Abstract and Discrete Models for Uncertain Spatiotemporal Data

Erlend Tøssebro and Mads Nygård

Department of Computer Science, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway
tossebro, mads @idi.ntnu.no

The theme of this presentation is uncertainty in spatial and spatiotemporal databases. Due to lack of accurate measurements, or rapid changes in time, spatial and spatiotemporal data are often uncertain. Our work presents new abstract and discrete models for uncertain spatial and spatiotemporal information. The models are based on the principle that one knows that the uncertain object, regardless of type, must be within a certain area.

The first part of this presentation concerns an abstract model. This is to the authors’ knowledge the first attempt to create a general type system that is capable of modelling positional uncertainty with spatial data. Individual uncertain types have been modelled before, but no paper has studied points, lines and regions and used the same principles to model all three. It also seems to be the first model to handle temporal as well as spatial uncertainty. Our work contains mathematical definitions of uncertain points, lines, regions and temporal versions of these. Our work also contains definitions of relevant operations on these types. These operations are also evaluated for their usefulness with regard to uncertain data.

The second part of this presentation concerns three discrete models which are all based on the abstract model mentioned earlier. One of these is an advanced model that manages to model almost all of the aspects of the abstract model, but at the cost of increased need for storage space. It is also difficult to compute probabilities in a consistent manner for this model.

The second model is of medium complexity, and balances storage use and modelling power. It also has the advantage that computing probabilities in a consistent manner is much easier than for the advanced model. The third model is an attempt to bring the storage space needed as low as possible. It therefore has somewhat limited modelling power. Unlike the two other discrete models, it cannot be extended to handle spatiotemporal data.

The handling of spatiotemporal data is based on how it is handled for crisp data in [1] and [2]. Our work makes two important additions to these models so that they can handle uncertain data. First, it presents ways of generating a sliced representation when the times the snapshots were taken are uncertain. Second, it details how operations change as a result of uncertainty. The Initial and Final operations, which in the crisp case return the initial and final shapes of an object, cannot be defined in the uncertain case. Our work discusses how these operations can be replaced in the uncertain case.

The medium complexity model has been partially implemented. This shows that it is possible to create an implementable model for uncertainty in spatial and spatiotemporal data.

However, analysis of storage requirements in the discrete models shows that storing uncertain data requires significant amounts of storage space. Even the simple model increases storage space by 1.75 times for curves and regions, and by 2 times for base types compared to similar models for crisp data. In the advanced model, regions require 2 times as much space, curves 3.75 times as much space and points N times as much space as the corresponding crisp types. This shows that there is a trade-off between modelling capability and storage space needed. The more complete models require more storage space.

Another conclusion from our work with the discrete models is that there is a trade-off between modelling capability and how easy it is to compute probability functions consistently. For the advanced model, special additions must be made if one wants consistent results from the probability functions. Some of these additions require extra storage space and impose limitations on the modelling capabilities. The less complex models do not require such special considerations.