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A Study on Agent Based Modelling for Traffic Simulation

Priyadarsini Ghadai[1], L.Prachi Shree[2], Lelina Chhatria[3], RVVSV Prasad[4]

Department of Computer Science & Engineering, Gandhi Institute of Engineering & Technology Gunupur, Odisha (India)

Abstract— **Computer simulations allow one to understand interactions of physical particles and make sense of astronomical observations. Today, Offices, administrations, financial trading, economic exchange, the control of infrastructure networks, and a large share of our communication would not be conceivable without the use of computers anymore. With the statistical analysis of data and data-driven efforts to reveal the prototype of transport traffic model, we focused the prospects of computer simulation and the features of agent-based modelling and multi-agent simulation (MAS). Agent based modelling has been widely accepted as a promising tool for urban planning purposes thanks to its capability to provide sophisticated insights into the social behaviours and the interdependencies that characterize transport systems. Traffic simulation can be implemented using agent-based modelling (ABM), which enables dynamic objects such as vehicles to be modelled individually and have control over their behaviour. In doing so, we studied and presented various issues agent-based simulation, and provide a way to do them right from a scientific perspective. This paper focuses on the use of traffic simulation in helping traffic engineers to reduce congestion. It aims to help in developing a unique traffic simulation system that can be used to study traffic theory and access network infrastructure and control changes.**

***Keywords*— Agent, multi agent system, simulation, congestion, traffic.**

I. INTRODUCTION

This study focuses on the use of traffic simulation in helping traffic engineers reduce congestion, in particular by use of high occupancy vehicle (HOV) lanes. Traffic congestion is a major problem, and with the volume of traffic increasing at a steady rate, it is set to get worse. There are many schemes for reducing congestion; one is the use of HOV lanes, which are now being introduced on congested roads. Traffic simulation can help to determine the likely effects of introducing various schemes without costly infrastructure changes.

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. 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.

Traffic simulation can be implemented using agent-based modelling, which enables dynamic objects such as vehicles to be modelled individually and have control over their behaviour. An Agent is a class or an entity with its own behaviour that is with its own attributes and methods in a mathematical manner. To be more precise the agents as individual units communicate with each other to induce intelligence to the system. An agent behaves differently under different situations. One of the most promising features of Agents is that they have the ability to adapt that is making decision in a changing environment.

Traffic congestion is a major problem in highly populated urban areas particularly in morning and evening times. Over the years the traffic density of the roads will keep on increasing in spite of governments efforts towards the improvements in road infrastructure and promoting the public vehicle transport systems. This is because the number of vehicles on the road is increasing indefinitely and makes it a most challenging problem for future like congestion, where technology requires coming into existence. There are many schemes for reducing congestion; i.e. using High occupancy vehicles(HOV), lane changing, controlling speed of vehicles, controlling the traffic light phases in case of urban traffic intersection. However when it comes to implementation these schemes remains at the back door. For countries like South Korea with advanced road infrastructure and use of navigators in every vehicle have considerably reduced congestion. However it is unreliable for populated countries like India, China etc. This is because of the high latency, overload of satellites, and the cost that comes with the implementation may induce more harm than good.

Agent- Based modelling (ABM) is an approach to simulate the behaviour of the complex system in which the agents interact with each other and with their environment using simple local rules of interaction. The Successes of this approach in predicting traffic flow in metropolitan areas have generated further interest in this powerful technology. One of the practical issues, that 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 behaviour of potentially many constituent units. Simulating the behaviour of all of the units can be extremely computation intensive and therefore time consuming. The high computational requirements of ABM remain a problem when it comes to modelling large systems [1].

The objective of this paper is to show the traffic simulation is a worthy tool for traffic engineers for evaluating alternating schemes; and then to study the effects of changes introduced through graphs. It aims at unique traffic simulation systems that can be used to study traffic theory and asses network infrastructure and control changes. This constitutes simulating different types of road networks. The other objectives include gaining an understanding of traffic theory, learning the major features and issues of traffic simulation and evaluating agent-based modelling as a means of simulating traffic. This is to show that the traffic simulation tool is a worthy tool for traffic engineers to reduce congestion in urban networks and simulation with the different models in concern. The changes and the effects included in the traffic simulations of various road networks helps to save a lot of time and economy.

II. Literature Review of the problem

The economic impact of traffic management grows each day. 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, one 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.

A. Traffic Flow

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. [2] Infrastructure improvements are costly; hence any such project must be carefully evaluated for its impact on the traffic. The theory 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 [2]. 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 [2][3]. The results from these models and from traffic studies show that flow rate and traffic density are linked in an interesting way.

B. Traffic 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. The main features of a microscopic motorway simulator are car-following and lane-changing behaviours. Practical uses include studying the effect of motorway accidents, stop-start congestion, speed limits, ramp metering and lane closures on traffic flow [4][5]. 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 [6]. Urban traffic networks are usually very complex with many road sections and intersection points, often with conflicting traffic flows. They usually have to manage a large number of vehicles on small road sections, which can result in a large amount of congestion [7].

C. Classification of Simulators

Ferber [8] describes simulation as a very active branch of computer science, which consists of analysing the properties of theoretical models of the surrounding world. There are many types of computer simulation; the relevant classifications are summarized below:

(i) Stochastic simulations use random number generators to model chance and randomness. It is unlikely that two runs of a stochastic simulation would be the same, but most generators use seeds that can be set to produce the same set of numbers each time, making reproducible results possible. Deterministic simulations are those that are inherently predictable, always producing the same output for a given input.

(ii) Deterministic models are useful for experiments where the results need to be reproducible, however most real-world phenomena such as traffic have some degree of chance and therefore require stochastic simulation[9][10].

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.

D. 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 [11][12][8]. 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 .However, it is fast and can be useful and accurate, but is not suited to urban models [11].

Microscopic simulators model individual entities separately at a high level of detail, and are classed as discrete simulations. 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[13][9]. Microscopic simulators can model traffic flow more realistically than macroscopic simulators, due to the extra detail added in modelling vehicles individually [11]. Microscopic simulators are widely used to evaluate new traffic control and management technologies as well as performing analysis of existing traffic operations [8][14].

III. 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.

A. Modelling Vehicles

In a simulation, vehicles and drivers would most likely be modelled 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 discharging.

B. Modelling Drivers

Paruchuri et al. [15] 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 ABM for traffic simulation 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.

C. Modelling 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.

D. 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 [12].

IV. MODELLING

An agent-based model (ABM) is one of a class of computational models for simulating the actions and interactions of autonomous agents (both individual and collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole.

A. Traffic Simulation Models

Traffic can be viewed as a complex system. Developing macro models is one of the primary approaches to modelling complex systems. Macro models follow a top-down approach, which simulation has the advantage that run-time can be fairly short and are helpful when only a coarse prediction of conditions is sufficient. Micro modelling 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. 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 [16][17][18][19], but do not incorporate realistic driver and vehicular behaviour. Vehicles are modelled 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 [20]. 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 behaviour on a cognitive level [21]. 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.

B. Agent-Based Modelling and Traffic Simulator

The 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 [14]. In many cases, ABM is the most natural for describing and simulating a system composed of behavioural entities. A number of urban traffic simulations have been developed using agent-based modelling, most utilizing toolkits/libraries. The Recent agent-based simulators are: SCANeR II by Champion et al. [5], Tang and Wan [22], Rigolli and Brady [4]. Burmeister presented an overview of the potential and the existing application of agent oriented techniques in traffic and transportation [14]. Rossetti assessed drivers' decision making with an agent-based framework [23]. Dia modelled driver route choice behaviour with an agent-based approach [24]. 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 [25]. Mandiau et al. presented a multi-agent coordination mechanism applied to intersection simulation situations [26].

C. Simulators and Tools

The applications of traffic simulation programs can be classified in several ways. Some basic classifications are the division between microscopic, mesoscopic and macroscopic, and between continuous and discrete time approach. Special areas are traffic safety and the effects of advanced traffic information and control systems.

Simulation software is getting better in a variety of different ways. With new advancements in mathematics, engineering and computing, simulation software programs are increasingly becoming faster, more powerful, more detail oriented and more realistic. The following are some of the simulator software tools available like NetLogo and Visual Simulator etc. The examples of these software tools [27] include NetLogo, Visual Simulator, AgentBase, Agent Modeling Platform (AMP), AgentScript, AnyLogic, JAS-MINE, JASON etc.

V. CONCLUSIONS

The objective of this work is to produce a realistic traffic situation by reproducing the behavior of drivers. These drivers interact among themselves and the produced traffic is an emergent behavior of such interactions. However the traffic is simulated with single lane for each direction and also without traffic lights at junction. This brings out an unorganized traffic with the traffic patterns dictated as the collective behavior of various agents rather than by some traffic rules. The simulation also allows the user to specify his own psychology and view him as a part of the whole simulation.

To ensure fast reaction times, the agent's driving task is divided in several competing and reactive behavior rules. The simulator can addressees an urban environment, multi lane roads, intersections, traffic lights, and vehicles. Every vehicle is controlled by a separate driving agent and all agents have individual behavior 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.

Further, 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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