Theoretical Model of Traffic Signal Timing Optimisation Improved On ant colony Optimisation and Symbiotic Organism Search

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Abstract. Due to the increasing in the number of vehicules on a daily basis, road congestion is becoming a key challenge. Therefore, it becomes essential to develop a signal optimization method for multi-intersections. In this paper, the proposed model is capable of minimizing waiting time of vehicule.an hybrid meta-heuristic algorithm (Ant Colony, Symbiotic Organism Search) is employed to solve the model. We proposed a hybridization of two bio inspired methods, the first based on the use of ant colony to determine the critical path, the critical path is the input of the next step. The second step is based on the minimization of vehicles with the metaheuristic SOS. The main focus of this study is on improving the quality of solutions for the traffic light optimization problem to minimize the waiting time of all the vehicles within a certain time period.

Keywords: SOS · ACO · Traffic light · Intersection · Red light · Green light.

1 INTRODUCTION

Vehicular travel is increasing throughout the world, congestion has become inevitable. humans have tried to find solutions that change depending on the country, the number of vehicles and inhabitants.

Today, traffic lights cause a lot of research work has been carried out on the development of traffic light optimization, Many studies have been carried out in optimizing the traffic light network. In this regard, Jovanovic et al [1] used the BC algorithm to solve problem of isolated intersection in an undersaturated and oversaturated traffic conditions. to control the flow of traffic many popular strategies have been implemented to optimize the traffic light for a single intersection to reduce the waiting time for vehicles on the road but the use of a single intersection is not the best solution to slight the city [2] [3] [4][[5], this is why the researcher proposed a new technology that are the sensors that collect information on the intersections of the city to improve the accuracy of the detected traffic information [6] and monitor the traffic characteristics in the city and dynamically adjust the traffic lights in the traffic control [7], [8].

The biologically inspired techniques can be grouped into two categories- Evolutionary and Swarm algorithms, Evolutionary algorithms like genetic programming (GP), differential evolution (DE). cellular automata (CA) [9], Swarm-based algorithms are inspired from social behaviour like ant colony [10], particle swarm optimisation [11], honey bees [12], Bat Algorithm (BA) [13], earthworm optimization algorithm (EWA) [14], Moth Search(MS)[15], elephant herding optimization (EHO) [16] and several others.

More recent research has introduced meta-heuristic approach for solving the problem of traffic control, In this study [17] the authors are improving the quality of solutions for the traffic light optimization problem to minimize the waiting time of all the vehicles and maximize the number of vehicles arriving at the destination within a certain time period, they hybrid metaheuristic algorithm Grey Wolf Optimizer (GWO) with the grasshopper optimization algorithm (GOA) which is used to solve large-scale traffic lights control optimization problems. In addition, new method of particle swarm optimization (PSO) for real road network to find out the best traffic light signal parameters, which can solve the traffic congestion on the real road network. the PSO has been applied to solve many different types of problems in this research, the main part is PSO that is employed to search the optimum offset, cycles, splits time of four nodes/junctions of the Ooe Toroku road network [18].

Among different meta-heuristics, the artificial bee colony (ABC) is a widely employed swarm intelligence algorithm for optimization problems, is based on the collective behaviour, Kaizhou Gao and all proposed a novel centralized traffic network model to describe the urban traffic light scheduling problem (UTLSP) in a traffic network. They minimize the total delay time of all vehicles in a fixed time window [19].

In this research, a new approach to find the optimal signal timing plan for a traffic intersection is investigated using ant colony optimisation and symbiotic organism search to find high quality solutions to the problem in several intersections.

The remainder of the paper organized as follows. in Section 2, we will present the proposed approach this approach contains ant system for determine critical path in addition objective function, we define Symbiotic Organism Search Adaptation , Section 3 summarizes the conclusion and future perspects.

2 Proposed Approach Traffic Light

2.1 Ant System: Determination of Critical Intersection

the ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. ACO methods inspired by the behavior of real ants. proposed by Italian scholar M.Dorigo in 1992 [20]. which is mainly used to solve the optimal solution of combinatorial optimization problem And traffic light problem has been proved as NP-Hard problem, so the ant colony algorithm used in traffic light can greatly improve efficiency.

In this paper, based on the study of the standard ant colony algorithm, it is applied to the traffic light problem to re-establish the model.
While walking from the nest to the food source and back again, the ants deposit pheromones as they pass. This is because other ants can detect pheromones. Ants choose their path, they tend to choose the track that carries the highest concentration of pheromones. This allows them to find their way back to their nest when they return. On the other hand, smells can be used by other ants to find food sources found by their fellows 10. this behavior helps to find the critical path (the most congested path), when the pheromone tracks are used by the entire colony. Objective of this step is to determine critical intersections in a city.

Description System The value of pheromone $\tau(i\text{j})$ which contacted with the ij between intersection i and intersection j updated with the following formula :

$$\tau_{ij}(t+1) = \rho * \tau_{ij}(t) + \sum_{k=1}^{m} \varDelta\tau_{ij}^{k}(t)$$

Where:
ρ: is the pheromone evaporate rate.
m : is the number of ants.
$\varDelta\tau_{ij}$: is the quantity of the pheromone on intersection i and intersection j by ant k.

$$\tau_{ij}^{k} = \begin{cases} \frac{Q}{L^k} & \text{k the ant travels on the intersection i to j} \\ 0 & \text{otherwise} \end{cases}$$

Where L^k is the length of the path which constructed by ant k.
During constructing process, ants will visit the following intersection through a stochastic mechanism: While an ant locating in intersection i has constructed the partial solution, the probability of move to intersection j is given by formula:

$$P_{ij}^{k}(t) = \frac{[\tau_{ij}]^{\alpha} * [\mu_{ij}]^{\beta}}{\sum_{L \in N_l^k} [\tau_{ij}]^{\alpha} * [\mu_{ij}]^{\beta}}$$

μ_{ij}: is the heuristic visibility of intersection (i,j), it is a value of $\frac{1}{d_{ij}}$.
d_{ij} : is the distance between intersection i and intersection j.
Intersection j is a set of intersections which remain to be visited when the ant is at intersection i.
α and β parameters contact with the importance between pheromone and the heuristic information.

2.2 Objective function

Urban road network congestion has been a problem of most cities around the world for several decades. So the performance indexes of signal timing optimization problem should pay more attention. the quality of a solution for Control traffic light problem can be measured by the object function that is defined as follows:

$$F = Min(\frac{LR^i_{jl}(K-1) + \sum_{i=1}^{I}(q^i_{jl}(K) - \lambda^i_{jl}) * g^i(K)}{C(K)} + \frac{LR^i_{jl}(K-1) + \sum_{i=1}^{I} q^i_{jl}(K) * R^i(K)}{M(K)})$$

F are the objective function, LR (k) are the delay vehicles in red time and green time of unit time(veh/s), $q^i_{jl}(K)$ is the average arrival rate (veh/s), $\lambda^i_{jl}(K)$ is The vehicles released of L lane at the direction j (vehi/s). k is the number of cycle, i presents the phase, j presents direction and 1,2,3,4 respectively presents the east , west, south and north of the intersection. l presents the lane and 1,2,3,4 respectively presents the left, straight and right,$g^i(K)$ is the green time of i phase in the k cycle. C(K) the sum of green lights of the cycle length K. $R^i(K)$ Red time of I phase in the K cycle. M(K)The sum of red lights cycle length of K.

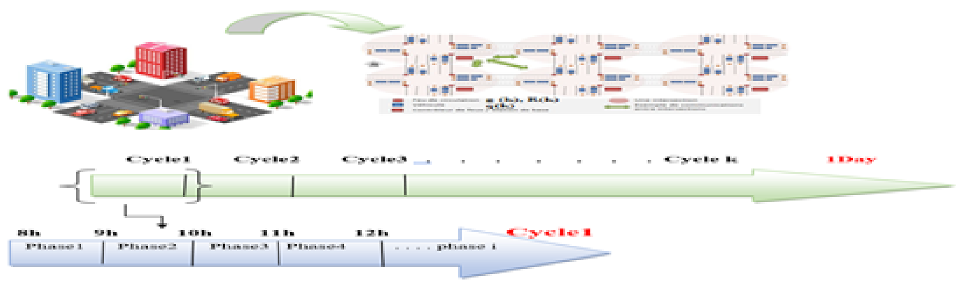

Fig. 1: *Representation of Constraint Objective function.*

2.3 Traffic Signal Optimisation

For instance, intersections $I_1, I_2, I_3, ..., I_n$ resulting of the first step (determination of critical intersection) are the input of the second step. our objective is to minimize the delay time of vehicle by finding the best group of time to be adapted on intersections.

Symbiotic Organism Search Adaptation The SOS starts it process by first randomly generating N numbre of organisms to populate the ecosystem. each organism in this case represente a candidate solution to traffic light problem With a specific objective function (reduce the delay time). The search process begins emmediately after the creation of the initial ecosystem.
The three phases of symbiosis considered here include mutualism phase, commensalism phase and parasitism phase are detayed in below [21]

Step 1 : Eco system initialization

Initial population is generated variables such as ecosystem size, maximum number of iterations. The positions of the organisms in the solution space are (real numbers)[21].

Step 2 : Selection of the organism with the best fitted objective function represented as x_{best} [21].

Step 3 : **Mutualism phase** The new candidate Solutions $x_{i_{new}}$ and $x_{j_{new}}$ are however, accepted only if they give better fitness values than the previous solutions.

$$x_{i_{new}} = x_i + rand(0,1) * (x_{best} - Mutualvector * BF_1)$$

$$x_{j_{new}} = x_j + rand(0,1) * (x_{best} - Mutualvector * BF_2)$$

$$MutualVector = \frac{x_i + x_j}{2}$$

$$BF_1 = \frac{f(x)_i}{f(x)_{best}} if x_{best} \neq 0$$

$$BF_2 = \frac{f(x)_j}{f(x)_{best}} if x_{best} \neq 0$$

$$BF_1 = BF_2 = 1 if x_{best} = 0$$

Mutual Vector represents the mutualistic characteristics between organism x_i and x_j to increase their survival advantage, x_{best} the organism with the best objective fitness value in terms of the maximum level of adaptation in the ecosystem, BF_1 and BF_2 represent the level of benefit to each of the two organisms x_i and x_j which varies automatically during the search process. the organisms are updated only if their new fitness is better than their pre-interaction fitness. After mutualism, the best ecosystem is shown in Equation [22]

$$X^M = [x_{i_{new}}, x_{j_{new}}]$$

Step 4 : **Commensalism phase** this step describe the symbiotic relationship between two different species in which one benefits and the other. The commensalism between organisms x_i and x_j is shown in Equation [22]

$$x_{i_{new}} = x_i + rand(-1, 1) * (x_{best} - x_j)$$

the best ecosystem is shown in Equation

$$X^C = x_{i_{new}}$$

Step 5 : **Parasitism phase** In this phase describe the symbiotic relationship between two different species in which one benefits and the other is actively harmed [22]. Parasite Vector is created by duplicating organism x_i in the search space using a randomly generated number. Parasite Vector tries to replace x_j in the ecosystem, Both organisms are then evaluated to measure their fitness. If Parasite Vector has a better fitness value, it will kill organism x_j and assume its position in the ecosystem. Otherwise x_j will have immunity from the parasite and Parasite Vector will no longer be able to live in that ecosystem [23].

Step 6 : **Stopping criterion.**

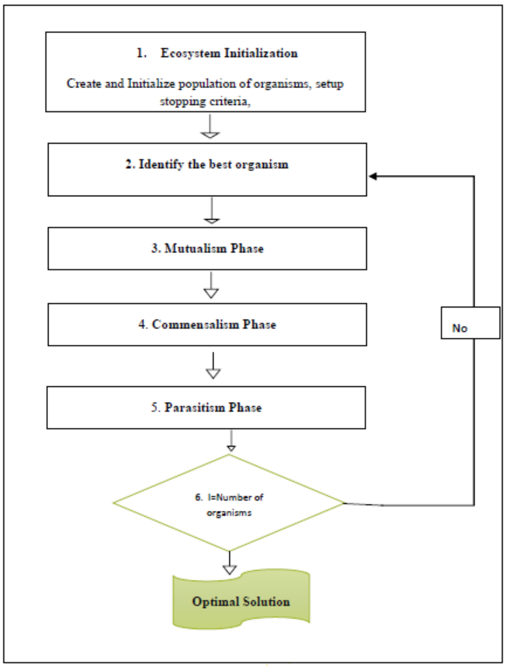

Fig. 2: *Flow chart for SOS.*

In the first step of the proposed optimization model is generating a population of solution candidates, called an ecosystem, using different initialization schemes, where each candidate solution is called an organism.
the ecosystem is expressed as X =[$X_1, X_2, X_3, , X_n].Thepositionofthei^{th}$ organism expressed as a vector of the 1 element, X_i represents Green lights and red lights for a cycle, can be given as $X_i = [x_{11}, x_{12}, x_{13}, x_{14}]$. So, each organism represents a potential solution to the problem.

x_i	x_{11}	x_{12}	x_{13}	x_{14}
Phase	1	2	3	4
(Green Light, Red Light)	[43, 12]	[52, 10]	[12, 34]	[8, 50]

Table. Example of an Oraganism representing SOS adaptation.

3 Conclusion

Today the urban intersection is often very crowd in cities, the vast network formed by these means of transport is immensely complex to manage.
In this study we discussed signal timing optimization method based on hybridation of two metaheuristic ant colony optimisation and symbiotic organism search is employed to obtain a signal control scheme by minimizing the dalay vehicules.
In future work we will implement our approach to improve a better performance.

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