Application of graf coloring for optimization of traffic light settings in Medan

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Abstract. Traffic congestion is a problem faced by various cities in Indonesia. One solution is to use traffic light. The existence of a traffic light lamp is very helpful to discipline road users, but in many cases, it is less optimal, related to determining which currents must be red or green and how long each one is. To overcome this problem, a graph approach is used with point coloring application as a scheduling problem. The purpose of this study was to determine the application of the graph at the intersection using the Recursive Large First Algorithm to optimize traffic light settings in the city of Medan and simulation of traffic light settings using Microsoft Visual Basic 6.0. The research method consisted of several stages, namely collecting data, transforming road intersections and their currents into graph shapes, coloring each node on the graph using the Recursive Large first Algorithm, determining the alternative completion of the green light duration and the flashing red light with a certain time cycle, designing simulations and withdrawals conclusion. From the analysis results obtained the calculation results showed that there is a more optimal level of effectiveness from the total duration of secondary data traffic light settings with primary data at the intersection of Gatot Subroto round about and aksara in Medan city.

1. Introduction
The theory graph is defined as a set of pairs (V, E), V is a non-empty set. Members of V are called vertices (vertices or nodes) and members of E are called edges (edges or arcs). Means G (V, E) is a graph with a set of vertices V and a set of sides E [1]. Otherwise, the graph coloring problem is a problem where adjacent vertices or edges in the graph must be colored by using different colors [2]. Graph coloring problem was proposed by Francis Gutrie to solve the problem of coloring the adjacent regions in a map using the minimum number of different colors [3]. The Gredy Graph Coloring focuses on carefully picking the next vertex to be colored [4].

This new self-organizing traffic paradigm thus holds the potential to revolutionize traffic control, especially in urban areas [5,6]. Detection of traffic lights is important in urban environments during the transition to fully autonomous driving. A lot of literature have been produced in recent years approaching different patterns of recognition strategies [7-9]. The traffic light control system is widely used to monitor and control the flow of the cars through crossroads which aims to realize the slow motion of the car on the transportation route. However, synchronization of the traffic light system at adjacent intersections is complicated and the problem of various parameters is involved. Conventional system does not handle variable flows which approach intersections. In addition, reciprocal interference between traffic adjacent to the light system, differences in cars running along with time, accidents, passing of emergency vehicles, and pedestrian crossings are not implemented in the existing traffic system. These problems can lead to traffic jams [10,11].
Traffic is the main problem faced by every country because of the increasing number of vehicles around the world, especially in large urban areas. Therefore the need arises to maximize and optimize the traffic control algorithm to better accommodate increased demand [12]. Traffic lights indicate the time which the vehicle must run stop alternately from various directions. There are several traffic lights with long red light duration and short green light duration. This causes queues to accumulate so that traffic jams often occur, for example on the intersections Aksara and Gatot Subroto road in Medan city.

Graph coloring is associated with two types of coloring as vertex and edge coloring. The goal of both types of coloring is to color the whole graph without conflicts. Therefore, adjacent vertices or adjacent edges must be colored with different colors. The number of the least possible colors to be used for graph coloring problem is called chromatic number [13].

Therefore, it is necessary to optimize traffic light regulation. Recursive Large First Algorithm is a graph coloring algorithm that searches for nodes which has the highest descending neighboring degrees. It is used to develop various kinds of schedule preparation software in graph coloring techniques [13]. Welch – Powell algorithm has been used by [7] to optimize traffic at the STIKES Tlogorejo intersection in Semarang city. The difference between the research of the writer and the previous research is using the Recursive Large First algorithm. This research discusses the problem of how to apply graph coloring using the Recursive Large First algorithm to optimize traffic light.

2. Recursive Large First Algorithm (RLF)

According to this recursive structure, the whole graph is colored with minimum different colors. For the given G graph, the set of the vertices is described as \( V = \{ v_1, v_2, \ldots, v_n \} \) and the set of the colors is described as \( R = \{ r_1, r_2, \ldots, r_k \} \). The steps of the RLF algorithm [12,14] are Vertex degree is calculated for each vertex and the degrees of vertices added to the set of \( \text{Deg}(v_i) \) color in the color set is selected as the active color. Select the uncoloured vertex which has the largest degree from set of \( \{ v_i \} \) for coloring. Then, the selected vertex is colored with active color. Adjacent vertices of the selected vertex cannot color with active color. But the uncoloured vertices which are not adjacent vertices of the colored vertex can be colored with active color. So RLF uses a recursive structure for selected the uncoloured vertices to color with active color. During this process the below steps are (1) Adjacent vertices of the selected vertex \( v_i \) are found from adjacency matrix. Adjacent vertices are added to the adjacent set \( U. \) \( (U = \{ u_1, u_2, \ldots, u_k \}) \) (2) The vertices which are not adjacent vertices of the selected vertex \( v_i \) are found from adjacent matrix. These vertices are added to the set of \( V' \). Calculate the number adjacent vertices which are in the set of \( U \) for every vertex in set of \( V' \). After that, a the uncoloured vertex whose has maximum adjacent vertices (which are in the set of \( U \) ) in the set of \( V' \) is selected for coloring. The selected vertex is colored with active color. (3) The colored vertex and the adjacent vertices of the colored vertex are deleted from \( V' \) and added to the set of \( U \) (4) If the set of \( V' \) is not empty, it is retured to the step 2. Otherwise move to step 3. Next, If the uncolored vertex exists, next color in the color set is selected as active color. Otherwise the program is terminated. Last, Calculate the number adjacent vertices for every uncolored vertex. After that, the uncolored vertex whose has maximum adjacent vertices is selected for coloring process. If more than one vertex provide this condition, the vertex which has the largest degree among them is selected. Then, it is returned to the step 2.

For the RLF algorithm; Table 1 shows the result for the graph shown in Figure 2. Selected order of the vertices and their colors are given Table 1. Table 1 which gives \( r_1 \) states blue, \( r_2 \) states yellow, \( r_3 \) states green and \( r_4 \) states red. The traffic control partition that can run concurrently is divided into 4, namely the first partitions of current \( v_9 \) and \( v_9 \), the second partition flows \( v_5 \) and \( v_6 \), the third partition flows \( v_2 \) and \( v_3 \) and the fourth partition \( v_{11} \) and \( v_{12} \).
Table 1. The result of the colored graph using the RLF algorithm

|   | v₁  | v₂  | v₃  | v₄  | v₅  | v₆  | v₇  | v₈  | v₉  | v₁₀ | v₁₁ | v₁₂ |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|Selected order | 6   | 5   | 4   | 3   | 2   | 1   |     | 8   | 7   |     |     |     |
|Vertex color   | r₃  | r₃  | r₂  | r₂  | r₁  | r₁  |     | r₄  | r₄  |     |     |     |

3. Result and discussion
The steps of node coloring application on a traffic light (1) Transformation the intersection of the road and its current into a graph. The node representing the current and the line representing the currents that cannot run together, then connected to each other, (2) Color each node using the Recursive Large First algorithm to determine which currents can run together and the number of chromatic numbers, (3) Determine the alternative to complete the duration of the green light and the red light turns on with a certain time cycle. This can be done by dividing the duration of the green light with chromatic numbers, the results of the division show the duration of the new green light. The next step is to calculate the effectiveness of new data compared to primary data.

Figure 1 shows that the vertex graph represents traffic flow while the graph side connects the node pair whose current must not run simultaneously or a current pair that causes conflict, it can be seen that v₁, v₂, v₃, v₄, v₅, v₆, v₇, v₈, v₉, v₁₀, v₁₁, v₁₂ according to the conditions prevailing in the field and there are several currents that cannot run simultaneously.
Transformation in the graph from Figure 2.

Figure 2 shows that from the transformation of the graph above, we can see vertices $V_1, V_4, V_7, V_{10}$ unconnected with other nodes, which means that they can go along with other currents. Next, for the other nodes, it is colored with the Recursive Large First algorithm. From the coloring graph, the chromatic number [15] is obtained $= 4$.

Table 2. Table of primary data aksara intersections

| Time          | Road                  | Red (Second) | Yellow (Second) | Green (Second) | Total |
|---------------|-----------------------|--------------|-----------------|----------------|-------|
| 06.30 – 07.30 | Jl. Wiliem Iskandar   | 120          | 4               | 75             | 199   |
|               | Jl. Letnan Sujono     | 145          | 4               | 50             | 199   |
|               | Jl. Aksara            | 147          | 4               | 48             | 199   |
|               | Jl. Prof. HM.Yamin    | 150          | 4               | 49             | 199   |
| 12.30 – 13.30 | Jl. Wiliem Iskandar   | 127          | 4               | 83             | 214   |
|               | Jl. Letnan Sujono     | 152          | 4               | 58             | 214   |
|               | Jl. Aksara            | 166          | 4               | 44             | 214   |
|               | Jl. Prof. HM.Yamin    | 157          | 4               | 53             | 214   |
| 16.30 – 17.30 | Jl. Wiliem Iskandar   | 130          | 4               | 75             | 209   |
|               | Jl. Letnan Sujono     | 155          | 4               | 50             | 209   |
|               | Jl. Aksara            | 165          | 4               | 42             | 209   |
|               | Jl. Prof. HM.Yamin    | 160          | 4               | 45             | 209   |

Table 2 shows that there are primary data, namely the duration of one cycle at 06.30 - 07.30 with a duration of 199 seconds, by dividing the chromatic number [11,14], which is 4 obtained by the duration of the green light burning 49.75 seconds and the duration of red light 149.25 seconds. Overall, new traffic lights can be seen in Table 3.
Table 3. Table of new data aksara intersections

| Time          | Road                  | Red (Second) | Yellow (Second) | Green (Second) | Total |
|---------------|-----------------------|--------------|-----------------|----------------|-------|
| 06.30 – 07.30 | Jl. Wiliem Iskandar   | 149.25       | 4               | 49.75          | 199   |
|               | Jl. Letnan Sujono     | 149.25       | 4               | 49.75          | 199   |
|               | Jl. Aksara            | 149.25       | 4               | 49.75          | 199   |
|               | Jl. Prof. HM.Yamin    | 149.25       | 4               | 49.75          | 199   |
| 12.30 – 13.30 | Jl. Wiliem Iskandar   | 160.5        | 4               | 53.5           | 214   |
|               | Jl. Letnan Sujono     | 160.5        | 4               | 53.5           | 214   |
|               | Jl. Aksara            | 160.5        | 4               | 53.5           | 214   |
|               | Jl. Prof. HM.Yamin    | 160.5        | 4               | 53.5           | 214   |
| 16.30 – 17.30 | Jl. Wiliem Iskandar   | 156.75       | 4               | 52.25          | 209   |
|               | Jl. Letnan Sujono     | 156.75       | 4               | 52.25          | 209   |
|               | Jl. Aksara            | 156.75       | 4               | 52.25          | 209   |
|               | Jl. Prof. HM.Yamin    | 156.75       | 4               | 52.25          | 209   |

Table 4 shows the calculation of the effectiveness of the total duration of primary data traffic with new data for the period of 06.30 - 07.30, 12.30 – 13.30, 16.30 – 17.30 shows that the resulting calculations are no more effective than primary data.

Table 4. The effectiveness of the duration of a primary data traffic light with new data

| Time Interval   | Traffic Light | Level of Effectiveness |
|-----------------|---------------|------------------------|
| 06.30 – 07.30   | Green         | -10,36%                |
|                 | Red           | 6,22%                  |
| 12.30 – 13.30   | Green         | -10,08%                |
|                 | Red           | 6,64%                  |
| 16.30 – 17.30   | Green         | -1,41%                 |
|                 | Red           | 2,78%                  |

In an analogous way, the effectiveness level of primary data traffic light duration with new data for the intersection of the Gatot Subroto intersections can be obtained.

Table 5. Table of primary data Gatot Subroto intersections

| Time          | Road                  | Red (Second) | Yellow (Second) | Green (Second) | Total |
|---------------|-----------------------|--------------|-----------------|----------------|-------|
| 06.30 – 07.30 | Jl. Guru patimpus     | 115          | 4               | 80             | 195   |
|               | Jl. Adam malik        | 113          | 4               | 82             | 195   |
|               | Jl. Sekip             | 110          | 4               | 85             | 195   |
| 12.30 – 13.30 | Jl. Guru patimpus     | 120          | 4               | 85             | 205   |
|               | Jl. Adam malik        | 115          | 4               | 90             | 205   |
|               | Jl. Sekip             | 125          | 4               | 80             | 205   |
| 16.30 – 17.30 | Jl. Guru patimpus     | 120          | 4               | 80             | 200   |
|               | Jl. Adam malik        | 115          | 4               | 85             | 200   |
|               | Jl. Sekip             | 125          | 4               | 75             | 200   |

Table 5 shows that for the other nodes, it is colored with the Recursive Large First algorithm. From the coloring graph, the chromatic number is obtained = 3.
Table 6. Table of new data Gatot Subroto intersections

| Time       | Road          | Traffic Light Setting | Total |
|------------|---------------|-----------------------|-------|
|            |               | Red (Second) | Yellow (Second) | Green (Second) |
| 06.30 – 07.30 | Jl. Guru patimpus | 130            | 4              | 65              | 195       |
|            | Jl. Adam malik | 130            | 4              | 65              | 195       |
|            | Jl. Sekip     | 130            | 4              | 65              | 195       |
| 12.30 – 13.30 | Jl. Guru patimpus | 136.67       | 4              | 68.33           | 205       |
|            | Jl. Adam malik | 136.67       | 4              | 68.33           | 205       |
|            | Jl. Sekip     | 136.67       | 4              | 68.33           | 205       |
| 16.30 – 17.30 | Jl. Guru patimpus | 133.34       | 4              | 66.66           | 200       |
|            | Jl. Adam malik | 133.34       | 4              | 66.66           | 200       |
|            | Jl. Sekip     | 133.34       | 4              | 66.66           | 200       |

Table 7 shows that the calculation of the effectiveness of the total duration of primary data traffic with new data for the period of 06.30 - 07.30, 12.30 – 13.30, 16.30 – 17.30 shows that the resulting calculations are no more effective than primary data

Table 7. The effectiveness of the duration of a primary data traffic light with new data

| Time Interval | Traffic Light | Level of Effectiveness |
|---------------|---------------|------------------------|
| 06.30 – 07.30 | Green         | -21,05%                |
|               | Red           | 15,38%                 |
| 12.30 – 13.30 | Green         | -19,61%                |
|               | Red           | 13,89%                 |
| 16.30 – 17.30 | Green         | -16,67%                |
|               | Red           | 11,11%                 |

4. Conclusion
Completion in calculating the duration of traffic light time with node coloring gives no more effective results than primary data. It is caused by the negative green light, which means the concentration density of the on-road segment increases.

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