Design of Smart Open Parking Using Background Subtraction in the IoT Architecture

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***Abstract*—The Internet of Things (IoT) has evolved and penetrated to our live since the end of the last century. Nowadays, many devices for any purpose are connected through the Internet. A smart node, in smart campus environment, can detect an availability of an open parking space by calculating the vehicle that enters or outs from the space. The node applies a background subtraction method, which is deployed in IoT architecture. The Gaussian Mixture Model (GMM) is utilized to determine foreground and background image, in order to detect a moving object at an open area. Furthermore, the node can discriminate the type of vehicle with a high accuracy. The result of vehicle type classification is transmitted by the node through the Internet, and then it is saved to the data server. We observe the designed system succeeds delivering a good performance in terms of average accuracy determining car and motorcycle are 93.47% and 91.73%, respectively.**

Keywords— Internet of Things; background subtraction; Gaussian Mixture Model; smart campus.

I. INTRODUCTION

Ashton [1] coined a term Internet of Things (IoT) architecture since two decades ago. The IoT uses the Internet as a communication medium to collect and exchange data from objects, such as sensor devices. The IoT presents no boundary connectivity, which supports the paradigm of anywhere and anytime connection [2]. Presently, it continually evolves and penetrates to our life, such as education, transportation, healthcare, utilities [3], traffic, disaster [4], etc. Many devices around us are connected in the IoT architecture. They perform machine-to-machine (M2M) connection, which sense, collect, and distribute information using the Internet with minimum or without human intervention [5]. The collected data are saved to a data or cloud server, which then can be accessed by the party who needs the information.

In a smart campus, the university management provides many features that deliver information of campus situations, such as an availability of open parking space, through IoT architecture. So that the people can ascertain a space to park his car or motorcycle at the university. At any place, which prepares parking area, the management installs a remote device. The device capture and autonomously distinguishes either a car or a motorcycle that enters or goes out open parking space. Furthermore, it calculates the number of vehicles that use the parking area.

In order to detecting and distinguishing the moving objects, some authors proposed algorithm for these purposes, such as in [6-11]. Rout and Puhan, in [6], proposed an algorithm to determine the object and background regions. They utilized a correlation function in order to compute the inter-plane correlation between three consecutive R, G and B planes. Then they performed correlation matrix process to build a segmented image that estimates an object, using the high resource computer. Godbehere, et.al., in [7], proposed an algorithm of the human visitor tracking with various lighting situations. The authors united Bayesian segmentation, statistical background images estimation, and multi-target tracking. They compared their' algorithm to three blob algorithms. Ramalingam and Varsani, in [8], proposed vehicle sensing algorithm utilizing a foreground detection and blob analysis (FDBA), and applied it with matlab in built vision object. The proposed algorithm reduces the foreground with the background. It defines a blob as pixels that are close to each other and shifting in the foreground. Xu, in [9], evaluated many foreground detection algorithms in order to discriminate either foreground moving or static objects from the background; i.e. kernel density estimator (KDE), Code book, Consensus-based method (SACON), Gaussian mixture model (GMM), and Adaptive Gaussian mixture model (AGMM). Based on the evaluation results, the authors declared the GMM-based brings the promising results. Jain, et.al., implemented ViBe (Visual Background Extractor), which is a universal sample-based background subtraction algorithm, for detecting the human presence [10]. The author used the algorithm to drive a surveillance system. In addition, Sofwan, et.al., in [11], implemented vehicle traffic analysis system using a background subtraction model in an IoT architecture. The implemented system calculates a number of vehicles that

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goes through a road. Furthermore, referring to the desire of management to present a smart campus, which provides smart open parking system that informs parking space availability, and the above literature, then we design a smart open parking system that using the background subtraction model in IoT architecture.

The paper has contributions in two manners, which are scientific and engineering manners. The former, it provides a background subtraction method for moving detection and discriminating vehicle with the GMM model. It also explores the various learning rates of the model to determine a moving object. The latter, it exposes a system description with hardware and software view in IoT architecture.

The remainder of this paper is organized as follows. In the next section, we describe the system architecture of the designed system in detail. The hardware and software designs are clearly exposed. In Section III, we exhibit the designed system results and discussions. In Section IV, we provide the conclusions of the paper and future work.

II. SYSTEM ARCHITECTURE

In this section, we expose the design of a smart open parking system in detail in IoT architecture. The parking system is composed of three main parts, which are the remote node, the Internet connection, and data server, as shown in Fig. 1.

The first part is the remote node, which consists of a camera, microcontroller, solar cell power supply, and 4G/GSM modem. Camera as the input device that captures vehicle enters parking area. The Raspberry Pi microcontroller acts as the thinker that applies background subtraction in detecting the vehicle and also distinguishing the object either car or motorcycle. The node is also equipped with solar cell power supply, which supports green technology. In addition, the 4G/GSM modem is utilized to transmit data from the raspberry. The modem sends data through Internet connection, which is served by Internet Service Provider. Internet cloud, as the second part, has a function to connect the remote node and the data server. The Internet is also utilized by users to access the node and the data server. The last part is the data server that provides database and web server functions. The data server is used to save data from the remote node. From the server part then we obtain the information of available parking space around the remote node.

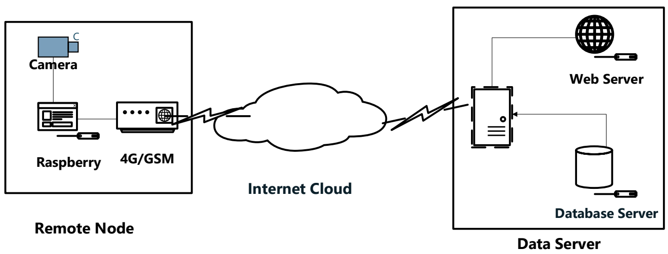

Fig. 1. The designed system in IoT architecture

A. *The Background Subtraction Method*

The moving vehicle is identified by applying the background subtraction method, which is searching for the difference pixels of foreground and background images. The method considers that the difference pixels' value of both images is caused by object movement. The unchanged pixels are assumed as background, while the changed pixels are considered as the moving object. The algorithm of background subtraction with gaussian mixture model for the designed system follows the implemented method in [11].

B. *Calculation of Vehicle at Parking Space*

In order to calculate the vehicle that enters the parking space, a camera is used as the input device that capture video of vehicle traffic at parking space. The camera is installed at a good position for viewing the car or motorcycle goes into/out the parking space. The illustration of camera installation is shown in Fig. 2. Furthermore, the camera view of the open parking space, is displayed in Fig. 3. The gate of parking space is located at northwest. And the parking spaces are at south and east. The camera captures video frames and learns to determine the vehicle. Then the captured frames are delivered to the Raspberry pi, as the image processor. Then, the processor calculates of the vehicles that enter the parking space. The processor applies three vertical lines, as the region of interest (ROI). The ROI is used to detect whether a vehicle goes through the area or not. The processor covers the vehicle with a bounding box, as shown in Fig. 4. The box is utilized to ensure an object that crosses the ROI will not be calculated twice or more. The processor also defines the centroid of the box. 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. If the centroid goes into the ROI, then the vehicle will be counted either enter or out of the open parking space. It depends on the direction of the vehicle. The flowchart of vehicle calculation is shown in Fig. 5.

The processor increments the number of the vehicle each time the vehicle crosses the ROI, whether from the right to the left side and vice versa. It saves the calculation value into the counter parameter. The calculation value then will be sent to the server with a period of five seconds through the 4G/GSM modem. The data server will stamp the arrival time whenever it receives data from the remote node.

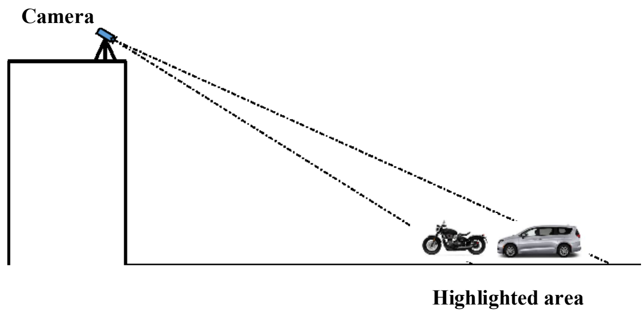

Fig. 2. Illustration of placing the camera that capture the vehicle

Fig. 3. The camera view to the open parking space.

Fig. 4. Three ROI which are applied in the designed system

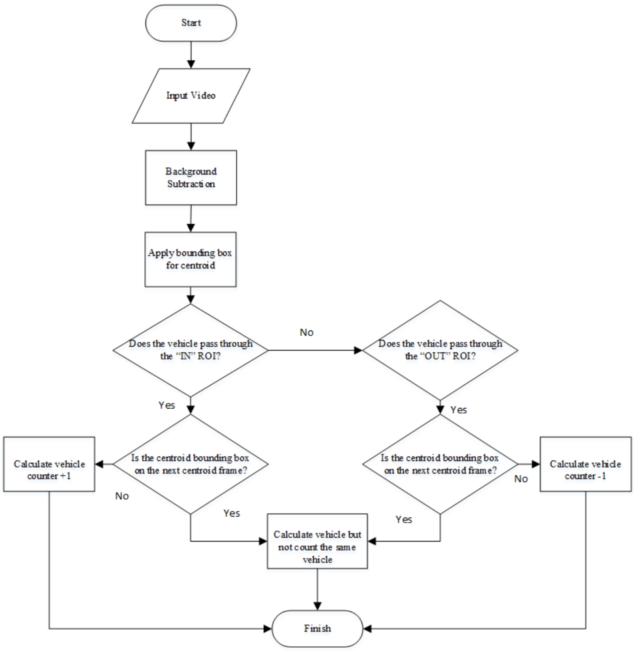

Fig. 5. Flowchart of vehicle calculation at parking space

Furthermore, in order to discriminate the vehicle either a car or a motorcycle, the processor measures the size of vehicle bounding box. It applies a rule, which measures the height and width of the vehicle. The bounding box of the motorcycle has smaller size than that of the car. Based on this rule, the processor can determine the type of vehicle.

III. Results and Discussions

In this section, we investigate the learning rate and performance of the designed system using background subtraction in IoT architecture. The designed system consists of hardware and software. The hardware is constructed by a camera, processor module, modem, and data server. The specifications of the camera are as follows: video capture of 960x720@30 frames per seconds, 1.3 mega pixels resolution, and AVI digital video format. The processor module is a Raspberry Pi 3 Type B, which has a chipset BCM2837, 1.2 GHz quad core ARM cortex-A53, RAM of 1GB, and MicroSD of 16GB. The modem is a 4G/GSM modem that supports Internet connection service. The data server is hosted at dstp.puskom.undip.ac.id. Furthermore, the designed system applies Linux Raspbian NOOBS, Python, OpenCV for Raspberry. While the HTML, PHP, AJAX, Javascript, MySQL database, and Apache are applied in the data server. The ROI parameter has value of $220 \leq cx \leq 280$ and $280 \leq cy \leq 340$. We analyze the operation of the designed system, which is installed at an open parking space of Diponegoro University, as shown in Fig. 3. The camera, as a node, grabs the cars or motorcycles that go in and out the parking space. Then the processor computes the number of the vehicle applying the GMM model. We analyze the learning rate of the model applied in the system. The learning rate of movement detection is shown in Fig. 6. The learning rate is performed by a formula as follows.

$$learning\ rate = \frac{1}{\text{frame history}} \tag{1}$$

With frame history value of 100, 200, 300, and 400, it is obtained the learning rate at value of 0.01, 0.005, 0.0033, and 0.0025 respectively.

From the Fig. 6, it can be seen each of learning rate has different time in determining object movement. With learning rate of 0.01, the designed system has determined the foreground image, which is considered as moving object, with the least number of frames.

Furthermore, the processor applies an operation to classify the type of vehicle. The discrimination results, either car or motorcycle, then are defined as counted values by the system. As comparison, we perform counting vehicles manually, that go through on the road using tally counter, in order to see the system performance. Fig. 7 shows the number of vehicles, cars and motorcycles, that are counted from 08.00-14.00 for five days. The system succeeds in discriminating whether the car or the motorcycle. The figure reveals the number of car and motorcycle counted by the system are different from that of counted manually. The black solid bar, the vertical black line bar, the crossed black line bar, the bold blue slash bar, the blue

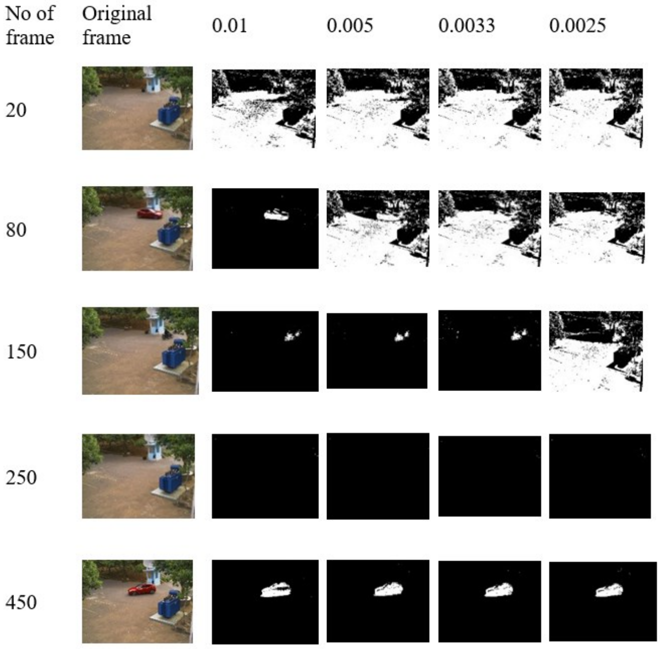

Fig. 6. Comparison of moving detection with various learning rate.

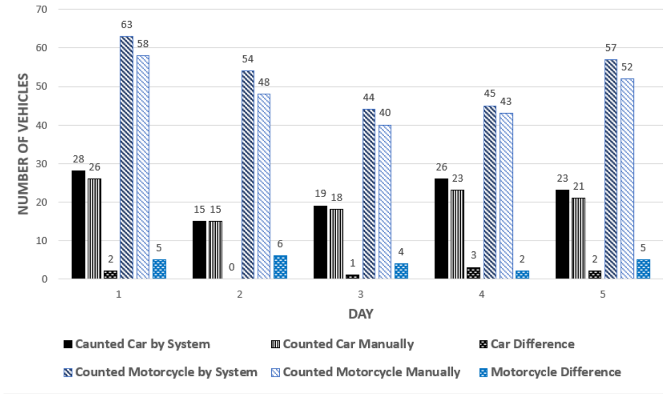

Fig. 7. Comparison of counted vehicles by system with counted vehicles manually from 08.00-14.00 for five days

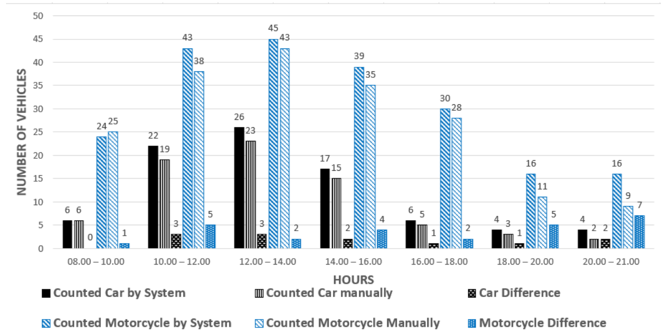

Fig. 8. Comparison of counted vehicle by system with counted vehicle manually from 08.00-14.00.

slash bar, and blue dot bar represent the counted car by system, the counted car manually, the car difference, the counted motorcycle by system, the counted motorcycle manually, and the motorcycle difference, respectively. From the figure, we obtain the average accuracies of the designed system for detecting car and motorcycle are 93.47% and 91.73%, severally. The total average accuracy with value of 92.60%. The designed system cannot provide a perfect calculation of vehicles that go to parking space, due to some causes. For instance, an overlap of bounding boxes of two or more motorcycles can be detected as one object. This because the size of overlapped bounding box is still less than a defined bounding box size. Moreover, quality of the camera also contributes in making difference of calculation. The utilized camera, which is a low quality, sometimes fails to provide a lagging video when a vehicle run with high speed.

Fig. 8 exhibits traffic of vehicles goes through the parking space for one day, from 08.00 to 21.00. The figure shows that the counted value by the system is different from that by manually. From the figure, implicitly we obtain the highest accuracies for the car and motorcycle detection is at 08-10 am, with value of 100% and 96%. The average accuracy of detection during the one-day observation is 83.40%. This low-value accuracy is influenced by a low accuracy during evening (18.00-21.00), although the accuracy during daylight is 91.76%. The system succeeds to provide a good calculation accuracy when it is sufficient light during the daytime, conversely it fails appears a high accuracy when there is insufficient lighting at the open parking space.

IV. Conclusion

In this paper, we design the smart open parking system, which applies a well-known background subtraction method, Gaussian Mixture Model, in IoT architecture. We deploy the system to accommodate the purpose of the research. The applied system consists of three parts, which are the remote node, Internet cloud, and data server part. The designed system succeeds to discriminate the type of vehicle, whether car or motorcycle, with accuracy values of 93.47% and 91.73%, respectively. The average accuracy performance of the applied system exceeds 92.60%.

Acknowledgment

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