A FORMAL CONCEPTUAL MODEL AND DEFINITIONAL FRAMEWORK FOR SPATIAL DATACUBES

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Spatial datacubes extend the datacube concept underlying the field of Business Intelligence (BI) into the realm of spatial analysis, geographic knowledge discovery, and spatial decision-support. The traditional computer science community has defined spatial datacubes and their fundamental components (e.g., spatial dimension and spatial measure) through formal models limiting spatial data as only those data that has a geometric representation. The geomatics community has pursued spatial datacube models with a much richer view of spatial data. However, the proposed models by the geomatics community have not yet been formalized using precise mathematical languages. This paper, for the first time, integrates the rigor of mathematical languages with the richer view of spatial data to provide a formal model and precise definitions of spatial datacubes and their fundamental components. The proposed definitions provide the scientific community with a common and precise terminology for the concepts involved in spatial decision-support databases.

Les cubes de données spatiales étendent le concept de cube de données sous-jacent au domaine de l'informatique décisionnelle aux domaines de l'analyse spatiale, de la découverte des connaissances géographiques et du soutien aux décisions spatiales. La communauté traditionnelle de l'informatique a défini les cubes de données spatiales et leurs composantes fondamentales (p. ex., la dimension spatiale et la mesure spatiale) au moyen de modèles formels limitant les données spatiales seulement à celles pouvant avoir une représentation géométrique. La communauté de la géomatique a approfondi les modèles de cubes de données spatiales avec une vision beaucoup plus étoffée des données spatiales. Toutefois, les modèles proposés par la communauté de la géomatique n'ont pas encore été officialisés en utilisant des langages mathématiques précis. Le présent article intègre, pour la première fois, la rigueur des langages mathématiques à la vision plus étoffée des données spatiales afin de présenter un modèle formel et des définitions précises des cubes de données et de leurs composantes fondamentales. Les définitions proposées offrent à la communauté scientifique une terminologie commune et précise des concepts impliqués dans les bases de données qui appuient les décisions.

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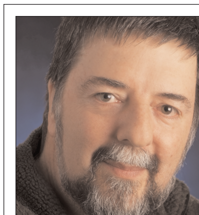

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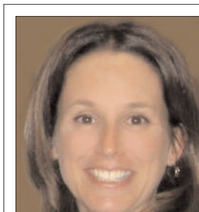

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1. Introduction

Strategic decision makers (analysts, executives, and managers) need to analyze and compare summarized data extracted from very large volumes of data. Indeed, it is more efficient to use aggregated and consolidated data covering a certain period of time rather than detailed individual records of transactional databases for strategic decision making. The difficulty in supporting both daily transactions and decision-support needs within a single database requires using a dual-database approach. This forms the typical backbone of data warehouses [*Bédard and Han* 2008]. A *data warehouse* is a subject-oriented, integrated, time varying, non-volatile collection of data that is used primarily in organisational decision making [*Chaudhuri and Dayal* 1997]. Data warehouses are typically modeled using the *datacube* (or *multidimensional*, in the sense of business intelligence) paradigm [*Gray et al*. 1997; *Abelló et al*. 2006]. In the datacube structure, analysis is performed along a combination of axes of analysis called *dimensions* (e.g., categories of products, administrative regions, periods), and hence the structure is termed *multidimensional.* Each dimension includes one or several *hierarchies*, each composed of different analysis *levels* (e.g., city-province-country hierarchy and city-county-region-country hierarchy which may compose a spatial dimension labelled "administrative regions"). The hierarchical structure allows users to view and analyze data at different levels of detail. An instance of a level is a *member* (e.g., "Montreal" is a member of the level "city"). *Measures* (e.g., population) are measurable quantities; these are analyzed against the members of different levels of dimensions. For instance, one may be interested in analyzing the measure "population" with respect to different levels of "administrative regions" and "time" dimensions.