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A FUZZY-FAULT CLASSIFIER SYSTEM FOR MALFUNCTION TRAFFIC LIGHT SYSTEM CLASSIFICATION

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ABSTRACT

The fuzzy-fault classifier (FFC) is a method which is employed as a subsystem in fault detection system. The system is normally utilized in a large and complex traffic light management system. This paper proposes a FFC system to classify the level of seriousness for traffic light failure based on two criteria which is faulty indication and road user manners. The system has been designed using 2-stage fuzzy approach techniques with two module classifications. The seriousness of the traffic light failures are classified to four conditions such as normal, non-critical, critical and highly-critical and a signal will be sent to the contractor and authority department via Short Message Service (SMS) for further action. The system has been testified using simulation and successfully implemented in Kuala Lumpur.

Keywords: *Classification, malfunction of traffic light, fuzzy-fault classifier, fuzzy technique*

1. INTRODUCTION

Traffic lights play an important role to control the flow of traffic in rural and urban areas. Without traffic lights or traffic light damage will cause confusion among drivers from different directions to cross the intersection. As mentioned in [1-5], the study shows that the road user behavior play the important factor causes the traffic congestion when traffic light malfunctions. Besides that, the bad attitudes of the road user also need an immediate action is taken by contractor or authority department to prevent unnecessary traffic conjunction and accident possibilities.

In Malaysia, Integrated Transport Information System (ITIS) is a comprehensive traffic information system developed for City Hall Kuala Lumpur (CHKL) to monitor traffic flow and analyze the data on road conditions in the Klang Valley to provide useful traffic information to road users [6]. In Kuala Lumpur, the traffic light system is build with the automatic detection system which can be used to detect the failure that occurred at the traffic light system. Therefore, the action for repair the failure can be taken as soon as possible. As a result, the traffic jam that may occur during the failure of the traffic light system can be reduced.

The traffic light system that obtained at the rural area is different from the urban area. If any failure that occurred at the traffic light system, there will be no intelligent traffic light control system which used to detect the failure. Normally, signboards are used to remind road users to call contractor and authority department, when failure occurs. But only responsible road users will take the initiative to call the contractor and authority department reporting the failure of traffic light operation. Therefore, the delay of report to local authority will cause the repairing work delayed.

Based on survey [7-9], there are two factors of failures which are electrical fault and mechanical fault. For electrical fault, there are two types of indicators used in traffic light pole which is filament and light emitting diode (LED). Both types of indicators are bound to faultiness in long run or due to wear and tear. The most common fault in the indicators is open condition (indicators blow off). Besides that, other electrical fault happened in case of electric black-out or trip. In most cases, when there is a power interruption it will never be notified to the monitoring station and this will result in unwanted miseries to the road users. For mechanical fault is the damage or bend of the pole causes the accident by road users. To overcome this problem, Sivarao *et al.* [9] developed prototype of

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traffic light electrical and mechanical fault detection system. This system alerts via wireless technology to the respective personnel to get them fixed immediately upon improper electrical malfunctions or mechanical damages are detected.

As reported in [7-9], the electrical faulty system is only focus on the 'on' and 'off' bulb of traffic light. However, in this case the problem is not considered critical compared to confusion of bulb colors for traffic light system. Bulb colors confusion will create a panic situation to the road users. The confusion of bulbs colors could be as (i) the intensity of bulb and (ii) the sequence order of bulb. From previous research, the fault detection system has been developed using a combination of logic circuit based on the colors of traffic signal. The classification of the malfunction has three categories such as non-critical situation, critical situation and highly critical situation [10-12]. Then, the research focused on integrating the malfunction detection system into a large traffic light monitoring system. However, the system is complex which requires many ICs chip. The detection system is also very conventional. Thus, there is an urgent need to transform the system to be more reliability and high efficiency with some implementation of intelligent method.

Based on this problem statement, the one part of the electrical fault detection system has been developed. The fuzzy-fault classifier system is used to analyze the type of the malfunction based on faulty indicator and road user behaviors. The system has the capability to analyze and determine the seriousness of the malfunction at the traffic light system. When a fault is detected in any of the traffic light pole or indicator, the centralized controller receives the signal and processes it for sending it via short messaging system (SMS) to the nearby monitoring station as programmed in the system. The entire process will be functioning with no human intervention at all. The intelligent fault detection of the traffic light system using fuzzy logic technology has the capability of mimicking human intelligence for the fault detection at the traffic light system. Furthermore, fuzzy logic technology allows the implementation of real-life rules similar to the way humans would think [13-15]. The fuzzy-fault classifier system for traffic light is proposed to improve the performance of the traffic system and the repairing work can do faster.

The paper is organized as follows. In the next section, the analysis of questionnaire based on road user behaviours is described. Section 3 briefly discusses the details of fuzzy-fault classifier system for classification of the malfunction traffic light system. Section 4 discusses the testing and simulation results of the system. The conclusion of this paper is summarized in the last section.

2. ANALYSIS OF QUESTIONNARE BASED ON ROAD USER BEHAVIOURS

Relatively, study shows that the road user behaviors have been identified as the main factor causes the traffic congestion when traffic light malfunctions. A survey has been conducted to evaluate the behavior of road users when approaching a junction. A questionnaire consisting 12 questions has been distributed to the road users for test the action and response of the road users when traffic light malfunctions. All the questions are described in Table 1.

Table 1. Analysis of the questionnaire questions

No of Question	Aim of Question
Q1 , Q2	To test the road users about their knowledge on traffic light operations at a junction.
Q3, Q4	To test the attitude of road users whether they follow the rules of traffic light system or not.
Q5	To test road users' action when the traffic lights ahead change from red to green.
Q6	To test road users' action when the traffic lights change from green to yellow.
Q7	To test road users' action when they approach a traffic light at the junction.
Q8	To test road users' action when the traffic lights turn red.
Q9, Q12	To test the action and responsibility of road users when the traffic lights at the cross road is not functioning as they approach the junction.
Q10	To test the responsibility of road users when the traffic lights malfunction.
Q11	To test the action and responsibility of road users when only the traffic lights on their lane are not functioning.

From the analysis, most road users have good knowledge on the traffic light operation, but their bad attitude has caused the intersection problem (Question 1 and Question 2). The survey shows that the road users always break the rules. Only 54% of the road users (Question 3) follow the rules of traffic light system and 58% of the road users (Question 7) slow down their vehicle and stay in

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the correct lane when approaching a traffic light at the junction. However, 46% of the road users (Question 4) are still breaking the rules of the traffic light when approaching a junction.

The green light means, the driver can precede the vehicle if it is safe. But from the survey, 90% of the road users (Question 5) of precede the vehicle hastily carelessly without slowing down. The road users do not care about the vehicle at the other lane. So, if two or more of the traffic lights from different direction at the junction show green lights, it is categorized as highly critical case and dangerous for road users.

When the traffic light changes to amber (Question 6), 50% of road users precede the vehicle quickly. Only 40% of road users stop the vehicle while the amber light is ON. The case situation becomes more critical when two or more amber lights from different direction are ON at the same at a cross junction. For the case when the traffic light turns red (Question 8), 92% of road users stop the vehicle and wait until the light turns green. This case is not critical until all traffic lights show red. This is because, when all the traffic light turns red, it can be categorized that all the traffic lights are malfunctions.

When the traffic lights at a junction is not functioning, only 40% of road users (Question 9) slow down their vehicle, stop and make sure the traffic condition is safe before they proceed. If only one traffic light at a junction is malfunction (Question 11), only 6% of road users proceed carelessly. This case is considered not critical because only one direction is facing the problem. However, if two or more traffic lights from different direction are malfunction at the same time, it becomes critical.

One attitude of a good driver is being responsible. If the road users are courteous and not selfish, the conflict problems occur at the intersection when the traffic light is failure can be reduced. However, only 26% of the road users (Question 10) take the responsibility to call the authority department to report the failure of traffic light system.

Traffic light system is considered malfunction when two or more bulbs are ON at the same time. Another aspect, the problem occurs at the junction when two or more traffic system is failure to operate as usual from different side or direction. Based on survey analysis, the road users always set in their mind to follow the colors of the bulb when approaching the junction. The road users also don't care to other directions and just follow their direction to cross the junction quickly. Based on behavior of road users, this two aspects will be inviting trouble or dangerous to other road users in the different direction. From the analysis of questionnaire, the fault classifier system for classification of malfunction traffic light system has been developed using fuzzy approach techniques. This system can be used to classify the types of malfunction based on this two aspect depending on four status situations such as NORMAL, NON-CRITICAL, CRITICAL and HIGHLY-CRITICAL.

3. A FUZZY- FAULT CLASSIFIER SYSTEM

In this research, the fault classifier system has been developed for classification of malfunction traffic light. The classifications are based on the road user behavior factors and faulty indicators. These two parameters are summarized from a statistical analysis of questionnaire which has been conducted earlier. Based on these factors, the classification of the traffic light failure is developed by using fuzzy method. In the most elementary sense, fuzzy logic can be defined as the control of a machine in linguistic terms. A fuzzy logic will operate a machine in a fashion similar to that of a human operator. A set of heuristic control rules, as stated by a human operator, are translated into an automatic control strategy using fuzzy logic.

The fault classifier system is designed for an isolated 4-lane traffic intersection: North, South, East and West as shown in Figure 1. In this system, two modules of classifications are needed before the output signal that represents overall status of situations can be sent to the control room via Short Message Service (SMS) or telephone.

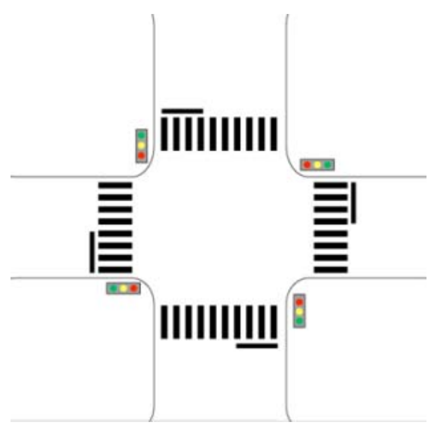

Figure 1. Isolated traffic model

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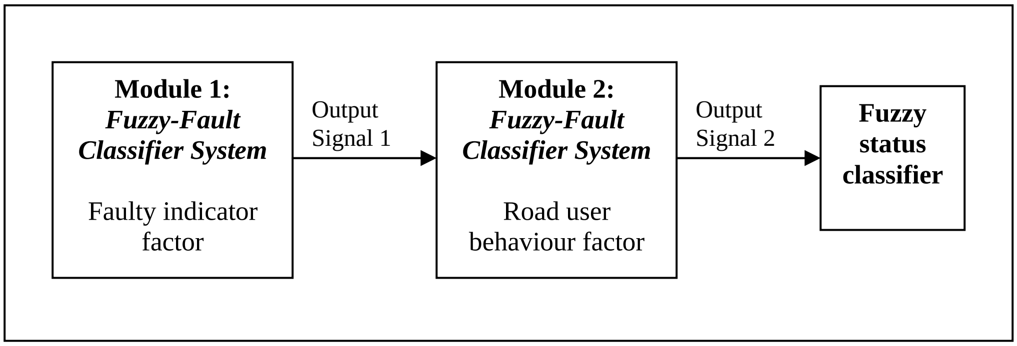

Figure 2. Block diagram of fuzzy-fault classifier system

For Module 1, the classification of malfunction traffic light is designed based on faulty indicators. In a junction shown in Figure 1, there have 4 sides of traffic light system with 12 bulbs which are function as light indicators.

For Module 2, the classification is designed based on the road user behaviour factors. In this module, there are two stages of classification are involved. In the stage 1, the conflict crossing from two different directions needs to be considered as the inputs. The conflict crossings for two different directions are classified as follow: North-East, North-West, South-East and South-West. Based on the analysis of questionnaire, these states consider is dangerous scenario when the traffic from each direction is crossing intersection at the same time. For the stage 2, the two groups of directions are compared depending on the criticalness of the fault based on the road user's behavior. The complete design of system for fuzzy-fault classifier is shown in Figure 2.

3.1. Classification: Module 1

First stage represents, the classification of the traffic light failure based on faulty indicators. The input was focused on the intensity of the traffic light bulb whether there are functioned in good condition or not. The input signals of first stage fuzzy-fault classifier system are obtained from the light sensor system. The brightness of the traffic light system is measured in the unit of lumen. In normal traffic light, the intensity of the light is from 0 to 3000 lumens. This standard intensity of the light is referred to the [26]. Therefore, the brightness of the traffic light is divided into 3 ranges which are OFF, DIM and BRIGHT. For the OFF condition, the intensity of the light is between 0 to 1000 lumens; for DIM condition, the intensity of the light is between 500 to 2500 lumens; for BRIGHT condition, the intensity of the light is between 2000 to 3000 lumens. Based on the brightness of the traffic light bulbs, it has the following linguistic input variables for each colour: OFF, DIM and BRIGHT. Figure 3 shows the respective fuzzy's input membership function of intensity for green bulb (G), red bulb(R) and yellow bulb(Y).

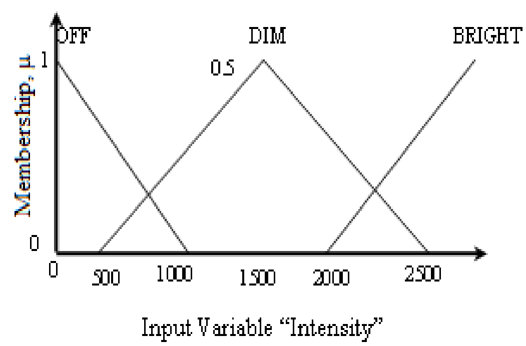

Figure 3. The membership functions of the input variables based on intensity of three bulb: green bulb (G), red bulb(R) and yellow bulb(Y).

The confusion over the brightness of the lights at the traffic signals causes the dangerous to the road users especially from the other direction to cross the junction at the same time. Therefore, the output of the first module it depends on the seriousness of the cases based on the intensity of three bulbs. The output of the controller can be divided into 4 ranges, which are NORMAL, NON-CRITICAL, CRITICAL and HIGHLY-CRITICAL. For the normal case, the range of the classification is from 0 to 0.1; for the non-critical case, the range of the classification is from 0.05 to 0.4; for the critical case, the range of the classification is from 0.3 to 0.75; for the highly-critical case, the range of the classification is from 0.6 to 1. It means that 0 is the normal condition, while the 1 is the serious condition. Figure 4 shows the membership functions of output variable.

Journal of Theoretical and Applied Information Technology
31st December 2011. Vol. 34 No.2

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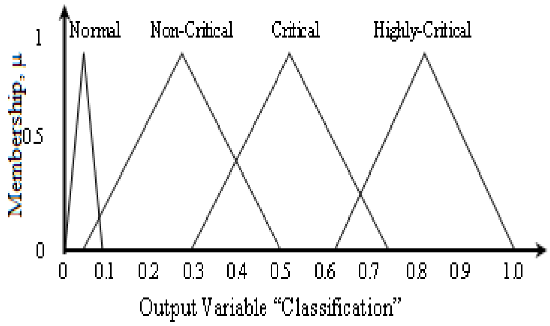

Figure 4. The membership functions of the output variable

The Table 2 shows the fuzzy rules of classification for malfunction traffic light in North direction of traffic light system. For other direction, the fuzzy rules are still referring to this table. The signal output from this module will be the inputs for next module classification. The block diagram is shown in Figure 5.

Table 2. Fuzzy rules of classification for Module 1 based on faulty indicator factor

IF (Rule)	Input 1 (G_N)	Input 2 (R_N)	Input 3 (Y_N)	Output (μ_{NC})
1	Dim	Bright	Bright	Non-Critical
2	Bright	Dim	Bright	Non-Critical
3	Bright	Bright	Dim	Non-Critical
4	Dim	Dim	Bright	Critical
5	Dim	Bright	Dim	Critical
6	Bright	Dim	Dim	Critical
7	Dim	Dim	Dim	Highly-Critical
8	Off	Bright	Bright	Non-Critical
9	Bright	Off	Bright	Non-Critical
10	Bright	Bright	Off	Non-Critical
11	Off	Off	Off	Highly-Critical
12	Bright	Bright	Bright	Normal

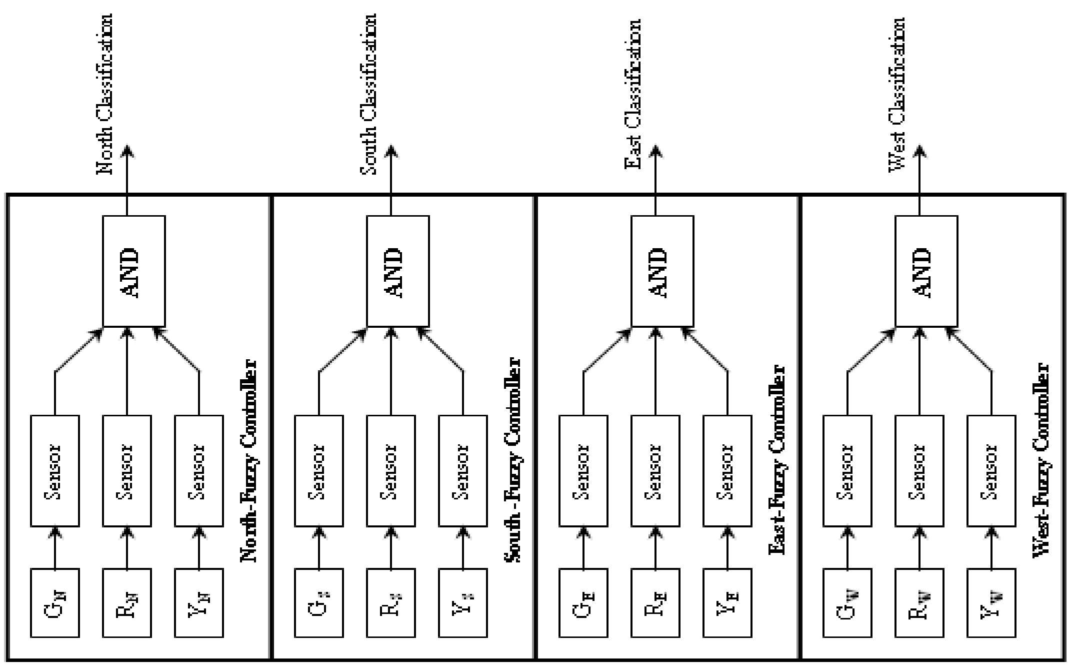

Figure 5. Fuzzy-fault classifier system for Module 1

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The AND operation was been used in the first module of classification based on the traffic direction, the antecedents will be

$$\mu_{NC}(x) = \min[\mu_{G_N}(x), \mu_{R_N}(x), \mu_{Y_N}(x)] \quad (1)$$

$$\mu_{SC}(x) = \min[\mu_{G_S}(x), \mu_{R_S}(x), \mu_{Y_S}(x)] \quad (2)$$

$$\mu_{EC}(x) = \min[\mu_{G_E}(x), \mu_{R_E}(x), \mu_{Y_E}(x)] \quad (3)$$

$$\mu_{WC}(x) = \min[\mu_{G_W}(x), \mu_{R_W}(x), \mu_{Y_W}(x)] \quad (4)$$

3.2. Classification: Module 2

For the second module, the classification was depending on the criticalness of the fault based on the road user's behavior. The criticalness of the fault can be obtained from the output of Module 1. For the first stage, there are 2 inputs for this classification which is output signal from North classification or South classification (Module 1) for input 1 and output signal from West classification or East classification (Module 1) for input 2. The fuzzy sets of input 1and input 2 are similar to output from the Module 1 respectively (see Figure 4). The two input of the stage 1 is considered as the conflict crossing area and the vehicles from these directions cannot cross the junction at the same time. Based on analysis results of questionnaire, the bad attitude of the road users causes the faulty traffic light from these two directions also can divide into 4 cases which were NORMAL, NON-CRITICAL, CRITICAL and HIGHLY CRITICAL. The fuzzy membership functions of the output for stage 1 also similar as shown in Figure 4. The AND operation was also been used in the second module of classification, the antecedents will be

$$\mu_{stage1_N}(x) = \min[\mu_{NC}(x), \mu_i(x)] \quad (5)$$

$$\mu_{stage1_S}(x) = \min[\mu_{SC}(x), \mu_i(x)] \quad (6)$$

where is $\mu_i(x)$ is classification from East direction $\mu_{EC}(x)$ or $\mu_{WC}(x)$ from West direction.

Table 3 indicates the 16 rules of this stage 1 for Module 2.

Table 3. Classification for Module 2 based on road user behavior factor

IF (Rule)	Input 1	Input 2	Output
1	Normal	Normal	Normal
2	Normal	Non-Critical	Non-Critical
3	Normal	Critical	Critical
4	Normal	Highly-Critical	Highly-Critical
5	Non-Critical	Normal	Non-Critical
6	Non-Critical	Non-Critical	Non-Critical
7	Non-Critical	Critical	Critical
8	Non-Critical	Highly-Critical	Highly-Critical
9	Critical	Normal	Critical
10	Critical	Non-Critical	Critical
11	Critical	Critical	Critical
12	Critical	Highly-Critical	Highly-Critical
13	Highly-Critical	Normal	Highly-Critical
14	Highly-Critical	Non-Critical	Highly-Critical
15	Highly-Critical	Critical	Highly-Critical
16	Highly-Critical	Highly-Critical	Highly-Critical

For the second stage classification, the two states from North direction or South direction is compared which is most serious fault from two conflict direction. The outputs from the first stage of this module will be the inputs for the second stage. Therefore, there are two input and the fuzzy sets of this variables are similar to output from the stage1 respectively (see Figure 4). Finally, the output of the system show the fuzzy status classifier based on this two input from comparison of this two direction. The fuzzy status classifier shows the types of malfunction traffic light system according

Journal of Theoretical and Applied Information Technology
31st December 2011. Vol. 34 No.2

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to four status situations such as NORMAL, NON-CRITICAL, CRITICAL and HIGHLY-CRITICAL. The fuzzy membership functions of the output for stage 2 is similar as shown in Figure 4. The classification on this stage is also similar rules with the first stage in this module as shown in Table 3. By using the AND operation, the antecedents of stage 2 as below:

$$\mu_{stage2}(x) = \min[\mu_{stage1_N}(x), \mu_{stage1_S}(x)] \quad (7)$$

The signal of fuzzy status classifier will be sending to control room or person in charge via Short Message Service (SMS) or telephone. The overall architecture of the proposed fuzzy-fault classifier system for Module 2 is shown in Figure 6.

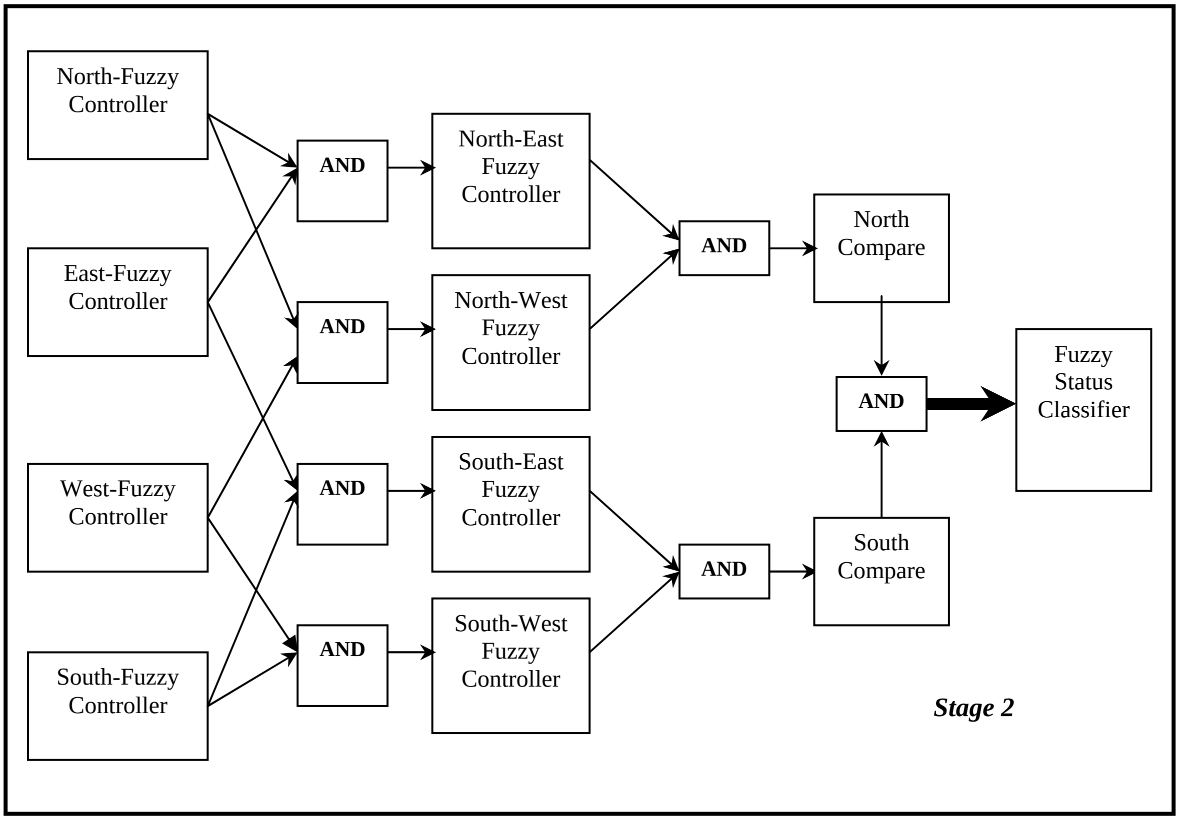

Figure 6. Fuzzy-fault classifier system for Module 2

4. RESULT AND DISCUSSION

4.1 SIMULINK Block Diagram

Fuzzy-fault classifier system was developed using SIMULINK block diagram from MATLAB® as illustrated in Figure 7. The system is divided into four subsystems; sensor circuit system, fuzzy controller (Module 1 and Module 2) and the coordination system. The light of the traffic light will be detected by the sensor systems; the intensity of the traffic light will be categorized as OFF, DIM or BRIGHT. The seriousness of the traffic light failure is identified based on the intensity of the traffic light. Then fuzzy controller in Module 1 and Module 2 will determine the seriousness of failure.

4.2 Fuzzy Controller Testing via Simulation

The result of the design fuzzy-fault classifier system obtained from the project was based on the rules that had been set in the rule viewer. The system inputs are the intensity condition of the light and it has been categorized as follows; (i) 0 lumens is OFF (ii) 1500 lumens is DIM and (iii) 3000 lumens for BRIGHT condition. The output of the classification depends on the lumens number which has been set prior to the testing. The larger the lumens number, the highest level of the fault and vice versa. The classification of the Module 1 can be obtained in the Table 4.

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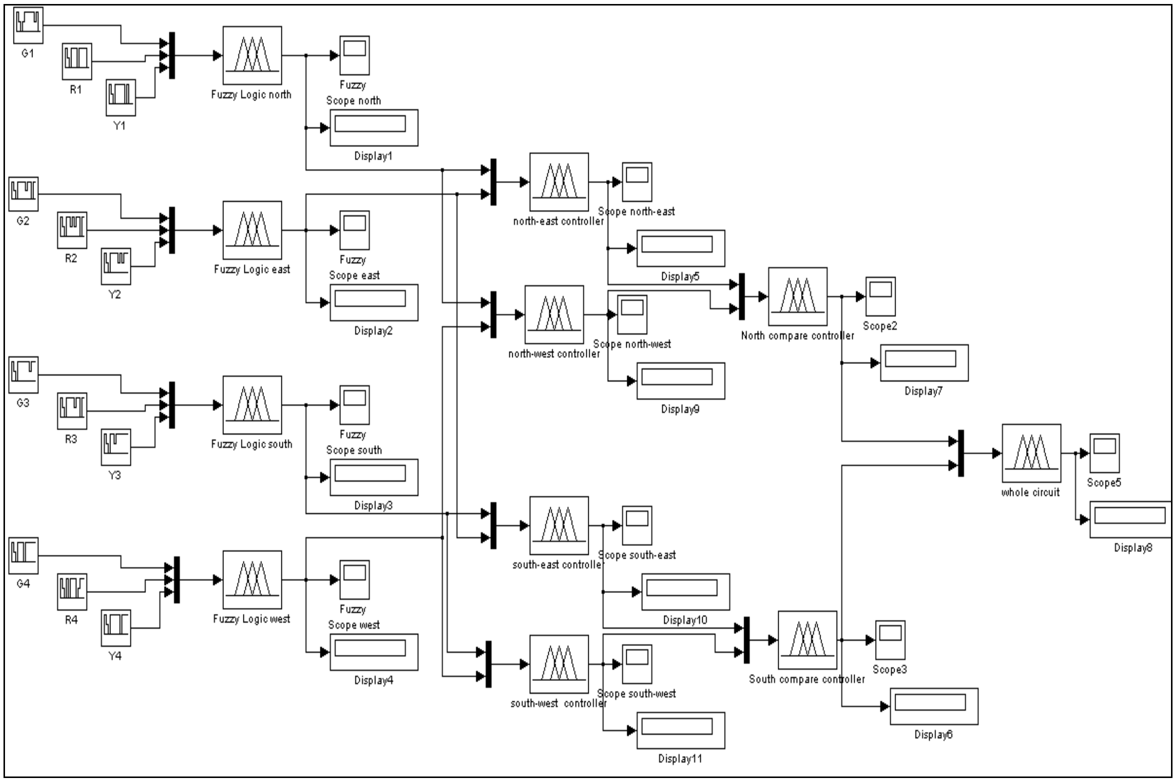

Figure 7. The SIMULINK circuit for overall fuzzy-fault classifier system

From analysis in Module 1, the input value of the system is set for testing purposes. For case 1, the intensity of each traffic light is in the median value which represents the light of each bulb of the traffic light has dimmed. This case occurs when the light for each color of the traffic light is not functional well. Therefore, it can be classified as HIGHLY-CRITICAL and the output weighted is 0.8. From the rule in the Table 4, rule 7 will be applied for this case. Example for case 2, the intensity of each colour of the traffic light will now be considered as bright which the density of each color was in 2510 lumens. For this case, all of the traffic lights were function well. According to the list of rules as tabulated in Table 4, rule 12 showed the de-fuzzified output of 0.05 where this classification can be considered as NORMAL condition. For another case scenario, the intensity of all traffic lights in OFF condition is 0 lumens. It means that the traffic lights are all malfunction. When this happens, the classification is weighted as 0.217 that is HIGHLY-CRITICAL condition.

All cases as described previously only valid for 1 direction of the traffic light system. However, a similar classification approach to the other direction also demonstrates comparable results if the input testing has the same value within the range of intensity as discussed above.

After classification in Module 1 is complete, the output signal from this module will be assign as input for Module 2. The input will classify 2 sides of the traffic light. In this module, four conflict area states is selected that is based on analysis from road user behavior. In this scenario, each side of the traffic light is put side by side; example the traffic light of north side is compared to traffic light of east side. There is no comparison between the west and east or north and south. This is due to the assumption that any fault that occurred between both of the direction, the vehicles still can be drive in straight line since no crossings within the vehicles. There are 16 rules for this module. After the rules are setups for controller in this module, the controller is tested with dissimilar cases based on output form the Module 1.

Journal of Theoretical and Applied Information Technology
31st December 2011. Vol. 34 No.2

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Table 4. Classification of the Module 1

If (Rule)	Intensity of Input 1 (Green) (lumens)	Intensity of Input 2 (Red) (lumens)	Intensity of Input 3 (Yellow) (lumens)	Classification
1	1500	3000	3000	0.217
2	3000	1500	3000	0.217
3	3000	3000	1500	0.217
4	1500	1500	3000	0.517
5	1500	3000	1500	0.517
6	3000	1500	1500	0.517
7	1500	1500	1500	0.8
8	0	3000	3000	0.217
9	3000	0	3000	0.217
10	3000	3000	0	0.217
11	0	0	0	0.217
12	3000	3000	3000	0.05

As tabulated in Table 5, the case of which each side of the traffic light will be in CRITICAL condition occurs when the weight is 0.5. It is categorized as case 1. The output will trigger a CRITICAL condition, when weighed is 0.517. For the second case, the input for both side of the traffic light will be in HIGHLY-CRITICAL condition with 0.75 weights. As the result, the output classification will also trigger HIGHLY-CRITICAL condition with 0.8 weights. When this case happens, the traffic at the junction will be highly congested. Thus, the possibility of accident is very high. The rule number 16 showed the HIGHLY-CRITICAL case when this take place. Another case is when each side of the traffic light will be in NON-CRITICAL case with weighted of 0.2 and the output of the classification will confirm rule number 6 will be applied. The rule weighted is 0.217 which represents NON-CRITICAL condition. For the last case, the input for each side of the traffic light is in NORMAL condition with weight of 0.05. When it occurs, the output will show a NORMAL case too. It means that each side of the traffic light is functional perfectly. Therefore, the output of the classification will show with NORMAL case. The summary results of other cases for the controller testing in the Module 2 as shown in Table 5.

The last stage in this module is comparison from the two states that are from North direction or South direction. Each direction is compared which signifies the most serious fault from two conflict direction. The maximum value from these two comparisons is send to the output signal which is later gives the fuzzy classifier status of overall system. The signal of fuzzy status classifier will be sending to control room or person in charge via Short Message Service (SMS) or telephone to take immediate corrective actions. This invention would be the best instantaneous solution to ensure all traffic lights are repaired immediately in making sure the road accidents at junctions could be reduced drastically.

4.2 A Fuzzy-fault classifier system testing via simulation

The malfunctions of traffic light based faulty indicator factor are chosen randomly to test the overall fuzzy-fault classifier system. All 12 inputs which represent the bulb of traffic light for each color are randomly setting using the different value of intensity such as OFF, DIM and BRIGHT condition. The input was set according to the Table 6.

Since there are a huge possibility of traffic light fault could occur, therefore only selected conditions are testified. For each condition, the simulation time is 0.1seconds and the total simulation is 1.2seconds for 12 conditions. From 0-0.1s, the entire traffic lights are in good condition where all traffic lights are in working order. After 0.1s, the entire traffic lights are in DIM condition. After that, all of the traffic lights are in OFF condition for the next 0.1s. The other inputs will be set according to the condition that has been set in the Table 6.

Journal of Theoretical and Applied Information Technology
31st December 2011. Vol. 34 No.2

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Table 5. Classification of the Module 2

IF (Rule)	Classification: Input 1	Classification: Input 2	Classification: Output
1	0.05	0.05	0.05
2	0.05	0.2	0.217
3	0.05	0.5	0.517
4	0.05	0.8	0.8
5	0.2	0.05	0.217
6	0.2	0.2	0.217
7	0.2	0.5	0.517
8	0.2	0.8	0.8
9	0.5	0.05	0.517
10	0.5	0.2	0.517
11	0.5	0.5	0.517
12	0.5	0.8	0.8
13	0.8	0.05	0.8
14	0.8	0.2	0.8
15	0.8	0.5	0.8
16	0.8	0.8	0.8

Table 6. The traffic light which was in fault condition that has been randomly chosen

Times (s)	Condition	Input
0-0.1	All BRIGHT	-
0.1-0.2	All DIM	G_N, R_N, Y_N, G_E, R_E, Y_E, G_S, R_S, Y_S, G_W, R_W, Y_W
0.2-0.3	All OFF	G_N, R_N, Y_N, G_E, R_E, Y_E, G_S, R_S, Y_S, G_W, R_W, Y_W
0.3-0.4	1 DIM	G_N
0.4-0.5	1 OFF	R_W
0.5-0.6	2 DIM	R_E, Y_S
0.6-0.7	2 OFF	R_N, G_W
0.7-0.8	3 DIM	G_E, Y_E, R_S
0.8-0.9	3 OFF	Y_N, R_W, Y_W
0.9-0.1	4 DIM	G_N, Y_E, G_S, R_W
0.1-0.11	4 OFF	Y_N, G_E, R_E, R_S
0.11-0.12	DIM at 1 side	G_N, R_N, Y_N

A set of square wave input to the system is illustrated in Figure 7. All inputs are shown below; it is in square wave for each condition in 0.1s period. The input as shown in below is for the input of G_N. During the 0-0.1s, the G_N is in ON condition, which the intensity is 3000 lumens. The G_N is in DIM condition during 0.1s-0.2s which the intensity is 1500 lumens. For the next 0.1s, the G_N is in OFF condition; therefore the intensity is 0 lumens. The input of G_N is as shown in Figure 8 below according to the condition that has been set initially. The simulation of the input will be in the 1.2s. The other inputs will be set according to the condition that has been set as tabulated in Table 6. In the Module 1, the comparison based on faulty indicator for each bulb in the four directions is compared and output for each direction also shown in this Figure 8. The output characteristics for each direction was depend on the rules that had been set in the fuzzy rules.

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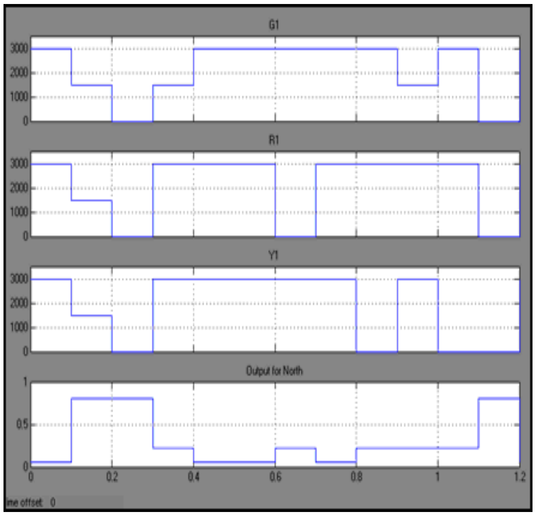
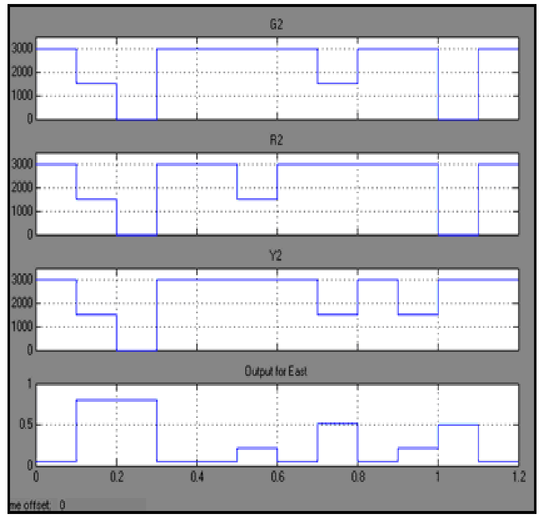
31st December 2011. Vol. 34 No.2

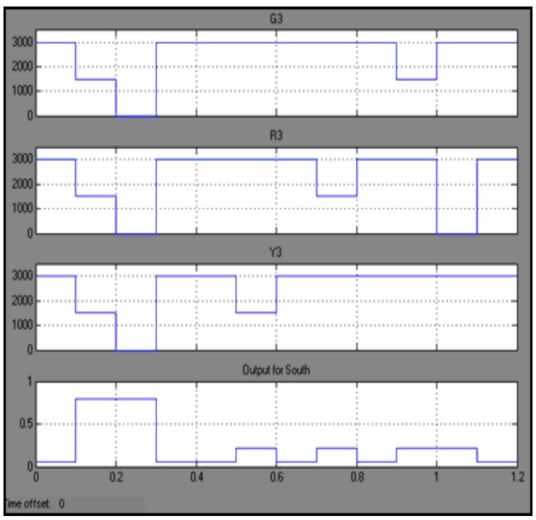
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195



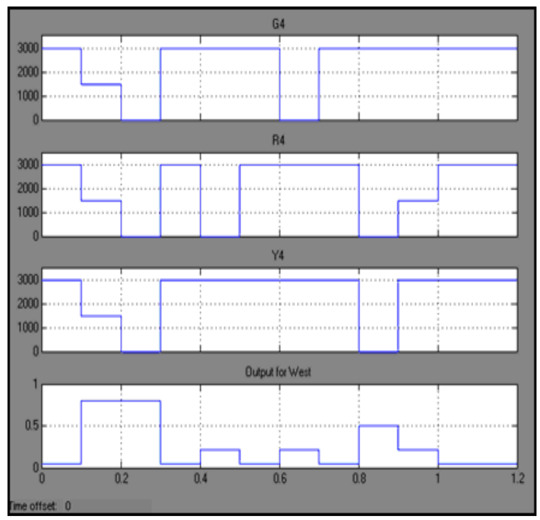
North Direction



East Direction



South Direction



West Direction

Figure 8. Input and output signal for classification of Module 1

For Module 2, the output for second classification is shown in Figure 9. In this module, there are four states classification which is one state classification is a comparison of two conflict direction. As shown in the graph, 0.8 means that it is HIGHLY-CRITICAL condition. However, if the graph shows 0.05, it means that it is NORMAL case. As the value become higher, it means that the condition of the traffic light is getting serious.

After the comparison between the 2 sides of the traffic light system, a comparison that involved of north direction for north whiles a comparison that involved of south direction for south. The results are shown in the Figure 10**.** For similar reason, the output characteristics for the north or south direction prompted the most serious case as the output. Again, the output is obtained from the most serious cases. Finally, the output of the whole system is shown in Figure 11, it can be noted that the output is in the range of 0.5 to 0.8, which means that the results are in critical or HIGHLY-CRITICAL cases. Since the setup of fuzzy-fault classifier system used in this design is the similar, therefore, the seriousness of the traffic light system will also depend on the most serious case from the Module 1.

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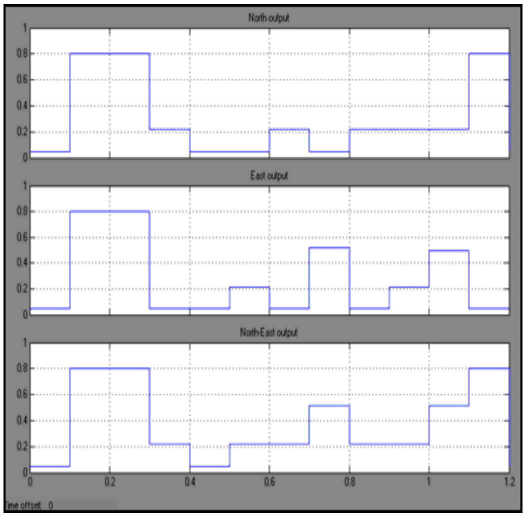
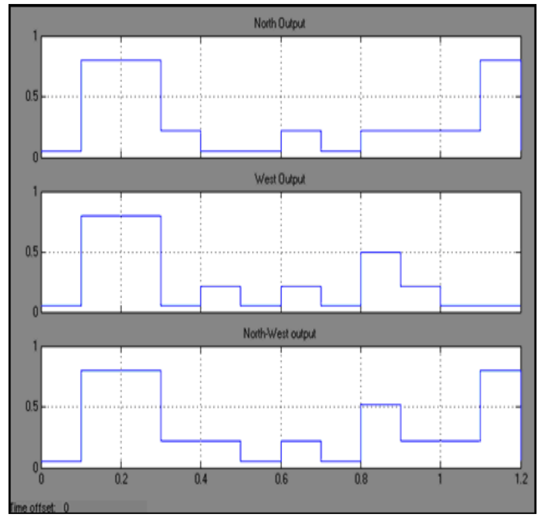
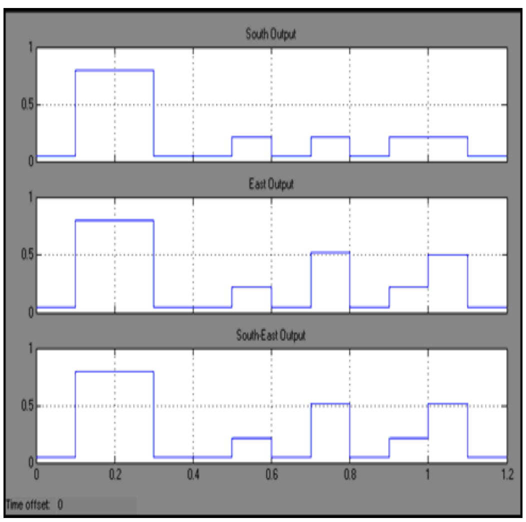


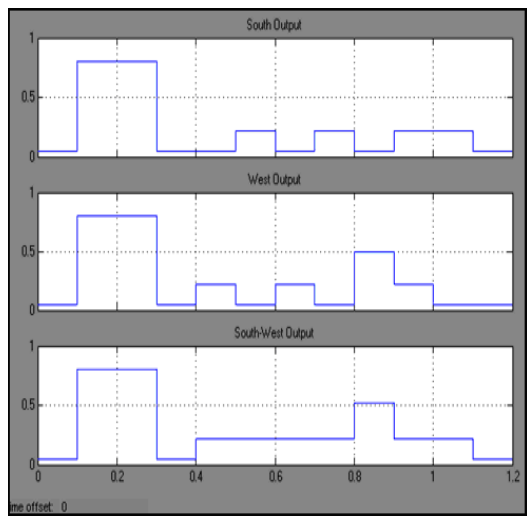
State 1: North-East



State 2: North-West



State 3: South-East



State 4: South-West

Figure 9. Input and output signal for classification of Module 2(Stage 1)

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31st December 2011. Vol. 34 No.2

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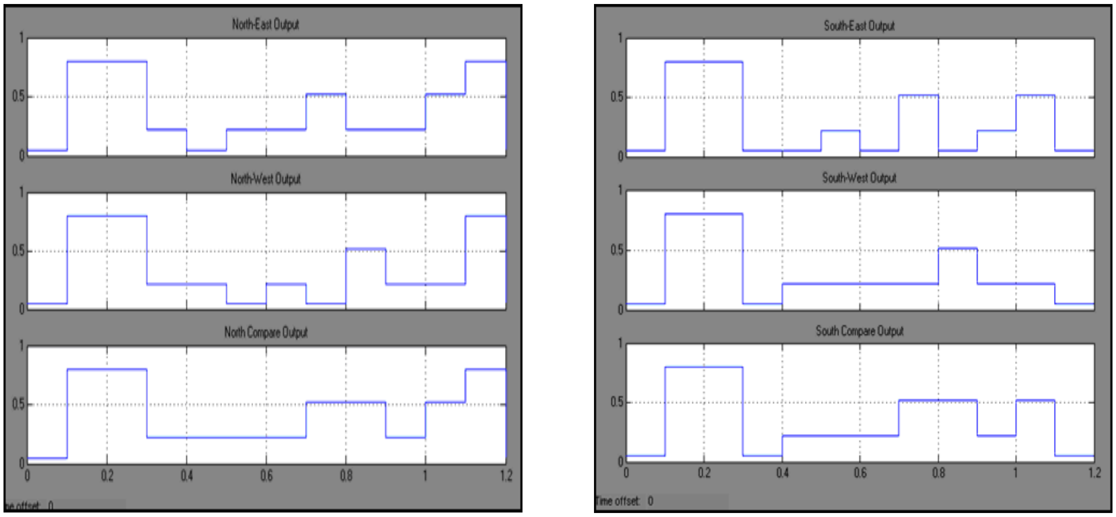

North South

Figure 10. Input and output signal for classification of Module 2(Stage 2)

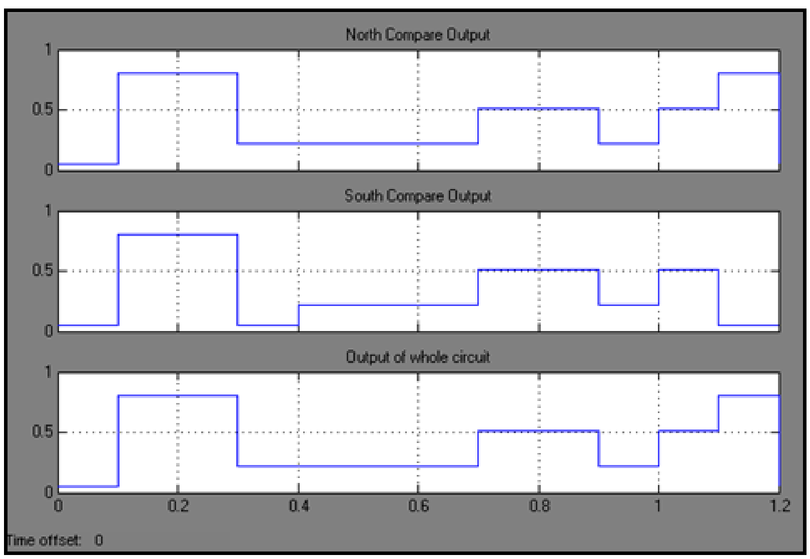

Figure 11. Output signal of fuzzy classifier for overall system

5. CONCLUSION

The malfunction of the traffic light system operation can cause major problem at the intersection. Therefore, an intelligent of fuzzy-fault classifier system has been successfully designed by using the fuzzy technology. The simulation results showed that this system has successfully implemented and testified the theory of fuzzy. The outputs for different cases are all as predicted. Also, the result showed that fuzzy-fault classifier system based on fuzzy technology is more efficient because it has a feature that simplifies the classification description. With the development of fuzzy-fault classifier system, it is expected that number of road accidents due to malfunctioning of traffic lights can be brought down rapidly. This system also ensures the contractors and authority department to carry out their task instantly without delay.

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