A Spatiotemporal Ontology for Semantic Trajectories: Extended Abstract

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Abstract

A geospatial query is a question where the concept of location is necessary for formulating the answer. In particular, we are interested in queries that can support location intelligence reasoning about the ways in which people can possibly move through space in the urban environment. In this project, we explore how can ontologies be used for automated reasoning to answer geospatial queries based on people's trajectories. In such context, a trajectory is the sequence of activities in which people participate while moving along a path. In order to do so we need an integrated set of ontologies that cover the notions of space-time, events, moving objects as well as the relations among them.

Keywords

spatiotemproal, semantic trajectory, ontology

1. Motivation

In urban areas, by using the Global Positioning System (GPS), moving objects like vehicles and human can be tracked in connection with city infrastructure such as buildings and roads. Large volumes of spatiotemporal data are collected in different fields, including transportation, human mobility, and business transactions. Nowadays, the trend of mobility analysis has been shifted from raw movement to semantically rich trajectories. Rather than tracks of moving objects, trajectories are considered as spatiotemporal entities that represent the sequence of activities in which physical objects participate while the objects are moving along a path, such as an individuals daily activities. Therefore, in order to represent semantic trajectories and answer queries of trajectories in natural languages, we need an integrated ontology that covers the notion of space, time, activities and participating objects. Though there exist a number of OWL ontologies for trajectories [1, 2, 3, 4], most of them just simply associate spatiotemporal points or objects to space, time and event data. They provide neither explicit axiomatizations for spatiotemporal relations nor formalisms of events or processes. Regarding formal representations of spatiotemporal knowledge, there is considerable foundational work on qualitative representation and reasoning about space [1, 2], as well as relationships between physical objects and spatial regions [3, 4]. Meanwhile, temporal formalisms have also been

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studied extensively together with actions and events [5]. However, to reason about a moving object, it is not only essential to represent its location and spatial relations to other objects in time but also changes in the spatial aspects over time. Thus, a practical concern of spatial and temporal reasoning is to deal with the historical and spatial changes of objects and hence the emerging need for developing spatiotemporal hybrids. There have been continuing attempts to integrate space and time, including temporalizing spatial relations and combining space and time as one primitive entity, such as BFO. Yet, existing approaches fail to provide a reasonable philosophical stance of space-time treatment nor a mereotopology of spatiotemporal entities. In addition to spatiotemporal formalisms, we also need representations of activities and their relations to space and time. Ontologies of events or activities have been well established such as Process Specification Language and Event Calculus; nevertheless, very little research has formalized the relation between event and spacetime. Some previous research discussed philosophical theories and some principles of locating events [6, 7], but none of these studies proposed formal axioms of the relation between an activity and space-time.

2. Research Questions

What ontologies are required to represent semantic trajectories for question-answering?

3. Objectives

- Assess existing approaches to representing space-time and activities.
- Develop a set of ontologies to represent spatiotemporal entities, activities, and relations between them.

4. Research Methodology

The research methodology follows the typical ontology design pattern driven by competency questions, and it includes three main phases. The first phase is to develop use case scenario and define the domain scope and requirements of the ontology. The second phase is developing the formal axioms. The last phase is to implement and evaluate the ontologies based on the use case scenarios. To capture the major concepts and requisites of knowledge representation on event locations, we develop a scoping scenario comprehending the motion of moving objects with respect to occurring activities, also called semantic trajectories.

> Alice leaves her house in Riverdale and crosses the Don Valley to Leaside. She purchases plumbing supplies at Canadian Tire (825 Eglinton Avenue East) and bathroom tiles at the Home Depot that is nearby on Wicksteed Avenue.

In order to represent this scenario, one of the fundamental notions that we need to cover is Alices trajectory which consists of a series of timely ordered activities at different locations, including moving from her house from Riverdale to Leaside, purchasing plumbing supplies at Canadian tire and bathroom tiles at the Home Depot. To further conceptualize and break down

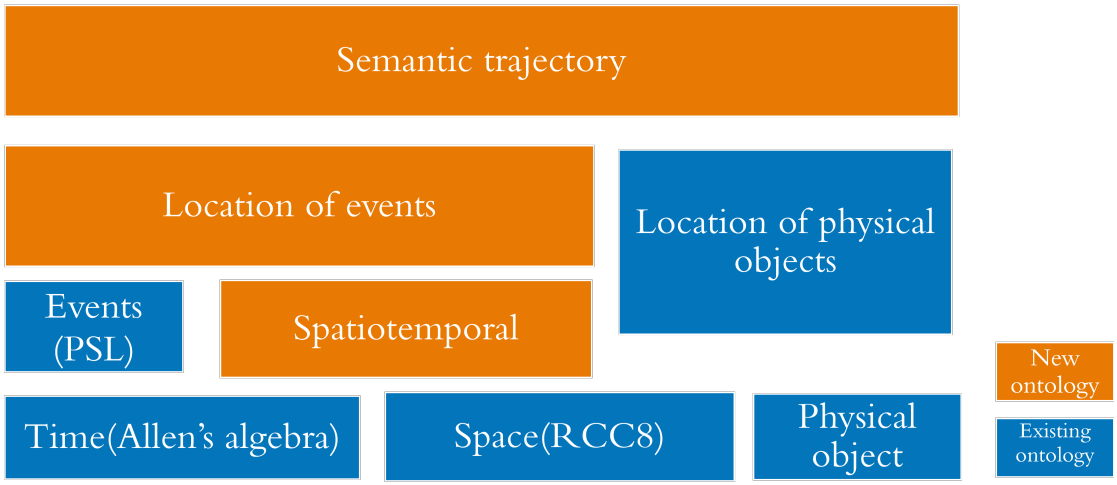

Figure 1: The structure of semantic trajectory ontology

the trajectory, it can be treated as tracks of Alice's movement (a moving object) plus a sequence of activities while the object is moving along a spatial path. In that case, we need two sets of ontologies to represent the locations of objects and locations of events respectively. In order to represent this scenario semantically, the key questions to investigate are:

- What are the relationships among events, space and time?
- Are there distinct types of relationships between an event and space-time and an object and space-time respectively? If so, how do these relationships relate to the mereotopologies of objects, events, space and time?
- Motion and spatial change: when an entity moves or has spatial change, what exactly changes?

The scenario and questions are used throughout the research to define the scope of the ontology, to evaluate existing work on spatiotemporal and event modelling and to address the needs for the proposed ontology. Based on these questions, we develop the architecture of the major components that the proposed ontology should include. Figure 1 presents an overview structure of the integrated ontology for semantic trajectories. There are two modules that we need to represent semantic trajectories. As noted earlier, a semantic trajectory is the sequence of activities in which physical objects participate while the objects are moving along a path. Thus, we divide the semantic trajectory into two modules. The first one is the location of physical objects. The fundamental trajectories are tracks of moving objects, so we need a location ontology for the relationship between a physical object and a spatial region, which is closely related to the mereotopology of physical objects and spatial regions. The second module is the location of events. In this module, we need the formalization of the relation between an activity and spacetime, and this formalization is related to two sets of ontologies: activities and spacetime. Events and activities are usually tied to time closely, and a spatiotemporal ontology requires integrating space and time specifications.

5. Research Results to Date

So far we have completed the work of developing a spatiotemporal ontology and the ontology for location events. The next step is to integrate our ontology for event locations and the ontology for physical object locations.

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