Dealing With a Problematic Roundabout by Optimizing a Traffic Light System Through Evolutionary Computation

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ABSTRACT

The Padre Anchieta roundabout (Tenerife) takes on a substantial amount of traffic which, at peak times, often causes significant traffic jams. With the aim of alleviating traffic congestion, this paper analyses the possibility of installing a set of traffic lights in the roundabout. The duration of the phases of traffic lights are optimized through a genetic algorithm. SUMO, an open source traffic simulator, is used to evaluate the traffic of the area by considering real traffic data. Seven different scenarios are evaluated with respect to the roundabout, three of them without traffic lights and the other four with them. Simultaneously, the number of pedestrians, and the particular location of the traffic lights, are modified in each of the aforementioned scenarios, when applicable. To determine which parameters of the evolutionary algorithm provided the best results, a previous parameter setting study based on a statistical comparison procedure was performed. Particularly, the crossover operator and the population size, were analyzed. From the results obtained in the experimental assessment, we conclude that the use of an optimized traffic light system would not improve traffic flow in the roundabout. Another important conclusion is that the larger the number of pedestrians, the slower the traffic flow.

CCS CONCEPTS

• **Applied computing** → *Transportation*; • **Theory of computation** → **Evolutionary algorithms**; • **Computing methodologies** → **Genetic algorithms**; Simulation tools; • **Mathematics of computing** → **Combinatorial optimization**.

KEYWORDS

Traffic light scheduling problem, evolutionary algorithm, genetic algorithm, optimization, simulation, SUMO

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1 INTRODUCTION

Nowadays, the Padre Anchieta roundabout has considerably increased its size and the traffic flow that circulates through it, especially at peak times. During these hours there are very important retentions and, in certain situations, a total traffic blockage; sometimes for several hours. Currently, the Padre Anchieta roundabout does not have any traffic lights. Traffic is regulated by two factors: signaling—yield signs, mainly—and pedestrian crossings, which we have taken into account when evaluating traffic behavior. What we propose in this work is an analysis to check whether the installation of traffic lights in the roundabout provides any advantage with respect to the current situation, where no traffic lights are present. Additionally, the duration of the phases of the traffic lights will be optimized through a standard Genetic Algorithm (GA). The problem to be addressed is the planning of the duration of the traffic light different phases, known as the *Traffic Light Scheduling Problem* (TLSP) [4].

The mathematical formulation of the TLSP is based on the one first proposed in [2]. It takes into account the following objectives: the number of vehicles V_R arriving at their destination, the number of vehicles V_{NR} that do not reach their destination in a given simulation time T_{sim}, the average journey time of all T_{trip} vehicles, and the total time T_{sw} that the vehicles have lost due to being stopped or going slower than they would like. All of the above objectives are combined into the following objective function:

$$f_{obj} = \frac{V_R^2}{T_{trip} + T_{sw} + V_{NR} \cdot T_{sim}} \quad (1)$$

The objectives that have to be maximized are placed in the numerator, while those that have to be minimized are placed in the denominator. Therefore, the objective function described by Eq. (1) must be maximized.

2 METHODOLOGY

The area around the roundabout has been extracted from OpenStreetMap (OSM) [3]. It was converted with NETCONVERT and processed with NETEDIT, both tools provided with the *Simulation of Urban MObility* (SUMO) distribution [1], to improve road shapes and fix wrong speed limits, right-of-way inconsistencies, and other data that was incorrect.

Table 1: Results obtained from the simulation of the different scenarios

	Case	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Vehicles	*Loaded*	14181.8	14182.8	14182.7	14184	14183.6	14181.7	14183.1
	Inserted	13057.8	12904.8	12878.1	11954.1	12397.3	12669.1	12699.2
	Running	614.6	623.4	640.1	761.8	781	678.4	737
	Waiting	1124	1278	1304.6	2229.9	1786.3	1512.6	1483.9
Statistics	*Length (m)*	1705.982	1713.93	1707.695	1739.027	1708.098	1726.209	1763.325
	Speed (m/s)	22.99	23.253	23.125	23.883	23.332	23.32	23.436
	Lost time (s)	88.34	91.304	94.263	145.692	130.275	106.309	115.69
	Wait time (s)	44.94	50.476	51.693	110.81	91.921	61.791	71.151
	Duration (s)	145.44	148.404	151.237	201.943	186.185	163.292	173.26
	Delay (s)	70.55	71.458	80.753	85.724	95.318	87.167	59.275

Traffic was generated thanks to a tool provided by SUMO called `dfrouter.py`, based on data from traffic gauges placed in the vicinity of the roundabout, in a study carried out by the Tenerife Island Council in the week from the 19 to the 25 of November, 2019. As our objective was to simulate a rush hour, we generated the traffic flow based on the data of Thursday, November 21, 2019, at 8:00 AM, as it was the day with the most traffic at that time.

Pedestrian traffic flow was generated randomly in a uniform way throughout the entire network, since there is no empirical data on the movement of people through the roundabout.

Seven different scenarios or network cases were designed, with variations in the number of pedestrians and the particular position of the traffic lights in the roundabout.

Three cases (S_{1-3}) were designed without traffic lights, varying only the number of pedestrians (S_1, no pedestrians; S_2, 500 pedestrians; and S_3, 2000 pedestrians). These scenarios provide a baseline whose simulation can be compared to the simulation of those cases where traffic lights have been located in the roundabout.

Other four scenarios (S_{4-7}) were designed by considering traffic lights. They are classified into two groups: scenarios (S_{4-5}) have traffic lights at each entrance and exit of the roundabout, while the scenarios (S_{6-7}) have traffic lights at two points in the roundabout, north and south. The traffic lights of the interior lane of the roundabout in S_4 are always in green where possible, while in S_5 the traffic lights of the interior lane change at the same time with the exterior lane. The main difference between S_6 and S_7 is the number of pedestrians: 500 and 2000, respectively.

3 EXPERIMENTAL ASSESSMENT

In order to improve the efficiency of the genetic algorithm and to know what parameters affect the performance the most, a preliminary parameter setting study was carried out. Two parameters of the genetic algorithm, the crossover operator and the population size, were selected for the parameter setting study. The remaining components and parameters of the genetic algorithm were fixed for both the parameter setting study. This study was performed by independently considering scenarios S_{4-7}.

The genotype used by the algorithm was implemented as an array of integer numbers that represent the duration of each of the phases of the traffic light intersections, as well as the delay among them. Individuals were evaluated by considering the output values provided after performing a simulation with SUMO and the objective function described in Eq. (1). The traffic light schedule represented by an individual was used as the input of the simulator.

4 CONCLUSIONS AND FURTHER RESEARCH

Once simulations were completed and the results were provided by SUMO (see Table 1) for the whole set of test cases, we concluded that no scenario with traffic lights provided better indicator values than those scenarios without traffic lights. The preliminary study showed that there were, in some cases, a significant differences in performance in the configuration of the parameters.

Including traffic lights in every entrance and exit of the roundabout offers the worst results. Allowing the traffic lights of the inner lane of the roundabout to always remain green where possible is a configuration that decreases the traffic flow, and as a result, its implementation is discouraged. At the same time, including traffic lights at the north and south parts of the roundabout shows an improvement with respect to including them at every entrance and exit, but they do not enhance the current situation of the roundabout. Similarly, results indicate a worsening of traffic flow efficiency when the number of pedestrians increases.

Finally, it is worth mentioning some lines of future work that would help to consolidate the results and provide more insight about traffic flow and the future of traffic light scheduling in the area: increase of the set of scenarios, configurations of the genetic algorithm, and the data of the traffic flow, inclusion of other desirable factors in the objective function, and the evaluation of a better time value before a vehicle gets teleported.

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