Automatic Vehicle Counting Using Raspberry pi and Background Subtractions Method in The Sidoarjo Toll Road

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***Abstract* —Traffic density can be controlled by acquiring and managing the volume data of the vehicle on the highway. Currently, the vehicle density calculating still use mechanical equipment or assign some people to calculate the vehicle, which passes the highway. However, the equipment is costly and requires many operators for manual counting. Therefore It is needed equipment that can calculate the traffic density precisely and adequately but also not expensive. This research made a simple system by using a raspberry pi, OpenCV, and Background Subtraction Method. This experiment also used real conditions in the Sidoarjo Toll Road. The experiment found that the accuracy of counting highest in the morning with an accuracy of 92.3%. Therefore the lowest accuracy result found in the afternoon counting process with accuracy 77.3%.**

Keywords—vehicle, density, raspberry pi, open cv, subtractions

I. INTRODUCTION

The number of vehicles continues to increase over time. In Indonesia, the number of vehicles is around 11% per year, and the road length is only 0.01% per year [1]. It happened because of the lack of public transportation that operates so that people choose to use private vehicles. To get data of vehicles passing on the highway, still using mechanical machines or still done manually by assigning two or more people (operators) to calculate the passing vehicles. The expensive equipment prices also become an obstacle in the process of calculating vehicle density. These problems make the process of calculating vehicle density more complex. So It is needed a technology with reasonable accuracy, easy to operate but also not expensive.

Raspberry Pi is an inexpensive embedded system but reliable [2]. With only around 60 USD have been able to make a reliable vehicle density detection system. There is a lot of research related to embedded systems using raspberries as a supporting device. In this study, the raspberry pi connected to a camera that records the vehicle through its camera. Then the video will be processed so that it found how many vehicles pass. Besides that, Open CV also used during video processing. The OpenCV was a C/C++ based open source program used as computer vision. Moreover, the background subtraction would do the image processing so that the system could count the vehicle pass in Sidoarjo Toll Road [3].

Sidoarjo Toll Road is a road with the highest density in East Java. This road has a length of approximately 49 km. This road also connects the capital city of East Java Province with southern cities, as shown in Fig. 1. That way, this toll road is vital, and this research focused on this highway.

Fig. 1. Sidoarjo toll road [4]

II. RELATED WORKS

A. *On-Road Vehicle Detection and Tracking Based on Road Context and Ambient Lighting Adaptive Framework.*

This research discusses how to detect and track vehicles by combining the use of road contexts, arbiter features based on lighting models, and adaptation metrics [5]. The context of the road was useful for the effectiveness of hypothesis generation (HG) when the arbiter's feature chooses the appropriate detection method for the region of interest (ROI) given as a human decision. To solve multiple detections and tracking problems using two separate algorithms in real-time vehicle detection and day and night tracking and the adaptive fusion feature framework for each method under lighting conditions.

B. *Vehicle Classification using Gaussian Mixture Model (GMM) dan Fuzzy Cluster Means (FCM).*

This study discusses the classification of vehicle types with the technique of recording moving objects and stored in the form of video files. In the Gaussian Mixture Model (GMM) processed method to filter moving objects that have 2 types of distributions: Background and Foreground distribution. Also, the vehicle extraction results will be used as a Cluster for the classification process of vehicle types using Fuzzy Cluster Means. Where in the vehicle classification is divided into three, namely motorbike vehicles, cars, and buses/trucks. From these studies showed satisfactory results with the level of classification accuracy reached 91.3% [6].

C. *Low-Resolution Vehicle Image Recognition Technology by Frame Composition of Moving Images.*

This research presents vehicle image recognition technology to detect distant vehicles with frame composition in moving images [7]. To detect vehicles using a camera mounted on the vehicle and using super-resolution (SR). The

purpose of this study is to increase vehicle resolution considerably by combining several frames of video input. In the method, average processing is used to combine multiple frames, with synthesis positions determined by template matching and opaque correction using unsharp masking to obtain super-resolution images.

D. State Machine and Downhill Simplex Approach for Vision-Based Nighttime Vehicle Detection.

This study discusses vehicle detection at night for road monitoring systems by combining the state machine and downhill simplex methods. Vehicle detection was targeted for situations in which the headlights cannot segment due to bright objects from the vehicle modeled as a problem in a sequence of vehicle transitions that is the arrival of the vehicle, movement, and departure. Then the system can detect the vehicle automatically with background subtraction and the vehicle lights indicator as a reference, by extracting the lighting object through the dynamic thresholding process and the number of bright pixels in the selected area [8].

III. THE SYSTEM OVERVIEW

The following is an overview of the system for detecting and counting vehicles on the highway:

A. The System Design

This traffic density monitoring system uses a camera to analyze road traffic density. The camera will be connected to the laptop and will store video files that can detect the vehicle and the number of vehicles. The road to passing on it must have a bridge that is used to put the camera. The camera is set to be immovable and stable in order to get a perfect recording. For data collection on one-way highways can be seen in Fig. 2.

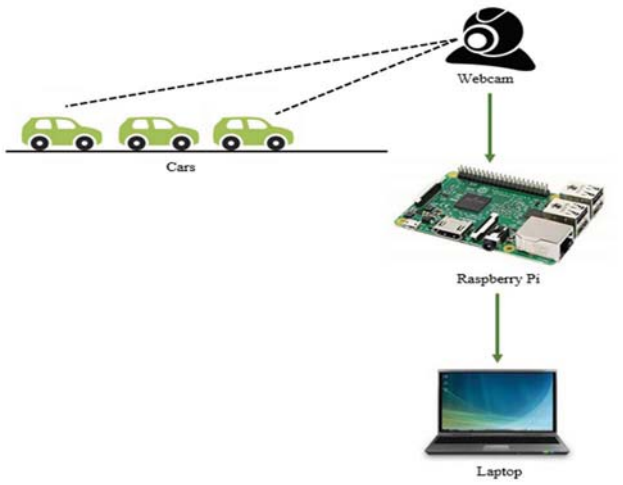


Fig. 2. The system design

Traffic density detection was working based on Fig. 2, where the camera was used to record images connected to the Raspberry pi. Then, Raspberry pi would save the image acquisition video file, and the video would be processed to counting the vehicle that passes the sensor. The image processed by using the background subtraction method, especially the GMM (Gaussian Mixture Model).

It is one of the primary key processes in the computer vision application. The output of this process usually uses for the input of next-level image processing suck as a tracking object identified. The purpose of this process is to produce sequence frames of the camera and detection of the foreground object. The foreground is taken from differentiating each frame [9].

GMM is one of a method in the background subtraction. This method is used to describe a pixel of background. This method is very good why it can receive a multimodal background [10].

The image processing process started with extracted into a 2-dimensional image. Video is processed using the image segmentation method with thresholding to detect background and foreground images. Then the foreground will be given ID as the frame identity. Background Subtraction method to predict foreground frames that have been given ID by GMM. If one ID moves, Background Subtraction will predict the ID movement in each frame. Frames ID visualized as tracking, so if the ID being tracked crosses the detection line, the ID will calculated automatically. The system will update the tracking of the new vehicle ID to continue the iteration. Also, the number of vehicles is displayed on the video. The last is Laptop (client) used for output in the form of video processing data that shows the function of Background Subtraction (GMM).

From the description of the system that has explained previously, there is a flow path of the traffic density monitoring system on Fig. 3. It explains that the first is input recorded video, which is the video recorded from the Pi camera with the .h264 file format. Extract the frame that is video extracted based on 2-dimensional image frames that are analyzed to the next stage. after the data frame output, video subtracted in the form of an image frame. At this preprocessing stage, the background image and the image obtained will be normalized R, G, and B to get a better image. Background Subtraction functions for the process of image reduction by reducing each pixel in the image with the background object. Object segmentation phase to erode the edges of the image (erosion) and add pixels to the object's boundary (dilation) to the previous image. Shadow remove is used to remove noise points and shadows that appear. Output density information generates information from traffic density analysis.

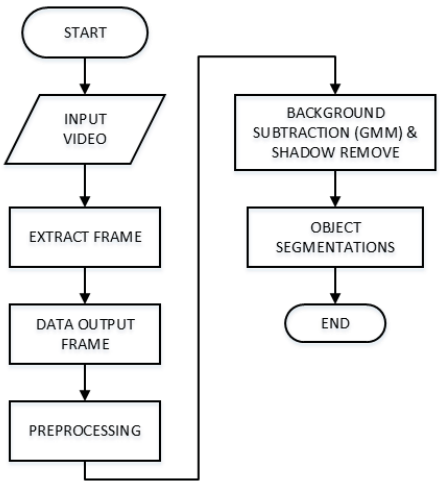


Fig. 3. Flowchart system

B. Image Capture Process

Pixel calculations are performed on the image to get data on the number of vehicles passing the highway. Background Subtraction is used to detect moving objects, and segmentation

is done through the Gaussian mixture model method that is used to recognize the foreground and background, which is displaying threshold and calculation [11].

In the Background Subtraction (GMM) method, the function is to provide ID to each vehicle that passes through the toll road. One moving ID will predict the movement of ID in each frame. ID frames visualized as tracking, so if the ID is tracked crosses the detection line, the ID will calculated automatically. The system will update the tracking of the new vehicle ID to continue the iteration. Moreover, the number of vehicles is displayed on the video.

To know the accuracy of measurement get from the difference in the calculation of the number of vehicles by the system compared to calculations manually [12]:

$$Error(\%) = \frac{|system - manually|}{\sum manually} \times 100\% \quad (1)$$

$$Accuration = 100\% - Error\ (\%) \quad (2)$$

Tools specifications:

- Camera, Sony IMX219 8-megapixel, resolution 640x480 pixels
- Laptop VNC Viewer
- Raspberry pi 3 model B+
- Power bank output 3A

Fig. 4. Video capture process

The video capturing process, as shown in Fig. 4, was done on the bridge of the Wunut, Porong, Sidoarjo (coordinate -7.516737, 122.696855). The height of the camera in Fig. 5 was about 6 meters from the highway.

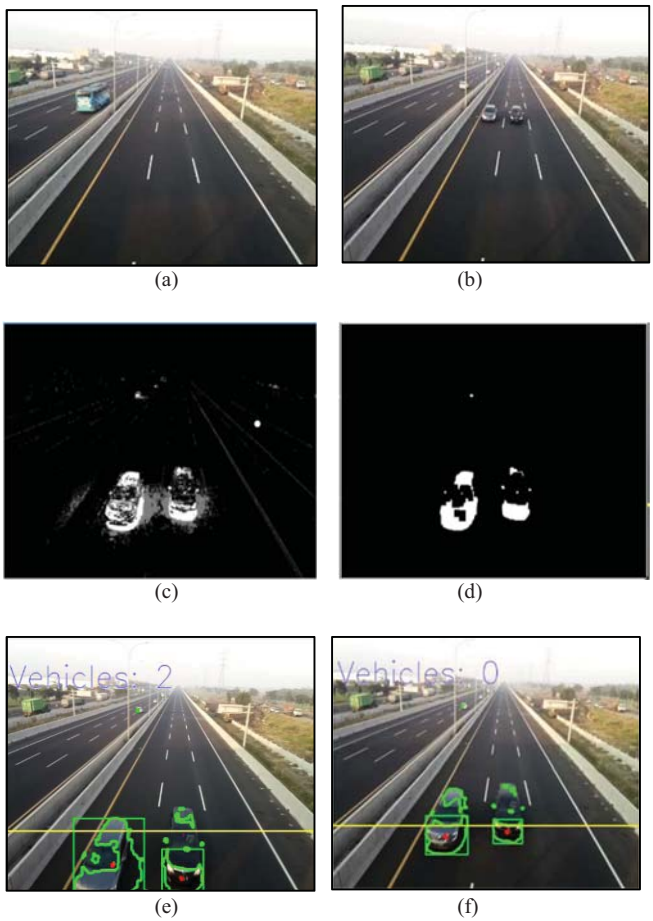
C. The Experiment

Based on a research by Nicholas on "A Background Subtraction algorithm for detecting and tracking vehicles" that there are three steps Background Subtraction algorithm [13]:

Fig. 5. Position of camera

- Initialization of background
- Foreground extraction
- Background maintenance

The experiment scenario of detection and counting vehicles, as seen in Fig. 6.



(a) (b) (c) (d) (e) (f)

Fig. 6. (a) Image empty, (b) Testing image, (c) Threshold, (d) Threshold2, (e) Vehicle detect, (f) Vehicle counting

The data were taken in the morning (7:00~8:00 am), afternoon (10:00~11:00 am) and evening (4:00 ~ 5:00 pm) as a result in Table I, Table II, and Table III.

TABLE I. MORNING EXPERIMENT RESULT

Vehicle Counting	Manual	13 unit
	System	12 unit
	Error	7.69%
	Accuracy	92.31%

TABLE II. AFTERNOON EXPERIMENT RESULT

Vehicle Counting	Manual	20 unit
	System	21 unit
	Error	5.00%
	Accuracy	95.00%

TABLE III. EVENING EXPERIMENT RESULT

Vehicle Counting	Manual	22 unit
	System	27 unit
	Error	22.73%

	Accuracy	77.27%

Refer to the data and Fig. 7 that the highest accuracy detection in the afternoon with an error rate of 7.6 %.

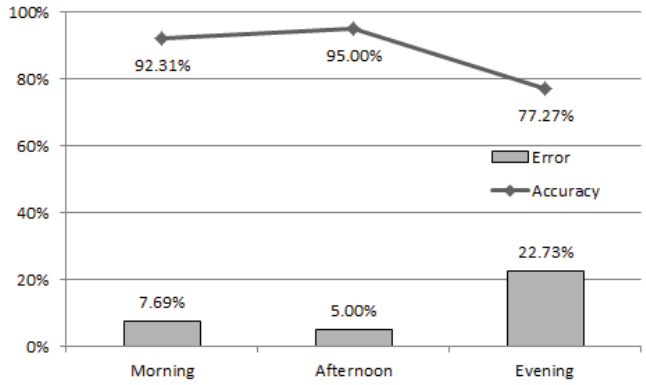


Fig. 7. Error and accuracy comparison

Besides that, we analysis that there are some differentiates conditions between morning, afternoon, and evening in the Sidoarjo Toll Road. So it can influence the accuracy of result experiment as below:

1. Lighting

   During the day, the weather at the Sidoarjo toll road is sweltering, making the video recordings white, so it affects the vehicle detection process.

2. Noise

   Noise is a disturbance that results from reflected light from a passing vehicle causing noise to form. For example, when in the afternoon, the headlights of a vehicle's headlight can affect the process of zinc. Because the light beam of the car changes and moves continuously so that it affects the foreground produced

3. Vehicle Speed

   Vehicles that go very fast give problems to the calculation, even though the vehicle successfully tracked. Because the computational process of vehicle calculations requires more time, and calculations are carried out precisely in the calculated area.

4. The Shooting Angle

   Shooting angle influential because it will produce a different perspective so that it can affect vehicle calculations. When the camera is facing upward, the object captured is vehicle that moves from a distance (small) and sky view. The shooting angle is ± 90º from the toll road with a height of ± 6 meters.

IV. CONCLUSION

From the results of system testing and analysis, it was concluded that using the Background Subtraction with the GMM method to detect and count vehicles on the Sidoarjo Toll Road gained an accuracy of 91%. This result taken from all input and output of all of the experiments. The experiment carried out in the morning, afternoon, and evening for 4 minutes. In the morning, it get an accuracy 92.31%, in the afternoon get an accuracy of 95.00% and in the afternoon get an accuracy of 77.27%. It means that in the afternoon have the highest accuracy, and the environment caused it, has a big influence on the detection result. The measurement results in the afternoon were very accurate because the lighting, car moving, and the lamp was very stabile compare to another time experiment. The main process of vehicle counting was starting from video capture. Then after the system is running, all moving objects will be given an ID. A Background Subtraction process will be performed to predict the movement of each frame. So if the ID tracked crosses the detection line, then the ID will be calculated automatically. The camera position also can influence the experiment result. Moreover, based on the experiment result give the camera position with a high position of ± 6 meters was very suitable to detect and count vehicles on the Sidoarjo Toll Road.

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