AGENT-BASED MODELING FOR TRAFFIC SIMULATION

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ABSTRACT.

In this paper we develop a multi-agent based traffic simulator by considering traffic flows as emergent phenomena. The main problem of agent-based traffic simulation is how to reproduce realistic patterns of traffic flow at both macroscopic and microscopic. The objective of simulation is a scenario of traffic generated by the model that should provide the illusion of a real road scenario.

KEYWORDS: Multi-AgentSystems, Agent-BasedModelling, Trafficsimulation, self- organization.

1 INTRODUCTION

Modeling is a powerful tool that allows a designer to observe cause-and-effect relationships in occurrences that happen too slowly or quickly to see; involve danger or safety concerns; occur on a scale too large or too small for study; are not a common occurrence or simply can hardly be realised in real environment with real entities.

Agent-based modelling (ABM) and simulation is a new approach to modelling systems comprised of interacting autonomous agents. ABM promises to have far-reaching effects on the way that businesses use computers to support decision-making and researchers use electronic laboratories to do research. Some have gone so far as to contend that ABM is a new way of doing science. Computational advances make possible a growing number of agent-based applications across many fields. Applications range from modeling agent behavior in the stock market and supply chains, to predicting the spread of epidemics and the threat of bio-warfare,from modeling the growth and decline of ancient civilizations to modeling the complexities of the human immune system, and many more.

The study of how traffic flows is essential to the design of better road networks. If traffic flow could be completely understood, then traffic levels could be predicted and congestion could be forecasted and avoided. Traffic congestion is a major issue for many drivers; it results in journey delays, wasted time, and increased pressure, and can make people late or cause loss of business. The environment and local residents may be affected by emissions or noise pollution associated to vehicles. At its most basic, congestion is caused when the volume of traffic exceeds road capacity. This holds for most perceived causes of congestion; for example, accidents, breakdowns and road works decrease the available road capacity, while school-run and holiday traffic increase the volume of traffic [1]. Congestion reduces the quality of life for many people and deserves to be tackled to improve transport for everyone [2]

In this context, we consider the agent based modeling field, and we are interested in a simulation model of road traffic. To define this model, a driver is considered as an autonomous agent whose behavior is based on decisional activities on its environment. The traffic generated is result from the interaction of each agent with the regulations, road infrastructure and other road users. The purpose of this paper is to show that agent based modeling for traffic simulation is a worthy tool for traffic engineers evaluating alternative schemes. It aims to develop a unique traffic simulation system that can be used to study traffic theory and assess network infrastructure and control changes. Main objectives include gaining an understanding of traffic theory, learning the major features and issues of traffic simulation, and evaluating agent-based modeling as a means of simulating traffic.

This paper is structured as follows: Section 2 examines the Traffic Flow. Section 3 looks in detail at the design features of traffic modeling and simulation systems, and section 4 introduces agent-based modeling along with its application to traffic. Section 5 follows the design of the traffic simulator proposed, its implementation with details

of results from testing on the problem. Conclusion and future works are presented in section 6.

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2   TRAFFIC FLOW

The economic impact of traffic management grows each day. Well-designed and well- managed highway systems reduce the cost of transporting goods, cut energy consumption, and save countless person-hours of driving time. To reduce congestion, many countries have been investing heavily in building roads, as well as in improving their traffic control systems. In order to understand traffic flow phenomenon, we need to start by looking at what already happens on the roads.Traffic surveys are used to provide measurements of the current situation, and involve counting the number of vehicles going past a point in a certain amount of time. However, simply knowing the flow rate is not too useful. The traffic density describes the number of vehicles in a certain amount of road, and requires the vehicle speed in addition to flow rate for calculation. Density is usually measured in vehicles per km, per lane. The optimal density on a standard road should be around 40 vehicles per km, per lane. [3]

Infrastructure improvements are costly; hence any such project must be carefully evaluated for its impact on the traffic. Computer simulation models can be very valuable in making those evaluations in a cost-effective manner. Such models can be used to evaluate modifications not only under nominal conditions, but also under hypothetical scenarios that would be difficult to observe in the real world.

Physicists have been trying to describe the phenomena of traffic for at least half a century. In the 1950s, James Lighthill, an expert on the physics of fluid flow, suggested

that the flow of traffic on a road was akin to the flow of liquid in a pipe. This theory (the Lighthill- Whitham- Richards model) represented the flow of traffic entirely with mathematical equations, and ignored the individual drivers. This sort of model is called macroscopic, and can often produce realistic output, but lacks the complexity to model realistic driver behaviours [3].

The next approach was to treat vehicles as individual units instead of a continuous flow, and see what behaviour emerges when the vehicles are given simple rules to follow. Each vehicle would move according to the vehicle ahead, speeding up or slowing down to match its speed while maintaining a safe distance between cars. This is a type of microscopic model, which can vary in complexity depending on the aims of the simulation. One well- known model is a cellular automata model designed by Nagel and Schreckenberg [3, 4]

The results from these models and from traffic studies show that flow rate and traffic density are linked in an interesting way. Normally, flow rate increases as density increases, that is, more vehicles are on the road. However, when the density reaches a so-called 'critical density', the flow rate begins to decrease and the traffic becomes congested.

3   TRAFFIC MODELING AND SIMULATION

Defining the model is one of the first stages of building a traffic simulation. This involves deciding how to represent objects (e.g. vehicles, drivers, traffic lights) in the simulation, and what parameters each object will require. It also involves determining how to represent the environment (e.g. road, lanes and intersections), and the effects it has on the other objects.

3.1   Modeling Vehicles

In a simulation, vehicles and drivers would most likely be modeled as one entity. However, in the real world they obviously are not, so when deciding on how to model them it makes sense to look at each in turn. Modeling a vehicle is quite straightforward; a few parameters can describe its features and behaviour: maximum speed, maximum vehicle acceleration and deceleration. Acceleration is especially important as it affects the rate of queue discharge. Dimensions are often implemented, enabling trucks and buses to be distinguished from cars. During simulation, current position and heading in the environment are required to keep track of the current state [1, 5].

3.2   Modeling Drivers

Paruchuri et al. [7] suggest that the decisions drivers have to make can be split into micro and macro goals. Macro goals are the destination and route taken, while micro goals involve decisions at each point of time in the

interest of achieving the macro goal. The macro goal involves daily planning and route generation functionality, often input from O-D data. Micro goals are decisions involving controlling the vehicle, such as desired speed, overtaking and turning. Drivers all have different driving styles, which are governed by their individual characteristics, such as aggressiveness, confidence and driving experience [6, 7].

3.3   Modeling the Environment

In traffic simulation, the environment in which vehicles drive is a road network which is made up of link segments (junctions and intersections) and control features which are usually part of the node. Each link can have one or more lanes, and may operate in one or both directions. Links have properties such as length, number of lanes, speed limit, etc.

3.4   Simulation Issues

Models of vehicles, drivers and the environment are of no use unless they can be manipulated during simulation. Simulation involves using behavioural rules to change the model over time. This involves moving each vehicle based on its parameters and its driver's decisions. To simulate a single car on a long straight road is rather simple, as the vehicle would just accelerate to the driver's preferred speed. It becomes increasingly complex as other vehicles, more lanes, and more roads are introduced; to deal with these, vehicle following and lane changing models are used [8].

3.5   Traffic Simulation Models

Traffic can be viewed as a complex system. Developing macro models is one of the primary approaches to modeling complex systems. Macro m o d e l s follow a top-down approach, witch simulation have the advantage that run-time can be fairly short and are helpful when only a coarse prediction of conditions is sufficient. Micro modeling that can potentially produce better quality is a bottom-up approach. Complex system is viewed as a large set of small, interacting components. Two issues with micro simulation are computational performance, and software development cost. Micro simulations run at a very detailed level, emulating the behavior of every individual entity in the system, and thus they are computationally very intensive. Microscopic vehicular traffic models focus on the study of the interaction between vehicles and investigate the synthesis characteristics of complex traffic phenomena.

There are several different types of traffic simulation models: vehicle-following (VF) models, Cellular Automata (CA) models and the multi-agent (MAS) models. Vehicle-following models are based on Newtonian dynamics. CA models have further been studied in recent decades [9-12], but do not incorporate realistic driver and vehicular behavior. Vehicles are modeled as particles having

unrealistic erratic acceleration and deceleration rates.

The agent metaphor has proven to be a promising choice for building complex and adaptive software applications, because it addresses key issues for making complexity manageable already at a conceptual level. Agent technology is a rapidly developing area of research and it has the potential to stimulate and contribute to a broad variety of scientific fields [13]. Multi-agent models offer an alternative interpretation of classical traffic flow models as well as the development of more general and effective frameworks to model driver behavior on a cognitive level [14]. The MAS models have received increasing attention in traffic management, signal control, route guidance. It offers certain advantages of: faster response, increased flexibility, robustness, resource sharing, graceful degradation and better adaptability of integrating pre-existing and stand-alone systems.

4   AGENT-BASED MODELING AND TRAFFIC SIMULATOR

A number of urban traffic simulations have been developed using agent-based modelling, most utilising toolkits/libraries. The Recent agent-based simulators are: SCANeR II by Champion et al. [22], Tang and Wan [23], Rigolli and Brady [24].

Burmeister presented an overview of the potential and the existing application of agent- oriented techniques in traffic and transportation [25]. Rossetti assessed drivers' decision-making with an agent-based framework [26]. Dia modeled driver route choice behaviour with an agent-based approach [27]. However, the Rosseti model and the Dia model are not concentrated on microscopic traffic modeling, but on traffic management and control. Ehlert introduced a microscopic traffic simulator consisting of driving agents, multi-lane roads, intersections and traffic lights [6]. Mandiau et al. presented a multi-agent coordination mechanism applied to intersection simulation situations [28]. Wei et al. discussed agent- oriented traffic micro simulation modeling process with a traffic flow generation model and car-following model [29]. Zhang et al. proposed a multi-agent framework of single lane traffic simulation [30]

5   PROPOSED MODEL

The main entities in the traffic simulator implemented in this paper are vehicles, road segments, intersections, traffic lights which are modeled as agents and objects. The proposed model uses reactive agents. A vehicle agent contains the physical attributes of the vehicle such as length, acceleration, type. It also includes the car-following and lane-changing behavior. In implementing those behaviors, the vehicle agent needs to continuously interact with the vehicles around it and with environnement. Reactive agents use stimulus-response rules to react to the current state of the environment that is perceived through their sensors. Pure reactive agents

have no representation or symbolic model of their environment and are incapable of foreseeing what is going to happen. The main advantage reactive agents is that they are robust and have a fast response time, and exhibit an emergent behavior with simple rules: an *intelligent behavior.*
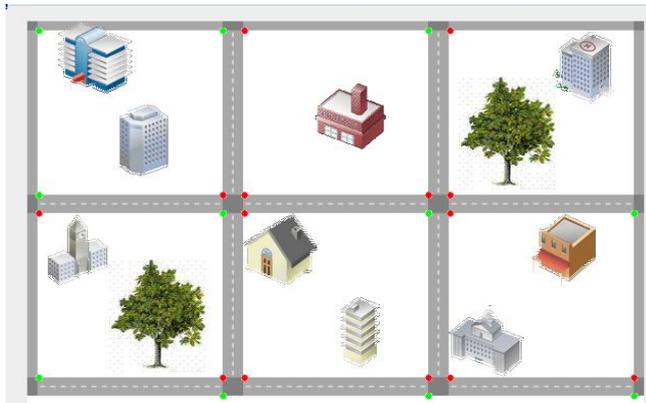

Figure 1: Environnement of Simulation

5.1 Behaviour Rules

The agent's driving task is divided into several subtasks that are automated by independent behaviour rules. This way the agent's functionality can be expanded easily without any modifications to the existing behaviours. The used behaviour rules are very much dependent of the agent's environment. Note that the design of our agent does allow driving in other environments. Only the agent's behaviour rules might need to be adapted or expanded. For our environment we designed the following behaviours:

5.1.1 Road following

The road-following behaviour is responsible for keeping the agent driving on the road. Besides controlling the lateral position of the agent's vehicle, based on the distance to the road and lane edges, the road-following behaviour also influences the agent's speed. It makes sure that it slows down for curves and on straight roads it will accelerate until the desired speed set in the agent's behaviour parameters is reached.

5.1.2 Intersection / changing directions

If the agent approaches an intersection, its speed is reduced, precedence rules are applied, and the agent will choose one of the side roads. This direction is chosen randomly and changing- directions behaviour can be split up into several sub-behaviours, one for each type of intersection.

5.1.3 Traffic lights

The traffic-lights behaviour makes sure that the agent stops for red traffic lights. The behaviour checks if the sensed traffic light regulates the agent's current lane and slows down the vehicle.

5.1.4 Car following

The car-following behaviour ensures that the agent does not bump into any other vehicle. If another car is driving in front of the agent, speed is reduced to match that car's speed. The precise braking pressure depends on the speed difference between the agent's vehicle and the other vehicle, the distance between them, and the set gap acceptance of the agent.

5.2 Implementation

We have constructed a prototype traffic simulator program to test our driving agent design. The programming language we used to build the simulator is Java eclipse. We have chosen this language in part since we were already familiar with it, but mainly because JAVA is an easy and puissant language, very suitable for quick prototyping.

5.2.1 The prototype simulator

The simulator program roughly consists of four elements: a user interface to provide visual feedback, a simulation controller, an environment containing simulated objects, and the driving agent model.The task of the simulation controller is to start, pause or stop a simulation run, and keep track of the elapsed time. The controller also initialises starts and stops the used driving agents. Different environments can be loaded via Load map. These files contain a description of a road network and traffic control systems. Loading a Map Data File initialises the environment and data about the simulated objects described in the file is stored in the environment. Our current simulator implementation contains multi-lane roads, intersections, traffic lights, traffic light controllers and vehicles.

The figure below depicts the simulation.
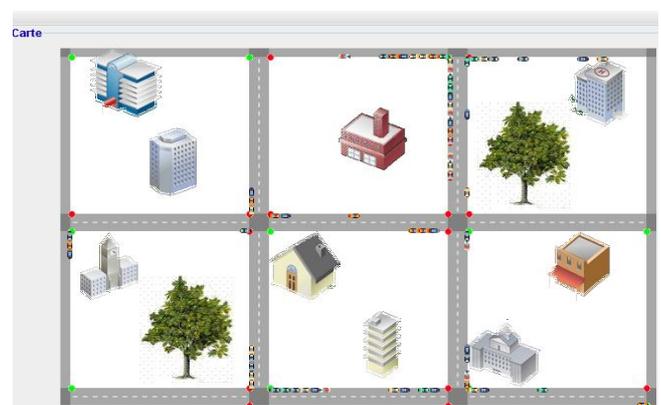
Figure 2: Traffic Simulation

We have presented a model of a reactive driving agent that can be used to control vehicles in a microscopic traffic simulator. Preliminary experiments have shown that the implemented agent exhibits human-like driving behaviour. Here we present the results of one of our experiments with these parameters of simulation

Number of vehicle = 70

Number of slow vehicle = 10

Number of priority (aggressive) vehicle =10

With these parameter settings, there is a traffic jam at one of Carrefour.
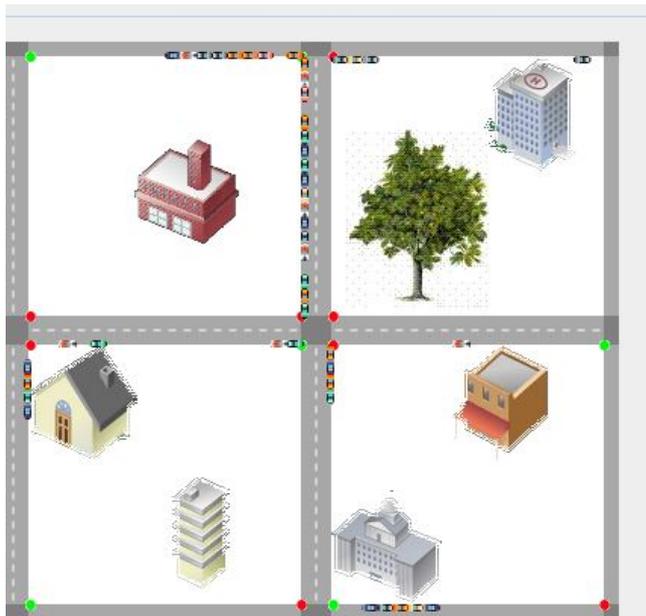
Figure 3: Traffic Jam

Indeed, the simulation allows us to see when there is congestion at the junction with different initialization parameters depending on delay waiting traffic lights and also capacity of lane

6   CONCLUSION AND FUTURE WORK

Computer traffic simulation is important for making new traffic-control strategies. Microscopic traffic simulators can model traffic flow in a realistic manner and are ideal for agent-based vehicle control. In this paper we describe a model of reactive agents that is used to control a simulated vehicle. To ensure fast reaction times, the agent's driving task is divided in several competing and reactive behaviour rules. The simulator consists of an urban environment with two lane roads, intersections, traffic lights, and vehicles. Every vehicle is controlled by a separate driving agent and all agents have individual behaviour settings The main advantage of agent-based microscopic traffic simulation over the more traditional macroscopic simulation is that it is more

realistic. Instead of using general traffic- flow models, traffic becomes an emergent property of the interaction between agents. Another advantage is that agent-based simulation is more flexible. Changes to traffic scenarios can be made quickly by changing agent parameters. Preliminary experiments have shown that our driving agent exhibits human-like driving behaviour and is capable of modelling different driving styles.

The simulation environment should be made more realistic by adding new objects, such as busses, trucks, emergency vehicles, pedestrian crossings, cyclists, traffic signs, trees and buildings. Once the simulator is improved with the new objects the agent's functionality must be extended to deal with these objects

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