An Automated Traffic Signal System Based on Traffic Queue Length

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Abstract- This study suggests an automate traffic signal system, which performs based on vehicle queues form at intersections. The presented system focuses on dynamic que length estimation, designing of traffic phases and signal coordination algorithms in a way that provide maximum opportunity for vehicles. The system was developed by considering a four leg intersection and graph theoretic concepts were adopted in designing traffic phases. Logical expressions have used for the signal coordination. This paper suggests using sensor networks arranged in an efficient geometry, as the estimator of traffic queue lengths. The proposed system results in four sets of traffic phase changes. The system optimizes the traffic flow by providing more opportunity for vehicles while eliminating unnecessary green time assigned for the traffic phases.

Index Terms- cycle time, peak hour, planar sets, traffic phases

I. INTRODUCTION

Traffic congestion is a massive problem experience by many urban cities in Sri Lanka. As a solution new roads and infrastructures can be constructed and this may improve the situation. But it is not an efficient solution due to the urbanization and motorization. Therefore use current existing infrastructures in an effective way are the most feasible solution that can be implemented.

The traffic signal system use in Sri Lanka is a pre-determined traffic light system. It is based on a fixed cycle time defined according to the junction. But due to high number of vehicles on roads, those traffic lights unable to manage the huge traffic queues that form during peak hours. In such situations traffic queues are manually operated even though there exist a signal system at the junction. Therefore, a traffic signal system which is much more sensed to the traffic queues is a requirement. This research provides a guidance to develop a traffic light system, which automatically operates by detecting traffic queue length.

II. METHODOLOGY

This system proposed here has developed based on 5 main steps. (1) Identification of traffic phases, (2) Design of sensor arrangement, (3) Que length estimation and green time allocation, (4) Selection of phases, (5) the optimum arrangement for phases.

1. Identification of phases in four leg junctions

Vehicles arrives at a junction may form one or more traffic streams. According to graph theoretic concepts, these traffic stream lines can represent as vertices and the compatibility of these traffic streams as edges of the graph. This graph can be called as the compatibility graph corresponds to the system.

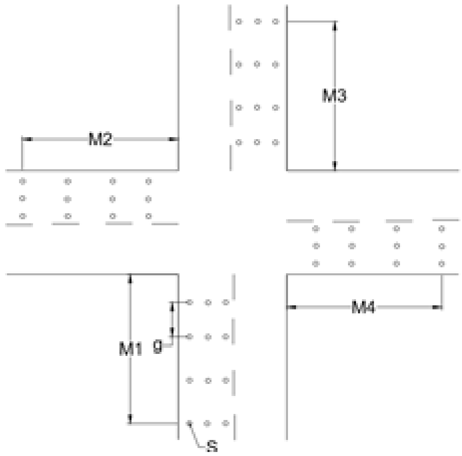
Traffic phases which can be manipulated without any conflict can represent by planar sets of the graph. To identify the planar sets, graph theoretic concepts can be used. Ex: graph coloring technique. It is needed to identify the minimum number of traffic phases in order to optimize the traffic signaling system. Therefore, by considering protected turns (traffic stream lines which not make severe conflict with other stream lines) compatibility graph can be reduced to a simpler one.

The corresponding complement graph needs to be taken to apply the graph coloring technique. To obtain planar sets vertices can color in such a way that two traffic stream lines get the same color only if they are compatible. The optimal proper coloring of vertices gives the minimum number of phases at a junction.

2. Sensor arrangement

The hardware component proposed for this system is the sensors. It is more effective to use a simple, well known and inexpensive hardware component to estimate the queue lengths. Sensor is a suitable hardware component can use for estimating queue lengths while satisfying the requirements.

A single sensor cannot accomplish the job. Therefore an array of sensors is required. Those sensors are needed to arrange in such a way that it gives the



maximum output of traffic data. Topology of sensor arrangement for effective queue length estimation is given below.

The number of sensors in the array needs not to be the same. It varies in each direction. Size of the sensor array can estimate by observing the nature of the traffic (queue lengths) at peak hour. Sensors should be placed in such a way that sensors can effectively detect the vehicles in the queue. The spacing between sensors should be neither small so that number of vehicles between sensors is high nor small so that more sensors will be needed for a small section of the road. This space between sensors will depend on parameters such as sensor type, types of vehicles, vehicle length, and nature of the traffic in the intersection. Therefore, the spacing between sensors should determine by a survey on various categories of vehicles that are in common use. The height of placing sensors is also a factor which depends on nature of vehicles on road.

3. Queue length estimation and Green Time allocation

The heart of overall proposed system is the estimation of queue lengths. The arrays of sensors placed along the road are used to determine the length of queue waiting at the signal. This que length is multiplied by a suitable factor to obtain the green time.

The algorithm starts when all the signals are on for red light. Then queue length detectors (sensors) are switched on in each direction. The output is high if a sensor detects a vehicle. It is low if sensor fails to detect a vehicle. There are four cases needed to be examined.

Case1: If the first sensor does not indicate any signal it is assumed to be there's very few vehicles (no at all) on the road. Therefore the green time is set to a minimum value. This minimum value considered as the least green time to be applied for a particular junction. This minimum value should assign in a way that it provides several vehicles, to move through the intersection.
Case2: If the last sensor indicates a signal, then the green time for the stream line set to the maximum value.
Case3: First sensor detects and the last doesn't, this is the situation of a partially completed queue. A binary search-like approach is use in this state. Assume there are `2k` number of sensors in the array. Check for the n^{th} sensor. If it is low, then check for the $(n/4)^{th}$ sensor of the first half. Else if check the latter part $(3/4n)^{th}$ sensor. Continue the process until it finds a high value. From this the length of the queue and the green time is estimated.

4. Selection of phases

The selected traffic phases are needed to arrange in such a way that it gives the maximum output through the intersection. Adhering Golden rule, road with maximum que length is given priority. In designing the algorithm checking of lengths can separated for major minor road stream lines. According to the queue lengths traffic phases can be ordered.

5. Design of an optimum system

Even though traffic phases have arranged according to the queue lengths there may be situations when one queue lengths is much smaller than the other queues in the same traffic phase. In that situation a different stream line in another phase can be allowed to move after the particular small queue finished its move. Therefore, adopting this concept provides an extra chance to another stream line irrespectively the arrangement made for phases.

A queue length of a stream line at a particular time is considered to be small if it is less than some suitable factor of the queue length formed in the same phase at the same time. The chance was given to a stream line in the next phase which can allow without having any conflict. The extra time remained for the current phase after the small queue moved is allocated to the particular stream in next phase. Then when the chance come to the second phase it checks for the maximum time from which required for the stream lines which didn't move and the reduced extra time from the original time allowed. And that maximum time was allowed for the second phase regardless of the original time allowed.

III. RESULTS

Consider a four leg junction with all possible traffic streams lines.

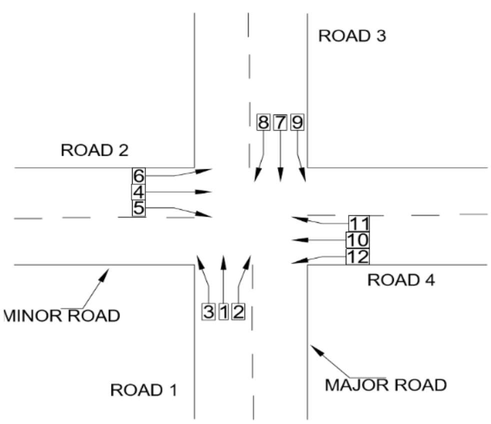


Figure1: Four Leg Junction

Following is the corresponding graph of the traffic stream lines at the junction, obtained by assigning vertices as the stream lines and the compatibility of flows (ability to move at once) as the edges.

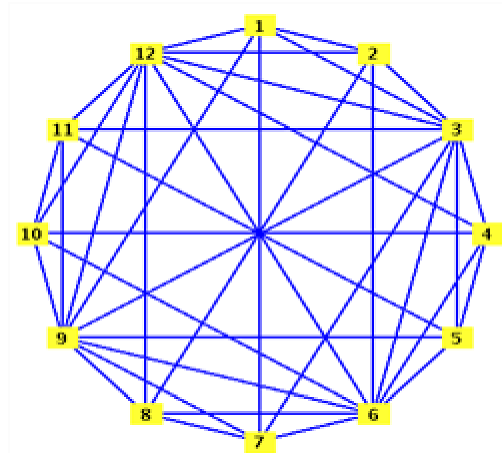


Figure 2: Compatibility graph of the intersection

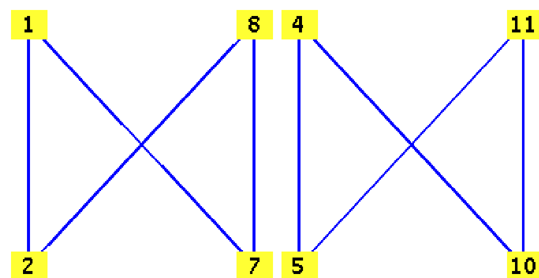


Figure 3: Simplified Compatibility graph of the intersection

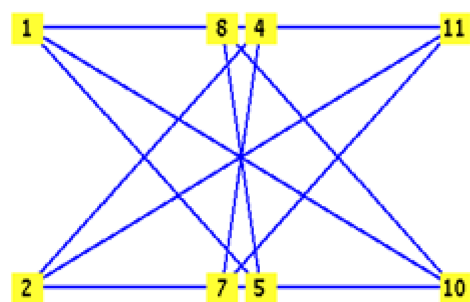


Figure 4: Complement graph of the simplified compatibility graph

System of traffic phases : = [[[1, 2, 3], [7, 8, 9], [4,5,6],[10, 11, 12]], [[1, 2,3], [7, 8, 9], [4, 6, 10, 12], [5, 11]], [[1, 3, 7, 9], [2, 8], [4, 6, 10, 12], [5, 11]], [[1, 3, 7, 9], [2, 8], [4, 5, 6], [10, 11, 12]]]

Let maximum queue length of four roads be 150m, 100m, 140m and 110m respectively and the gap between sensors as 15m. Then the numbers of sensors are 10, 7, 9, 7 respectively. Allocate 60s of maximum green time for a main road considering the actual situation of a junction.

Suppose sensor outputs are high at [150,30, 135,75,15,105,15,45,45,75,75, 45]. m in 1-12 stream lines respectively. The most suitable activated traffic phases as [[1,3,7,9],[2,8],4,6,10,12],[5,11]] original green time allocation as [60,19,40,31]s for four phases and total green time for cycles as 150s. There is a considerable length gap between direct up and down streams at phase1. Therefore, a chance is given to the right turn in the second phase. There hence, the green time for the second phase will be reduced and the new time allocated is 12s. This decreases the total green time to 143s. Therefore, the cycle changes faster than previous while decreasing the waiting time of traffic participants.

IV. DISCUSSION

This proposed system shows advantages over the current existing traffic signal system in Sri Lanka. This proposed system assures that it will change the system based on queue length without any interference of human, automatically. This saves much time and cost expended for the pre-timed system.

The alternative system allows traffics to move in an optimum way so that the waiting time of traffic participants is reduced. In current system even if there's no vehicles on some roads, the roads with large queues have to face long unnecessary waiting time until get their chance to move. This doesn't happen in the proposed system, since it gives the priority to the long queues and further, allocate extra chance to move.

This system proposes a simple low-priced hardware – sensors to detect the queue length. The placement and maintenance of sensors is easy. It is an effective method rather than using inductive loops as detectors. In inductive loop system the road has to damage to place the loop and the maintenance and replacing is difficult. Since proposed system use sensors no matters arise in placing nor maintenance or replacing.

In the proposed system pedestrian crossing hasn't been taken into account by considering the current traffic light system. Pedestrians are allowed to move when direct and left turn stream lines are allowed.

The main aim of this algorithm is to ensure efficient flow of traffic. This performs signal update and the system is not fixed cyclic. Therefore no road user can predict what will be the next phase. But this is not a completely dynamic system. . I.e. if a direction has been allowed for some time then it will not consider until all other directions have been given chance. Therefore all the stream lines will be given at least one chance.

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