Chapter 3
A Web–Based Tool for Spatio–Multidimensional Analysis of Geographic and Complex Data

Sandro Bimonte
Cemagref, France

ABSTRACT

Spatial OLAP (SOLAP) integrates spatial data into OLAP systems, and SOLAP models define spatial dimensions while measuring spatio-multidimensional operators. In this paper, the author presents the concepts of geographic and complex measures that allow integrating geographic and complex information as subjects of analysis in spatial data warehouses. The concept of geographic measure extends the concept of spatial measure to the semantic component of geographic information. The concept of complex measure allows introducing complex data as subjects of multidimensional analysis. To reduce the gap in flexibility between spatial and multidimensional analysis, this paper proposes a symmetrical representation of measures and dimensions. Additionally, the author presents a Web-based SOLAP prototype, GeWOlap, that enriches existing SOLAP tools by effectively and easily supporting symmetrical geographic/complex measures and dimensions for modeling and visualization. To validate this approach, the simulated environmental data concerning the pollution of the Venice lagoon is used.

1. INTRODUCTION

Data warehousing and On-Line Analytical Processing (OLAP) systems are technologies intended to support business intelligence. OLAP models are based on the concepts of dimensions and facts (Inmon, 1996). A fact is a concept that is relevant for the decision-making process, and it is described by a set of numerical indicators (measures). Dimensions, composed of hierarchies, allow for the analysis of facts along different analysis axes and at different levels of details.

Nowadays, new information and communication technologies allow the collection of huge amounts of geo-referenced agricultural and environmental data. These data come from remote sensing systems or other computer applications that record agricultural practices. OLAP systems

were recently successfully used to analyze agricultural and environmental data (Bédard et al., 2008). Therefore, a new kind of Decision Support System, called Spatial OLAP (SOLAP), has been developed in order to introduce Geographic Information Systems (GIS) functionalities (memorizing, analyzing and visualizing) into OLAP and data warehousing systems. SOLAP tools extend the tiers of the classical OLAP system architecture in order to manage spatial data, provide a cartographic representation of facts on maps, and perform SOLAP operations through simple user interactions with the maps. Spatial OLAP integrates spatial data into multidimensional models by defining the concepts of spatial dimension, spatial measure, and spatio-multidimensional operators.

In our opinion, SOLAP models only partially exploit the complex nature of geographic information in the multidimensional decision-making process, as they only partially use the semantics of geographic information and the flexibility of spatial analysis. The subjects of analysis SOLAP models (spatial measures) are generally spatial objects or numerical values derived from geometry (i.e., surface area, distance, etc.). Thus, in (Bimonte et al., 2006) we define the concept of geographic measure, introducing the descriptive attributes and spatial/thematic/ "map generalization" relationships of geographic information in multidimensional analysis. We also provide a symmetrical representation of measures and dimensions in spatial data warehouses: each level of a dimension can be used also as a subject of analysis. This increases the multidimensional analysis capabilities since it allows the system to analyze and discover possible trends and relationships among all the elements (levels and measures) of the data warehouse (Pinet & Schneider, 2009). The need for symmetry of measures and dimensions is very important for multidimensional geographic applications, since

the process of spatial analysis is flexible, in the sense that the analyst can iteratively change and/ or reformulate its goals (subjects of analysis) throughout the spatial analysis process. Therefore, in this paper we extend the concept of geographic measure to that of complex measure. This enables the multidimensional analysis of complex data in functions of geographic information.

In this paper, we describe the implementation of these concepts in our prototype, called GeWOlap. GeWOlap enriches the functionalities of existing SOLAP tools in order to support the modeling and visualization of complex/geographic measures and the symmetry of dimensions/measures more easily and fully. For this purpose, we have selected a particular logical multidimensional model, redefined the aggregation process of the OLAP server aggregation process, and applied some geo-visualization techniques. GeWOlap extends our previous work presented in (Bimonte et al., 2006; Bimonte et al., 2007) and is based on the spatio-multidimensional model GeoCube (Bimonte et al., 2006b). To validate the method, we use simulated environmental data concerning the pollution of the Venice lagoon. We present some SOLAP applications to analyze water pollution phenomena in the Venice Lagoon in terms of several factors, such as time, pollutant, and location. However, it is important to note that we have used simulated pollution data, and these applications have not been used by the Consortium for Coordination of Research Activities concerning the Venice Lagoon System (CORILA) experts to draw any conclusions on the phenomenon of pollution.

The paper is structured as follows. Section 2 presents the functionalities of GIS and the main concepts of data warehousing, OLAP, and Spatial OLAP. Section 3 describes our new concepts of geographic and complex measures. Section 4 describes the three tiers of our prototype. Section 5 presents the environmental case study, and Section 6 discusses related work.

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