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Simulation System for Optimizing Urban Traffic Network Based on Multi-scale Fusion

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Abstract

The research on Urban traffic simulation is more widely, But there are some problems, For example, the traffic system in the spatial scale is from microscopic to macroscopic highly integrated. In the time scale is from the second grade to the height of continuous integration. Simulation and objective traffic system complexity determines that any single scale are difficult to be better traffic phenomena. On this basis, the simulation system was proposed based on multi-scale fusion, from the macro, meso, micro in three dimensions using the corresponding algorithm, and carries on the design to the system. Finally, Based on multi-scale fusion of urban traffic network optimization simulation system has carried on the experiment. Through the example of Nanjing Fujian road and Traffic Signal Priority of the three arches to analyze network simulation experiment. The experiment proves that the system is practical and reliable.

Keywords: *Multi-scale, Macro, Outlook, Microscopic, Traffic network optimization, Simulation system*

1. Introduction

With the increasing advancement of social economy and improvement of living standard, people's demands for transportation have been growing and thus problems relating to the Urban traffic have been attracting more and more concerns. Among them, the critical one refers to the study on Urban traffic network [1-2]. Urban traffic network state analysis method for Urban traffic network is an important theoretical issue in the intelligent transportation system (ITS) and the foundation for evaluating and solving traffic congestion in the practical traffic management. Currently, researchers draw a conclusion on the study of Urban traffic network state from measured data. Take for instance, in the paper [3-4], by applying the theory and method of pattern recognition to probe into the mode in Urban traffic network, it reached the conclusion that the traffic state could be converted into recurrent modes in limited quantity and different types. The work [5] extracted feature vectors of crossroad traffic flow state with the use of pattern recognition method and then established the assessment model of traffic state according to similarities of intersection parameters. In [6-7], global data management strategy was adopted to analyze temporal and spatial traffic data, obtaining the representation method for the traffic condition. After literature survey made in the field of intelligent traffic network simulation, it reveals that a large number of scholars concentrate on studies on traffic micro-simulation technology based on multi-agents, traffic flux loading of medium-micro integration, traffic signal control technology based on parallel simulation technique, Urban micro simulation technology based on cellular automaton [8-9], complex network analysis method [10-11], as well as pedestrian micro-simulation technology [12-13].

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Those technologies have so far been the state-of-the-art in the field of Urban traffic simulation. However, Urban traffic system integrates highly from the micro level to the macro in the spatial scale and a continual system from second level to annual level in the temporal scale, which determines it quite difficult to simulate the transportation in a better and objective way. Problems are seen in the macro-simulation analysis in the complex Urban traffic system network [14-15]. The flow loading model uses a statistical technique for the generation, attraction and iterative and equalized distribution of loading according to the historical Origin-Destination (OD) demands [16-17].

2. The Basic Concept

2.1. Simulation Technology

The simulation technique is based on the computer and special equipment for tools, it is integrated technology of dynamic test system by using the system model of the actual or assumed, control theory, system theory, similarity theory and information technology is the foundation. There are currently 2 simulation methods in common, simulation model and simulation experiment, it can be divided into two categories: simulation method of continuous system and discrete event systems [18]. The way people sometimes will establish a mathematical model are also included in the simulation method, this is because the continuous system has a set of theoretical modeling and experimental modeling method, but in the simulation system is often the first through the approximate model hypothesis obtained to verify the correctness of the assumption, if necessary, to modify the model, making it more close to the real system [19].

The most common is the microscopic traffic simulation model of car following model, moving track each vehicle. In the microscopic model, the movement of the vehicle is determined by the driver characteristics, vehicle performance, vehicle surrounding environment and road geometry. Through the investigation of macroscopic traffic simulation traffic flow characteristics, namely the team "average" behavior to describe the system state. To study the system characteristics from an overall point of view, the elements and the behaviors of the traffic system is in the lowest level of detail. In Macroscopic traffic simulation model, the movement of traffic in accordance with the mechanism to deal with fluid. Meso-scopic traffic simulation model can describe the macroscopic traffic flow model with time and space dimension state properties (such as density, flow and speed), and can preserve the core data- in microcosmic model, such as the operation results of single vehicle characteristics of different, such as the actual speed, travel time and travel distance. The simulation method which is used in this paper.

2.2. Multi-scale Fusion

Simulation technology is a comprehensive technology which conducts dynamic test on physical or assumed system with computer and special-purpose devices as tool and the use of system model. Control theory, systematic theory, similarity principle and information technology are its foundations. Frequently used simulation methods include those with regards to setting up simulation model and making simulation experiment, which are classified into two broad categories: simulation method for continuous system and the one for discrete event system. In some cases, the method for creating mathematical model is included, for the reason that as to a continuous system, despite there is a complete set of theoretical modeling and experimental modeling methods, when system simulation is performed, the approximate model which is obtained through hypotheses is usually applied to validate whether those assumptions are right or not. If necessary, such model should be modified as to make it closer to a real system.

For traffic micro-simulation model, the commonest one is car-following model, tracking the movement of every single vehicle [20]. In such microscopic model, car's movement is dependent on driver's features, vehicle performance, surroundings and geometric conditions of roads as well. Traffic macro-simulation model depicts the system status through examining characteristics of traffic flow, *i.e.*, the "average" behaviors of fleet, investigating system performance mainly from a global perspective and describing elements of transportation system and detailed behaviors to the minimum degree. In the traffic macro-simulation model, movement of traffic stream is traced by fluid mechanism [21-22]. Traffic medium-micro simulation model can not only portray state features (*e.g.*, density, traffic volume and veloUrban) of both temporal and spatial dimensions in micro traffic flow model, but also retain core data in the microscopic model, such as running results of every single vehicle with different features, like actual speed, travel time and distance and etc. That is also the proposed method here.

Multi-scale fusion makes analyses from multiple angles in the process of fusion work. In many circumstances in the actual road network, network traffic is out of balance. Even if it will change, there shall be transition, which has association with people's driving habits. Such a microscopic scale can't be taken into account when network simulation analysis is macroscopically made. Besides, it is unlikely to provide signal timing with fine simulation support through medium micro- and macro-simulation. Yet, in the micro-simulation system, individual behaviors vary with its surroundings. Since the scale is too small, any tiny change in the real traffic system would affect outcomes, for instance, a pedestrian jumps the red light and a bus stops on the wayside. Such microscopic factors would randomly occur in a real context at any time, making it is difficult for micro-simulation to bring about simulation effects matched with the true situation. In the paper, we take multi-scale fusion scheme to discuss from microscopic medium-view and macroscopic viewpoint.

3. Design of Simulation System for Urban Traffic Network Based on Multi-scale Fusion

3.1. Design of System Modules

The proposed system takes advantage of multi-agents to integrate simulation models in different scales. Such system has generally five modules as indicated in Figure1.

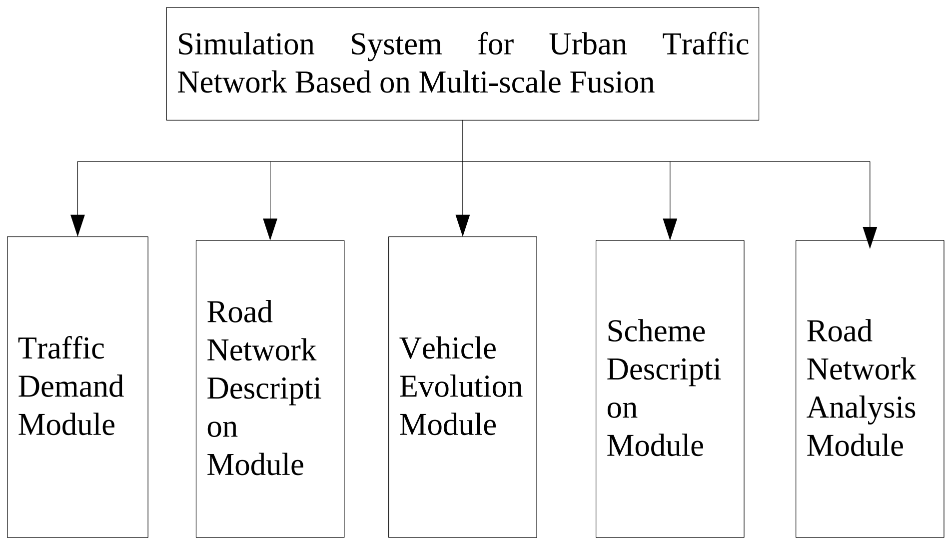

Figure 1. Schematic Diagram of the System's Modules

We'll introduce them separately in the following paragraphs:

Traffic demand module: for real-time collection of data on the road net nodes, fusion of historical macro OD data, collection of medium-micro statistics about road segments and crossroads through analysis and the real-time micro traffic flow data output by vehicle detector, to finally generate microscopic vehicle agents;

Road network description module: build geographically descriptive data on topology and real structure of road net, road segment, road junction, driveway, parking lot, bus station and the like; apply complex networking techniques to provide macroscopically empirical statistical data such as degree distribution, node cluster and paths in graph of the road network.

Vehicle evolution module: vehicle agents recognize and react to micro-scale environment like cars forward and backward, carriage way, crossing, traffic lights; moreover, main drivers of such agents simulate the congestion status of road network from a macro-scale point and analyze medium-view parameters like road impedance and flow fluctuation as to make proper decisions, e.g. to change paths, driving speed and so on, nesting the results emulated microcosmically by agents in the evolutional process of path flow in the macroscopically complicated network.

Scheme description module: update online signal lights of every controlling road junction or data on traffic inducing solution in the simulation system to support signal control system with parallel online iteration operation.

Road net analysis module: employ complicated network analysis strategies along with agents to simulate microcosmically volume loading, time-domain clustering analysis through vehicle detector in the intersections to find out weak points, route resistance and congestion coefficients in crossings, which are relating to the gradual cascade of road network on consecutive scale in the current moment and any time in the future, to ultimately complete the time sequence analysis of various traffic parameters and medium-view statistics of traffic stream and pedestrians on the macroscopic scale. It's additional to perform multi-scale online simulation of different transportation elements in the road net like networking, road section, signal light, throughput, vehicle in accordance to the updated modes.

3.2. Design of Sampling Algorithm in the Simulation System of Urban Traffic Network Based on Multi-Scale Fusion

In order to enable better macroscopic and medium-view emulation with evolutionary features and solve the problem that it's difficult to perform lengthy and big-domain simulation.

The proposed algorithm is designed following these steps:

Step one: when detection starts, controlling unit returns vehicle flow rate N to zero, and meanwhile check the electrical level of current scanning moment. When the status is 0, follow (i) to calculate the passing time Δt by the current vehicle; base on (ii) to compute the passing time Δt by the current vehicle when the state is 1.

(i) The control unit checks in sequence the status of electrical level of every scanning moment subsequently. When the status reads 1, the corresponding scanning moment is ta; then, the unit continues checking in proper order the level of every scanning moment afterwards. When it is again 0, the moment is tb; the controlling unit estimates vehicle passing time as Δt=tb-ta;

(ii) The controlling unit checks the electrical level of every moment prior to the current point in reverse order through the storage device. When the level is 0, the moment is ta; next, the unit examines that of every moment after the current point in positive sequence. When it is 0, the right moment is accordingly tb; at the same time, the unit calculates vehicle passing time like Δt=tb-ta-0.25;

Step two: convert vehicle passing time Δt into traffic flow incremental ΔN as per lane type and being-on traffic lights of the lane. When it is left-turn lane convert based on (iii), or (iv) and (v) when it's right-turn lane and straight-through lane respectively.

(iii) When signal light of the lane is green, $0.25s \le \Delta t \le 3.75s$, then $\Delta N=1$; $4s \le \Delta t \le 7.5s$, then $\Delta N=2$; $7.75s \le \Delta t$, then N=3; if the light is red or yellow, then $\Delta N=0$;

(iv) When signal light of the lane is green for being no more than 10s, and $0.25s \le \Delta t \le 4s$, then $\Delta N=1$; if the green light on lasts for more than 10s, and $0.25s \le \Delta t \le 3.5s$, then $\Delta N=1$; and $3.75s \le \Delta t \le 6.25s$, then $\Delta N=2$; and $6.5s \le \Delta t \le 10s$, then $\Delta N=0$; if the light is red or yellow, $\Delta N=0$;

(v) When the light is green for being no more than 5s, and $0.25s \le \Delta t \le 2.5s$, then $\Delta N=1$; $2.75s \le \Delta t \le 5s$, then $\Delta N=2$; if the green light on lasts for more than 5s, and $0.25s \le \Delta t \le 2s$, then $\Delta N=1$; $2.25s \le \Delta t \le 2.5s$, then $\Delta N=2$; $2.75s \le \Delta t \le 3.75s$, then $\Delta N=3$; $4s \le \Delta t \le 5s$, then $\Delta N=4$; $5.25s \le \Delta t$; then $\Delta N=5$; if the light turns red or yellow, $\Delta N=0$;

Step three: the control unit adds the present value of traffic flow N and the incremental ΔN obtained in step two to produce a result, which is then given to traffic volume N.

Step four: estimate the passing time of follow-up vehicle based on (i) in step one, which is then scaled to get traffic flow rates incremental ΔN according to step two; at last, repeat step three to update vehicle volume N; re-do the work till the detection is over. When it ends, the value of car volume N is exactly the one in the traffic crossing road for the detection time.

4. Simulation Experiment of the Proposed System

The simulation experiment based on multiple scales was validated preferentially on signal schemes of Fujian road and Sanpailou in Nanjing Urban.

4.1. Experiment Preparations

Step one: build simulation environment, elaborate the relationship of associated structures of road net, the formation of each road section and crossroad, as well as the channel planning type by means of parameter input. Use complicated network analysis technique to explain empirical statistical data of the current road network, such as the shortest path and the second-shortest between different OD nodes. In Figure 2.

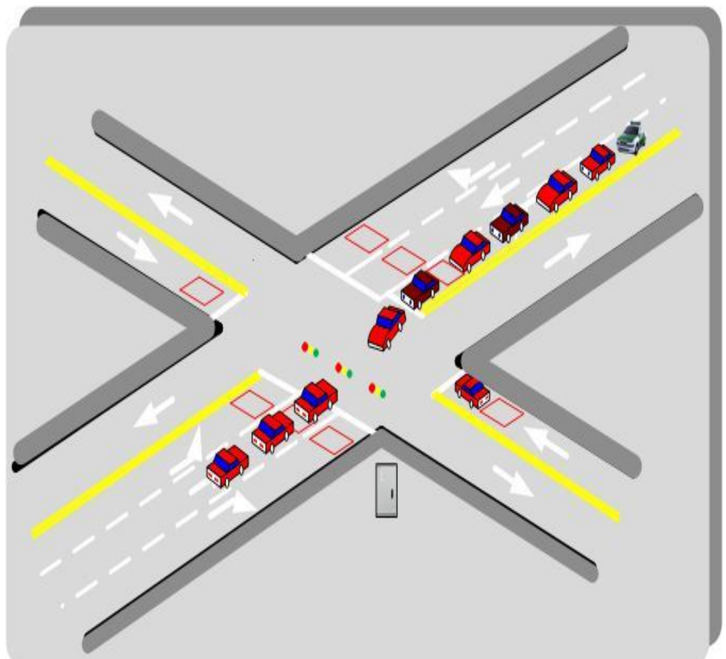

Figure 2. Experimental Diagraph of the Proposed System

Step two: Through simulation analysis of macro and medium-view and three arches Nanjing Fujian Road near the intersection of sections of the current road impedance, rate of arrival rate road sections on Fujian road intersection in Nanjing Urban, then, utilize vehicle input data at the upstream crossroads of those segments, which are acquired in real-time, to generate vehicle agents.

Step three: vehicle agent cognize via macroscopic and medium-view emulation the transportation on the present road net, segment and road junctions and then make response, changing driving habit based on certain statistical probability and pre-set route and so on. Besides, in the microscopic simulation context, microcosmic evolutional simulation can be achieved between such agents, e.g. tail-driving, lane changing, overtaking and parking. Use microscopic simulation as vehicle loading model and upload to macroscopic and medium-view simulation in the form of vehicle flow statistics or vehicle. It puts medium-view simulation, simulation, virtual reality, macro scale and other scale into together by the microscopic simulation of vehicle agent.

Step four: synthesize time sequence of every historical traffic parameter and true value of the current parameter to enable multi-scale fusion so as to make fine microscopic simulation for the future traffic information. Alter timing plan by signal timing interface in real time or at regular time. Repeat iterative operations about the future traffic evolution in various signal timings with optimization algorithm.

Step five: by the multi-scale parallel simulation operation of complicated adaptive network acquire the number of times for delay at crossroads and parking places, and their comparison curves which are optimized by the future fuzzy control method, with regards to the current timing program, so as to provide online multi-scale fusion simulation for the prioritized choice of road net timing project.

4.2. Experimentation Process

Experimental process: it chooses scheduled time in sunny or foggy days or days after rain to carry out the following verification for many times. On one hand, detecting the condition of road net with the method in this embodiment to reckon numerical value of traffic flows every ten seconds; on the other hand, count manually the actual number of vehicle in every ten seconds with the help of surveillance cameras on roads. See results in Figure 3 and 4.

As indicated in both pictures, precision rate of car flow reached by the proposed method is at least 95%.

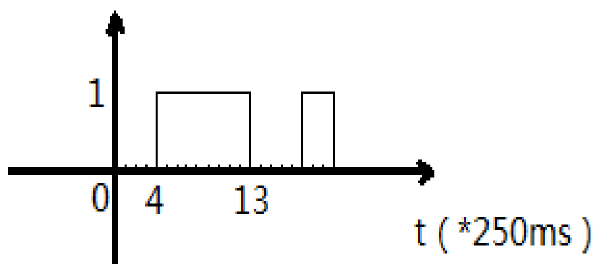

Figure 3. Schematic Diagram of Manual Statistics

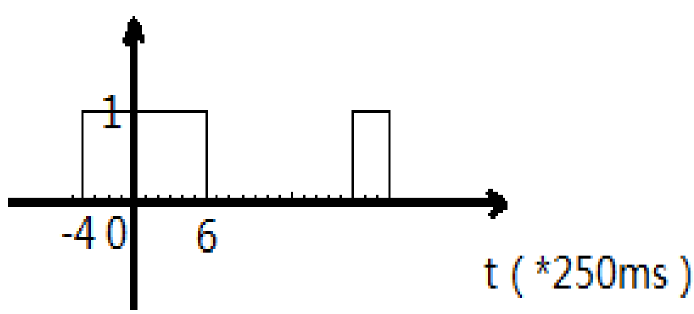

Figure 4. Schematic Diagram of Statistics by the Proposed System

Also within 1500 seconds in one peak hour, the proposed solution executed the process as before. The numeric value of vehicle throughput detected by the method is 141, while, manual count is 148, with precision rate 95.27%. Figure5 gives the screenshot of simulation results.

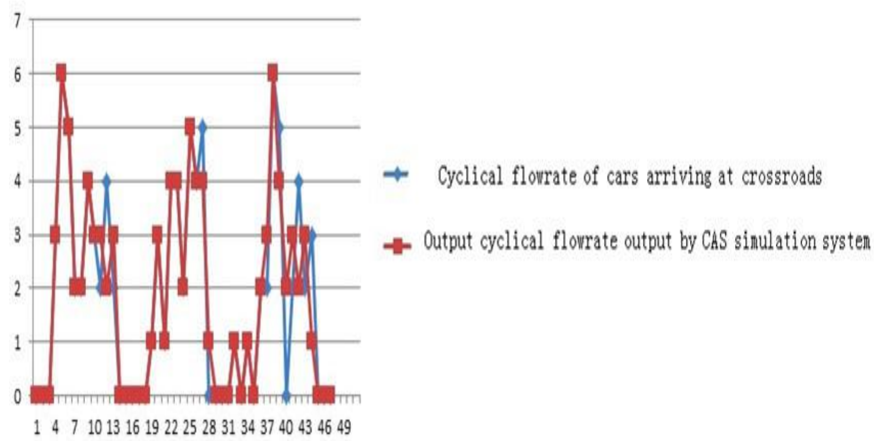

Figure 5. Comparison Curves about Cyclical Flowrate and Observed Output by the System

In the above picture, we can find curvilinear comparisons within eight minutes between simulation values and true values obtained by the vehicle detector at down-stream crossroads on Fujian road in Nanjing, which evolved from the microscopic simulation after multi-scale fusion. In the third signal period, simulation data fluctuated out of bus stop, which, however, was determined by medium-view simulation not to suffice to cause continuous effects. Therefore, such kind of undulation is recorded by vehicle agents and the number of vehicle on segments is modified. Yet, those agents do not change the driving behavior.

A general view of online preferential timing scheme for the urban traffic network simulation system based on multiple scales is present by system in the following graph (Figure 6).

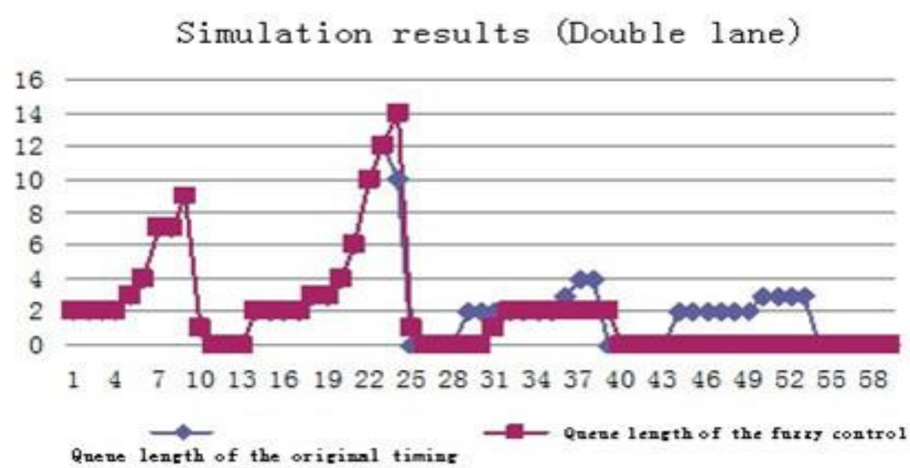

Figure 6. Simulation of Online Preferentially-selected Timing Scheme

5. Conclusion

This paper is based on the existing technologies for the urban transportation simulation, simulation system based on multi-scale fusion was proposed here through studies at the macroscopic, medium-view and microscopic scale, for the purpose of using the appropriate algorithm for integration. The system was designed to validate its performance on the optimized simulation system of ubran traffic road net. The innovative point to the paper rested with applying vehicle agents to merge systematically at the spatial scale the macroscopic, medium-view, microscopic, realistic and virtual emulation and temporally the past, present and future simulation. The proposed solution proved its ability to employ the multi-scale depiction method to carry out consecutive synthetic simulation, making the results more real and efficient. Such vehicle agents can be reliable inner core of traffic simulation for the intelligent control of urban transportation.

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