

Chapter XXX

Query Processing in Spatial Databases

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INTRODUCTION

Spatial data management has been an active area of intensive research for more than two decades. In order to support spatial objects in a database system several important issues must be taken into account such as: spatial data models, indexing mechanisms and efficient query processing. A spatial database system (SDBS) is a database system that offers spatial data types in its data model and query language and supports spatial data types in its implementation, providing at least spatial indexing and efficient spatial query processing (Güting, 1994).

The main reason that has caused the active study of spatial database management systems (SDBMS) comes from the needs of the existing applications such as geographical information systems (GIS), computer-aided design (CAD), very large scale integration design (VLSI), multimedia information systems (MIS), data warehousing, multi-criteria decision making, location-based services, etc.

Some of the most important companies in the commercial database industry (Oracle, Informix, Autodesk, etc.) have products specifically designed to manage spatial data. Moreover, re-

search prototypes as Postgres and Paradise offer the possibility to handle spatial data. The main functionality provided by these products includes a set of spatial data types such as the point, line, polygon and region; and a set of spatial operations, including intersection, enclosure and distance. The performance enhancement provided by these operations includes spatial access methods and query algorithms over such indexes (e.g. spatial range queries, nearest neighbor search, spatial joins, etc). We must also cite the Open Geographic Information Systems (OGIS) consortium (<http://www.opengis.org/>), which has developed a standard set of spatial data types and operations and SQL3/SQL99, which is an object-relational query language that provides the use of spatial types and operations.

In a spatial database system, the queries are usually expressed in a high-level declarative language such as SQL; therefore specialized database software has to map the query in a sequence of spatial operations supported by spatial access methods (Shekhar & Chawla, 2003). Spatial query processing refers to the sequence of steps that a SDBMS will initiate to execute a given spatial query. The main target of query processing in the database field is to process the query accurately and quickly (consuming the minimum amount of time and resources on the computer), by using both efficient representations and efficient search algorithms. Query processing in a spatial environment focuses on the design of efficient algorithms for spatial operators (e.g. selection operations, spatial joins, distance-based queries, etc.). These algorithms are both CPU and I/O intensive, despite common assumptions of traditional databases that the I/O cost will dominate CPU cost (except expensive distance-based queries) and therefore an efficient algorithm is one that minimizes the number of disk accesses. In this article we focus on spatial query processing and not spatio-temporal query processing, where the queries refer to both spatial and temporal characteristics of the data (Manolopoulos et al., 2005).

BACKGROUND IN SPATIAL QUERIES AND PROCESSING

From the query processing point of view, the following three properties characterize the differences between spatial and relational databases (Brinkhoff et al., 1993): (1) unlike relational databases, spatial databases do not have a fixed set of operators that serve as building blocks for query evaluation; (2) spatial databases deal with extremely large volumes of complex objects, which have spatial extensions and cannot be sorted in one dimension; (3) computationally expensive algorithms are required to test the spatial operators, and the assumption that I/O costs dominate CPU costs is no longer valid.

We generally assume that the given spatial objects are embedded in d -dimensional Euclidean space (E^d). An object obj in a spatial database is usually defined by several non-spatial attributes and one attribute of some spatial data type (point, line, polygon, region, etc.). This spatial attribute describes the geometry of the object obj . $G \subseteq E^d$, i.e. the location, shape, orientation and size of the object. The most representative spatial operations, which are the basis for the query processing in spatial databases (Gaede & Günther, 1998; Shekhar & Chawla, 2003), are: (1) update operations; (2) selection operations (point and range queries); (3) spatial join; and (4) spatial aggregate queries, and (5) feature-based spatial queries.

- *Update operations*: Standard database operations such as modify, create, etc.
- *Point Query (PQ)*: Given a query point $p \in E^d$, find all spatial objects O that contain it.
- *Range Query (RQ)*: Given a query polygon P , find all spatial objects O that intersect P . When the query polygon is a rectangle, this is called a window query.
- *Spatial Join Query (SJQ)*: Given two collections R and S of spatial objects and a spatial predicate θ , find all pairs of objects

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