Implementation of Vehicle Traffic Analysis Using Background Subtraction in The Internet of Things (IoT) Architecture

Aghus Sofwan[1], Fuad Ashabus Surur[2], M. Arfan[3], Eko Handoyo[4], Yosua Alvin A.S.[5], Maman Somantri[6], Enda W.S.[7]
Department of Electrical Engineering
Diponegoro University, Indonesia
asofwan@elektro.undip.ac.id[1], ashabusurur@gmail.com[2], arfan@ft.undip.ac.id[3], eko.handoyo@undip.ac.id[4], yosua@live.undip.ac.id[5], mmsomantri@live.undip.ac.id[6], sinuraya_enda@elektro.undip.ac.id[7]

***Abstract*—Vehicle traffic analysis is one of the features that are provided in a smart city application. A camera is used to capture vehicles that are moving through on the road. Background subtraction is applied in order to detect the moving object, i.e., Gaussian Mixture Model. The system is developed under the Internet of Things (IoT) architecture, which all devices are associated using Internet connection. The calculated value is transmitted into cloud and received at the virtual server. Data are saved to a database and are able to be accessed through a web interface. We observe the applied system provides a good performance in terms of average accuracy exceeds 95.64%.**

Keywords*— *Internet of Things; background subtraction; Gaussian Mixture Model; vehicle traffic; smart city.

I. Introduction

The term Internet of Things (IoT) was first coined by Ashton at the end of the last century [1]. It is a network of Internet-connected objects that gather and exchange data using embedded sensors. Nowadays, after almost two decades, the IoT continuously evolves and penetrates to our live like transport, healthcare[2], education, utilities, disaster [3], etc. It delivers the paradigm of anytime and anywhere connectivity [4]. Many of the devices that surround us now perform machine-to-machine connection using the Internet [5]. They harvest, sense, and share information from the environment without the aid of human intervention [6]. In a smart city, the government serves many features that provide information of city situations, such as a vehicle traffic of a road, through IoT architecture. The remote device as node captures and detects the vehicles that go through a road, and then it autonomously analyzes the traffic. Along with decreasing of the price of sensor devices and processor, and easiness in obtaining the Internet broadband connection, it is more convenience to provide the vehicle traffic system in IoT architecture.

In order to detecting the moving vehicle, there are many literatures exposed algorithms of this need, e.g. in [7-11]. In [7], the authors proposed an algorithm for visual tracking of the human visitor under variable-lighting conditions. The algorithm combines estimation of statistical background images, Bayesian segmentation, and multitarget tracking. The proposed algorithm was compared to three blob algorithms. In [8], the authors proposed an algorithm to classify the object and background regions. The algorithm uses a correlation function to calculate the inter-plane correlation between three consecutive R, G and B planes. Then the correlation matrix results were utilized to develop a segmented image that predicts the object. This process needs a computer with high resources. In [9], the authors described vehicle detection using foreground detection and blob analysis (FDBA). The algorithm subtracts the background from the foreground, and then connects those pixels that are moving and close to each other in the foreground as a blob. The authors applied the algorithm using matlab in built vision object. In [10], the authors evaluated many foreground detection methods in order to distinguish foreground objects either moving or static objects from the background; i.e. Gaussian mixture model (GMM), kernel density estimator (KDE), Code book, Adaptive Gaussian mixture model (AGMM), and Consensus-based method (SACON). Many typical challenges were used to evaluate model methods, such as illumination change, dynamic background, and shadows. Based on the evaluation, the authors stated GMM-based provides promising results. In [11], authors applied universal sample-based background subtraction algorithm called ViBe (Visual Background Extractor) for detecting the human presence. The algorithm is used to trigger the surveillance system. Referring to those literatures and the need of providing a vehicle traffic analysis features in a smart city, we implement a system that using the background subtraction model to calculate a number of vehicles that goes through a road in IoT architecture. The paper has many contributions to the scientific and engineering manner, such as: providing a background subtraction method for moving detection and description of a system in IoT architecture. The contribution of this paper is providing the implementation of the GMM model for vehicle traffic with its performance in an IoT architecture.

The rest of this paper structured as follows. In Section II, the system architecture of the designed system, which considers IoT architecture, is described in detail. The background subtraction method is explained in clearly steps. In Section III, the results from the system and discussions are provided. And in the last section, we provide the conclusions of the paper.

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II. SYSTEM ARCHITECTURE

In this section, we describe the applied system of the vehicle traffic using background subtraction method in IoT architecture. The system consisted of three main parts, which are the node, Internet cloud, and virtual server. The first part, the node is composed of a camera, raspberry pi micro controller, and 4G/GSM modem. Camera has function as the input device that capture image of a road. The Raspberry Pi controller acts as image processor that applies background subtraction in detecting the moving vehicle. The 4G/GSM modem is used as transmitter data from the raspberry. It transmits to any Internet service provider (ISP) that allocates Internet connection. The second part is Internet cloud that connects the node to the server. It is also used by users to access the server and the node. The third part is the virtual server that provides web and database server functions. This server is used to save delivered data from the first part. Furthermore, from this part we obtain the output of traffic analysis.

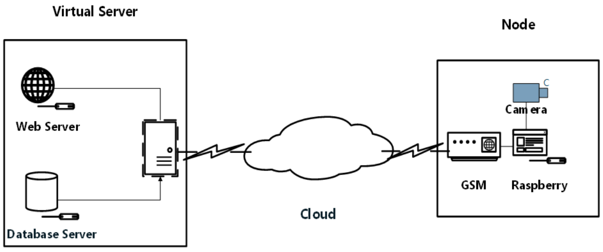

Fig. 1. IoT architecture of the applied system

A. Background Subtraction Method

The background subtraction method is a process for seeking the difference of foreground image with background image, so that the moving object can be identified. The method assumes that the difference value of both images is caused by moving object. The unchanged pixels can be considered as background, while the changed pixels can be assumed as moving object. This method is more applicable in detecting moving objects since its effectiveness in conveying data contains the object. The algorithm of background subtraction with gaussian mixture model for the applied system can be described as follows.

1. Image of background subtraction is obtained from input device, i.e., camera. The obtained image is utilized as input, either static images or moving images (video). Then the input images are converted into grey scale. The mathematical model for converting RGB into grey scale is defined as follows.

$$Greyscale = 0.299R + 0.587G + 0.114B \quad (1)$$

2. Seeking operation of background and foreground is performed at any of pixel, which is started with searching of the highest weight. This operation uses a fitness formula as follows.

$$F_{k,t} = \frac{\omega_{k,t}}{\sigma_{k,t}} \quad (2)$$

here $\omega_{k,t}$ is weight and $\sigma_{k,t}$ is variance. The weight is sequenced from the lowest to the highest. Then, match condition is searched through all pixels. Subsequently, the pixel is considered as a match condition when the value is less than 2.5 of deviation standard. Background identification is performed by using following equation.

$$Background = \underset{b}{\arg\min}\left(\sum_{k=1}^{b} w_k > \tau\right) \quad (3)$$

3. Adding consecutively the weight of the highest fitness until the number is greater than τ. The τ represents the threshold for detecting the pixel value either it is in background or foreground category.
4. Detecting small moving object or particle, which will be then eliminated. This is considered as a background with learning rate. The learning rate is utilized to enhance detection performance, in order to eliminate unwanted noise.
5. Then the detection result is shown in bounding box. Furthermore, the centroid is applied to the bounding box.

B. Traffic calculation

The camera in a node acts as the input device that capture video of road situation. It is placed at a good position for viewing the moving vehicle on the road. The illustration of camera position is exposed in Fig. 2. Meanwhile, the camera faces to the road, as shown in Fig. 3. The captured video is sent to the processor, which is raspberry pi. Furthermore, the processor performs the calculation of the vehicles that go through a road. In order to count the vehicle traffic of a road, the processor applies region of interest (ROI), which consists of two lines, as shown in Fig. 3. The green lines are set perpendicular to the road. The ROI is utilized to detect whether a moving object goes through the region or not. If the centroid of the bounding box, which indicates the moving object goes into the ROI, then the vehicle will be counted as an object cross the road. The system must have an ability to avoid detection of the same object. The applied system generates a bounding box, which shackles the moving object..

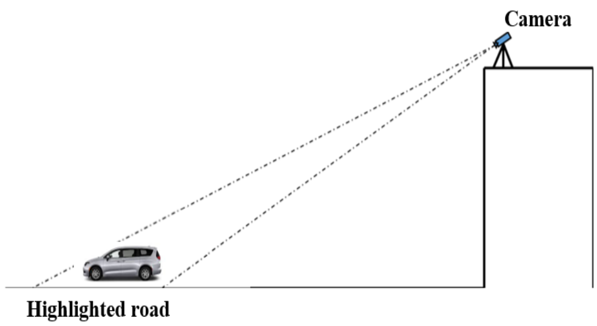

Fig. 2. Illustration of placing the camera on the road

Fig. 3. Input device faces on the road

Fig. 4. Region of interest (ROI) that is applied in the applied system

In Fig. 4, the blue rectangle line bounds the vehicle. The box is utilized to ensure an object that crosses the ROI will not be counted twice or more. It is only calculated as the same object as long as the centroid of the current frame is inside of bounding box of the next frame

The processor increments the number of vehicle each time the vehicle crosses the ROI. It saves the increment value into the counter parameter. The counter value will be transmitted to the virtual server every five seconds through 4G/GSM modem that supports Internet connection. The value is the number of vehicle goes through the road for five seconds. Once the data is delivered then the counter parameter will be reset. The virtual server will log the arrival time whenever receives data from the node. Furthermore, the traffic analysis is composed from received data in the database.

III. Results and Discussions

In this section, we investigate the system performance of vehicle traffic analysis using background subtraction in IoT architecture for various of time observations. The system is constructed by hardware and software. The former consists of camera, processor, 4G/GSM modem, and virtual server. The camera in the node has specification as follows: resolution of 1.3 mega pixels, video capture of 960x720@30 fps, and AVI digital video format. The processor is Raspberry Pi 2 Type B, which has a chipset BCM2836, 900MHz quad core ARM cortex-A7, and 1GB RAM. We use a 4G/GSM modem that bundled with Internet connection service. The virtual server uses hosting domain at dstp.puskom.undip.ac.id. While the latter utilizes Linux Raspbian, OpenCV, Python, HTML, PHP, AJAX, Javascript, MySQL, and Apache webserver. The ROI parameter has value of $110 \leq cy \leq 190$. We observe the operation of the applied system, which is set up on a road in Diponegoro University, as shown in Fig. 2. The camera, as a node, captures the image of vehicles that go through the road. The node performs calculation number of the vehicle using GMM model automatically. The results then are defined as counted value by system. Furthermore, as comparison we count manually vehicles that go through on the road using tally counter, in order to see the performance of the system. Fig. 5 exposes the traffic of vehicles that counted from 10.00-11.00am for five days. The figure shows the values of counted manually are different from that of counted by the system. The solid bar represents the value of counted manually. The striped bar denotes the value that generated by the system. And the transparent bar informs the difference of the both counts. We obtain the average accuracy of the system with value 91.56%. The system cannot reach a perfect calculation of vehicles that through on the road. Throughout the observation, we found many causes behind of this phenomenon. For instance, the speed of the vehicle is greater than 60km per hour. The changing of the object frames cannot be anticipated by the camera, due to the low-quality camera. In addition, if two or more objects are close together, e.g., motorcycles, then the algorithm does not succeed to create two bounding boxes. This happens when the traffic is high, e.g. on the fifth day on Fig. 5.

Fig. 6 exhibits vehicle traffic on the observed road on sixth day from 09.00 to 15.00. The figure reveals that the counted traffic value by the system is different from the counted manually. However, the system provides the average accuracy performance with value of 95.64%. As long as the

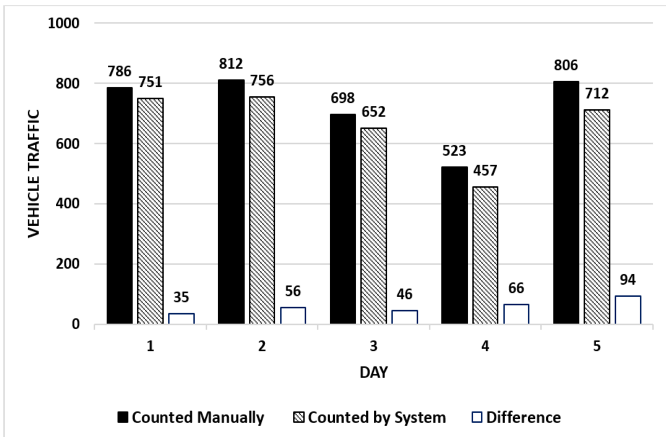

Fig. 5. Comparison of counted traffic by system with counted traffic manually from 10.00-11.00am for five days

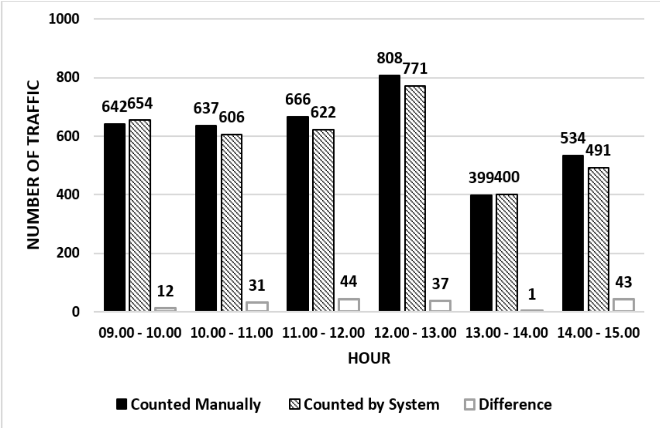

Fig. 6. Comparison of counted traffic by system with counted traffic manually from 09.00-15.00 on sixth day.

observation, we found the reasons behind this result. For instance, at 09.00-10.00 am, we watched many students walk through the observed road. We did not count manually the people who cross in front of the camera, but the system did it.

IV. Conclusion

In this paper, we show the implementation of vehicle traffic analysis using well known background subtraction method, i.e., Gaussian Mixture Model method, in IoT architecture. We deploy the system to accommodate the purpose of the research. The applied system consists of three parts, which are the node, Internet cloud, and virtual server part. The average accuracy performance of the applied system exceeds 95.64%.

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