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Identify Traffic Flow Volume using Image Processing for Intelligent Transport System

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Abstract

Detection of traffic flow volume is needed to get information about the number of vehicles on a street section. This information is required for traffic control. This study uses video data taken from four adjution street section in Manado City. Video data are processed using the background subtraction method in the segmentation process. Then morphological operation techniques are applied to improve segmentation results. The binarization method with a threshold value of 220 to eliminate shadows on vehicle objects. Vehicle shadows must be removed because it can reduce system accuracy especially if vehicle shadows are too large and connected to other vehicles. Accuracy results from vehicle detection are 95.04% for the Toar street, 94.62% for the Diponegoro street, 91.47% for the Lumimuut street and 95.18% for the 14 Februari street. Vehicle detection results will be calculated to get the number of vehicles then divided by the duration of observation time to get the traffic flow volume. The results of the traffic flow volume information are expected to be implemented on Smart Traffic Light.

Keywords—Traffic flow volume, Vehicle Detection, Background Subtraction, Morphological Operation, Telling, Manado.

1. INTRODUCTION

As the number of vehicles increases, traffic lights will be needed to support traffic control management. But on the other hand traffic lights may cause congestion because the density conditions occurs due to in balance traffic light timing [1]. In addition to the development of street infrastructure, congestion can be overcame by planning intelligent traffic management at each intersection.

Several previous studies have been conducted to reduce traffic density — Amirullah designed a traffic control system using the Fuzzy Logic approach. In this study shows that the Fuzzy Logic method used can reduce vehicle density [2]. As with subsequent study, Chabchoub used fuzzy logic in managing traffic light to control four adjuction intersections [3]. But there are drawbacks from the studies that are not yet real-time and vehicles are counted manually. The automatic real-time system is expected to be able to see the traffic conditions directly.

Research by Ghazal measured density using a PIC microcontroller which evaluates density using an IR sensor. The use of IR sensors have limited capabillities in counting numbers of vehicles [4].

Therefore we need a system that can see the vehicle directly. The following research relates to vehicle detection directly — first research by Basri, which performs vehicle calculations using the Gaussian Mixture Model optimization method. The study was carried out at different locations and obtained an accuracy of 84.42% for cars, and 57.78% for motorcycles [5]. Also, Dubey detected vehicles with Haar Cascade & Background Subtraction to get objects from vehicles [6]. From several studies related to vehicle detection, each has advantages and disadvantages. Besides, different road conditions and various data collection techniques affect the results of the system.

Based on data obtained during the seven-days pre-study in Manado City, the condition of vehicle queues at intersections were varies in density on each side of the street in terms of time. The results were traffic time that is not very effective for use on the road. In addition, the waiting time for traffic lights that were not very useful results in the saturation of vehicle drivers, especially those on Toar street and Lumimuut street which have uphill roads. Determining the location of the camera also affected the frame that will be taken because of the stated road conditions.

This study uses Background Subtraction and Morphological Operation methods for vehicle detection. The results of the total number of vehicles calculated are divided based on the duration of observation to get the volume of traffic flow. The results of the traffic flow volume are expected to be integrated into the traffic lights so that it can be a parameter for determining the timing of traffic lights.

2. PROPOSED METHOD

In this study, the authors conducted seven stages for the process of determining the volume of traffic flow. The steps are video input, pre-processing, segmentation, morphological operations, counting vehicles, and determination of traffic flow volumes.

2.1 Input Video

Video data will be retrieved using IP cameras placed on each section of the street. The following Figure 1 is the locajktion of the camera at the intersection.

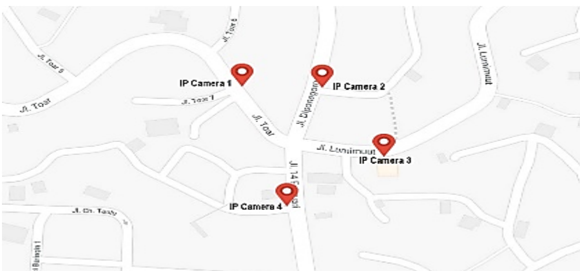

Figure 1. IP Camera location in the intersection.

IP Camera is placed 50 meters before the traffic lights so that it can control the vehicles that are heading in the direction of the traffic lights. Video data generated by the IP Camera is input into the system and then resized first becomes a size of 640 x 480 pixels.

2. 2 Pre-processing

In this study, the preprocessing stage consists of two parts, as shown in Figure 2.

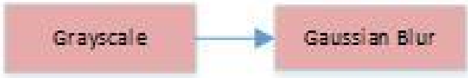

Figure 2. Preprocessing

The first stage is the grayscale process, which aims to convert the RGB color intensity into a single scale; in this case, the gray level. Grayscale is the intensity of pixels that are in the range of black (0) to white (255). The transformation of RBG to grayscale aims to flatten the pixel values from RGB to one scale [7]. The next process is the Gaussian Blur, which aims to eliminate noise in the frame. The kernel used in the gaussian blur process is (5.5).

2. 3 Segmentation

The segmentation process aims to separate the foreground from the background. The method used in this process is Background Subtraction. The use of this method is because in previous studies [8] [9] [10] obtained the result that this method is suitable for use on moving objects.Background Subtraction method can be seen in equation 1.

$$P(x, y, t) = \frac{1}{t} \sum_{t=1}^{t} I(x, y, t) \qquad (1)$$

Where (x, y) is the pixel coordinates, t is the time in a video frame, and I is the color intensity. The determination of the threshold in the segmentation process aims to provide a threshold value to the pixel of the grayscale value. The goal is that there are only two threshold results, namely 0 for black and 1 for white. Where in this process, the given threshold value is 20. Can be seen in equation 2.

$$g = (x, y) = \{1,\ f(x, y) \geq 20\ 0,\ f(x, y) < 20 \qquad (2)$$

Determination of whether there is a value of 1 from the results of the Background Subtraction method, if yes then the pixel has the most significant possibility as a foreground, if not then the pixel is considered the background.

2. 4 Morphological Operation

In previous studies, Morphological Operation is an excellent method for removing noise in segmented images [11]. Morphological Operation aims to refine the results of the foreground and eliminate shadows on the vehicle [12]. The shadow of the vehicle can be connected to other vehicle objects so that more than one vehicle can count as only one object or one vehicle.

Therefore the removal of vehicle shadows is essential. Morphological processes carried out in this study are closing, opening and dilation.

Closing is a morphological operation that begins first with a process of dilation (enlarging the foreground) then erosion (reducing the foreground). The closing process can be seen in equation 3.

$$Closing = A \bullet B = (A \oplus B) \ominus B \qquad (3)$$

The opening is a morphological operation that begins first with the process of erosion (reducing the foreground) then the process of dilation (enlarging the object). The opening process can be seen in equation 4.

$$Opening = A \circ B = (A \ominus B) \oplus B \qquad (4)$$

The last morphological operation is dilation. This technique is used so that objects can appear larger and clearer. The equation of dilation technique can be seen in equation 5.

$$Dilasi = A \oplus B \qquad (5)$$

2. 5 Counting Vehicle

At the vehicle counting stage, there is an ROI (Region of Interest), which is a vehicle counting area. The calculation is done by giving a blue line boundary, which is the ROI area for the vehicle to be calculated. Before the vehicle counting process, each BLOB is given a bounding box, and then the centroid position of the bounding box is calculated. This centroid position aims to be the calculation parameter if the BLOB is right in the middle of the line to do the calculation. Figure 3 is an example of a vehicle with a bounding box to calculate the centroid position.

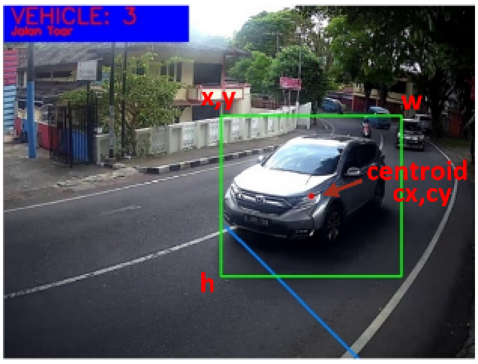

Figure 3. Centroid of vehicle on system.

To get the centroid position on the vehicle, the first step is to determine the coordinates (x, y), w, h of the bounding box. (x, y) are the initial coordinates of the bounding box, then w is the width of the bounding box and h is the height of the bounding box. To get the centroid used the following equation.

$$x_1 = w / 2 (6)$$

$$y_1 = h / 2 \quad (7)$$

$$cx = x + x_1 \quad (8)$$

$$cy = y + y_1 \quad (9)$$

From the equation above, a new coordinate point obtained, cx, cy which is the centroid coordinate of the vehicle. Furthermore, the method used in this calculation is to provide conditions on the system where if y <(point position + offset) + (y> line position + offset) then vehicle + 1. The offset parameter intended here is the pixel position, which is the ROI area parameter used to calculate vehicle centroids in that area. Giving a line on each street section has a different point position because there are different data collection technique positions in each street according to street conditions along with the frame position which is certainly different from each street segment. The position of the line points on each street section can be seen in table 1.

Table 1. Line position on each road section

	Toar Street	Diponegoro Street	Lumimuut Street	Februari Street
(x,y)	303,303	267, 267	275, 275	200, 200
(x,y)	480,480	480, 480	480, 480	480, 480

2. 6 Determination of Traffic Flow Volume

Traffic flow is the number of vehicles that cross a point on a particular street, at a certain period, measured in units of vehicle divided by a specific time duration while the volume is the number of vehicles that cross a street at a particular period of time measured in units of vehicles per unit time such as (days, hours, minutes) [13]. The volume of traffic under 1 hour like every minute is known as the Rate of Flow. Traffic volume can be calculated using equation 10.

$$q = \frac{n}{t} \quad (10)$$

Where q = the volume of traffic passing through a point, n = the number of vehicles passing through that point in the duration of observation time, t = duration of observation time. In this study, we are using a time duration of 1 minute (60 seconds) to calculate the number of vehicles. The timing is due to the schedule of the APILL (Alat Pemberi Isyarat Lalu Lintas) requiring information on the number of vehicles every 1-15 minutes. Therefore, choosing 1 minute is a minimum time choice of setting the APILL time. The results of the traffic flow volume in each street flow will be distinguished between one street with another street section so that we can get a comparison of traffic flow from each street section.

3. RESULTS AND DISCUSSION

Based on the proposed method, the following are the results of the system. In figure 4 describes the results of the preprocessing process that has been carried out by the system.

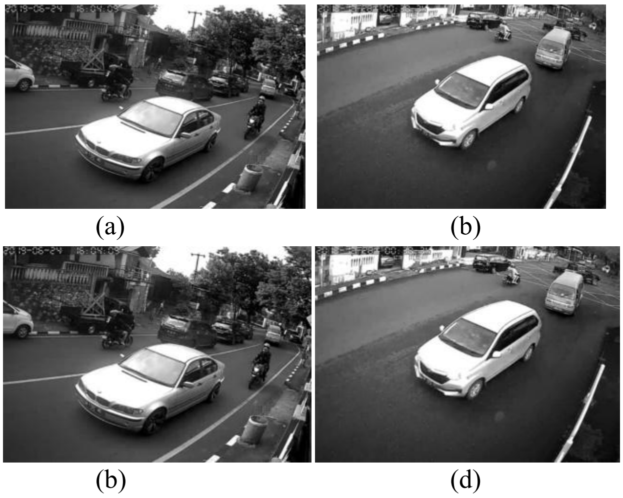

Figure 4 Preprocessing result : (a) Toar Street, (b) Diponegoro Street, (c) Lumimuut Street and (d) 14 Februari street

Furthermore, the results of the preprocessing process continued with the segmentation process using Background Subtraction and two trials to determine the appropriate threshold value at 100 and 25. The result of segmentation can be seen in Figure 5.

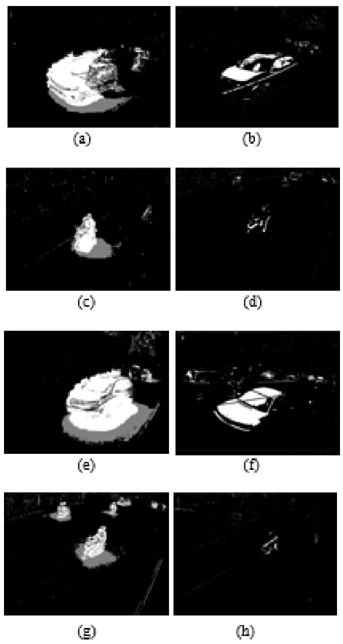

Fig 5. The result of segmentation and threshold (a) Toar threshold = 25, (b) Toar threshold = 10, (c) Diponegoro threshold = 25, (d) Diponegoro threshold = 100, (e) Lumimuut

threshold = 25, (f) Lumimuut threshold = 100, (g) 14 Februari threshold = 25, (h) 14 Februari threshold = 100

From the results of segmentation and threshold in the picture above, there is a comparison of the results between the threshold values of 25 and 100 of each street section. Of the four street segments, the threshold value that clearly shows the object is the threshold value of 25. While the threshold value of 100 is not very clear in showing objects, especially for (d) Jl. Diponegoro and (f) Jl.14 Februari, where both streets have the same height of the camera pole in data collection techniques. In the Toar street and Lumimuut street, which has the same camera height, the object is more visible because the camera position is closer to the object. But from the result of the threshold 100, there are still holes in the foreground. Therefore the selection of a suitable threshold value in the segmentation process is a threshold value of 25 for all frames of each street segment.

After the segmentation phase, the vehicle detected as a foreground/object. There are still a few frames that still have noise and shadow of the vehicle. The shadow is too large so that it can reduce the accuracy of the system. Therefore morphological operation aims to get a better shape of the object. The kernel used in the morphological process is (5.5). Figure 6 shows the entire morphological operation, followed by determining the threshold value = 220.

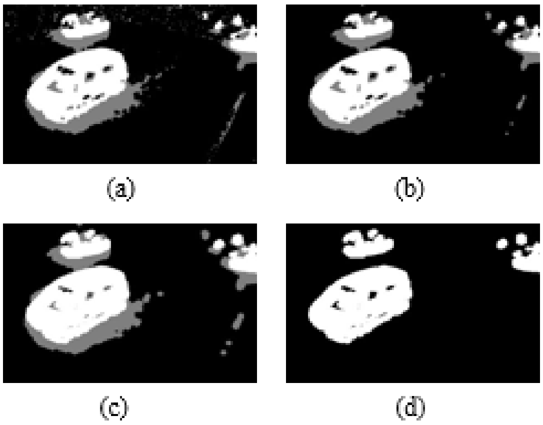

Figure 6. Morphological operation (a) Closing, (b) Opening, (c) Dilasi, (d) threshold = 220.

The results of dilation process the vehicle object have been enlarged, but the shadow from the vehicle is still detected. This can reduce the accuracy of vehicle counting because shadows from vehicles can be connected to other vehicles. As a result, the vehicle calculation process is not valid because there are two or more vehicles, but only one vehicle counted. Therefore the threshold is done again in the last method to reduce the shadow on the vehicle. The threshold value obtained in this process is 220.

Vehicle calculation starts when the BLOB crosses the ROI (Region of Interest) that has been set. In this study, each street section has an ROI. The distance from ROI to the traffic lights is 50 meters. An overview of the ROI position for each street section can be seen in Figure 7.

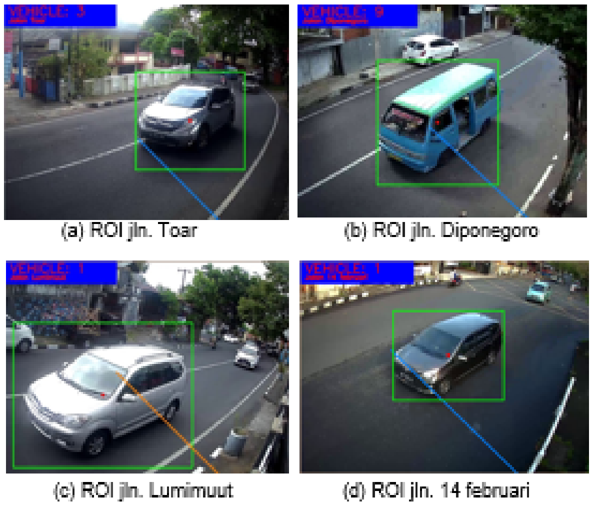

Figure 7. ROI from every road section

Traffic flow volume calculation uses equation (11) where the parameter used is the number of vehicles that pass a specific duration. The system designed will automatically calculate the flow of traffic from each street for 1 minute then send the data to be stored in the database.

System analysis is carried out by calculating the average vehicle detection results. The parameter used for comparison is the monitoring of vehicle data generated by the system. In the analysis of the system used several parameters. These parameters are TP (True Positive), namely the object that wants to be detected and detected by the system. TN (True Negative), that is, the object that does not want to be detected and not detected by the system. FP (False Positive), that is the object that wants to be recognized but detected. FN (False Negative) is an object that want to detect but not detected. Equation analysis of system work using confusion matrix can be seen in equation 12.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \times 100\% \qquad (12)$$

Based on the data that has been tested into the system, the data amounted to 20 videos with five videos each for each section to get the results shown in table 2.

Table 2. System accuracy for vehicle detection

Streets	Data	TP	TN	FP	FN	Acc(%)	Average Acc (%)
Toar Street	1	12	19	0	2	93,94	95,04
	2	14	17	1	1	93,94	
	3	13	16	1	0	96,67	
	4	16	20	2	0	94,74	
	5	21	26	2	1	95,92	
Diponegoro Street	1	10	14	0	2	92,31	94,62
	2	12	15	1	0	96,43	
	3	9	12	1	0	95,45	

	4	20	19	0	1	97,50	
	5	19	13	3	0	91,43	
Lumimuut Street	1	20	26	1	2	93,88	91,47
	2	21	27	2	3	90,57	
	3	23	25	2	4	88,89	
	4	19	24	2	3	89,58	
	5	24	27	1	2	94,44	
14-Feb	1	12	12	1	0	96,00	95,18
	2	14	12	0	1	96,30	
	3	19	11	1	1	93,75	
	4	12	17	0	2	93,55	
	5	14	12	1	0	96,30	
Average							94,08

In table 2, which shows the results of accuracy on the streets with an average accuracy of 95.04%. First, the accuracy on oar street from the analysis that has been done from the five data obtained several system errors. Several things cause detection errors that occur on every video. The first vehicle was not detected due to the vehicle passing in an area that is not the ROI area. So the centroid point of the vehicle does not pass through the vehicle calculation area. Figure 9 shows a vehicle that is not detected by the system

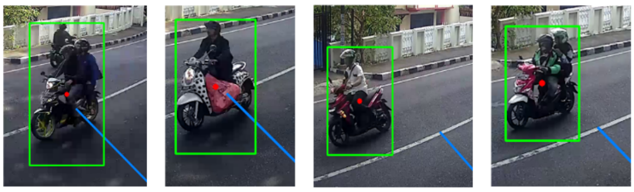

Figure 9. Vehicles that are not detected by the system on the Toar street.

The next error system is caused by movement on the IP camera pole resulting in video results from the IP camera swaying. The results of the segmentation of the Background Subtraction detect the effects of changes that occur in the frame are objects. The case caused no vehicle but was counted by the system. Figure 10 shows the results of detection due to camera movement.

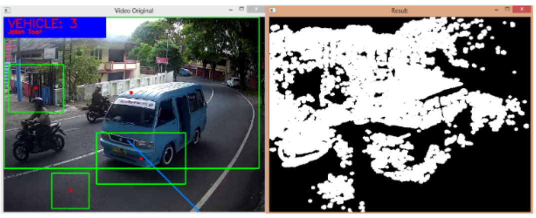

Figure 10. Error detection due to camera movement on Toar street.

Second, the accuracy of vehicle detection results on Diponegoro street is 94.62%. The system error that occurred in Diponegoro street same as the detection error that occurred in Toar street. Where a detection error occurs because the vehicle going to the traffic lights does not pass through ROI area.

The accuracy result on the 14th February street is 95.18%. The results of system errors on the 14 Februari street are dominated by system errors that occur when there is movement on the IP camera pole. Movement on the IP camera causes the video to sway so that the segmentation of the Background Subtraction reads the results of the change that occurs in the frame as an object. Figure 11 shows a system error that occurred on the 14 Februari street.

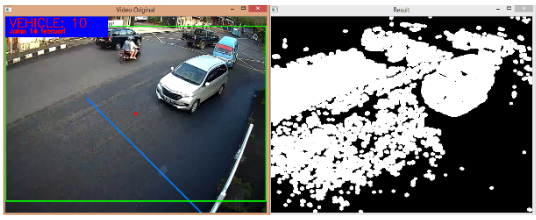

Figure 11. Error detection due to camera movement on 14 Februari street.

The accuracy results on Lumimuut street are 91.47%. The detection error on Lumimuut street is different from the detection error of the other three streets. On Lumimuut streets tend to have a higher density than the other streets. Therefore, on Lumimuut street, it is more common for two vehicles to pass ROI simultaneously, resulting in a False Positive (FP) system error. Vehicles that pass ROI together can be seen in Figure 12.

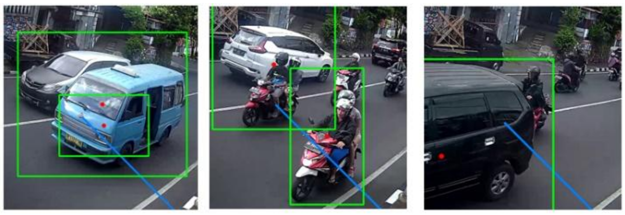

Figure 12. The vehicle passes ROI simultaneously on the Lumimuut street.

System errors that occur from every street section are caused by data collection techniques and methods that need to be optimized so that they can produce higher accuracy. In this case, the data retrieval in question is the stability of the camera so that it can create a good video. The method that needs to be developed is a method that can calculate the vehicle when the vehicle passes ROI simultaneously using Background Subtraction.

The results of the volume of traffic flow that becomes output after the calculation are entered into the database automatically. The duration of time taken for observation is 60 seconds. Table 6 shows the volume of traffic flow from the Teling intersection. Figure 13 shows a comparison between the volume of traffic flow from each street section.

Table 2. Result of traffic flow volume

Street	V 1	V2	V3	V4	V5
1	0,200	0,233	0,217	0,267	0,350
2	0,167	0,200	0,150	0,333	0,317
3	0,333	0,350	0,383	0,317	0,400

4	0,200	0,233	0,317	0,200	0,200
5	0,200	0,233	0,217	0,267	0,350

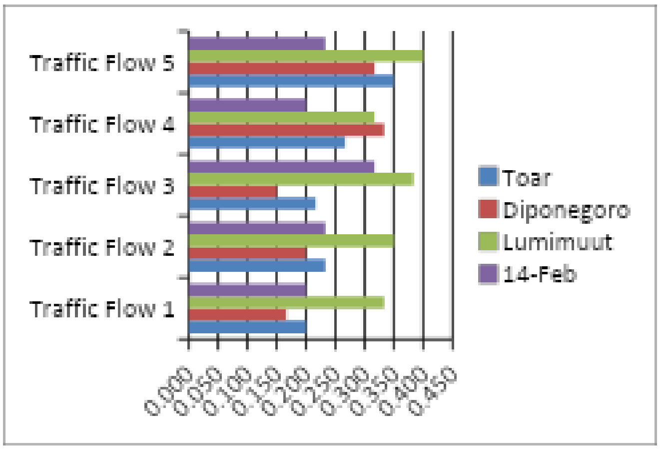

Figure 13. Traffic flow volume graph at Teling intersection

From the comparison of the traffic flow, it is obtained that the amount varies, where there are conditions of several road sections that have higher traffic flow conditions than other road segments. From the graph obtained in traffic flow 1, Lumimuut road has the highest traffic flow volume and Diponegoro road has the lowest traffic flow volume. In traffic flow 2, Lumimuut road has the highest traffic flow volume and Diponegoro road has the lowest traffic flow volume. On traffic flow 3 Lumimuut road has the highest traffic flow volume and Diponegoro road has the lowest traffic flow volume. In traffic flow 4, Diponegoro road has the highest traffic flow volume and 14 February road has the lowest traffic flow volume. In traffic flow 5, Lumimuut road has the highest traffic flow volume and February 14 road has the lowest traffic flow volume. From the five videos, Lumimuut road tends to have the highest traffic flow conditions in several tests, while the lowest traffic flow volume is on Diponegoro & 14 February roads. In accordance with the background presented where this system is expected to be able to detect the volume of traffic flow from each road section so that it can be distinguished the volume of traffic flow from the Toar road, Diponegoro road, Lumimuut road and February 14th road.

From some previous studies that have been carried out several stages of accuracy comparison with this research. Basri research [5] obtained an accuracy of 86.54 and 69.21 with the Gaussian Mixture Model method. In the study of Zu [14] obtained an accuracy of 88.06 using the viola jones method. In the Pawar [15] study obtained an accuracy of 91.02% using the morphological operation method. In this study an increase of 94.08% using the method of background subtraction and morphological operation.

4. CONCLUSION

This study uses video data taken at the Teling intersection in Manado, North Sulawesi. The position of the camera is very important to calculate the volume of traffic flow. Therefore the location of the camera is placed at 50 meters before the traffic lights. The area determines to count the vehicles that are heading towards the traffic lights. Besides, the background subtraction method does not produce a good result when the vehicle is slowing down or even stopping. Therefore it is not possible if the camera is placed near the traffic lights because at that location there are many vehicles that slow down and also stop. The object of the vehicle is carried out in morphological processes in order to get better object results and can eliminate shadows from the vehicle. Vehicle shadows can combine two or more vehicles so that the actual vehicle is more than one only counted one vehicle. The results of the detection and calculation accuracy of vehicles on four roads is 94,08.Vehicle current volumes are obtained from varying from each street, where Lumimuut street, which has the highest traffic volume. While on the Toar and Diponegoro streets, traffic volume tends to be low from several trials of several video inputs into the system. The results of this study are expected to be applied directly to Smart Traffic Light.

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