

# An Intelligent Algorithm for Traffic Signal Scheduling

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**Abstract**— Traffic congestion is an increasingly important problem that has drawn attention of the public and hence proper counter measures need to be devised to facilitate better and efficient transportation. Several conventional approaches to managing traffic flow at crossed junctions are practiced at present but exhibit poor efficiency owing to certain disadvantages. An Intelligent Traffic Signal Controller (ITSC) algorithm is being proposed in this paper for a Two-lane crossed junction with dividers (road system in Malaysia) where each intersection serves two lanes. The design of the ITSC comprises of sensors placed at all four phases of a crossed junction and an intelligent fuzzy controller. The working of the ITSC is based on two modes of timings: Non-Peak and Peak hours. Simulation showed positive results for improved phase scheduling and green signal allocation. Analysis also showed that for most cases, the ITSC performed better than the conventional controllers in minimizing the delay incurred at signalized intersections.

**Keywords**—: Crossed Junction, ITSC, Non-Peak Hour, Peak Hour.

## I. INTRODUCTION

**T**RAFFIC density is an important factor that grows exponentially with more vehicles joining the roads day by day. Hence devising a solution should take into account all possible dimensions of the problem to ensure a smooth traffic flow.

Roundabouts are one of the initial steps adopted to reduce vehicle speed and thereby prevent accidents at intersections. This approach works well until the increased traffic demand results in bottlenecks caused due to frequent deadlocks [1]. The two other approaches to control traffic signals include the fixed time controllers and the vehicle actuated method. The fixed time controllers to be the most commonly used approach works quite well during off peak periods but fail to cope with the sudden traffic changes that lead to increased delays. On the other hand a vehicle actuated method that uses sensors to detect vehicle presence appears to be more dynamic in scheduling extensions for green signals according to arrival rates but fails to consider the queuing length at all the red signal phases thus making it less efficient [2].

From a human's perspective, a traffic signal controller needs to allocate sufficient amount of green signal time to an

intersection depending on its traffic characteristics and at the same time take into account the starvation of vehicles on the other phases. Fuzzy Logic is one successful technique that has proven its remarkable ability to map human mind into intelligent logic for appropriate decision making. An in-depth understanding of the technique facilitated the design of the Intelligent Traffic Signal Controller (ITSC).

## II. RELATED WORK

Several conventional approaches to controlling traffic signals include TRANSYT (Traffic Network Study Tool), SCOOT (Split, Cycle and Offset Optimization Technique) and SCATS (Sydney Co-ordinate adaptive traffic system) form some of the best pre-determined off-line timing methods to account for traffic congestion.

The Adaptive Signal-Vehicle Co-operative control system [3] provides an optimal traffic signal schedule as well as an optimal vehicle speed advice. The traffic signal scheduling is achieved using Adaptive Dynamic Programming which has the advantage of reducing the computational requirement so as to bring about a feasible implementation. The Intelligent Transport System (ITS) technique to detect congestion comprises of a wireless sender-receiver pair installed between two points of the road [4]. The sender sends packets while the receiver measured some metrics like signal strength, packet reception and link strength indicating the traffic congestion conditions.

The Autonomous Agent Oriented Traffic control system [5] uses a hybrid approach wherein the internal working such as the traffic data collection and processing is performed by agents while the traffic from each side is controlled by a single controller.

The fuzzy traffic-signal controller introduced in [6] for a roundabout consists of two fuzzy layers: Green extension time and urgency degree. The input to the controller being the queue length and the waiting period, the output decides the signalling of the appropriate phase subset (from the predefined set) of a chosen phase based on its urgency degree and later computes its extension factor at the second layer.

An interactive fuzzy signal controller proposed in [7] makes use of neighbouring traffic information to tackle congestion especially during cases of over-saturation. The output of the controller decides whether to extend, early cut or terminate the current signal phase depending on the observed traffic conditions.

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### III. PROPOSED ITSC ALGORITHM

#### A. Terminologies and Definitions

The following are the terminologies used for the ITSC algorithm:

- **Peak Hour** – Time of a day the traffic congestion on the road is at its highest and is normally found twice a day [8].
- **Non-Peak Hour** – The day apart from the Peak hours and the weekends where the traffic congestion is not very high [8].
- **Arrival Rate** – It can be defined as the average number of customers arriving to a particular system.
- **Service Time** – The average time taken by a server to service the customers waiting at a system [9].
- **Poisson Process** – A stochastic process that deals with the count of events and the time of occurrence of each such event. This time of occurrence for each pair of consecutive events is assumed to be independent for each event and follows an exponential distribution [9].
- **M/M/1 Queuing model** – A discipline within the classic Queuing theory representing a length of queue served by a single server. The arrival process by the customers to the systems assumes a Poisson process and its corresponding job service time assumes an exponential distribution [9].

#### B. Basic Assumptions

The following are the basic assumptions made for the development of the ITSC algorithm:

- The research is done for the road system in Malaysia (See Fig 1).
- Each intersection of the crossed junction has one lane for upstream vehicles and the other lane for downstream vehicles.
- Traficam video detector over-roadway sensors placed at all the four intersections of a crossed junction can detect the presence of vehicles up to 100 m starting from the stopping line of the intersection.
- Only Red and Green signals are taken into account. The Amber signal (yellow signal) is not considered for the study.
- Pedestrian Crossing is not considered.
- Vehicles such as cars and small vans form the participants of the system.

- Standard length of a car recorded is 5.25 m.
- Based on the observations performed on three strategic locations in Malaysia, the mean number of waiting cars at each intersection during Peak and Non-Peak hours was recorded, generalized and the following numerical results were derived (See Table I, Table II and Table III).

TABLE I

FUZZY PARAMETERS FOR TRAFFIC RANGE

Traffic Range (Non-Peak Hour)	Traffic Range (Peak Hour)	Fuzzy Membership Value
0 to 15.75 m	0 to 25 m	LESS
15.76 to 36.75 m	26 to 50 m	MODERATE
36.76 to 52.5 m	51 to 75 m	HIGH
52.6 to 100 m	76 to 100 m	VERY HIGH

TABLE II

FUZZY PARAMETERS FOR INTER-ARRIVAL TIME

Inter-Arrival Time	Fuzzy Membership Value
0 to 0.703 sec	SHORT
0.704 to 7 sec	LONG

TABLE III

FUZZY PARAMETERS FOR SERVICE TIME

Service Time	Fuzzy Membership Value
0 to 0.332 sec	SHORT
0.333 to 0.5 sec	MODERATE

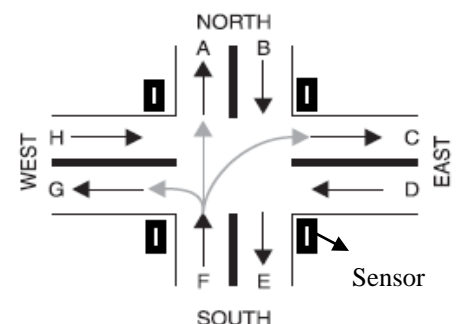


Fig. 1 Model of Two-Lane Crossed Junction with Dividers

#### IV. WORKING PRINCIPLE OF THE ITSC ALGORITHM

The ITSC works under two different phases: Non-Peak Hour and Peak Hour. The main module, ITSC\_Main () first initializes the sensors at each intersection and determines the day and time of recording event. A call to the Non-Peak\_Hour () subroutine is made during the Non-Peak hour timings and during weekends by default. If the time of recording is that for Peak hours, a call to the Peak\_Hour () subroutine is made.

##### A. Pseudo code For ITSC Algorithm

###### Algorithm 1:ITSC\_Main ()

**Input:** RecordingTime, RecordingDay, Interarrivaltime

**Output:** Intelligent Traffic Signal Schedule

1. Start
2. Initialize variables: RecordingTime , RecordingDay and Interarrivaltime
3. for i = 1 to 4 // variable: i refers to the phase direction. [The inter-arrival time of vehicles arriving at an intersection is categorized as SHORT and LONG].
  - If (interarrivaltime <=SHORT)
    - Phase[i].time = 0;
    - Elseif (interarrivaltime >= SHORT && interarrivaltime <=LONG)
      - Phase[i].time=1;
  - End (if)
  - Time[i] <-Phase[i].time // Time[i] is an array containing information on the inter-arrival time for each phase.
4. End of for loop
5. Return (Time[i])
6. If RecordingDay != weekends // traffic control for weekdays
7. If (RecordingTime == Non-Peak hour)
  - Call Non-Peak\_Hour () subroutine
  - Else
    - Call Peak\_Hour () subroutine
  - End (if)
8. Call Non-Peak\_Hour () routine
9. End(if)

10. Call Fuzzy\_Controller ()

11. End

###### Algorithm 2: Non-Peak\_Hour ()

**Input:** Phase ID, Area Covered

**Output:** Sequence of scheduled Phases

1. Initialize the Phase ID for each sensor
    - Phase[1]:= North
    - Phase[2] :=East
    - Phase[3] :=West
    - Phase[4] :=South
  2. Read Sensor Inputs for each phase and initialize a structure //Structures stores details about traffic conditions for each phase.
  3. Read Time[i]
  4. Initialize Var State: = n // the variable: state is to identify the congestion condition for a particular phase.
  5. For i = 1 to 4 // variable: i refers to the phase direction. [The area covered by vehicles at an intersection is categorized as follows: LESS, MODERATE, HIGH and VERY HIGH].
    - If (areacovered <= LESS)
      - Phase[i].state = 0;
      - Elseif (areacovered >LESS && areacovered <= MODERATE)
        - Phase[i].state = 1;
      - Elseif (areacovered >MODERATE && areacovered<= HIGH)
        - Phase[i].state = 2;
      - Elseif (areacovered > HIGH && areacovered<= VERYHIGH)
        - Phase[i].state = 3;
    - End (If)
    - Phase[i] <- Phase[i].state
  6. End of for loop
  7. Return (Phase[i])
- Algorithm 3:Peak\_Hour ()
- Input:** Phase ID, Area Covered,ServiceTime
- Output:** Sequence of scheduled Phases, Extension Interval
- Steps 1 through 7 remain the same as in Non-Peak\_Hour ().

## Algorithm 4: Fuzzy\_Controller ()

**Inputs:** Phase[i], Time[i]**Output:** Green Signal Interval assignment

- for i=1 to 4 // var i refers to direction.  
Read Phase[i] and Time[i].  
Evaluate inputs against fuzzy rule set.
- End of for loop.
- Schedule output to external traffic signal controller.
- If (RecordingTime== Peak-Hour)  
Call Fuzzy\_Extension ()  
End (if)
- End

## Algorithm 4.1: Fuzzy\_Extension ()

Input: ServiceTime, Phase[i], Time[i]

Output: Green Extension Interval

- for i=1 to 4 //// var i refers to direction.  
If (ServiceTime <=SHORT)  
Phase[i].servicetime = 0;  
Elseif  
(ServiceTime >=SHORT && ServiceTime <=MODERATE)  
Phase[i].servicetime = 1;  
End (if)  
Stime[i] <-Phase[i].servicetime
- End of for loop
- for i=1 to 4

Read Phase[i] and Time[i].

Evaluate inputs against fuzzy rule set.

- End of for loop.
- Schedule output to external traffic signal controller.
- End

## V.SIMULATION OF TRAFFIC AT A CROSSED JUNCTION

The process of traffic signal scheduling is achieved by programming in C language. The appropriate green signal duration for the scheduled phases is determined using the Fuzzy Logic toolbox of Matlab. The process of phase scheduling is facilitated using two inputs to the Fuzzy Logic Controller (FLC): Area covered and Inter arrival time with four and two membership functions and a single output: Green

signal duration with four membership functions. The extension of green signal duration to the currently servicing phase is also determined similarly with two inputs to the FLC: Inter arrival time and Service time with two membership functions each.

## VI. RESULTS

The results obtained after the simulation of the ITSC algorithm are shown below. Fig.2 shows the rule viewer window of the Fuzzy Logic Controller (FLC) for Non-Peak hour. It indicates the choice of selection of the appropriate green signal duration for a particular phase for varying input values.

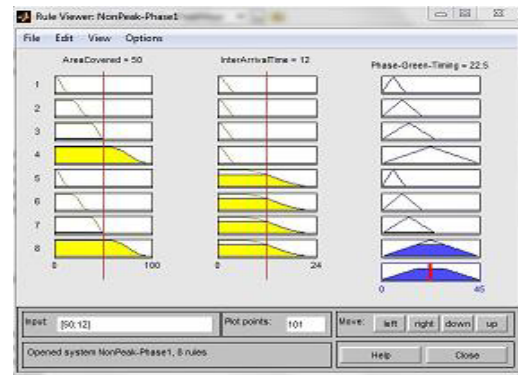


Fig.2 Fuzzy Rule Viewer for Non-Peak Hour

The Fuzzy Rule Viewer window of the FLC for peak hour is illustrated in Fig. 3. The fuzzy rule viewer for peak hour operations indicate the decision for selection of phase green signal duration for the varying input values. The extension requirements for the currently servicing phase are also modelled similarly in Fig. 4.

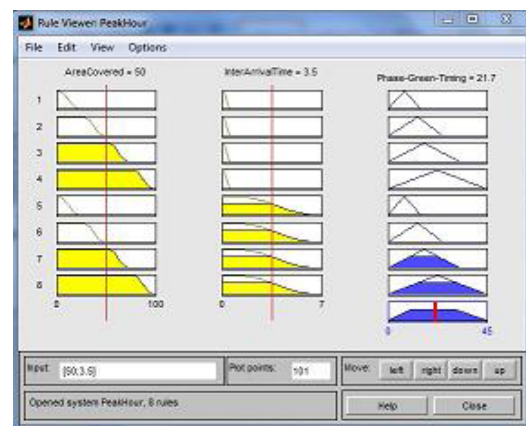


Fig. 3 Fuzzy Rule Viewer for Peak Hour

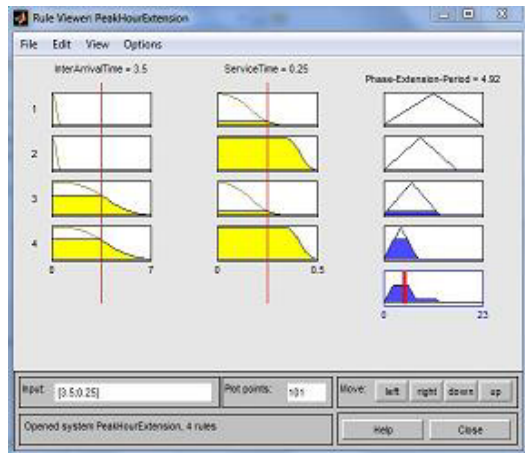


Fig.4 Fuzzy Rule Viewer for Extension

It is also found that the ITSC compared to the conventional traffic signal controller in most cases exhibited better performance in minimizing the delay at signalized intersections. The comparisons are shown for both Non-peak and Peak hours from the observed results (See Fig.5 and Fig. 6).

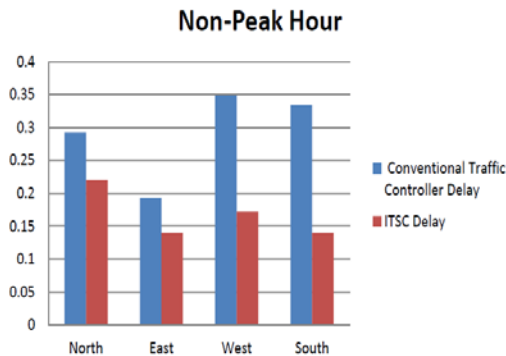


Fig. 5 Delay incurred during Non-Peak Hour

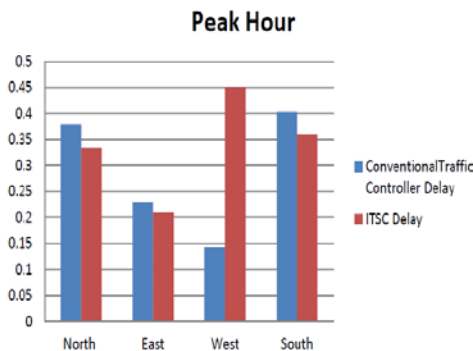


Fig. 6 Delay incurred during Peak hour

## VII. CONCLUSION

The characteristics of road traffic have seen to evolve enormously. It would be a hard procedure to enforce a control on the entry of new cars on the road. Hence one possible solution available would be to devise methods to effectively control the congestion by facilitating an uninterrupted traffic flow. The Intelligent Traffic Signal Controller (ITSC)

algorithm proposed in this research is an attempt to bring about such a kind of a solution. The design of the ITSC comprises of sensors placed at all four phases of a crossed junction and an intelligent fuzzy controller. The data provided by sensors determine congestion characteristics in terms of area covered by vehicles at an intersection. Simulation of the ITSC showed positive results for improved phase scheduling and green signal allocation. Future work could be the improvement of the capacity of the sensors to facilitate detection range up to 200 m and above. Traffic caused by Pedestrian crossing can also be considered.

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