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ScienceDirect

Transportation Research Procedia 22 (2017) 55–64

Transportation Research Procedia

www.elsevier.com/locate/procedia

19th EURO Working Group on Transportation Meeting, EWGT2016, 5-7 September 2016, Istanbul, Turkey

Cognitive learning approach for travel demand modeling: estimation results

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Abstract

The paper reports progress in the development of an agent-based model of cognitive learning, which simulates spatial perception updating in connection with daily travel behavior based on the principle of Bayesian perception updating. This model is embedded in a multi agent-based model of activity-travel scheduling and choice behavior. The aim of this paper is to empirically estimate the proposed model using data on individuals' landmark recognition in a field survey. The main findings of the study show that the model fits the data satisfactorily and results are reasonable. The comparison between the proposed Bayesian model and a more basic binary logit model shows that the model improves when prior probabilities are taken into account, which provides evidence for the proposed Bayesian model.

Peer-review under responsibility of the Scientific Committee of EWGT2016.

Keywords: Cognitive learning; perception updating; agent-based model; activity-travel behavior; landmark; dynamic urban networks

1. Introduction

The implementation of activities in space and time is an important issue in analyzing and modeling activity-travel patterns. The urban planning and transportation research communities have been developing and applying choice models to predict activity-travel patterns over the last decades. Theoretical developments and applications of

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2214-241X
Peer-review under responsibility of the Scientific Committee of EWGT2016.
10.1016/j.trpro.2017.03.007

activity-based models are the prominent outcomes of this research interest. Current models of activity-travel demand, including ALBATROSS (Arentze & Timmermans, 2004), Bowman and Ben-Akiva model (Bowman & Ben-Akiva, 2001), MATSim (Balmer, Meister, Rieser, Nagel, & Axhausen, 2008), TASHA (Roorda, Miller, & Habib, 2008), CEMDAP (Bhat, Guo, Srinivasan, & Sivakumar, 2004), FAMOS (Pendyala, Kitamura, Kikuchi, Yamamoto, & Fujii, 2005), Aurora (Joh, Arentze, & Timmermans, 2006), and the ADAPTS model (Auld & Mohammadian, 2011) have been developed to predict activity-travel patterns.

The shortcomings of existing activity-based models of travel demand have led to the need of developing dynamic activity-travel models (Timmermans et al., 2010). Considering that existing models do not pay enough attention to spatial cognition and that research on modeling cognitive learning of urban networks is still limited, this situation presents an opportunity for exploring the dynamics of spatial relations of an environment with its habitants and developing applications of such models. Arentze and Timmermans (2005) developed a model that is derived from existing Bayesian theories of belief updating, and following their study, a modeling approach to simulate spatial perception updating based on individual observations in the built environment is proposed and illustrated in Cenani, Arentze, and Timmermans (2012; 2013). A specific contribution of this study is the inclusion of an important aspect, landmarks, in the observation-sensitivity function.

The aim of this paper is to empirically estimate the model proposed in an earlier work (Cenani et al., 2012; 2013) including the parameters of the sensitivity function, using data about individuals' recognition of landmarks in an in-field experiment conducted by Wielens, Cenani, Kemperman and Borgers (2011). To estimate the model, the recognition data from the experiment is augmented by data about individuals' judgments of saliency of landmarks collected specifically for this study.

The remainder of this paper is structured as follows: The following section gives information on the experiment, and then the next section describes a complementary survey in connection with the experiment. This is followed by a section about the estimation method and then the results. Finally, the last section draws conclusions with a discussion of the main findings.

2. Experiment

The experiment is conducted in the context of the study by Wielens et al. (2011). The goal of their study is to measure the effect of different navigation aids on spatial knowledge acquisition while walking through an unfamiliar environment. To that effect, several cognitive tasks are implemented. Landmark, route and survey knowledge are measured via these tasks. The task explained in this paper is one of the landmark recollection tasks. Recollection data alone does not suffice for estimation of the proposed Bayesian perception updating model. The Bayesian model to be estimated is about perception updating after an observation. This means that, in addition, data about initial probabilities (beliefs before an observation) are needed. Thus, two data sources are combined. In order to use the data about recognition to estimate a model of perception updating, it is assumed that the extent to which an individual recognizes a landmark after walking the route gives a scale about the individual's belief of the presence of that landmark (after an observation). Then in the complementary survey, a new scale is used to measure the saliency of a landmark before an observation.

The experiment took place between November 2010 and January 2011 in Eindhoven, the Netherlands. Two circular routes were chosen in Eindhoven, the Netherlands. Both routes consisted of the same number of turns (10 turns), the same length (1.6 km) and the same land-use type (mostly residential buildings along with commercial buildings). Each participant walked one of the two predetermined routes, either with a paper map or an electronic navigation device, during daytime.

The experiment consisted of two parts: the route finding task (in-field) and cognitive tasks. After the completion of the route finding task, participants came to the university, where cognitive tasks (e.g., giving written wayfinding directions, drawing a sketch map of the experiment location, recollecting landmarks, etc.) took place. All participants did the tasks individually. Prior to scheduling of the experiment, all participants were asked a series of screening questions to ensure minimal experience with the experiment locations. Therefore, participants did not have prior knowledge about the experiment locations as well as the tasks they performed.