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Contribution of GIS to ATIS

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Introduction

Transportation planning has been turning away from the solutions of building highways and transit routes to changing people's travel choices and making more efficient use of existing facilities. With the recent research focus on Advanced Traveler Information Systems (ATIS), it is imperative to understand the travel behavior of people and the information required to change their travel choices.

IVHS (Intelligent Vehicle Highway Systems) have aimed at the utilization of advanced information processing and communications technologies to achieve improvements in travel efficiency and safety. As one of the major components of IVHS planning, ATIS essentially is targeted to assist drivers in trip planning and decision making on destination selection, departure time, route choices, congestion avoidance and navigation. ATIS is to provide travel information for two types of traveler, namely, the pre-trip traveler and the en-route traveler. It deals with spatial decision-making at an individual level.

Under a IVHS context, we need to know not just what type of information is needed and how people process information, but also how the individuals interact with the environment in real time, especially how people make choices in activity scheduling, and routes and destination choices.

Micro-simulation techniques have been widely used to model the driver's response to information in reducing recurrent and non-recurrent traffic congestion. For example, computer-interactive simulators have been developed to study commuter behavior through laboratory experiments as an alternative to real world situations. Bonsall et al. (1991) developed IGOR (Interactive Guidance on Routes), which investigates factors affecting drivers' compliance with route guidance advice, such as quality of advice and familiarity with the network. Allen et al. studied the impacts of different information systems on drivers' route diversion and alternative route selection. Adler et al. (1992) suggested a framework to model individual en-route behavior in response to real time traffic information based on conflict assessment and resolution theories. Nevertheless, these simulators are deterministic, with all traffic conditions and consequences of driver actions predetermined. They interact with one subject at a time, without considering the interaction among drivers. Also, Allen et al. and Adler et al. assume perfect and static information, which is not realistic in real traffic situation (Chen and Mahmassani, 1993).

Route choice in the presence of information is studied by Ben-Akiva and Kaysi (1991), who propose a framework for modeling the process of drivers' information acquisition and behavior. Khattak et al. (1992) investigated commuters' diversion propensities and evaluated how drivers use real-time information. Lotan and Koutsopoulos (1992) developed route choice models in the presence of limited information, using concepts from fuzzy set theory, fuzzy control and approximate reasoning.

The simulation-assignment model by Chen and Mahmassani (1993) consists of a traffic performance simulator, a network path processing component, and the user decision-making component. Driver behavior and response to real-time traffic information systems is regarded as a complex process involving human judgement, learning and decision-making in a dynamic environment. The decision of one driver in the system is affected by other drivers, and this interaction is highly nonlinear. However, the context of the paper is restricted to the morning peak-period of commuters in congested traffic corridors.

Kaysi et al. (1993) developed an integrated approach to vehicle routing and congestion prediction for real-time driver guidance. The system design consists of a surveillance system, a congestion prediction element (COP) and a control and routing element (CAR). Congestion prediction is based on infrastructure data, historical origin-destination data and the updated O-D data. In the system, COP should provide CAR with projected traffic condition as the bases for prediction. A dynamic traffic assignment model (DTA) should be used for COP. Lastly, CAR should maintain guidance/prediction consistency.

However, these researchers have been concerned with traffic condition as the mere factors for travel decisions. They either take traffic condition as given , or try to model the traffic condition and the drivers' response. The fact that travel is a derived demand and travel is generated by the decision of individual to participate in activity is largely absent. In the routing model for planning a trip, however, it is usual to assume a fixed (known) origin and destination. The problem is then how to find the best route for this link, largely by the shortest path algorithm. Nevertheless, route choice in the presence of information depends on how activities are scheduled in time and space. The origin and destination may be different if there is a change in the trip chain due to adaption to real traffic conditions. In the case of diverting to another route in face of congestion or accident, the scheduling of activities may be adaptively changed, resulting in changes on routing in space and time. Prediction of traffic condition would be affected as such. Activity scheduling is thus an important component missing in current ATIS research.

Most research also ignored the interdependencies of travel decisions. Interrelated decisions for pre-trip traveler include the decisions required by each household members. For the en-route traveler, decisions made by other drivers in the system are important. The consistency issue is then important (Kaysi et al., 1993). However, they propose a concurrency check system but this problem is not dealt with directly in the database design. In addition to quality of traffic information provided to a traveler, the assurance of privacy is also important. Value-added information like the yellow pages and tourist guide, including locations of restaurants, tourist spots, etc. would greatly improve the usability of the system. This also can hardly be achieved if the system just concentrated on the network system and traffic conditions.

Proposed model of integrating CPMs into GIS

Most ATIS models assume that a traveler would take the rational approach to minimize travel distance and/or time in traveling, without paying attention to individuals' preference in route choices. Also, the facts that individuals are opportunistic, and that activity scheduling is highly dynamic and adaptive to real world traffic conditions, are not considered. In order to build a system that take into account the preference of individuals and their adaptive behavior, a computational-process modelling (CPM) approach is adopted. CPM examines how an individual interacts with the environment and adapts to changes. It allows us to investigate the relationship between travel behavior and the cognitive representation of the environment and describes explicitly the steps in the process of individual decision-making in the form of a computer program. It is a flexible and recursive process for modelling individual decision-making in a dynamic environment. Also, it allows us to take into account the preference and priority of individuals that interact with a cognitive environment.

It is argued in Garling et al. (1993) that activity/travel decisions need to be treated in a single coherent conceptual framework operationized as a CPM. Various efforts have been made to implement a conceptualization of travel decisions in a computer program mimicking people's decision-making processes. Kuipers (1978) developed TOUR to model individual's memory representation of the environment and its acquisition and use in wayfinding. The NAVIGATOR model (Gopal et al. 1984) is based on empirical results reported in Golledge et al. (1985). Route planning is modelled by TRAVELLER (Leiser and Ziberschatz, 1989) and ELMER (McCalla et al., 1982). However, none of the models examine the dependencies between different travel decisions and between travel decisions and activity choices (Garling et al., 1993).

STARCHILD (Recker et al. 1986a, 1986b) proposed a psychologically more plausible noncompensatory decision rule for selecting among the generated alternatives. However, the notion that all feasible activity schedules are generated is unrealistic. Garling et al. (1989) offered a conceptual framework to perform activity scheduling. The selection of destination in the model is based on the nearest neighbor heuristic. The application of the heuristic assumes people travel via euclidean distances. When applied in a IVHS context, in which route information can be dynamically retrieved from the system, the interplay of the activity scheduling and route choice would be an important area to look at. In order to implement this in reality and in the presence of information, a time-dependent network and the GIS operations would be used.

Need for a GIS

Salient problems of the CPMs are the requirement of detailed data of the environment and the interaction between the individual and this environment. Usually detailed travel surveys are carried out to record individual travel patterns towards route, mode, and destination choice. It is hoped that geographic information systems (GIS) can provide a comprehensive database and the necessary analytical methods to handle these refined and disaggregate data (Replogle, 1989). GIS operations can help to define individuals' spatial and temporal constraints of accessibility (Golledge et al., 1993). However, how to form a GIS as a base for both the static and dynamic environment needed for activity scheduling is still an unexplored area.

Most IVHS research focuses on the network system to provide congestion prediction and real-time traffic information. Activity scheduling literature suggests that the decision of people to participate in an activity affects network performance. In order to address this interrelationship, a coherent working system is needed. GIS provides such a comprehensive database system to work with.

Most IVHS is based on simplified network elements (Vaughn et al., 1993). GIS, on the other hand, provides a realistic representation of the environment for modeling. Different information can be integrated through geo-referencing. GIS also provides a comprehensive database for both aggregate and disaggregate information. Also, a GIS is highly flexible in terms of manipulating spatial objects and distance according to rules, it also facilitates the representation of environment according to individual's behavioral characteristics. For network modeling, these rules include putting high impedance on a link to represent the lower probabilities of traveling on that link.

How to represent people's movement in time and space has been explored in Miller (1991). GIS operations can also help to model destination choice by defining a feasible opportunity set (Golledge et al. 1993). Research on complex travel behavior usually generates all the possibilities for activity scheduling by a combinatorial algorithm. It is computational demanding and inefficient. By defining such a set we can eliminate this problem.

Similarly, path selection by an individual can be benefitted by defining a feasible route set. With the detailed network with spatial topology, a routing algorithm can be implemented to determine this feasible route for a route choice model.

When faced with changes in traffic condition under ATIS, a traveler would consider an alternative route. A CPM could model how an individual adapts to changes in the environment. In a GIS, information in the environment can be modified and spatial relationships recalculated. Different scenarios can also be simulated to test the "what-if" cases.

Proposed tasks

In this research, work will be done on GIS data model and database to provide a computer-simulated environment for micro-simulation in the IVHS context. The focus would be to examine how GIS provides a basis for dynamically integrating travel decision models. GIS is, however, not without problems. The proposed tasks to explore the GIS data model issues for integrating travel decision models are as follows:

1) Activity scheduling and destination choice:

Feasible opportunity set: since individuals will only consider certain places for an performing activity, a feasible opportunity set should be defined for searching. It will not just define a static set for an individual, but dynamically check the opportunity set when in a particular location. It may result in changes in schedules. Rules for defining such a set would be from experiment to relating to different criteria. For example, buffer zones by travel time or distance can be manipulated and checked with real data or secondary sources. The interrelationship between the travel decisions of a household member for pre-trip planning and other drivers on the road for en-route traveling, as well as the effects on defining the feasible opportunity set will be examined.

2) Routing elements:

Feasible route set: store different route and possible sets based on different criteria. Research to find out how people attempt to minimize total distance when they choose a path between several destinations (TSP) can be used as a guide for routing in a CPM (Hirtle and Garling, 1992). Using the rules, which can then be written as heuristic algorithms, the actual and alternative path selection may then be modelled.

Develop a time-dependent network for routing: Research from Ziliaskopoulos et al, (1993) on a time-dependent shortest path algorithm, Ran et al. (1992) on travel time function network model, and Chen and Mahmassini (1993) on a time-dependent network to model real-time information processing will be explored. Travel time function will be formulated.

Turn penalty on routing has not been widely incorporated into the routing literature in IVHS. However, in reality people may prefer not to make left-turns. This research explores the opportunity of incorporating turn penalty into the routing elements.

Behavioral assumptions: Recognizing that it's people that travel. The behavioral characteristics are important for providing useful information for the traveler. Some may prefer freeway to local street while the others may have a reversed preference. The routing alternatives have to be provided accordingly.

For en-route traveler, travel information will be updated quite frequently. To take into account the effects of other travelers on overloading a particular route with diversion information from the ATIS, concurrency control has to maintain in the GIS database.

Data set

Travel diaries data will be used to validate the formation of feasible opportunity set and feasible route set. These data should consist of detailed information on the traveler's time of day, origin and destination of each link, mode, duration, purpose, usage of freeway, and route information of travel. Socio-economic data from this data set is also available. The California Telecommuting Pilot Project provide such information. Also, the Peuget Sound Panel Data set record such data. Travel diaries from the Peuget Sound Telecommuting Demonstration Project will also be useful. Network data will be from simulated data and the TIGER file from the Census Bureau. Other aggregate socio-economic data would be from the Census to the most disaggregate level.

Conclusions:

The range of physical, environmental, behavioral, and decision making components required in the ATIS part of an IVHS lends itself to representation in a GIS. Although there are difficulties to be overcome in making such a system operational in real time, we feel the long run advantages of a GIS based ATIS will justify the needed basic research. The principal author of this paper is pursuing this problem as a dissertation and will undoubtedly develop a menu of additional problems to be resolved by future research.

Reference

Adler,J.L., Recker,W.W. and McNally,M.G. (1992), A conflict model and interactive simulator (FASTCARS) for predicting enroute assessment and adjustment behvior in response to real-time traffic condition information. Paper presented at the 71st Transportation Research Board Meeting, Washington, D.C.

Ben-Akiva,M. and Kaysi,I. (1991), Drivers information processing in the context of advanced driver information systems (ADIS). Paper presented at the 70th Annual Transportation Research Board Meeting, Washington, D.C.

Bonall,P.W. and Parry,T. (1991), Using an interactive route choice simulator to investigate drivers' compliance with route guidance advice. Transportation Research Board, 70th Annual Meeting, Washington, D.C.

Booch, G. (1991), Object-oriented Design with Applications. The Benjmin/Cummings Publishing Compny, Inc.

Chen,P.S. and Mahmassani,H.S. (1993), A dynamic interactive simulator for the study of commuter behavior under real-time traffic information supply strategies. In Transportation Research Board 72nd Annul Meeting, Washington,D.C.

Garling, T., Brannas, K., Garvill, J., Golledge, R.G., Gopal, S., Holm, E. and Lindberg, E. (1989), Household activity scheduling. In Trasnportation policy, management and technology towards 2001: Selected proceedings of the fifth world conference on tranportation research, Vol. IV, Western Periodicals, Ventura, CA.

Garling, T., Kwan, M.-P. and Golledge, R.G. Computational-process modeling of travel decisions: A review. Submitted for publication.

Golledge, R.G., Kwan, M.-P., Garling, T. (In press), Computationl-process modeling of household travel decisions using a geographical information system. Papers for regional science.

Gopal, S., Klatzky, R.L. and Smith, T.R. (1989), Navigator: A psychologically based model of environmental learning through navigation, Journal of Environmental Psychology, 9, 309-331.

Imielinski, T. and Badrinath, B.R. (1992), Querying in highly mobile distributed environments. In Proceedings of the 18th International Conference on Very Large Datbases.

Kaysi, I., Ben-Akiva, M. and Koutsopoulos, H. (1993), An integrated approach to vehicle routing and congestion prediction for real-time driver guidance. Paper presented at the 72nd Tranportation Research Board Annual Meeting, Washington, D.C.

Khattak,A.J., Koppelman, F.S. and Schofer,J.L. (1992), Stated preferences for investigating commuters' diversion propensity. Paper presented at the 71st Transportation Research Board Annual Meeting, Washington, D.C.

Kuipers, B. (1978), Modeling spatial knowledge, Cognitive Science, 2,129-153.

Leiser,D. and Zilberschatz, A. (1989), The TRAVELLER: A computational model of spatial network learning, Environment and Behavior, 21,435-463.

Lotan,T. and Koutsopoulos,H.N. (1992), Models for route choice behavior in the presence of information using concepts from fuzzy set theory and approximate reasoning. Submitted for publication in Transportation.

McCalls, G.I., Reid, L. and Schneider, P.K. (1982), Plan creation, plan execution and knowledge execution in a dynamic micro-world, International Journal of Man-machine Studies, 16, 89-112.

Recker, W.W., McNally, M.G. and Roth, G.S. (1986a), A model of complex travel behavior: Theoretical development, Transportation Research A, 20,307-318.

Recker, W.W., McNally, M.G. nd Roth, G.S. (1986b), A model of complex travel behavior: An operation model, Transportation Research A, 20,319-330.

Replogle, M. (1989), Integration of a Geographic Information System with computer transportation models for land use and transportation planning. Paper presented at the Second Conference on Application of Transportation Planning Models, April 24-28, Orlando, Florida.

Ziliaskopoulos, A.K. and Mahmassani, H.S. (1993), A time-dependent shortest path algorithm for real-time intelligent vehicle/highway systems applications. Paper presented at Transportation Research Board 72nd Annual Meeting, Washington, D.C.