Simulation of Dynamic Traffic Light Setting Using Adaptive Neuro-Fuzzy Inference System (ANFIS)

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Abstract. Traffic congestion is a common problem in so many big cities. The occurrence of traffic congestion can be caused by various reasons, one of which is the increasing number of vehicles while the available facilities are not worth the amount. Congestion can cause many losses, including the amount of time wasted and spent fuel in vain. To solve the problem of congestion, it can be solved by building a new road. But the solution will make the environment more crowded and require more operational costs. Due to this reason, there is a good solution given that the renewal of the traffic control system by building intelligent traffic light control system based on road density at each traffic intersection and the width of the road. The method used in this research is Adaptive Neuro-Fuzzy Inference System (ANFIS), this method will process the data of road density and road width to determine the duration of green light to be given. The road density will be calculated based on the video that will be captured by the system and will go through the pre-processing and processing stages until the labelling stage of the object on the road using the Connected Component Labelling (CCL) method, the image pixel of this CCL result will be compared to the image of the empty road condition (no vehicles) to get the percentage of road density. The system testing process used 36 images captured from the video and obtained the accuracy of 98.6%.

1. Introduction
Traffic congestion is a common problem in many developed and developing countries, especially in big cities. It also happens in the Republic of Indonesia, especially in Medan, which is one of the major cities in the country. The occurrence of traffic congestion can be caused by various things, one of which is the increasing number of vehicles while the available facilities are not worth the amount. Congestion can cause many losses, including the amount of time wasted and spent fuel in vain. To solve the problem of congestion, it can be solved by building a new road. But the solution will lead to new problems that make the environment more solid and require more operational costs. Due to this reason, it is a good solution given that updating the traffic control system by building intelligent traffic light control system based on road density at each traffic intersection. The benefits that can be gained from building such a system...
are fewer operational costs and do not make the environment more solid. Currently, traffic lights in Medan city already use dynamic timer based on road density. But the road density is still reported by field officers who are at a traffic light intersection.

In this research, Adaptive Neuro Fuzzy Inference System (ANFIS) is proposed to process density and road width data to determine the duration of green light and Connected Component Labelling (CCL) method to determine the object on the road. Several studies related to traffic light arrangement include traffic light arrangement using Fuzzy Inference System (FIS) Tsukamoto method on traffic light simulation by processing road density and road width in manual input [1]. The next research is determining the duration of green light by comparing empty streets with road conditions there is a vehicle using image processing techniques [2]. The next study was a traffic light simulation showing the duration of the green light based on vehicle volume and road width, the value in the input manually, the method used is fuzzy logic [3]. Furthermore, traffic lights are discharged using Adaptive Neuro Fuzzy Inference System (ANFIS) based on street density alone [4]. The next research was to control the traffic light using Fuzzy Logic Control Sugeno Method [5] and prediction of rubber milk production using ANFIS [6].

2. Problem Identification
Congestion often occurs at crossroads, especially in big cities, especially during rush hours and causes many new problems, including wasted time and fuel wastage. For that we need a system that can dynamically control the flow of traffic so that the vehicle can move smoothly and no vehicle accumulation at the intersection of the road.

3. Methodology
The proposed method for simulating traffic light settings dynamically consists of several stages. The first is the data collection of road conditions around the traffic light (data in the form of video recording of road conditions). Road image capture when there is no vehicle or empty. The image of this empty road will be a comparison with the road conditions when there is a vehicle later. This empty road image will be processed in several stages as in figure 1. And for video data of street console will become system test data, the system will perform automatic capture from video, image of capture result will be processed using image processing with some stages like in figure 1. When the object in the test image has been obtained, will calculate the density of its road by comparing the image of the empty road that has been in if before, the data of road density and width of this path will be input for ANFIS to determine the duration of green light to be given. A general architecture that describes the stages for simulating dynamic traffic light settings as shown in figure 1.
Figure 1. General architecture.

Stages for empty streets:

3.1. Input
- ROI image
  ROI image is an image of empty road conditions. This image will be used as a comparison of road conditions that have vehicles on it to produce a percentage of road density with a resolution of 360 x 240 pounds. Example of ROI image as in figure 2.

3.2. Pre-processing
- Segmentation
  After image ROI selected next stage that is segmentation which aims to produce binary image by using thresholding process. Result of image ROI segmentation as in figure 3.

  - Canny Edge detection
    The next stage is edge detection using canny edge detection, which aims to clarify the edge of the line from the previous image segmentation, the result of edge detection as shown in figure 4.

3.3. Processing
- Hough transform
  After canny and line edge stages have been obtained, then use Hough transform. In this process will be obtained straight lines that will be used as a barrier area to determine the area of the road that will be used.

  - Hough transform selection
    After the Hough transform stage, the system has mapped the straight lines of all objects present in the image that can be seen in figure 5. The next stage is Hough transform selection that serves to determine the object that becomes the highway. In this process will be determined the boundary of the highway. The result of this process as in figure 6.
• Elimination
After the Hough transform selection stage, the final stage is elimination. This stage serves to remove other objects outside the boundary of the red line so that will only remain the position of the highway as in figure 7.

Stages for test images are captured automatically from the video system of street conditions.

3.4. Input image
The input image is obtained from video capture of road conditions at traffic lights that can be seen in figure 8. Subtraction aims to eliminate or reduce certain parts of an image. In the subtraction process in this system, some parts of the input image will be omitted or subtracted, the removed portion adjusted to the elimination image when the road state is empty.

3.5. Pre-processing

• Grayscale and threshold
After the subtraction process is complete, the next process is grayscale and threshold. The image in figure 9 will be converted into a gray image with a threshold value of 128 to produce a brighter object than its background that can be seen in figure 10.

• Morphology (opening and closing)
The morphology of the opening process is useful for refining the contours of objects and eliminating all pixels in areas too small to be occupied by the structural elements. And the closing morphology process is useful for smoothing contours and eliminating small dots on previous binary images. The result of the morphological process as in figure 11.

3.6. Processing

• Connected Component Labelling (CCL)
The next stage is the Connected Component Labelling that serves to classify the object and region in the image as shown in figure 12. The region to be classified is the region whose pixel object or region is connected or connected.

3.7. Result
The last process is the process of Labelling objects that have been classified in the previous process. For objects that have been identified will be given a red box label. An example of the result is as shown in figure 13.

• Calculation of road density
The process of calculating the density of the road by calculating and comparison of pixels between the image of the elimination result (image of empty road condition) as in Figure 7 with image that has been through several stages until the image is given Labelling object. Both images will be compared to their pixels to calculate the percentage of road density in the test image.

• Calculation duration
When the percentage of road density is obtained, the density value will be processed using Adaptive Neuro-Fuzzy Inference System (ANFIS) plus the width parameter of the path. ANFIS will do the calculation and check to fuzzy rule to get the duration of green light to be given.
The following images to describe the above stages are:

**Figure 2.** ROI image.

**Figure 3.** Image of segmentation results.

**Figure 4.** Image of edge detection result.

**Figure 5.** Image of Hough transform result.

**Figure 6.** Image results Hough transform selection.

**Figure 7.** Image of Elimination result.

**Figure 8.** Input image subtraction.

**Figure 9.** Image of subtraction result.

**Figure 10.** Image of grayscale and threshold results.

**Figure 11.** Image of morphological results.

**Figure 12.** Image of CCL results.

**Figure 13.** Image labelling results.

### 4. Result and discussion

At this stage will be tested for the system. System test results as in table 1.

Information:

- \( S \) = Intersection
- \( P \) = Percentage of road density
- \( L \) = Road width (meters)
- \( D \) = Green light duration provided (sec)

| No | \( S \) | \( P \) | \( L \) | \( D \) |
|----|--------|--------|--------|--------|
| 1  | 1      | 14,6\% | 3      | 24     |
| 2  | 1      | 17,46\%| 3      | 25     |
| 3  | 1      | 15,12\%| 3      | 24     |
| 4  | 1      | 20,25\%| 4      | 24     |
| 5  | 1      | 20,4\% | 4      | 24     |
| 6  | 1      | 17,3\% | 4      | 23     |
| 7  | 1      | 8,66\% | 5      | 18     |
| 8  | 1      | 15,52\%| 5      | 21     |
| 9  | 1      | 5,23\% | 5      | 17     |
| 10 | 2      | 24,6\% | 3      | 28     |
From the application that had already been built, the results of the effectiveness of detecting the correct labelling objects showed in figure 14 the error labelling object showed in figure 15.

| No | S  | P     | L | D |
|----|----|-------|---|---|
| 11 | 2  | 8,8%  | 3 | 21|
| 12 | 2  | 4,7%  | 3 | 20|
| 13 | 2  | 0,81% | 4 | 16|
| 14 | 2  | 5,97% | 4 | 18|
| 15 | 2  | 26,17%| 4 | 27|
| 16 | 2  | 10,51%| 5 | 19|
| 17 | 2  | 22,8% | 5 | 23|
| 18 | 2  | 21,36%| 5 | 23|
| 19 | 3  | 96,01%| 3 | 52|
| 20 | 3  | 84,06%| 3 | 52|
| 21 | 3  | 96,74%| 4 | 53|
| 22 | 3  | 31,04%| 4 | 29|
| 23 | 3  | 61,53%| 4 | 43|
| 24 | 3  | 97,17%| 4 | 56|
| 25 | 3  | 70,28%| 5 | 43|
| 26 | 3  | 1,02% | 5 | 14|
| 27 | 3  | 97,77%| 5 | 57|
| 28 | 4  | 25,72%| 3 | 28|
| 29 | 4  | 19,94%| 3 | 26|
| 30 | 4  | 11,84%| 3 | 23|
| 31 | 4  | 23,58%| 4 | 25|
| 32 | 4  | 1,98% | 4 | 17|
| 33 | 4  | 29,86%| 4 | 28|
| 34 | 4  | 11%   | 5 | 19|
| 35 | 4  | 17,29%| 5 | 21|
| 36 | 4  | 17,18%| 5 | 21|

From the application that had already been built, the results of the effectiveness of detecting the correct labelling objects showed in figure 14 the error labelling object showed in figure 15.

Figure 14. Correct labelling results.
Based on the results of the test data in table 1, the performance of Connected Component Labelling (CCL) at the image processing stage in determining vehicle density on the highway is calculated using precision and recall calculations. Precision is the level of accuracy of information requested by the user to the system and recall is the success rate of the system in rediscovering the information.

### Table 2. Calculation of system work.

| TP | TN | FP | FN | Precision | Recall |
|----|----|----|----|-----------|--------|
| 33 | 35 | 1  | 1  | 0.972     | 100%   |

\[
F - Score = \frac{(Precision + Recall)}{2} = \frac{(97.2 + 100)}{2} = 98.6\%
\]

Based on Table 2, the value of precision is 97.2% and recall 100%. From the results of these two values can be calculated system performance by using the value of f-score. The f-score value is the accuracy value used to declare a system has worked effectively or not. The f-score value generated by the calculation is 98.6%. With f-score value exceeding 50%, CCL performance can be considered effective, although several times in the testing process still found Labelling error that can affect the process of determining the duration of green light. Error Labelling in the sense that when there is no vehicle on the road, but the system still detects that on the road there is a vehicle with a label in the form of a red box, or when there is a vehicle on the road but the system is not able to detect it and do not provide a red box label.

In the system built using Adaptive Neuro-Fuzzy Inference System (ANFIS) in determining the duration of green light also work effectively. The duration of the given green light can change flexibly depending on the density of the detected path and the specified path width. Thus, it can be concluded that CCL and ANFIS use in dynamic traffic light regulation system can work well in vehicle detection and determination of green lamp duration required.

### 5. Conclusion

The conclusion that can be taken based on the result of the simulation system test of dynamically determining the duration of traffic light using Adaptive Neuro-Fuzzy Inference System (ANFIS) is as follows:
Adaptive Neuro-Fuzzy Inference System (ANFIS) method can determine the duration of green light to be given at traffic intersections dynamically based on the density and road width of 60 fuzzy rule data.

Connected Component Labelling (CCL) can determine the objects on the road by comparing pixels between empty roads and roads containing vehicles with a percentage of success of 98.6%.

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