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MOVING OBJECT ACTIVATOR IN BACKGROUND SUBTRACTION ALGORITHM FOR AUTOMATIC PASSENGER COUNTER SYSTEM IN PUBLIC TRANSPORTATION

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ABSTRACT
Buses are the most used transportation by people in Indonesia when traveling between cities. However, to improve passenger comfort, a tool is required to determine the number of passengers on the bus. This research presents an automated system to count the number of passengers based on a background subtraction algorithm and moving object activator. This research aims to provide the number of passengers based on video images taken from the entranceway. The system is built with a camera, Raspberry Pi, and LCD. The APC system starts the counting process by removing the video background image from the captured object image. The entry and exit direction of the object is determined using the concept of moving object activator. The experiments were applied in several scenarios to determine the robustness of the system. The best APC performance was achieved when the system is positioned perpendicularly above the entranceway at a height of 230 cm and a light intensity of 800-1000 lux. Meanwhile, the moving object activator is effective in supporting the system's performance to determine the passenger's direction. In this scenario, the results stated that the accuracy of APC system performance reached 93.8%.
Keywords: *Automatic Passenger Counter, Bus, Public Transportation, Background Subtraction Algorithm, Activator Moving Object*

1. Introduction

Transportation is a sector related to various aspects, including economic, industrial, social, political, and environmental aspects. In the economic aspect, transportation plays a significant role in the distribution process of goods and services. Hence, the circulation of the distribution process can run quickly and optimally. Likewise, industrial aspects cannot be separated from the role of transportation in distributing industrial products. In Addition, transportation also helps people in terms of mobility, moving from one place to another in a short time.

One of the transportations often used by the Indonesian people is the bus. It provides travel facilities within and outside the city. Tourism sectors also use it to take tourists from one tourist spot location to another. Several facilities were also implemented to increase the passenger's comfort. Due to the variety of types of public transportation makes, private bus companies need to implement several strategies to improve the bus passengers' comfort. This is conducted to increase public interest in choosing buses as a transportation mode. One approach to improve bus passengers' comfort is to enhance system services and human resource management (Cahyadi & Efranto, 2012).

Meanwhile, the parameter used to increase passenger comfort is the number of passengers who choose buses as the transportation to move from one place to another. The decline in service performance can decrease the number of passengers (Prof. Dr. Ir. Mudjiastuti Handajani et al., 2020). The convenience factors used as a benchmark in passengers' point of view are bus regulations, the suitability of the number of passengers with seats, and safety when travelling (Hanifa et al., 2022). As for the company side, the number of passengers is a representative component of the services provided, thus affecting the business processes for efficient operational requirements (Mukti et al., 2021). The greater the number of passengers using a company's bus fleet, it can be concluded that passengers are comfortable utilizing the fleet.

Therefore, the passenger counting system becomes crucial as the system requirement for transportation operators and passengers (Yahiaoui et al., 2008). It is because the implementation of passenger counting can also affect several systems. It can be related to the accuracy of the number of passengers in each recorded departure, preventing the mismatches between the number of passengers seats, improving financial management from corruption problems (Sojol et al., 2018) and also fixing the security factor in buses.

Meanwhile, rapid technological developments in embedded systems and affordable sensing technology support the creation of a low-budget passenger counting system. The use of classic RGB cameras in collaboration with smart deep sensors can be embedded into the Automatic passenger counting system (Burbano et al., 2016), Then the counting data is sent to the server using the Internet of Things Technology (IoT). Therefore, the bus company can control the suitability of the monitoring results with reports on the number of passengers in the field.

Several Automatic Passengers Counter (APC) research have been carried out, including the APC system to count the train passengers using wavelet technology (De Potter et al., 2012). A simple APC system is also provided using electronic magnetic coupling stored in the passenger seat, thus relying on the passenger's weight (Olivo et al., 2020), Then, the APC application was developed and determined based on mobile device activity signals designed to distinguish between passenger and non-passenger MAC address signals (Sterner et al., 2012).

However, all of these applications still have some shortcomings, especially in accordance with the characteristics of bus passengers and the condition of bus companies in Indonesia. Based on these parameters, this research aims to create an automatic passenger counter system by utilizing camera technology that embeds smart deep sensors at the bus entrance according to the characteristics of buses in Indonesia. The camera is located at the entrance adopts the application rules in several countries that have implemented it first. Thus, this rule will contribute to a change in passenger behavior to be well-ordered and improve convenience. The data captured by the camera is then processed by background subtraction algorithm with Raspberry Pi into APC counter data and sent to the server by utilizing IoT technology. For this reason, the bus can have a record and can remotely monitor the bus in operation.

This research contributes to simplifying and lightening the removal process between the background and the counter object that is calculated directly and in a real-time. While the practical contribution is in terms of changing the behavior of the ecosystem of passenger boarding and disembarking procedures on bus, helping companies to able to monitor bus operational activities, and increasing passenger safety and comfort.

The remaining paper is organized as follows. Section two presents the methods, review, and state-of-the-art of APC system. Section three describes the designed system. Section four presents the scenarios and experimental results, discussion also presented in this section. Finally, Section 5 provides the conclusion and future works.

2. Literature Review

A literature review of the state-of-the-art APC can be seen in Fig. 1. The development of an APC sensing system with various active and passive sensors embedded with Raspberry Pi or Arduino, then collaborated with various methods or algorithms. For the interaction system, APC is integrated using IoT with various devices such as local displays, monitors, mobile phones or computer devices. All these passenger counters aim to detect the passengers, count the number of passengers, increase the passenger's comfort, eliminate corruption or as data to manage the company HRD and improve services.

Some studies use different methods in conducting the passenger counting process. In Indonesia, there was a study that aimed to improve the quality of transportation services from the Transjakarta public sector to develop a passenger counting system (Kadafi & Setiadi, 2019). The system also implements a bus location monitoring system using a web application. Meanwhile, the APC counting system uses infrared obstacle detection sensor (Olivo et al., 2020). Various methods involving the use of various sensors have also been implemented (Sojol et al., 2018). They used pressure sensors on the passenger seat or installed them at the passenger entrances (Moser et al., 2019). Other sensors installed on passenger door can be infrared (Sundaramoorthy et al., 2018) or ultrasonic light sensors (Baltes & Rey, 1999)(Afriani et al., 2022). However, the sensors used above have shortcomings. The system cannot distinguish objects that pass through it whether they are persons or objects.

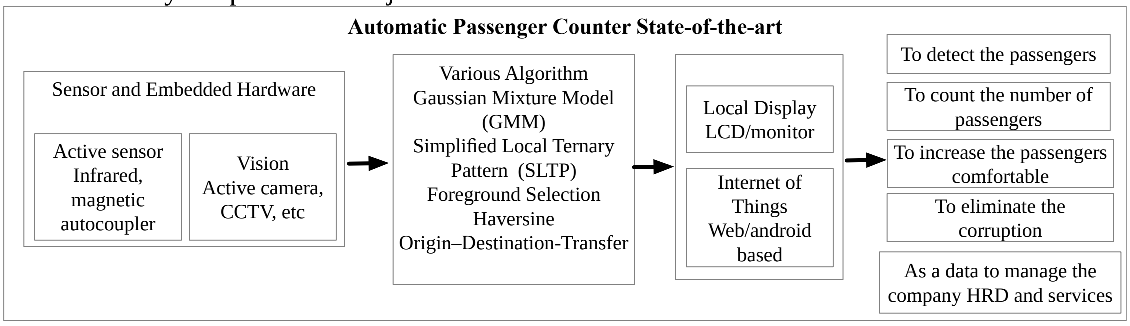

Fig. 1. APC's state-of-the-art research

Other research for APC systems that use multiple sensors to count passengers. The fusion of Bluetooth HC-05 sensors, pressure pads, and potentiometer data and can also count the number of passengers at a low-cost (Sojol et al., 2018) (Murdan et al., 2020). There is also APC research that uses RFID sensors as a ticketing process on school buses. Data collection of students who entered and exited the bus was conducted using RFID. In addition, the research also added GPS which is used for the bus tracking systems. GPS coordinates are sent through IoT every time student enter and exit the bus. Data sent through IoT can be monitored by parents (Pradana et al., 2020).

Along with technological developments, contactless passenger counting sensors were introduced and developed using computer vision and image processing. The involvement of cameras as sensors (De Potter et al., 2012)(Khan et al., 2020)(Khoudour, 2010), and radar technology became a new breakthrough to create a passenger count detection applications (Greneker, 2001). The passenger counter method with image processing is a method that allows for further image processing with various algorithms. Therefore, it can produce more varied information to support transportation management information systems. In terms of accuracy, this method also has high accuracy. Hence, it becomes a consideration to use image processing and deep learning methods in passenger counter applications (Benezeth et al., 2014). The use of 3D sensing cameras has been introduced and can also be used to detect the number of passengers (Burbano et al., 2016) (Moser et al., 2019). Another application is a passenger's counter method based on head detection using a local binary pattern (LBP). Unfortunately, this system must be placed perpendicular straight to the head, (Li et al., 2014)(Nakatani et al., 2012) as well as a dense and close stereovision-based counting application (Yahiaoui et al., 2008).

Another study developed a passenger counting system using the haversine method to calculate the number of passengers on a bus. This research provides output in the form of information on the number of passengers using estimated travel time information (Aprilinda et al., 2018). The development of network technology and IoT also detects bus passenger counters using WIFI passenger mobile phone devices. One of the studies using this method is iABACUS. This system performs passenger calculations based on WIFI. This system aims to observe and analyze people's mobility by tracking passengers through their journey using bus transportation. iABACUS detects WIFI from mobile phone, tablets and others (Nitti et al., 2020). Unfortunately, this research also has a weakness where the number of passengers may not be appropriate because there are passengers who carry more than one mobile device.

Meanwhile, object detection technology is also expanding. Many algorithms have been developed to detect a moving object. One of them is the Background Subtraction Algorithm. This algorithm is commonly used because of its simplicity and the ability to recognize moving objects (Hossein et al., 2022). This algorithm is then mostly used for people tracking and counting applications (Perng et al., 2016) or vehicles (Adi et al., 2018). Furthermore, these algorithms are integrated with other algorithms (Gomaa et al., 2019)or methods (Mahamad et al., 2020) to become a smart applicative system.

According to APC's state-of-the-art, there is a potential improvement for this research to apply the automatic passenger counter that are low-cost and easy to monitor. This research proposes a passenger counting system that adopts a high-resolution camera as a sensor placed at the entrance or exit way. This research fusion and utilizes image processing technology using the Background Subtraction Algorithm and Moving Object Algorithm. Thus, it is expected that the system can determine the passenger's direction and count properly.

3. Research Methods

This research was developed based on the research and development framework, with the output being a prototype that will be implemented on the system. This research will be described starting from a literature review, prototype design, determining test scenarios, and conducting tests based on predetermined scenarios. Finally, analyze the result and draw conclusions.

The literature review stage is the step where Background Subtraction Algorithm (BSA) material is reviewed and studied by searching for papers and journals as well as similar work regarding applications that implement the BSA algorithm. Next, study the material on how the system can recognize and determine the passengers' direction using Moving Object Activators (MOA) which are commonly used to detect pedestrians.

Furthermore, conduct an assessment in determining the components to be used in the system, and start designing the proposed system to build a passenger counter application. After designing the system, BSA and MOA are applied to the system. Next, experiments are conducting based on several scenarios to test the BSA and MOA performance in the system. Finally, the testing data is analyzed in the form of tables and graphs. Then, it is ready to be analyzed and drawn the conclusion.

3.1 Automatic Passenger Counter Design

The APC system designed hardware is shown in Fig. 2. The APC design consists of switch relay that is installed at the bus entrance, a web camera Logitech C615 is installed on the door ceiling, a Raspberry Pi 4, and a display.

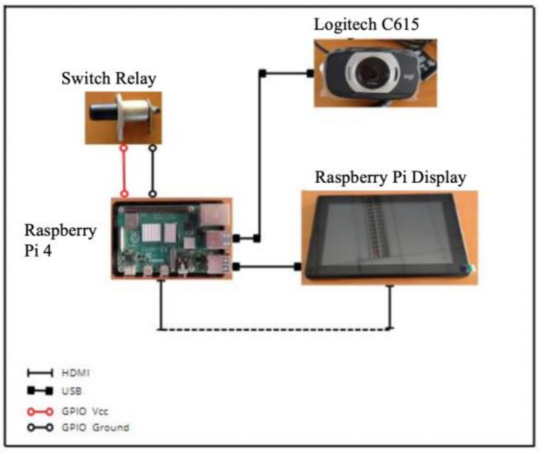

Fig. 2. APC's hardware

The APC module is a module that calculates the number of passengers. The number of passengers is calculated by subtracting the incoming (step-in) and outgoing (step-out) passengers. The web camera on the bus door is embedded with image processing using BSA and MOA. The web camera is connected to a Raspberry Pi as a processor to process the counting data from the web camera. Meanwhile, the software used is OpenCV which provides a program for image processing, Raspbian OS, and Thonny Phyton IDE.

3.2 Background Subtraction Algorithm (BSA)

Background subtraction is a process of detecting human objects by comparing images that have objects with background images that do not have objects. Images that have objects and images that do not have objects are further reduced to get a complete object without background (Kaloh et al., 2018). To find out whether there is motion or not, the motion detection system on the .mp4 extension video file will compare consecutive frames of image frames (Barnich & Droogenbroeck, 2010). In addition, on the camera screen frame, two-virtual line activator parameters are defined to detect the object's movement (in-out). In this case, human detected in the frame will be likened to moving object. The results of this comparison will be processed again to get the number of recorded humans.

As seen in Fig. 3, the video is extracted into frames in the BSA to be processed at the next stage. Then, a background model corresponding to the scene must be prepared to be compared with the extracted frames. Background modelling is the stage of determining the background to be used as the background location of the video. The background modeling must not contain human objects, be consistent, static (not moving), and be sensitive to moving objects (Garcia-Garcia et al., 2020). The BSA is implemented on the resized frame after frame extraction. It is aims to remove noise on frames that are too large in the vicinity.

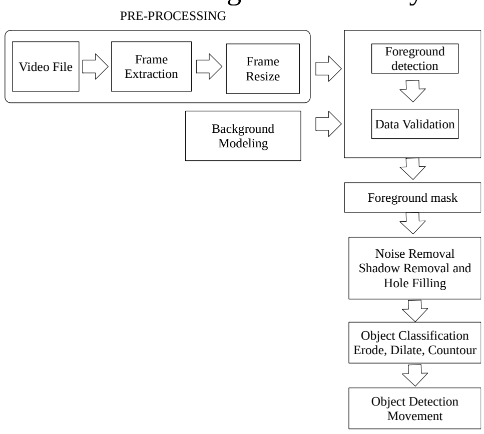

Fig. 3. Background subtraction algorithm

The next step is the extraction and foreground detection from the background file. At this stage, there is a specified threshold value (Otsu et al., 1979). This threshold value is determined to tolerate errors in digital images that may occur due to noise. The foreground used as comparison is a moving object.

$$R(r,c) = I(r,c) - B\,(r,c)$$

According to formulation (1), *R(r,c)* is defined as the result image in coordinates *(r,c)*. *I(r,c)* is denoted as current image in coordinates (r,c), while *B(r,c)* is the background model image in coordinates *(r, c)*. *(r, c)* are determined as row and column. *R*-value is compared with a predefined threshold value. If it is greater than the threshold value, then the pixels in *I(r,c)* can be considered different from the pixel in *B(r,c)*. The object detection step is the stage to detect and find the objects' movement in each frame (Garcia-Garcia et al., 2020)

After this stage, the resulting image still contains several holes, therefore noise removal and hole patching are required. During this stage, the image is denoised and patched by masking and foreground detection, as shown in Fig. 4(a). Therefore, the image becomes smoother. Then, the objects are classified based on erosion as seen in Fig. 4(b), dilatation as seen in Fig.4(c), and contour processes as shown in Fig. 4(d). This stage serves to distinguish human objects from other objects (Yao et al., 2017). At this stage, object selection is conducted by looking at the size of the object. The size is obtained from the boundary detection of each detected object. It aims to detect one human object and several adjacent objects more accurately. Therefore, the object detection motion is determined, and the virtual lines of the two activators appear on the screen display.

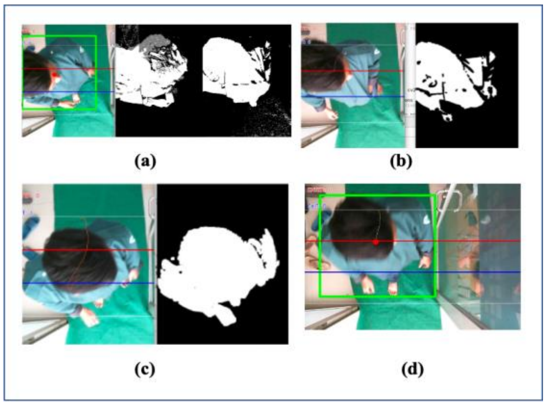

Fig. 4. Background subtraction process

3.3 Moving Object Activator (MOA)

Moving object activator is proposed to determine the passenger direction (Rahman et al., 2020), whether to enter or exit the bus. This MOA is embedded with the BSA algorithm and implemented with a web camera. The implementation sequence of the MOA algorithm can be seen in Fig. 5. First, the frame is set at 480x640 pixels, then create two virtual lines by setting the threshold distance between the virtual line's activator at 14500 (the width of the human head circle diameter) and place them in the middle of the frame. Finally, set the MOA rules.

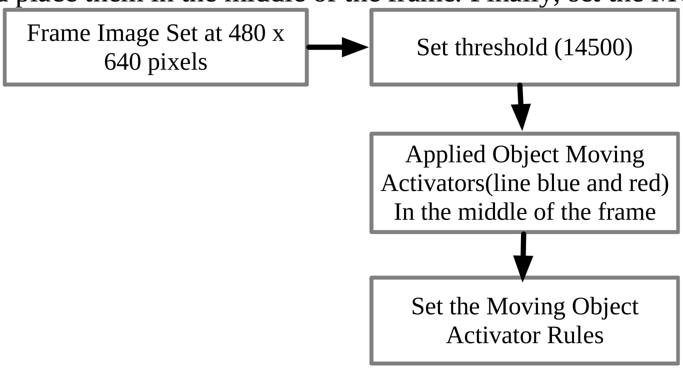

Fig. 5. MOA algorithm

The MOA rules are customized with the passenger counter variables. These variables are defined in formula (2) as follow. *pass_in* is a variable for counting incoming passengers, while *pass_out* is a variable for outgoing passengers. Meanwhile, *APC_count* is defined as the variable for the number of passengers on the bus.

$$Pass_{in} = Pass_{in} + 1$$

$$Pass_{out} = Pass_{out} + 1$$

$$APC_{count} = Pass_{in} - Pass_{out}$$

After determining the formula for counting passengers, the next step is to determine the MOA rules. As seen in Fig. 6, there are several MOA rules. Fig. 6 (a) is a situation where passengers are about to enter the bus. Red and blue virtual lines have been implemented to detect passing passengers. The MOA variables are set at zero. Furthermore, Figure 6 (b) is the situation when the passenger object is detected by the system. The activator variables are set at 0 (zero). When the passenger crosses the blue line from the entry direction, the MOA variable becomes 1 (one). Now, when the activator variable is 1 (one) and the passenger object crosses the red line from the entry direction, then the *Pass_in* variable increases by 1 (one) and the MOA variable returns to 0 (zero). This rule locks the *Pass_in* variable. Therefore, the red line will reflect back the MOA variable to its default position.

The MOA rules for exiting the bus, can be seen in Fig. 6 (c). The MOA variable is in default state (0). When the passenger object will exit the bus and is detected by the system, the MOA variable becomes 2 (two). When MOA equals 2 (two) and the passenger object crosses the blue line towards the exit, then *Pass_Out* is incremented by 1 (one) and the MOA variable returns to 0 (zero).

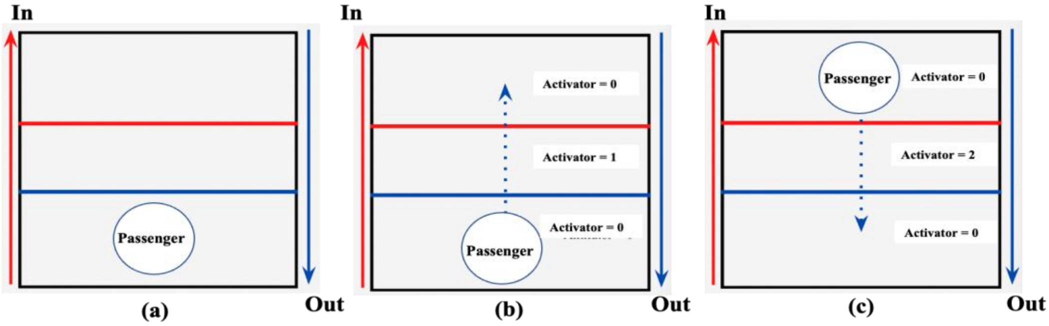

Fig. 6. MOA mapping rules

In brief, the mapping of MOA rules can be seen in table 1.

Table 1 - MOA rules

Direction	Blue Line	Red Line	MOA Sequences	Remarks
In	cross	not yet	T0=0 T1=1	not cross
In	cross	cross	T0=0 T1=1 T2=0	$Pass_{in}$ increased by 1
Out	not yet	cross	T0=0 T1=1	not cross
Out	cross	cross	T0=0 T1=2 T2=0	$Pass_{Out}$ increased by 1

3.4 Flowchart System

After integrating the BSA and MOA rules, the next stage is to determine the flowchart of the proposed system. The description of the proposed system can be seen in Fig. 7. The system starts with a system trigger that activates the system from the switch installed on the bus door. If the bus door is not open, the text file on the system will still send information stating that the door is still closed. When the door opens, the switch will activate the cameras which has been embedded by BSA and MOA and the system will prepare to count the number of passengers who will board and exit. In addition, the system will send a text file messages to the system in the form of timestamp stating that the bus door has open. Then, passengers start getting on or off the bus. If the blue and red MOA counter do not return back to zero, the *pass_in* and *pass_out* parameters will not increment.

Meanwhile, if there are passenger getting on or off the bus, and the MOA counter bounces from zero to one (in) or two (out) then return to zero again (bouncing), the *pass_in* and *pass_out* parameters in formula (2) or (3) will increase according to the number of passengers entering or exiting. The system will keep repeating until the door is closed again and the switch is triggered to send the text file information regarding the time when the bus door was closed. Next, the system will calculate the number of the passengers in the bus using formula (4). The system will the return to the relay to check the status again.

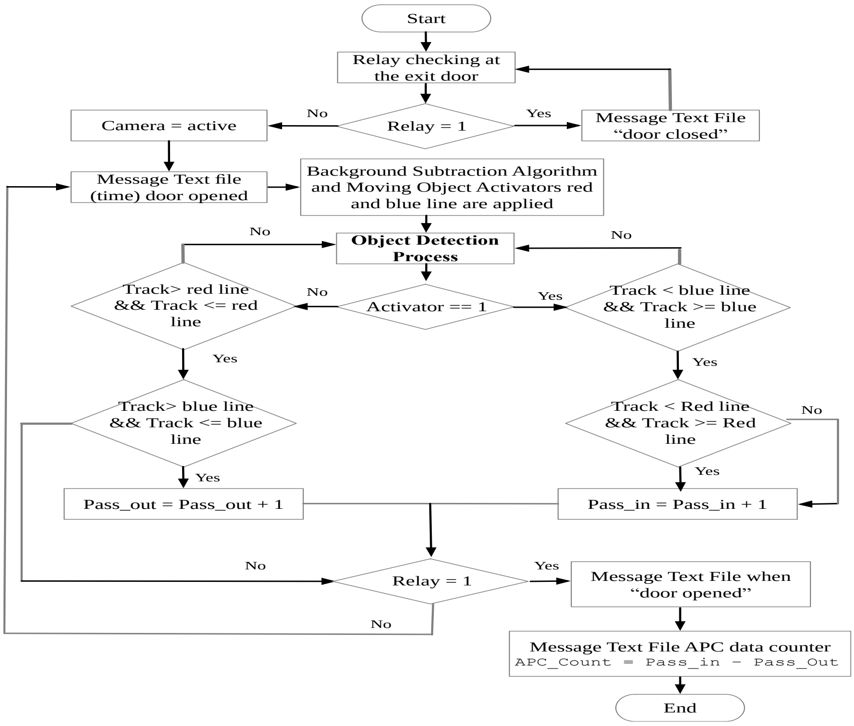

Fig. 7. APC's system flowchart

4. Results and Discussions

The experiments are carried out by implementing the proposed system on actual environmental conditions. It can be seen in Fig. 8 that the system is implemented directly on the bus and travels for several stopping points. Fig. 8 shows the switch location on the bus door, and the camera is placed directly above the door. System testing is carried out with several scenarios to test and measure the robustness and performance of the APC system.

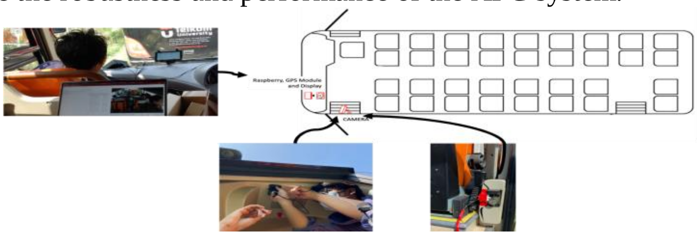

Fig. 8. APC's implementation

The performance's system is calculated using detection rate, recall and accuracy through the following three formulas, where TP is true positive indicating the number of passengers detected correctly, FP is false positive indicating the number of passengers detected incorrectly, FN is false negative indicating the number of passengers not detected, and TN is true negative indicating the number of passengers due to other factors were not detected as a passenger. These parameters are formulated to calculate detection rate, recall, and accuracy (Godil et al., 2014).

$$Detection\ Rate = \frac{TP}{TP+FP}$$

$$Recall = \frac{TP}{TP+FN}$$

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN}$$

4.1 APC Performance Testing based on Height position.

The first test is a camera performance experiment that has been integrated with BSA and MOA. This test aims to test algorithm's performance in determining the objects entering the bus based on camera placement to get the best position with minimal error in determining and recognizing objects entering the bus.

Initially, the camera was placed right above the bus entranceway with a certain slope. This test is conducted to get the most appropriate position for the camera to get the best capture and minimize errors. As seen in Fig. 9, the camera was placed at an inclination of 180 cm, 200 cm, and 230 cm at 0, 10, and 20 degrees.

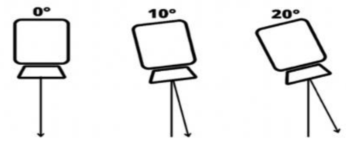

Fig. 9. Camera positioning based on angle.

The test scenario can be seen in Fig. 10. The passengers move and board the bus to count the number of passengers which is boarding, and then perform the test to count the number of passengers getting off the bus. Fig. 10(a) was taken during the APC test at 230 cm height, Fig 10(b) was taken during the APC test at 200 cm height, and Figure 10(c) was taken during the APC test at 180 cm height.

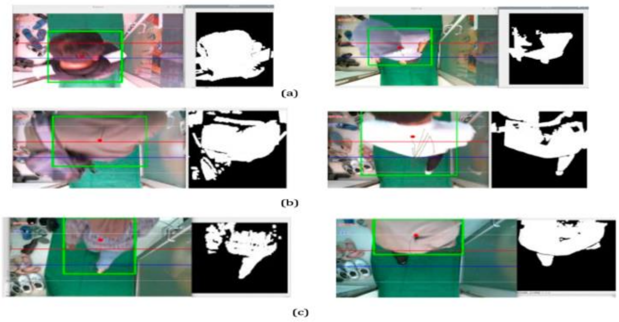

Fig. 10. APC scenario testing (a) 230 heights, (b) 200 heights, (c) 180 heights.

The result can be seen in the Table 2. It shows that the test was carried out on 50 passengers with different heights ranging from 160 cm to 180 cm in different angles.

Table 2 - Camera's position result testing.

Heights (cm)	Angle (degrees)	Detection rate (%)	Recall (%)	Accuracy (%)
230	0^0	100	100	100
	10^0	100	100	100
	20^0	92	100	92
200	0^0	80	100	80
	10^0	94	100	94
	20^0	96	96	92.3
180	0^0	72	94.74	69.2
	10^0	56	97.5	51.9
	20^0	72	94.74	69.2

The Table shows that placing the camera at a 230 cm height with an angle of 0 degrees and 10 degrees gets the best detection results by achieving 100 % of detected samples. This is because the relatively high position of the camera and the truncation of the BSA makes passengers with 180 cm height are detectable by the camera.

4.2 APC Performance Testing based on Light Intensity

The second experiment is testing the performance system depending on the light intensity. This experiment was conducted to test system performance based on time period with measured lighting on the aisle located in front of the bus door. Tests were carried out in three light intensity ranges in Lux units: in the range of 100-400 lux (5pm-8 pm), 400-700 lux (7-10 am), and above 700 lux (10am-4pm). The test was carried out on 40 passengers with different heights varying from 160 cm to 180 cm in different angle.

The test result can be seen in Table 3.

Table 3 - APC's performance result testing.

Luxmeter Range	Detection Rate (%)	Recall (%)	Accuracy (%)
100 – 400	72.22	86.67	65
400 – 700	89.47	94.44	85
700 – 1000	95	100	95

Meanwhile, Fig.11.a shows the experimental results indicating abnormal detection causing miscalculation in APC system against light intensity. This is due to the presence of shadows that cause the calculation to increment two times (double). Whereas in Fig.11.b, the APC system does not show the number of increments because the system unable to capture the passengers entering the bus.

(a) (b)

Fig. 11. Miscalculation in APC performance result testing: (a) two times counting, (b) no capture

4.3 APC Performance Testing based on Special Events

The third test was to test the performance of APC on some special events based on passengers' behavior. This experiment was conducted to test APC performance on two virtual lanes on the BSA in terms of counting the number of passengers. This test was carried out for several special events as shown in Figures 12(a)-12(h). This experiment was taken by placing the camera based on the best accuracy results that have been carried out in previous tests; at a height of 230 cm, 0^0, and with a light intensity of 800 Lux. Tests were carried out on 20 passengers with varying heights from 160 cm to 180 cm.

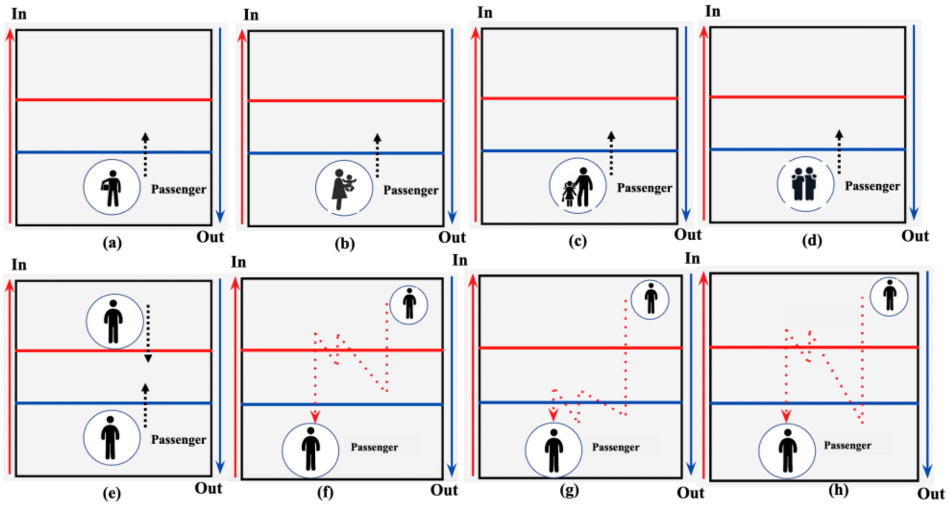

Fig. 12. Special Scene of Passenger' behaviour (a). passengers carrying things, (b). passengers carrying babies, (c). passengers holding hands with children, (d). two passengers standing face to face in front of the exit, (e). two passengers standing side by side in the aisle, (f). model behavior-1, (g). model behavior-2, (h). model behavior-3

Fig. 12 shows specific events based on the passenger's behavior, such as passengers carrying things (fig.12 (a)), passengers carrying infants (fig.12 (b), a passenger's holding hands with a child (fig. 12) (c)), two passengers standing face-to-face in front of the exit (fig. 12 (d), and two passengers standing side by side in the aisle (fig. 12 (e)). In addition, a scenario tests were carried out on behavior passengers as in fig. 12 (f) where the outgoing passenger crosses the red virtual line several times, then ends up crossing the blue virtual line as model behavior-1, fig 12 (g) where the outgoing passenger crosses the red virtual line and ends up crossing the blue virtual line multiple times model behavior-2 , and fig.12 (h) where the outgoing passenger crosses the virtual line straight across the blue line and returns across the blue line straight through the red line several times, ending up with crossing the blue line model behavior-3.

The result can be seen in the Table 4. Based on the test results on several special events, it can be seen that in behavioral events such as model behaviour-1, Model behaviour-2, Model behaviour-3, standing side by side, and standing facing each other, the system can work and calculate the number of passengers properly. Meanwhile, in other special events, such as carry things, holding a baby, and standing side by side with a child, there is a decrease in performance of 5% to 20%. This is because the system represents the tools that are carried along with the passengers as an object or other passengers. Meanwhile infants and children are also counted as adult passengers.

Table 4 - APC special events performance result testing.

Special Events	Detection Rate (%)	Recall (%)	Accuracy (%)
Carrying things	89.47	94.44	85
Holding a baby (infant)	88.89	88.89	80
Side by side with a child	88.89	88.89	80
Stand facing each other	100	100	100
Stand side by side	100	100	100
Model Behaviour-1	100	100	100
Model Behaviour-2	100	100	100
Model Behaviour-3	100	100	100

Discussion

The proposed APC system will be discussed and compared with several other approaches that have been worked on by previous researchers based on several criteria which can be seen in table 5.

Table 5 - APC comparison result.

Methods	Detection Rate (%)	Recall (%)	Accuracy (%)
Face Detection (Chen et al., 2010)	86.1	83.3	87
Head detection with crossing line judgement (Li et al., 2014)	96.2	86.5	91.9
Passenger detection with foreground extraction (Khan et al., 2020)	91.21	-	86.24
BSA and one counting line (Perng et al., 2016)	90	-	84.3
Proposed Methods (BSA + MOA)	97.95	96.91	93.8

The proposed system is compared with systems that can be installed in a restricted spaces such as public transportation. The proposed system is compared with previous studies that use face detection algorithms and head detection algorithms with crossing-line judgement. These systems both have the feature of being able to count the number of people but have different algorithms implemented. Based on Table 5 above, it can be seen that the proposed system has a better detection rate than systems that use face detection (Chen et al., 2010), head detection algorithm with crossing line judgement (Li et al., 2014), or foreground extraction (Khan et al., 2020). This is because face detection algorithm requires placing the camera more obliquely to be able to detect the passengers' faces, hence many passengers are not detected by the system, especially if their faces are not detected by the camera. Meanwhile, head detection with crossing-line judgement is not suitable to be deployed in the application of counting the number of passengers in a public transportation. This is because there are some special events based on passengers' behavior that are difficult to apply to crowd-type calculations with one line judgement and one tracking parameter to calculate the number of passengers in detail.

Meanwhile, if the proposed system is compared to research that uses BSA with a single counting line, the proposed system obtains much better detection rate and accuracy results than the system that uses a single line (Perng et al., 2016). This is because the system with one line is difficult to determine the direction of entry or exit of passengers. Thus, the system performance is insufficiently improved. This single-line system is better implemented if passengers have really cultivated the behavior of getting on and off at different doors. In the proposed system, the two-virtual lines applied to the system can handle passenger counting based on multiple special events simply, effectively, and separately in detail. In addition, this system is very suitable for public transportation that has one gate for boarding and exiting, thus the movement of passengers is more visible and monitored.

In terms of cost, the use of cameras in the proposed system as a tool to count the number of passengers also makes the system built low-cost. Compared to using pressure sensors on each passenger seat (Moser et al., 2019), the system is more costly and easily broken, because the resistance of the pressure switches to the weight of the passenger load also affects the lifetime of the system.

Overall, the use of cameras in the proposed system as a tool to count the number of passengers combined with BSA and MOA, has much better performance, durability, and accuracy compared to systems that use infrared (Olivo et al., 2020) (Sundaramoorthy et al., 2018) (Jain, 2019), ultrasonic light sensors (Baltes & Rey, 1999)(Drăgulinescu et al., 2018), Bluetooth HC-05 (Sojol et al., 2018) (Murdan et al., 2020), or RFID (Pradana et al., 2020)(Rajkumar, 2020). This is because systems that use these sensors can only detect passengers if something passes through the sensor, without recognizing whether it is human or other objects. Meanwhile, the use of RFID is very useful when dealing with costs and fare. But RFID makes the use of bus transportation become limited because it must have an RFID when traveling.

5. Conclusion

This research presents an automatic passenger counter based on human detection method and the way they enter or exit the bus. The proposed method consists of a Background Subtraction Algorithm with two moving object activators. The system is proposed in the expectation that it can be implemented in public transportation and can be used for more advanced recording applications. It can be concluded; this system can perform with 93.8% accuracy by placing the camera at 230 cm above the exit door with a light intensity of 800-1000 lux. Two activators moving objects are applied to determine the direction of passengers and resolve special events based on the behavior of passengers in front of the exit. Thus, MOA can help improve system performance. Performance can also be improved even further when using a thermal camera therefore picture-taking is no longer dependent on lighting.

In the future, the application of passenger counter data can be developed and expected to produce performance index functions for public transportation, such as monitoring the behavior of drivers and passengers, predictive information about the transportation, and digital accident reconstructions. In addition, this system can also be developed and constructed with a device that can capture images and videos regarding the conditions on the bus during the travel. The implementation of Event Data Recorder server can be advantages for various kinds of reliable information.

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