
An Adaptive Controller of Traffic Lights using Genetic Algorithms

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1 Introduction

Road traffic system is one of the primary modes of private and public transport. Due to the massive growth of modern cities in terms of population and number of vehicles on the roads, has put an enormous pressure on the road traffic system. Therefore, there is a constant need for more effective and efficient traffic management systems [4]. Many modern cities such as Beijing, London and Paris are suffering from the traffic congestion problem. This traffic congestion problem has also resulted into a lot amount of time wastes and energy. Apart from economic impact, there is also an environmental impact like pollution of CO₂ and black carbon emissions that cause a high temperature on ozone and many serious illnesses [6]. In 2007, the Urban Mobility Report estimated that the total annual cost of congestion for the 75 US urban areas at 89.6 billion dollars, 4.5 billion hours of delay and 6.9 billion gallons of excess fuel consumed [7].

One way to alleviate this problem of roads and highway's congestion is to build new high capacity roads and highways but this solution is very expensive, time-consuming and in majority of scenarios, it is not feasible due to space limitations. On the other hand, the most realistic solution is to optimize the usage of existing roads and highways by

better management and control strategy of traffic light systems. Therefore, in this paper, we are proposing a model based on Genetic Algorithms that can optimize the usage of traffic light systems and reduce time wastes, money and energy.

2 Related Work

In order to control and manage this problem, most present traffic light control systems use static models of flow patterns at intersections, where the shape and cycle of flow at regular or rush hours are assumed to be the same at all times. Some researches fixed the cycle time and over flow of each intersection and changed only on green split [1, 2, 8].

Our objective in this paper is to reduce the delay and optimize the flow ratio at intersections. In [1], the probability to enter main road is 80 %, and side road is 20 % (with the exception of intersection of two main roads where the probabilities of the choice of the two target roads are equal). A fixed cycle time, however, causes crowding in junctions with lost time because in each intersection, the length of overflow queue will grow from cycle to cycle [5]. The assumption in the older delay models is that the overflow queue is static, constant from cycle to cycle [5, 2, 8]. The offset has proven that we can attain better results by using the coordinating control method when the distance between neighboring intersections is not more than 800 meters [8].

3 Our Approach

In developing countries, most traffic light control systems are pre-timed. These systems correspond to the predicated traffic changes via preset changes on a time clock. Moreover, there are different places that have congestion at junctions where a study is required to reduce the delay time. Our work presents a dynamic Genetic Algorithm

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Traffic Signal Timing Management System (GATSTMS) that adapts and coordinates most traffic light models. In order to execute the GATSTMS there are two files as inputs, the structure file which contains structure of traffic lights where the user can define the parameters such as number of intersections N , number of phases (group lights) P at each intersection, number of roads R connected to the intersections, and number of lanes movement L at each road. There is also the data file that contains the traffic lights data such as arrival, departure rate for each lane and vehicles distribution for each intermediate lane. In addition, the user can change phase shape and the sequence order. The GATSTMS can get the optimal solution for cycle times, green splits and offset times.

3.1 Genetic Algorithm in Traffic Signal Optimization

The Genetic Algorithm (GA) is a search technique that solves optimization problems. The structure of GA is same as the evolution algorithm. In order to solve any problem as traffic lights using GA, four questions should be answered [3]:

- What fitness function is used in traffic lights?
- How an individual is represented?
- How individuals are selected?
- How individuals do reproduce?

In GA, we represent a solution of our problem as a chromosome. The main idea is to maintain a population of chromosomes that symbolize acceptable solutions to the particular problem that evolves over continuous iterations (generations) through a process of competition and controlled variation. Each chromosome in the population has an associated fitness to control which chromosomes. We should use to form new ones in the competition process. The new chromosomes are created using genetic operators such as crossover and mutation. In GA model [9], we represent the chromosome as binary digits with length Ch_L for each intersection and calculate it as follows:

$$Ch_L = (N + \sum_{i=1}^N (G(i) + R_{intermediate}^i)) \times 8 \quad (1)$$

Chromosome length depends on a total number of intersections N , a number of lighting groups $G(i)$ inside i^{th} intersection and a number of intermediate roads $R_{intermediate}^i$ connected to i^{th} intersection. Each chromosome represents parameters Cycle Times (CT), Offset Times (FT) and Green split Times (GT). Eight multiplies each parameter because the highest value for CT is 256 seconds and some of intersections may have one GT .

Table 1 Directions lane movement for one intersection

lane move \ direction	Right=1	Left=2	Direct=3
N=1	NE=11	NW=12	NS=13
E=2	ES=21	EN=22	EW=23
S=3	SW=31	SE=32	SN=33
W=4	WN=41	WS=42	WE=43

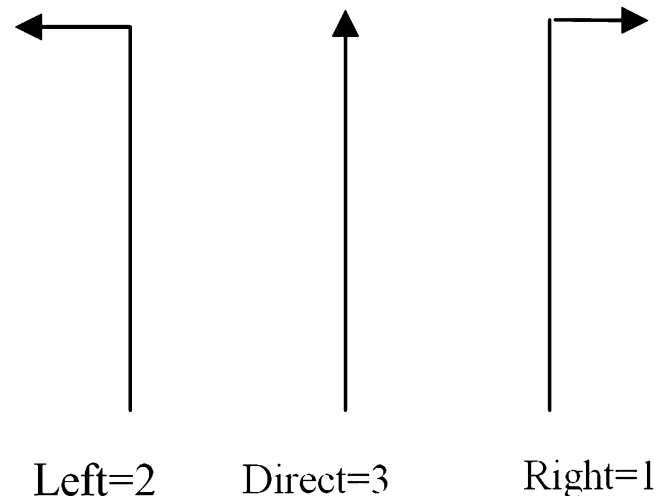


Fig. 1 Type of lanes for one road

4 Proposed Model

The proposed model is a general dynamic model based on GA, where the number of intersections is in the range $(2-N)$, number of road R that connected to the desired intersection is in the range $(1-4)$ ($N = 1, E = 2, S = 3, W = 4$) see Table 1, number of group lights P for each intersection are in the range $(1-4)$. If group light is 1 this means there is one stage for the cycle in the desired intersection. In addition, the lanes movement type L for each road is in the range $(1-3)$ as shown in Figure 1. We assume that each lane of the input road has detector to detect the arrival vehicles, flow ratio dependence on the priority of the road, and average speed for each road will optimize the offset time. In this model, we assume that every vehicle is on the desirable lane of the road.

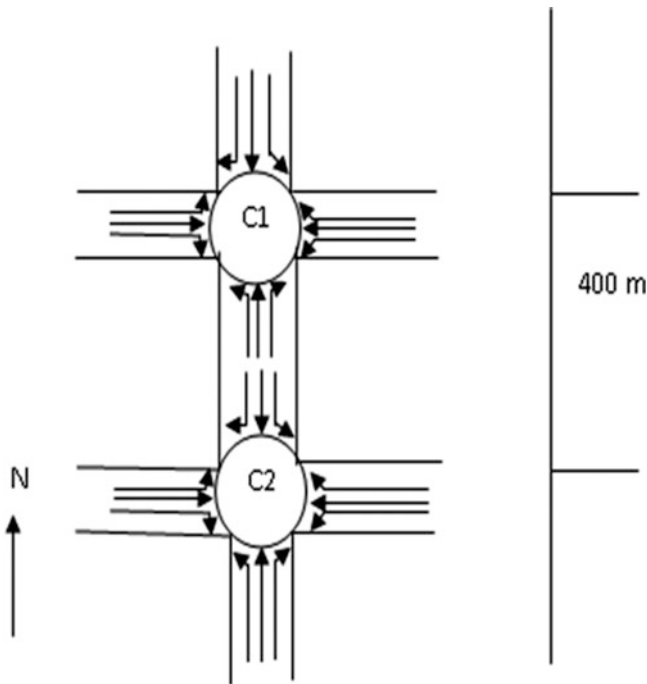


Fig. 2 Suggested network

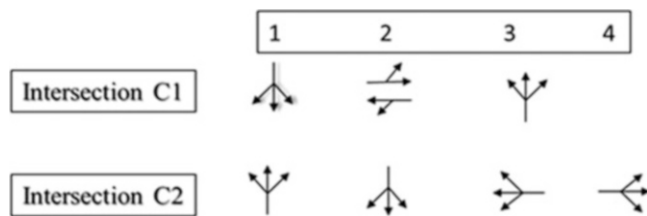


Fig. 3 Sequence order for network

5 Simulation and Results

The proposed model of the GATSTMS is simulated using input from two files that contain structure and data of traffic lights. The structure file contains all parameters needed to define the dynamic model, while the data file contains the data needed for this model. We assume the detector detects flow per hour, and then the GATSTMS update the data file with arrival and departure for each lane. In Figure 2, the modeled network consists of two intersections (C1 and C2) with three phases for C1, four phases for C2, also, each intersection consists of four roads (N, E, S and W).

Figure 3 shows the phases for intersection C1 and intersection C2, where the sequence order in the GATSTMS select phase 1 from intersection C1 and C2, then select phase 2 from intersection C1 and intersection C2, etc.

The results of the simulation show that the GATSTMS can deliver an optimal solution (see Figures 4 and 5). We test

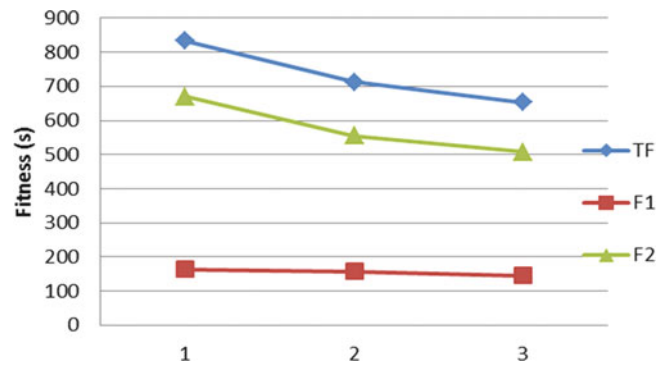


Fig. 4 Fitness's VS generation

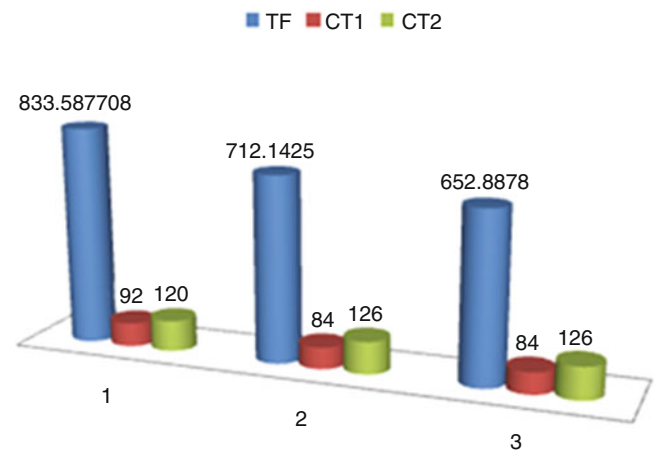


Fig. 5 Fitness for optimal CT

our network under values $48 \leq CT \leq 120$, $16 \leq GT \leq 40$ for intersections C1 and C2. Figure 4 shows the results for the minimum of Total fitness (TF), minimum Fitness for intersection C1 (F1) and minimum fitness for intersection C2 (F2) for each generation based on data table and interaction of vehicles for each generation, where in first generation TF recorded was 833.5877's, F1 was 163.4693's and F2 was 670.1184's. In the second and third generation, the GATSTMS get the optimal solution respectively (712.1425's, 652.8878's) for TF, (157.5795's, 145.7803's) for F1 and (554.563's, 507.1075's) for F2.

Figure 5, shows the relation between TF and optimal CT for intersection C1 and C2 for each generation, where the TF, CT1 and CT2 respectively (833.5877's, 92's and 120's), (712.1425's, 84's and 126's) and (652.8878's, 84's and 126's).

6 Conclusions and Future Work

In this paper, we have addressed the vehicle traffic congestion problem that is one of the most prominent problems. We have presented a dynamic model for most of

the current traffic light control systems using the Genetic Algorithm. In our work, the user defines the structure of the traffic lights, while the GA program optimizes the traffic lights fluency, which can be achieved by finding the minimum delay in the entire system. The cycle time is defined at each intersection to enhance the fluency and avoid long queues in each intersection. The work presents a more efficient GATSTMS that is suitable for wide range of different traffic models while considering a number of dynamic constraints. The paper presents the green splits such as dynamic as to control lanes movement of any road.

In the future, we will use our proposed GATSTMS on more complex road networks, especially when there are more intersections and evaluate the performance of our model in more details.

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