Traffic Lights Control with Adaptive Group Formation Based on Swarm Intelligence

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1 Introduction

Several traffic control approaches address the problem of reducing traffic jams. A class of them deals with coordination of traffic lights to allow vehicles traveling in a given direction to pass an arterial without stopping. However, in cities where the business centers are no longer located exclusively downtown, this approach is not appropriate: simple offline optimization of the synchronization in *one arterial* alone cannot cope with changing traffic patterns.

This paper is an extension of our previous models: In [1] a decentralized, swarm-based approach was presented, but we have not collected and analyzed information about the group formation. In [2] groups were considered and a technique from distributed constraint optimization was used, namely cooperative mediation. However, this mediation was not decentralized: group mediators communicate their decisions to the mediated agents in their groups and these agents just carry out the tasks. Also, the mediation process may take long in highly constrained scenarios, having a negative impact in the coordination mechanism. Therefore, a decentralized, swarm-based model of task allocation as presented here is necessary. The dynamic group formation without mediation combines the advantages of those two previous works (decentralization via swarm intelligence and dynamic group formation).

2 Approach, Scenario and Results

Our approach seeks to replace the traditional arterial green wave by "shorter green waves" in *segments* of the network. Of course, in some key junctions conflicts may appear because in almost any practical situations, a signal plan does not allow synchronization in more than one traffic direction. However, our approach dynamically deals with the question of which traffic direction shall be synchronized. In this paper, each junction (plus its traffic lights) behaves like a social insect. A signal plan is a unique set of timing parameters comprising basically the cycle length and the split. Due to lack of space, we refer the reader to [1,3] for a detailed explanation about traffic control related concepts. Several plans are normally required for an intersection (or set of intersections in the case

* Authors partially supported by CAPES and CNPq respectively.

M. Dorigo et al. (Eds.): ANTS 2006, LNCS 4150, pp. 520–521, 2006.

of a synchronized system) to deal with changes in traffic flow. As a measure of effectiveness of such systems, one generally seeks to optimize a weighted combination of stops and delays, a measure of the density, or travel time. Here we are focussing on how the coordination is working, so we measure the number of coordinated agents and the number of groups formed.

For the task allocation, we use the mathematical model of division of labor in colonies of social insects [4]. The levels of the stimulus increase if tasks are not performed, or not performed by enough individuals. These concepts are used in our approach in the following way: each agent (traffic light/crossing) has different tendencies to execute one of its signal plans (i.e. an available task), according to the environment stimulus and particular thresholds. The approach also considers that each vehicle leaves a pheromone trace that can be perceived by the agents at the junction. The stimulus s_j of plan j is based on a weighted sum of the accumulated pheromone in each phase of this plan, and on the number of agents in the area of coordination of the signal plan. Every signal plan is associated with a given stimulus according to the direction towards this signal plan is biased.

When there is a change in the traffic flow, there must be an adaptation to the new situation. Traffic lights in the street with intense traffic flow tend to adopt the synchronized plans.

For the experiments, we use a 5x5 Manhattan-like grid, with a traffic light at each junction. We change the insertion rate of vehicles, emulating *unexpected* changes in the scenario. At the beginning of the simulations, all agents have neighbors with different plans, so that no group is formed a priori.

We have performed different experiments. Due to lack of space, these cannot be discussed here. Please go to `http://www.inf.ufrgs.br/~mas/maslab` for the extended description. We measure the number of groups created and the number of agents in the groups. In the experiments, agents were able to create groups of coordination and to coordinate in the direction with the higher traffic flow. In summary, the results show an adaptation to the changes in a fast and independent form, without any hierarchical organization.

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