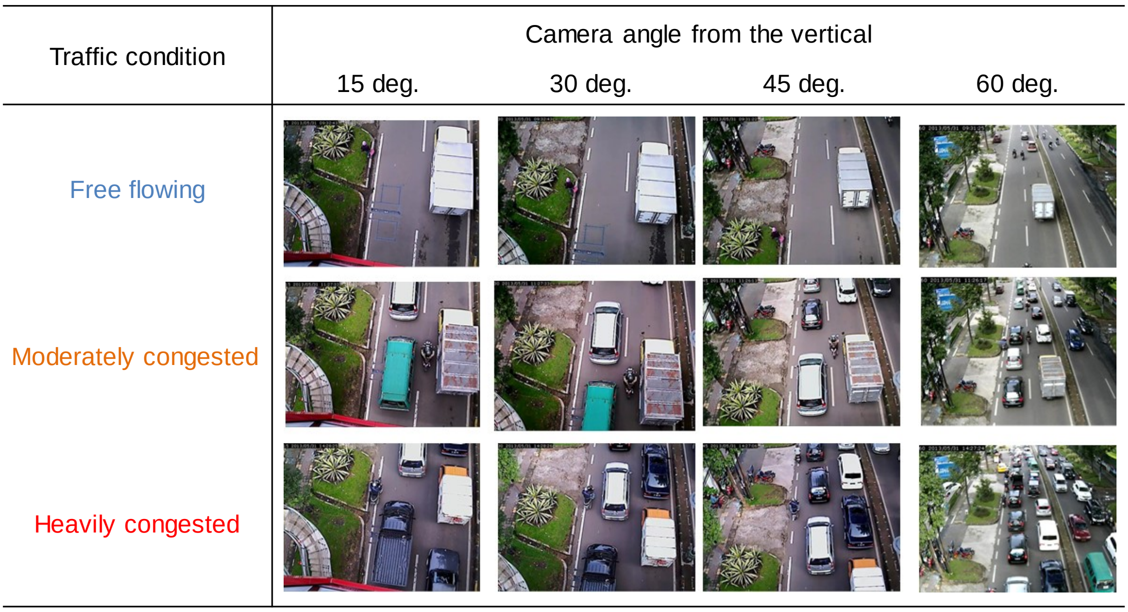

FIGURE 4 Images obtained from the field survey

3 RESULTS

From the traffic images obtained in the field survey, we measured traffic volume with the IPT device and calculated the error ratio as:

$$\text{Error ratio} = \frac{V_M - V_{IPT}}{V_M} \quad (1)$$

where, V_M : *traffic volume manually counted from video images*

V_{IPT} : *traffic volume measured with IPT device*

3.1 Overall error ratio

Figure 5 shows how the error ratio differed according to camera angles and traffic conditions. When traffic was "free flowing," the lowest error ratio was observed at an angle of 45 degrees from the vertical. The lowest error ratio for "moderately congested" and "heavily congested" was at angles of 30 and 15 degrees from the vertical, respectively. This indicates that the closer to the vertical the optimum angle gets, the more heavily the traffic is congested. This result tells us that the camera angle should be determined according to the objective of the traffic survey or the targeted traffic condition. For example, if the purpose is to identify the traffic volume during congestion, the camera angle should be closer to the vertical, whereas if the purpose is to identify the general traffic volume, the optimum camera angle is 45 degrees from the vertical.

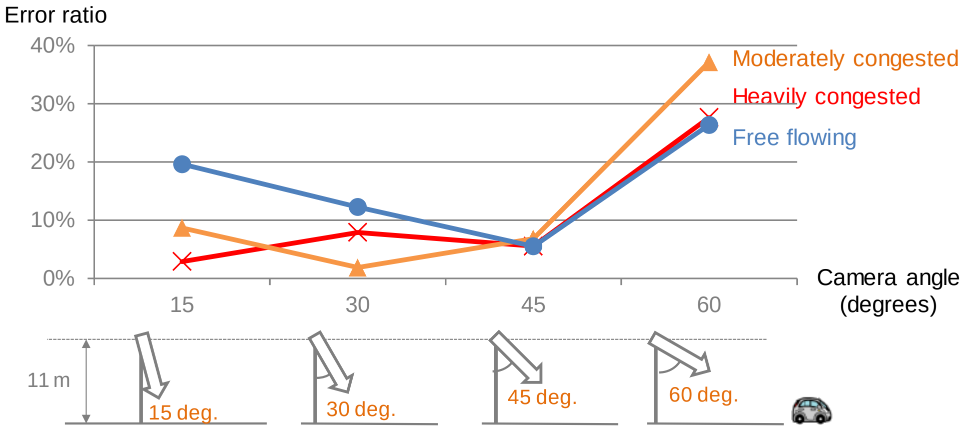

FIGURE 5 Overall error ratio

3.2 Error ratio by type

Through the analysis of the images, we learned that there are two types of errors in traffic counts with the IPT: failing to count a vehicle (Error type 1), and counting several vehicles as one (Error type 2). The error ratio shown in Figure 5 is a mixture of Error type 1 and Error type 2. In this study, we calculated the error ratio of Error type 1 and Error type 2 separately and investigated how each occurs according to different camera angles and traffic conditions. The error ratio here is calculated by vehicle type: cars and motorbikes.

3.2.1 Error type 1

Error type 1 is the error of failing to count a vehicle. This type of error tends to occur when the IPT does not have sufficient time to observe moving objects in the image (see Figure 3). We had assumed that turning the camera angle away from the vertical (e.g. from 15 to 45 degrees from the vertical) would reduce Error type 1, as the length of longitudinal roadway in the image increases, which helps the IPT to observe vehicles for a longer time.

First we looked at how the ratio of Error type 1 differs between camera angles of 15 degrees and 45 degrees when traffic was "free flowing." As shown in Figure 6, the error ratio for 45 degrees was much smaller than that for 15 degrees, as expected. Especially, the error ratio of motorbikes for 45 degrees was 10 times smaller than that for 15 degrees. On the other hand, such difference in the error ratio was not observed when traffic was "heavily congested." We assumed that this was attributable to the difference in travel time of vehicles in the image. When traffic was "free flowing," it took 0.7 second on average for vehicles to travel from the bottom to the top of the image. For "heavily congested" it took 1.9 seconds, much longer than for "free flowing." This indicates that even when a camera is installed at an angle of 15 degrees, there is enough time for the IPT device to recognize a vehicle, which travels slowly under congestion. This analysis shows that, only for "free flow" traffic, turning the camera away from the vertical (45 degrees from the vertical) can reduce Error type 1.

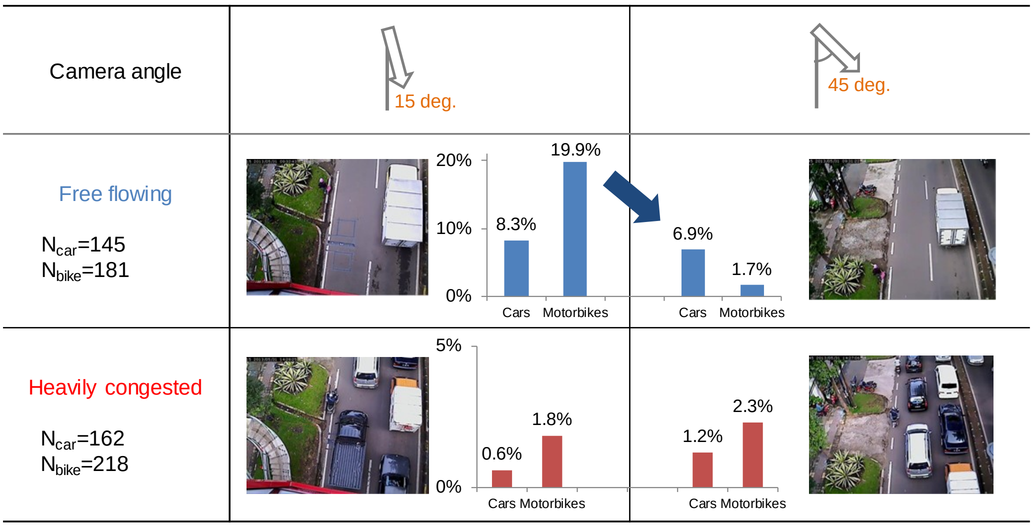

FIGURE 6 Ratio of Error type 1

3.2.2 Error type 2

Error type 2 is the error of counting several vehicles as one due to the overlapping of vehicles in the image. This error is more likely to occur when a gap between vehicles does not clearly appear in the image. It is obvious that, geometrically, observing vehicles from a position closer to the vertical can reduce Error type 2.

We compared the ratio of Error type 2 for 15 degrees and 45 degrees when traffic was "free flowing" and "heavily congested," as shown in Figure 7. The greatest error ratio was observed for 45 degrees when traffic was "heavily congested," where the gap between vehicles is the smallest among the four categories (see the picture in Figure 7). For the same traffic condition (heavily congested), the error ratio for 15 degrees is much smaller, as expected. However, when traffic was "free flowing," the error ratios of cars for 15 degrees and 45 degrees were the same (0.7%). This indicates that the camera angle does not influence Error type 2 when traffic is "free flowing." This is because, even at an angle of 45 degrees, there appears in the images enough space between vehicles in free flowing traffic. This analysis demonstrated that turning the camera closer to the vertical can reduce Error type 2, but only for congested traffic.

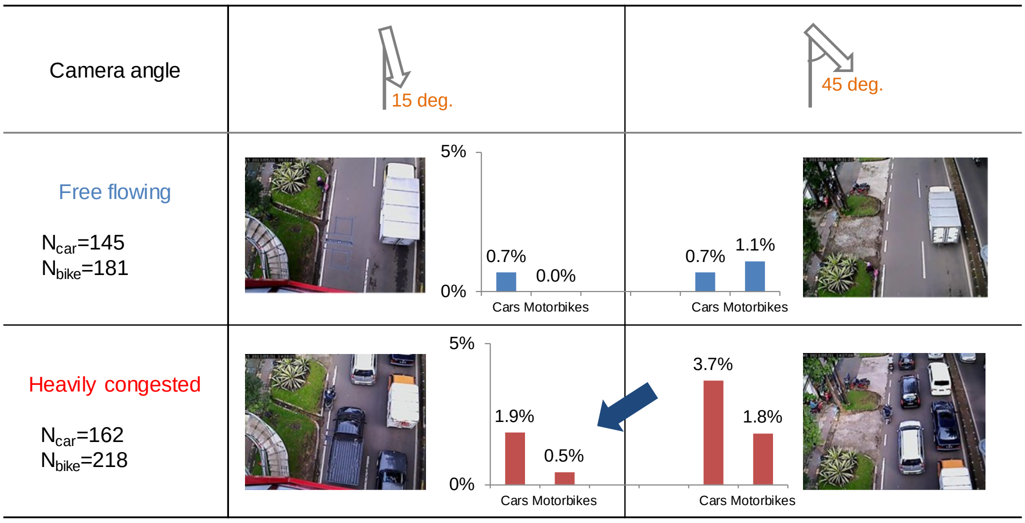

FIGURE 7 Ratio of Error type 2

4 DISCUSSION

4.1 Camera settings regarding lateral position

The primary objective of this study was to obtain knowledge about the optimum camera settings to count vehicles with the IPT. Regarding camera settings, we only examined how the error ratio differs according to the angle of the cameras, which are installed in the middle of the roadway (11 meters above the road surface).

During the study, we found that not only the camera angle but also the lateral position of the camera could influence the error ratio: the IPT can recognize a vehicle more accurately when observing from the side of the roadway than from the middle. However, we did not examine how far to the side of the roadway the camera should be installed for the most accurate measurement. We need to conduct a further study to identify the optimum lateral position as well as camera angle under given traffic conditions.

4.2 Camera settings for after dark

This study revealed the optimum camera settings for accurate traffic counts with the IPT. However, the results were derived from traffic images obtained in the daytime, which means that they cannot be applied to traffic surveys after dark. Also we only analyzed traffic images in which the vehicles traveled away from the camera, and thus the back of the vehicles was videotaped.

Practical use of the IPT device in Japan has informed us that the error ratio can often be significantly great for traffic images in which the vehicles travel toward the camera after dark. This is because the headlights cause halation in the image, thereby rendering the IPT device unable to recognize any vehicles.

We assume that this negative impact of headlights can be alleviated by installing the camera higher up with its angle closer to the vertical. Therefore, further study is necessary to clarify the effect of headlights on the accuracy of traffic counts by revealing the relationship between the camera settings (height and angle) and the error ratio for traffic images of the front of vehicles with their headlights on after dark. Such a study would help us to identify the optimum camera settings for traffic surveys 24 hours a day.

4.3 Study on combined use of the LPS and IPT device

The road authority in Indonesia wishes to understand not only how many vehicles are using roads, but also what types of vehicles, especially heavy vehicles, are using them. The IPT device we are using in this study allows us to set several thresholds to classify vehicles into more than two categories (see Chapter 2). However, it has been learned that the accuracy drops when attempting to count vehicles with several categories. On the other hand, the LPS device (see Chapter 1) has a function to count the number of axles of passing vehicles and thus classifies vehicles accordingly.

We need to conduct an additional study to verify the possibility of adding a record of the number of axles obtained from the LPS device, to the corresponding record of vehicles obtained from the IPT device, and examine how accurately those records can be matched as well as whether or not heavy vehicles can be classified accordingly.

5 CONCLUSIONS

By analyzing traffic images obtained on an arterial road in Indonesia, we were able to determine the optimum camera settings for the most accurate traffic counts with the IPT, as shown below:

- When traffic is heavily congested, eliminating Error type 2 (counting several vehicles as one due to the overlapping of vehicles in the image) is more significant than Error type 1 (failing to count a vehicle due to a limited time to observe the vehicle in the image) because the gap between vehicles is smaller, and the optimum camera angle is 15 degrees from the vertical so as to observe a greater space between vehicles in the image.
- When traffic is free flowing, eliminating Error type 1 is more significant than Error type 2 because vehicles travel faster, and the optimum angle is 45 degrees so as to observe a vehicle in the image for a longer time.

These results indicate that the camera setting should be determined according to the objective of the traffic survey:

- If the emphasis is placed on congested traffic, the optimal camera angle is closer to the vertical (such as 15 degrees).
- Otherwise, the optimal camera angle is 45 degrees from the vertical, which will allow for counting vehicles under broader traffic conditions.

The IRE and the NILIM will continue our joint studies to identify the most efficient and effective way of utilizing both the IPT and the existing LPS devices for understanding traffic flows on the road networks.

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