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USING INTELLIGENT AGENTS FOR URBAN TRAFFIC CONTROL SYSTEMS

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Abstract

The usability and effectiveness of traffic management and traffic control systems greatly depends on its ability of reacting upon traffic patterns and permutations. There are several factors that affect the performance of conventional traffic control systems, for instance: changes in traffic flow, accidents, different behaviour and travel demand. In this research we investigatehow to apply autonomous intelligent agents in Urban Traffic Control.

1 Introduction

Designing, implementing, optimising and adjusting urban traffic control systems involves quite some effort and knowledge. Due to several reasons, changing environments not always lead to changes in the traffic control units. Adjusting a traffic control unit is a costly and timely affair. Often a traffic control unit is not adjusted for short term road works, nor for changing traffic patterns. The effectiveness of (urban) traffic control systems greatly depends on its ability to react upon changes in traffic patterns. When this ability to react becomes an integral part of the traffic control unit, the better it can react to changes in traffic conditions. The responsive control system should have sufficient knowledge of the situation to be able to handle unforeseen changes in traffic flow, such as accidents. Intelligent signal control systems must have the capability to optimise the traffic flow by adjusting the traffic lights and co-ordinate operation between each signal in order to maximise the person and vehicular throughput and minimise delay. For intelligent urban traffic control we ideally need a fully pro-active, real-time traffic control system; anticipating what will happen within the next 15 minutes (Roozemond, 1997). For such a system the control plans used, optimised by some sort of performance criteria, are based on actuated traffic conditions and are updated frequently and possibly even during a cycle.

In urban traffic control, responsive plan generation is a much discussed, but little implemented idea. The basic premise is that existing signal-plan generation tools (e.g., UTOPIA-SPOT or SCOOT) make rational decisions about signal plans under varying conditions. True as this maybe, these tools cannot be used in a real-time setting for more than traffic control as no real meta- rules are incorporated into the system. Other systems capable of self-optimising are MOVA (UK) and LHOVRA (Sweden). Both are designed for optimising isolated intersections and noexplicit interaction takes place between intersections.

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2 Agent Based Urban Traffic Control

We propose a system that autonomously can adapt to changing environments. In that system we get an Urban Traffic Control system (UTC) based on agent technology that is able to adaptand respond to traffic conditions in real-time and still maintain its integrity and stability withinthe overall transportation system and in the meantime get a system that makes better use of the capacity of intersections. The key aspects of improved control, for which contributions from artificial intelligence (AI) and artificial intelligent agents (IA) can be expected, include (Ambrosino et al., 1994):

- the capability of dealing with multiple problems and conflicting objectives;
- the capability of making decisions on the basis of temporal analysis and developments;
- the ability of managing, learning, and responding to non-recurrent and unexpected events;
- self adjustabilty is an integral part of IA based units;
- the, more flexible, control unit can, pro-active, optimise while operating.

The most useful agent in UTC would be a traffic signal control device. Saito et al. (1997) havefound that the use of quick response demand prediction models in saturated situations (degree of saturation > 0.5) could improve delay's per vehicle on a single approach intersection by 5%to 15 %. In saturated situations such an improvement is huge and is achievable by intelligent signal control. Such an UTC system requires: monitoring system of traffic, a rule- or model- base for evaluation and adjustment, a model of the surrounds and an efficient diagnostic routinefor both traffic light operations as well as rule- and parameter adjustments.

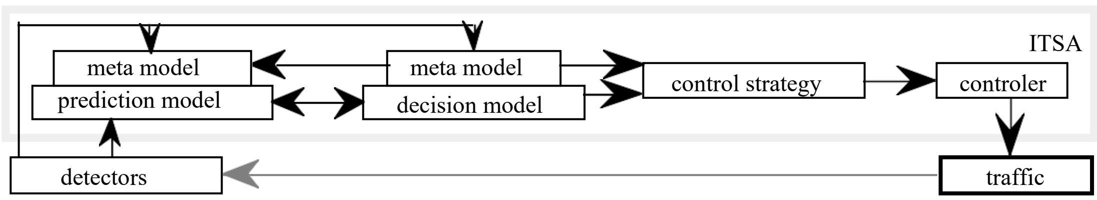

Figure 1: Actuated control strategy based on agents

The essence of an, demand responsive, pro-active, UTC system can be based on several, coupled, intersection control ITSA's (Intelligent Traffic Signalling Agent). The design of a multi-agent system requires flexible autonomy. Meaning that agents will be required to work autonomously, but will often be influenced by others. For a specific ITSA, implemented to serve as an urban traffic control agent, the following aspects are taken into account (Roozemond, 1998):

- The ITSA has some goals to accomplish: maximising traffic flow, given its rule-base;
- The ITSA has rules to obey and roles to perform;
- The ITSA decide on what actions to take; helped by its controller, the view and knowledge it has of its environment, its abilities and its state;
- The ITSA has skills and tasks that it can perform depending on situations. The agent solvesa problem mostly acting on its own 'feeling' and its knowledge.

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3 Intelligent Agent Based Urban Signal Control System

An intelligent, agent based, urban traffic control system should be capable of calculating and optimising control strategies, as well have knowledge about the intersection(s). The ITSA candirectly influence the control strategy of their intersection(s) and are able to get insight in on- coming traffic. Using all available information the ITSA (re)calculates the next, most optimal, state and operates the traffic lights accordingly.

In figure 2 a more specific example of a simplified UTC system is given. An authority agent controlling several intersection ITSA's , which in their turn manage the intersection controls. The authority agents are not discussed here, but their tasks are controlling and leading the ITSA's towards a more global optimum. An ITSA, capable of controlling or advising in real- time, should perform the following actions: (Roozemond, 1996 & 1998):

- The agent receives at (given) time intervals the information on the current state of traffic(data collection).
- The agent receives information on other adjoining signalised intersections from otherITSA's (data collection).
- The agent has an accurate model of the controlled intersection and knows the traffic rules(analysis).
- The agent knows the recent trends (analysis/interpretation of data).
- The agent should be able to calculate the next cycle mathematically correct (analysis/decision).
- The agent should be able to actuate the next cycle and operate the signals accordingly (control).
- The agent should be able to detect and handle current traffic problems by itself (analysis/decision and control/action) and should inform other agents of the nature, severityand possible cause of the problem, if necessary (data distribution).
- The agent passes information on to other adjoining agents (data distribution).

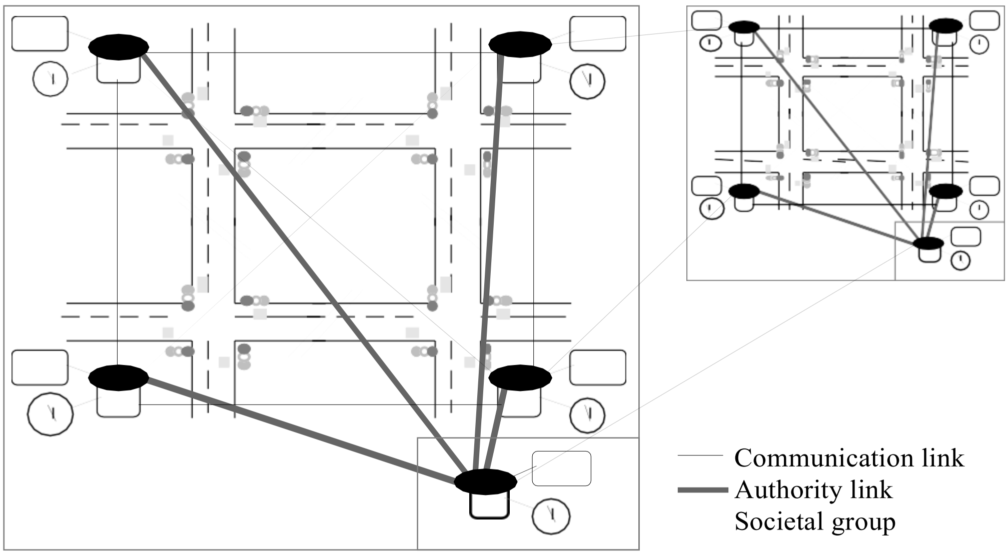

Figure 2: Simplified, agent based, UTC system.

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The essence of an intelligent UTC system can thus be based on several Intersection Traffic Signalling Agents and some authority agents (see figure 2). An ITSA makes decisions based on goals, capability, knowledge, perception and data. For a better overview of the internal ITSA models and functions see figure 1. The ITSA-prediction model estimates the states in the near future. The prediction model gets its data specified and related to intersection and road segments; as an agent that 'knows' the forecasting equations, actual traffic conditions and constraints; thus future traffic situations can be calculated by way of an inference engine and it's knowledge- and data-base. The kind of calculus used is effectively a state prediction model: predicting the states on time t_j, given the state on time t_{j-dt}. The knowledge is presented as production rules: IF <condition 1><condition 2>...<condition n> then <prediction rule 1>…<prediction rule m>. The ITSA-decision model calculate signal plans to pro-act on these predictions, checks with other adjoining agents and the plans signal control strategy. Normallyin non conflicting cases when only optimisation plays a role, a decision model agents' choice based on a number of criteria with different weights will be sufficient. Minimising objectives is, in theory, quite simple: $Min \sum_{i=0} objective_i * weight_i$. That process in this system becomes far more complex due to several different, continuously changing, weights and different goals of the different ITSA's. The effectiveness of an controlled intersection largely depends on the actual traffic and the cycle plan. An optimisation procedure in which the cycle plan may be calculated minimising several criteria, such as total delay, total number of stops, total costs of losses, fuel consumption, time of day, etc., can be included (Bruno et al. 1994). Operation of the traffic lights is left to an ITSA-controller.

Traffic dependent intersection control normally works in a fast loop. The detector data is fed into the control algorithm. We suggest the introduction of an extra, slow, loop where rules andparameters of the prediction- and decision model can be changed (see figure 1). The prediction model is fed by several inputs: vehicle detection system, control strategies, communication with ITSA's of nearby intersections and the urban traffic control centre. The prediction-meta-modelshould be artificial intelligent so it may change the parameter settings of the prediction model. It performs some kind of check if recent predictions were accurate and id not adjusts the parameter settings. The same principle will be used for the decision model.

Single junction controllers often make use of mathematical programming methodologies based on constraints for evaluation and optimisation of the cycle. In arterial and agent based systemsthis subject becomes more complex due to co-ordination and synchronisation. Moreover, sincethe decisions are not centrally controlled, the agents independently and a-synchronously selects from the available choices the one with the highest efficiency. A blackboard architecture or a voting system may be helpful for agents to prevent deadlocks, co-ordinate and choose betweencontradicting actions or non-optimal phases between agents. Meta-rules and authority agents will be included to handle contradictory or unforeseeable system wide traffic control situations.If necessary an agent can request for additional information or receive goals or orders from itsauthority agent. Often an ITSA should sacrifice some performance in favour of co-operative behaviour caused by appointment of an authority agent or self control of ITSA's. Here we should ad that finding the optimal situation often isn't just an optimisation problem, but more often a problem of finding a feasible solution.

5 Conclusions

The particular techniques proposed are experimental and not yet mainstream, especially whenproposed for such a large, on-line, application. The pro-active and re-active nature of agents can be a helpful paradigm in intelligent traffic management and control. Further (real-life) testson a control strategy, based on intelligent and autonomous agents, are necessary to provide appropriate evidence for operational use as relatively little is known about the global behaviourof these intelligent agent systems when they are scaled up to deal with more realistic problems.As this research is still ongoing we hope, in the end, to demonstrate that an integrated dynamicurban traffic control system based on agent technology can adapt and respond to real world traffic conditions in real-time. A working prototype of such a system should give appropriate evidence on the usability of AI agent based control systems.

Signal control systems that have the capability of optimising and adjusting the traffic light settings are able to improve the vehicular throughput and minimise delay through appropriate response to changes in demand patterns. With the introduction of two un-coupled loops, whether agent technology is used or not, a different theory of traffic control can be met. Artificial agents is a metaphor to be used for theoretical and implementation purposes. Primarilyresults indicate that given an automated control strategy implemented in the traffic signalling devices we can get a system that makes better use of the capacity of the intersection. It has beenshown that control systems based on agent technology can adapt and respond to changing conditions in real-time and in the meantime making better use of the infrastructure.

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