

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

Matthias Delafontaine¹, Tijs Neutens¹, Nico Van de Weghe¹

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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 is however 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 & Hong 1998, Wu & Miller 2000, Weber & Kwan 2002, Kim & Kwan 2003, Neutens et al. 2007, Kuijpers & 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 obtained concepts to infer additional

¹ CartoGIS cluster, Department of Geography, Ghent University, Krijgslaan 281 (S8), B-9000 Ghent, Belgium, Matthias.Delafontaine, Tijs.Neutens, Nico.VandeWeghe@UGent.be

knowledge about trajectories and to measure the accessibility in space and time. An implemented prototype tool is already at a far developed stage.

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