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Traffic Light Control System With Image Segmentation Technique and Pattern Matching Technique Using NI myRIO

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Abstract -- Traffic congestion is still a serious problem in many big cities in Indonesia, one of which is due to traffic light settings that are less adaptive to vehicle conditions on the road. This research aims to design and analyze the performance of an adaptive traffic light control system with image segmentation and pattern matching techniques using NI myRIO. The tests include selecting the optimal resolution, comparing fps with webcam input and AVI video, determining the best camera angle, and testing the system in bright, dim, empty streets, and early morning conditions. The results showed that a resolution of 176 × 144 and a camera angle of 90° provided the best performance. AVI video can be used as an alternative in system testing as the results are similar to webcam. The system performed optimally in bright conditions with an F-1 Score of 79.33% and a match rate score of 100% with an average fps of 9.93 fps. However, in dim conditions the performance decreased with an F-1 Score of 69.33% and a Match Rate Score of 41.67% with an average of 10.25 fps. In empty streets and early morning conditions, the system can still operate but sometimes experiences processing delays.

Keywords:
IMAQ Count Objects
Image Segmentation
NI myRIO
Pattern Matching
Traffic Light

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I. INTRODUCTION

Traffic congestion is still a serious problem faced by many major cities in Indonesia [1]. Although data from the Badan Pusat Statistik (BPS) shows that Indonesia's population growth rate over the past 5 years has slowed from 1.31% to 1.13% [2]. However, this does not affect the number of motorized vehicles in Indonesia. Based on the latest data from the Badan Pusat Statistik (BPS), the number of motorized vehicles in Indonesia from 2019-2021 was recorded to increase every year, from 133,617,012 units to 141,992,573 units [3]. Meanwhile, based on actual data from the Korlantas Polri in mid-2023, the number of motorized vehicles in Indonesia amounted to 156,375,106 and could still increase until the end of 2023 [4]. In addition to this, traffic congestion is also caused by road infrastructure that has not been able to cope with the surge in the number of vehicles, causing an imbalance between the number of vehicles and the existing road capacity [5].

Road intersections are parts of the road that often experience traffic congestion. This situation can be observed at an intersection where there are many queues of vehicles in each section [6]. This is because intersections are where traffic lights are installed which play an important role in controlling and regulating daily traffic [7]. Therefore, traffic lights must be controlled as effectively as possible to facilitate traffic flow at intersections.

Currently, the determination of traffic light performance in Indonesia is regulated by the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 49 of 2014 and the methodology is regulated in the 1997 Indonesian Road Vehicle Manual (MKJI) [8]. However, after being applied in the field, it turns out that the results are not aligned between the duration of traffic lights and the volume of vehicles that often change every time [9]. The reason is the traffic light timings that cannot adjust the road conditions and vehicle density on each road section [1].

Indonesia itself has actually developed a centralized traffic light control system to overcome traffic congestion problems called the Area Traffic Control System (ATCS). ATCS is a system used to monitor traffic using CCTV and also functions as a timer for traffic lights. ATCS itself has been widely implemented in many urban areas in Indonesia. However, ATCS is still not effective in overcoming traffic congestion problems due to the absence of an integrated system between real time traffic conditions and timing in ATCS [10].

Some previous studies related to traffic light control systems have been widely discussed such as those conducted by [6] using edge detection with the decision to give time to turn on the green light using fuzzy logic and the results are displayed on MATLAB and in prototype form with 3 intersections. This research requires a longer process in making green light timing decisions because you have to wait for the fuzzy logic process to complete. Other research uses edge detection, image matching, and video background removal methods with Raspberry Pi as a processor and the results are displayed on VNC Viewer. This research only reaches the stage of displaying the time duration of the green light or in other words there is no traffic light control process [5]. Another research uses a deep learning object detection algorithm, namely Quantized MobileNet- Single Shot Multibox (SSD) with Raspberry Pi as the processor and controller. However, this research is not effective enough because it only produces Frames per Second (FPS) of 4.56 fps below the minimum standard of the American Public Transportation Association (APTA) for the low traffic area category of 5 fps [11]. Other research uses image processing, namely image segmentation and Deep Learning Algorithms, namely K-Nearest Neighbor (KNN) Classification and Color Classification techniques with NI myRIO as the processor and controller and the results are displayed on LabVIEW and in prototype form with 4 intersections. However, the testing is only done at 1 intersection. This research is more focused on developing a system to prioritize emergency vehicles, namely ambulances [12].

From some of these studies, this research uses image segmentation techniques and iMAQ Count Objects 2 to count the number of vehicles and pattern matching techniques to determine vehicle density. The integration of the two techniques is expected to provide a more accurate decision in giving the green light on the traffic light. The image segmentation, iMAQ Count Objects 2, and pattern matching techniques were chosen by considering the efficiency of processing time so as not to burden NI myRIO as a real time video processor. This research uses NI myRIO because of its ability to process in real time thanks to the embedded hardware. In addition, this research also uses LabVIEW software which is used as a place to create source code and also as a Graphical User Interface (GUI) of the program that has been created. This research is also in the form of simulations and prototypes with 4 intersections and there is field testing to determine the best angle in vehicle detection.

II. METHODOLOGY

The flowchart in Figure 1 illustrates the stages of the research.

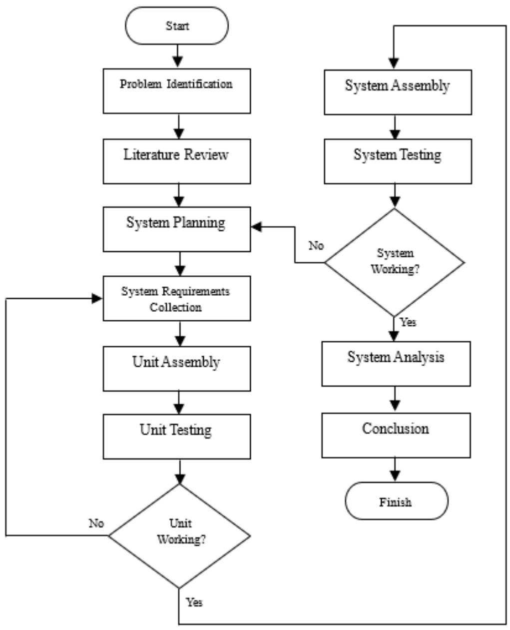

FIGURE 1.
Research Flowchart

From Fig. 1, it can be seen that the initial stage carried out in this research is the identification of problems and literature studies related to traffic light control based on existing systems in Indonesia and related studies in order to get new research from the gap of previous studies or combine several previous studies so that it becomes better research. The result is to integrate several techniques with the hope of being able to provide more accurate decisions in giving green light timing in traffic light control. The techniques used are Image Segmentation technique, IMAQ Count Objects, and Pattern Matching technique using NI myRIO.

Then the system workflow is shown in Fig. 2 in the form of a block diagram.

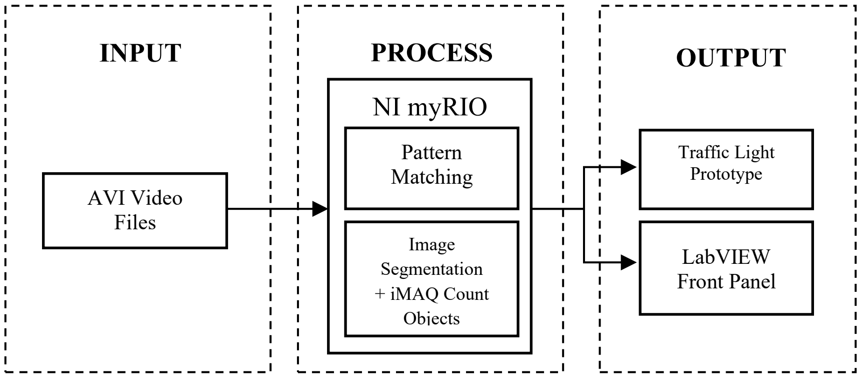

FIGURE 2.
System Block Diagram

From Fig. 2, it can be seen that there are 3 workflows in this system, namely input in the form of video of vehicles on the highway during a red light which is then processed by NI myRIO by applying image segmentation techniques and iMAQ Count Objects to obtain the number of vehicles and applying pattern matching techniques to obtain vehicle density. The result is a green light duration that will be input into the traffic light control logic. This result is sent to the output section, namely to the traffic light prototype and to the laptop displayed through the LabVIEW front panel.

Before conducting system testing, the unit must be tested first to determine the optimal parameters to be used in the system, including resolution selection based on processing time and vehicle detection performance, fps comparison with webcam and AVI video input, and determination of the best camera angle in detecting vehicles. The results of this stage are used as the final configuration of the system.

After the system is configured, system testing is then carried out to analyze the overall performance of the system. The test is carried out in 4 different conditions, namely bright, dim, empty streets, and early morning conditions. The results of this test are then used to determine whether the system can control traffic lights as expected.

The traffic light control scenarios are as follows.

1. If all intersections have vehicles, then 1 intersection will have a green light and the other 3 will have a red light.
2. If one intersection has no vehicles, then the intersection that has done the processing will remain red and the green light will be allocated to the next 1 intersection and the other 2 intersections will remain red.
3. If there are no vehicles at two intersections, the two processed intersections will remain red and the green light will be allocated to the next one and the other one will remain red.
4. If there are no vehicles at three intersections, the three intersections that have been processed will remain red and the green light will be allocated to the next one.
5. If there are no vehicles at all intersections, then all intersections will have yellow lights and will revert to red and green lights when there is at least one intersection with detected vehicles.
6. If the time is 00:00 to 05:00, then all intersections will be yellow even if there are vehicles.

Then for the scenario of giving the duration of the traffic lights, it is as follows.

1. For pattern matching, the scenario is shown in Table I with reference to the scenario created by [7] with minor modifications to suit the system created.

TABLE I.
Pattern Matching Green Light Time Duration Scenario

Vehicle Density	Green Light Duration
> 950	Default (1 second)
> 850-950	10 seconds
> 750-850	20 seconds
> 650-750	30 seconds
> 550-650	40 seconds
0-550	60 seconds

2. For image segmentation and iMAQ Count objects 2, the scenario is shown in Table II by referring to the scenario created by [8] with slight modifications to fit the system created.

TABLE II.
Image Segmentation Green Light Time Duration Scenario

Vehicle Density	Green Light Duration
0	Default (1 second)
1-4	10 seconds
5-8	20 seconds
9-12	30 seconds
13-16	40 seconds
> 16	60 seconds

3. The results of the two techniques are integrated and the green light duration is calculated by averaging them. Mathematically, the equation is written as follows.

$$t_n = \frac{t_{pmn} + t_{scn}}{2} \tag{1}$$

Description:

t_n = Green light time duration for the nth intersection (seconds)

t_{pmn} = Pattern matching green light time duration for the nth intersection (seconds)

t_{scn} = Image segmentation green light time duration for the nth intersection (seconds)

4. The system will work clockwise with different green light durations at each intersection depending on the processing results. The yellow light has a fixed duration of 3 seconds if each intersection has vehicles or 4 seconds (3 seconds plus 1 second for processing) at intersections where there are no vehicles. Meanwhile, the red light adjusts to the current traffic conditions.

Then for system performance evaluation, for Image Segmentation and iMAQ Count Objects, the evaluation is done using Confusion Matrix by calculating Accuracy, Precision, Recall, and F-1 Score based on the number of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). These metrics are calculated using the following equation.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{2}$$

$$Precision = \frac{TP}{TP + FP} \tag{3}$$

$$Recall = \frac{TP}{TP + FN} \tag{4}$$

$$F - 1\, Score = \frac{2 \times Recall\ x\ Precision}{Recall + Precision} \quad (5)$$

As for Pattern Matching, the evaluation is done with several approaches depending on the objective. Resolution selection is evaluated based on the accuracy of score derivation, best angle selection based on score consistency, and system testing based on score range associated with green light duration.

III. RESULTS AND ANALYSIS

A. *Testing Vehicle Detection Performance with Various Resolutions*

This test uses images of vehicles at intersections with various numbers of vehicles that have been predetermined. The goal is to analyze the performance of the techniques used in detecting vehicles and how fast they can process 1 frame. There are 2 test conditions, namely bright conditions and dim conditions and there are 8 resolutions used, namely 1280 x 960, 1280 x 720, 864 x 480, 640 x 480, 640 x 360, 320 x 240, 176 x 144, and 160 x 120. A summary of the test results is shown in Table III for bright conditions and Table IV for dim conditions.

TABLE III.
Summary of Test Results in Bright Conditions

Resolutions	Accuracy	Precision	Recall	F-1 Score	Total (ms)	Matching
1280 x 960	61,02%	70%	81,4%	75,27%	3.371,7	70%
1280 x 720	63,79%	73,47%	81,82%	77,42%	2.554,8	70%
864 x 480	63,16%	81,4%	72,92%	76,92%	1.118,3	70%
640 x 480	63,16%	72,92%	81,4%	76,92%	850,5	80%
640 x 360	66,67%	73,58%	86,67%	79,59%	637,6	80%
320 x 240	65%	69,09%	90,48%	78,35%	229,4	70%
176 x 144	71,93%	78,43%	88,89%	83,33%	94	80%
160 x 120	66,67%	80,43%	78,72%	79,57%	79	70%

TABLE IV.
Summary of Test Results in Dim Conditions

Resolutions	Accuracy	Precision	Recall	F-1 Score	Total (ms)	Matching
1280 x 960	51,85%	60%	77,14%	67,5%	3.258,6	80%
1280 x 720	39,62%	45,45%	71,43%	55,56%	2.476,2	80%
864 x 480	48,21%	53,06%	81,25%	64,2%	1.128,9	80%
640 x 480	47,27%	53,19%	78,13%	63,29%	841,5	80%
640 x 360	45,28%	51,11%,	76,67%	61,33%	624,5	80%
320 x 240	38,89%	51,28%	58,82%	54,79%	209,6	80%
176 x 144	50%	64,86%	66,67%	65,75%	85,3	80%
160 x 120	40%	70,37%	46,34%	55,88%	71,8	80%

From Table III and Table IV, it can be seen that the performance of the techniques used with various resolutions in the two conditions yields mixed results. To determine the best resolution, it is necessary to consider the balance between vehicle detection performance and processing time per frame. For processing time per frame with reference to APTA, which is at least 5 fps or at least 200 ms for the low traffic category, there are only 2 resolutions that meet the 176 x 144 resolution and the 160 x 120 resolution. As for vehicle detection performance, in this study F-1 Score is more suitable for use because it requires a balance between the precision value and the recall value and F-1 Score combines both. The result is 176 x 144 resolution is better than 160 x 120 resolution.

From the description above, for processing time per frame, 176 x 144 resolution is not better than 160 x 120 resolution with a difference of 2.02 fps in bright conditions and 2.21 fps in dim conditions, but this result is not so influential because the detected vehicle is at a red light. As for vehicle detection performance, 176 x 144 resolution has better performance than 160 x 120 with a difference of 3.76% in bright conditions and quite far in dim conditions with a difference of 9.87%. This vehicle detection performance becomes more important as it affects the duration of green time for traffic light control. From this analysis, it was decided that 176 x 144 resolution is the best resolution because it has a small difference in processing time per frame but with much better vehicle detection performance compared to 160 x 120 resolution.

B. *FPS Comparison Testing with Webcam and AVI Video Input*

This test aims to find out if there is a difference in fps with different inputs, namely from a webcam and from an AVI video. This needs to be done because this system uses AVI video as input in order to maintain the consistency of system performance with the performance of unit test results because if using a webcam, the vehicle is not using the original vehicle because it is not possible to test the system directly on the road.

There are 2 test conditions, namely bright conditions shown in Table V and dim conditions shown in Table VI.

TABLE V.
FPS Comparison with AVI and Webcam Video Input in Bright Conditions

Seconds	Initial FPS	FPS Output	
		AVI Video	Webcam
1	30	10	9,93049
2	30	10,6178	9,61538
3	30	10,0917	9,95025
4	30	10,0917	9,93049
5	30	10,4762	9,9108
6	30	10,4167	9,92063
7	30	10,3093	9,97009
8	30	10,29	9,92063
9	30	10,5163	9,60615
10	30	9,99092	9,93049
Average	30	10,2801	9,8685

TABLE VI.
FPS Comparison with AVI and Webcam Video Input in Dim Conditions

Seconds	Initial FPS		FPS Output	
	AVI Video	Webcam	AVI Video	Webcam
1	30	15	12,0818	7,5188
2	30	15	10,9671	7,54717
3	30	15	10,978	7,5188
4	30	15	10,9671	7,54717
5	30	15	10,9671	7,5188
6	30	15	11,3529	7,54717
7	30	15	10,7212	7,5188
8	30	15	11,6618	7,54717
9	30	15	11,4286	7,5188
10	30	15	10,4265	7,54717
Average	30	15	11,1552	7,533

Based on Table V and Table VI, the fps value generated in bright conditions is very similar, namely a difference of 0.4116 fps, while for dim conditions it has a quite different fps value with a difference of 3.6222 fps because the maximum fps of the webcam is 15 fps. From these results, although they have different ways of working, but with fps that are quite similar can describe the conditions when this system is applied in real situations using a webcam.

C. Testing the Best Angle Determination using a Webcam

This test aims to determine the best webcam viewing angle in detecting vehicles. This test uses a resolution of 176 x 144 pixels and for the angles to be tested, namely 90 °, 60 °, and 45 ° angles. The components used are Logitech C270 Webcam, 5 meters USB Active Extension cable (UTP cable with USB 2.0 Extender via UTP Cable cannot be used due to compatibility issues), NI myRIO 1900, and bamboo as a place to place the webcam. This test was carried out from 06.45 WIB to 07.30 WIB at one of the Traffic Light on Jalan Cihaurbeuti, Ciamis Regency using a bamboo as high as 5 meters and placed near the Traffic light installation as illustrated in Figure 3 and a summary of the test results is shown in Table VII.

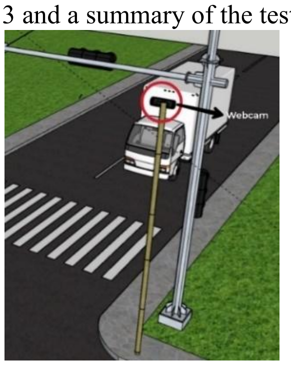

FIGURE 3.
Webcam Placement Illustration

TABLE VII.
Summary of Test Results for the Three Angles

Analysis	90° Angle	60° Angle	45° Angle
Visual	Quite broad but not focused	Quite narrow but focused	Narrow but more focused
Accuracy	73,91%	69,77%	91,59%
Precision	91,8%	53,57%	64,71%
Sensitivy/Recall	69,14%	100%	78,57%
F-1 Score	78,87%	69,77%	70,97%
Pattern Matching	Scores don't drop easily, but are still good enough	There are some scores that drop excessively	Similar to 60° angle but too many empty states
Blind spot	2,37 meter	3,5 meter	2,25 meter
Longest Distance	42,71 meter	6,44 meter	3,65 meter

From Table VII, it can be seen that each angle has its own advantages and disadvantages. However, overall the 90° angle has better results than the other two angles especially in the webcam visibility which is much wider than the other two angles. This visibility is a major factor in vehicle detection because it will better describe the conditions on a highway if the view is wide. Despite the unfocused view, the score generated by this 90° angle is still within reasonable limits and from the detection based on the number of vehicles, the F-1 Score has the highest percentage than the other two angles. The Pattern Matching Score also produces a score similar to the score produced when using AVI video, so this AVI video is still relevant if used for system testing. So, it can be concluded that in this case, namely placement on the roadside using a Logitech C270 Webcam at a pole height of 5 meters and using a resolution of 176 x 144 with 3 angles tested, the 90 ° angle is the best angle for vehicle detection.

D. System Implementation

This system uses AVI video as input, NI myRIO 1900 as processor and controller, and for the output, this system has 2 outputs, namely output in LabVIEW displayed on the front panel and prototype output. For what is displayed on the LabVIEW front panel, there is only 1 video that will be displayed, namely the intersection that is processing. The intersection that is currently green light will only be seen from the green light. As for the prototype, it is in the form of a highway mockup that has been installed with traffic lights from LEDs connected to myRIO. There are 12 LEDs used with each color (red, yellow, and green) and will be used for 4 intersections. Figure 4 shows the GUI on the LabVIEW front panel and Figure 5 shows the assembly of the prototype traffic light control system.

FIGURE 4.
Traffic Light Control System GUI

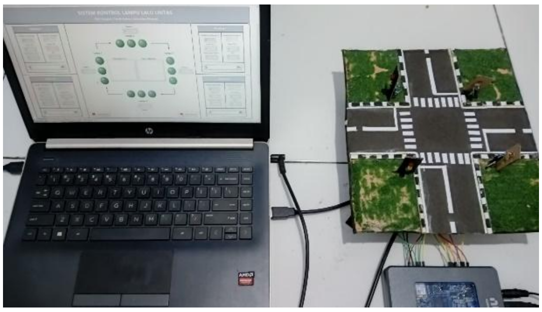

FIGURE 5.
Traffic Light Control System Prototype Assembly

E. Testing Traffic Light Control in Bright Conditions

This test aims to analyze the performance of the traffic light control system that has been made in bright conditions, which is a condition where vehicles can be more easily distinguished from the road due to sufficient lighting so that it is easier for the techniques/algorithms used to detect vehicles.

From the tests that have been carried out, the system is analyzed for its performance using Confusion Matrix. Table VIII shows the Confusion Matrix for the system test results in bright conditions.

TABLE VIII.
Confusion Matrix of System Testing in Bright Conditions

Total = 108 data		Actual	
		Vehicle	Non-vehicle
Predicted	Vehicle	71 (True Positive, TP)	27 (False Positive, FP)
	Non-vehicle	10 (False Negative, FN)	0 (True Negative, TN)

Based on the values in Table VIII, the Accuracy value is 65.74%, Precision 72.45%, Sensitivity/Recall 87.65%, and F-1 Score 79.33%. Based on the results obtained, F-1 Score is more suitable for use because F-1 Score better describes the performance of the technique used because it combines the precision value and recall value. Then, the pattern matching evaluation is shown in Table IX.

TABLE IX.
Analysis of System Testing Matching Score in Bright Conditions

Test to-	Conditions	JKS	KK	Expected score	Match/Not Match
1	5 Motorcycles	5	875	> 850-950	Match
2	3 Cars 8 Motorcycles	11	729,63	> 650-750	Match
3	5 Motorcycles	5	879,08	> 850-950	Match
4	3 Cars 8 Motorcycles	11	749,48	> 650-750	Match
5	1 Car 4 Motorcycles	5	811,92	> 750-850	Match
6	6 Cars 4 Motorcycles	10	687,39	> 650-750	Match
7	2 Cars 4 Motorcycles	6	799,43	> 750-850	Match
8	3 Cars 8 Motorcycles	11	746,30	> 650-750	Match
9	2 Cars 4 Motorcycles	6	804,14	> 750-850	Match
10	6 Cars 4 Motorcycles	10	684,83	> 650-750	Match
11	6 Cars 4 Motorcycles	10	684,06	> 650-750	Match
12	3 Cars 8 Motorcycles	11	744,04	> 650-750	Match

From Table IX, it can be seen that in bright conditions, pattern matching successfully produces scores that fall into the expected score range. This score range is taken from the score range for green light duration. Based on these two evaluation results, the result of the integration of these techniques produces a better decision than using only 1 decision so that it can provide a better green light duration.

The resulting fps is still quite good because it is still above the minimum fps value recommended by APTA for the low traffic area category, which is 5 fps.

Finally, for traffic light control, the system is able to control and change the color of the traffic light according to the set duration and logic that has been set in the program, both on the GUI in LabVIEW and on the prototype. The system in this condition is successfully synchronized between input, processing, and output so that the system runs as expected.

F. Testing Traffic Light Control in Dim Conditions

This test aims to analyze the performance of the traffic light control system that has been made in dim conditions, which is a condition where vehicles are quite difficult to distinguish from the road because the lighting is not good enough so that it is more difficult for the techniques/algorithms used to detect vehicles.

From the tests that have been carried out, the system is analyzed for its performance using Confusion Matrix. Table X shows the Confusion Matrix for the system test results in dim conditions.

TABLE X.
Confusion Matrix of System Testing in Dim Conditions

Total = 53 data		Actual	
		Vehicle	Non-vehicle
Predicted	Vehicle	28 (True Positive, TP)	18 (False Positive, FP)
	Non-vehicle	7 (False Negative, FN)	0 (True Negative, TN)

Based on the values in Table X, the Accuracy value is 52.83%, Precision 60.87%, Sensitivity/Recall 80%, and F-1 Score 69.14%. Based on the results obtained, F-1 Score is more suitable for use because F-1 Score better describes the performance of the technique used because it combines the precision value and recall value. Then, the pattern matching evaluation is shown in Table XI.

TABLE XI.
Analysis of System Testing Matching Score in Dim Conditions

Test to-	Conditions	JKS	KK	Expected score	Match/Not Match
1	2 Motorcycles	2	921,84	> 850-950	Match
2	2 Cars 4 Motorcycles	6	741,26	> 750-850	Not Match
3	No Vehicle	0	993,78	> 950	Match
4	2 Motorcycles	2	920,37	> 850-950	Match
5	1 Car	1	852,84	> 850-950	Match
6	1 Car	1	854,39	> 850-950	Match
7	2 Cars 4 Motorcycles	6	732,06	> 750-850	Not Match
8	3 Cars 5 Motorcycles	8	560,58	> 650-750	Not Match
9	2 Cars 4 Motorcycles	6	662,48	> 750-850	Not Match
10	2 Cars 3 Motorcycles	5	736,57	> 750-850	Not Match
11	2 Cars 3 Motorcycles	5	736,48	> 750-850	Not Match
12	2 Cars 4 Motorcycles	6	732,06	> 750-850	Not Match

From Table XI, it can be seen that in dim conditions, pattern matching succeeds in producing scores that fall within the expected score range, although there are more mismatches due to the difficulty in determining the score because the pixels are not clear due to poor lighting. In this condition, both image segmentation and patten matching can complement the shortcomings of the other technique. So, the result of the integration of these techniques can produce a better decision than just using 1 decision alone so that it can provide a better green light duration.

The resulting fps is still quite good because it is still above the minimum fps value recommended by APTA for the low traffic area category, which is 5 fps.

Finally, for traffic light control, the system is able to control and change the color of the traffic light according to the duration set and the logic that has been set in the program, both on the GUI in LabVIEW and on the prototype. The system in this condition is successfully synchronized between input, processing, and output so that the system runs as expected.

G. Testing Traffic Light Control in Empty Street Conditions

This test aims to analyze the performance of the traffic light control system that has been made on empty road conditions. In this case, the system must pass through an intersection where there is no vehicle and processing continues to the next intersection.

From the tests that have been carried out, the result is that the system can skip the green light at an intersection that is detected to have no vehicles in all conditions both on the GUI in LabVIEW and on the prototype. In this condition, the FPS also increases because the processing load is reduced. However, in some conditions when applied in real life (uncontrolled), the system sometimes delays in performing the control so that there is an unsynchronization between processing and control. This condition occurs in all conditions, but most often occurs in the condition of 2 and 3 empty consecutive intersections. However, it does not mean that the condition of 1 empty intersection and all empty intersections is much better because sometimes after the intersection is passed, if it continues to occur repeatedly, the system starts to delay and it affects the control process, so the only way to overcome it is by restarting the system so that the system returns to normal. So, we can conclude that the system is not robust enough to handle this scenario.

H. Testing Traffic Light Control in Early Morning Conditions

This test aims to analyze the performance of the traffic light control system that has been made in early morning conditions where in this condition the number of vehicles is usually very minimal or even empty. In this test, whether there are vehicles or no vehicles, the traffic lights must remain yellow. This test scenario is carried out every 30 minutes from 00:00 to 05:00.

From the tests that have been carried out, the result is that the system can change the lights at all intersections to yellow lights after the time shows 00:00 to 05:00 and return to normal after the time shows 05:01 both on the GUI in LabVIEW and on the prototype. However, in some conditions when applied in real life (uncontrolled), the system sometimes delays when changing the traffic light back to normal. This condition occurs because it comes from an empty intersection as happened in the previous test, so the only way to overcome it is by restarting the system so that the system returns to normal. In addition, myRIO also has a system time that does not follow the current time, so it needs to be changed first so that the time is the same as the current time. This is a problem when applied in real conditions because there is a possibility that the myRIO connection is lost which can make myRIO have to be restarted and have to change the time again. So, it can be concluded that the system is not robust enough to handle such a scenario.

IV. Conclusion

This research successfully designed a traffic control system with image segmentation and pattern matching techniques using NI myRIO. From the test results, 176 x 144 pixels resolution and 90° angle gave the best performance. AVI video proved to be an alternative for system testing as the results were similar to webcam. The system performed optimally in bright conditions with an F-1 Score of 79.33% and a score match rate of 100% with an average fps of 9.93 fps, but its performance degraded in dim conditions with an F-1 Score of 69.33% and a Score Match Rate of 41.67% with an average of 10.25 fps. In empty streets and early morning conditions, the system can still operate but sometimes experiences processing delays so the system needs to be restarted. Overall, the system can adaptively control traffic lights but still requires performance improvements especially in low lighting conditions and in conditions involving intersections with no vehicles to make the system more responsive so as to reduce processing delay.

V. References

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