Chapter 12
Describing Spatio-Temporal Phenomena for Environmental System Development:
An Overview of Today's Needs and Solutions

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ABSTRACT

This paper is composed of two parts dealing with the modeling of environmental phenomena. The first part presents the traditional ER and OO formalisms dedicated to geographic information modeling. These languages focus mainly on representing the spatial and temporal properties of this type of information. Many of these languages express these properties visually by using pictograms. After a quick historical presentation of the languages, the authors show the various types of spatiality and temporality usually encountered in these languages. Often qualified as primitive, some of these spatialities and temporalities are simple. Others, which are more complex, result from combinations of simple spatialities and simple temporalities. Still others are used in very specific situations encountered during the development of geographical information systems. These different spatialities and temporalities are presented via examples provided in the field of environmental dynamics.

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1. INTRODUCTION

Recently, geographic information has become strategic information. In the agricultural and environmental fields, geographic information can help to improve agricultural practices, food traceability or decision-making. Decisions concerning the environment should be made based on reliable data Collecting quality data requires monitoring of agricultural practices and their impact, and, consequently, any information records linked to these practices. Information used for food traceability is very often geo-referenced. It is important to maintain spatiotemporal monitoring within agricultural and environmental practices.

According to two specific studies (Claramunt, Coulondre, & Libourel, 1997; Gayte, Libourel, Cheylan, & Lardon, 1997), geographic information has:

- Thematic properties describing business concepts within the domain of study (for example *land use* or *hydrographic network*),
- Spatial properties depicting the geometrical features of these business concepts,
- Temporal properties characterizing the state of an instance of a concept at a given date or the evolution of that instance.

Spatial and temporal properties concern a large number of objects: static objects (e.g., fields), moving objects (e.g., vehicles) or evolving objects (e.g., evolutions of the boundary of a wetland across seasons).

A large number of studies have been proposed to model and develop *Geographic Information Systems (GIS)* based applications. The nature of the information in this type of applications is complex and modeling GIS-based applications is a major challenge (Bédard, Larrivée, Proulx, & Nadeau, 2004). The first paper to present and demonstrate the advantages of using pictograms to simplify entity-relationship models in GIS was written 21 years ago (Bédard & Paquette, 1989). Later, this formalism was adapted to be used in the object-oriented paradigm (Bédard, 1999b). The work of (Kösters, Pagel, & Six, 1995) also shows that models of GIS-based applications can be simplified by using formalisms dedicated to geomatics applications. Several authors also addressed this issue as presented the *Encyclopedia of GIS* (Shekhar & Xiong, 2008).

After an overview of the different modeling languages designed by researchers or companies (Section 2), in Section 3, this paper shows how geographic information can be modeled using the specific method proposed in (Bédard, 1999b). This method is currently the richer formalism; it allows modeling numerous spatial and temporal concepts. A conclusion finalizes this paper in Section 4.

2. OVERVIEW OF THE LANGUAGES FOR MODELING GEOGRAPHIC INFORMATION SYSTEMS

A large number of methods and formalisms have been developed during the last twenty years to facilitate modeling of GIS-based applications (Bédard & Paquette, 1989). During the past decade, the number of methods and formalisms has exploded, and we are witnessing a new level of maturity with the availability of tools, tool extensions, web sites, publications and the recognition of this expertise in the *Encyclopedia of GIS (Shekhar & Xiong, 2008)*. Table 1 presents the main methods and formalisms dedicated to geographic information modeling. Most of these methods and formalisms are based on the Entity-Relationship (ER) or Object-Oriented (OO) paradigms. Amongst the latter, several formalisms are based on the *Unified Modeling Language* (UML), today's *de facto* standard that has been adopted by the *Object Management Group*, the *Open Geospatial Consortium* (OGC) and the ISO/TC211 Geographic Information/Geomatics Technical Committee.