Modeling Motion Relations for Moving Objects on Road Networks

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Introduction

I have been working on topics relating to spatio-temporal data modeling for some time. One of these topics, relates particularly well with the focus of this workshop, *Agent-Based Modeling of Complex Spatial Systems*. With this research, I am interested in modeling the semantics associated with different types of moving entities, in particular, the semantics of moving vehicles on road networks, and the corresponding extensions to data models that are necessary for next-generation information systems to support vehicle navigation more fully. The movement semantics that we are examining relate to the position of one moving vehicle relative to another on the road network. These *motion relations*, based on the relative positions of pairs of moving vehicles on roads, capture the kinds of cognitive semantics that are especially meaningful to drivers and other active participants (e.g., bicyclists) as they travel and interact with each other on roads. For example, *is the car behind my vehicle a police car? Is that an ambulance coming towards my vehicle in the other lane? What kinds of vehicles are currently in the vicinity of Maple Street and 4th Avenue?*

For this work, it is assumed that vehicle positional data are collected from a geosensor network and stored in a spatial database. These datasets are used to compute a set of basic motion relations including *isBehind*, *driveBeside*, and *passBy*. The motion relations describe the positions of one vehicle relative to another in lanes of traffic and serve as a foundation for representing *individualized* perspectives of dynamic transportation networks. These perspectives capture details of movement of entities (vehicles) modeled as objects, for a user-defined spatio-temporal region of interest in the transportation domain. For example, for any given region of interest and an interval of time, it is possible to derive the kinds of moving objects and their corresponding relations to each other with respect to a reference object, affording a refined perspective of the kinds of moving objects currently in the vicinity of that object. These semantics are important for understanding, modeling, and querying the behavior of moving entities in a modeled road network, as well as for annotation and enhanced indexing.

Moving object data from geosensor networks

For this work, a fixed-length linear referencing model is used in conjunction with a point-location approach to represent traffic movement data. The network of sensors is distributed along a roadway so that each one observes a specific number of fixed reference positions. We assume that at any given time *t*, only one object can be at a specific reference position for any lane (e.g., one object can not be on top of another object). Data collection begins when movement is detected. From the initial point of movement, a series of sensor readings are collected at a fixed time from one another. The positions of each individual object within the range of the sensor (relative to a reference point) are then stored for each reading. Each moving object is assigned a unique identifier, and the linear extent of the moving object and its midpoint are stored as well. Based on this framework, a database representation is developed to provide the basis for supporting queries that describe different kinds of motion relations. A relation *SensorDat* with attributes, *objectID*, *sensorID*, *laneID*, *position*, and *time* is defined for storing location readings within the sensor from the network. Details of the moving objects, on the other hand, are stored in relation *ObjData* with attributes, *objectId*, *class* and *length*. The attribute *class* corresponds to object classes that model the kinds of vehicles moving on the road network.

Basic motion relations for moving objects

The basic actions of two or more moving vehicles on a road form the foundation for a typology that distinguishes a set of basic *motion relations* (i.e., an elementary set of relations between two moving objects). These movement types are restricted to movements that result in a change of location. The basic motion relations that are the focus of this research are *isBehind(A,B,T)* and its converse relation, *inFrontOf(A,B,T)*, *driveBeside(A, B,T)* and *passBy(A,B,T)* (Figure 1). The relation *isBehind(A,B,T)* and its converse relation, *inFrontOf(A,B,T)* describe the relative spatial relation between two moving objects *A* and *B* (e.g., land vehicles) in the same lane of traffic at time *T*, such that no other object is between *A* and *B*. The case where one vehicle goes by another in an adjacent lane of traffic while traveling in the same direction at time *T*, and assuming no vehicle is in between, is captured by *driveBeside(A,B,T).* The alternative case of two vehicles moving in adjacent lanes of traffic while traveling in opposite directions at time *T*, is referred to as *passBy(A,B,T)*. The *driveBeside* and *passBy* relations are both symmetric.

The role of agents

At present, we have been working on the database aspects of this research, formulating queries in SQL that compute the motion relations for a given set of vehicles. However, it is very interesting to consider how agent-based approaches could be applied to this work. For example, each vehicle could have an embedded sensor that allows it to receive communications from the road sensors. These communications would inform the agents of the position of the vehicle on the road network. In addition, the onboard sensors would allow for communication with other vehicles that are around it on the road network. In this setting, the data streams for the agents would come from within the vehicles themselves as well as from the sensors in the transportation network. And in this way, vehicles would be informed by agents about the position and types of vehicles around them, allowing them to move into the lane of traffic that will facilitate their progress, or communicate with other vehicles such that they change position with each other. Based on this, one could foresee scenarios where, for example, service vehicles (e.g., taxis) could communicate with each other with respect to their position in the network via agents, and move to optimize their travel routes.