Traffic Light Regulatory System Based on Fuzzy Algorithm Using Microcontroller

Abdul Latif1, Prisma Megantoro2

1Department of Electrical Engineering, [Universitas Muhammadiyah Yogyakarta]
2Department of Electrical Engineering and Information Technology, [Universitas Gadjah Mada]

*4bdullatif_te@umy.ac.id

Abstract. Basically, control system for traffic lights only perform control based on a fixed time. In fact, the arrival rate of vehicles at the intersection of the road is not always the same so of course congestion at the crossroads can not be controlled. This study presents a simulation control system which can perform automatic traffic light control based on vehicle arrival rate. In this control, the duration of the flame is not constant but follows the arrival rate of vehicles. The method used to control the flame duration is fuzzy logic algorithm with the Mamdani fuzzy reasoning using Matlab software. Test results based on the simulation of fuzzy logic in fuzzy MatLab toolbox show that the fuzzy logic algorithm can be used to meet the goal of optimal traffic control, the duration of a given time based on the arrival rate of vehicles. The higher rate of arrival of the vehicle, the longer the duration of a given time, and the lower rate of the arrival of the vehicle, the more briefly given time duration.

1. Introduction

With the rapid development of technology, especially in the field of motor vehicles [1], various kinds of vehicle technology were created to facilitate humans in carrying out all forms of activity. One of the problems that will arise due to the increasing number of motorized vehicles [2] is traffic congestion due to the undisciplined motorists in traffic. The congestion that arises can be caused by several factors, one of which is the traffic lights that are not good [3].

One solution to the above problem is to create a traffic light control system that can automatically adjust to the number of vehicles coming from each lane. The system of setting the duration of the lights will follow changes in the level of arrival of vehicles at each lane crossing. Lines that have a denser vehicle volume will get longer lights, which will reduce the arrival rate for congestion.

2. Methodology

The focus of the research in this article consists of 2 parts, namely the design of fuzzy algorithms [3] – [4] and their implementation on a microcontroller [5].

A. Fuzzy logic [6] – [11]

Fuzzy logic is an appropriate way to map an input space into an output space. Fuzzy is expressed in the degree of membership and the degree of truth. Fuzzy logic imitates the way of human thinking by using the concept of the disguised nature of a value. The concept of fuzzy logic was first introduced by
Professor Lotfi A. Zadeh from the University of California, in June 1965 to express groups / sets that could be distinguished from other sets based on the degree of membership with unclear boundaries (vague), unlike the classical set that distinguishes the membership of the association becomes two, the membership of members or non-members.

Fuzzy Inference System (FIS) [10] – [13] is a computational framework based on set theory, IF-THEN fuzzy rules and fuzzy reasoning. The Mamdani inference method uses the fuzzy membership function in the output section. So after the rule process has been applied, there is a fuzzy set that must be defuzzified. Generally the defuzzification process takes place more slowly due to the computational process at its output and to get the output it takes 4 stages namely:

1) Formation of fuzzy sets. In the fuzzification process, the first step is to determine the fuzzy variable and the fuzzy set.
2) Application function implications on the Mamdani method. The implication function used is min.
3) Composition of Rules. The inference method used is the max method.
4) Defuzzification.

B. Microcontroller ATMega16 [14] – [16]

The ATmega16 microcontroller [17] – [19] used in this study is a microcontroller output from Atmel Corporation. This type of microcontroller is included in the type of AVR (Alf and Veg's Rise processor). The AVR microcontroller has an 8-bit RISC architecture, where all instructions are packaged in 16-bit code and most instructions are executed in one clock cycle. This difference occurs because of different architectures, AVR already uses RISC (Reduced Instruction Set Computing) technology while MCS51 uses CISC (Complex Instruction Set Computing) type (Atmel Corporation, 2010).

AVR also has an On-System Programmable Flash on-chip that allows program memory to be reprogrammed in the system using the SPI serial link. In addition, ATMega16 has a throughput of close to 1 MIPS per MHz so that system designers can optimize power consumption and process speed (Datasheet ATmega16) [20] – [23].

The features of ATmega16 [24] – [27] are:
8 KBytes Flash Program, 512 Bytes EEPROM, 512 Internal Bytes SRAM, 2 Timer 8 bit and 1 Timer 16 bit, Analog to Digital Converter (ADC) and USART.

3. Implementation

The design and manufacture of this simulation tool consists of two parts, namely hardware and software.

![System block diagram](image-url)
A. Hardware design

The hardware design consists of miniature mechanics for simulation of crossing traffic (Figure 2), ATmega16 microcontroller, 7-segment BCD (Binary Code Decimal) circuit, comparator circuit with infrared sensors and other supporting components. The components used are shown in the system block diagram in Figure 1. While the schematic circuit system is shown in Figure 3.

![Figure 2. System prototype or miniature](image)

![Figure 3. Overall system hardware schematic](image)
B. Software design

The design of the software consists of the design of fuzzy logic control algorithms and the implementation of programming with C language.

![Program flow chart](image)

**Figure 4.** Program flow chart

The design of the traffic light system arrangement with fuzzy logic in this study is shown in Figure 4.

1) Vehicle detection

In this step, infrared sensors are used to detect the arrival of vehicles entering the intersection through certain pathways. The sensors used are 1 piece in each lane.

2) Input processing

The input processing stage includes signal conditioning and initialization of the microcontroller port.

a) Signal conditioning

This process uses a comparator circuit as a signal conditioning circuit with LM324 IC. LM324 is an IC Op-Amp (Operational Amplifier) that is used to amplify the signal from the detection sensor.

b) Port initialization

The results of each signal conditioning process become input for ATmega16. Therefore, the operation needs to be set to determine which ports and pins of the ports are available to function as input and as output.

3) Fuzzification

Fuzzification [28] – [31] is a process carried out to change real variables (crisp) into the form of fuzzy variables. It is intended that the fuzzy controller [32]–[35] input can be mapped to the type that matches the fuzzy set. In this study the triangular and trapezoidal type membership functions are used due to
simple and efficient computerization. Table 1 [35] – [38] shows the fuzzy variables and sets used

| Function | Variable | Set     | Domain      | Member function |
|----------|----------|---------|-------------|-----------------|
| **Input**| **Counts**| Least   | [0.3]       | Left arm        |
|          |          | Less    | [1.5]       | Triangle        |
|          |          | Normal  | [3.7]       | Triangle        |
|          |          | Many    | [5.9]       | Triangle        |
|          |          | Very much| [7.10]      | Right arm       |
| **Counts change**| Greatly decreased | [-10,-3] | Left arm |
|          | Decreased | [-6,0]  | Triangle    |
|          | Constant  | [3,3]   | Triangle    |
|          | Increased | [0,6]   | Triangle    |
|          | Greatly increased | [3,10] | Right arm |
| **Output**| **Time**| Very briefly | [5,12] | Left arm |
|          | Briefly  | [7,17]  | Triangle    |
|          | Medium   | [12,22] | Triangle    |
|          | Long     | [17,27] | Triangle    |
|          | Very long| [22,30] | Right arm   |

This process utilizes the reading of data from an infrared sensor which is then processed with the following calculation.

\[ \text{Counts change} = \text{counts} - \text{previous} \] (1)

Counts is the number of vehicles detected, while the time is taken from the results of fuzzy processing in Matlab. The fuzzy logic input set is shown in Figure 5 and Figure 6.
Figure 6. Fuzzy set from input Counts change

The output set is a representation of the results of the fuzzy logic of decisions in the form of variations in the time value for each path. The set for fuzzy logic output is shown in Figure 7.

Figure 7. Fuzzy set from output Time

4) Inference system

Inference here can also be referred to as the application of function implications. In this study the Mamdani method was used. The determination of the basis for fuzzy logic rules is based on experience and is arranged in the form of If-Then reasoning. The inference method used is the min-max method. The reasoning system is written in a FAM (Fuzzy Associative Memory) table which is shown in Table 2.

| Counts | Input                |扁平 | 减少 | 常数 | 增加 | 非常增加 |
|--------|----------------------|-----|------|------|------|---------|
| Least  | Very briefly         | 非常增加 | 非常增加 | 非常增加 | 非常增加 | 非常增加 |
| Less   | Very briefly         | 检查 | 检查 | 检查 | 检查 | 检查 |
| Normal | Briefly             | Medium | Medium | Medium | Long |
| Many   | 长                       | 长 | 长 | 长 | 长 | 非常长 |
| Very much | 非常长                 | 非常长 | 非常长 | 非常长 | 非常长 | 非常长 |
From Table 2, 25 fuzzy rules can be made that are used in the inference process. The basis of these rules is shown in Table 3.

Table 3. Fuzzy basic rule

| No. | Rule |
|-----|------|
| 1   | If (counts is least) and (Counts change is greatly decreased) then (Time is very briefly)(1) |
| 2   | If (counts is least) and (Counts change is decreased) then (Time is very briefly)(1) |
| ... | ... |
| 25  | If (counts is very much) and (Counts change is greatly increased) then (Time is very long)(1) |

5) Defuzzification

Defuzzification is the process of converting fuzzy output to crisp output. Defuzzification results are used to set the length of time for each path. The defuzzication method used is the Center of Gravity (COG).

6) FIS simulation

![Figure 8. FIS Simulation test.](image)

The first column in Figure 8 shows the level of enumeration membership in the enumeration variable, the second column shows the membership level of the enumeration change in the enumeration change variable, and the third column shows the consequences of the implication function that is in accordance with the conditions rule.

4. System test

In this research, the process of changing the traffic lights starts with the initial conditions of the green lights flashing on lane 1 and the red lights on lanes 2, 3 and 4. The traffic lights change continuously and work like traffic lights under actual conditions. The testing step can be explained as follows:

1) The initial condition is to turn on the green light on line 1 and the red light on the other line with 7-segment showing the number 60 seconds for the red light is on, 17 seconds for the green light is on and 3 seconds for the yellow light is on. When the yellow light is on, 7-segment is not activated
only the light is on, for the 7 segment countdown display is turned off.

2) The automatic adjustment condition is when the red light is on one of the lanes and detects the arrival of the vehicle in the first cycle (counts) and the second cycle (changes in counts). So that the green light on the second cycle depends on the number of detection of arrival in the first cycle and second cycle. For the duration of the red lights on each path will adjust to the green lights.

3) The infrared sensor will provide logic 0 when it detects an object (active low) and stores it in the register of each predetermined path. Thus, when the path will get a green light turn, the microcontroller can process how long the green light will be issued on the path.

| Lane number | Counts | Counts change | Time (second) |
|-------------|--------|---------------|---------------|
| 1           | 7      | 3             | 22            |
|             | 3      | -4            | 8             |
|             | 3      | 3             | 12            |
|             | 5      | -1            | 17            |
| 2           | 6      | -5            | 16            |
|             | 3      | -3            | 7             |
|             | 8      | 5             | 24            |
|             | 4      | -4            | 13            |
| 3           | 2      | 0             | 10            |
|             | 5      | 3             | 17            |
|             | 4      | -1            | 13            |
|             | 9      | 5             | 27            |
| 4           | 2      | -5            | 10            |
|             | 3      | -1            | 11            |
|             | 7      | 4             | 22            |
|             | 10     | 3             | 27            |

From the test results in Table 4, it appears that the system is able to produce an output in the form of a green time that varies depending on the size of the existing input. This shows that the fuzzy control system can adjust the output state in the form of the length of the green light is in accordance with the number of vehicles coming in a lane.

The input value is the number of arrival detections on the line with any value that is between 0 to 10. The process of detecting (scanning) the arrival input on the count is done in a red light, after the red light goes out the detection process will reset and the detection value will be stored in the microcontroller. This work process also applies to the detection process to produce changes in the counts.

The results of the detection process at the count and the change in the count are when the green light is on. The length of time a green light is on in a path depends on the amount of density in the count and the count change. The greater the amount of density in a lane, the longer the green light in the lane.

5. Conclusion
The traffic light control system using the fuzzy logic algorithm based on the Mamdani method gives the value of the length of time the green light is on depending on the number of arrivals of a path in the first cycle and second cycle of lights. The greater the number of arrivals in a path, the longer the green light is on the path, and vice versa. A traffic light system with a fuzzy logic algorithm is more effective than a conventional traffic system. This is because the traffic control system with fuzzy logic algorithm can adjust to the arrival that is happening at a crossroads. This is different from the conventional traffic light control system which is a system with a predetermined cycle time.
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