Proceeding of International Conference on Green Technology
ISSN:2355–3456
September 10th, 2015, Semarang, Indonesia

Traffic Light Duration Arrangement Based on CCTV Recording and Analysis Signalized Intersection Algorithm

Henning Titi Ciptaningtyas[1], Handayani Tjandrasa[2] and Iqbal Akhmad Ghufron[3]
[1, 2, 3]Department of Informatics, Faculty of Information Technology,
Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia
henning.its@gmail.com[1]

***Abstract*—Common problem in big cities is traffic congestion. It causes fuel loss, time loss, and productivity loss. Inappropriate traffic light duration has contribution to traffic congestion. To reduce the traffic congestion that is caused by the inappropriate traffic light duration, we propose adaptive traffic light duration arrangement based on the road conditions (number of passing vehicles and road width). This system use Closed Circuit Television (CCTV) to capture video footage and send it to data server via Virtual Private Network. The data server stored the video recording, then uses it in processing server with restoration and morphology process to calculate the number of passing vehicles. Number of vehicles and road width is processed using an analysis signalized intersection algorithm to obtain optimum traffic light cycle time duration.**

Keywords*—Traffic Light Duration, Restoration, Morphology, CCTV, Analysis Signalized Intersection Algorithm.

I. INTRODUCTION

Transportation is an integral part of human life, especially in the distribution of goods and mobility of people. Transportation is basically a tool to overcome the distance to meet the needs of geographically separated from one place to the others. Transportation is also essential to improve the development, to improve the economy, and to support regional growth movement.

Guarantee the smooth transport of goods by transportation, which is a transport problem in terms of microeconomics, has become a difficult thing to obtain. Congestion has become the obstacle of the vision and mission of transportation. By a number of economic analysts, transportation problem potentially causes inflation [1].

Impacts of congestion in the economic aspects are the lost of benefits and unnecessary costs. Congestion causes vehicle speed slowed or even stopped. Of course this causes unnecessary consumption of fuel. On the other hand, the company also decreased employee productivity as a result of delays due to stuck in traffic jams. From the aspect of labor themselves, they lose the opportunity cost, time that should be used for other activities wasted. Even the costs incurred losses due to congestion reached IDR 42.9 trillion, with the biggest losses from the aspect of time, which reached IDR 20.3 trillion [2].

To reduce the traffic congestion, we need to optimize the functionality of CCTV cameras at the crossroad intersection. With the CCTV cameras, we can obtain valuable information related to the traffic and congestion in an area or the intersection.

By using pattern recognition in digital image processing, the machine can recognize a vehicle pattern in the input video from CCTV cameras. Computer analyzes object in the video based on the predetermined vehicle characteristics. In this research, the CCTV camera is used as a device to capture video footage. The video recording will be used as input files to be processed by restoration and morphology process. Number of vehicles and road width is processed using an analysis signalized intersection algorithm to obtain optimum traffic light cycle time duration. The optimized traffic light cycle time duration can reduce congestion.

II. METHODOLOGY

Humans have the ability to acquire, integrate, and interpret visual information from images, graphics, or video. The digital device can also has the same capability, but it needs storage capability, processes capability, transmission capability, pattern recognition capability and interpretation capability of visual media [4].

Digital image is formed from a set of pixels. Each pixel represents the color (or gray levels in a grayscale image) at each point in the image. A digital image (sometimes called bitmap) is a rectangular array of pixels [5]. In this research, the data input is in the form of color images created from CCTV camera and the output of Image Processing phase is a binary image.

The data input from CCTV camera at the road intersection is transmitted to the data server in the Department of Transportation using Virtual Private Network (VPN). VPN will create a tunnel through the public network, typically the Internet. Both computers will be connected and communicate within the public network, as if there is a connection between point to point. The data will be encapsulated (sent encrypted) so it remains confidential [3].

Those image data is processed using Wiener Filter and Morphology, then calculate the optimum traffic light cycle time duration using analysis signalized intersection algorithm.

A. *Wiener Filter*

Wiener filter is a low pass filter which process degraded images by additive noise with a constant force. Wiener filter using adaptive Wiener method based on a statistical estimation of the local environment of each pixel. Wiener filter estimate the local average and variance of the environment for each pixel.

The local average search and variance in this filter are described in (1) and (2).

$$\mu = (1/MN) \sum_{n1,n2\in\eta} \alpha(n_1,n_2) \quad (1)$$

$$\sigma2 = (1/MN) \sum n1,n2\in\eta\ \alpha(n1,n2)-\mu2 \quad (2)$$

At (1) and (2), ŋ is a local neighborhood of each pixel. The Wiener filter creates a pixel results as stated in (3). V2 at (3) is the noise variance used in this phase[6].

$$b(n1,n2) = \mu+((\sigma^2-v^2)/\sigma^2)\ (\alpha(n1,n2)-\mu) \quad (3)$$

Wiener filter is used as the restoration operator because it has higher accuracy to restore the image with noise and can maintain detail in a high-frequency [7].

B. *Morphology*

Morphology is an image processing operation which processes the image based on its shape. Morphological operations apply a structural element in an input image and generate output images with the same size. In morphological operations, the value of each pixel in the image depends on the results of the comparison of the pixel values in the original image and the neighborhood pixels. By determining the size and shape of the structural elements, morphological operations can be performed to determine the specific forms depicted in the image.

Basic operations of the morphology are dilation and erosion operations. Dilation operator adds pixels to the boundaries of the object in the image, while the erosion operator subtracting pixels from the boundary line to the object. The number of pixels which are added or subtracted depends on the size and shape of the structural elements that had been predetermined previously. In dilation and erosion operation, each pixel which is displayed on the image result is determined based on the implementation of the structural elements in that pixels and the other pixels located around the original image. Rule used in the operation depends on the operator, the sum of the dilation operator, and a reduction of the erosion operator [8].

1) *Opening Operator*

The opening operator process the original image with a combination of dilation and erosion operations. The opening operator performs erosion operation on the image with a structural element, followed by dilation operation with the same structural element. Opening operation aims to smooth the outline object, cut the connected object, and also eliminates bulges on the object [9].

2) *Closing Operator*

The closing operator process the original image with a combination of dilation and erosion operations. Closing operators perform dilation operation on the image with an element of the structure and proceed with the operation erosion with the same structural elements. Closing operation aims to smooth part of the boundary line on the object, combining separate object, also filling or eliminating holes in objects [9].

C. *Analysis Signalized Intersection Algorithm*

Intersection is part of the fixed time assembled control system or isolated vehicle signal actualization, usually requires special method and software in its analysis. The use of a traffic light signal with three lights colors (red, yellow, and green) are assigned to separate the movement trajectory of the conflicting traffic in the dimension of time. This is an absolute necessity for the movement of traffic coming from the intersecting street (main conflict). The signal can also be used to separate the traffic of veer and straight movement, or separating the traffic of veer movement from the pedestrian crossing (secondary conflict) [10]. An explanation of the main and the secondary conflicts at the intersection can be seen in Fig.1.

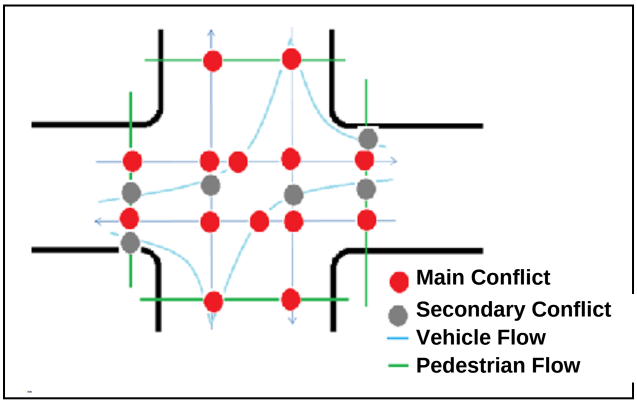

Figure 1. Conflict at the intersection

The steps of determining the duration of a traffic light intersection analysis algorithm is written in (4) to (14) [11] as follows:

1) *Calculate the number of vehicles passing through each arms during a certain time unit.*

2) *Convert the number of vehicles in the passenger car unit (PCU).*

   a) *Light vehicle e.g. jeep, pick-up, city car.*

   $$q = 1 * LV \quad (4)$$

   b) *Heavy vehicle e.g. bus, truck.*

   $$q = 1.3 * HV \quad (5)$$

   c) *Motorcycle.*

   $$q = 0.4 * MC \quad (6)$$

   d) *Unmotored e.g. tricycles, bikes, buggy.*

   $$q = 1 * UM \quad (7)$$

3) *Calculate the capacity of the mouth of the intersection for each intersection arm.*

$$s = 525 * Wc \quad (8)$$

4) *Calculate the ratio of saturated flow per capacity with the following steps.*

a) *Calculate the ratio of the volume per capacity for each intersection arm.*

$$Y = q / s \quad (9)$$

b) *Calculate the ratio of the volume per capacity per phase.*

$$Yi = \max (Y) \quad (10)$$

c) *Calculate the ratio of saturated flow per capacity.*

$$YEmax = \Sigma Yi \quad (11)$$

5) *Determine the L lost time in the cycle.*

$$L = yellow + red\ all \quad (12)$$

6) *Calculate the optimal cycle time.*

$$Co = (1{,}5L + 5) / (1\text{-}YEmax) \quad (13)$$

7) *Calculate the effective green time of each intersection arm.*

$$WHE = Yi\ (Co\text{-}1\text{-}L) / YEmax \quad (14)$$

Whereas,

q = the number of vehicles in units of PCU
LV = Light Vehicle, the number of light vehicles.
HV = Heavy Vehicle, the number of heavy vehicles.
MC = Motorcycle, the number of motorcycles.
UM = Un-Motored, the number of non-motorized vehicles.
Wc = Road Width.
s = the capacity of the intersection mouth.
Y = the ratio of the volume per capacity.
Yi = the ratio of the volume per capacity per phase.
YEmax = saturation flow rate per capacity.
L = lost time, the amount of time lost in each cycle.
Co = optimal cycle time.
WHE = effective green time.

III. DESIGN AND IMPLEMENTATION

General architecture of the system is described in Fig. 2. CCTV cameras record the condition of the intersection (number of vehicles). The recorded video is sent over Virtual Private Network and stored on the Data Server. The system load the videos and processed the footage to calculate the optimum traffic light duration based on Analysis Signalized Intersection Algorithm.

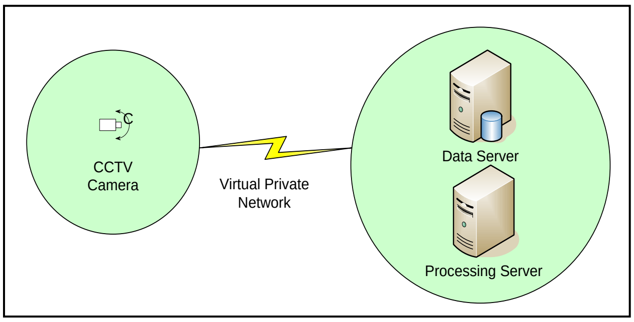

Figure 2. System Architecture

The system was implemented at Pabean Intersection, Sidoarjo City, East Java, Indonesia. The geographic location (altitude longitude coordinates) of this intersection is 7.369468, 112.763411. The area can be seen in Fig. 3.

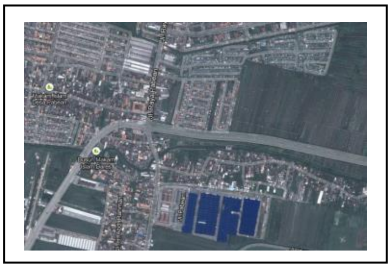

Figure 3. Pabean Intersection

The intersection has four arms with the north arm is to Rungkut (road width = 14 meters), the south one is to Sedati (road width = 14 meters), the west one to Aloha (road width = 22 meters), and the east one to Juanda Airport (road width = 21 meters). Details of Pabean intersection can be seen in Fig. 4.

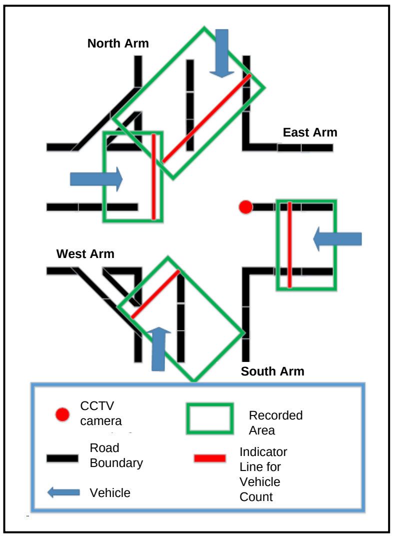

Figure 4. Pabean Intersection Details

ISSN:2355–3456
September 10th, 2015, Semarang, Indonesia

Camera locations at this intersection lie on the east road separator. On the road separator there is a pole with four CCTV cameras which record the condition of the road at each intersection arm. The camera range (images recorded on each intersection) of west and east arm are about 8 meters, the north and south ones are about 11 meters.

Major processes of the system are as follows:

A. Accessing CCTV video on the network

CCTV camera record the road condition of each intersection arm. The CCTV recording then transmitted to the data server through VPN connections over fiber optic. The VPN network creates a tunnel through the Internet network and encrypts the transmitted data (to guarantee the data confidentiality).

B. Image processing

In the image processing phase, the CCTV recording in the data server is sent frame by frame to the processing server. System tries to identify the vehicle objects based on the image background. For each video frame, the processing server will do these actions: preprocessing, restoration and morphology.

The Preprocessing step is a subtraction between the image in each frame and a background image. The image result will be converted into a binary image and eliminates other objects, e.g. trees, buildings, and sidewalks.

The restoration step is using Wiener filter with the formula described in (1) to (3). This process uses a 3x3 mask.

The last step is morphological process using closing and opening operation. This process uses disc structural elements and the size varies depends on the processed video.

C. The number of vehicles calculation

In this phase, the system counts the number of passing vehicles which detected in the video. The system created a virtual line in the video frame as an indicator to detect vehicles. If an object is detected on the line indicator, then the value of the pixels in the intersection will be saved. The pixel value of the object is 1 (white color). If the value of all pixels are changed to 0 (black color), it is considered that the detected object is passing through the line indicator. For each object that has been passing through the line, the vehicle counter is incremented. At the end of the video, the system can count the number of passing vehicles.

D. The traffic lights duration calculation

In this phase, the system calculates time traffic light duration cycle at the intersection based on the passing vehicle number and the road width of each intersection arm. This phase uses Analysis Signalized Intersection Algorithm as in (4) to (14).

The application interface of input video is in Fig. 7 and processed video can be seen in Fig. 5. Visualization of Four Phase Traffic Light Duration Cycle can be seen in Fig. 6.

Figure 5. Input Video and Processed Video

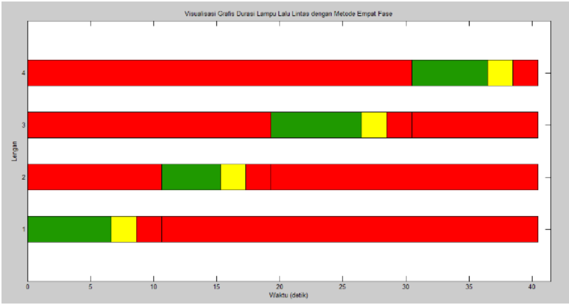

Figure 6. Visualization of Four Phase Traffic Light Duration Cycle

Figure 7. Original Data Input

IV. EXPERIMENT RESULT

A. Functional Test

This test compares the number of passing vehicles detected on the system and the actual number of passing vehicles. This experiment tested 12 different videos on the system. The purpose of this experiment is to test the accuracy of the process. The actual number of passing vehicles calculated manually using visual observation. Experiment result of the functional test is shown in Table 1.

The experimental result shows the accuracy of the system is 86.67%. Within 12 experiments, 10 of them show correct result. Two experiments show improper result because the input videos are not optimal.

The second video input shows two vehicles which are very close together so they are considered as one large object. In this condition, the recorded vehicle is only 33.33% of the actual number of passing vehicles.

The fourth video input recorded in the rainy condition. This caused the color of asphalt in the recording video different with the one in background image. The wind was blowing pretty hard, so the CCTV camera shakes and exposed to droplets of water. The result of these conditions is a blur video recording. In this condition, the number of vehicles counted in the system is only 75% of the real number of passing vehicles. The average number of detected vehicles when there is a disruption of 54.17%.

TABLE I. NUMBER OF DETECTED VEHICLE

Video No.	Number Of Vehicles		Video No.	Number Of Vehicles	
	Real Number	*Detected By System*		*Real Number*	*Detected By System*
1	2	2	7	2	2
2	1	3	8	2	2
3	2	2	9	2	2
4	3	4	10	2	2
5	1	1	11	4	4
6	2	2	12	3	3

B. *Performance Test*

The input video that will be processed on the system placed on the different server, so it is necessary to know the video load time. At this performance test, we calculate time to load video from the data server to the processing server. Video load time is the time needed for the application to run until the application window appears.

We also calculate video processing time. Video processing time is time needed for processing the first frame of the video until the last one. There are three sets of data were tested in this performance test. Video file size of the performance tests are shown in Table 2. Each video has 90 frame numbers, 3 seconds duration, 30 frame / seconds, and 10 fps processed video. The first, second, and third dataset has video load time 05:7,18; 05:16,39; 06:41,39 minutes and video processing time 12,99; 12,75; and 12,51 second respectively.

The experimental results show that video load times from the data server are varies with an average time of 3 minutes and 41.65 seconds. Video load time can vary depends on the internet connection during the experiment.

The average video processing time requires 12.75 seconds. The duration of the video input is 3 seconds only but the processing time takes longer because the system implements restoration process, morphology process, and also counting the number of vehicles process on each video frame.

TABLE II. VIDEO FILE SIZE

Data Set	Video	File Size (KB)	Data Set	Video	File Size (KB)
1	North	2032	2	West	3036
1	South	1773	2	East	2016
1	West	3822	3	North	1822
1	East	2571	3	South	3700
2	North	1541	3	West	3650
2	South	5621	3	East	1130

V. CONCLUSION

From the experimental results, it can be drawn the following conclusions:

1. Applications received input data in the form of a video by a VPN connection to the server. By performing image processing such as restoration and morphology of the CCTV video footage, the system can obtained the number of vehicles recorded on video.
2. The application can generate output data in the form of the duration of the cycle time of traffic.
3. The accuracy of the process of calculating the number of vehicles reached 86.67%.
4. The most optimal video frame is processed in a quiet and sunny weather condition, while at the crowded or bad weather conditions the average numbers of vehicles reach only 54.17% in the average.
5. The average video load time is 3 minutes 41.65 seconds and the average processing time is 12.75 seconds.

REFERENCES

[1] A. M. Mirlanda, “Kerugian Ekonomi Akibat Kemacetan Lalu Lintas di Ibukota,” Universitas Indonesia, pp. 38-39, 2011.

[2] D. Sasono, "Kebijakan Umum Transportasi Perkotaan : Menuju Sustainable Urban Transportation di Indonesia," Yogyakarta, 2012.

[3] D. L. Shinder, Computer Networking Essentials, 3rd ed., Indianapolis: Cisco Press, 2002.

[4] A. K. R. Tinku Acharya, "Image Processing : Principles and Applications," Wiley, 2005.

[5] J. Sachs, "Digital Image Basics," 1999.

[6] MathWorks, "2-D Adaptive Noise Removal Filtering - MATLAB wiener2," Mathworks, [Online]. Available: http://www.mathworks.com/help/images/ref/wiener2.html. [Accessed 23 Mei 2015].

[7] L. Xie, "Departement of Electrical Engineering," 23 Maret 2009. [Online]. Available: http://www.ee.columbia.edu/~xlx/ee4830/. [Accessed 2 Mei 2015].

[8] MathWorks, "Morphology Fundamentals : Dilation and Erosion," MathWorks, 2013. [Online]. Available: http://www.mathworks.com/help/images/morphology-fundamentals-dilation-and-erosion.html#f18-14379. [Accessed 4 Juni 2015].

[9] H. Coetzer, "Stellenbosch University," [Online]. Available: dip.sun.ac.za/~hanno/tw444/lesings/lesing_21.pdf. [Accessed 5 Juni 2015].

[10] The Directorate General of Highways of the Ministry of Transportation, “Manual Kapasitas Jalan Indonesia”, Jakarta, 1997.

[11] Department of Transportation and LLAJ East Java province, "Pengandalian Lampu Lalu Lintas," Surabaya.