Various Strategies for Optimizing Traffic Lights: A Review

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Abstract: In recent years, enhancing the vehicular traffic flow became a mandatory task to minimize the impact of unsustainable consumption of fuel and polluting emissions in our cities. Smart mobility optimization emerges then, with the goal of improving the traffic management in the city. Consequently, an optimization strategy based on swarm intelligence to find efficient cycle programs for traffic lights were deployed in large urban areas. After several comparisons between different optimization techniques (Differential Evolution and Random Search), as well as other solutions provided by experts; I learnt that there is a need to obtain significant reductions of fuel consumption and gas emissions. Thus metaheuristics are strongly advisable techniques for future development in this domain.

Keywords: Traffic Lights Optimization, Different Techniques, Optimization with Metaheuristics.

I. INTRODUCTION

Traffic congestion has become a challenging task and a large burden on both the governments and the people in cities with large population. The main problem originally initiated by several factors, carry on threatening the stability of modern cities and the livelihood of its habitants; thus improving the control planning that oversees the traffic operations is a powerful solution that can solve the congestion problem. These improvements can be attained by enhancing the traffic control performance by adjusting the traffic signal timing.

Traffic congestion is a crucial problem in large urban areas characterized by high population densities. Waiting times increases, massive queues build up, and the overall productivity is affected, as the working strength may never reach its destination at the right time [1]. Environmental effect also represents another phase of the problem due to the high rates of fuel utilization, energy losses, toxic exhausts and gas emissions. Traffic signal timing optimization when done appropriately, could significantly improve network performance by reducing delay, reducing number of stops, increasing network throughput, or increasing average speed in the network. The optimization becomes hard due to large solution space caused by many number combinations of different parameters that affect traffic operation.

Traffic Optimization are the methods by which stopped time in road traffic (particularly, at traffic signals) is reduced. Number of techniques exists to reduce delay of traffic [2]. Generally the algorithms attempt to reduce delays (user time), stops, emissions, or some other measure of effectiveness [1]. Optimal staging of traffic lights and in particular optimal light cycle programs is a essential task in present day cities with potential benefits in terms of energy consumption with traffic flow management and environmental issues.

The number of traffic lights is rising in modern cities, and its scheduling is becoming more and more complex due to their huge number of combinations that should be considered. Thus, the use of automatic intelligent tools for the optimal cycle programming of traffic lights is an essential task in traffic flow management [2]. As the high level of pollution in the air and the hydrocarbons consumption derived from the urban traffic are becoming serious issues, since they affect the citizens’ health, the global economy, and the difficulty of city management. Hence, the improvement of vehicle mobility is a key task in urban areas, and might have a positive impact in the efficacy of traffic flow management. Thus in following sections, the overview of different optimization techniques are discussed; among which Technique 1 is Genetic Algorithm Coupled With The CORSIM. Technique 2 is “Isolation Niches Particle Swarm Optimization” and Technique 3 is “Optimization Of Traffic Lights With Metaheuristics: Reduction Of Car Emissions And Consumption”.

II. DIFFERENT OPTIMIZATION TECHNIQUE’S OVERVIEW

Several works can be found in the related literature that deals with the traffic congestion problem by means of accurate signal lights timing programs. In mathematical optimization, a metaheuristic which is a higher-level procedure designed to find, generate, or select a (partial search algorithm) heuristic that may provide a sufficiently good solution to an optimization problem [2] especially with incomplete information or limited computation capacity. Thus the focus is on the use of metaheuristic approaches for optimizing traffic light staging problems.

A. Genetic Algorithm Coupled With The CORSIM

Genetic Algorithm is a method to find the most optimum solutions for the problem through the processes of selection reproduction and mutations; these are the concept adapted from the genetic evolution in biology studies. Characteristics of the genetic algorithm are to copy the development theory of the nature, allow it to reproduce a generation after generation while eliminating the unhealthy solution. In GA the optimum solution will survive throughout the processes in the end. Answer to these problems are represented by chromosomes within a population here population is the area or boundary of the
chromosomes exists. In genetic algorithm population means the set of chromosomes within a boundary of interests where the range can be determined and the number of the chromosomes [6]. Fitness function is a function or the rule of genetic algorithm to select the fit solution (gene). Fitness function can filter ever solution and the fitness of each chromosome is then determined or calculated. Fitness of every chromosome is used for ranking process. Ranking is used to produce a list of chromosomes which is according to their fitness after that the rank will be used for selection process which then fitter chromosomes will be selected and the unfit chromosomes will be filtered[4]. The large number of the chromosomes maintain the same with original population size. After the selection stage, the selected solution will go through another stage for processing which is reproduction, in this reproduction stage, selected chromosomes will become the parents of next generation; the new chromosomes produced are now the population of the new generation of the genetic algorithm. Genetic algorithm will end when the stopping criteria is reach [4]. The stopping criteria can be the numbers of generations or key search the limit of the fitness functions.

A first attempt was proposed by Rouphail et al. [3], in which a Genetic Algorithm (GA) was coupled with the CORSIM [5] microsimulator for timing optimization of nine intersections in the city of Chicago (USA). Genetic Algorithms (GA) applied to optimize isolated intersections, also arterial roads and traffic networks(Rouphail et al., 2000). GA is a guided random search that also uses the concepts of natural section and the evolution to evaluate and suggest improved solutions by optimizing a given objective. GA meet to an optimal (not necessarily global) solution [3]. A difficulty in CORSIM application is inherent variability in system output, which then slows down convergence. GA also prevents the occurrence of long queues on the network as a consequence of large penalties associated with such queues.

The development phase encompasses preparation of computer codes to interface with CORSIM input and output files, and also the testing of a variety of model parameters and solution spaces. That stage of work produced a direct optimization method which is applicable to small size networks [3]. The evaluation phase includes collecting various observed data for model input and evaluation, and comparison of the signal setting derived from the direct optimization with those obtained from traditional methods.

Different comparisons were made on the basis of repeated observations of the CORSIM traffic model. Since GA makes no assumptions about the traffic environment, interact with CORSIM to produce the most favorable plans based on CORSIM’s predicted system performance [3]. Implementing GA in connection to CORSIM require an interface between programs that enable the full functionality of direct optimization.

TSIS-CORSIM (tm) is microscopic traffic simulation software package for signal highway, freeway systems, or combined signal, highway and freeway systems. TSIS (Traffic Software Integrated System) is an integrated development environment which can enable users to conduct traffic operations analysis. CORSIM (CORridor SIMulation) consists of an integrated set containing two microscopic simulation models that represent the entire traffic environment [3]. Microscopic simulation mold movements of individual vehicles that include the influences of geometric conditions along with control conditions, and driver behavior. CORSIM can explicitly model many elements of modern traffic systems. Many of the other features can be approximated using the essential elements of CORSIM along with engineering judgment.

B. Isolation Niches Particle Swarm Optimization

The Particle swarm optimization which is a swarm intelligence method was proposed by James Kennedy and Russell Eberhart in 1995 firstly. It aimed to keep balance of global and local searching ability and also to overcome the slow convergence, prematurely of the particle swarm optimization isolation niches technique is been embedded in particle swarm optimization. It can keep the competition between individuals and also niches. Using improved PSO the time of green and red lights could be optimized and make the average waiting time of vehicles shorter.

Isolation niches technique is a fundamental concept, evolution strategies in accordance with the geographical isolation technology [5]. The initial particle swarm is to be divided into several sub-groups. Moreover, the evolution speed and population scale of various sub-groups depends on aggregate fitness level of every sub-group. The group having high average value has large population size; also the group scale is small. In PSO algorithm, the total number of population is certain. To ensure the diversity of species in the group, the size of some sub-groups must be limited. The maximum number of sub-groups allowed is known as the maximum allowable size. Peng et al. [5] presented a Particle Swarm Optimization (PSO) with isolation niches for the scheduling of traffic lights [2]. In this approach, a purely academic instance with restrictive one-way road and two intersections was used to test.

Isolation niche technique used to maintain the diversity of groups, the smallest scale of groups must be provided. If fitness of a certain sub-groups sustained worst in required time, this group should be made extinct and be replaced by new solutions of search space. This is defined as an inferior species which do not live [5]. If two sub-groups are found similar then one of the two is removed and replaced by new solutions. Such strategy is called struggle between different sub-groups, thus when a new group comes out; it is too weak to compete with another group in the early evolution for its lesser fitness. The protection against competitions should be given to this new group [5]. While solutions are close to the most favorable location the evolution will retard. The sub-group with these kinds of solutions also needs to be removed and then replaced with new solutions in search space. Such strategy is called as the old and new replacement. But the same strategy is not so suitable for the sub-group that has best performance for the global optimal solution may exist in the best performance sub-group.

C. Optimization of Traffic Lights with Metaheuristics: Reduction of Car Emissions and Consumption

An optimization approach has been developed, in which a particle swarm optimizer (PSO) is able to find successful traffic light cycle programs. Solutions obtained are simulated with simulator of urban mobility, a well-known microscopic traffic simulator. Optimization strategy follows stages as: first the particular implementation of a Particle Swarm Optimization for traffic lights (PSO-tl) to generate optimal cycle programs [2], to reduce the vehicular contaminant emissions. Next, gathering data from the
SUMO micro-simulator to enhance the optimization process with the information extracted from the simulation of the realistic scenarios. In this sense, the application of intelligent optimization techniques, like metaheuristic algorithms, has become important since their adequacy has been already demonstrated for the generation of traffic lights programs [2] with the aim of enhancing the global traffic flow. Thus there is no related work focusing on the environmental perspective, with the aim of reducing contaminant emissions and fuel consumption [2].

An optimization strategy based on a Particle Swarm Optimization algorithm (PSO) [2] named PSO-tl, used to efficiently obtain cycle programs of traffic lights from an environmental perspective, with the target of reducing CO2 and NOx emissions, also the total fuel consumption of vehicles [2]. PSO is an easily configurable algorithm, which in general, develops a quick convergence towards high quality solutions. This is a desirable characteristic, since it allows us to obtain good solutions with fast techniques. For the evaluation of the cycle programs (coded as vector solutions) the Simulator of Urban Mobility (SUMO) is used [2]. From the simulator a continuous source of information about the vehicle flow is obtained. This is a key aspect when using an advanced algorithm to generate automatic timing programs for traffic lights. In addition, SUMO allows us to work with the standard model of emissions (HBEFA) HandBook Emission FActors [2], by which the information about pollution and fuel consumption is obtained. In a road network, the traffic lights are located in the intersections. The traffic flow is controlled according to the cycle programs and their phase duration [2]. In an intersection, all traffic lights are controlled by a common cycle program because they should be synchronized for security reasons.

In addition, for all traffic lights in an intersection, the color combination during their phase must be always valid, obeying real traffic rules with the aim of avoiding collisions and accidents, in general [2]. Here the combinations of color states for any intersection, which are constant during all the optimization process. In this way, invalid combinations of color states are avoided, while at the same time; it also restricts the search to only valid states. Finding the optimized cycle programs for all traffic lights located in a specific urban area. A cycle is defined as the period of time, in which a set of traffic lights in the same intersection has the same color state [2]. In addition, these cycle programs should be coordinated with the traffic lights of the adjacent intersections, with the intention of improving the traffic flow according to the provisions of road traffic regulation.

### III. COMPARISON BETWEEN TECHNIQUES

Thus the Technique 1-“Genetic Algorithm coupled With the CORSIM” and Technique 2- “Isolation Niches Particle Swarm Optimization” which deals with only traffic flow management for obtaining the optimal cycle programming of traffic lights and in Technique 3- “Optimization Of Traffic Lights With Metaheuristics: Reduction Of Car Emissions And Consumption” the application of intelligent optimization technique, like metaheuristic algorithm is used. It became important for the generation of traffic lights programs with the aim of enhancing the global traffic flow. However, the main emphasis is on reduction of contaminant emissions and fuel consumption for the environmental perspective.

#### Table 1: Comparison Between Various Techniques For Traffic Light Optimization

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<th>Genetic Algorithm Coupled With The CORSIM</th>
<th>Isolation Niches Particle Swarm Optimization</th>
<th>Optimization with metaheuristics</th>
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<tbody>
<tr>
<td>Traffic Flow Management</td>
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<td>Emphasis on reduction of fuel consumption and emissions</td>
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### CONCLUSION

Thus optimal light cycle program is an important task in present day cities with benefits in terms of energy consumption, traffic flow management, safety, and environmental issues. Technique-3 achieves the significant improvements in terms of polluting emissions and consumption of hydrocarbons, in comparison with techniques 1 and 2. In technique-1, Genetic Algorithm interact with CORSIM to produce optimal plans and brings out the optimal solution for traffic flow management, while in technique-2, a Particle Swarm Optimization (PSO) with isolation niches is used for proper scheduling of traffic lights in order to reduce the traffic. Thus technique-3 is more beneficial as it focus on reduction of contaminant emissions and fuel consumption for the environmental perspective along with the traffic flow management.

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### References


