Management of An Intelligent Traffic Light System by Using Genetic Algorithm

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Abstract—**In this paper, an intelligent traffic light that controls the flow of traffic was introduced. The proposed system detects the level of congestion and the abnormal situations in two main highways and four intersections. The system collects the data and the information from a video imaging system, which captures and interprets images to detect, and count of the vehicles. This data will be sent to another system based on genetic algorithm. This system makes a real time decision that determines the interval of green light time for each traffic light at each intersection. This system is simulated theoretically and the results indicate the efficiency of the system. We suggest other inputs from VANET techniques and Mobile track system, which can be added to the system, to improve its output.**

Index Terms—**Intelligent traffic light, genetic algorithm, VANET, and video image detection system.**

I. Introduction

The concept of smart city began in the early 1990s with the rising of new technologies of mobiles and wireless networks; in addition to the huge development in the internet technologies such as semantic web and internet of things IoT Ref. [1].The intelligent transportation system is considered as one of the major applications of the smart city. This system includes intelligent traffic light system, which is proposed is this paper, in an effort to reduce traffic jams , congestions as well as reduce vehicle emissions in the city. Our proposed system may compose of many technologies such as: Video Image Detection Systems, Vehicular Ad Hoc Networks (VANETs) Ref. [2], and Mobile phone tracking, and Global Position System (GPS). Using these technologies with artificial intelligence could be creating an intelligent traffic light that take a decision of green lights time by itself.

There are many goals that could be achieved through this proposed system; such as changing the traffic conditions to reduce the amount of trip time and the time that cars spend idling which decreases the fuel consumption thus will cause decrease the amount of CO2 emissions.

The other dynamic control signals adjusts the timing and phasing of lights according to limits that are set in controller programming, while the proposed system adjusts the timing and phasing by the traffic lights itself. Reviewing some of works published, Barba et al. Ref. [2] designed a smart city framework for VANETs that includes intelligent traffic lights that transmit warning messages and traffic statistics. Singh et al. Ref. [3] used a genetic algorithm and traffic emulator, developed in JAVA, to represent dynamic traffic conditions. Lozano Ref. [4] presented an overview image of processing and analysis tools used for traffic applications on traffic monitoring and automatic vehicle guidance Ref. [5]. Babaei Ref. [6], proposed an unsupervised vehicle's tracking and recognition methods for urban Traffic surveillance in a distributed cooperative manner.

This paper proposes the use of technology to count the vehicle numbers by video image detection system. Then discusses the implementation of the genetic algorithm, and offers some suggestions intended to improve the efficiency of the system and to determine the vehicle numbers and the estimated number of people in the region by mobile cell location; where the system can makes changes in real time to avoid congestion wherever possible. The other application of the system can detect abnormal situations like car accidents, and the level of congestion.

The system is based on a genetic algorithm that receives inputs from the video image detection system which will make a decision and determines the greens light time to minimize the congestions and flow of traffic jam.

II. Algorithm Architecture and Modeling

The algorithm of our proposed system can be divided into two major parts: the first part is acquiring the data from video image detection system by detecting the objects. The second part is optimization the interval of green lights time by using a genetic algorithm. This proposed system can be summarized in following points:

A. Video Image Detection System

Vehicle detection and counting is important in computing traffic congestion and this represents the inputs to our system. The objects here are defined as vehicles moving or stopping on the roads. There are different sizes of the vehicles that use the road, some of them cars and buses that can be differentiated and the different traffic components can be observed and counted for violations, such as lane crossing, vehicles parked in

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no parking zones and even stranded vehicles that are blocking the roads Ref. [7]. The basic algorithm starts with a pre-image processing step, consisting of digitization and segmentation. The next step is called video segmentation which can be defined as the following: given a scene of the road without any object; captures this frame as a reference frame, which will be considered as background to our video segmentations that may contain one or more objects. The algorithm has four major functions, the first one is convert the video segmentation into frames and select the last frame and will call it current image, the second function is convert the current image to black and white in order to prepare for boundary tracing and remove the noise by using morphology functions. The third function subtracts the background from the current frame. The last function counts all distinct objects in the image.

The accuracy of the result depends on: the size of the objects (vehicles), and whether or not any objects are touching. The numbers of the vehicles in each side of the intersection are counted when the traffic light is red. Figure 1 show an example of the intersection between two main roads. Suppose section one and three has traffic green light will be represent by 0, while section two and four has red traffic light be represent as 1,N2 ,N4; where N2 represent the number of vehicles in section two, N4 the numbers of the vehicles in section four.

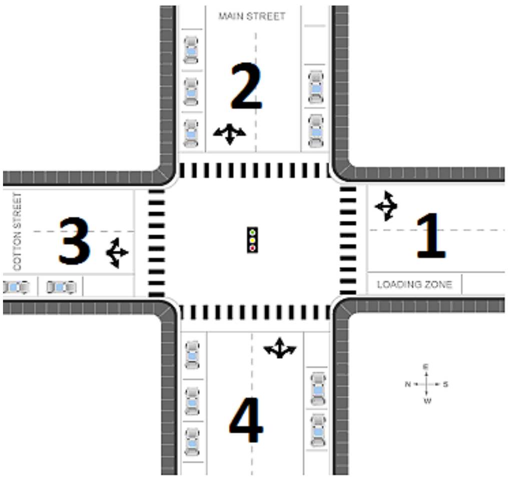

Figure 1. Intersection between two main roads

The algorithm was tested by 5 videos and the results are shown in the table below with the accuracy rate:

TABLE I. RESULT OF COUNTING VEHICLES ALGORITHMS

Input	Actual number of vehicles	Detection number of vehicles	Accuracy rate
1	8	8	100%
2	16	15	93.8%
3	12	12	100%
4	11	10	90.9%
5	7	7	100%

III. SYSTEM DESIGN AND NOTATIONS

This section describes the decision making algorithm; the second part of our proposed system. The decision making algorithm is designed to provide optimal performance of traffic lights system, which will decrease the congestion and traffic jam of some abnormal traffic pattern. This algorithm consists of a genetic algorithm. The goal of this algorithm is to develop an intelligent system that makes decisions in real time.

The management of the traffic lights, and decisions making to each one, is extremely challenging and complex Ref. [8]. To simulate the real world several assumptions had to be made in order to accommodate all possible situations that can occur either normally or abnormally; such as car accidents, special events (sport events, festivals ... etc.) and even emergency situations. But here we simulate our system for normal conditions.

In both cases various assumptions are made and are as what follows:

- The system control for four intersections, I1, I2, I3, and I4 as shown in Figure 2. Each intersection is controlled by an intelligent traffic light.
- The intersections are assumed to be relatively “busy” and under-saturated with significant demand variations in all the approaches.
- The intersection is assumed to be four roads label by following number 1, 2, 3, and 4.
- All vehicles are travelling in the same speed 40 km/h.
- The distance between each intersection is 200 m.

So many rules can be created, which reflect the current situation of the traffic.

C_{IM}: is the vehicles number in the intersection I and in road M.

RE_{IJ}: the intersection I is connected to intersection J by road labeled in even number.

RO_{IJ}: the intersection I is connected to intersection J by road labeled in odd number.

By these terms we can create the following logical statements:

Rule1

$$(C_{11}+C_{13}) \geq (C_{12}+C_{14}) \& (C_{21}+C_{23}) \geq (C_{22}+C_{24})$$

Rule 2

$$(C_{11}+C_{13}) > (C_{12}+C_{14}) \& (C_{21}+C_{23}) < (C_{22}+C_{24})$$

Rule 3

$$(C_{11}+C_{13}) < (C_{12}+C_{14}) \& (C_{21}+C_{23}) > (C_{22}+C_{24})$$

Rule 4

$$(C_{11}+C_{13}) < (C_{12}+C_{14}) \& (C_{21}+C_{23}) < (C_{22}+C_{24}) \text{ .etc.}$$

If the congestions are coming from outside of the four intersections as shown in the following cases, the input traffic to the intersection I_1 from (road 1 and 2) will affect road one of the intersection I_2 and can be represented by $I_{21;}$ and I_{42}. Similarly intersection I_2 (road 2 and 3) will affect I_{13} and I_{32}, intersection I_3 (road 3 and 4) will affect I_{24} and I_{43}, and lastly intersection I_4 (road 4 and 1) will affect I_{31} and $I_{14.}$

If the congestion is one of the following cases: the traffic at I13 will affect I_{42}, I_{42} will affect I_{31} ... etc.

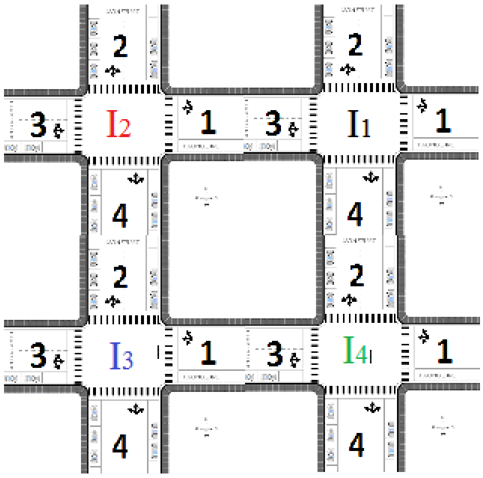

Figure 2. The proposed of four intersection

The genetic algorithm used in this work has the following details

- Codification of a chromosome. A candidate solution (chromosome) is a vector of 16 random numbers (genes). Each gene corresponding to a green traffic light time consists of a random number, between15 to 35 sec.
- Evaluation of a chromosome. A fitness value is given to each chromosome in the following way: We assume here each vehicles needs on average 3 seconds to leave the current location.

  $$C'_{IM} = C_{IM} - t_g/3$$

  Where the C'_{IM} is the number of vehicles after the green light, tg is time of green light.

  Fitness function: $1/\sum_{i=1}^{4} W_i$

Selection of mating pool. We have followed the Baker roulette method Ref. [9]. In this method, each chromosome is given a circular section of a roulette wheel directly proportional to its fitness. Then the selection is made by playing a ball in the roulette wheel. This way, chromosomes with high fitness are more likely to be passed onto the mating pool and also to next generation.

- Crossover operator. The crossover operator is applied with probability p_c. We have used the standard one-point crossover. Two chromosomes are randomly chosen from the mating pool $x'_i; y'_i \in p'_i$. Then, a cross point is chosen randomly and the operator is applied producing two new chromosomes $x''_i; y''_i \in p''_i$.
- Mutation operator. The mutation operator is applied with a probability per gene p_m. This operator flips a random bit of the chromosome.

The algorithm below is repeated each 30 sec. according to this time allowing to a certain number of vehicles to pass away and change their location. So the situation conditions of the intersection will be changed.

1) Weight of traffic is calculated for each intersection $W_I = \sum_{M=1}^{4} C_{IM}$.
2) The maximum weight selected over all intersections.
3) The maximum C_{IM} is selected.
4) The extension time is added according to our constraints.
5) Generate 10 random population
6) Evaluate the generation by fitness function
7) Select best generation

IV. System Simulation

The system is simulated by Matlab program. The following steps summarize the simulation:

1) Run the algorithm of video image detection system. The five video scenes were recording by normal video camera surveillance.
2) The C_{IM} 's will be calculated and sent to the decision making algorithm, after it fulfilled all road constraints.
3) Run the genetic algorithm.
4) The output of genetic algorithm is applied to a program that calculates the change of the number of vehicles in each road for each intersection.
5) Comparing the results between the actual results and the results of proposed system.
6) Initial results from the running of the simulation are encouraging: the amount of the traffic is reduced and the amount of time that motorists spent idling at lights was reduced almost by 40%.

V. Future Plane

The other inputs can be added to our proposed system, and can improve the management of intelligent traffic lights system to decrease the congestion in the city. These inputs can be acquired by using various techniques like VANET and Mobile tracking system and can be used to track the cars that break the traffic rules. The system will send a warning message and will make announcements for abnormal scenes (e.g. car accident...etc.). Theoretically, the travel times across the city could be reduced by 20%, when the drivers use VANET techniques and GPS to change the track when there are traffic jams.

Another input can be added to our system to determine the emergency situation by detecting the siren of emergency units and special vehicles using the microphone placed at the camera sites, as these vehicles have the priority over regular city traffic. Based on real time traffic conditions, these vehicles will obtain the best route to their destination, involving the cooperation of other vehicles, which will create a virtual corridor for emergency units.

VI. Conclusion

This paper presents a system that can be used in the smart city platforms to manage the transportation system through the control of the intelligent traffic lights. The system depends on some theories and rules that made to order the priority and the green light interval time, genetic algorithm used in this proposed system and the input to GA is based on the data that got from the video image detection system.

The system is able to track and count most vehicles successfully. Although the average accuracy of counting vehicles was 96%.This is due to noise which is caused detecting objects size too large or too small to be considered as a vehicle. However, two vehicles will persist to exist as a single vehicle if relative motion between them is small and in such cases the count of vehicles becomes incorrect.

The program could be run in real time by using desktop computer core duo processor. The system was tested during day light, whereas during night light it was not tested yet, but it may need to special infrared cameras in cases where there is some noise from the cars lights or street lights.

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