

# DETECTION OF TRAFFIC DENSITY WITH IMAGE PROCESSING USING PIN HOLE ALGORITHM

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**ABSTRACT:** Intelligent traffic monitors have developed and have become more attractive in recent years. A detection system in the monitoring traffic system is proposed using different algorithms. Pin Hole Algorithm used to detect the car that passes the road (the studied area). A fixed camera mounted at a predetermined point is used with known height (of the camera), the intensity of the light, and the visibility of the camera. The classification process is important to know the traffic congestion status. The traffic congestion status will be sent to the server address already provided. In the congestion detection test, results were obtained with an accuracy value of 85% using the 64x64 grid division and obtaining good detection results for susceptible light intensity values between 5430 and 41379 LUX with an accuracy value of between 60% and 90%.

**ABSTRAK:** Sejak beberapa tahun ini, sistem pengawasan trafik pintar telah dibina dan terus berkembang luas. Sistem pengesanan dalam sistem trafik pengawasan telah dicadangkan menggunakan pelbagai algoritma. Algoritma lubang pin digunakan bagi mengesan kereta yang melalui jalan (kawasan kajian). Kamera dipasang tetap pada titik tertentu iaitu dengan menyelaras ketinggian kamera, keamatan cahaya, dan kebolehlihatan kamera. Proses klasifikasi sangat penting bagi menentukan status kesesakan trafik. Status kesesakan trafik akan dihantar ke alamat pelayan yang telah disediakan. Nilai ketepatan ujian pengesanan kesesakan yang diperoleh adalah 85% iaitu menggunakan pembahagi grid 64x64 dan dapatan kajian menunjukkan pengesanan yang baik bagi nilai keamatan cahaya antara 5430 dan 41379 LUX dengan nilai ketepatan antara 60% dan 90%.

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**KEYWORDS:** *intelligent traffic density; pin hole algorithm; congestion monitor; car detection; traffic details; image processing*

## 1. INTRODUCTION

Traffic lights with less efficient distribution can cause overcrowding at crossroads and can cause congestion that causes traffic jams to the detriment of road users [1]. Congestion is a condition where there is a stagnant or interrupted flow of vehicles passing through the road due to the accumulation of vehicles exceeding the existing traffic capacity [2].

Congestion problems are caused by a lack of available facilities and infrastructure such as road monitoring systems, road widths, traffic signs. Generally, traffic monitoring systems that are running today still use traditional systems. The system used now is to use cameras installed at various points, which are monitored manually by the Transportation Agency. Overall, this system can work well, detecting congestion in accordance with the

rules of the city of Bandung in Indonesia. It's just that congestion validation is still a bit challenging because there is no definite data comparison yet.

Pin Hole algorithm was used to obtain the congestion status for traffic control on the toll road section. Before that, the camera is fixed to take images (video) for the studied area, pre-processing of the image, contrast limited adaptive histogram equalization, edge detection, enhancement, then image segmentation and classification. The presented algorithm can work with different city roads.

## 2. RELATED WORK

To maximize the detection of traffic jams using Image Processing, according to previous research that has been done [3], several factors must be considered. The first is the camera settings. This setting is required to be able to determine the shooting results. The accuracy depends on many factors such as the width of the road, the height of the camera installation and the angle of the camera. The second is image segmentation. In object detection, before filtering using a certain algorithm, the initial process is to convert the data format. The data in MPEG form is converted to JPEG. In the form of JPEG format will be searching the edge value or background image, edge value is used to distinguish between road and object to be processed [4]. The edge value taking is done continuously in order to get perfect results [5].

Detection of vehicle objects on a road segment to determine the status of traffic jams can use the Pin Hole Algorithm [6]. Pin Hole algorithm works by using an IP camera. The result of detection from the camera will be MPEG4 which will be converted back into MJPEG to be processed to the next stage [7]. Then the obtained image is filtered using a Greyscale filter to determine the background value of the image. The background value is used to separate where the object is to be detected and which image is just the background of the image [7]. The picture shooting takes place within three minutes, and it is because if the image is taken less than three minutes sometimes still has data that is not yet valid and not perfect. Then determined the parameters of the results in an emphasis on three parameters, namely the first parameter is the size of the image based on terms of connection, the speed of data as a data source. The second parameter is the large image download and the third parameter is the pixel pin hole size.

Another method that can be used in vehicle counting in traffic control is Blob analysis [8]. The Blob Filter algorithm is able to detect congestion well. The steps required in this algorithm are as follows:

1. Vehicle Segmentation, settings in a location of picture shooting on camera.
2. Background Updating, define the background of the image by segmenting.
3. Feature Extraction and Vehicle Classification used to be able to define different objects when detecting images.
4. Vehicle Tracking is used to determine the amount of vehicle current based on the distance of each vehicle.
5. Vehicle Flow Analysis and Counting is used for the final count of the number of vehicles and the speed of the coming vehicle on the line.

The output of this method is the number of vehicles outside the track with the average speed of the vehicle so that it can be concluded whether the situation can be said to be

stuck or not. This method also has an average accuracy value in three conditions of 90% with an estimated error of less than 5 km/hour.

Detecting traffic jams in the city in real-time with the help of a UAV can be chosen as another alternative in analyzing traffic conditions. Traffic data in the form of videos taken from drones is then detected using a Deep Learning Algorithm, namely Mask RCNN. Several steps must be taken, namely, firstly counting the number of vehicles, and estimating the speed of the vehicle. Second, estimate the geometric space for pixels in the image to perform vehicle recognition and tracking [9].

### 3. RESEARCH METHOD

#### 3.1 Illustrations

Acquisition Video is the process of taking the recording of toll road conditions taken with the \*.mp4 video format then saved in a personal computer. The video acquisition is taken based on the entrance to the Bandung city with the criteria of having one common goal and having multiple branches as an alternative way. The video acquisition was taken using GoPro Hero5 Black with 720 pixels video quality and 1280 x 720 pixels resolution at 30 fps. The video acquisition is taken at the top of a person crossing the bridge (JPO) which is on a 5.1 m highway toll road. An illustration of video acquisition can be seen in Fig. 1.

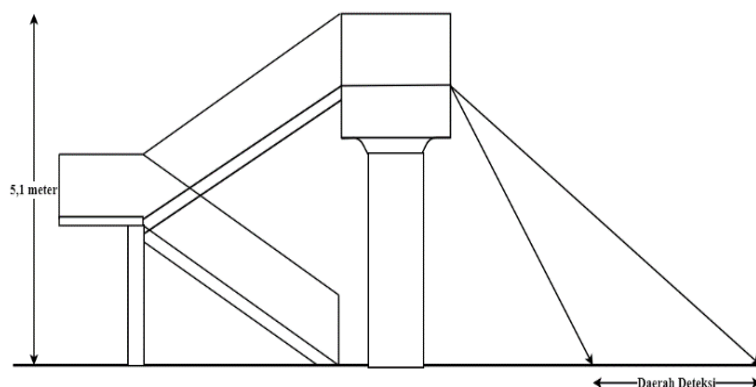


Fig. 1: Illustration of video acquisition.

#### 3.2 Algorithm Steps

Traffic congestion detection is achieved by many steps such as image acquisition from video acquisition, pre-processing on image, Pin Hole processing to perform vehicle calculation on image and result from classification. The process of the suggested algorithm can be described as follows:

##### 3.2.1 Image Acquisition

The image acquisition process is a step to get a sample image based on video recording. Image captured with \*.mp4 format and stored in \*.png format. Figure 2 shows the acquisition of the saved image with the format of \*.png given region Region of Interest (ROI) to detect congestion. ROI is an area marked as the boundary area of toll roads that will be calculated using digital image processing. The original image that has been given the ROI region can be seen in Fig. 2.

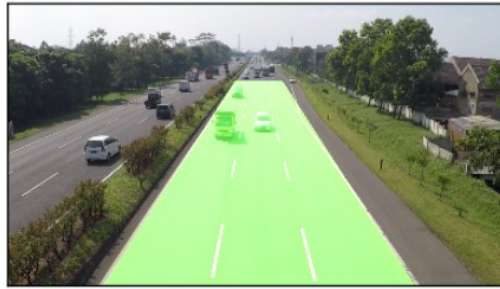


Fig. 2: Image acquisition with ROI.

### 3.2.2 Pre-Processing

The pre-processing step is used to perform calculations by processing the image by combining filters in the image processing. The process that runs in this stage is like capturing the image of the video, changing the grayscale filter, inserting the image into the CLAHE filter, determining the border of the image, inserting the image into the low pass filter, and performing the image segmentation.

#### a. Greyscale

Greyscale is a color in pixels that are still between the range of black and white values 0-255 which means 0 is a value in black and 255 is white. Gray degree in greyscale can be done by using digital image processing by adjusting the gray degree of the image using a threshold value. Thresholding is the method used to be able to adjust the number of gray-degree values in digital images [10]. The colored image has a matrix value for each pixel in which each pixel has a value of red, green, and blue (r, g, b). To be able to change the color image into greyscale and set the gray degree using thresholding will be explained as follows

- Calculate the value of greyscale using the equation

$$s = \frac{r \times g \times b}{3} \quad (1)$$

where S is greyscale value

- Calculate the value of thresholding using the equation

$$x = \frac{W}{b} \quad (2)$$

Where  $x$  is gray degree values after thresholding,  $W$  is gray degree values before thresholding, and  $b$  is the desired quantization values.

The result of color image processing being the greyscale image can be seen in Fig. 3.



Fig. 3: Greyscale image result.

### b. Contras Limited Adaptive Histogram Equalization (CLAHE)

CLAHE is a digital image processing process that improves image contrast by increasing contrast in local images by providing a maximum threshold value [11]. The CLAHE process functions to divide the local image contrast in a symmetrical grid called the area size. The image's division region size can be divided into sections such as CR for the corner region, BR for border region, IR for the inner region [12]. The existence of the division of region sizes due to the division of the grid there are different characteristic values for each value of the neighborhood. The structure of region size can be seen in Fig. 4.

CR	BR	BR	CR
BR	IR	IR	BR
BR	IR	IR	BR
CR	BR	BR	CR

Fig. 4: Region size CLAHE.

After dividing the local image into a symmetric grid, the calculation is performed by obtaining a new gray level on each local grid using the cumulative function distribution of histograms used in each local region (i, j).

- Calculates the distribution using an equation

$$g(k) = \frac{(N - 1)}{M} \cdot \sum_{k=0}^n h(k); n = 1, 2, 3, \dots, N - 1 \quad (3)$$

where M is the number of pixels, N is the greyscale value, and h(k) is the histogram on grey value.

After calculating the distribution of cumulative function, then regional on local image give maximal threshold limit on the image using CLAHE.

- Calculates threshold limits using equations

$$\beta = \frac{M}{N} \left( 1 + \frac{a}{100} (S_{max} - 1) \right) \quad (4)$$

Where M is wide of region size, N is greyscale value, and a is minimum and maximum limit values of histograms ranging from 0-100.

The result of image processing into CLAHE filter can be seen in Fig. 5.



Fig. 5: CLAHE image result.

### c. Edge Detection Using Canny Method

Edge Detection or abbreviated as ED is an object detection process in digital image processing that produces an edge output of the image object used to mark the detail part of the image [13]. ED is processed using Canny method. The Canny method is used because it produces a visible edge shape compared to Robert, Sobel, Prewitt, and LoG methods after being processed using the Global Thresholding method [13]. ED in the process is done by giving gaussian filter greyscale image which then convoluted by using method of Canny to get result of fine edge image. Gaussian filter is done by using gaussian filter equation as follows [14]:

- Calculate Gaussian filters using equations

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (5)$$

$\sigma$  = standard deviation distribution ( $\sigma = 1,4$ )

e = exponential value (e = 2,71828183)

(x,y) = the midpoint of the Gaussian function

- Convolution with the Canny method is done by equation

$$\frac{1}{159} \begin{pmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 4 & 4 & 2 \end{pmatrix} \quad (6)$$

- Calculate magnitude gradient using equation

$$G = |G_x| + |G_y| \quad (7)$$

- Determining the edges by using the equation

$$q = \tan^{-1} \left( \frac{G_x}{G_y} \right) \quad (8)$$

- Gives the threshold value of the threshold to the ED by using equations

$$g(x,y) = f(x) = \begin{cases} 1, & \text{if } T_{min} \leq f(x,y) \leq T_{max} \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

The results from image processing in canny method can be seen in Fig. 6.



Fig. 6: Edge detection image result.

#### d. Low Pass Filter Using Bilateral Filter

Low Pass Filter is a method by using a filter type that passes low-frequency frequencies and dampens high-value frequencies in imagery [15]. In the process, LPF uses the Bilateral filter method. The BF method is a noise reduction filter on the ash image and also maintains edge detection for smoother image results [16]. Benefits of using the Bilateral filter method include:

- Maintain edge detection while eliminating image disturbance and refining the resulting image
- Eliminate the opacity of the color image
- An easy method to apply [16].

The Bilateral filter method is calculated using the kernel filter equation

$$K = \frac{1}{Ksize.w \times Ksize.h} \begin{pmatrix} 1 & 1 & \dots & 1 \\ 1 & 1 & \dots & 1 \\ \dots & \dots & \dots & \dots \\ 1 & 1 & \dots & 1 \end{pmatrix} \quad (10)$$

K = kernel bilateral filter

Ksize = wide of blur in the kernel

w = width image

h = high image

The result of image processing in the Bilateral filter can be seen in Fig. 7.



Fig. 7: Bilateral filter image result.

#### e. Image Segmentation

Image segmentation is the process for recognition of objects in images and also feature extraction [13]. By doing image segmentation in the final stage, it will show the results of objects and backgrounds on the image. Segmentation is done by assigning a threshold value (threshold) that applies to all parts of the input image. Segmentation is done using the following equation

$$g(x,y) = f(x) = \begin{cases} 1, & f(x,y) \geq T_{max} \\ 0, & f(x,y) < T_{max} \end{cases} \quad (11)$$

g(x,y) = image after thresholding

f(x,y) = edge detection image result

T = limit threshold value



Fig. 8: Segmentation image result.

### 3.2.3 Pin Hole Algorithm Processing

Determination of the area in the image is the process of determining the area by following the length and width of the toll road to be detected. After the image acquisition process, area masking is carried out by providing a detection area limit on the toll road section. The masking area is done by connecting the four coordinates in the image so that it becomes a 2D shape. Then the detection area is calculated using the equation for the area of an irregular trapezoid.

The preprocessed black and white image is divided into a small symmetrical grid (Pin Hole). The number of grids used is 8x8, 16x16, 32x32, 64x64 pixels. The process of dividing into a grid is done when inserting the CLAHE filter into the grayscale image.

The next step is to find the centroid point (middle value) in the image in each grid area (Pin Hole). To calculate the vehicle capacity in the area to be detected, it can be done using Background Elimination (BE) [17]. BE is processed by eliminating everything that is considered, not including the object in the image so that the value of the object and the background of the image will be separated [17]. BE can be done by first calculating the mean of the RGB value of the image with the  $p$ -value in the selected background image using equation

$$B(p) = \sum_k \frac{I_B(k,p)}{n} \quad (12)$$

$I_B(k,p)$  = pixel color value for point  $p$  in frame  $k$

Then BE from the process was calculated with equation

$$D(k,p) = \{I_B(k,p) - B(P)\} \quad (13)$$

$\{.\}$  = value Euclidean Distance between  $I_B$  and  $I_B$

After the BE value is obtained, the image of the result of the process is only the centroid value of the object of the detected vehicle object. To obtain the value of congestion capacity in the area specified, then used equation

$$G(x) = 1 - \frac{D(k,p)}{I_B(k,p)} \quad (14)$$

$G(x)$  = congestion value

After doing the calculation on the input image, we will get the result of the number of centroid values contained in the box Pin Hole of the filled capacity of the box.



### 3.2.4 Classification

Results classification is an advanced process of calculating the number of centroids from the Pin Hole area by grouping the calculation results into several categories determined based on the amount of capacity of the detected object. According to Rudi Herianto (2018), as the Head of the Satlatas Bojongsoang Unit, the congestion category can be grouped into 3, namely:

**a. Traffic Jam**

The jam status is used when the resulting value of the congestion capacity calculation reaches a value of more than 70%.

**b. Crowded Smoothly**

The current status is smoothly used when the value of the result of the congestion capacity calculation reaches a value of more than 10% and less than 70%.

**c. Fluent**

The current status is used when the value of the calculation of congestion capacity reaches less than 10%.

## 4. RESULTS

### 4.1 Testing the Conversion of Pixel Values into Meter Units

Testing the conversion of pixel values into units of meters aims to see the effect of the results of the detection performed using imagery with the existing conditions significantly. To do this test needs to be done in several stages by taking several image samples that have a smooth and crowded classification smoothly. The stages that need to be done can be described as follows:

**a. Determine the true value of the actual detection**

The actual detection area value is obtained by calculating the area of the road that is on the Moh. Toha Toll Road based on Toll Road Geometry Standard [18].

**b. Calculate the actual detection area**

The image ROI is calculated using the formula of building a free trapezoidal space. Where both sides of the trapezoid are the length of the toll road and the height of the trapezoid is the width of the toll road.

**c. Calculate pixel area and conversion to meters**

Calculating the area of pixels then converting them into meter units is done by calculating the area obtained from the image of the detection result into the equation

$$area = LP \times dpi \times pixel \text{ to cm} \quad (15)$$

dpi = dot per inch

pixel to cm = 0.0264583333 cm

**d. Determine the Image Scale Value**

Determine the value of the image scale by dividing the original area by the area of the pixel area converted into meters. It is helpful as a comparator value between the image of the detection result and the condition on the actual toll road.

Based on the process of testing the conversion of pixel values to meters, the results are obtained for the actual detection area as shown in Table 1. The result of the pixel value conversion to the unit meter can be seen in Table 2. After getting each of the required values as in Tables 1 and 2, conclusions can be drawn based on the sampling of the detected images. Conclusions can be seen in Table 3.

Table 1: Wide actual toll roads

No.	Explanation	Value
1.	DPI	72 pixels per inch camera
2.	Actual Toll Road Length	91 m
3.	Actual Toll Road Width	10.5 m
4.	Actual Toll Road Area	955.5 m <sup>2</sup>

Table 2: Scale and area of conversion

No.	Area (pixels)	Area of Conversion Area (m <sup>2</sup> )	Actual Toll Road Area (m <sup>2</sup> )	Conversion Area Scale with Real Area
1.	237900 pixels	4531.93	955.5	4:1

Table 3: The final conversion result to the pixel value

No	Pixel Value			Value After Conversion (m <sup>2</sup> )			
	Area	Object Area	Percentage of Congestion	Classification	Area	Object Area	Percentage of Congestion
1.	237900	17900	7.52%	Fluent	4531.93	340.9907	7.52%
2.	237900	34800	14.62%	Smoothly	4531.93	662.939	14.62%

## 4.2 Pin Hole Grid Testing

The value of detection accuracy for 20 frames can be seen in Fig. 9. Pin Hole grid test aims to see the effect of the number of Pin Hole boxes during the image segmentation process. This step is used to detect congestion when segmentation in the image entered in the CLAHE filter on the accuracy obtained in the process. CLAHE filter was used because the filter input image is divided into the symmetrical grid where the number of grids affects the Pin Hole's accuracy.

### a. Image Conformity Results

This test is done by running 5 different Pin Hole grid values, i.e., grid images 8x8, 16x16, 32x32, and 64x64 with the image without grid division. The grid value used for the original image and the segmentation image of the CLAHE filter results. The following results from the process can be seen in Table 4.

Based on the segmentation image conformity using CLAHE filters with the original image in Table 4, the results of segmentation images have a lot of noise due to the inadequate CLAHE filters caused by the small number of grids that cause excess calculation results when the process is done. The Histogram Equalizer that causes the calculated vehicle object does not match the input

image. Many noises in the results image are obtained in the image with a grid of 8x8, 16x16 and 32x32.

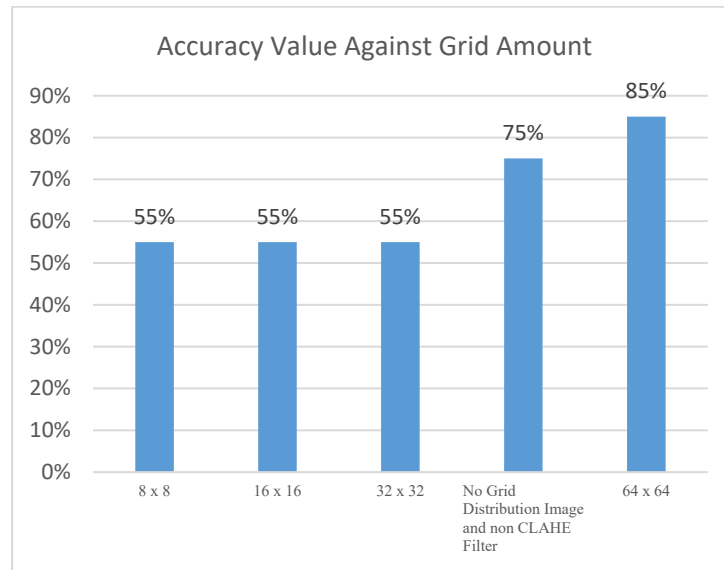

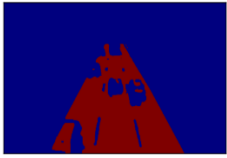

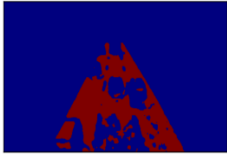



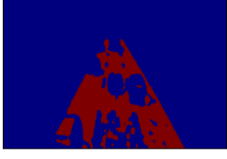




Fig. 9: Value of accuracy to the number of grids.

Table 4: Image conformity results

No.	Grid Amount	Results		Similar	Not Similar
		Original Image	CLAHE Segmentation Image		
1.	0x0			✓	
2.	8x8				✓
3.	16x16				✓
4.	32x32				✓
5.	64x64			✓	

#### a. Image Detection Results

This was done by comparing the detection value of the image with the correct value to get the accuracy value. The correct value is obtained from interviews conducted with Mr. Rudi Herianto is the Chief of the Indonesian National Police Traffic Department in Bandung.

### 4.3 Light Intensity Testing

Testing will be carried out by taking sample data on the results of recording traffic conditions on the toll road with different light intensity values. Different light intensity values will be obtained by detecting at different times, i.e., morning, afternoon, evening, and night. After that, the comparison of results will be made based on the accuracy values obtained. From this stage, the conclusion will be drawn based on high accuracy values on the value of the light intensity obtained by concluding the vulnerable value of the appropriate light intensity to detect congestion. The results of this test can be seen in Fig. 10.

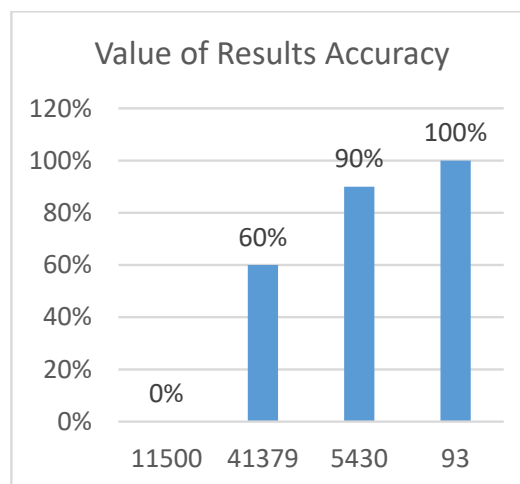


Fig. 10: Value accuracy of results based on light intensity.

Based on the graph in Fig. 10, the value of light intensity affects the result of the accuracy value obtained from the detection of congestion. The difference in the value of accuracy obtained is based on several factors as follows:

#### a. Toll Road Conditions

As seen in Fig. 10 that the detection error that occurred on the Toll road segment at light intensity is 11500 with an accuracy value of 0%. This is due to the detection of the image background as an object; after an analysis of the original image and the segmentation results obtained results that the error lies in the color of the uneven markers.

#### b. Car Light

Although in Fig. 10 the detection at night, the accuracy value reaches 100%, because the results of true values obtained from subjective opinions do not guarantee that the results are always correct. Reflection of light from car lights is considered to have an excessive amount of light intensity from the specified threshold. Therefore, the value of the excess light intensity is detected as an

object when image segmentation and is calculated in the search for congestion capacity values.

## 5. CONCLUSION

Based on the results of the analysis of the testing scenario on the congestion detection system using image processing with Pin Hole algorithm, which is carried out on 5 toll roads that will enter the city of Bandung, the following conclusions are obtained:

1. Based on the conversion of pixel values into units of meter obtained results from the image of the sample taken that the area of detection value using the image of 237900 pixels equal to the area of 4531.93 m<sup>2</sup> on the actual condition with a scale of 1:4
2. The congestion capacity for the classification results smoothly in the sample image will be the same value when the total object value of 340.9907 m is in the area of the detection area of 4531.93 m<sup>2</sup> in the real condition.
3. The implementation of the system can produce an accuracy value of 85% by using symmetrical 64x64 grid images with an average computing time of 5 seconds.
4. The detection results are assessed in the light intensity range from 5.430 to 41.379 LUX, assuming good road conditions.
5. The algorithm used still require modification with other algorithms in order to do detection at night.
6. Based on the weather obtained when sampling is not so influential as long as the light intensity values obtained are still in the susceptible 5.430 to 41.379.
7. This system is helpful as an alternative to find the value of congestion capacity based on the number of vehicles that will enter the city of Bandung through the highway.

## REFERENCES

- [1] Royani, Tahere, Haddadnia J, Pooshideh MR. (2010) A simple method for calculating vehicle density in traffic images. In 6th IEEE Iranian Conference on Machine Vision and Image Processing: October 2010; pp 1-4.
- [2] Fibriliyanti, Yanita, Faradila LR, Taqwa A. (2017) Implementasi Pengolahan Citra dengan Metode Histogram Of Oriented Gradient (Hog) untuk Pengaturan Waktu pada Traffic Light Berdasarkan Deteksi Kepadatan Kendaraan. In Prosiding SNATIF: 2017; pp 403-412.
- [3] Directorate General of Land Transportation Ministry of Transportation Republic of Indonesia. (2008) Technical Instructions for the Implementation of Road Equipment. Jakarta.
- [4] Nurhadiyatna A, Hardjono B, Wibisono A, Sina I, Jatmiko W, Ma'Sum MA, Mursanto P. (2013) Improved vehicle speed estimation using gaussian mixture model and hole filling algorithm. In 2013 IEEE International Conference on Advanced Computer Science and Information Systems (ICACSIS): September 2013; pp 451-456.
- [5] Kim KI, Jung K, Kim JH. (2002) Color texture-based object detection: an application to license plate localization. In Springer International Workshop on Support Vector Machines: August 2002; Berlin, Heidelberg. pp 293-309.
- [6] Bas E, Tekalp AM, Salman FS. (2007) Automatic vehicle counting from video for traffic flow analysis. In 2007 IEEE intelligent vehicles symposium: June 2007; pp 392-397.
- [7] Mahatmaputra S, Permata E, William. (2011) Deteksi kemacetan lalu lintas melalui kamera menggunakan pin hole algorithm. *ComTech.*, 2:821-834.

- [8] Cucchiara R, Massimo P, Paola M. (2000) Image analysis and rule-based reasoning for a traffic monitoring system. *IEEE transactions on intelligent transportation systems*, 1(2):119-130.
- [9] Chen TH, Lin YF, Chen TY. (2007) Intelligent vehicle counting method based on blob analysis in traffic surveillance. In *Second IEEE International Conference on Innovative Computing, Informatio and Control (ICICIC)*: September 2007; pp 238-238.
- [10] Zhang H, Liptrott M, Bessis N, Cheng J. (2019) Real-time traffic analysis using deep learning techniques and uav based video. In *16th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS)*: September 2019; pp. 1-5.
- [11] Saepudin D, Rizal A. (2014) Analisis Contrast Limited Adaptive Histogram Equalization (Clahe) Dan Region Growing Dalam Deteksi Gejala Kanker Payudara Pada Citra Mammogram. *Jurnal Elektro Unika Atma Jaya.*, 7(1):15-28.
- [12] Reza AM. (2004) Realization of the contrast limited adaptive histogram equalization (CLAHE) for real-time image enhancement. *Journal of VLSI signal processing systems for signal, image and video technology.*, 38(1):35-44.
- [13] Junior RA, Nurhasanah N, Sanubary I. (2014) Perbandingan Penggunaan Beberapa Metode Deteksi Tepi Pada Pengolahan Citra Radiologi Fraktur Tulang. *Prisma Fisika.*, 5(3):122-130.
- [14] Triono P, Murinto M. (2015) Aplikasi Pengolahan Citra Untuk Mendeteksi Fraktur Tulang Dengan Metode Deteksi Tepi Canny. *Jurnal Informatika Ahmad Dahlan.*, 9(2):103-842.
- [15] Panda DK, Sukadev M. (2013) A gaussian mixture model with gaussian weight learning rate and foreground detection using neighbourhood correlation. In *2013 IEEE Asia Pacific Conference on Postgraduate Research in Microelectronics and Electronics (PrimeAsia)*: December 2013; pp. 158-163.
- [16] Tomasi C, Manduchi R. (1998) Bilateral filtering for gray and color images. In *Sixth IEEE international conference on computer vision (IEEE Cat. No. 98CH36271)*: January 1998; pp. 839-846.
- [17] Deswal S, Gupta S, Bhushan B. (2015) A survey of various bilateral filtering techniques. *International Journal of Signal Processing, Image Processing and Pattern Recognition.*, 8(3):105-120.
- [18] Atkočiūnas E, Blake R, Juozapavičius A, Kazimianec M. (2005) Image processing in road traffic analysis. *Nonlinear Analysis: Modelling and Control.*, 10(4):315-332.
- [19] The Directorate General of Directorate General of Marga The Ministry of Public Works and Housing Republic of Indonesia. (2008) Standar geometri jalan bebas hambatan untuk jalan tol. Jakarta.