Automatic vehicle counting using background subtraction method on gray scale images and morphology operation

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Abstract. Traffic monitoring on road needs to be done, the counting of the number of vehicles passing the road is necessary. It is more emphasized for highway transportation management in order to prevent efforts. Therefore, it is necessary to develop a system that is able to counting the number of vehicles automatically. Video processing method is able to counting the number of vehicles automatically. This research has development a system of vehicle counting on toll road. This system includes processes of video acquisition, frame extraction, and image processing for each frame. Video acquisition is conducted in the morning, at noon, in the afternoon, and in the evening. This system employs of background subtraction and morphology methods on gray scale images for vehicle counting. The best vehicle counting results were obtained in the morning with a counting accuracy of 86.36 %, whereas the lowest accuracy was in the evening, at 21.43 %. Differences in morning and evening results are caused by different illumination in the morning and evening. This will cause the values in the image pixels to be different.

1. Introduction

The conventional method of calculating the number of vehicles requires humans as surveyors. This method requires a large cost and survey results that are highly dependent on the surveyor's motivation to conduct the survey. The advantages of this method can be done easily by anyone. So it is necessary to develop a system capable of performing calculations automatically. Image processing methods are able to process video files to detect moving objects. The field of image processing, especially the method of object tracking is already widely used to detect and classify all sorts of moving objects. The advantages of this system is to calculate the number of vehicles automatically by using a camera device, even for further development can be used to measure the speed of vehicle. With this system will get data in real time and can be done for monitoring the density of traffic. In addition, the advantages of this system can perform the classification of types of vehicles. The weakness of this system is its accuracy is very dependent on the illumination, with good illumination this system will have a very good accuracy. However, if the illumination is not good, as at night, the accuracy of this system will decrease significantly. Some earlier research applied this method to calculate and classify certain types of motor vehicles. Some research on digital image processing worth mentioning is a system to detect and classify motor vehicles based on videos. This research yielded an accuracy of 97% [1]. A similar research is on the use of image processing to calculate traffic density [2-4]. Traffic management based on artificial neural network has also been developed by researchers with the use of

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prediction function of traffic congestion [5]. Some other research make use of image processing to address similar traffic problems [6-7]. Objective of this research was applied of image processing method for automatic vehicles counting based on background subtraction on gray scale images and morphology operation.

2. Theory

Some research in the field of image processing that is applied to transportation management systems include among others by [1][3-4][8-11]. Research on video processing for traffic application and vehicle classification conducted by [4]. Technique of image processing to control traffic light, based on traffic densitydeveloped by [12]. Research on the application of image processing to monitor traffic and analyze congestion on the road conducted by [8]. This research employed automated vehicle tracking, measured vehicle speed, and recognize license plates. The software developed here made use of CCTV to acquire images. This software is integrated with the internet as to allow the monitoring system to be operated from distance in real time. Research on video processing to monitor traffic and classify vehicles on the road conducted by [1]. Research to classify vehicle types and measure traffic density on the road in real time using artificial neural network algorithm [9] and application of image processing to control traffic adaptively conducted by [13]. Another researcher to predicted congestion status by comparing real vehicle volume against its standard value [10]. A similar research was also developing a smart traffic light system based on image processing [3]. Other image processing application to detect traffic congestion using segmentation was also carried out by [11]. Intelligent Transport System (ITS) has also been studied by some researchers [5,14]. Based on those aforementioned researches, this research is aimed at developing a system that is capable of vehicles counting on the highway using digital image processing.

Background subtraction is used to detect objects by comparing two different frames with matrix distance differences. Most background subtraction techniques assume that the observed video sequence is the static background in front of the observed moving object. Some of the background subtraction methods that have been developed by researchers are Basic Motion Detection (BMD), Gaussian Mixture Model (GMM), Kernel Density Estimation (KDE), and Codebook. Based on testing the results obtained that the method of GMM and KDE has a pretty good performance, but in real time applications both methods are not good enough [15].

Based on the all research above, then in this research will be developed background subtraction method on grayscale image which applied for automatic counting of vehicle. Background subtraction method on grayscale image in principle is to find the distance of background with object with background without object on grayscale image that will generate image of object. Background subtraction can be generalized as three stages of the process ie, pre-processing, background modelling, and foreground detection. At the pre-processing stage involves simple image processing in the input video, such as format conversion, image resizing and others for the next steps [16].

Then, the background modelling stage is responsible for constructing a statistical model of the image, followed by the classification of pixels in the foreground detection phase. The purpose of this stage is to establish a consistent background model but still be able to adapt to changes in the existing environment. The model should be able to tolerate the level of environmental change, but remain sensitive in detecting the movement of the relevant object. The next step is Foreground Detection, at this stage the foreground extraction process from the background. Simply can be explained in equation (1)

$$h(x,y) = f(x,y) - g(x,y) \tag{1}$$

Where $h(x,y)$ is background subtraction result, $f(x,y)$ is image frame, and $g(x,y)$ is background modelling.

One way to extract objects from the background is to select this model through a threshold value of T. Then, the image at the point $g(x, y)$ at the value $f(x, y) \geq T$ is called the object (foreground), while the other is called the background. The equation of the thresholding value can be written according to equation (2)

$$g(x,y) = \begin{cases} 1, & if f(x,y) \geq T \\ 0, & if f(x,y) < T \end{cases} \quad (2)$$

While for multi thresholding conditions as in the following equation:

$$g(x,y) = \begin{cases} 0, & if f(x,y) > T_2 \\ 1, & if T_1 < f(x,y) \leq T_2 \\ 0, & if f(x,y) \leq T_1 \end{cases} \quad (3)$$

Where T_1 and T_2 is thresholding value.

Dilation is a morphological operation used to add or bold objects in an image. In other words, a dilation operation is performed to increase the size of the object segment. This operation causes the image of dilated results to tend to thicken. Dilation of A and B, described by A⊕B, and defined in the operator equation (4) [17]:

$$A \oplus B = \{z | (\boldsymbol{B})_z \cap A \neq \emptyset\} \quad (4)$$

with $\emptyset$ is the empty set and $\boldsymbol{B}$ is the structuring element

3. Methods

The vehicle detection system in this research went through some stages in its development. The first one was video acquisition using records of traffic on the highway taken from a flyover. It was carried out with a 13 MP cell phone camera. These videos were then processed with a computer. The camera was set as such to make it still for the best result. Recording angle was 45^o- 70^o with the help of a tripod. Timing was varied for morning, noon, afternoon, and evening. Variation is meant to find out the effect of illumination on system performance. System design for video processing comprises some stages as depicted in figure 1.Video file recording with camera, next step is frame extraction to get Red Green Blue (RGB) image, then RGB image conversion to gray scale image to get gray scale image. After the gray scale image is obtained, background subtraction from the background image without object with background image and object to get the image of the object. After that the object image is converted from gray scale image to binary image and morphological operation. The next step of feature extraction by calculating the area of the object in the binary image used to vehicles counting.

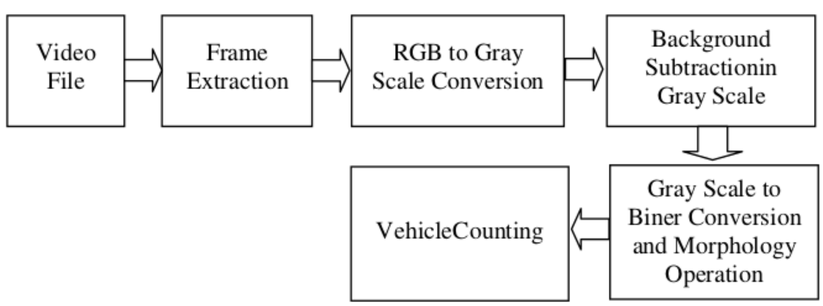

Figure 1. System design for Vehicle Counting

4. Result and Discussion

Vehicle counting system include processes of video acquisition, frame extraction, and image processing for each frame that involves segmentation, features extraction, and counting. Video acquisition was carried out in the morning, at noon, in the afternoon, and in the evening. The resulting acquired video specifications are given in table 1.

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Table 1. Data from video acquisition and frame extraction.

No	Time	Duration (s)	Number of Frame
1.	Morning	97,588	3148
2.	Noon	112,406	3626
3.	Afternoon	107,198	3458
4.	Evening	107,601	3471

Vehicle detection was managed with stages of pre-processing, background subtraction, gray scale to binary conversion and morphology operation as figure 2

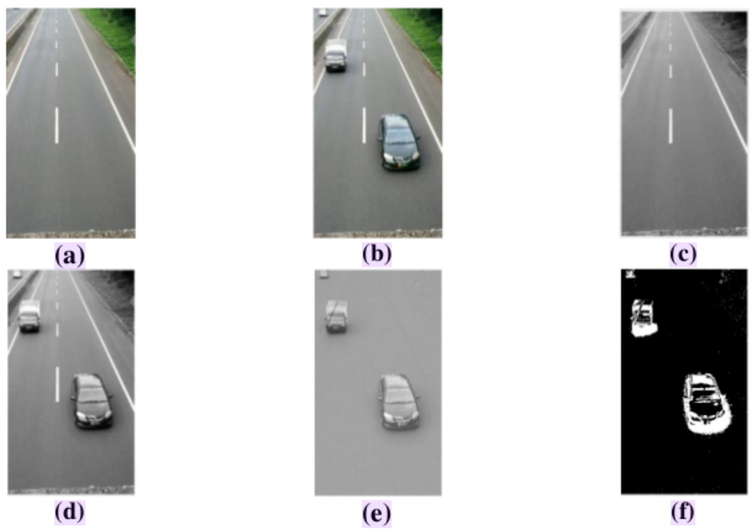

Figure 2. Vehicle detection for counting (a) and (b) Original Image, (c) and (d) Conversion from RGB to Grayscale, (e) Background subtraction from (c) and (d), (f) Multi-thresholding with $\boldsymbol{T_1 = 143}$ and $\boldsymbol{T_2 = 200}$

Based on some trials, the best threshold values gained in the morning are $T_1 = 143$ and $T_2 = 200$. Results of multi-thresholding that use both values are binary images.After segmentation with multi-thresholding, the resulting foreground image still come with gaps or little holes or pixels jostling outside object area. This requires morphological operation to perfect results of foreground images. The morphology operation involves holes filling, median filtering,and dilation. Holes filling are an operation aimed at covering holes or filling holes on the foreground image. Median filtering functions to filter foreground image as to reduce noise on the image. The following dilation is meant to add pixels on object edges on the image. The next morphological operation includes processes of black white area opening orsmall area removing.This stage is administered to get rid of small pixels. Afterwards, object labelling is done to label all pixels or area of the binary image resulted from the earlier process. Therefore, the resulting object can be detected. The final result of region foreground is visualized using a bounding box in the shape of a rectangle that adjusts itself to vehicle length. Figure 3 shows the process of morphological operation.

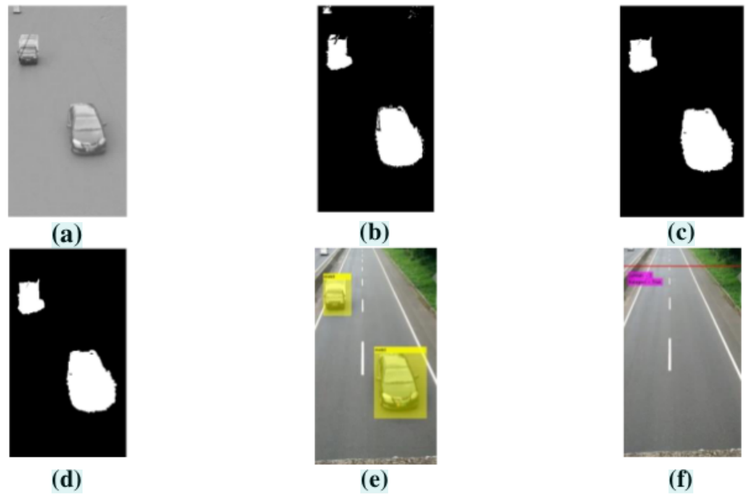

Figure 3. Morphology operation for vehicle tracking (a) Background subtraction Result, (b) Median Filtering, (c) Morphology operation (black and white opening), (d) Morphology dilation, (e) Morphology final result and tracking, (f) An image with a bounding line to vehicle Counting

Once objects have been identified and visualized using a bounding box (bbox),the next step is vehicle counting. Vehicles will be counted once detected objects pass a given bounding line. Bounding line is designated the colour red, as shown in figure 3 (f). Based on vehicle calculation in the morning, the number of correctly vehicles counting is 19 from a total actual counting of 22 vehicles, whereas the number of incorrectly calculated vehicles is 3. Table 2 shows results of manual and automatic vehicle counting in overall time. Based on the counting results given in table 2, there are mistakes in the counting process in the morning. This is due to the fact that there are object counted twice and there are also object that are not detected.Automatic vehicle counting has the ability to detect the object consistently and can be applied for monitoring the speed and traffic density in real time. So this system is very promising to be applied to the intelligence transport system as a system for traffic management. In contrast conventional methods with surveys conducted by humans are strongly influenced by the motivation and concentration of the surveyors.

Table 2. Result of Actual Counting and Automatic Counting

Time	Actual Counting	Automatic Counting	Accuracy (%)
Morning	22	19	86.36
Noon	29	18	62.07
Afternoon	37	27	72.97
Evening	28	6	21.43

5. Conclusion

This research has successfully developed a system of vehicle counting on the road. This system includes processes of video acquisition, frame extraction, and image processing for each frame. Video acquisitions were carried out in the morning, at noon, in the afternoon, and in the evening. The detection system employed grayscale image subtraction method. The highest vehicle counting accuracy is in the morning, at 86.364%, whereas the lowest vehicle counting accuracy is in the evening, at 21.429%. This method can be applied to the intelligence transport system that can be integrated in the traffic monitoring system conducted by the Indonesian Police. In addition this method in the future can be applied to automated toll gates (ATG). This method needs to be done continuous development especially to overcome the illumination problem which will affect the accuracy.

6. Acknowledgements
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