Chapter 8.8
Enhancing Decision Support Systems with Spatial Capabilities

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ABSTRACT

This chapter introduces spatial dimensions and measures as a means of enhancing decision support systems with spatial capabilities. By some way or other, spatial related data has been used for a long time; however, spatial dimensions have not been fully exploited. It is presented a data model that tightly integrates data warehouse and geographical information systems — so characterizing a spatial data warehouse (SDW) — ; more precisely, the focus is on a formalization of SDW concepts, on a spatial-aware data cube using object-relational technology, and on issues underlying a SDW — specially regarding spatial data aggregation operations. Finally, the MapWarehouse prototype is presented aiming to validate the ideas proposed. The authors believe that SDW allows for the efficient processing of queries that use, jointly, spatial and numerical temporal data (e.g., temporal series from summarized spatial and numerical measures).

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INTRODUCTION

Decision support systems aim to identify historical and localizable tendencies, behaviors and information patterns, which help the decision support process. The technologies that underpin this process, using time and space dimensions as decisive factors, are: data warehouse (DW) — with online analytical processing (OLAP) interface — and geographical information systems (GIS). DW/OLAP systems are responsible for both data extraction from several operational sources and data organization according to a historical, thematic and consolidated multi-dimensional model (Malinowski & Zimányi, 2004), composed by facts (numerical measurements related to business processes) and dimensions (descriptive aggregated information, often hierarchically disposed, which is arranged to define the facts). Conceptually, a DW is a multi-dimensional array, or simply a data cube. OLAP queries over a DW provide data exploration and analysis operations by means of aggregate navigation through dimension hierarchies — drill-down, roll-up. Other typical OLAP operations are data cube slicing, dicing and pivoting. Materialized data cubes aim to guarantee high performance of OLAP operations. On the other side, GIS provide manipulation, storage and visualization of spatial data, so that decision-makers may enhance the quality of their analysis using the spatial dimension.

The main objective of this chapter is to present a spatial data warehouse (SDW) (Rivest, Bédard, & Marchand, 2001; Pourabbas, 2003) conceptual model which tightly integrates DW and GIS. Also, we rigorously define a logical model suitable for implementing decision-making processes using spatial data. The other two main contributions of the chapter are: (1) the proposal of a query language for the logical model with query optimization techniques, and (2) the presentation of a prototype developed in order to validate our ideas.

The advantages separately provided by GIS and DW technologies have motivated research on their integration. Existent integration approaches do not fulfill the requirements for a *stricto sensu* integration, which are: (1) to summarize spatial data (e.g., map-overlay, region merge) through spatial dimensions — spatial roll-up and its counterpart, spatial drill-down —, and (2) to synchronize spatial and numerical historical summarized data.

A case study on agricultural crops in Brazil is discussed throughout the chapter. In order to have an efficient seed distribution policy to Brazilian farmers, several issues ought to be taken into account including soil type, rainfall and type of seed. Hence, a SDW may help authorities in finding the best policy for a particular situation, based on dynamic maps, tables, graphics, reports, and so on. As it can be noticed, this application encompasses space, time and analytical dimensions. Query examples exploiting these dimensions in this particular application domain include:

- Which cultivation better adapts to each municipality, region or state following the plantation conditions of last year (semester or month, etc.)?
- What are the favorable pattern conditions to the corn (mango or coffee, etc.) cultivation for a particular geographical region?
- Where is the best place to plant a particular crop?
- When is the best season for planting a given crop?

The remainder of this chapter is organized as follows. A background with discussion of related work is presented in the following section. Then our spatial multidimensional model is addressed, followed by the proposal of an object-relational spatial data cube. Query optimization techniques and a description of a prototype which aims to validate the proposed ideas — the MapWarehouse Project — are presented. Finally, the conclusion and further research to be undertaken are highlighted.

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