# Chapter 19
# Methodical Spatial Database Design with Topological Polygon Structures

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## ABSTRACT

*Spatial databases form the foundation for a Spatial Data Infrastructure (SDI). For this, a spatial database should be methodically developed to accommodate its role in SDI. It is desirable to have an approach to spatial database development that considers maintenance from the early stage of database design and in a flexible way. Moreover, there is a lack of a mechanism to capture topological relations of spatial objects during the design process. This paper presents an approach that integrates maintenance of topological integrity constraints into the whole spatial database development cycle. The approach is based on the concept of Abstract Data Types. A number of topological classes have been identified and modelling primitives developed for them. Topological integrity constraints are embedded into maintenance functions associated with the topological classes. A semi-automatic transformation process has been developed following the principles of Model Driven Architecture to simplify the design process.*

## INTRODUCTION

With the current advances in Information and Communication Technology, there has been a problem shift from data availability to data maintenance. A database is a large, structured and integrated collection of data. A Database Management System (DBMS) is a software system used to create and manage databases. Today's best approach to managing huge amounts of data is to use a DBMS. The field of Geographic Information Systems (GIS) makes no exception. However, in GIS the problem becomes much more complex due to the nature of spatial data that make a spatial database (Tveite, 2001). A spatial database is a special type of database which, in addition to containing con-

ventional attribute values of the objects, contains data about their geographic location and shape. In the field of spatial database development, a lot of work has been done to capture the semantics of spatial objects such as their geographic location and shape (Shekhar et al., 1999). However, less importance has been given to capturing their spatial relations. For instance, spatial objects such as provinces of a country can be modelled as polygons and their geographic coordinates are recorded to indicate their geographic location. However, their spatial relations that they cannot overlap and they form a contiguous area which is the country, are not modelled or it is done in an inflexible way if done. These spatial relations will later form database integrity constraints that need to be maintained. The spatial integrity constraints of the objects are among the most important problems in modelling spatial databases (Shekhal et al., 1999). These considerations highlight the need for a mechanism to capture spatial relations, and an improved methodology for spatial database design which considers the maintenance of spatial integrity constraints throughout the database development cycle.

Egenhofer and Franzosa (1991) distinguish three categories of spatial relations; topological relations, metric relations and relations concerning the partial and total order of spatial objects. Topological relations are spatial relations that are not affected by elastic transformations such as rotation and scaling (Egenhofer et al., 1994). This paper presents an improvement to existing spatial database design methodology by including also topological relations in the conceptual model of the database. Through a semi-automatic transformation process, topological relationships are carried at all design steps till the implementation where they become database integrity constraints that are enforced using a set of maintenance functions. The work presented in this paper focuses on collections of area features that display topological dependencies. The paper is structured as follows; after this introduction, we present an overview of currently existing approaches of data modelling in spatial databases. Next, we describe the proposed spatial database design methodology. To show the applicability of the proposed approach, we then present an example of implementing the proposed transformational design. Finally, we give some conclusions and the direction for future work.

## Related Work

The practice of data modeling has been adopted in the field of spatial database design because it simplifies the task of database design (Worboys et al., 1990). The data modeling approaches that have been widely used are Entity Relationship (ER) or Extended Entity Relationship (EER) and the Unified Modeling Language (UML). The extensibility of UML has made it the best choice as a modeling language for sophisticated applications, such as GIS dealing with complex objects and complex relationships (Marcos et al., 2003). In the domain of GIS, Tveite (2001) suggests a technique of extending the EER and the UML approaches with geographical icons. In his work, Tveite proposed different geographical icons for different object types (e.g., points, lines, regions, volumes). The geometry of a spatial object is modeled by adding the appropriate geographical icon to a standard modelling primitive. In this approach different object types are identified and their geometry is modeled but different topological relationships are not modeled. The consequence of this is that if the translation of the model into the database model is ever done, the spatial relationships are not included and the design does not provide any support for maintaining spatial integrity constraints. Wang and Reinhardt (2007) present a method to extend geographic data modeling also taking into account topological relations. This method uses a Constraint Decision Table (CDT) to store the topological integrity constraints. The problems of this approach are linked to the separation of the constraints from the UML conceptual schema and the mastery required for defining the constraints.

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