Towards Building an Intelligent Traffic Simulation Platform

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Abstract

Traffic congestion has become a major concern for many cities throughout the world. Simulations provide useful tools for engineer to plan traffic systems and government to make decisions. The microscopic traffic simulation approach defines the behavior of each interactive object in the traffic network, such as a vehicle and a traffic light through an individual model so that we can observe the detail traffic information of a scenario. Since microscopic model requires large computational power and data storage power, new simulation system architecture is needed. In the paper, the background of this research work is introduced. The simulation platform which combines grid, agent and HLA is given. Some considerations about microscopic traffic simulation models and technical issues of this platform are also discussed.

1. Introduction

Traffic is a major concern in modern cities throughout the world, especially in large city like Shanghai. Although Shanghai government invests heavily into building roads, improving their traffic control systems in recent years, the challenge still becomes larger with more and more people buy their private cars.

From year 2004, under the support of a long-term project, Shanghai Grid, which is sponsored by the Science and Technology Commission of Shanghai Municipality, a intelligent traffic information service grid are developed to integrate traffic information, share traffic data and traffic resources so that to provide better traffic services to traffic participators, help remove traffic bottlenecks and resolve traffic problems. The first stage of this intelligent traffic information service grid project was finished in 2005 and the second stage began from 2006. With the aims of developing more useful traffic services and improving the usability and reliability of this grid, providing decision support by applying traffic simulation is also listed as one of the research topics.

Traffic simulation has already gained much attention since it can help government optimize their infrastructure investments and traffic management policies in a cost-effective manner. Therefore, in the last a few years, and several packages such as CORSIM, CONTRAM, CORFLO, PARAMICS, have been implemented [1].

There are two different approaches used to simulate the traffic in a network. The first one, the macroscopic approach is based on an analogy between traffic flow and a real fluid flow. The second one, the microscopic approach simulation deals with the individual behaviors of each vehicle [2]. The macroscopic approach presents a higher level of abstraction than the microscopic one so that it can model large scale traffic network and needs less data and computational power. However, macroscopic simulator simplifies the model too much and many complex factors and details can not be modeled and analyzed. On the other hand, the microscopic approach defines the behavior of each interactive object in the traffic network, such as a vehicle and a traffic light through an individual model so that we can observe the detail traffic information of a scenario. Although the microscopic approach can provide more information, it needs large data and more computational power and to simulate a relative large area the computational time can become prohibitive.

Since the processing capability of computer increases rapidly, the use of traffic micro-simulation models in traffic operations, transportation design, and transportation planning has become widespread. But to develop a more useful traffic micro-simulation platform is always a challenge since we can add more details into the model if we have stronger computing power. Some new technology such as grid offers great opportunities to explore more complex models in traffic simulation.

This paper introduces an ongoing research, which combines grid, agent and HLA to support microscopic traffic simulation.

The paper is organized as follows. Section 2 gives a belief introduction to the background of this research work. Section 3 discusses related supporting technologies. In Section 4, a simulation platform is introduced. Section 5 presents some considerations about microscopic traffic simulation models and technical issues. Section 6 discusses related works and finally Section 7 concludes the research and points out some future works.

2. Research Background

2.1 Shanghai Grid

In 2003, under the support of Science and Technology Commission of Shanghai Municipality, a long-term project called Shanghai Grid was started. Shanghai Grid aims to construct a metropolitan-area Information Service Grid (ISG) and establish an open standard for widespread upper-layer applications from both communities and the government. It is one of five top grand Grid projects in China. The first test bed is based on the current four major computational aggregates and networks in Shanghai, including Shanghai Supercomputing Center (SSC), and various campus supercomputer centers in Shanghai Jiao Tong University (SJTU), Tongji University (TJU) and Shanghai University (SHU). It is planned to enable the integration of heterogeneous and distributed resources seamlessly and transparently. Shanghai Grid has connected several major grid nodes to form a 0.6 Tflops aggregate computing power, a 4 TB aggregate storage power and a sophisticated information service environment [3].

The aim of shanghai government is to use the grid technology to construct a basic infrastructure for e-science, e-business, e-education, e-government and e-life, as the basic facilities of the city, similar to transportation and communication systems, water and power lines. Therefore Shanghai Grid as an infrastructure will fully use the existing techniques and resources to provide rich functionality of information services. Currently, several applications have been developed and put into use in the Shanghai Grid, such as computational fluid dynamics, medicine image processing, drug discovery Grid, et al. The core of Shanghai Grid is the SHGOS, which is a middleware providing services and tools to satisfy the needs of building the ISG. Moreover, the SHGOS hides the complexity of the Grid techniques for developers building grid applications.

2.2 Intelligent Traffic Information Service Grid

Shanghai has become the largest economic center and an important port city in China, with a land area covering 6340 km^2 and a population of 16 million people. With the rapid development of economic and the increasing number of automobiles, the problem of urban traffic congestion has become more and more serious. To solve such problems, Shanghai government puts its focus not only on road infrastructure construction, but also on transportation control systems. These systems play important roles in solving the traffic problems in Shanghai, acting as subsystems of ITS.

In using these systems, one problem has emerged gradually. The design of these systems does not consider the interoperation among each other. These systems belong to different government agencies, use different technologies and the traffic data cannot be shared among them. Another problem is how to store, fuse, and utilize the transportation information data (TID) in these systems. TID is fundamental to ITS, as a big city, the amount of TID of Shanghai in each system are huge. Even more, different systems use different ways to store their data. It is difficult to provide a good way to interoperate among these systems.

Shanghai government has already noticed the weakness of the non-interoperation of these systems. In order to provide better services to citizen, further reduce the traffic congestion, provide real-time traffic information to decision makers, it launches the ITIS project, which aims to build a platform to integrate various transportation systems as a whole. ITIS will be based on Shanghai Grid.

ITIS comprises five sub-projects, including 1)Development of open protocols and standards for transportation information service applications; 2)Research on Grid supporting platform; 3)Transportation resources integration; 4)Dynamic parallel traffic simulation; 5)implementation of intelligent traffic information services.

As one sub-project of ITIS, the aim of traffic simulation is to construct a platform to support research on microscopic traffic phenomenon and explore how to define appropriate traffic control rules under different situations, especially under the emergent situations in a dedicated area. This kind of simulation needs large amount of computational power and also the storage power, which can not be satisfied be a single computer. Therefore, we will base this research on the technologies such as grid, HLA and distributed agent systems which can be used to construct a scalable system.

3. Related Technologies for Traffic Simulation

3.1 Agent and Traffic Simulation

The concept of agent is now broadly used not only as a model for computer programming units displaying certain kinds of characteristics but also in a more abstract and general way, as a new metaphor for the analysis, specification, and implementation of complex software system [4]. In order to support development of agent based systems, in recent years, a number of agent infrastructures have been developed to facilitate the implementation of multi-agent systems. Some systems such as JADE [5] provide the bare bones of distributed communication.

There is by now some agreement that multi-agent simulation may be a viable technology for microscopic traffic simulation. In a multi-agent based traffic simulation system, each traveler, and potentially each entity of the simulation, such as traffic lights or variable message signs, is represented as individual objects or "agents," which make independent decisions about their actions.

Although the concept of applying agent into traffic simulation is quite straightforward, there are some difficulty implementation issues. The first issue is how to maintain the causality, which is the basic feature of parallel simulation. The second one is the computational power requirements are very large and the third one is the communication overheads may be too heavy if each agent should exchange information with each other.

3.2 Grid and Traffic Simulation

In order to solve complex scientific problems, geographically distributed and heterogeneous resources should be connected together through the high-speed network. Grid, which provides virtual organization with capabilities to solve the problems cooperatively, is put forward to meets these more and more critical requirements [6]. As a new infrastructure, grid is extending its role as a high performance computing environment and bringing deep impacts on the human life and the society [7].

Grid technologies also provide exciting new opportunities for large scale distributed simulation, enabling collaboration and the use of distributed computing resources, while also facilitating access to geographically distributed data sets. Since traffic simulation needs resources, grid can be applied to this application.

Since grid is a platform for resource sharing among dynamic virtual organization, some necessary simulation facilities are not provided in grid and should be realized on the top of grid services. Comparing with agent technology, the grid services are passive, it can not reflect complex behaviors of entities and there are no direct interactions among grid services. From the viewpoint of simulation, the traffic model can not map to the grid directly.

3.3 HLA and Traffic Simulation

The HLA (High Level Architecture) [8] is an industry (IEEE-1516) standard for modeling and simulation. It is increasingly being used in various simulation areas, including education, training, analysis, engineering, entertainment and games. In the HLA, a distributed simulation is called a federation, and each individual simulator is referred as a federate, one point of attachment to the Runtime Infrastructure (RTI). A federate can be a computer simulation; it can also be a physical device, a passive data viewer or an interface to a human participant.

While the High Level Architecture (HLA) enables interoperability and the construction of large-scale distributed simulations using existing and possibly distributed simulation components, it does not provide support for simulation application development, nor does it provide any mechanism for managing the resources where the simulation is being executed.

Obviously, agent, grid and HLA can compensate each other in some degree when they are applied to microscopic traffic simulation. This project will explore how to combine these technologies into a unified framework.

4. The Traffic Simulation Platform Architecture

Fig.1 shows an intelligent simulation platform which based on agent, RTI and grid. The user can design the simulation model through the tool of modeler. The generator will produce and remove agents by using some services provided by the agent platform according to the simulation model dynamically when simulation begins. These agents represent the entities of the traffic, such as passenger, vehicle, police or road. When an entity agent is created, it will be given the behavior model according to the simulation model but with different characters which reflects the individual differences. All agents are deployed into distributed computers which are connected through an agent platform. There are a set of special agents called coordination agents, which play the role of federates connecting to the RTI. Each entity agent should belong to a coordination agent and it only communications with the corresponding coordination agent. The entity agent reports its current status to the corresponding coordination agent and it also obtains the environment information from the coordination agent. Coordination agents exchange information through the RTI and the simulation times of coordination agents are advanced through time management service of RTI.

The computational tasks of entity agent can be allocated to grid services and the grid service can also collect real data from the real traffic system to store into the model base.

A "perception-interpretation-action" model is adopted in that an agent continuously assesses or "senses" the surrounding environment from the coordination agent and makes decisions based on its decision model in a proactive fashion. Each agent includes a sensor so that an agent can analyze the environment. Agent's actions are represented in terms of decision rules. When a situation is perceived, an agent activates a decision rule to produce an action. The choice of a decision rule is determined by the situational cues and the agent's status (i.e., perceived importance, uncertainty and urgency) at that moment. For a mobile entity, such as passenger, bike or vehicle, its corresponding agent's behaviors can be categorized into several hierarchical layers (from simple to complex), for example, the locomotion, steering, social and objective layers. The behaviors on a higher layer are constructed using the behaviors from a lower layer. The locomotion layer defines the basic actions the agent can take. The steering layer defines a group of actions or a sequence of actions that the agent can take. The social layer defines the group behavior this agent follows. For example, the passenger or the vehicle follows other passengers or vehicles when they meet the emergency. The objective layer defines what kind of aim this agent has when it enters into this area. For example, walking from the current location to the destination can be defined as the objective of a passenger agent.

5. Simulation Model and Simulation Mechanism

5.1 Entity Agent Model

Within the traffic environment, the entity which has different behaviors under different situations can be modeled as a separate agent. These agents include passenger agent, bicycle agent, vehicle agent, road agent, traffic light agent, police agent and control center agent.

1) Passenger Agent: the behaviors of passengers have a great impact on the traffic flow especially when some passengers do not obey the traffic rules and this is often the case in China. Human individuals are different from each other by age, body dimension, motility, and personality. Therefore the generator will create the individual passenger randomly according to the models defined. The sensor of passenger agent can obtain the geometrical distance from the intersecting object, and also determine the type of object. The actions of passenger agent includes walking forward, running forward, stopping, side-shifting, turning, and moving backward. The steering behaviors include random walk, collision avoidance, seek, negotiation, target following, Social behavior includes competitive, queuing, herding [9]. The objective behavior includes passing this area, going to some places in this area. The decision rules include avoiding collision, walking faster as possible, following traffic light, et. al..

2) Bicycle Agent: Since a large part of people use bike as their transportation tool in China, we should

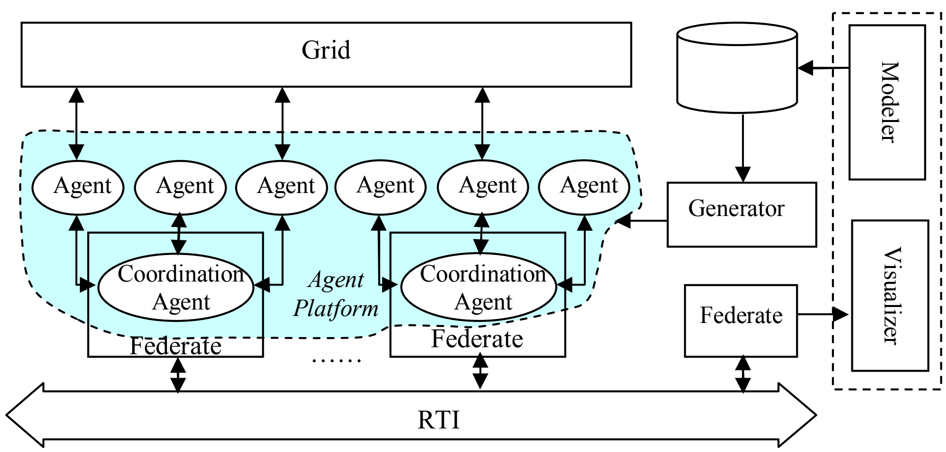

Fig.1 An Intelligent Simulation Platform

consider the affections of bikes. The model of bike is some kind of mixture of passenger and vehicle agent models. Some road has a special lane for bike while some road has no this lane. The locomotion actions of bicycle agent include driving forward, speeding, slowing down, stopping, side-shifting, turning. The steering behaviors include random walk, collision avoidance, seek, negotiation, target following, Social behavior includes competitive, queuing. The decision rules include voiding collision, walking faster as possible, following traffic light, et. al.

2) Vehicle Agent: The vehicle model is researched extensively and there are already quite a few mathematic models to describe the behaviors of a vehicle. What we have to do is to map these models to the structure of agent. The sensors of vehicle agent will obtain the speed of itself, the vehicles around itself and traffic signals. The locomotion actions include driving forward, speeding up, slowing down and stopping. The steering behaviors include collision avoidance, seek, negotiation, target following. The social behaviors includes competing, queuing. The decision rules include voiding collision, walking faster as possible, following traffic light, et. al.

3) Road Agent: this agent is relatively simple because it has less intelligence and only act as an information broadcasting place. The road agent may provide some guide information to the vehicles and it also calculates the status and reports it to the control center.

4) Traffic Light Agent: traffic light agent can be simple or complex. For a passive traffic light, it only changes the light color according to the predefined rules. But the traffic light can be complex one, and it can change the rule according to the commands coming from the control center.

5) Police Agent: Police agent can change the road rules according to the commands from the control center. It affects the behaviors of passengers, bikes and vehicles.

6) Control Center Agent: The control center will monitor the situation and send the commands to the police, traffic light and the road agents. The sensor of this agent should collect all the data from the road agents. Some complex decision making models can be defined in this agent and the user can also change the decisions of this agent interactively.

5.2 Simulation Mechanism

For a complex multi-agent based distributed and parallel simulation system, three major concerns have been pointed out in Section 3.1. Our solution is based on coordination agent, which connects all related entity agents together and also maintains the corrections of time sequences. Each entity agent obtains the data from the coordination agent, and then triggers the actions based on decision rules and reports the renewed status to the coordination agent. When received the responds from all entity agents, it notifies entity agents it managed to obtain the information again.

How to design coordination agent and allocate entity agents to the coordination agent is a very important research topics. We can divide a road into several pieces and each piece is allocated to a coordination agent, other agents which locate in this piece of road will connect to the corresponding agent. Then an important concern is some agents, such as passengers, bikes, vehicles, moves from one place to another. Their move is controlled by themselves. Therefore, each coordination agent should have a global map and it knows which coordination agent is responsible for which pieces of road so that it can transfer a mobile agent to another one. Another issue is the agents in the border of road pieces affect each other. Since agents staying in different road pieces can not exchange information directly, we should define a mechanism to allow them exchange information through their corresponding coordination agents.

6. Relate works

Simulation based on multi-agent systems has gaining more and more attentions in recent years. Despite of many applications, some researches are focusing on how to develop such a system. For example, the synchronization of the participating agents with respect to the global simulation time is a necessary requirement of testing and simulation of process flows within multi-agent systems. A design proposal and a service implementation for testing and simulation is presented, which takes care of the special requirements imposed by multi-agent settings [10]. Time service is implemented as a FIPA-compliant agent, and can be used to couple heterogeneous subsystems implemented on different agent platforms. Another approach to support agent based simulation is to integrate agent platform and HLA RTI together [11]. Although HLA provides some services that distributed and parallel simulations needs, there are still some important issues should be addressed, especially for large scale simulation system. For example, the communication problem is discussed in [12]. In our proposed structure, agent platform and HLA RTI are also combined together, those problems, such as communication still remains. A more challenge problem is the connecting relationships among agents are changing in simulation process and we are also carrying out research on the mechanism.

Traffic simulation based on agent has been researched extensively. For example, there is an ongoing research to implement a multi-agent simulation for all of Switzerland, which, with about 7 million inhabitants, also serves as a proxy for a large metropolitan area. In this system, each traveler is modeled as an agent, which makes independent decisions about their actions. In [13], a research which is based on swarm intelligence to observe emergent behavior patterns in traffic is introduced. Comparing with these works, our system will use a layered behavior model so that we wish we can find more interesting results when we define more complex models.

7. Conclusions and future work

Traffic control in a city like Shanghai is a major concern of government. The information technology is widely applied in transportation systems. The emergent new technologies provide new possibilities to explore innovative applications for traffic control. The agent, grid and HLA technologies can be applied together to construct a new generation of traffic simulation system. The agent model provides new ways to allow considering different complex behavior patterns.

We have defined the architecture of simulation system, the next step is to develop such system and we wish until the end of year 2006 we could have one prototype system.

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