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Implementation of Traffic Monitoring Technology Using Smart Surveillance in Intelligent Transportation System

Ihsan Lumasa Rimra [a,1,*], Lifwarda [a,2], Yuliano Komanjali [a], Miguel Botto-Tobar [b,c]

[a] Department of Telecommunication Engineering, Politeknik Negeri Padang, West Sumatera, Indonesia
[b] Department of Mathematics and Computer Science, Eindhoven University of Technology, Eindhoven, 5600 MB, The Netherlands
[c] Department of Mathematics and Physical Sciences, University of Guayaquil, Guayaquil, 090514, Ecuador
[1] ihsanlrimra@gmail.com; [2] lifwarda@pnp.ac.id
* corresponding author

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ABSTRACT

Currently transportation is very attached to human life, almost every family and even every adult human being has a vehicle as a means of transportation. Based on this, a conclusion can be drawn that population growth will trigger an increase in the number of vehicles in Indonesia. The implementation of Traffic Monitoring Using Smart Surveillance in the Intelligent Transportation System is research on information and communication technology in the transportation system in order to increase mobility, reduce congestion resulting from the buildup of vehicles in one lane, and be taken into consideration by road users before crossing a road section. This system uses the Background Subtraction method, and object detection. This system was created by utilizing OpenCV and Python programming language. This research obtained an accuracy of 93.1% on camera A and 93.5% on camera B in calculating passing vehicles in the test using simulations monitored via cameras in real time.

1. Introduction

Nowadays transportation is very embedded in human life, almost every family and even every adult human being has a vehicle as a means of transportation [1]. Hence, a conclusion can be drawn that population growth will trigger an increase in the number of vehicles in Indonesia. Data collected from the Indonesian Police institution shows that the number of motorized vehicles in Indonesia reached 152.51 million units as of December 31, 2022. The distribution of the data shows that 126.99 million units or 83.27% are motorcycles. A total of 19.31 million motorized vehicles in Indonesia are passenger cars. Then there were 5.76 million passenger vehicles in Indonesia as of the end of last year. The Indonesian Police institution also noted that there are 212,744 buses operating in Indonesia until December 31, 2022. While the other 84,378 are special vehicles [2].

The increase in the number of vehicles creates new problems such as lack of parking space, congestion, and increased risk of accidents [3], [4]. Vehicle density analysis at strategic locations such as intersections, public parking lots, and busy roads can be done by observing and counting the number of vehicles per day. The process of observing and counting vehicles manually for a long time can cause calculation errors because humans can lose the ability to concentrate if they do something for a long time. So, it is necessary to build a system to help monitor and count vehicles automatically [5].

Currently, the calculation and data collection of the number of vehicles determining traffic density is still done manually, by assigning a number of people to count every vehicle that passes on a particular lane. Human errors can occur due to vehicle density, environmental influences, or not all vehicles are visible. Such errors lead to reduced accuracy in the calculation process. In addition to being prone to human error, calculations performed manually by humans have separate costs for each task, making it less efficient [6]. In this case, the best solution that can be taken to deal with the problem is to use the Background Subtraction method as an object detection tool in artificial intelligence (AI) which is useful for knowing the number of vehicles passing in real time [7]. Furthermore, maintaining communication between moving vehicles has become mandatory so as to guide seamless communication between vehicles [8].

Based on the facts, research regarding controlling and managing vehicles is important in order to determine the traffic density using the highway simulation method as a sample for future development on the highway. Simulation of the system built using a camera that will send data in real time to the Raspberry pi device as a server if there are vehicles passing by. Hopefully with this system, it can be applied to the streets and can provide information related to traffic density and can provide consideration for road users regarding the road to be traveled to avoid congestion.

2. Research Methodology

The vehicle detection system in this study undergoes several stages, according to Figure 1.

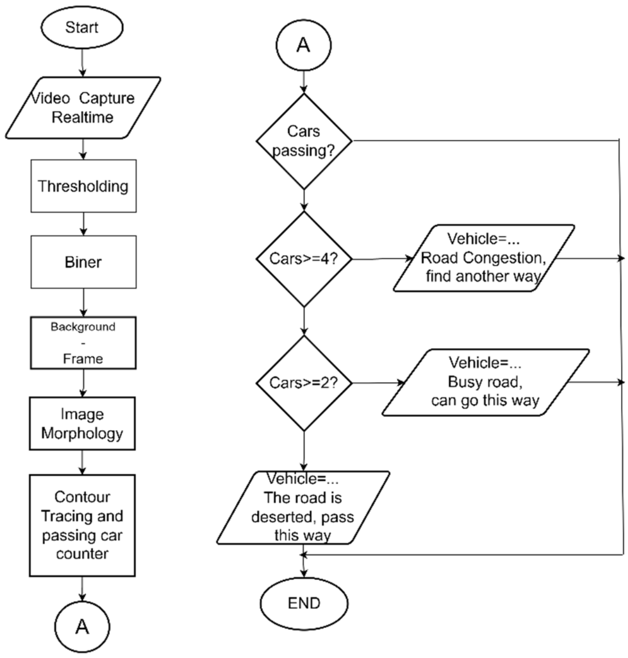

Figure 1. Research Flow Chart

The research starts from the discussion of studies that have been done for a long time, then the block diagram design is carried out. After that, the tool is built in accordance with the planned system, namely first the introduction of frames and backgrounds from the capture of the installed camera. This recognition is done using the Background Substraction algorithm. In simple terms, the Background Substraction algorithm can be seen in Figure 2.

The background subtraction method is a suitable method for detecting the movement of passing vehicles. Because the function of this method is used to describe the background pixels. background subtraction process by reducing each image pixel between the object and the background image.[9], [10]. The background subtraction method has disadvantages in terms of lighting, but it is also difficult to detect objects that move very fast. Therefore, this system is made in real time by increasing the frames per second so that the system always updates the background by itself and is able to cover other shortcomings [11].

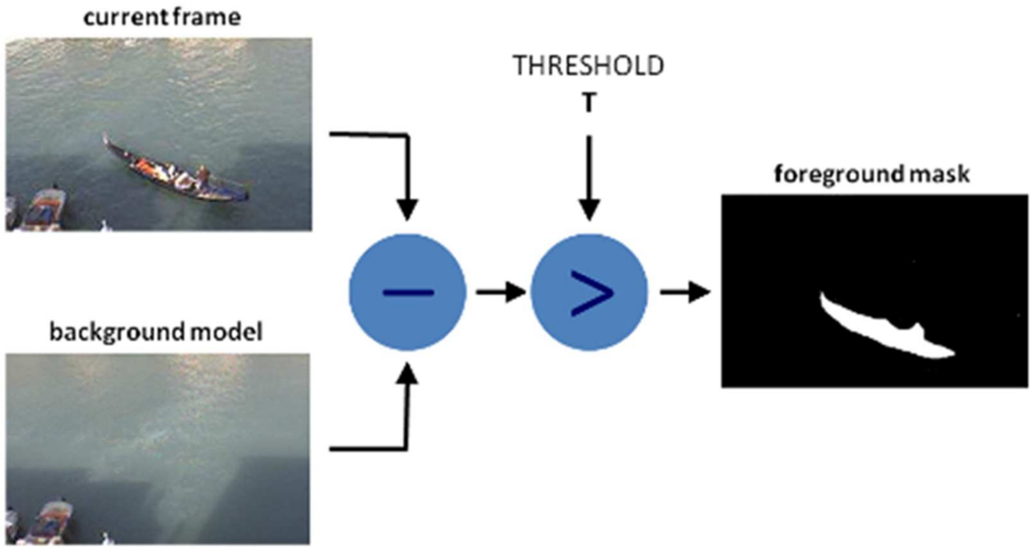

Figure 1. Illustration of background substraction [8]

Formula 1 is the background substraction calculation formula.

$$D(x,y) = \begin{cases} 1 \; if \; F(x,y) - B(x,y) > T \\ 0 \; if \; F(x,y) - B(x,y) \leq T \end{cases} \quad (1)$$

Description:
B = background
F = displayed frame
T = threshold value

The system is built with an architecture where each device has its own function and role, the camera acts as a monitor that will send a capture in real time to the raspberry pi when an object passes, the raspberry pi will process the video capture using the Python programming language so that the system will display the number of vehicles passing on the screen and the user can analyze the density of vehicles on the route. The surveillance system uses Raspberry pi as a mini PC paired with a monitor and camera capable of capturing and processing real time/ streaming video. The schematic diagram of the system is shown in Figure 3.

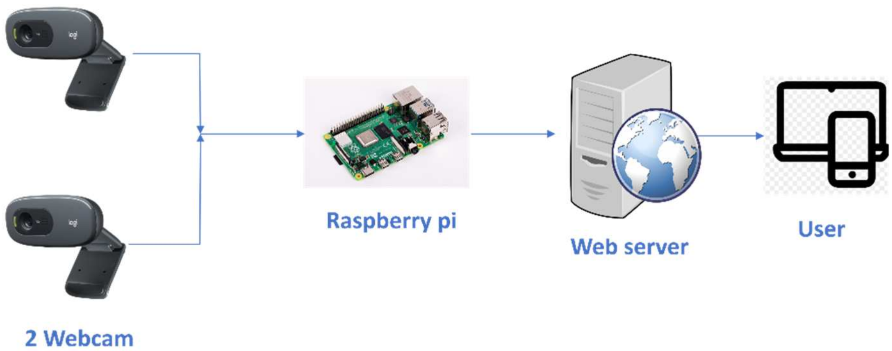

Figure 3. Architecture of the tool

After the tool is built, testing and evaluation are then carried out. Testing is carried out with a variety of passing vehicle conditions, ranging from 1 vehicle to so on[12]. After testing, then validation of the accuracy of the number of cars passing on the simulation path is carried out. The formula for calculating the percentage of accuracy is shown in formula 2.

$$A = \frac{M - nM}{M_a} \tag{2}$$

Where:
A = Accuracy
M = number of car objects read
nM = number of non-car objects that are considered cars
M_a = number of actual car objects

3. Results and Discussion

The designed system is then applied to a Raspberry pi device and a camera on the highway simulation made. This is to minimize external interference if installed directly on the highway. The position of the Raspberry pi and camera is installed in such a way that the camera can monitor the highway simulation made, the installation of the Raspberry pi and camera can be seen in Figure 4 and the highway simulation made can be seen in Figure 5.

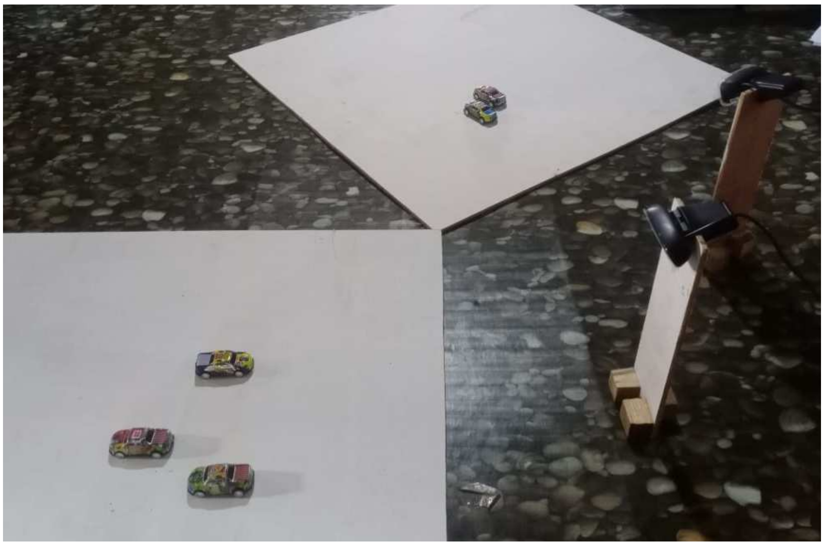

Figure 2. Raspberry pi and camera device installation

Figure 3. Roadway simulation

The resulting coverage of the installed cameras can monitor the entire simulated highway. Based on the width of the installed camera coverage, a line is drawn in the center of the image where any object that moves past this line and meets the reading requirements of a car will be considered a passing vehicle. The line is marked in blue as shown in Figure 6. If there is a car passing on the lane and crossing the line created, the system will record the passing car increasing by 1.

Figure 4. Counter lines on the system

In the next step, the system will perform background subtraction on each frame recorded by the camera installed to detect cars crossing the simulated road. The camera records in real time and is set with an image reading of 10 frames per second (fps), but the weakness of the device which is the weakness of the method used is that very fast car movements cannot be detected by this system, so to simulate the car must be moved slowly so that the system can read the movement of the car. The system will detect all objects that enter the scope of the camera. Objects that enter the scope of the camera will be analysed by the system, if the object is stationary, it means that it is included in the background, but if the object moves, it is included in the frame or foreground as shown in Figure 7 below.

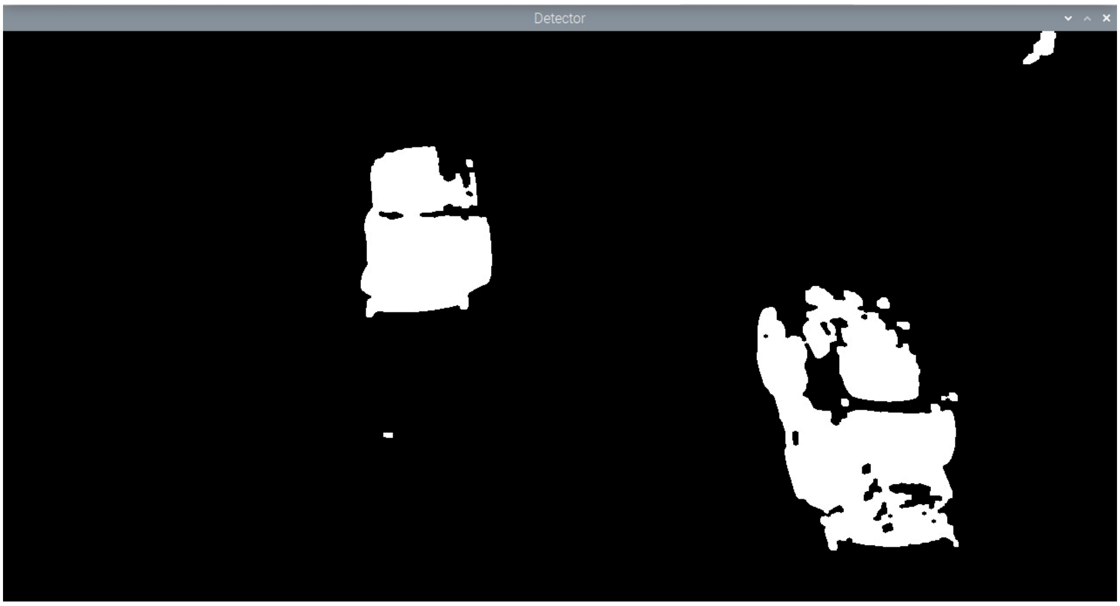

Figure 5. Example of the background substraction result

After the background substraction method, the system will determine whether the detected object is a car or not based on the minimum height and width of the car that has been determined as shown in table 1. The minimum value is obtained based on experiments conducted several times on the size of the toy car used in the simulation. The minimum size of the height and width of the car set is 80 pixels.

In accordance with the previous discussion that if the detected object moves to meet the minimum height and width requirements specified then the system will assume it is a car and if the object moves past the blue line created in the system then the system will immediately read and add the number of cars passing by as shown in Figure 8.

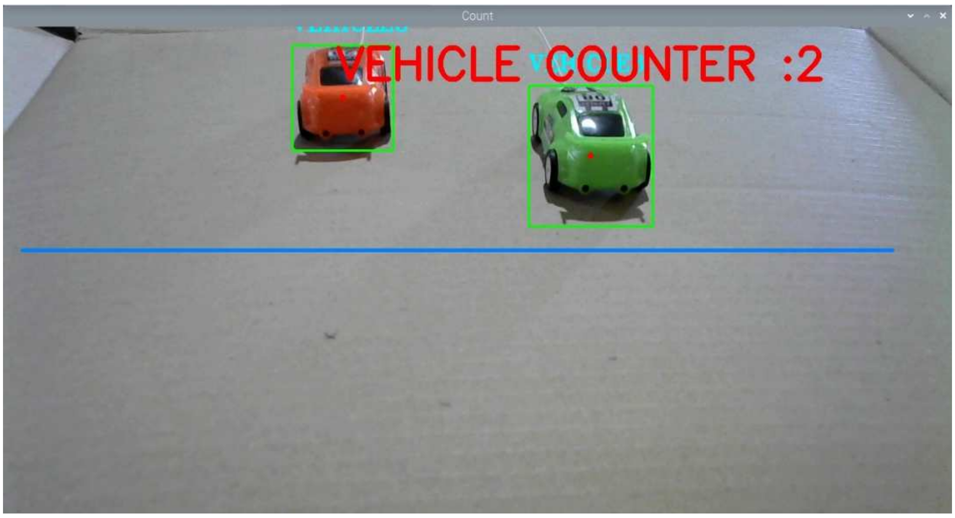

Figure 6. Car detection result according to the size

The output of the system is displayed through an online website so that users can access it anywhere and anytime as shown in Figure 9.

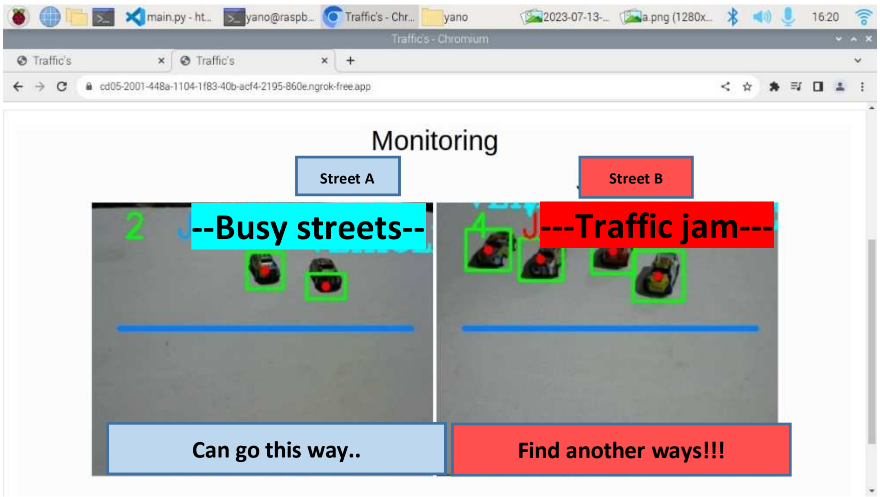

Figure 9. Online website interface

The table corresponds to the description of the accuracy calculation formula, where M is the number of objects in the form of cars that are read, nM is the number of non-car objects that are considered cars, Ma is the number of real cars, and A is the accuracy calculated using formula 2.

Table 1. Testing table of passing cars on camera A

No	M	nM	Ma	A
1	2	0	2	100%
2	3	0	3	100%
3	4	0	4	100%
4	5	0	5	100%
5	6	0	6	100%
6	7	2	7	63%
7	8	0	8	100%
8	9	2	9	78%
9	10	0	10	100%
10	11	1	11	90%
		AVERAGE		**93.1%**

Table 2. Testing table of passing cars on camera B

No	M	nM	Ma	A
1	0	0	0	100%
2	2	0	2	100%
3	3	0	3	100%
4	4	0	4	80%
5	5	0	5	100%
6	6	0	6	83%
7	7	1	7	75%
8	8	0	8	100%
9	9	0	9	100%
10	10	0	10	100%
		AVERAGE		**93.5%**

Based on the test result data summarized in accordance with table 1 and table 2 where testing is carried out with a variety of cars 10 times on each camera. In camera A, the average accuracy result is 93.1%, while camera B gets an average accuracy result of 93.5%. Basically, the accuracy is good enough, but there are some problems with the system caused by many factors, one of which is the shadow at the bottom of the car which is sometimes read by the system as a car. The next factor is because the speed of the car is too fast resulting in the system not being able to read the passing car.

4. Conclusion

Based on the research conducted, the average system accuracy obtained on camera A is 93.1% and on camera B is 93.5%, which means that the system has worked optimally and obtained good results. However, not achieving an accuracy value above 95% is caused by several obstacles that create miscalculations in the system such as lighting that sometimes creates shadows on the bottom of the car. But overall, this research has provided an overview for the user to be able to know and consider the density of the road to be traveled. Problems in the form of errors in the system can be taken as the input for similar research in the future to overcome the problems that have been detailed in this study.

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