Solutions to the generalized alibi query in moving object databases

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In Moving Object Databases (MODs), various data models and query languages have been proposed to deal with moving objects whose position is recorded by location-aware devices (such as GPS), at not always regular moments in time [1]. The movement data of an object is therefore discrete in nature and can be seen as a sequence $\langle (x_1, y_1, t_1), \ldots, (x_n, y_n, t_n) \rangle$ of measured space-time locations, which we call a *trajectory sample*. Between measured space-time points, the trajectory of a moving object is unspecified and unknown and several models have been proposed to deal with this uncertainty. Based on the assumption that moving objects have some physically determined or law imposed speed bounds, the *space-time prism* model delimits the region in space-time which a moving object may have visited between two sampled points. This model, originating from the field of "time geography" in the 1970s, has found its way into MOD research. The uncertainty on the movement of an object associated with a trajectory sample, is then modeled by a chain of space-time prisms.

One query of particular interest in this context is the *alibi query*, which asks whether or not two moving objects may have met, given their trajectory samples and speed bounds. The difficulty of answering this query can be reduced to deciding whether two space-time prisms intersect. Using a geometric argument, a solution to this problem was given by Othman et al. [2]. We address the *generalized alibi query*, which asks the same question, but for any (finite) number of moving objects. Because a space-time prism can be described by a system of polynomial inequalities, the generalized alibi query can be expressed as an existential first-order logic formula over the ordered field of real numbers. While there are algorithms for deciding the truth of such sentences, existing implementations cannot solve the query in practice (that is, within an acceptable amount of time). Using geometric properties of space-time prisms, we developed a method that decides whether n space-time prisms intersect, with a time complexity of $O(n^3)$. Additionally, our method is capable of producing a *sample point*, which is a point in the intersection of the n space-time prisms, if it exists. Furthermore, we introduced a variant of the generalized alibi query, called the alibi query at a fixed location, which asks whether or not the moving objects may have met at a specific position in space. We found a new description of the spatial projection of the intersection of n space-time prisms, which is exactly the region in space where the objects may have met (between two measured points), and allows answering the spatial variant of the generalized alibi query in linear time.

References

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