Reducing a congestion with introduce the greedy algorithm on traffic light control

Puji Catur Siswipraptini, Wisnu Hendro Martono, Dian Hartanti
Informatics Department
Sekolah Tinggi Teknik PLN, Jakarta-Indonesia
Email : pujicatur@sttpln.ac.id; wisnuhendro@sttpln.ac.id; dianhartanti@sttpln.ac.id

Abstract. The density of vehicles causes congestion seen at every junction in the city of jakarta due to the static or manual traffic timing lamp system consequently the length of the queue at the junction is uncertain. The research has been aimed at designing a sensor based traffic system based on the queue length detection of the vehicle to optimize the duration of the green light. In detecting the length of the queue of vehicles using infrared sensor assistance placed in each intersection path, then apply Greedy algorithm to help accelerate the movement of green light duration for the path that requires, while to apply the traffic lights regulation program based on greedy algorithm which is then stored on microcontroller with Arduino Mega 2560 type. Where a developed system implements the greedy algorithm with the help of the infrared sensor it will extend the duration of the green light on the long vehicle queue and accelerate the duration of the green light at the intersection that has the queue not too dense. Furthermore, the design is made to form an artificial form of the actual situation of the scale model or simple simulator (next we just called as scale model of simulator) then tested. Sensors used are infrared sensors, where the placement of sensors in each intersection on the scale model is placed within 10 cm of each sensor and serves as a queue detector. From the results of the test process on the scale model with a longer queue obtained longer green light time so it will fix the problem of long queue of vehicles. Using greedy algorithms can add long green lights for 2 seconds on tracks that have long queues at least three sensor levels and accelerate time at other intersections that have longer queue sensor levels less than level three.

1. Introduction
Base on daily data of Kompas, data Departement Transportation of DKI in 2015, the number of vehicles in Jakarta is 5.4 million private vehicles, 84,891 vehicles with 9.5% growth this year. As more and more vehicles are increasing every year causing frequent traffic jams, especially on the road junction. Meanwhile, losses due to congestion are estimated to reach 12.8 trillion rupiah as measured by time, fuel and health. According to a traffic light survey at Grogol intersection, West Jakarta, at the intersection of Kedoya West Jakarta, at the junction of Pasar Baru Gunung Sahari, Central Jakarta, the Fatmawati road junction in South Jakarta can be inferred if there is an imbalance of volume, speed, time and length of queue compared to availability roads cause congestion that is difficult to solve.

This case study was conducted at the intersection of four matramans. The intersection of four matramans was chosen from the four intersections surveyed, at the intersection of four things that still apply conventional traffic light systems, not based on length of queue of vehicles, and also four intersections are one of four intersections Having vehicle density causing congestion due to queue of...
vehicles the long one. A special problem with traffic light crossings is the period of red and green lights that remain/does not change at any time/static and can only be changed green period and red/off by the operator. In solving the problem of vehicle density causing congestion will be used a model of smart traffic lights with Greedy Algorithm equipped with infrared detection sensor with Arduino Mega 2560 microcontroller as its processor, which allows reading the length of the queue of vehicles as a determinant of the Green light Time.

2. Literature Review
Researchers have been attempting to model a new algorithm in order to come up with the optimization of the traffic control. Control design such as a decentralized and self-organizing control strategy for a traffic signal network adapting to dynamical environmental changes based on only local traffic information [1], design of a new urban traffic control system which simulated the Ant Colony Optimization (ACO) based system as an adaptive path length and path traffic [2], a smart traffic control system based on the wireless sensor network [3] and an alerting system for red light crossing scenario to alert the drivers on other sides to save their lives based on the queue length of the vehicles on the traffic lights [4]. The studies in [5][6][7] pose the traffic signal control as an optimization problem such as a combination of reinforcement learning to maximize local traffic at each intersection and global optimization by Evolutionary Computational Method [5][8], minimization of the total delay experienced by all network traffic at each section in a given network using a dynamic programming technique [6] and adjustment of green period by reinforcement learning [7].

However, we have found no studies concerned with adjusting all the three parameters (cycle time, split and offset) based on the completely decentralized approach.

3. Research Method
The objective of this paper is designing traffic control management to obtain models of traffic control devices using Greedy Algorithm. This research is in the form of a model 4 arm -shaped intersection with 6 lanes consist of one lane bus way, 3 fast lane, 2 slow lane. In this paper, first we describe the real data involving such kind of some intersection in Jakarta to intents model, second we describe a kind of a board model of traffic light with some detector, while the detector output will be used as a computer model. Output from a number of bound detector will race with other adjacent output detector in the same intersection. The first process analyzed with TSP algorithm to get light exchange in normal condition and the second analyzed with Greedy algorithm to get up normal time condition in order to win the race (scheduling). And the third, we develop intersection traffic light control system with 6 lanes consist of one lane busway, 3 fast lane, 2 slow lane according the model analyzing TSP and Greedy algorithm.

Based on the description above, a design of smart traffic light that has an infrared sensor as a control system for the adjustment based on the density of vehicles the roads is required. It is expected that traffic control system will be well-adjusted with the density that is detected by the infrared sensor at every intersection. This smart traffic light system is not constant (real-time) and will be followed by changes of the density of the vehicles at the intersection. This sensor sends traffic density input to controlling unit, according to these input traffic pole timer works. [9]. The principle of the control system at traffic lights will be using infrared sensors as a vehicle density level control system with media control utilizing AVR microcontroller ATmega16, because this microcontroller is able to access program and data simultaneously. The algorithm used in this design of smart traffic light is a greedy algorithm that is expected will be able to determine which path has the longest time delay and which path has the shortest and it will purposely prevent and decrease bottlenecks in order to increase the effectiveness of the traffic lights. The design of smart traffic light system is going to reduce the number of traffic/bottlenecks that usually happens at crossroads/intersection with the design that is very dynamic and real-time (duration of green light is adjusted with density of vehicles on the roads).
Figure 1. The graph of greedy algorithm and tsp

Generally traffic lights are located at the crossroads such: T Junctions, Multi Junction, etc that is why a mechanism to control the sequences of each lamp is required in order to prevent a congestion and colliding. Travelling Salesman problem above could be solved with the Greedy Algorithm [10]:

\[
g(j, j+1) = 1, \ \text{for} \ j = 1, \ldots, m - 1 \\
g(m, 1) = M \ (\text{for some large number } M) \\
g(j, k) = 2, \ \text{otherwise Optimal trip as shown in Figure 3} 
\]

Figure 2. Travelling salesman problem

Figure 3. Optimal trip

The solution of Greedy Algorithm is in figure 4

Figure 4. Greedy algorithm optimal solution
4. System Architecture

Our research has the concept of a traffic light regulation system based on dynamically operating greedy algorithm, meaning the green light on this traffic system is based on the length of its queue of vehicles at each intersection. If the intersection is not queue of vehicles, then the traffic light at the intersection operates normally, otherwise if at the intersection there is a long queue, resulting in the duration of the green light increases more. To find out the length of the vehicle queue on the models is read from the infrared sensor.

In the scale model of simulator device that is built equipped with five sensors equipped and installed equipment within a distance of 0 cm - 10 cm, and 10 cm - 25 cm for each intersection and two sensors dedicated to the busway lane. Placement of this sensor will be able to detect the length of the queue of vehicles that have been determined by researchers. The determination of the green light duration of the traffic system on the scale model of simulator not only on the queue difference, but also applied greedy algorithms that will increase the performance of traffic lights at the intersection.
4.1 Components diagram
Each components works as bellow:

- Car is an object to be detected by an infrared sensor.
- The infrared consist of a receiver and transmitter emits infrared light. If the light is blocked by an object, then the infrared as receiver will detect the object and the signal will be on. Arduino Mega 2560 microcontroller as the controller will process the input received from an infrared sensor, which will then be processed and applied to the greedy algorithm to be forwarded to the LED lighting circuit components.
- On the set of LED components, will accept the process of Arduino Mega 2560 and adding the application of greedy algorithm used as outputs. This output will set the length of time which the green LED was on.

5. Design of greedy traffic light simulator model
Design of greedy traffic light simulator model (GTLS) as shown in Figure 6, New traffic light scale model are built using Arduino processors and Greedy algorithms equipped with sensor devices, which provide a more accurate response.

![Figure 6. Diagram of research](image)

![Figure 7. A number of vehicle (traffic) simulation movement in the given time](image)

The measurement results with the scale model can be applied to a set of traffic lights that are applicable at the Matraman intersection. At each junction is given the value of five sensors that represent the distance each has been determined by the researchers
Table 1. Level sensor for distance

| Level Sensor | Distance (m) |
|--------------|--------------|
| 1            | 0 - 25       |
| 2            | 25 - 50      |
| 3            | 50 - 100     |
| 4            | 100 - 200    |
| 5            | 200 - 300    |

Table 1. represents the distance of each sensor. In GTLS, each sensor is provided with a distance of 10 cm. Only on the busway lane is equipped with a set of sensors, while on the path to another vehicle is equipped with four sets of sensors.

Figure 8 and 9 are design of GTLS which equipped with hardware devices include LED that are used as traffic lights, that are infrared sensors on each lane to detect the length of queues of vehicles simulators, Arduino Mega 2560 as mikrokontroller, and 20x04 LCD character to indicate the state of the traffic. The junction has a length of 50 cm, then the middle path length is 37 cm, total size scale model simulators is 137 cm x 137 cm.

6. Greedy algorithm for smart traffic light

The above flow chart is a flow of Greedy algorithm as a complement to smart traffic light processor. The sensor will read the traffic density and the data will be sent to Arduino. What is interpreted as a sensor reads the length of the vehicle queue, greater or equal to X.

- X is a sensor that is greater or equal to level three. Then the sensor puts the value into the resolution circuit, is there an N path in the solution set?
• N is a value greater or equal to the three that are in the set of solutions, then the next step is to add time to a green light like P.

P is the amount of time that will be added to the green light at the intersection that has a queue of vehicles on three or more sensors, and will reduce the green light time like P at another intersection. We can see in figure 10

![Flowchart](image)

**Figure 10.** Greedy algorithm for smart traffic light
7. Optimising traffic light control using greedy algorithm
The greedy algorithm yields an optimal solution, it proof show that for all $1 \leq j \leq m$ the following holds, there exists an optimal solution $S^*$ with [11]:

$$S^* \cap \{a_1, \ldots, a_j\} = S_i$$

$j = 1$:

Let $S^* \subseteq \{a_1, \ldots, a_n\}$ be some optimal solution, $S^* = (a_{j_1}, \ldots, a_{j_k})$

$$S^* = a_{j_1}, a_{j_2}, a_{j_3}, \ldots, a_{j_k}$$

$j - 1 \rightarrow j$:

Let $S^* \subseteq \{a_1, \ldots, a_n\}$ be some optimal solution with $S^* \cap \{a_1, \ldots, a_{j-1}\} = S_{j-1}$

Consider $R = S^* \setminus S_{j-1}$

**Figure 11.** The greedy algorithm yields an optimal solution

The Observation, R is an optimal solution to the problem of finding a maximum-size set of activities in $\{a_i, \ldots, a_n\}$ that are compatible with all activities in $S_{j-1}$.

**Case 1:** $s_j < f_{last}$

$S_{j-1} = a_j, f_j, \ldots, a_{last}, f_{last}$

$S_j$ is not compatible with $S_{j-1}$

$S_j$ is not contained in $S^*$

$S^* \cap \{a_1, \ldots, a_j\} = S_{j-1} = S_i$

**Case 2:** $s_j \geq f_{last}$

$S_{j-1} = a_j, f_j, \ldots, a_{last}, f_{last}$

$S_j$ is compatible with $S_{j-1}$

There is: $R \subseteq \{a_1, \ldots, a_n\}$

$R = b_1, b_2, b_3, \ldots, b_j, a_j$

$B^* = S_{j+1} \cup (R \setminus \{b_j\}) \cup \{a_j\}$ is optimal

$B^* \cap \{a_1, \ldots, a_j\} = S_{j+1} \cup \{a_j\} = S_j$

**Figure 12.** Optimal solution of finding maximum size

8. Result
From the simulation results, it can be obtained that the quantity can be used as a decision in the optimization of traffic light control by using greedy algorithm as shown in Figure 5 about GTLS
performance. From 118 simulation experiments on scale model of simulator, it was found that greedy algorithms can add long green lights for 2 seconds on tracks that have long queues at least three sensor levels at 100 m of infrared sensor distance, and accelerate time at other intersections that have longer queue sensor levels less than level three, seen in Figures 13 and 14.

**Figure 13.** Numbers of vehicles in any given time between Jl. matraman, bus way lane and Jl. salemba

**Figure 14.** Optimum time for green light on at jl.Pramuka Tambak, jl Pramuka and jl. Salemba

**Figure 15.** Optimum time for the 5 junction branch
From figure 15, it shows that optimum time for green light is reaches at 12<X<18. The meeting point of the red line, blue and green will cause traffic jam.

\[
\begin{align*}
A & \leq 12 \leq B \\
A &= \text{means stagnancy} \\
B &= \text{means smooth traffic} \\
C &= \text{means optimum time for green light}
\end{align*}
\]

**Figure 16.** Consideration

9. Conclusion

In this paper, we describe a new architecture of the control system to reduce the duration of fixed traffic lights by using Greedy and Infra Red sensors as well as Arduino. The result of scale model simulator by using traffic signal control modification based on Greedy method can be applied to handle simple and complex traffic light system in Indonesia. The Greedy algorithm works successfully on the traffic system in the case of this research by accelerating or increasing the green light at each intersection of a certain level.

**References**

[1] W. Jatmiko, A. Azurat, A. Wibowo, H. Marihot, and M. Wicaksana, “Self-Organizing Urban Traffic Control Architecture With Swarm-Self Organizing Map In Jakarta: Signal Control System And Simulator,” *Int. J. Smart Sens. Intell. Syst.*, vol. 3, no. 3, pp. 463–465, 2010.

[2] R. Foroughi, A. Montazer, and R. Sabzevari, “Design of a New Urban Traffic Control System Using Modified Ant Colony Optimization Approach,” *Iran. J. Sci. Technol. Trans. B Eng.*, vol. 32, pp. 167–173, 2008.

[3] W. Zang and G. Tan, “Traffic Congestion Evaluation and Signal Control Optimization Based on Wireless Sensor Networks: Model and Algorithms,” *Hindawi Publ. Corp. Math. Probl. Eng.*, 2012.

[4] A. Faisal, A. Nasser, and H. Rowaihy, “Simulation of Dynamic Traffic control system based on Wireless sensor network,” in *IEEE Symp on Computers & Informatics*, 2010, pp. 40–45.

[5] M. Sadayoshi and K. Yukinori, “Genetic Reinforcement Learning for Cooperative Traffic Signal Control,” *IEEE Conf Evol. Comput.*, pp. 223–228, 1994.

[6] I. Porche, R. Segupta, M. Sampath, and Y. L. Chen, “A Decentralized Scheme for Real-Time Optimization of Traffic Signals,” in *IEEE Int Conf on Control Application*, 1996, pp. 582–589.

[7] M. Tadnobu, K. Haruhiko, H. Sadaki, and O. Nobuyasu, “Multi Agent-Based Traffic Signal Control with Reinforcement Learning,” in *Trans. IEICE*, 2000, pp. 478–486.

[8] N. Ikuku, I. Takeshi, and S. Kazutoshi, “No TitleImprovements of the Traffic Signal Control by Complex-Valued Hopfield Networks,” in *IEEE Int Conf World Congress of Evolutionary Computational*, 2006, pp. 1186–1191.

[9] D. Mayee, L. Jindal, A. K. Yadav, and Chintoo, “Smart Traffic Light Signals,” *Int. J. Sci. Res. Dev.*, vol. 4, no. 2, pp. 1919–1921, 2016.

[10] P. C. Siswaipraptini, W. H. Martono, and D. Hartanti, “New Smart Traffic Light Using Travelling Salesman problem and Greedy Algorithm,” in *The 3rd Asia Future Conference Proceeding*, 2016, pp. 1412–1419.

[11] S. Albers, “10-Greedy algorihm.” Technische Universitat Munchen, 2008.