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Techniques, Advantages and Problems of Agent Based Modeling for Traffic Simulation

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Abstract

Agent-based modeling (ABM) is a powerful simulation modeling technique in the last few years.

ABM, as an approach to simulating the behavior of a complex system in which agents interact with each other and with their environment using simple local rules, is gaining popularity and widespread use in many areas. Successes of this approach in predicting traffic flow in metropolitan areas, the spread of infectious diseases, and the behavior of economic systems have generated further interest in this powerful technology.

In this paper we focus on agent-based approach to traffic simulation, and investigate its benefits, difficulties and (microscopic-macroscopic) techniques.

Keywords: *ABM, simulation, traffic, benefits, microscopic, macroscopic and problems*

1. Introduction

The use of computer systems to solve problems of interest in physics, biology, chemistry, economics, and social sciences has been well-established for decades. The great advances in computing power, software development, computer graphics, communications networks, and a host of other technologies have elevated the domain of applicability to problem solving from simple arithmetic calculations to advanced numerical methods and the creation of large simulations solving myriad systems of complex equations in real-time.

2. ABM Advantages

The advantages of ABM over other modeling techniques can be captured in four statements: (i) ABM captures emergent phenomena; (ii) ABM provides a natural description of a system; (iii) ABM is flexible. and (iv) ABM is low cost and time saving approach. It is clear, however, that the ability of ABM to deal with emergent phenomena is what drives the other benefits.

2.1 ABM and emergent phenomena Adjacency

Emergent phenomena result from the interactions of individual entities. By definition, they cannot be reduced to the system's parts: the whole is more than the sum of its parts because of the interactions between the parts. An emergent phenomenon can have properties that are decoupled from the properties of the part. For example, a traffic jam, which results from the behavior of and interactions between individual vehicle drivers, may be moving in the direction opposite that of the cars that cause it. This characteristic of emergent phenomena makes them difficult to understand and predict: emergent phenomena can be counterintuitive. ABM is, by its very nature, the canonical approach to modeling emergent phenomena: in ABM, one models and simulates the behavior of the system's constituent units (the agents) and their interactions, capturing emergence from the bottom up when the simulation is run.

2.2 Natural description provided by ABM

In many cases, ABM is most natural for describing and simulating a system composed of “behavioral” entities. Whether one is attempting to describe a traffic jam, the stock market, voters, or how an organization works, ABM makes the model seem closer to reality. For example, it is more natural to describe how vehicles move in a lane than to come up with the equations that govern the dynamics of the density of vehicles. Because the density equations result from the behavior of vehicles, the ABM approach will also enable the user to study aggregate properties.

2.3 ABM flexibility

The flexibility of ABM can be observed along multiple dimensions. For example, it is easy to add more agents to an agent-based model. ABM also provides a natural framework for tuning the complexity of the agents: behavior, degree of rationality, ability to learn and evolve, and rules of interactions. Another dimension of flexibility is the ability to change levels of description and aggregation: one can easily play with aggregate agents, subgroups of agents, and single agents, with different levels of description coexisting in a given model. One may want to use ABM when the appropriate level of description or complexity is not known ahead of time and finding it requires some tinkering.

2.4 ABM is cost-effective and time saving approach

Champion et. al [1] describe simulation as an effective tool used for reproducing and analysing a broad variety of complex problems, difficult to study by other means that might be too expensive or dangerous. Traffic can be viewed as a complex system [Faieta et. al., Sanford in [2]], therefore simulation is a suitable tool to analyze traffic systems. Traffic simulation is the state-of-the-art method used to assess and evaluate transport schemes for reducing congestion [3]. Rather than implementing a scheme without knowing whether the outcome will be a success, the scheme can be implemented in a simulation to determine its effectiveness:
Infrastructure improvements are costly, hence any such project must be carefully evaluated for its impact on the traffic.[4]

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. The 1998 budget for Federal Highway Administration of USA is $19,680,000,000. Of this amount, $1,047,000,000 is allocated for congestion mitigation and air quality improvement [US Budget '98] [5].

On the other hand once the computer environment is established for social phenomena, the research cost will be much lower than the traditional research approaches. Also computers can implement complex simulation processes in several minutes at most.

3. ABM techniques

Simulations can be classed as continuous or discrete. Continuous models take the form of equations using variables that correspond to real values. By solving the equations, the state of the model at any given point in the simulation can be calculated. Discrete simulations represent reality by modelling the state of the system and its state changes after time or events have passed. There are two types of discrete simulation: discrete time models and discrete event models. Discrete time models (time-sliced) are those that split the simulation into fixed time intervals. At each interval, the state of the model is updated using functions that describe the interactions. Discrete event models (event-oriented) are those which maintain a queue of events scheduled to happen in order of time, each event representing the change of state of an element in the model. The simulator processes the events in order, and each one can alter the event queue. [6], [7], [1]

3.1 Macroscopic vs. Microscopic

Traffic simulators can be microscopic or macroscopic depending on the level of detail required. Macroscopic simulators model the flow of traffic using high-level mathematical models often derived from fluid dynamics, thus they are continuous simulations. They treat every vehicle the same, and use input and output variables such as speed, flow and density. These simulators cannot differentiate between individual vehicles, and usually do not cater for different vehicle types. They lack the ability to model complex roadways, detailed traffic control features or different driver behaviours. [4], [8], [9]. Macroscopic simulators are most useful for the simulation of wide-area traffic systems, which do not require detailed modelling, such as motorway networks and interregional road networks [6]. This approach is not very realistic because in real life there are many different types of vehicle driven by different individuals who have their own styles and behaviours. However, it is fast and can be useful and accurate, but is not suited to urban models. [4]

Microscopic simulators model individual entities separately at a high level of detail, and are classed as discrete simulations. Each vehicle is tracked as it interacts with other vehicles and the environment. Interactions are usually governed by car-following and lane-changing logic. Rules and regulations are defined to control what can and cannot be done in the simulation, for example speed limits, rights of way, vehicle speed and acceleration. [6], [9]. Traffic flow details usually associated with macroscopic simulation are the emergent properties of the microscopic simulation. Microscopic simulators can model traffic flow more realistically than macroscopic simulators, due to the extra detail added in modelling vehicles individually [4]. Microscopic simulators are widely used to evaluate new traffic control and management technologies as well as performing analysis of existing traffic operations [9].

A very simple form of microscopic simulation is cellular simulation, which involves modelling the road as a series of cells and moving the vehicles between cells based on vehicle parameters. This method can implement links using an array with length equal to the number of cells in the link. Cell length has to be determined and must be the same for all cells, which is a disadvantage because it assumes all vehicles occupy the same amount of space. When the simulation is run, each cell can be either empty or occupied by one vehicle. Vehicles are moved forwards by their speed and are restricted by vehicles in front. Links are connected to nodes and rules exist which determine where vehicles go when they reach a node. This method can be very efficient because of the simple array structure, but it lacks some realism. [10], [11]. An even simpler approach is queue-based simulation, where vehicles always move at a set speed until they reach a queue at the end of each link. [12], [13].

What is often mentioned as multi agent based simulation is microscopic modeling of emergent phenomena. Of course, macroscopic parameters can be result of microscopic simulation.

The agents used in the microscopic level for example are following types [14]:

- vehicle agent
- road agent
- intersection agent
- signal agent

3.2 Classification of simulation and simulators

Traffic simulations can be broadly classified by the type of road network and features they can simulate. The two main classes for simulators are those designed for motorway and urban environments. Simulators supporting a motorway environment focus on multiple-lane high-speed motorways. Much of the complexity required for a city environment does not need to be modelled, and the simulation can focus on vehicle behaviour and interaction. Motorway environments can be simulated accurately by both macroscopic and microscopic simulators [15]. The main features of a microscopic motorway simulator are car-following and lane-changing behaviours. Junctions are sometimes modelled, allowing entry/exit rate to be varied to test the efficiency of the motorway under varying traffic load. Practical uses include studying the effect of motorway accidents, stop-start congestion, speed limits, ramp metering and lane closures on traffic flow. [16], [15]

An urban environment is one of the most difficult and complex traffic scenarios [4]. In contrast to motorway environments, urban environments have a traffic flow that is interrupted by intersections, traffic lights, roundabouts and other features. In addition to the extra road features, realistic urban simulators should model not only different classes of vehicle, but also pedestrians, cyclists and public transport systems. [17]. Urban traffic networks are usually very complex with many road sections and intersection points, often with conflicting traffic flows [18]. They usually have to manage a large number of vehicles on small road sections, which can result in a large amount of congestion [19]. Microscopic simulators are well suited to urban environments as vehicles can respond individually to the road features. Macroscopic simulators are not able to model the complexity of urban environments; they are only used to provide abstract flow details.

Some simulators can model both motorway and urban environments at the same time; these are classed as integrated or combined simulators. This is useful for the simulation of large areas encompassing both motorway and urban roads, especially where the performance of one affects the other, and is advantageous to the user as one package can simulate various scenarios. [20], [8]. Some simulators have focussed instead on modelling specific objectives such as to test intelligent vehicle control units, to analyse vehicle safety and comfort, or traffic at toll booths [7].

4. Problems & Challenges

Considering the nature of social phenomena with too many (known & unknown) complex factors is the first problem in simulating these systems (For example in traffic systems, driver behaviors vary dramatically with geographic location and change over time. In reality they most often involve human agents, with potentially irrationally behavior, subjective choices, and complex psychology—in other words, soft factors, difficult to quantify, calibrate, and sometimes justify). Of course, it is better that we count this problem as a characteristic of social phenomena.

Although a lot of academic attention has been given to the subject, there are very few traffic applications, perhaps because of the “soft” nature of the variables and the difficulty in measuring parameters. Social simulation in traffic has not been very successful so far, because the emphasis has been on using it as a predictive tool rather than as a learning tool. For example, a traffic engineer can understand congestion better by playing with an agent-based model of it. Then, of course, quantifying the tangible benefits of something intangible is difficult, and a traffic engineer cannot claim to have reduced congestion of a lane by playing with a simulation of vehicles.

One issue related to the application of ABM to the traffic simulation is common to all modeling techniques: a model has to serve a purpose; a general-purpose model cannot work. The model has to be built at the right level of description, with just the right amount of detail to serve its purpose.

Another problem is that a lot of agent based toolkits include performance limitations: with a large number of agents, execution speed drops considerably. Usually these tools are not designed for extensive simulations.

5. Conclusions

Although above problems may constitute a major source of problems in interpreting the outcomes of simulations, it is fair to say that in most cases ABM is simply the only game in town to deal with such situations. Having said that, one must be careful, then, in how one uses ABM: for example, one must not make decisions on the basis of the quantitative outcome of a simulation that should be interpreted purely at the qualitative level. Because of the varying degree of accuracy and completeness in the input to the model (data, expertise, etc.), the nature of the output is similarly varied, ranging from purely qualitative insights all the way to quantitative results usable for decision-making and implementation.

The last major issue in ABM is a practical issue that must not be overlooked. By definition, ABM looks at a system not at the aggregate level but at the level of its constituent units. Although the aggregate level could perhaps be described with just a few equations of motion, the lower-level description involves describing the individual behavior of potentially many constituent units. Simulating the behavior of all of the units can be extremely computation intensive and therefore time consuming. Although computing power is still increasing at an impressive pace, the high computational requirements of ABM remain a problem when it comes to modeling large systems.

References

[1] CHAMPION, A. et al., 1999. Traffic generation with the SCANeR II simulator: towards a mulit-agent architecture. DSC ’99: Proceedings of the first Driving Simulation Conference, 1999, pp 311-324

[2] EROL, K. et al., 1998. Application of Agent Technology to Traffic Simulation. [online] Available from: http://www.tfhrc.gov/advanc/agent.htm [Accessed April 2006]

[3] CLARK, J. and DAIGLE, G., 1997. The importance of simulation techniques in ITS research and analysis, WSC '97: Proceedings of the 29th conference on Winter simulation, 1997, ACM Press pp1236-1243.

[4] EHLERT, P. and ROTHKRANTZ, L., 2001. A Reactive Driving Agent for Microscopic Traffic Simulation, ESM ‘01: Proceedings of the 15th European Simulation Multiconference, 2001, SCS Publishing house pp943-949

[5] Kutluhan Erol., Renato Levy. and James Wentworth. 1999. Application of Agent Technology to Traffic Simulation, United States Department of Transportation - Federal Highway Administration (www.tfhrc.gov/advanc/agent.htm)

[6] SCHULZE, T. and FLIESS, T., 1997. Urban traffic simulation with psycho-physical vehicle-following models, WSC '97: Proceedings of the 29th conference on Winter simulation, 1997, ACM Press pp1222-1229.

[7] ALGERS, S. et al., 1997. Review of Micro-Simulation Models. SMARTEST Deliverable D3, Institute for Transportation Studies, University of Leeds, Leeds, UK, Aug. 1997.

[8] BOXILL, S. A. and YU, L., 2000. An Evaluation of Traffic Simulation Models for Supporting ITS Development. Center for Transportation Training and Research, Texas Southern University, October 2000.

[9] OWEN, L.E. et al., 2000. Street and traffic simulation: traffic flow simulation using CORSIM, WSC '00: Proceedings of the 32nd conference on Winter simulation, 2000, Society for Computer Simulation International pp1143-1147.

[10] TANG, W. and WAN, T.R., 2005. Multi-agent Animation Techniques for Traffic Simulation in Urban Environment. WSCG (Short Papers), 2005, pp161-164.

[11] NAGEL, K., Draft as of 02 Feb 2004. Multi-agent Transportation Simulation. [online] Available from: http://www.vsp.tu-berlin.de/publications/matsim-book/ [Accessed December 2005]

[12] NAGEL, K., and SCHRECKENBERG, M., 1992. A Cellular Automaton Model for Freeway Traffic. Journal de Physique I, 2, pp 2221-2229.

[13] NAGEL, K., 2004. Multi-Agent Traffic Simulations. Presented at ETH Zurich: Institute for Computer Science.

[14] Kosuke Ono1, Takashi Hata1, Toyofumi Maetani1, Masateru Harao and Kouichi Hirata2 , T. Washio et al. "Development of a Multi-Agent Based Generic Traffic Simulator". (Eds.): JSAI 2005 Workshops, LNAI 4012, pp. 249–260, 2006. c_Springer-Verlag Berlin Heidelberg 2006.

[15] RIGOLLI, M. and BRADY, M., 2005. Towards a behavioural traffic monitoring system, AAMAS '05: Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems, 2005, ACM Press pp449-454.

[16] CHAMPION, A. et al., 1998. Behavioral Road Traffic Simulation with ARCHISIM. SCSC: Proceedings from the Summer Computer Simulation Conference, Society for Computer Simulation International, pp. 359-364.

[17] DONIKIAN, S. and PHANE, 2001. HPTS: A Behaviour Modelling Language For Autonomous Agents, AGENTS '01: Proceedings of the fifth international conference on Autonomous agents, 2001, ACM Press pp401-408.

[18] LINDSEY, R. and VERHOEF, E., 2002. Congestion Modelling. Handbook of Transport Modelling. 1st reprint 2002 edn. Pergamon, pp. 377-397.

[19] TOMAS, V.R. and GARCIA, L.A., 2005. A cooperative multiagent system for traffic management and control, AAMAS '05: Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems, 2005, ACM Press pp52-59.

[20] PREVEDOUROS, P.D. and WANG, Y., 1999. Simulation of a Large Freeway/Arterial Network with CORSIM, INTEGRATION and WATSim. Paper presented at the 78th Transportation Research Board Annual Meetings, Washington, DC. January 1999.