AUTONOMIC TRAFFIC LIGHTS CONTROL USING ANT COLONY ALGORITHM

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ABSTRACT

The increase in the number ofpopulation, especiallyin large citiesled to the problem oftraffic jams,wherejamsrequiresqualifiedexisting systems, especially systemsof artificial intelligence.In this research proposed control method management intersections automatically using the concepts of autonomic systems and the concept of self-organization in the ant colony algorithm to increase the flexibility of the system and accreditationon variables associated with the environment directly, also implementedadaptation algorithm and the fixed algorithm for comparison with ant colony algorithm.

KEYWORDS: *Autonomic system, traffic light, Ant colony, self-organization.*

I. INTRODUCTION

The delay time that occurs in the traffic intersections and its negative aspects led to thinking over the past few years to implement new controls method that reduce this delay time especially in high traffic flow times such as in the morning.

The traffic lights systems are different from other systems that it cannot be a fixed system depends on a few static data change. On the contrary, it is depended on high degrees of adaptive values and could not be predicted so its need to intelligent systems that able to any change occurs.

The problems of traffic lights are studied in many researchesusing different search algorithms and intelligent systemssuch as using genetic algorithm, fuzzy system, self-organization and swarm intelligent.

Ant colony is one of the important algorithms of swarm intelligent that found in literatures and have all the characteristics of adaptive system like traffic control systems. One of the most surprising behavioral patterns exhibited by ants is the ability of certain ant species to find what computer scientists call shortest paths. Biologists have shown experimentally that this is possible by exploiting communication based only on pheromones, an odorous chemical substance that ants may deposit and smell. It is this behavioral pattern that inspired computer scientists to develop algorithms for the solution of optimization problems [1]. So in this research used the ant colony algorithm to find the optimal green time to reduce the delay time that occurs in the intersection. Computer simulation provides that this work performed and give good result.

The rest of the paper is structured in following manner. In section 2 a brief background to the related work is provided. Section 3model of traffic intersection explained. Section 4 introduces an introduction about swarm intelligence with examples. In section 5 the ant colony algorithm introduced. Section 6presents the T-Test function. Section 7explains applying ant algorithm in traffic light signal. Section 8 summarizes the simulation results. The conclusion and future work appear in the final section of the paper.

II. BACKGROUND

There are several systems that implemented for management traffic lights problem during previous years.
In the 1996 Kok Khiang Tan et.al. discussed the implementation of an intelligent traffic lights control system using fuzzy logic technology which had the capability of mimicking human intelligence for controlling traffic lights.The fuzzy logic traffic lights controller performed better than the fixed-time controller due to its flexibility [2].
In 2004Marco Wiering et. al. used reinforcement learning with road-user-based value functions was used to determined optimal decisions for each traffic light. The decision was based on a cumulative vote of all road users standing for a traffic junction, where each car votes using its estimated advantage (or gain) of setting its light to green. They were performed three series of experiments, using the Green Light District traffic simulator [3].
In 2008 R. Foroughi et.al. proposed a new ant colony based optimizer to improve the traffic flow in a city. They used an ant colony optimizer as its main part to select the optimum path from origin to destination. To applied ACO on this problem they have changed the original version of ACO and the modified algorithm can be used for other applications like designing intelligent data routers, intelligent data mining, etc[4].
In 2009 David Renfrew and Xiao-Hua Yu implemented a new approach to found the optimal signal timing plan for a traffic intersection is investigated using ant colony optimization algorithm. They considered two different ACO algorithms, namely, the Ant System (AS) and the Elitist Ant System (EAS) algorithm. The two algorithms are applied to control signals at traffic intersection to reduce the vehicle waiting time. Rolling horizon algorithm was also employed to achieve real-time adaptive control [5].
In 2011 Carlos Gershenson and David A. Rosenblueth used elementary cellular automaton following rule 184 to mimic particles in one direction at a constant speed. They extended studied and evaluated to behavior of two different kinds of traffic light controller for a grid of six-way streets allowing for either two or three street intersections. They implemented three different types of traffic lights control method: A green-wave method, this method has advantages, e.g. when most of the traffic flows in the direction of the green wave at low densities. A self-organizing method, each intersection independently follows the same set of rules, based only on local traffic information. And a random method, which simply changed the lights with fixed periods but random phases. The simulations presented showed that the self-organizing method is highly scalable, and has a graceful degradation of performance as density increases [6].

III. MODEL OF TRAFFIC INTERSECTION

The modeling of computer simulation have single intersection Corresponds to the traffic intersection in real life. It contains four streets each street with two directions and each direction have a width of two cars. All cars in any street are able to turn around in any direction such as in the real intersection. One street green light and three red lights.

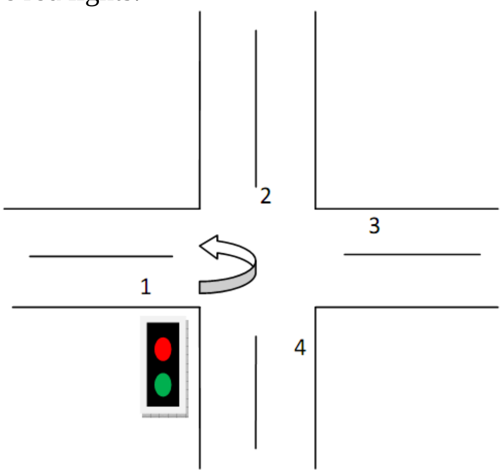

Fig. 1 Traffic intersection

It is assumed that the intersection is "clear" when the simulation starts (i.e., zero initial conditions, or no queue at the beginning).It is also assumed that the number of vehicles at the intersection is known, i.e., sensor type detectors are available at the intersection. We choose the maximum and minimum green time to be 30 seconds and 0 seconds, respectively. Both arrival and departure headway are 0 seconds. Loss time (human reaction time) is 0 second.

Time is the most important value in the system is the measure of efficient. In Non-adaptive traffic system each street has a fixed green time equal to 30 second and there is no sensor, the green light move from street to other in order.

In intelligent traffic system (Adaptable) each street have an account of cars and wait time and depending on these two values the green time can be calculated.

Each street work as a line and the sensor calculates cars number in the line in a given time such as Li (t), where i represent the street number in the time t.

The total number of all cars in the intersection is calculated by the sum of the four accounts of the streets:

$$L_{total}=[L^{1}_{count}+L^{2}_{count}+L^{3}_{count}+L^{4}_{count}] \quad (1)$$

When the system give one street green signal and the three others red, the line of the three red streets will increase and Not less so the line length denote:

$$L^{i}_{red}(t_2-t_1) = L^{i}(t_1)+ ac \quad (2)$$

Where ac is number of arrival cars and for each second the ac may be 0 or 1 if sensor senses a car give 1 and if not give 0, hypothesis that all the cars are moving at a constant speed.

The length line for a street with green light can be denoted as:

$$L_{green}(t_2-t_1)= \left[L_{green} + \lambda \right] - 2 \quad (3)$$

Where 2 is thenumbers of departure cars and is set to two as we know that the street width with two cars and all cars are moving at a constant speed so the line of green light will increase in random values between (0,1) and decrease by two cars in each second.

For each time the traffic intersection have four states for four streets each state have one green light and three red lights and can be categorized:

$$S_1=[L_1+ac-2\ ,\ L_2+ac,\ L_3+ac,\ L_4+ac]$$
$$S_2=[L_1+ac\ ,\ L_2+ac-2,\ L_3+ac,\ L_4+ac]$$
$$S_3=[L_1+ac\ ,\ L_2+ac,\ L_3+ac-2,\ L_4+ac]$$
$$S_4=[L_1+ac\ ,\ L_2+ac,\ L_3+ac,\ L_4+ac-2]$$

For a special case in adaptable traffic system that if there is a high load in a single or multiple street with a lower in another street and the last one cannot arrival to the max street to get green time, In this case the wait time will used to determine the time in which this street will arrival to green time as:**if wait time equal to or greater than 50 seconds.**

The system will check the wait time for each loop and depending on this, the system will sure that if a few cars in some street will not take an infinity wait time.

The wait time for each loop can be calculated depending on this equation:

$$L^{i}_{WAIT}(t) = \max_{i}\left(FST^{i} + gt(t-1)\right) \quad (4)$$

Where FST is a first sense time (The oldest car arrival time), and gt is green time for pervious loop.

From above the dynamic equation of traffic system will be:

$$L(t)= \sum_{i=1}^{4} L^{i}_{C} + \sum_{i=1}^{4} L^{i}_{IN} - L^{i}_{OUT} \quad (5)$$

Where $L^{i}C$ is the number of currant cars in the intersection, $L^{i}IN$ is the number of arrival cars that arrived to intersection in time t and Li OUT is the number of departure in a green street.

IV. SWARM INTELLIGENCE

The expression "swarm intelligence" was first used by Beni, Hackwood, and Wang in the context of cellular robotic systems, wheremany simple agents occupy one- or two-dimensional environments to generate patterns and self-organize through nearest-neighbor interactions[7].
The mechanisms identifying swarms behavior are: 1. Multiple interactions among the individuals; 2. Retroactive positive feedback (increase of pheromone when food is detected); 3. Retroactive negative feedback (pheromone evaporation); 4. Increase of behavior modification (increase of pheromone when new path is found)[8].
There are several examples of swarm intelligence, where the role of nature is the most important sources of examples of swarm intelligencesuch as:fish schooling, bees, Termites' nest,Wasps' nest and ant colony etc. which has been relied upon in the construction of many algorithms.

V. ANT COLONY ALGORITHM (AC)

Ant colony algorithm is one of a metaheuristics approach used to solve complex computing problems and find the optimal solutions. The algorithm inspired from the behavior of ants in the real world. AC Algorithm is a multi-agents system each agent called Artificial Ant, It is one of the most examples of intelligent swarms systems that used to solve several types of problems such as TSP and routing problems in networks [5].
Ant colony algorithm proposed by M. Dorigo in 1991 in his Ph. D. dissertation then this approach has become widespread and has since start development until reached several successful developments such as ELITIST AS in 1992, ANT-Q in 1995, ANT Colony system in 1996, MAX-MIN AS in 1996, RANK-BASED AS in 1997, ANTS in 1999, BWAS in 2000 and HYPER-CUBE AS in 2001 …etc [9] but all ant colony optimization algorithms share the same idea which can be summarized in four steps[1][5][10]:

1. Initialization: pheromone is the most important characters of ant algorithm and must set to a constant value in each node.
2. Solution construction : the ant location and the probability of ants moving from one node to another are important in ant algorithm, The probability of ants moving from node i to node j can be denote:

$$P\ ij = \begin{cases} \frac{tij\eta ij}{\sum tij\eta ij} if j \in Ni \\ 0 \qquad otherwise \end{cases} \tag{6}$$

Where N_i is the set of neighborhood nods of i . tij is the pheromone value between node i and j ; and ηij represents the heuristic information (which is available already) .

3. Update pheromone: The algorithm updates pheromone on each path using the following equation:

$$t\ ij = t\ ij + \Delta t\ ij \tag{7}$$

where Δtij is the value of pheromone changing in each loop.
This is the standard updating of pheromone value and different for each types or developments of ant colony algorithms.

4. The above solution construction and pheromone update procedures (i.e., step 2 and 3) are repeated until a stop criterion is met.

VI. T-TEST STATICS FUNCTION

The t-test was developed by W. S. Gossett, a statistician employed in a factory. However, because the factory did not allow employees to publish their research, Gossett's work on the t-test appears under the name "Student" (and the t-test is sometimes referred to as "Student's t-test.")[11].
There are two types of t-test one simple t-test and two simple t-test. In this research the two simple t-test is used and the purpose is to know is there are a difference between the two methods value.

VII. APPLYING ANT ALGORITHM IN TRAFFIC LIGHT SIGNAL

In each intersection there are a four streets and number of cars have a wait time in each one. The goal is find an optimal green time for each loop that reduce the wait time and cars number in the intersection.

In Ant colony algorithm number of artificial ants that represent the problem. In this model there (m) ants distributed in the streets randomly and (k) ant work as an observed ant move from one street to another depending on the probability of Ant algorithm moving.

Each ant of m ants calculate the cars number and wait time coming from sensor and depending on it the ant deposit a pheromone represent the green time to this street, the equation of ant pheromone value can be denoted:

$$gt\ m^{i} = L^{i}_{count} / 2 \tag{8}$$

where gt is a green time for ant (m)for street i, the cause of divided over tow driving from the model of computer simulation that each street have width of two cars and all cars move under constant speed so at each green second the cars in green street will less tow cars.

The ant k which is an observed ant as remember move from street to another and give the green signals to max street such as in adaptive method but under the condition of probability of ants moving from street i to street j:

$$P\ ij = \begin{cases} \frac{tij}{\sum tij} if j \in Ni \\ 0 \quad otherwise \end{cases} \tag{9}$$

Where N_i is the set of neighborhood street of iand not visited yet. tij is the pheromone value of each neighborhood street which divided on the summation of all pheromone value of other street.

The probability of ants movingabove means in each loop the observe ant (k) will not repeat it visitor to any street until visited the another streets.

The result of two method give a convergent result but in the special case that talking about it before, The Ant colony algorithm give good result and more efficient from adaptive method.

The proposed method is tested and compared using t-test function. In the next section the simulation result will be explain.

VIII. RESULTS

The two proposed method are tested in the simulation and compared between themresults.

Table (1) shows the value of cars number and wait time in the intersection when it running for the two method.

The two methods gave a good result and reduce the waiting time but when compare between the two method, the ant method result approximately similar to adaptive method and denoted that using t-test where the compare between two sets of value gave p = 0.47 and the initial p value is 0.05 so there is no different or too small different.

When applying the two methods and from observing them we found that in a special case occurring in the system where in which one street has less load from the other three streets, and when calculated the result of this special case, results show that the Ant colony algorithm is bester from adaptive method and the wait time has reduce too mach. Also ant algorithm resultfor the special case compared and tested using t-test where the compare between two sets of value gave p = 0.00013 and the initial p value is 0.05 so there is a different between the two methods.

Table (2) show the value of cars number and wait time in the intersection when it running for the two method in a special case.

Table 1: Adaptive and Ant colony method result

Adaptive traffic		Ant traffic	
Car num	Wait time	Car num	Wait time
4	0	4	0
8	1	9	0
13	3	13	1
24	6	22	3
35	9	33	7

48	14	45	11
59	19	64	17
69	20	77	22
80	24	89	28
108	33	93	30
122	38	104	33
158	50	120	36
197	66	142	47
226	81	158	53
251	94	189	65
319	120	215	78
336	128	319	117
403	156	336	122
462	184	411	147
530	211	504	190
618	244	620	237
645	256	653	248
711	287	713	271

Table 2: Adaptive and Ant colony method result for special case

Adaptive traffic		Ant traffic	
Car num	Wait time	Car num	Wait time
2	0	2	0
6	0	4	0
11	1	7	0
16	2	10	0
25	4	15	1
32	7	21	2
37	9	28	4
45	12	34	6
52	15	39	8
58	17	47	10
64	19	58	14
69	22	67	17
80	26	82	24
108	43	135	30

The array of green traffic lights also shows the different between the methods:

Table 3: Adaptive signals array

0	3	0	2	0	3	2	0	3	1
2	0	2	0	3	1	0	2	3	0
2	3	0	1	0	2	0	3	2	0
1	3	2	0	3	0	2			

Table 4: Ant signals array

0	2	3	1	0	3	2	1	2	3
0	1	0	2	3	1	0	2	3	1
0	2	1	3	0	2	1	0	3	2
1	0	2	3	1	0	2			

The street number 1 is a lower street cars of this special case and explain the different between the two method by street 1 getting green signal.

IX. CONCLUSION AND FUTURE WORK

Traffic light is one of the most important problems in the life. In this research two methods were proposed to solve this problem. They are adaptive and ant algorithm methods.By applying T-test on thecomputer simulation results show that the two methods are efficient and there are no much different between them, but when applying the two algorithms on a special case in which one streethas alessTrafficratiofrom otherstreetsthere were differencesin the obtained results and thet-test showed that the ant algorithm is more efficient and reduce delay time when comparing it to the adaptive method.

There are several suggestions given below that could be implemented in the future to make the project more optimal:

- There are no amber lights in the current model. The behavior behind amber lights is equivalent to that behind red lights, i.e. vehicles should stop.
- Pedestrians were not considered in our simulation.
- The proposal simulation implemented one intersection only, for future work the simulation can include several intersections instead of one intersection.
- Applying other metaheuristics algorithm and comparing with our ASAS algorithm.
- Fixed vehicle speed where it can take several fast instead of one and the response humans can be taken into consideration.

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