Multi-User-Type Travel Simulator based on Open Travel Data

Rie Tanaka, Satoko Itaya, Naoki Yoshinaga, Taku Konishi, Shinichi Doi, Keiji Yamada
NEC Central Research Laboratories
8916-47, Takayama-cho, Ikoma,
Nara 630-0101, Japan
r-tanaka@ak.jp.nec.com

Peter Davis
Telecognix Corporation
Yoshida Shimooji-cho 58-13, Sakyo-ku,
Kyoto 606-8314, Japan
davis@telecognix.com

***Abstract*— We have developed a simulator for evaluating changes in travel quality experienced during travel in multi-modal transit systems. The simulator has a new behavior model for users of multimodal systems that includes changes of user satisfaction, route and mode choices during travel, and interaction with on-line route guidance. This paper proposes a method for implementing user behavior models based on travel survey data, and describes an application example using open data for the city of Sydney.**

***Index Terms*—Smart City, ITS Multi-modal transportation simulator, multi-type agent model, service quality**

I. Introduction

Today, due to the increasing and diversifying demands of users, and the increasing financial burdens of providing infrastructure and services by traditional methods, it is becoming increasingly important for service operators to respond to different levels of service satisfaction for a variety of user types. It is necessary to develop methods for monitoring and responding to a variety of types of users and variety of user behaviors, such as service guidance.

This has motivated our work on computer models which can be applied to simulation of user behavior and user service quality in the context of service guidance systems. As a particular example of a system with service guidance, we have studied multimodal transit systems. Transit service operators use computer modeling to analyze and predict user behavior in transit systems for development planning, as well as service optimization. Moreover, computer models are being used to predict travel times, including congestion effects, for real-time guidance systems. However existing computer models are limited in their ability to incorporate the dynamic effects of choice behaviors by users, and also the effects of interaction with real-time guidance systems.

This paper presents a new method for modeling the interaction between users and services in multimodal transit systems. Users of multimodal transit systems travel by routes that may include transfers between different modes such as walking, bus and train. On-line traveler information services, which are examples of service guidance, provide real-time access to route recommendations. The new method presented in this paper makes it possible to model user behavior that includes changes of user satisfaction and route selection during travel, and interaction with on-line route guidance. Moreover, this paper newly proposes a method for implementing behavior models for multiple types of user behavior using openly available travel survey data. As a particular example, we have applied the proposed method to simulation of multimodal travel in Sydney using open travel data.

II. Related Works

Models of user choice preferences are considered in standard equilibrium transport models used by transport planners for evaluation of transport systems. For example, the Sydney Strategic Travel Model (STM) has been developed to assess transport in Sydney, projecting travel patterns in Sydney under different land use, transport and pricing scenarios [1].

A pioneering work on travel simulation that incorporates the effects of guidance in the simulation model was done at MIT - DynaMIT is a proposed Dynamic Traffic Assignment (DTA) system which generates transit guidance based on predicted traffic conditions [2]. Different categories of user behavior are also considered.

The concept of a Symbiotic Service Guidance System was proposed as a method for service users and service operators to achieve dynamic balance of satisfaction [3]. The guidance system consists of separate sub-systems handling the generation of recommendations to users and operators based on data obtained from system monitors and simulation engines.

III. Simulation System

A simulation system has been deveoped that allows consideration of dynamic effects of user interaction with guidance systems and a variety of user satisfaction types, in evaluation of transit service quality. In this section we describe the overall structure of the simulation system and the significant new features.

Fig. 1 shows an overview of the simulation system. The system builds on existing multi-agent transit simulation models, and adds five key new modeling components and methods for constructing user models based on available statistical data sources which are highlighted in Fig. 1..

978-1-4799-0540-9/13/$31.00 ©2013 IEEE

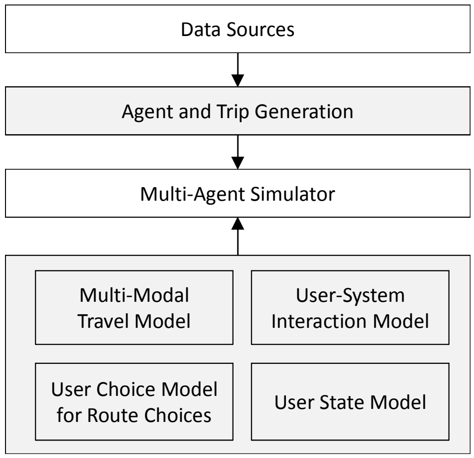

Figure 1. Structure of simulation system.

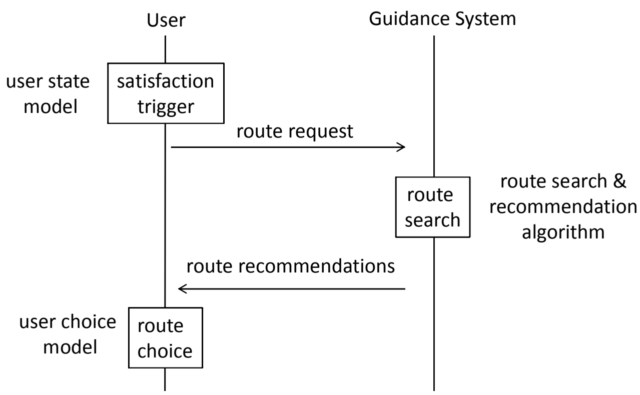

Figure 2 User-System Interaction Model

A. Multi-Modal Travel Model

The multi-modal travel model models people traveling on trips from departure points to destination points using multiple modes of transport. Agents are used to represent transport vehicles, including trains, buses, cars, as well as people who walk and ride on the transport vehicles. The motion of bus and trains is a combination of routes and itineraries obtained from open data and autonomous motion affected by road conditions and congestion. The new feature of the multi-modal travel model is that an agent can switch its travel plan during the trip. For example, after getting off a train, a user can decide to catch a bus or a taxi instead of walking if he is running late.

B. User-System Interaction Model

A key new component is the user-system interaction model, shown in Fig. 2. Each user agent has an internal state that evolves with time while the user is traveling. In particular, the satisfaction of the user changes with time. If certain satisfaction criteria (specified in the satisfaction model) are not satisfied, a user makes a request for an alternative route. The guidance system reports a number of recommended routes which are the best routes discovered according to general search criteria such as travel time and travel cost. The user evaluates and selects one of the recommended routes using its own criteria (specified in the choice model).

Details of the procedure for implementing the user -system interaction are shown in the pseudo-code below.

```
1.  Initialize trip
2.  Time to start trip?
      Yes: Go to 3
      No: Go to 2
3.  Request new route
4.  Select route
5.  Move to next via-point in route
6.  Arrived at destination?
      Yes: Finish Trip
      No: Satisfaction-Trigger?
          Yes: Go to 3
          No: Go to 5
```

C. User Choice Model for Route Choices

User agents make choices of travel routes at route via-points such as road intersections and bus or train stops. A multinomial logit model [4] is used as the route choice model. Although the user mobility model is a micro dynamical model rather than a macro equilibirum model, the use of a logit-type choice model is most suitable for comparison with other equilibrium transit models, including the Sydney Transport Model. According to the logit model, the utility U_r for a route r with M attributes like cost or time is calculated as follows.

$$U_r = \left(\beta_{r1}X_{r1} + \beta_{r2}X_{r2} + \ldots + \beta_{rM}X_{rM}\right) \qquad (1)$$

β_{rm} is the utility coefficient for the m-th attribute and X_{rm} is the value of the m-th attribute. The probability by which route r is selected from a set of T routes is calculated as follows.

$$P_r = \exp(U_r) / \sum_{t=1}^{T} \exp(U_t) \qquad (2)$$

Utility coefficients are assigned to user agents at the beginning of a trip using a statistical distribution that depends on the user type and trip purpose.

D. User State Model and Satisfaction Triggers

User states, denoted S, evolve according to a dynamic user state model that is executed at discrete time steps t,

$$S(t) = G(S(t-1), q(t)) \qquad (3)$$

using an update function G that depends on various system variables q, such as cumulative trip time and congestion. The state vector includes variables for fatigue and stress, which increase in proportion to cumulative travel time and congestion, with proportionality coefficients depending on user type. (The coefficient for an attribute affecting state changes may be different to the coefficient for the same attribute affecting route choices.) Trip satisfaction is defined as a function of the user state, and requests for route changes are triggered when trip satisfaction falls below specified threshold values.

E. Agent and Trip Generation Algorithms

The agents and trips are generated in the simulator by models based on available real world data. Available statistics for number of people travelling from one zone to another, and statistical information about distributions of user types and trip purpose are converted to probability distributions for generating agent trips between specific source and destination locations within each zone.

IV. IMPLEMENTATION

The simulator was implemented using the Scenargie® simulation platform [5]. Implementation details will be presented in a separate publication [6]. New models for the key new features and GUI were created. Moreover, software tools in python and perl were developed for processing input data and preparing the input agent profiles in the format required by Scenargie as an implementation of agent and trip generation algorithms.

Fig. 3 shows an example of a viewer interface showing simulation results for a travel scenario in Sydney. The center window shows the motion of agents with a detailed representation of spatial features including roads and buildings. Mobile agents include people, cars, taxis, trains and buses. Graphs on the right side of the viewer interface allow inspection of statistical measures, including user satisfaction, within and across scenarios.

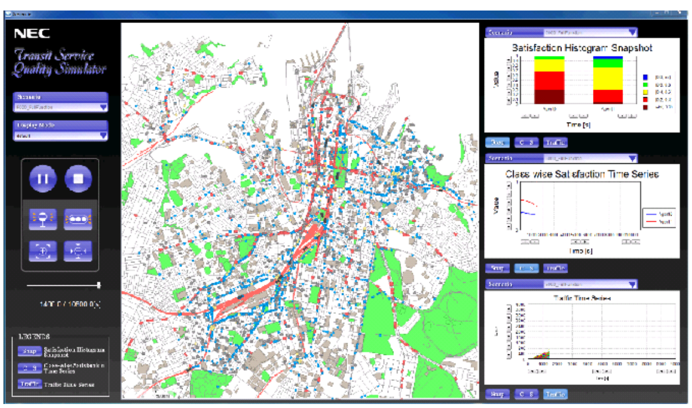

Figure 3. Viewer interface showing simulation of Sydney travel scenario

V. SIMULATION OF TRAVEL IN SYDNEY

The effectiveness of the simulator has been demonstrated with a large-scale simulation of user behavior in the Sydney city transit system.

A. Transport System Data

Road and rail network data was obtained from OpenStreetMap [7] and transit service data in TransXchange format (an implementation of the Transmodel open standard for public transport information) was obtained from NSW Public Transport Data Exchange site [8].

B. Traffic Data

Traffic zone-dependent statistics (a package containing zone GIS data and inter-zone travel statistics) published by the NSW Bureau of Transport Statistics were used to generate traffic [9]. The standard set of travel zones covers the whole Greater Sydney Metropolitan area [10]. Traffic to and from zones outside the simulation area can be handled by reallocating start and destination points at zones on the boundary of the simulation area. Start and destination points within travel zones are chosen from the set of buildings inside the travel zone.

C. User Behavior Data

Utility coefficients for route choices using the logit model (Eqn. 1) can be obtained from analysis of openly available Sydney travel statistics. Previous work on Sydney Transport Model (STM) have obtained coefficients based on travel purpose [11,12]. Table II shows utility coefficients for cost, access time and number of transfers, depending on a set of five different purpose types, reported in [11,12]. Here it is assumed that the value of cost will be in AUD and the value of time will be in minutes.

TABLE II. DEPENDENCE OF UTILITY COEFFICIENT ON PURPOSE TYPE

Trip Purpose Type	Cost	Access Time	Transfers
Business	-0.817	-0.0184	-0.092
Shopping	-0.757	-0.0426	-0.1705
Primary Education	-1.67	-0.0199	-0.116
Secondary Education	-2.5	-0.0174	-0.14
Tertiary Education	-0.46	-0.012	-0.1075

The transfer coefficients are not directly available from the STM study for all purpose types, so for some types they were estimated from related coefficients. For Business and Shopping and Tertiary Education, they were estimated from the wait time coefficients using the relation 1 transfer = 5 minutes. In the case of Primary and Secondary Education, the so-called boarding coefficients were used as equivalent coefficients for the disutility of making public transport interchanges.

The ratios of the coefficients in Table II indicate the relative weights for each user type. For example the cost-coefficient/ time-coefficient ratios for Business and Shopping are 1:44.4 and 1:17.7 respectively, indicating that Shoppers are less sensitive to time than Business purpose travelers.

The purpose of a trip is decided at the same time as the source and destination points are decided, using available statistical information about the purpose of trips. It would also be possible to use openly available statistical information about correlations between trip purpose and user attributes (such as age, income and location) and time of day. However, this was left for future work.

D. Travel Scenario: Event at Sydney Cricket Ground

This section shows a specific simulation result which shows the satisfaction of people travelling to a big event held at the SCG (Sydney Cricket Ground) stadium near the center of Sydney city.

This simulation example focuses on two types of people, students and business types, and compares several different service scenarios. The difference between students and business types is in the utility weights for time and travel fee – students have less negative weights for time and more negative weight for travel fee.

We first compared scenarios with and without mid-trip route updates. When there is no mid-trip route updates, then users who travel by bus could experience large delays on congested routes, because if they fail to get on a bus due to the bus being full, then they must wait for the next bus on the same route. On the other hand, with mid-trip route updates, they could choose to switch route if the route update service informed them that switching to another route should get them to the destination earlier than waiting for the next bus on the first route. The simulation showed improvement in satisfaction due to mid-trip route updates was larger for business types than for student types, because business types are more likely to choose to use a bus for a trip between Central Station and SCG stadium.

Figure 4 presents examples of satisfaction distributions displayed as bar graphs. The first two bars show the satisfaction distributions for student types and business types. The last bar in Fig. 4 shows the satisfaction of business types in a scenario with additional express bus service. Express buses travel non-stop between the Central Station to the SCG stadium and have a higher bus fare. Express buses are more likely to be chosen by business types rather than student types. The result for the scenario presented in Fig. 4 shows clearly that business types are well satisfied by the express bus service even though it costs them more. This result was obtained after optimizing the number and capacity of express buses. The simulation clearly showed that having too many express buses could result in increased congestion and delays at express bus stops and surrounding roads.

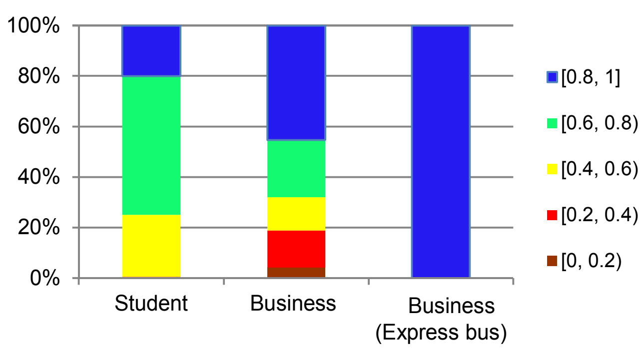

Figure 4. Distribution of satisfaction of student and business user types

VI. Conclusion

In this paper, we presented a multi-modal transit simulator which allows the simulation of transit behavior with multiple types of user behavior. The simulator implements new simulation models that model changes of user states over time during trips and dynamic mid-trip switching. We also presented methods for preparing multi-type user models from statistical data and demonstrated insightful simulation results obtained using actual travel survey data in Sydney.

There rigorous statistical validation of dynamical models is a difficult open challenge for user choice and behavior modeling sciences. The simulation model presented here could serve as an effective platform for studying these difficult issues. On the other hand, the current implemented simulation system provides an intuitive and practically useful way of examining dynamical effects of interactive guidance in public transport systems, identifying weaknesses in services and testing of effects of new services, which will be useful for service operators, event organizers and city development planners.

Acknowledgments

The authors thank Yun Zhang of NSW BTS for introducing them to Sydney data, and intern students Syed Saqib Bukhari (TUK), John Nakano, Emily Korby (GT) and Cecile Grometto (EPFL) for assistance with simulations and analysis.

References

[1] Sydney Strategic Transport Model, NSW Bureau of Transport Statistics, Feb. 2011, http://www.bts.nsw.gov.au/ (2012/11/28)

[2] D. Greenwood, C. Dannegger, and K. Dorer, "Dynamic dispatching and transport optimization – Real-world experience with perspectives on pervasive technology integration", 42nd Hawaii Int. Conf. on System Sciences (Hawaii, 2009/01/05-08).

[3] S. Itaya, P. Davis, N. Yoshinaga, R. Tanaka, T. Konishi, S. Doi, and K. Yamada, "Symbiotic service guidance and its application to transport services", in Proceeding of The 37th International Conference on Local Computer Networks (Florida, 2012/10/22-25).

[4] Scenargie®, http://www.spacetime-eng.com/en/products.html (2012/11/13)

[5] M. Ben-Akiva, and S. R. Lerman, 'Discrete Choice Analysis: Theory and Application to Travel Demand', The MIT Press, Cambridge, Massachusetts, 1993.

[6] S. Itaya, P. Davis, N. Yoshinaga, R. Tanaka, T. Konishi, S. Doi, and K. Yamada, "Multi-type multi-modal simulator for transit service quality evaluation", ITS World Congress, Tokyo 2013, IS08-3025.

[7] OpenStreetMap, http://www.openstreetmap.org/ (2012/11/13)

[8] Transport_Data_Release_Notes_20090918.pdf, http://www.bts.nsw.gov.au/ (2011/11/24)

[9] Bureau of Transport Statistics, Transport for NSW. Household Travel Survey. June 2009. Available: http://www.bts.nsw.gov.au/Statistics/HTS/ (2013/04/11).

[10] Sydney Greater Metropolitan Area Traffic Zones 2006_TZ_GMA_ESRI-2006_TZ_GMA_ESRI.zip, NSW Bureau of Transport Statistics, http://www.bts.nsw.gov.au/ (2011/11/24).

[11] NSW Government Transport Data Centre. Sydney Strategic Travel Model Stage 2 Model Estimation Technical Report. July 2002.

[12] NSW Government Transport Data Centre. Sydney Strategic Travel Model Stage 2 Further Model Estimation Technical Report. July 2002