Delineating potential trajectories in constrained environments using rough space-time prisms

Delafontaine, M; Neutens, T.; Van de Weghe, N.

In: Goossen, M.; Elands, B.; Van Marwijk, R. (Eds.), Recreation, tourism, and nature in a changing World. Proceedings of the 5th International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas (MMW 2010), Wageningen, The Netherlands, p. 130-131, 2010.

Delineating potential trajectories in constrained environments using rough space-time prisms

Matthias Delafontaine, Tijs Neutens and Nico Van de Weghe

{Matthias.Delafontaine, Tijs.Neutens, Nico.VandeWeghe}@UGent.be
CartoGIS cluster
Department of Geography
Ghent University
Krijgslaan 281 (S8)
B-9000 Ghent (Belgium)

Workshop on Movement Research (MMV5)

5th international conference on Monitoring and Management of Visitors Flow in Recreational and Protected Areas (MMV 2010)

Keywords: time geography, space-time prism, location-aware technology, spatiotemporal uncertainty

Recently, technological advances have enabled the development of a range of widely and readily available location-aware technologies (LAT) and geosensor systems. Trajectory data resulting from these technologies, however, is affected by at least two important sources of spatiotemporal uncertainty. First, trajectories are typically approximated as a sequence of spatiotemporal sample points that are to be interpolated. The sampling frequency may be inherent to the tracking device at hand or may result from the incomplete coverage of a geosensor network (i.e. positions outside the radio range of the sensors). In addition, sampling frequency may be affected by system failures (e.g. when a signal is blocked by obstructions). A second source of uncertainty arises from measurement inaccuracy. While individuals may be traced with an acceptable accuracy using GPS, the accuracy of wireless radio-communication systems is often much lower.

Both finite sampling and measurement inaccuracy hamper a straightforward reconstruction of individual trajectories on the basis of LAT data. Hence, the question rises on how to deal with tracking data from which individual trajectories cannot be acceptably obtained by simple interpolation? To this end, we propose a time geography approach, using a representation by space-time prisms. Traditional time geography (Hägerstrand, 1970) has two major shortcomings: (i) measurement uncertainties are ignored, and (ii) a homogeneous travel environment is assumed.

To tackle the first problem, we rely on the work of Neutens et al. (2007) where a conceptual model is elaborated for space-time prisms under uncertain constraints, applying the basic principles of rough set theory (Pawlak, 1982). A rough space-time prism is obtained, which consists of a lower and upper approximation prism. We will employ this model to deduce a formal definition of lower and upper approximation prisms in the case of tracking data with a certain spatial and temporal accuracy.

Regarding the second issue, a number of researchers have already addressed the assumption of a homogeneous travel environment, most of which have focused on the case of transportation networks instead (e.g. Kwan and Hong, 1998, Wu and Miller, 2000; Weber and

Kwan, 2002; Kim and Kwan, 2003, Neutens et al., 2007; Kuijpers and Othman, 2009). Despite these efforts, only few studies have been concerned with modelling non-motorised, non-network yet spatially constrained movements through space-time prisms. A recent example is Miller and Bridwell (2009), who set up an analytical theory to derive field-based space-time prisms using velocity fields. This approach requires a reliable assessment of such a velocity field at an acceptable field density, which is often unavailable or difficult to estimate accurately in real-world situations. Therefore, we take an alternative approach by assuming a homogeneous travel environment populated with discrete, impassable obstacles. We formally define and set up a methodology to determine space-time prisms within such an obstacle-constrained space.

Finally, we combine both solutions in order to handle space-time prisms with uncertain constraints in an environment constrained by obstacles. We argue that many real-world travel environments, both indoors and outdoors, might be abstracted as such (e.g., urban and built environments). With our approach, the concept of a rough space-time prism has now an acceptable degree of realism in order to become a useful tool to analyse common tracking data in such environments. Therefore, we are planning to validate this methodology by means of extensive data sets. Particular emphasis will be placed on how to employ the yet obtained concepts to infer additional knowledge about trajectories and to measure the accessibility in space and time. An implemented prototype tool is already at a far developed stage.

References

HÄGERSTRAND, T. (1970), What about people in regional science? *Papers of the Regional Science Association*, **24**, pp. 7-21.

KIM, H.M. and KWAN, M.P. (2003), Space-time accessibility measures: A geocomputational algorithm with a focus on the feasible opportunity set and possible activity duration. *Journal of Geographical Systems*, **5**, pp. 71-91.

KWAN, M.P. and HONG, X.D. (1998), Network-based constraint-oriented choice set formation using GIS. *Journal of Geographical Systems*, **5**, pp. 139-162.

KUIJPERS, B. and OTHMAN, W. (2009), Modeling uncertainty of moving objects on road networks via space-time prisms *International Journal of Geographical Information Science*, **23**, pp. 1095-1117.

MILLER, H.J. and BRIDWELL, S.A. (2009), A field-based theory for time geography. *Annals of the Association of American Geographers*, **99**, pp. 49-75.

NEUTENS, T., WITLOX, F., VAN DE WEGHE, N. and DE MAEYER, P. (2007), Human interaction spaces under uncertainty. *Transportation Research Record*, **2021**, pp. 28-35.

PAWLAK, Z., 1982, Rough sets. *International Journal of Information and Computer Science*, **11**, pp. 341-356.

WEBER, J. and KWAN, M.P. (2002), Bringing time back in: A study on the influence of travel time variations and facility opening hours on individual accessibility. *Professional Geographer*, **54**, pp. 226-240.