Chapter 4
Geographical Process Representation: Issues and Challenges

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ABSTRACT
This chapter discusses the issues and challenges arising when building a general spatio-temporal ontology for representing and reasoning of geographical processes as part of a desired universal semantic reference system of geographic space. It examines the foundations and formalisms upon which the development of such an ontological model of geographical processes can be based. The chapter begins by providing a background of essential concepts related to the representation of geographical processes. Then overviews of several approaches to representing spatio-temporal processes and how to associate them with geographic space are given. Following this, the chapter discusses several open issues on the topic and presents a set of desiderata for representing and reasoning about real-world dynamic geographical phenomena. This discussion covers aspects of space, time, object, event, state, and process as the essential concepts to represent geo-processes. It also covers aspects of spatial-temporal granularity and spatio-temporal aggregation, describing how they relate to geographical processes. Finally, this chapter also explores the phenomenon of vagueness and how it affects the representation and reasoning about geo-processes. The chapter concludes by indicating directions for future research and recapitulating its overall coverage.

INTRODUCTION
In recent years, there has been an increasing awareness of the importance of ontologies as an effective resource for representing knowledge in the geographical domain, providing a precise conceptualisation of the entities present in geographic space and the relationships between them (Winter, 2001; Egenhofer & Hirtle, 2005). Coupled with this, substantial efforts have been made by many scientists in Geographical Information (GI) Science community to include time...
and the representation of dynamic geographic phenomena as elemental constituents of GI science (Peuquet, 2001, 2002). The development of a universal semantic reference system of geographic space is an intricate research challenge which raises numerous issues. This chapter presents a perspective on these issues by examining what has been and is currently being done towards the development of a comprehensive ontology of geographical processes.

Geographers have been also making notable contributions in the field of geostatistics, and have been producing an increasing amount of useful data related to a variety of fields (e.g., hydrology, geology, climate, urban planning, logistics, and epidemiology). Furthermore, the advance in remote sensing techniques, geo-sensor networks and other areas of computer science has been contributing for the production of effective mechanisms for generating spatio-temporal geographic data. Nevertheless, such data shall be fully exploited only when we provide intelligent ways to enrich these data semantically. This chapter surveys the object-based and the field-based views of spatio-temporal data representation and gives an insight about the challenges for the development of a comprehensive ontology of dynamic geographic phenomena which is able to manipulate both views.

In GI Science, some research has been presented as an approach to handling dynamic geographic phenomena. Nonetheless, the development of such systems has been frequently limited to a particular area of application (e.g., meteorology, traffic studies and population studies) and usually with the purpose of simulation and prediction. Examples can be found in Parker, Manson, Janssen, Hoffmann, and Deadman (2003), and White and Engelen (1993). In the field of Knowledge Representation, spatio-temporal reasoning (Frank, Campari, & Formentini, 2000) and reasoning about spatio-temporal changes (Hornsby & Egenhofer, 2000) have been investigated. Theories involving objects, events, states, and process have also become of interest (Galton, 2007; Grenon & Smith, 2004). We examine existing models to deal with space, time, event and process and point out important aspects which should be considered for building a universal ontology of geographical process.

A characteristic of geographical information is that it may be affected by vagueness, leading to additional representational difficulties (Bennett, 2010). Different methods have been proposed to handle vagueness in geography, such as Fuzzy Logic (Zadeh, 1965, 1968) and Supervaluation Theory (Fine, 1975). In addition, ontologies have emerged as a suitable resource for identifying, classifying and reasoning about vague geographical features, as demonstrated in Bennett, Mallenby, and Third (2007, 2008). In this chapter we draw special attention to the phenomenon of vagueness and how it affects modelling of geographical processes. Different approaches to handling vagueness in geography shall be surveyed and a discussion is given about the issues which arise in applying them to a spatio-temporal geo-ontology.

Vagueness in geographical processes is intimately related to the granularity of spatial and temporal information, and different interpretations may arise depending upon the level of granularity at which some process is observed. Spatial granularity has been treated in Geographical Information (GI) science and in the field of spatial data mining, respectively, to improve the capability of the system to work appropriately with different map scales and to develop clustering algorithms which group spatial regions according to a set of characteristics (spatial or not), as shown in Anders (2003), Bailey-Kellogg and Zhao (2003), Yaolin, Molenaar, Kraak, and Yanfang (2002). This chapter examines how spatial and temporal granularity relates to the conceptualisation of geographical process and to methods of handling vagueness in geographical process ontology.

The remainder of this chapter is organised as follows. The next section presents a background on the main topics discussed in the chapter to