GreenWave Distributed Traffic Intersection Control

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ABSTRACT
This demonstration proposal is for a distributed traffic intersection traffic-light control called GreenWave. The solution couples camera sensors with a novel collaborative multiagent goal-oriented control algorithm to outperform both conventional and theoretical approaches. The system is designed for real use, although simulated traffic data will be used for the demonstration.

Keywords
Distributed Multiagent traffic intersection phase control, emergent green wave, video camera sensor.

1. APPLICATION DOMAIN
The application domain of this proposal is distributed traffic intersection traffic-light control. Globally the volume of road traffic increases every single day, as does correspondingly the volume of consumed energy resources and emitted pollutants. Many counter measures seek means to reduce the volume of vehicles, but our approach reduces overall traffic congestion, and thus travel times, fuel consumption and emissions by increasing the throughput of vehicles crossing town and city networks. We achieve this with real-time video sensor monitoring serving as input to goal-driven agents controlling the phase-change of intersections, rather than the standard sequential model deployed universally today. The control algorithm is implemented as a distributed multiagent system built using the LS/TS multiagent middleware [2] with network/traffic simulations performed with the SUMO [1] open source network simulator.

The demonstration will present our distributed multi-agent control algorithm running on multiple SUMO road network simulations. Core features include comparative demonstration of algorithmic behaviour and performance against other approaches, and illustrating the spontaneous emergence of green wave behaviour and the positive effect it has on traffic throughput.

2. SYSTEM SETUP
The software architecture of the system consists of the SUMO network simulator with an overlaid multiagent control system where each controlled intersection is managed by an autonomous agent. Each agent communicates only with adjacent agents according to the road network topology. There is no central controller.

Multiple traffic generation models and network topologies will be demonstrated, both in terms of road and intersection layout. An overview of our basal intersection model is illustrated in Figure 1.

We use this model, often extended to grids, to test and measure algorithmic alterations.

Vehicle detection sensors consist of induction loops embedded in the road surface and video cameras installed in strategic locations to monitor traffic entering and passing through intersections. Experiments have been conducted with data from real sensors, but for the purposes of demonstration we simulate both induction and video sensors within the SUMO environment. Video sensors are critical to our approach as they allow the tracking of vehicles through an intersection from point of ingress to point of egress. Vehicles are not identified and individually tracked, but rather treated as statistical entities.

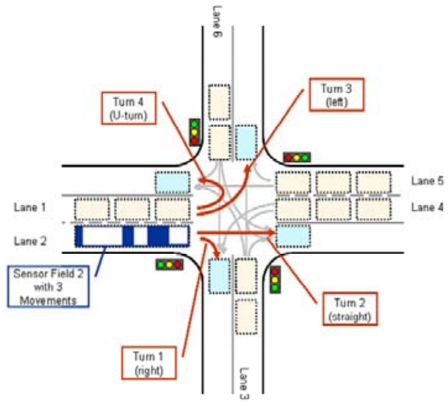

Figure 1: Basal intersection layout

The software agent control system is designed for deployment to the real-world where agents can be installed on equipment locally at intersections, or run in a remote server sending control messages. Each agent implements a goal-oriented BDI logic where the goal is to maximize the value of a utility control function determining which traffic-light phase will optimize local intersection throughput. The utility function is also affected by collaboration between agents controlling adjacent intersections to encourage the emergence of green waves and thus approach an optimal level of traffic throughput across the entire road network.

3. INTERSECTION CONTROL
Real-time traffic light optimization is an inherently complex problem [3, 4] with optimal solutions difficult to locate for single intersections, let alone multi-intersection city networks. In our solution each intersection ingress lane is considered as a statistical queue populated with vehicles entering, in most cases, from

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another intersection. The length of this queue is adjusted as vehicles leave and the road which they take as egress from the intersection is assigned a weighting which is subsequently passed as a notification to any adjacent intersection controller on that road. This is a probabilistic measure as it is entirely possible the vehicle may not arrive at an adjacent intersection for a variety of reasons (e.g., turning off the road, stopping, etc.). By retaining oversight of all ingress queues into the intersection for which it is responsible, the agent is able to estimate per-vehicle waiting times (when vehicles are within monitoring zones) and average waiting times. Using this and information received from adjacent intersections the agent is able to formulate a continuous real-time solution to the optimal selection of traffic light phase using goal-oriented logic.

The heart of the intersection control logic is a utility function which estimates the utility of each allowable light phase using parameters including waiting vehicles, moving vehicles, waiting time, and vehicle distance to intersection. These parameters are continuously subject to weighting by statistical information shared by adjacent intersections. If a specified threshold is reached, i.e., if one or more phase utility is sufficiently larger than the active phase utility, the intersection will switch to the winner phase. The utility calculation also accounts for whether it is for the active phase or not. With this differentiation one can, for example, assign moving vehicles a higher priority the lower their distance to the intersection. This helps to ensure that moving vehicles close to the intersection need not stop. For the moving vehicles of an inactive phase the distance to the intersection is measured dynamically, weighting an immediate phase switch to green when the vehicles arrive at the intersection. This assists with encouraging the emergence of multiple green waves.

4. DEMONSTRATION

This interactive demonstration will offer a real-world grounded view of how a multiagent system can directly improve on standard models of sequential phase control of traffic intersections. A video sensor traffic detection model allows input from standard induction loop sensors supplemented with real-time tracking of traffic movement towards and through intersections. This data is then used by the novel, control function distributed to each controlled intersection which changes intersection light phases according to queued and incoming traffic.

Through the SUMO tool, the system can manage any network of intersections with the control algorithm either deployed to every intersection, or critically, to only a selection of intersections, i.e., mixed control networks are an option. Distributed deployment will automatically adapt and improve as more intersections adopt the new control scheme. The demonstration will nominally use a collection of pre-generated traffic networks, from a simple grid network to a complex city-wide simulation, see Figure 2.

The traffic generation model is stochastic and simulated video-sensing will be activated. The simulation is highly visual and interactive; visitors will be able to adjust control parameters and observe the impact on traffic flow patterns in real-time. By either turning on automatic flow adaptation or by manually tuning control parameters the user may observe the emergence of multiple green-wave traffic flows in suitable networks.

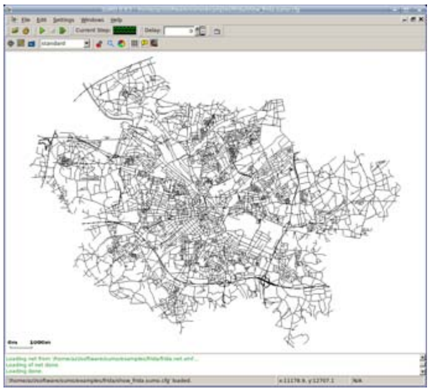

Figure 2: Simulated city network

As illustrated in Figure 3, available KPI statistics include number of waiting vehicles, number of vehicle stops, vehicle fuel consumption, and estimated CO2 emission reduction. Comparative, side-by-side simulations will be shown.

Figure 3: Monitoring tool

5. ACKNOWLEDGMENTS

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