Chapter 1
Spatial and Spatiotemporal Data Types as a Foundation for Representing Space-Time Data in GIS

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ABSTRACT

A data type comprises a set of homogeneous values together with a collection of operations defined on them. This chapter emphasizes the importance of crisp spatial data types, fuzzy spatial data types, and spatiotemporal data types for representing static, vague, and time-varying geometries in Geographical Information Systems (GIS). These data types provide a fundamental abstraction for modeling the geometric structure of crisp spatial, fuzzy spatial, and moving objects in space and time as well as their relationships, properties, and operations. The goal of this chapter is to provide an overview and description of these data types and their operations that have been proposed in research and can be found in GIS, spatial databases, moving objects databases, and other spatial software tools. The use of data types, operations, and predicates will be illustrated by their embedding into query languages.

INTRODUCTION

The term *data type* is a concept of computer science to describe a set of homogeneous values together with a collection of operations defined on them. Examples are the data types *float* and *integer* with the numerical operations +, -, and /. Independent estimations (Daratech Inc., 2004; DeMers, 2008; Gonzales, 2000) state that approximately 80% of all data in the world have spatial features (e.g., location, shape) or a spatial reference (e.g., address, landmarks). Corresponding data types are therefore essential to model and represent the variety of these data in GIS. It is the author's opinion that the three notions of *space*, *time*, and *uncertainty* (*STU*) express the main, characteristic features of data dealt with in a large number of geospatial application areas like geography, geology, earth science, meteorology, hydrology, oceanography, and disaster management, to name a few only. Figure 1 indicates this by the *Space-Time-*

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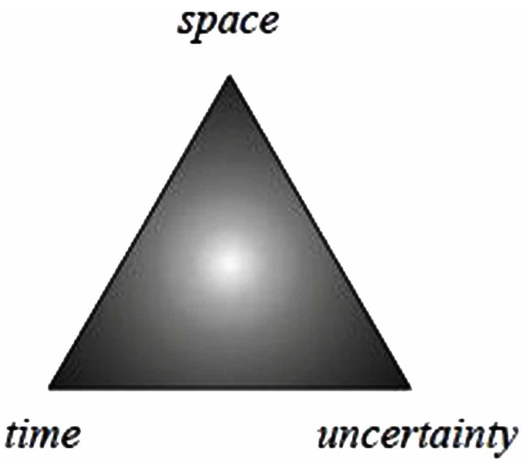
Figure 1. The Space-Time-Uncertainty (STU) triangle



Uncertainty (*STU*) *triangle*. The final goal, which has not been reached so far, is to appropriately combine all three features and reach the "center of the triangle".

The main objectives of this chapter are to:

1. Describe why and which special data types are needed in computational systems like GIS, spatial database systems, and moving objects database systems in order to represent and process the different feature combinations and
2. Motivate, introduce, and illustrate suitable STU data types and their properties and operations. In the context of this handbook we are especially interested in all combinations of features that involve space.

This means we are interested in the combinations of:

1. Space alone (*crisp spatial data types*),
2. Space and uncertainty (*vague*, *rough*, and *fuzzy spatial data types*),
3. Space and time (*spatiotemporal data types*), and
4. Space and time and uncertainty.

BACKGROUND

Figure 2 shows the STU feature combinations for which data types have been defined. A large amount of research and literature has focused on *crisp* spatial data stored in *spatial database systems* and *Geographical Information Systems*. The adjective "crisp" emphasizes the assumption that the location, shape, and extent of spatial phenomena are precisely known and/or represented. A general introduction to spatial databases is provided in two textbooks (Rigaux, Scholl, & Voisard, 2002; Shekar & Chawla, 2003) and a review article (Güting, 1994). The computational aspects of Geographic Information Systems (GIS) have been described in (Worboys & Duckham, 2004). The aforementioned references as well as