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Improvement in Traffic Light System with Ant Colony Optimization Technique

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ABSTRACT
It is easy to control traffic light system on highways but difficult in urban areas. This problem can be solved by decreasing the stoppage time at the junction to zero, instead of broaden the available traffic network. In this paper, different tools or algorithm are used and everyone has its own contribution in solving the traffic light system. Here sensors are used to control the speed of cars in such a way that, as soon as drivers come across a junction, they will find green light. After that control cycles are generated with the duration of green and red light, such that vehicles move from source to destination without any stoppage at red light. In case of busy hours, it is necessary to give preference to the traffic light which is done with the help of DCOP protocol. Sometimes roads are blocked due to accident on the road, modified neural network map is send to the drivers by using text or internet and then driver change the route by ant based routing algorithm. The purpose of this paper is to develop a systematic route for the vehicles by using above technique, so that they achieve the target quickly as well as successfully.
Keywords - Ant colony algorithm, Neural network, Path planner, Sensors, Swarm intelligence.

I. INTRODUCTION

Swarm intelligence is a branch of intelligent system, deals with the artificial and natural environment in which group of living being interact locally with each other to perform any task without the control of central agent. The goal of task depends on the performance of individual agent but if any agent fails to give its maximum contribution, other agents compensate it. The agents like bees interact with other agents by producing pheromones chemical or sound, by dancing, by changing the environment etcetera. The interaction between the agents is helpful to control robot and traffic light system. For this, Ant Colony Optimization and practical swarm optimization technique are used. Here Ant Colony Optimization technique is used for solving traffic light problem[8].

1.1 Classification

1.1.1) Scientific versus Engineering: In case of natural swarm intelligence, there is a complete study of biological environment but in case of artificial swarm intelligence, study is related to human nature[1].

1.1.2) Natural versus Artificial: In case of natural swarm intelligence, there is a complete study of biological environment but in case of artificial swarm intelligence, study is related to human nature[1].

These two terms natural versus artificial and scientific versus engineering are orthogonally related to each other. If studies are related with the natural environment then it is studied by the scientist. But if studies are related with the artificial field then engineers can do a better job in this field[8].

1.2 Communication medium

1) By producing chemical like pheromones for the identification of path for food source. Occurrence of more pheromones between two paths represents the shortest path for the food source.
2) By producing sound.
3) By dancing.
4) By changing the environment[1].

II. TECHNIQUE AND ALGORITHM USE

2.1 Ant Colony Optimization Technique

This is the technique used for finding the shortest path for food source by the agents.

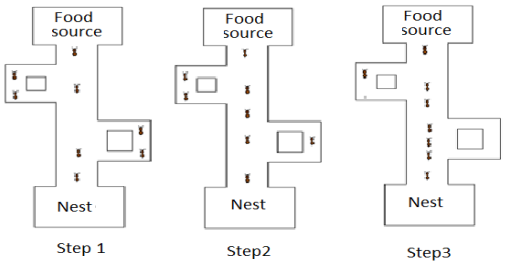

Fig. 1. Shortest path[3].

1) In step 1, each bee comes out from the nest and start searching for food source in their surroundings.
2) After some time, about 75% of bees start moving toward a same food source but from different routes.

3) In final step, almost maximum bees move in a particular direction[2].

There are two optimization methods, heuristic and meta-heuristic used for solving a traffic related problems. But preference is given to the meta-heuristic method because it solve optimization problem faster in comparison of a heuristic method. Basically this algorithm is related with the searching behaviour of ants for food sources. In initial state every ant come out from the nest and start searching for the food source, and in the return journey a chemical name pheromone is produced on the path. Different ant produce different concentration of chemical, it depends on the path length or in other words, more concentration of pheromone shows the shortest path. Then every ant starts selecting this path for the food source. Same behaviour is used for solving traffic light problem[3].

In traffic light system, every traffic light is treated as an agent and by generating good communication between them; traffic light problem can be solved. An agent performance depends on its behaviour. It is compulsory for an agent to do work in a group of agents but with in a predefined boundaries or with a certain sets of rules. An agent should have powerful memory so that it can store information up to maximum value just like a bee store its previous path direction in a brain[9].

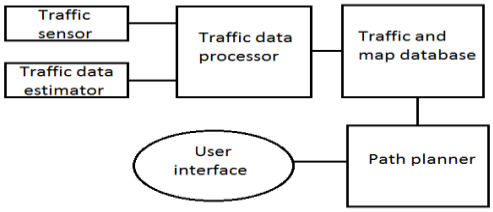

Fig. 2. A prototype desidned ABUTCS schema.

As shown in figure above, various equipments are used for traffic light control. Sensors are used for calculating the number of vehicles. The calculated output of sensor and pre estimated data of traffic flow is sent to the traffic data updater or processor. Then processor modified the data according to the global result obtained from the links. After that processed data is forwarded to the path programmer or planner and applies ACO (ant colony optimization) algorithm with the use of traffic and map database. Final output is then transferred to the user by using text or internet[9].

2.2 Ant Colony Algorithm

1) Fetch map from map database, user information and traffic data from sensors.
2) Initialize ant colony optimization parameter.
3) Check vehicle is moving or not.
4) If moving, connect the possible nodes or junctions with links and calculate probability of each link.
5) Select link of highest probability of pheromone and check the next junction is destination or not.
6) If not, process repeat, otherwise modify pheromone amount and sent back to the source.
7) If vehicle not moving, then go to end[3].

So this algorithm optimizes length of path and load of traffic on the road.

2.3 Characterstics of ACO algorithm: This type of algorithms is used for solving the combined optimization problems.
1) Continuous space search.
2) Group of components are finite.
3) Each step of algorithm declares a cost function.
4) Transition is limited.
5) Result is in proper order[10].

III. TOOLS USE

3.1 Sensors

Sensors with display are used for detecting the speed of the vehicles running on different lanes of the road and they are attached between the two common poles located on the either sides of the road. This whole operating system is embedded two or more times at a certain distance which depends on the distance between two consecutive intersection points. Here first sensor measure the speed of vehicle and rest of the sensor of each lane adjust the vehicle speed in such a way that as soon as there is a vehicle in front of it, it tells the driver that it should have in order to have the signal ,ahead of it ,green. So display of speed alert the driver to increase or decrease speed to make a continuity of green light between the source and destination. The figure shown below is an example for only one lane.

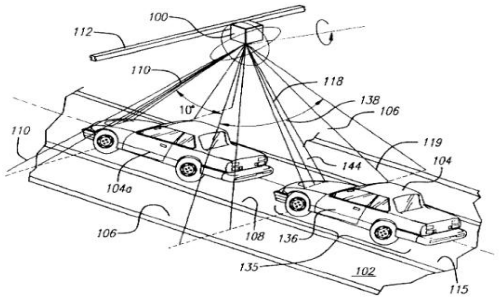

Fig. 3. Single sensor for lane[11].

3.2 Traffic Data Processor

It use optimal asynchronous partial overlay algorithm for making synchronization between two continuous traffic junctions. Synchronization is possible by controlling through online or offline. For offline control TRANSYT and SCOOT software tool can be used and for online APO algorithm is adopted. The main problem in former system is that, a traffic expert is needed for removing confliction at the intersection point but not used in latter system. Synchronization of traffic light means here is that, a car should not stop at the junction due to red light or

it continuously run from source to destination without any stoppage at the intersection point. For design such a synchronize system, a number of traffic cycles are used where each cycle indicates a duration between the two intersection points and end of cycle tells about the intersection points represented by the circles in a figure shown below[12].

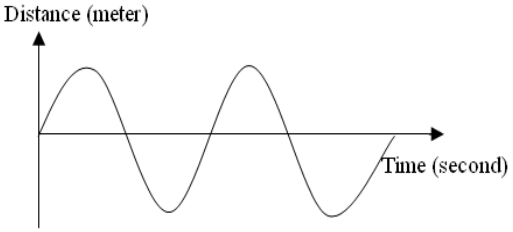

Fig. 4. Control cycle.

Let us take an example; a driver wants to move from street 1 to 5. The above generated cycles are run for each street traffic light and synchronization between two street traffic lights is done by calculating the distance between them. This flow of cycles is shown below:

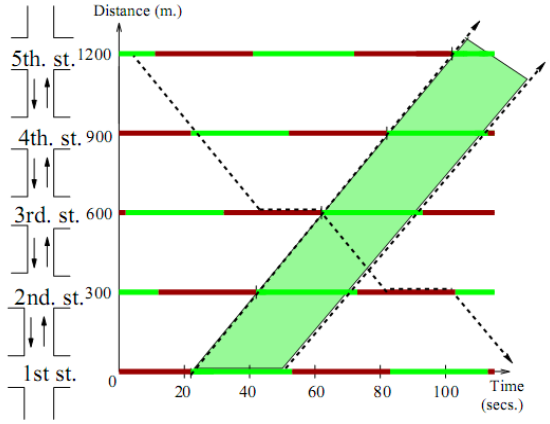

Fig. 5. Time-space diagram of a progression in an arterial[13].

Here red and green light shows the two signal of the traffic light and green path shows the continuous movement of the vehicles. When they move from street Ist to street 2nd, they will get a green light for 20 seconds and same time duration is set for further traffic lights in their route.

If synchronization between adjacent traffic lights is more, then queue at the intersection point start shorter. For this Manhattan grid like structure is used, where the distance and speed between the adjacent meeting points is same and predefined.

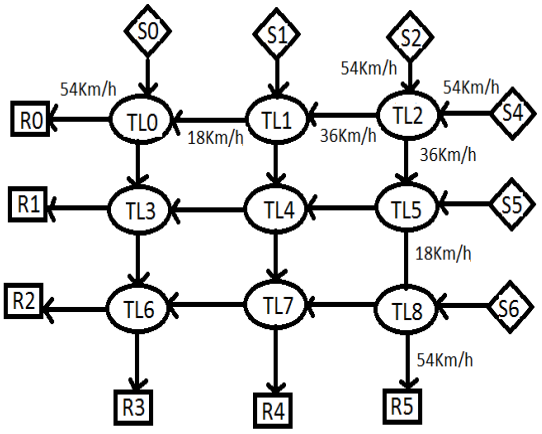

Fig. 6. A network with nine intersection[14].

Here S0 to S2 are the incoming vehicles from north and R3 to R5 are their destination in south direction. Same in other direction east and west, S4 to S6 and R0 to R2 are source and destination. The incoming and outgoing speed is constant to develop the flow of traffic in the congestion area constant. So if driver, drive a car with more or less speed, it will be controlled with the help of sensors as it discussed above. In this structure, synchronization is possible only in two direction north and south or east and west. Actually this system works as a multi-agent system in which, each traffic light is treated as an agent just like an ant and run on predefined rules. It means, traffic light adjust the above cycles with the duration of day in such a sequence that, it looks like a flow of liquid[10].

Working of Manhattan grid like structure can also be more defined by using Net logo software tool. The screen shot of Net logo software is shown below:

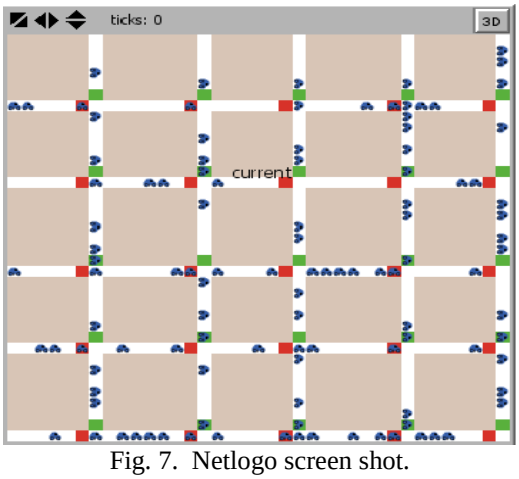

Fig. 7. Netlogo screen shot.

In Net-logo software, traffic light junction is represented by an intersection of grid axes and it can be adjust by scrolling the number of the y axis and x axis. Here vehicle speed is controlled by increasing or decrease speed with respect to the car in front of it. User can change the number of cars,

speed and cycles manually. If this is done with the help of speed sensor and counter, then traffic light problem can be solved up to a certain limit. But the drawbacks of this software is that, it is designed only for one lane and traffic jam occur at intersection with the increase in number of vehicles which is due to inability to give priority to the agent.

For getting an optimal level between preference of agent and synchronization, DCOP protocol is used. In which each agent is assigned a number of variables and these variables consist of set of constraints. These constraints calculate the cost function for each agent by calculating the number of vehicles at the traffic light. The vehicles are counted by using counter with each sensor and overall number is send to the agent. Then output cost of every agent is collected and generates a global cost function. So the main requirement is to minimize this cost and it is possible with the help of optimal APO algorithm[12].

This algorithm is represent in the form of graph, in which nodes are agent and links are constraints. Each constraint has a cost factor which describes the amount of confliction between the agents. It is processed in three steps: In first step, it initialize itself with the setting of variables and in next step, it start calculating the cost function. If this cost function is greater than the optimal cost function, then agent put either in active mediation or passive mediation depends on the agent priority of mediation. In third step, a request of mediation is received by the agents for comparison of cost function. This is done by using branch and bound searching technique for reducing the overall cost[8].

If this mediation process is used for distributed coordination between traffic lights in which each agent pointed with a single variable then problem occur at the time of heavy load on the way and create more delay at the intersection point. To solve this, it is necessary to compromise between either the system is online or offline and number of vehicles. But consideration of vehicles is very essential because number of vehicle on the road increasing day by day. Let us consider that, if number of vehicles in north-south direction is more than in east-west direction then additional cost function or relation cost f(x(i), x(j)) (where x(i) and x(j) are the ith and jth agent) is added in the actual cost function. The value of this cost function may be zero, ratio of incoming vehicles to total number of vehicles or twice of previous ratio, it will depends on the priority to the direction or number of vehicles[12].

1) If both are considered, its value is zero.
2) If it gives priority to the direction instead of maximum number of vehicles above ratio is used for calculating cost for each incoming direction
3) If preference is given to the maximum number of vehicles, the above ratio become twice[12].

It can be explained with the help of SeSAm (Shell for stimulated agents systems) tool in which role of agent designed in the form of number of nodes and they are connected by an incoming and outgoing link with an indication of number of vehicles. The whole connections are shown below:

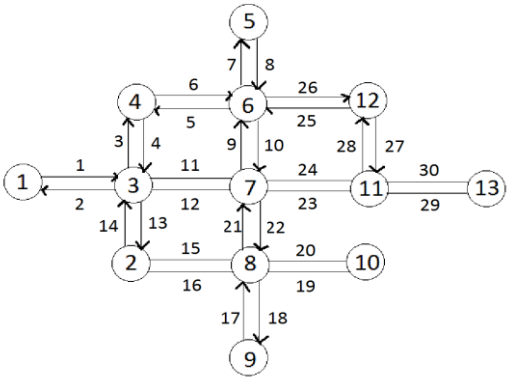

Fig. 7. A semi-urban network with 13 nodes and 30 links[15].

Here node 3, 6, 11, 8 are designed for east-west direction and rest of them for north-south direction. Now take a node 3 as an example and consider only the incoming vehicles from north-south and east-west direction. As shown in figure, total number of incoming vehicles at node 3 is 31, out of which 12 from east to west, 1 from west to east, 4 from north to south and 14 from south to north direction. So total number of vehicles in north-south direction is 18 which are more in comparison of east-west direction but node or agent 3 is designed for east-west direction, it creats a confliction in the system. The main aim of this algorithm is to minimize the number of vehicle by reducing the cost function of each agent. It is calculated as:

Global cost function F= cost function of agent in north to south direction + cost function of agent in south to north direction[8].

= (2* (incoming vehicles from north to south/ total incoming vehicles) + (2* (incoming vehicles from south to north/ total incoming vehicles)

= (2*(4/31)) + (2*(14/31))

= 1.16 approximately

But this global function value is greater than optimal value of zero and due to this, central agent is put in the active mediation state. And when same calculation is done for adjacent nodes, is comes out to be less than that of node 3. For example calculated value for node 7 is 1.05 approximately which is less than 1.16.

Adjacent nodes of 3 are 7, 4, 1 and 2. All these nodes are predefined for a particular direction but if the number of vehicles increases between any two junctions, Shell for stimulated agent system take decision when the light is red and orange. So this method will give priority between the adjacent

nodes. The table shown below represents the priority between the same directions of nodes.
TABLE I. PREFRENCE TABLE

Node	No. of vehicles north to south	No. of vehicles south to north	Total no. of vehicles	Global cost function
6	8	9	48	0.71
11	27	0	80	0.70
8	22	17	73	1.06

So, node 3 has highest priority or more preference with respect to the other nodes designed for east-west direction.

3.3 Path Planner or Traffic Management

Path planning is done in case of accident on the road or road is blocked due to any genuine reason. Due to this blockage, traffic congestion will increase on the road. So traffic management is necessary to take away the vehicles from that route. It is done by using decision support and regulation system. By using former, the shortest path is obtained and latter use back propagation model to control the traffic system. In regulation system, road traffic is modeled in such a way that agents are controlled with the help of neuron model. An agent may be of three types; aspectual agents which provides the information of number of vehicles in that particular area, morphological agents collects vehicles location and their average speed of movement, and analytical agents consists of number of rules. These rules are used for planning a path in the neural network. In neural network, each node of network is represented by an agent and links with numbers of vehicles between the adjacent agents. After that, the designed paths are broadcast to the drivers moving in that area, by using base station, text or internet. Drivers receive the information and check what and where is the problem. If they find that it is in the way, they start changing their direction to another one by using routing algorithm which is based on ant colony[4].

3.4 Ant Colony Based Routing Algorithm

In this method two ants are used, forward ant and backward ant. But these ants works in opposite direction, forward ant track the path by producing pheromone chemical from source to destination with the update of its destination node address, next hope and value of pheromone ,and at destination, backward ant is created and start tracking towards source in the same way as by forward ant. Due to this the concentration of pheromone is more only on one path and other paths have low concentration. So driver select high concentration path and follow it to reach the destination[16].

3.5 Advantages and Disadvantages of swarm intelligence system

3.5.1 Advantages

1) No boundries: A number of agents can be added in a system, due to which more interaction occur in between the agents and best solution can be obtained to solve the particular problem.
2) Self Organization: Agents do their work without taking any help from supervised agent and central agent.
3) Flexibility: Agents can change their work according to the change in environmental conditions.
4) Robustness: A goal is achieved by the agents whether one or more agents fail to perform its work[9].

3.5.2 Disadvantages

1) Difficult to control: It cannot be controlled from the outsider.
2) Difficult to understand: Swarm system consists of intersection logic that is why it is difficult to understand this system.
3) More complex: For performing a single task, many rules are applied which increase the complexity of the system.
4) Slow process: It takes more time to warm up that is why it is a slow system[7]

3.6 Examples of swarm intelligence

1) Shortest path: A chemical named pheromone is produced by an ant when it comes back towards its nest. When two ants comes out from the nest and one them found a food source, it produces a pheromone chemical in its return path which attracts other ants present in nest to move towards that food source. The ant which comes back first will provide a shortest path to the other ants[6].

2) Call formation: A computer program was developed by the researcher which was based on ant foraging principles that routes the call from one destination to the other destination. In a telecommunication network there are number of routing nodes through which a call is transferred in a proper manner[6].

3) ABEC protocol: It is an ant based energy conservation protocol. It use swarm intelligence technique which include positive or negative feedback for getting a better solution. Agents can be transferred maximum information by doing changes according to the change in the environmental conditions, and if fluctuations comes out it can be amplified. This protocol conserves energy through ad hoc nodes. When any information is transferred between ad hoc nodes, at that time some nodes are used for transfer the information but some are not used. This ABEC protocol put these unused nodes in a sleep mode so that energy is conserved[6].

IV. CONCLUSION

In the end, we conclude that, due to increase in number of vehicles on the road, the network is so much complex that it is difficult to plan and design a single model to reduce the complexity. Different algorithms were discussed to solve traffic light problem but no one algorithm show its maximum tendency to handle it. New technique swarm intelligence is used to analyze the transportation system. This technique is based on power of thinking instead of computational tool. It mainly works on three types of algorithm such as particle swarm optimization, ant colony optimization and bee colony optimization. Here we use ant colony optimization technique because it is not so much complex and based on foraging behavior of ant. The main aim is to use the foraging behavior of bees to find the shortest path between the source and destination. By using this, we find that, decentralized approach is better than centralized approach to control traffic light system. The main problem in any traffic light system is of synchronization and path planning. But here optimal APO algorithm and ant based routing algorithm is used to solve these problems. Here sensors play a very important role because they not only determine the pheromone concentration which is related to congestion of vehicles on the road but also limit the speed of the vehicle to protect from accident. The algorithm which we discussed in the paper is used on grid like structure but problem occur for more than 4 paths of intersection on single point. So, Future work should do on to handle traffic congestion for more number of paths so that driver moves from one location to other without stopping at any junction.

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