An Extension of Simple Feature Database Schema for Spatiotemporal Observations

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Abstract. *Recent technological advances in spatiotemporal observation gathering have prompted new applications which handle spatiotemporal information. Such information treatment in database management systems (DBMS) has been a growing research agenda in geographic information science. Existing DBMS have been extended to deal with spatial data, complying with the Simple Feature Access (SFA) specification. This compliance has assured a fair degree of spatial data interoperability. This paper presents a summary of an ongoing work whose objective is to extend the SFA database schema to deal with spatiotemporal observations. The proposed schema also addresses three data types, moving object, geosensor time series and coverage, which are built on spatiotemporal observations.*

Keywords: *spatiotemporal database; spatiotemporal observations; moving object; coverage.*

1. Introduction

Although most spatiotemporal phenomena are continuous over time and space, they are often measured by using discrete observations. For instance, in order to study the temperature variation in a city, we usually measure its values in some distinct time instants and spatial locations within the city limits. When tracking an animal, for behavioral and ecological studies, its path is represented by a set of discrete observations, each one containing the spatial location of the animal at a certain time instant. These two examples illustrate how discrete observations play an important role on representing continuous phenomena, being the sampling units available for it.

Regarding observations, OGC and ISO have proposed a specification called *Observations and Measurement* (O&M) [OGC 2010]. According to O&M, an *observation* is the result of a measurement associated to a discrete time instant or period which assigns values to a phenomenon. We define *spatiotemporal observation* as an observation whose one of its values represents a spatial location or extent.

A set of spatiotemporal observations can be viewed from different perspectives, depending on the kind of information that an application or user is interested in extracting from it. In the city temperature example, the spatiotemporal observations are taken to represent a property variation over time within a spatial extent, whereas in the animal tracking, they are taken to represent an object trajectory over space and time. In the former case, an application is interested in *how a property varies within a spatiotemporal extent*, while in the latter, in *how the objects move over time and space*.

In computer science, a way to view a data set from a certain perspective is to assign a type to it. According to Guttag et al. [1978], a *data type* is a class of objects and a collection of operations on those objects which define their behavioral characteristics.

For instance, in order to view and handle the animal observations as trajectories, we can encapsulate them as a *moving object* data type [Guting and Schneider, 2005]. Or, in order to extract information about the temperature variation over time within the city limits, we can encapsulate the temperature observations as a *coverage* data type [OGC 2006c].

Recent technological advances in spatiotemporal observation collecting, such as Earth Observation and GPS satellites, mobile computing as well as geosensor networks, have motivated new applications which have to deal with spatiotemporal information. Therefore, such information treatment in database management systems (DBMS) has been a growing research agenda in geographic information science and system technologies.

Regarding spatial information management in database systems, open and proprietary DBMS have been extended to treat spatial data, such as PostGIS and Oracle Spatial. Most of these spatial extensions have conformed with the Simple Feature Access (SFA) specification defined by the International Organization for Standardization (ISO) and the Open Geospatial Consortium (OGC) [OGC 2006a] [OGC 2006b]. This compliance has assured a fair degree of spatial data interoperability at the DBMS level. All OGC compliant geographical software tools and libraries are able to store, load and query spatial data in these extensions

Considering that spatiotemporal observations are available sampling units for representing continuous phenomena and that they can be viewed from different perspectives according to the application they are involved with, we consider spatiotemporal observations as basic and atomic units to represent spatiotemporal information in database systems.

This paper presents a summary of an ongoing work whose objective is to extend the SFA database schema to accommodate *spatiotemporal observations*, aiming to keep the existing spatial data interoperability at database system level. The proposed schema is composed of metadata tables that describe other ones which store *spatiotemporal observations* and additional information when such observations are viewed as *moving object*, *geosensor time series* and *coverage* types.

2. Spatiotemporal Observations

This work considers spatiotemporal observation as an atomic data type which is basic to build other spatiotemporal types, such as *moving object*, *geosensor time series* and *coverage*. Actually, these other types define different views over spatiotemporal observations.

Guting and Schneider [2005] define *moving objects* as entities whose spatial positions or extents change continuously over time and propose a set of operations on them, such as distance between two of them and intersection between a moving object and a region. In order to be encapsulated as a moving object type, a spatiotemporal observation has to contain, at least, two elements: a spatial position or extent (represented by a geometry type) and a time instant or period (represented by a temporal type) when the object is at this position.

This paper defines *geosensor time series* as a variation of a property value over time measured by a geosensor, that is, a sensor associated to spatial locations. The spatial location of a geosensor can be fixed (stationary) or unfixed (moving). Operations on geosensor time series are related to the attribute variation over time in each sensor, for instance, *when* the attribute value was lower than a given value or *how long* it remained higher than we expected. In order to be encapsulated as a geosensor time series type, a spatiotemporal observation has to contain, at least, three elements: the sensor spatial location (represented by a geometry type), a time instant or period (represented by a temporal type), and the property value (represented by a numerical or textual type) measured by this sensor at this time.

OGC and ISO specifications use the term *coverage* to refer to *field* [Worboys and Duckham, 2004] and define it as a function that associates positions within a bounded space (its domain) to attribute values (its range) [OGC 2006c]. Its domain can be of a spatial, temporal or spatiotemporal type. Operations on coverage are related to *how* the attribute values vary within its domain, such as *where/when* the attribute value is lower than a given value or *how* the attribute variation is over time in a certain region or location.

In order to be encapsulated as a coverage type, a spatiotemporal observation has to contain, at least, three elements: a spatial location (represented by a geometry type), a time instant or period (represented by a temporal type), and an attribute value (represented by a numerical or textual type) measured in this location and time.

3. Extending the Simple Feature Database Schema

This work extends the SFA database schema to accommodate spatiotemporal observations. The proposed schema is presented in Figure 1, where the two tables inside the cyan region are defined in the SFA specification and the other ones in this work.

In our proposal, feature properties whose values are measured over time are stored in a *st_observations* table, where each spatiotemporal observation is represented as a row. On the same way that the SFA proposes a table called `geometry_columns` to describe the available *feature* tables and their geometry properties, this work proposes a table called `st_observations_tables` to do so for available *st_observations* tables and their properties. Moreover, there is a table to describe the temporal properties of a *st_observations* table, called `temporal_columns`.

A spatiotemporal observation has three temporal properties, *phenomenon*, *valid* and *result time*. The *phenomenon* time represents the time, instant or period, when the observation is actually measured. The *valid* time describes the time period during which the observation is available to be used. The *result* time represents the instant when the observation becomes available, typically when the observed values must be processed before being used. These properties are of a temporal type and must be registered in the `temporal_columns` table.

Besides temporal properties, a spatiotemporal observation can have two kinds of observed properties, *basic* and *spatial*. Each one is stored in a *st_observations* table column. Observed basic columns are of basic types, such as *String*, *Float*, *Integer* and *Boolean*, whereas observed spatial columns of *Geometry* types.

The spatiotemporal observations of *a st_observations* table can be associated to a *feature of interest* that is stored in another table, the latter being a *feature* table. In this case, in order to do this association, a *st_observations* table must have a column that can be linked to a *feature* table column. The information about how to link both tables is described in the `st_observations_tables` table.

This work also proposes three new tables, `moving_object_observations`, `coverage_observations`, and `gs_time_series_observations`, to describe additional information about *st_observations* tables that store spatiotemporal observations associated to *moving object*, *geosensor time series* and *coverage* types, respectively.

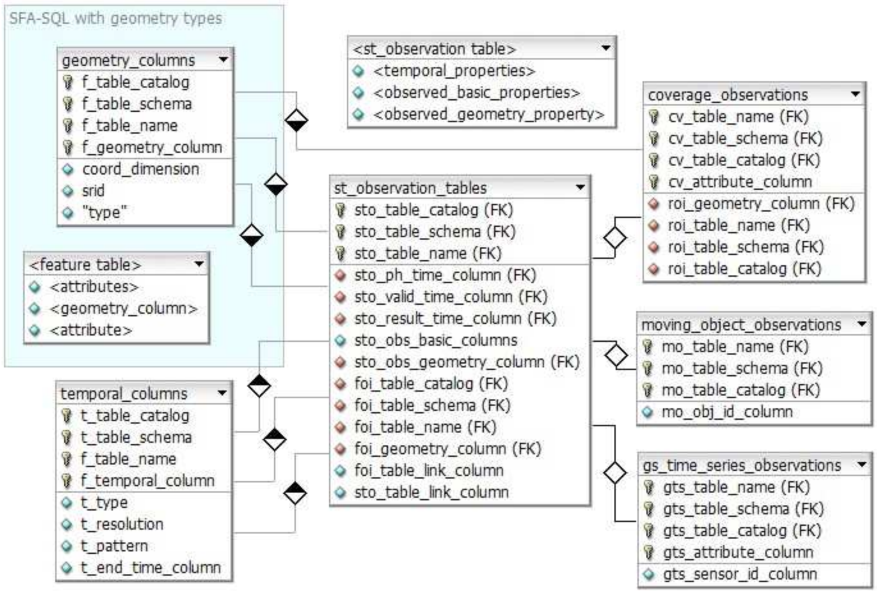

Figure 1. Extension of SFA database schema for spatiotemporal observations.

4. Conclusion

This paper presents a summary of an ongoing work whose objective is to extend the SFA database schema to accommodate spatiotemporal observations.

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