Independent Agents for Urban Traffic Control Problem with Mobile-Agent Coordination

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Abstract: - For a intelligent traffic system (used for controlling traffic lights at intersections) to be useful in practice it needs to be adaptive to outer situation and to be scalable for different urban areas and streets. That is because patterns of the traffic networks and intersections are very diverse and changing in time. In this research scalability and adoptability have been in our center of interest. Other parameter which is very important in controlling traffic lights is prediction of traffic. This prediction would require having the big picture of the flowing traffic and thus centralized kind of Control (which conflict with scalability). Our aim was to design a model that is scalable and adaptive and at the same time has a sort of prediction mechanism. To achieve this we have worked on a model with high abstraction which has three levels of control. Every intersection is controlled by its own traffic situation, its neighbor intersections recommendation and a mobile agent that goes through different intersections in a particular section in the urban area and has a wider view of the traffic.

Key-Words: - urban traffic control, intelligent traffic system, intelligent intersection agent, mobile agents.

1 Introduction

You may have been stuck in heavy traffic many times during every day activities. Problem of traffic is one of the main turn downs of cosmopolitan areas. As day by day the numbers of cars grow, our traffic gets heavier and at the mean time we are not able to expand our road system as quick as the growth of cars. Two main obstacles for expanding roads in urban areas are space and money. So we must look forward for other means for solving traffic problem. Intelligent Traffic System (ITS) seams a good solution. It would be much better if we could enhance our traffic flow trough the current road system. ITS's aim is to make more cars to flow in the same road system by using intelligent systems which its actuators will be current traffic lights and varying traffic signs. For this purpose much research has been done, but much more seems to be needed. As mentioned in [15]:

"In contrast to the aforementioned control strategies, TUC (Traffic-responsive Urban Control) has been developed so as to provide coordinated, traffic-responsive control in large-scale urban networks, even in cases of saturated traffic conditions."

In this paper our point of view to the problem is scalability. We have classified the works done into three major groups and have discussed which approach would be better. We have mentioned some factors that a good solution for this problem should have. According to these factors then we have developed a model for satisfying the them. We suggest use of independent agents for each intersection and using of mobile agents for coordination and determination of a general strategy for each area of a specific city. According to [11] benefits of adaptive traffic control are:

- Increased lane carrying capacity;
- Increased travel speeds;
- Reduction in vehicle-hours of delay;
- Drop in crash rate;
- Reduction in number of stops and queue length; and
- Reductions in fuel consumption and mobile source emissions.

2 Background

Different methods have been used for dealing with AUTC (Automatic Urban Traffic Control) Problem. These different methods have been result of different views and approaches to the problem. Use of intelligent agents goes back to a suggestion from Roozemond in 1999 [3]. Some of the have papers considered AUTC as an adaptation problem rather than an optimization problem [7] [9] [10] [11].

In the case of centralized and decentralized control both have been used. We will categorize these methods into three groups and will discuss about which one might be better according to the presented factors.[7] Suggests a completely decentralized approach which calls it a *"self-organizing traffic light control"*. In this method each intersection uses a number of simple rules for controlling the traffic lights. This way each intersection as an agent operates by its own regardless of any kind of hierarchical [13] or centralized control. Each agent's goal is to empty its intersection as quickly as possible noting that this will help minimize the waiting time of vehicle in the overall system. This approach seems not to be considering any prediction method, so in our proposed model we have suggested a method for arranging some kind of a simple prediction.

On the other hand some implemented ideas such as SCOOT [12] and SCAT [1], divide city to some areas and use a centralized approach for controlling those areas which each area will contain a couple of intersections and the are controlled via one control center. These ideas appear to be not expandable and scalable as our proposed model. This is because we have almost a completely decentralized approach.

Gathering information on traffic during different times of day and year for using that information for helping the agents for making decision is suggested by [5]. It introduces problems for that and suggests a solution.

Using Fuzzy control [6], timed Petri Nets [14], Ant Algorithm [2] and Knowledge based MultiAgent system [5] has also been suggested. In using these techniques a centralized or distributed control has been taken into consideration. It appears that all these approaches lack a unified model. For this we have proposed a model with a high abstraction.

In all above assume is that the control is through traffic lights and variable message signs; while [8] considers vehicles as autonomous agents that can be controlled through traffic control system. In this case control system knows destination of each vehicle to decide for vehicles which path to use for reaching their destination. In our opinion this approach is not suitable for current and in use vehicles and intersections.

According to reviewed papers we have based our research on developing a *Self-Organizing MultiAgent System*. Next we will classify different method and introduce our approach.

3 Three Level Control Approach

In our work first we have mentioned three types of control for that might be used for this problem and impact of each one on the matter of scalability. These three types would be centralized control, stand alone (decentralized) control, and a third type which we will call it island control. We will look forward a type that it would be most scalable at the level of design. Then we put forward our model for the problem and will describe it. There are different characteristics of a good design in UTC problem which we will see if our model is capable of satisfying those characteristics.

In our opinion after efficiency the most important matter for an applicable solution for UTC problem is scalability. We might be able to develop a very good solution for a particular urban area, but this solution must be scalable. i.e. the solution must be in a way that it is free of parameters of a specific city, or at least it would cover a wide range of similar urban areas. So that, little alteration would be needed for using a solution that has been developed in a specific urban area to other similar cities.

Goals of this research are to achieve the followings in the urban areas:

-Minimize total waiting time at traffic lights
-Maximize average speed of cars
-To avoid traffic jams

3.1 Characteristics of a Good Design

It seems any methodology used as a solution should have these characteristics [1]:

- *High efficiency* as suggested by the results of all the investigations under both simulated and real-life traffic conditions.
- *Robustness* with respect to measurement inaccuracies and disturbances.
- *Reliability* with respect to hardware failures (detectors, communication links, etc).
- *Generality* that leads to easy applicability (via available software tools) in networks of arbitrary characteristics and dimensions.
- *Extreme simplicity*.
- *Limited measurement requirements* (one detector per significant street).
- *Low computational effort*.

3.2 Classifying of Different Control Approaches

We have classified different approaches as being one of the following groups:

1. Centralized Control
2. Semi-centralized (island) Control : such as SCAT and SCOOT
3. Stand alone Control : such as [7]

Among these three forms of control stand alone systems seem to be much more scalable, reliable, robust and easy to install. On the other hand decentralized approach may be less efficient than centralized and semi-centralized approaches because each independent agent knows little (considering message passing between neighboring agents) or nothing of the status of other agents and the environment other than its control area. This problem rises up when we want to decide on a general control strategy for one particular urban area.

Prediction plays a very important role in UTC problem. If we would be able to predict the volume and the flow of traffic we could manage traffic much more efficiently. Other problem with decentralized control would that each agent might use little prediction because it hasn't the full picture of the traffic in an urban area.

As we mentioned earlier, in our thought after efficiency, scalability is the most important factor for an applicable solution to this problem, so we thought of a model that used stand alone and independent agents to keep its advantages such as more scalability, robustness and reliability. For two problems explained for decentralized approach we proposed a three level control approach with the use of Mobile Agents at the highest level for prediction and deciding on a general strategy according to their observations on different intersections.

3.3 Proposed Model

This model consists of two types of agents: Intersection agents and a number of mobile agents that decide on the traffic control strategy for each region. Control of traffic is done through three levels. In the first level which we call it intersection level, each intersection's goal is to empty the intersection as quick as possible. With only this level very good results are achieved [7].

The second level is message level. In this level after considering the first level's decision, each intersection agent tells its neighboring intersection agents the amount of traffic in that intersection. So each intersection can consider the information about the volume of traffic in joint intersections in its decisions. This will provide some kind of weak prediction for intersection agents.

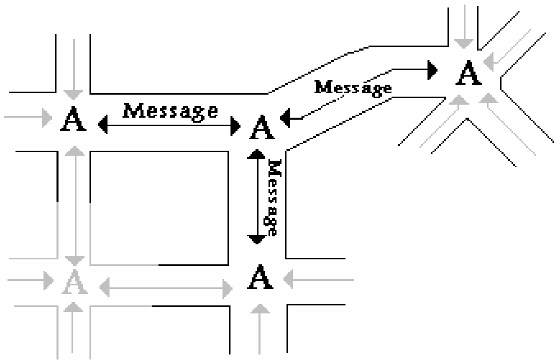

Fig 1. An Intersection Agent with message passing with its neighbors

One of the most important problems to deal with is keeping the traffic flow in some more important roads. By important we mean some particular roads that when they are jammed, traffic becomes much heavier in the roads leading to those specific streets and this causes very heavy traffics.

On the other hand if we control the amount of cars streaming into these important streets (i.e. by stopping the cars entering these streets at the joint intersections traffic lights in the roads leading to the important streets) and sustaining the traffic flow in the important ones, overall traffic in that specific area will be less heavy. This problem and some other problems in the traffic control that consist more than one intersection and its neighboring intersections may lead to centralized or semi-centralized approach for the whole model of control.

Here we suggest for preserving decentralized control approach for its benefits as noted and using a new mechanism for empowering the intelligent traffic systems for dealing with problems such as problem mentioned above where solving the problem requires coordination of a couple of intersections in a specific urban area. This will be satisfied by the highest and last level of control.

The last and third level will consist of a mobile agent for each area consisting of several intersections. This way urban area should be divided to different parts and areas where each of these areas may consist of one (or more) important streets and the streets leading to it. For doing this we may have different degrees of importance for different intersections and the goal of mobile agents in this case will be to sustain the amount of traffic in a certain level in intersections with higher degrees by controlling intersections with lower degrees influencing on them. In each area a mobile agent will do the work of coordinating the intersections under its control. Each mobile agent's job will be to observe the traffic in different intersections in its area and to decide between different control strategies according to its observations.

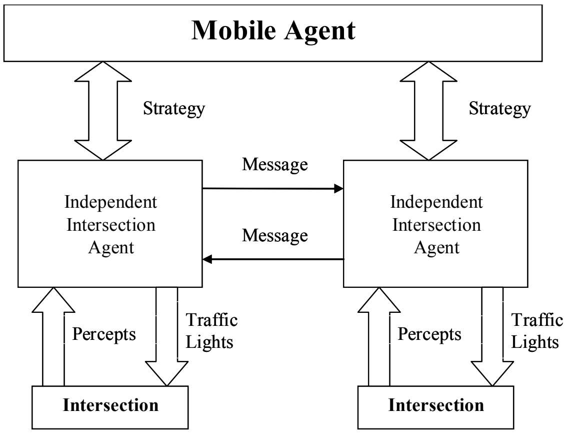

Fig 2. A view of two neighboring intersections with coordination of a mobile agent

When For installing such model we will need to install an independent agent for each intersection and connecting the joint intersections (for example via dedicated telephone lines) and then introducing a couple of intersections for each mobile agent. These mobile agents will perform their duties on deciding strategies in their introduced intersection domains. If some connections between intersections are broken (in the worst case all the connections are broken) intersections will still go on controlling traffic in an acceptable manner [7], but with less intelligence and less performance. But the whole system wont break down because of failure in some part of it.

Several intersections are assigned to a Mobile Agent. This can be done manually and on the next phase automatically. These assignments can be dynamic and according to changing situation. One might think of using a Multiagent system instead of Mobile agents. Mobile Agents use in computer network management and network diagnosis [16] has been studied and the studies show promising results. In our thought an Multiagent model will not be as scalable and dynamic as Mobile Agents. Some possible benefits (of our concern) as mentioned in [16] are: Reduction in Network Traffic, Interaction with Real Time Systems, Robustness and Fault Tolerance and Support for Heterogeneous Environment.

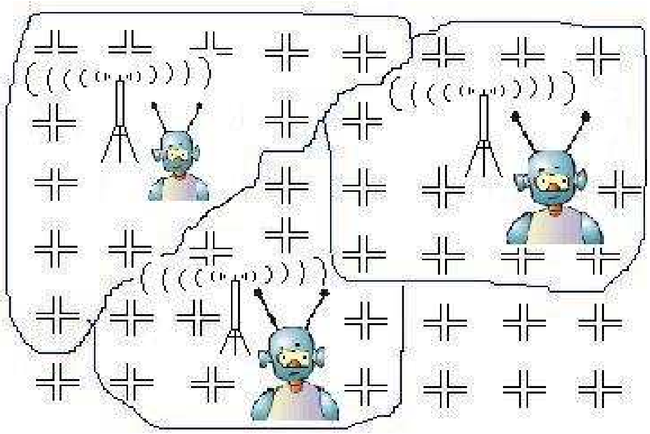

Fig 3. A symbolic view of three urban areas and Mobile agents coordinating intersections

As you see this three level model can be viewed as a model that preserves the qualities of a decentralized control approach as scalability, reliability and robustness but it will also be viewed as a model that practices qualities of a centralized control approach disregarding its shortcomings.

4 Conclusion and Future Work

In this paper we introduced a new abstract model for intelligent urban traffic control through independent intersection agents, message passing between joint intersections and coordination of a group of intersection agents through a number of mobile agents. We believe a system based on this models can reach an applicable efficiency while preserving being a decentralized approach that has a great deal of scalability.

As for future work we think three research approaches would be appropriate:

1. A simulation of the proposed model for checking out its qualities in comparison with other models present seems inevitable. Although intuitively it seems that our model has more expandability, scalability, robustness and reliability a simulation would be needed to see if it meets efficiency requirements of an applicable Intelligent Traffic System (ITS).

2. Other researches should be done on the strategies that mobile agents can handle. As mentioned in previous chapter, mobile agents could be used for solving traffic problems where coordination of more than one intersection including its neighboring intersections is needed. As so by studying real world traffic it would be feasible to develop different strategies for traffic control by using mobile agents.

3. Studying a method for dividing urban areas i.e. clustering the intersection agents for control of mobile agents has also to be done. This could be done manually. But it would be better to develop a method for doing this automatically by mobile agents through their observations, learning the new environment and adapting themselves to the new environment.

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