

Agent Based Intelligent Traffic Management System for Smart Cities

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Abstract

The performance of traffic systems is greatly dependent on their ability to react to changing traffic patterns and different situations. On traditional traffic systems, the lights run green for fixed intervals of time no matter what the density of the traffic is. Here, we implement an intelligent-agent traffic model that controls the amount of time a light runs green for, based on the number of cars (density) standing in the light.

Keywords: *Number of cars (density), Traffic system, Intelligent-Agent*

1. Introduction

With an increase in the pace at which we lead our lives, time is of the essence. One place where time is wasted is on the road being stuck in traffic jams due to mismanagement of traffic. The effectiveness of (urban) traffic control systems greatly depends on its ability to react upon changes in traffic patterns, however, conventional traffic control systems, being unintelligent are unable to do this. Be the traffic density, high or low, the signals are timed and run according to those times only. This results in increased congestion along the roads which also results in significant air pollution, an increased safety risk and also has a negative effect on the populace's mental wellbeing. It is only when the ability to react becomes an integral part of the traffic control unit, its ability to react to changes in traffic conditions improves. The responsive control system should have sufficient knowledge of the situation to be able to handle unforeseen changes in traffic flow, such as accidents or car break-down. Intelligent signal control systems must have the capability to optimize the traffic flow by adjusting the traffic lights and coordinate operation between each signal in order to maximize the person and vehicular throughput and minimize delay. For intelligent urban traffic control, we ideally need a fully pro-active, real-time traffic control system; anticipating what will happen within the near future.

2. Need for Smart City

A smart city (also smarter city) uses digital technologies or information and communication technologies (ICT) to enhance quality and performance of urban services, to reduce costs and resource consumption, and to engage more effectively and actively with its citizens. Smart city applications are developed with the goal of improving the management of urban flows and allowing for real time responses to challenges [18].A

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smart city may therefore be more prepared to respond to challenges than one with a simple 'transactional' relationship with its citizens [19].

Intelligent traffic control systems are an important feature of smart cities and are used to both control the flow of traffic as well reduce traffic congestion. People need to get wherever they need in a timely manner, emergency teams need to reach their destination urgently. Classical traffic lights are rigid and do not adapt to the always changing traffic situation. Cars waiting in line for the traffic lights to change green continue to consume gas and pollute heavily. During peak times cars and pedestrians need equal chances to pass, while at night, maybe there's no need to stop according to a pre-programmed traffic light. Compared to classic traffic lights, intelligent Traffic Control Systems takes into consideration what happens in the environment and triggers the lights to react as needed. The traffic lights at any one given intersection will be connected to every other traffic light in the city, in order to keep a fluent traffic everywhere.

Though solutions are still under development, some big cities like New York and Singapore have already adopted some form of smart traffic control systems, while others like New Delhi are in the process of adoption, in order to significantly improve their city's overall well-being. Though the first and foremost concern in an intelligent traffic system is to reduce delays, estimations say that the time spent by motorists waiting for the lights to change green could be reduced by over 28% with the introduction of smart traffic lights and that CO₂ emissions could be cut by as much as 6.5%. In addition, such a system can also reduce car crashes and driver frustration, an important asset while trying to improve public well-being [20]

3. Related Works

To construct a fuzzy-logic traffic control model capable of making optimal traffic predictions. This model is applicable to a number of different types of road, signal permutations and provides a framework for implementing flexible traffic control system [1]. A hybrid methodology, obtained by the crossing of the Structured Systems Analysis and Design Methodology (SSADM) and the Fuzzy-Logic based Design Methodology was used to develop a fuzzy-logic based system that was then implemented at a busy traffic intersection in Nigeria with positive results [2]. This paper reviews existing congestion management techniques and discusses their limitations. The paper, further, comprehensively surveys multi-agent techniques for congestion management in ITS (Intelligent Transport Systems) and describes their advantages over other existing techniques [3]. A reservation based traffic control system is implemented at intersections assuming that cars are controlled by agents [4]. This paper proposes an agent model with adaptive weight-based multi-objective algorithm to manage road-network congestion problem [5]. Here, RFID (Radio Frequency Identification), which is economical and easy to install, has been used along with the existing traffic control systems to create smart traffic management [6]. This study focuses on the use of radio frequency identification (RFID) as a form of traffic flow detection, the information is transmitted to a control system through an RS232 interface where sensors apply algorithms on the obtained information to control traffic. The traffic flow situation is also transmitted to a remote monitoring control system through ZigBee wireless network communication technology [7]. The application of autonomous intelligent agents in Urban Traffic Control has been researched [8]. Three modules have been implemented: 1) Congestion detection to provide user real time feed about traffic, 2) Intelligent Public Transport System to provide user real time information about real time traffic and 3) Signal Synchronization to control traffic at junctions and traffic signals [9]. The impact of agent reward functions on two types of traffic problems is explored and it is observed that agents respond better to system rewards compared to local or global rewards. The first problem is studying how agents learn the best departure times in a daily commuting environment and how

following those departure times alleviates congestion. The second problem is studying how agents learn to select desirable lanes to improve traffic flow and minimize delays for all drivers [10]. The proposed agent based approach uses case-bases reasoning to provide green light intervals according to the demand level of the intersection [11]. The report proposes a method for real time estimation of density using synchronized loop detector data and the VII (Vehicle Infrastructure Integration) probe vehicle data [12]. Here traffic density estimation is done by each vehicle estimating its local road traffic density using some simple measurements only, i.e. the number of neighboring vehicles. A maximum likelihood estimator of the traffic density is obtained based on a rigorous analysis of the joint distribution of the number of vehicles in each hop [13]. This paper presents the algorithm to determine the number of vehicles on the road. The density counting algorithm works by comparing the real time frame of live video by the reference image and by searching vehicles only in the region of interest (i.e., road area) [14]. Here, a method to count the number the number of objects in an image and thereby compute the density using image processing techniques written in MatLab code is given. It has been suggested that these techniques can also be implemented for calculation of traffic density [15]. Advantages and drawbacks of the background subtraction technique and frame distinction methodology are analyzed and compared in this paper. Then supporting the background subtraction methodology, a BFS target detection rule is projected [16]. This paper shows the effectiveness and robust nature of fuzzy logic in performing background subtraction in dynamic environments [17].

Evidence of the existing works suggests that implementing an intelligent traffic system that computes the density along different lanes and times the traffic lights accordingly will be very useful in reducing delays and will smoothen the flow of traffic.

4. Proposed Architecture

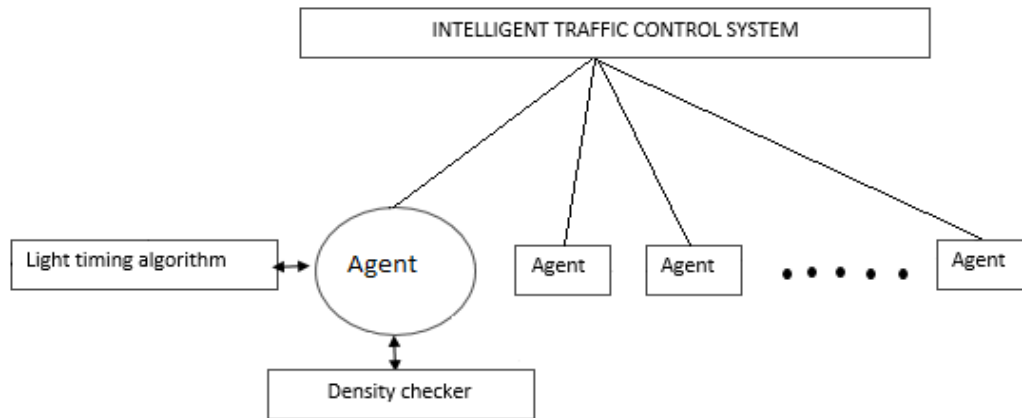


Figure 1. Architecture Showing Working of the Intelligent Traffic Control System

The architecture we propose for the traffic system consists of a number of independent agents (one for each lane being handled). Each agent incorporates a density checker to calculate the number of vehicles (using a vehicle count algorithm based on the same logic as the one given in [15]) used along its assigned lanes. Each agent also runs the algorithm that is responsible for timing the traffic lights based on the input densities for its respective lane. The traffic light timing algorithm computes what color signal is to be shown by a traffic light for what duration of time. Given below is a basic representation:

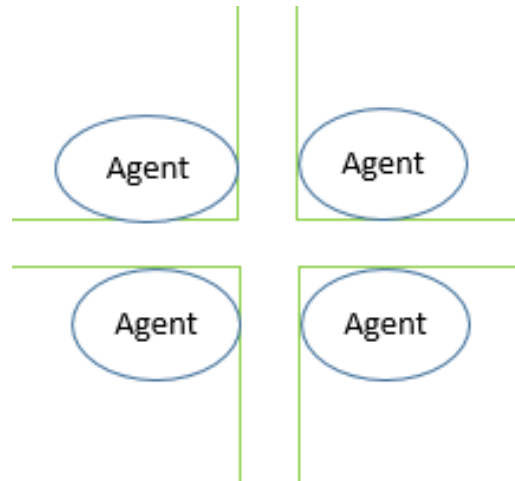


Figure 2. A Traffic Intersection

5. Key Aspects

- The capability of making decisions on the basis of temporal analysis and developments.
- The ability of managing, learning and responding to non-recurrent and unexpected events.
- Self-adjustability.
- Instead of using a physical sensing device such as RFID, etc. for calculating traffic density at an intersection, our technique only requires the use of just one physical component (a camera) and everything else is software based, thereby saving setup cost as well as time otherwise spent in installation. Also maintenance of said devices will also not be a problem.
- Accurate measurements of vehicle count and density that are otherwise mostly not obtained.

6. Algorithms

6.1. Algorithm for Vehicle Count and Density of Traffic

Here, we take two inputs, an image of just the background and another with vehicles. The two images are then converted to grayscale and they are compared to find the frame difference. The difference is compared to a threshold value. Choosing the threshold properly is important as if it is too small, it will produce a lot of false change points, and if the threshold choice is too large, it will reduce the scope of changes in movement [17]. Then the image is converted to binary, and only the large blobs are opened to get the count.

Step1: Start.

Step2: Input the background image of the empty road.

Step3: Input the new image with vehicles on road.

Step4: Convert the images to grayscale format using double precision.

Step5: Find the width and height of the image.

Step6: Set the threshold value as suitable.

Step7: Find the difference between frames.

Step8: If the frame difference is greater than the threshold, then retain that image else discard.

Step9: Convert the image to a binary image.

Step10: Remove small objects from binary image using `bwareaopen()`. That is, only open objects with sufficiently large area.

Step11: Morphologically close the resulting image using `imclose()`.

Step12: Count the number of cars using `bwlabel()`.

Step13: Finish.

6.2. Algorithm for Timing of Traffic Lights

Take the number of vehicles (density) calculated from the above algorithm as an input here. To do this, you will have to call MATLAB from your existing code (we have made use of C/C++ here). You can convert your MATLAB code to C/C++ code using the MATLAB Compiler. The translated C/C++ code can then be converted into a MEX file which can be called from MATLAB. The translated code can also be compiled into a stand-alone application that can run independently of MATLAB, or can be integrated with your existing C/C++ application as a shared library. To run the translated code outside of MATLAB, you need to link it to the MATLAB C/C++ Math Libraries. The timer of a traffic light will be set subject to certain conditions that consider the number of vehicles calculated in the respective lane. Once the timer has finished, the next traffic light in clockwise order runs green.

According to this algorithm, the maximum waiting time for the first car to halt after the light turns red (assuming the halting of the car coincides temporally with the light turning red) is 60 seconds (assuming all other lanes have between 20 to 50 vehicles-which are normal traffic conditions). Also, since the lights only run for as long as required, no light will run green for an unnecessarily long time if no incoming traffic is detected in that lane.

Here, less than 20 vehicles are considered light traffic, between 20 to 50 vehicles are considered moderate traffic and equal to or greater than 50 vehicles is considered heavy traffic.

Step1: Start.

Step2: Take input for number of vehicles in that lane.

Step3: If the number is lesser than or equal to 10, run timer for 10 seconds.

Step4: If the number is greater than 10 but lesser than 20, run timer equal to the number (of vehicle) seconds.

Step5: If the number is greater than or equal to 20 but lesser than 50, run timer for 20 seconds.

Step6: If the number is greater than or equal to 50, run timer equal to half the number (of vehicle) seconds.

Step7: Move to next traffic light in a clockwise direction.

Step8: Finish.

7. Experiment

Here, the intersection shown in figure 2 has been considered. The east traffic light is the first to run green (Simulation_Step = 0) and then control moves in a clockwise order. Inputs for number of vehicles (Num_Vehicles) were taken and the corresponding times for which the traffic lights run green (Timer) were calculated. The maximum waiting time (Max_Time) for the first car to halt after the light turns red was also computed. The resultant values are given in the table.

Table 1. Table Showing Values of Num_Vehicles, Timer and Max_Time at different Simulation_Steps

Simulation_Step	Num_Vehicles	Timer	Max_Time
0	12	12	0
1	10	10	12
2	5	10	22
3	15	15	32
4	8	10	35
5	20	20	35
6	27	20	45
7	9	10	50
8	30	20	50
9	15	25	50
10	17	17	55
11	23	20	62
12	13	13	62
13	35	20	50
14	9	10	53
15	58	29	43
16	20	20	59
17	16	16	59
18	18	18	65
19	32	20	54

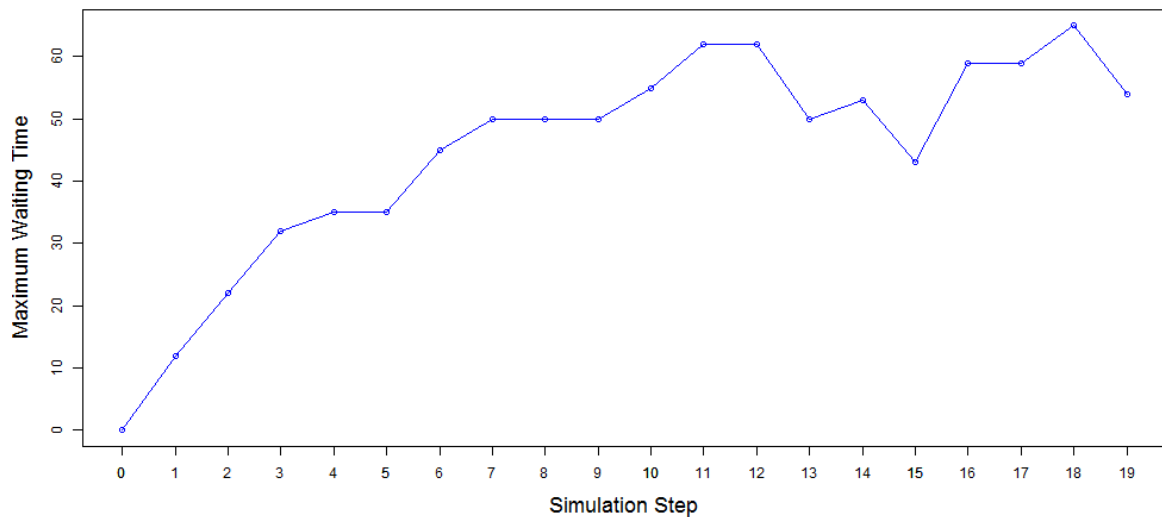


Figure 3. Graph for Maximum Waiting Time versus Simulation Step

The above graph shows the Maximum Waiting Time for a car in each lane till their respective simulation steps, *i.e.*, till that respective lane's traffic light runs green.

8. Performance

According to the above plot, we observe that the maximum waiting time at a traffic light is 65 seconds and the average waiting time at a traffic light is 44.65 seconds despite a few lanes having to handle heavy traffic at certain instances. Comparing these results

with the manually timed traffic lights that tend to run for 100-120 seconds normally, we observe that the average waiting time tends to become almost one third the original and the maximum waiting time also decreases to almost half the original amount.

9. Conclusion

We can thus conclude from the obtained results that an intelligent traffic system that times the traffic light according to real-time scenarios and is flexible as such is much more efficient than the currently existing manually timed traffic lights. Thus intelligent traffic systems smoothen the flow of traffic and reduce/completely remove unnecessary delays.

10. Future Works

There is scope for further addition to our work. We have only made reducing delays the priority, future systems can also include considerations for fuel conservation and reduction of pollution. Also, the timer conditions set here have been taken for the purpose of carrying out simulation only, therefore before implementing the system, the user can choose to time the traffic lights based on real time data (of the traffic pattern, density) of that area.

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