JOURNAL OF TRANSPORTATION
SYSTEMS ENGINEERING AND INFORMATION TECHNOLOGY
Volume 13, Issue 2, April 2013
Online English edition of the Chinese language journal

Cite this article as: J Transpn Sys Eng & IT, 2013, 13(2), 27−33.

RESEARCH PAPER

Path-Flow-Based Cross-Resolution Conversions for Simulation Model

DU Peng[1,*], TIAN Zongzhong[2], ZHOU Xuesong[3]

1 MOE Key Laboratory for Urban Transportation Complex Systems Theory & Technology, Beijing Jiaotong University, 100044 Beijing, China
2 University of Nevada, Reno, NV 89557, USA
3 University of Utah, Salt Lake City, UT 84112, USA

Abstract: Sub-area traffic analysis is one of critically needed capabilities in practical traffic engineering applications. This paper aims to develop a fully automated network conversion and calibration tool to assist engineers easily extract a portion of a macroscopic planning network to construct a consistent sub-area of interest, and then convert it into a detailed model suitable for microscopic simulation. A cross-resolution simulation (CRS) method is adopted in this paper, which allows a rapid extraction of selected sub-areas from a regional planning network with OD matrix, and a lane-based expansion of the network topology, a consistent regeneration of subarea path flow and link volume. This paper integrates the above-mentioned key modeling components into an open-source package and conducts a case study to demonstrate its effectiveness.

Key Words: traffic engineering; cross-resolution simulation tool; consistent conversion; sub-area analysis; lane-based expansion; connector conversion

1 Introduction

Sub-area analysis has become an important research method in traffic engineering field in recent years. This requires representation of traffic dynamics across different resolutions and a suitable tool is crucial. It is commonly held that simulation tools used in traffic engineering filed can be categorized into three different levels according to its simulation scale and model intensity: macro-level, meso-level and micro-level. Though many tools have been developed in this field, they are usually dedicated to one single type of resolution, namely, they have the inflexible precision of traffic network and traffic dynamics. Therefore, cross-resolution conversion has become a hot spot in sub-area traffic analysis.

Though each of the single resolution tools has its own advantages and applicable areas, it seems that none of them alone is capable of conducting sub-area studies. Therefore, it is of high importance to develop a multi-resolution simulation tool which can fulfill the need to conduct sub-area studies. However, it is reasonable to take advantage of those single resolution tools rather than building from scratch. In this paper, we provide path flow based cross-resolution simulation (CRS) method, which can benefit from both mature models and legacy data of the tools above-mentioned and provide more accurate results with less labor work.

Horowitz[1] developed a meso-microscale traffic simulator which allows a region of micro simulation to be defined within a larger, meso-scopic simulated AHS. A layered organization of data is adopted for cross-resolution representation, which has network layer, link layer, coordination layer, regulation layer and physical layer. The layered organization greatly increases computational efficiency when making analysis from vehicle level to traffic flow level. Burghout *et al*.[2,3] developed hybrid traffic simulation models integrating Mezzo, an event-based meso-scopic model, and two micro-simulation models, MITSIMLab and VISSIM respectively. In these hybrid simulation models, Mezzo is used to simulate regional network and the sub-area of specific interests is studied by micro-simulators. Consistency is given high priority in the integration in route choice, network representation, and traffic dynamics, and so on. Though component-based technique is

Received date: Jan 28, 2013; Revised date: Feb 22, 2013; Accepted date: Feb 27, 2013
*Corresponding author. E-mail: pdu@bjtu.edu.cn

DOI: 10.1016/S1570-6672(13)60102-6

applied in the integration of micro-simulators, some of the functionality had to be implemented in different way. Vilar *et al*.[4] developed a hybrid simulation system which can provide both meso-scopic and micro-scopic simulation runs. A Meta-event-oriented simulator is designed to synchronize both models. It is reported that this hybrid approach can take advantage of the microscopic simulator's accuracy without sacrificing the computational benefits offered by the meso-scopic model. Li *et al*.[5] constructed a GIS-based multi-resolution complex network, providing platform for the dynamic evolution of urban traffic network failures.

From most of the cross-resolution model researches, we can find that integration is a trend. Researchers tend to integrate existing single resolution software tools together instead of developing a brand new multi-resolution tool. With the integration of existing tools, both mature models and data source can be utilized and the cross-resolution models are more convincing.

In this paper, we present a path-flow-based cross-resolution simulation method in the need of micro-simulation in macro-level model. Using this method a sub-area extracted from macro-level model can be easily converted into a micro-simulation model to conduct detailed sub-area analysis. It is discussed in the paper key issues as node expansion, creation of path flow and handling of virtual objects. Detailed methods are given and a case study is also conducted.

2 Path-flow-based cross-resolution simulation model

It can be pointed out that two issues are critical to the conversion from macro level to micro level. First, link-based regional network need to be expanded to lane-based network. Second, flow-based volume need to be re-generated to vehicle-specific route assignment. From the above reviews, it can also be summarized that a generic multi-resolution tool demanded by sub-area studies require that the following functions should be included: (i) definition from regional network a sub-area and extraction of the sub-area network. (ii) Expansion of node to required level of detail. (iii) Reconstruction of OD centroids in sub-area in consistent with original network. (iv) Extraction of trips in sub-area in consistent with original trips.

The consistency of network topology and vehicle dynamics cannot be violated when converting from macro-level model to micro-level model. It is therefore presented the path-flow-based cross-resolution model. Fig. 1 shows the main conversion process and the mapping between objects of different resolutions.

A universal macro-level planning data model consists of a network and aggregated vehicle behaviors, as is shown in the left column of Fig. 1, and there are both physical nodes/links and virtual centroids/connectors in the network. Data needed by a typical micro-simulation tool can also be categorized into network data and vehicle data, as is shown in the right column of Fig. 1, however with different resolution requirements. For example, the micro-level network should be lane-based, and the each individual vehicle should have its own behavior. The center column of Fig. 1 shows the framework of the consistent conversion from macro-level model to micro-level. Lane-based expansion module expands physical nodes into intersections, and links into highways, to generate lane-based network. Turning volumes will be utilized to create appropriate signal timing. Virtual centroids are converted into vehicle sources and sinks, and connectors are approximated into side streets. For the traffic volume, a meso-scopic traffic assignment is conducted to achieve path flows.

In the extracted sub-area, new zones need to be generated along the boundary. Though link volumes are the same as original network, it is obvious that they cannot be used to generate the new OD matrix. We cannot distinguish from the aggregated link volume the exact OD of each individual vehicle. Only when we know the exact path of each vehicle can we regenerate the new OD matrix, as well as turning volumes and path volumes of a sub-area. Therefore, the light-weight traffic assignment tool DTALite[6] is encapsulated into our model to generate path flow.

3 Consistent conversions

3.1 Multi-layer node expansion

It is proposed a hierarchical node expansion method based on classification of requirements. Each layer is a step further in detailed expression of a junction. It is shown in Table 1, a node is expanded through three layers as physical, logical and operational, to accommodate lane-based resolution of micro-simulation.

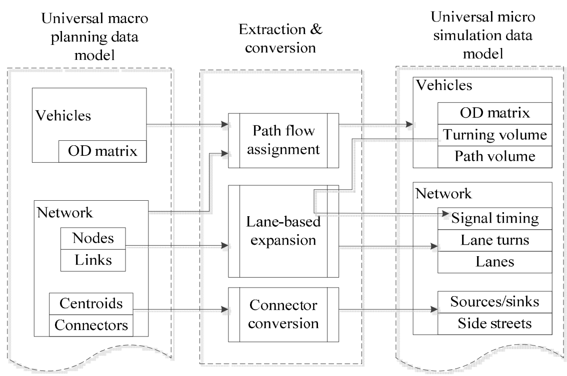

Fig. 1 Cross-resolution simulation framework

Table 1 Hierarchical expansion from macro-model to micro-model

Layer	Demand model	Micro-simulation model
Operational layer	(Turn penalty)	Control type and signal timing
Logical layer	Movements	Lane turns
Physical layer	Links	Lanes (extra pockets)