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Adopting Novel Joint Algorithm In Traffic Light System For Urban Intersection Junction

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ABSTRACT

This paper presents a study for conventional traffic light system, and a proposed a novel joint algorithm to improve the efficiency of traffic light system. As we know, traffic light system is a common system which can be found at any places especially in urban area. Normally, traffic congestion happen at urban area is mainly caused by high volume of vehicles. In this moment, traffic light system act as a signaling system to ensure the traffic flows smoothly at urban area. The main function of traffic light system is to ensure the road users can follow the traffic signals such as green light and direction arrows provided by the traffic light system. Apart from that, it also can minimize the confusion of the road users at the intersection point of traffic. As standardized, different countries have different regulation and different standard of traffic light mechanisms, but the general concept of traffic light system is still the same. Therefore, traffic light systems can be defined as a stop-and-go signaling light which installed on traffic intersection point. The performance of traffic light system is depending on the method used by the controller. The most common method used by traffic engineering is sequencing method and sensor demanding method. Yet, until now the traffic light system in most the countries still not achieve the expected efficiency such as traffic congestion still happen. The missing part of the conventional traffic light system is the controller incapable to handling the large volume of vehicles at traffic junction. In short, traffic congestion happen when the volume of vehicles on the junction is greater than the common road capacity. As to solve the particular issues of traffic from happening, a method which using the new sensor placement is strongly proposed. In this proposed method, more sensors will be used to measure the total volume of vehicles on each lane. Furthermore, the proposed method can be easily enhanced by adding more sensors to ensure the smoothness of a traffic light system at certain junction of traffic.

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INTRODUCTION

Around the world, traffic light system is an automated device which used to control the traffic flow in urban junction and ensure the safety of road users. Road users will be obvious with the traffic flow by following the instruction given by the traffic light to take turn for crossing the junction. Therefore, traffic light systems need to install at the junction to control the traffic flow and assign timely direction. In general, a junction is made up which few components. In a junction, it has two or more road segments and one point of intersection point where the segments meet. Basically, traffic light system is installed at two common junctions such as T-junction and cross junction. When road users enter to an intersection point which is without installation of traffic light system, they will easily get confused with the priority of crossing the junction. In that case, any driver with bad attitude may intend to jump queue and ignore the traffic guide. Scenario that cause accidents happen on road is normally due to negative behavior of the road users (Wastavino, L.A., 2007). T-junction is formed between one often minor road connecting to another often major road in a "T" shape. The angle between the two roads is 90o as shown in Fig. 1 (a), so that road users can turn either left or right from the often minor road (S.K. Subramaniam, 2012). Next is cross junction where two tracks cross over or four roads connected to a junction. The angle of the tracks connection is depends on the structure of the road, but mostly is close to 90^o as shown in Fig. 1 (b).

Therefore, an intelligent traffic light systems need to be installed for both types of junction. An intelligent traffic light system can manage a high volume of vehicles, control the traffic flow and make the flow be smoothest. Apart from that, the system can give a clear instruction to the road users and the timing and clearance of each lane is determined. So that, road users will not get confuse to across a junction.

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(a) (b)

Fig. 1: (a) T-junction traffic light system, (b) Cross junction traffic light system.

A traffic light system is build by three components such as display unit, controller unit and sensor unit (Department of Transportation Traffic Engineering Division, n.d.) as shown in Fig. 2. Basically, display unit is used to visualize the colors of green, amber and red in giving instruction to road users (Douglas, E. Betts, 2007). Apart from that, sensor unit is act as a device that generates the input signal when it sense present of vehicle to trigger the controller unit (S.K. Subramaniam, 2009). Thus, controller unit is an automation device which also considered as a heart of traffic light system which used to manage the incoming signal from sensor and visualize the output as display (Lalit, S.N., 2006). Most of the traffic light controllers are implemented based on same rule. Different region or countries will refer to different standards, but the idea in programming on controller will still the same, which is by using logics.

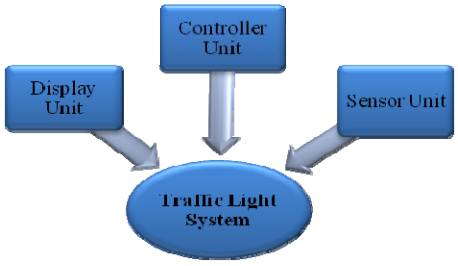


Fig. 2: Block diagram of component for a traffic light system.

Traffic Light Control Device:

A programmable logic controller (PLC) is an industrial computer which is used to control and to automate complex systems. Usually, industry uses PLC to control and monitor a wide range of machineries and other movable components with many individual systems by linking them to one another. Besides that, PLC can also used to monitor an input signals from a variety of input sensors. Therefore, PLC is more suitable and reliable device in controlling traffic lights, as they operate for long hours ideally without pause regardless of the weather (S.K. Subramaniam, 2012; Papageorgiou, M., 2003; Roses, R.P., 1990). The red circle in Fig. 3 shows the PLC based traffic light controller which is located on road site at the traffic junction.

Fig. 3: PLC controller on certain junction.

Basically, traffic light control device is used to control the vehicle movement at the traffic junction. Based on the incoming signal from sensor unit, controller unit will know the presence of vehicles and controller will make decision based on the logic (McNeil, D.R., 1968). Most of the traffic light system manufacturers are using PLC as the main controller to control incoming signal from sensor unit and outgoing signal to display unit. The Fig. 4 illustrates the relationship between incoming signal, traffic light controller and outgoing signal.

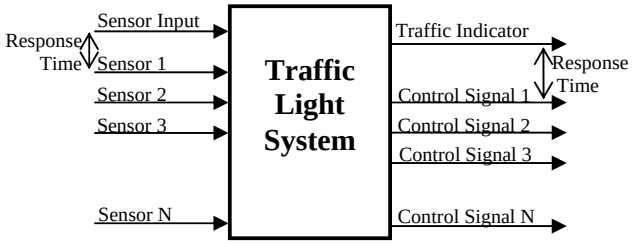


Fig. 4: Relationship between sensor unit, control unit and display unit.

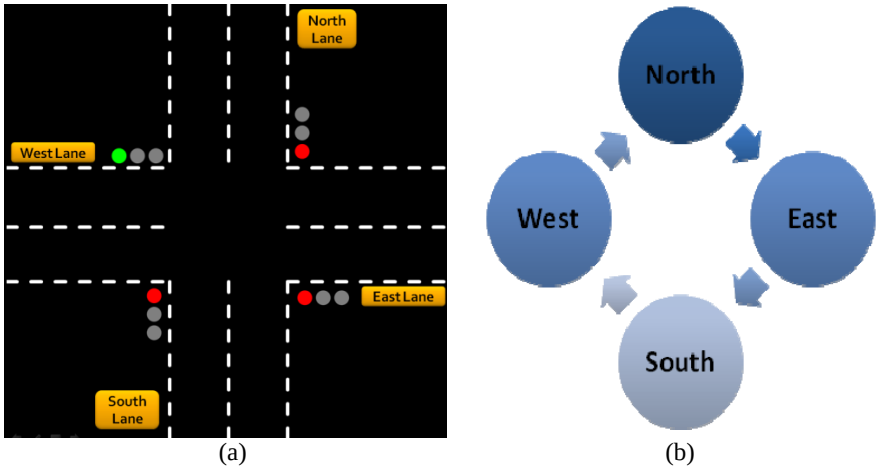
Every traffic light systems are using the same rule. But, different companies will use different brands of controller. This is because there are several standards at their country based on limitation of budgets and etc.

Conventional Traffic Light Programming Method:

The traffic light control device need to be programmed according to the standard method. There are two conventional method widely used in most of the counties which is sequencing method (SM) and sensor demand method (SDM). SM is the common method which is work in a prefix timing based on the pre-programmed sequence without considered the real time changing. SDM is based on the sensor detection which operates with real time changing (V.R. Gannapathy, 2012).

Sequencing Method(SM):

SM is the most straight forward method in traffic light programming. In SM, traffic light controller only operates in fixed timing without considering on any real time changes (Roses, R.P., 1990; McNeil, D.R., 1968). In short, the intersection point was free of sensor as illustrated in Fig. 5 (a). Next, when a vehicle enters to the intersection point, the driver need to wait for the traffic indicator to turn green according to the timing fixed in the traffic light controller. Basically, the traffic light controller will provide a fixed timing and fixed sequence for West Lane to North Lane to East Lane to South Lane and cycle back to the West Lane (S.K. Subramaniam, 2012). The overall motion diagram is shown in Fig. 5 (b) below.



(a) (b)

Fig. 5: (a) Conventional traffic light system without detection sensor, (b) Motion diagram of sequencing method.

Sensor Demand Method (SDM):

Basically, SDM is commonly used in urban cities where the traffic light control device is embedded with detection sensor which operates based on real time changes (S.K. Subramaniam, 2012). The sensors are placed at the end of each lane towards the traffic light junction as shown in Fig. 6 (a). SDM, it able to decide the

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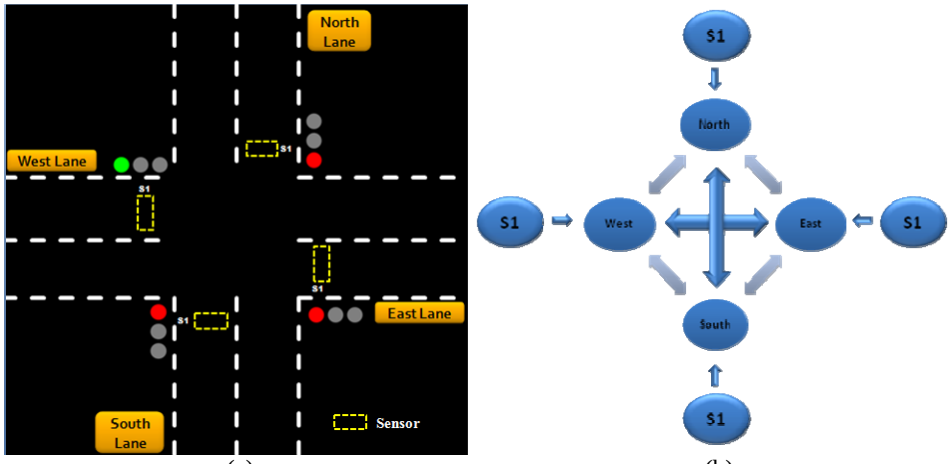
sequence and timing of a lane based on the priority method. For the lane in first priority, the green light period will be longer compare to the second priority as shown in Fig. 6 (b).



(a) (b)

Fig. 6: (a) Conventional traffic light system with detection sensor, (b) Motion diagram of sensor demand method.

Furthermore, the ability of SDM is to sense the presence of vehicle in each lane. If there is no vehicle in the lane all the time, the controller will decide to bypass that lane all the time. By comparison, SDM is better compare to SM because inductive loop sensor is used in SDM. The sensor able to generate an input signals to traffic light controller as a presence of vehicle. So that, the traffic light controllers can decide whether bypass the lane or provide green light for the lane (S.K. Subramaniam, 2009).

Downfall of Conventional Traffic Light System:

Even though, most of the traffic light controllers in Malaysia are using Sensor Demand Method yet traffic congestion still happening (S.K. Subramaniam, 2012). This is due to there is only one sensor used at each lane for Sensor Demand Method. Only one sensor used to sense the presence of vehicle on each lane at traffic junction is not enough. The sensor is installed at the end of the road, once the sensor malfunction; the traffic light control device will run the sequencing flow. During peak hours such as before and after working hours, volume of vehicles at urban junction is high and it will cause the traffic congestion happen (Shilpa, S.S., 2009). Traffic congestion can be defined as the volume of incoming vehicles greater than the available road capacity is considered traffic will be congested as shown in Fig. 7.

Fig. 7: Traffic is congested because the volume of vehicle in that junction is higher than the available road capacity.

Traffic congestion causes time loss as it will add to wasting time, travelling time and other time such as unplanned case likes road accident, bad weather. (Jochen, E., 2004). Fig. 8 below show traffic congestion is caused by a road accident.

Fig. 8: Traffic congestion cause by a road accident.

The time wasting spent at urban junction will delay the daily activity of drivers such as late arrival for meeting, education and employment which can result in lost business, disciplinary action or other personal losses. Therefore, the impact for the delay is very high.

Besides that, traffic congestion will increase the content of carbon dioxide in the air; in worst case will cause air pollution (Jochen, E., 2004). During traffic congestion, the vehicles are static on the road but the engine still in active mode, therefore the fuel is keep burning for the use of air conditioning in the car only. In this case, carbon dioxides are release from the vehicles especially during the heavy traffic crawl as shown in Fig. 9.

Fig. 9: Carbon dioxide is emitted from vehicles during waiting long hours in traffic congestion.

Even though the fuel price is always on hike, but the solution is nowhere near to enhance the traffic management system especially in big cities. Next is on safety issue; traffic cop is needed to give the instruction to the road users when the junction is heavily congested as shown in Fig. 10.

Fig. 10: Traffic cop is standing in the middle of the junction to give instruction to driver or road users.

Sometimes, the instruction of traffic cop is hardly to be seen by drivers or road users at a faraway distance from the junction. This will affect to road accidents happen. This is some of the most crucial problems in regards to the conventional traffic light system (Andrew, D., 2008).

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New Sensor Placement:

New sensing method will be a practical solution for a cross traffic light junction. By using this method, self-routing program can be incorporated. On this method, new sensor placement is able to measure the total volume of vehicles entering or exiting at certain junction. According to this proposed method, better sensor to be implemented or detection approached should be used. New sensor placement is focus on detecting vehicle going in and out within a certain traffic light junction.

Furthermore, the new sensor placement eases for further improvement of traffic light system in ensuring the efficiency of traffic flow even in bad weather. The basic idea of this proposed method is just by adding two additional sensors on each lane compare to the conventional sensor demand method as show in Fig. 11.

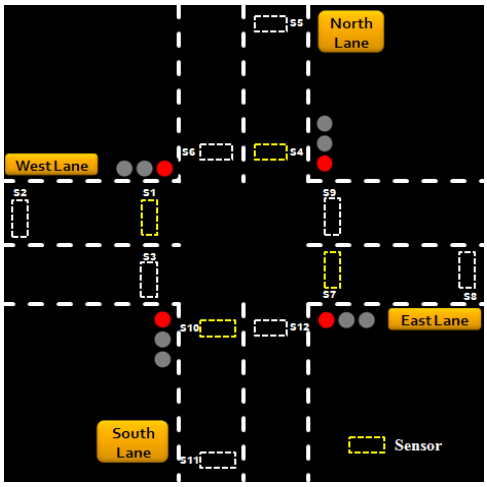

Fig. 11: New sensor placement.

In Fig. 11, the yellow color sensor is the conventional traffic light system sensor placement which is called Sensor 1. The white color sensor is which the sensor adding in certain junction is so called the Sensor 2 and Sensor 3 to measure the volume of vehicle. Sensor 2 is placed on the same side as Sensor 1 with a certain distance. Sensor 3 is placed on exit lane which used to count the existing vehicle.

By applying the new sensor placement in the traffic light control device, it should create an intelligent model to control the traffic flow at certain junction. It works based on the real time changes as being detected by the sensors placed on the strategic location in each lane. Based on the input signal from the sensor, the controller will be able to make decision and give the right priority and sufficient time for the vehicles to pass through. Once the input signal is accurately received, the change of vehicles on that lane can also be measured accurately. This method can be called as Self-Routing Traffic Light System (SRTL).

Basically, the Sensor 1 and Sensor 2 are used to sense the volume on the entering lane at junction. Then, Sensor 3 is used to count the vehicle exiting from the junction. Fig. 12 shows the block diagram of the new sensor placement traffic light controller work (S.K. Subramaniam, 2012).

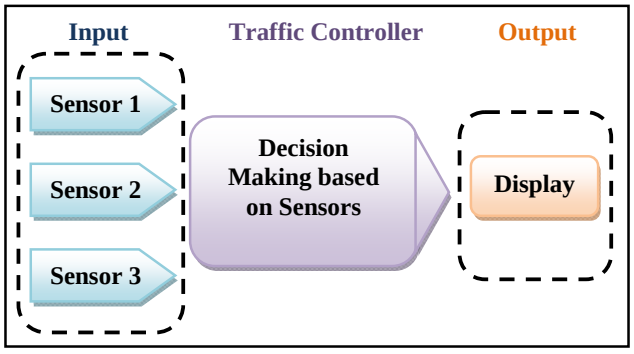

Fig. 12: Block diagram of new sensing method.

In details, SRTL controller will check on all the sensors of each lane first. If the junction is empty, the green light of the lane will be triggered when Sensor 2 senses a presence of vehicle by applying the first come first serve concept (Jochen, E., 2004). The motion diagram is shown in Fig. 13.

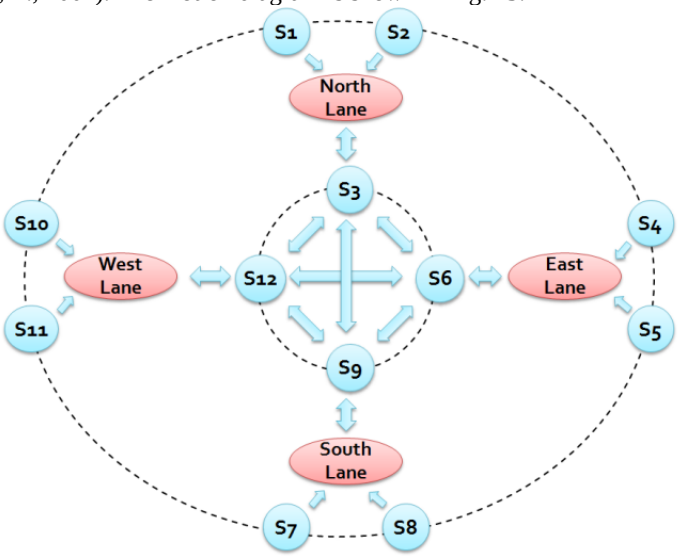

Fig. 13: Motion diagram of SRTL method.

Apart from that, this method able to load the pre-program in the traffic light controller which is based on the response from the sensor. The timing provided for each lane is depends on the Sensor 1 and Sensor 2 on each lane. If only a Sensor is triggered, the timing provided for that lane is shorter compare to the lane which is triggered by Sensor 1 and Sensor 2 at the same time.

Comparison:

There are two types of conventional traffic light system and one proposed system was discussed above. Therefore, some comparison is make among the method to manage the traffic light system is as shown in Table 1. Table 1 show the result in side by side about the factors of the traffic light system.

Table 1: Comparison of several method of traffic light system.

Factors	Traffic Light System	
	Conventional System	New Sensor Placement
Traffic congestion	High Probability	Low Probability
Human monitoring	Require	Not Require
Safety	No	Yes
Air pollution	Increases	Decreases
Waiting time	Increases	Decreases
Off peak hours	Effective	Effective
Peak hours	Not Effective	Effective
Road Accident	High Probability	Low Probability
Cost	Cost for 1 sensor on each lane	Cost for 3 sensor on each lane
Controller	PLC – Sensor Demand Method	PLC – New Sensor Placement Method

Conclusion:

The important of traffic light system is to manage the traffic flow at urban cities around the world. Without traffic light system, the traffic flow will become unplanned and traffic congestion happened. This is because there is no regulation on road and driver will behave on their own way when they enter to an intersection point. Their attitudes will affect the cities become chaos. Even the conventional traffic light system is installed in most of the cities, traffic congestion still happening. This is because of the conventional system unable to manage a large volume of vehicle at urban junction. Apart from that, the efficiency of traffic light system is depends on the traffic controller. An intelligent traffic light system will perform better compare to normal traffic light system. In proposed system (SRTL), by just adding more sensors at urban junction, SRTL system will reduce the waiting time and travel time of road users. At the same time, the probability of traffic congestion will be reduced also. So, the proposed method is a practice solution to overcome the problems faced on the conventional system.

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