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# Spatial Data System: Architecture and Applications

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**ABSTRACT**
Database Management System has attained the highest level of changes and evolutuion in different types. It's process became very complex. It is become very difficult to store large and different types of data. One such data type is "Spatial data" i.e. data related to space. The System that manages this type of data is Spatial Database management System (SDMS). This paper discusses the evolution of Spatial Database Management System, its architecture and application in real world.

***Keywords:-*** **S**patial data, RDBMS, OODBMS, ORDBMS, GIS, MMIS

## I. INTRODUCTION

There are various areas that require management of geographic, geometric or spatial data i.e. data related to space. Spatial data represents multi-dimensional data with points, surfaces and lines, as a list of numbers using a particular coordinate system. With the advancement in IT Technology, Space information Technology has also developed with a wide application in Geographic Information System, Computer Aided Designing fields, data warehousing and NASA's earth observation system. The management system that helps in attaining this is Spatial Database Management System. Spatial database management system [1] is one which focuses on effective and efficient management of data such as space [2](including points, lines and polygons), parts of living organisms, engineering designs and a conceptual information space. Spatial databases are suitable for answering transactional queries where there are not a lot of historical components or aggregation. Spatial database do not use indexes for looking up values instead it uses spatial indexing for speeding up database operations[2]. Some commercial examples of spatial database management system are [1] Informix's spatial data-blades, Oracle's universal server and ESSRI's Spatial Data Engine.

## II. EVOLUTION OF SPATIAL DATABASE

The evolution of spatial database has gone through three stages:

### *1) Spatial database based on relational model(RDBMS)*

The technologies based on relational model for spatial database are used for commercial GIS software, such as ARCIINFO of ESRI, MGE of Intergraph etc. Its lacks in processing and packaging of data. It also cannot deal with the coinciding relationships, aggregation relationships and relationships between specifics and generals.

### *2) Spatial database based on Object-oriented spatial database(OODBS)*

With reference to object-oriented thinking, each surface features can be abstracted as a class object with public properties, such as point , line , area and so on. Specific surface features are an instance of the object. It also has its own attributes and manages various objects hierarchically. It is good at describing the complex data types. Its shortcomings are lack of OODBS standard, development tools and defense mechanism. Its model is complex.

### *3) Spatial database based on Object - Relational Spatial Database (ORDBMS)*

ORDBMS has the features inherited from both of SQL of relation world and object world in essence. It also adds flexibility in data server. It supports complex "user-defined" application object and logic. It uses abstract data type which can hide any complex internal structure and properties to express spatial object. It also adds that type's operation in user-defined data types.

Spatial databases in ORDBMS must support (at minimum):

- Complex (geometry) data types
- Spatial data within related tables – feature classes, feature datasets
- Validation rules - subtypes and domains
- Spatial metadata

- Spatial reference (coordinate) systems and transformations
- Topologies and methods for analyzing spatial relationships
- Geometric networks
- Multi-dimensional, hierarchical indexes for searching spatial data
- Storage of both spatial and non-spatial data in the same database

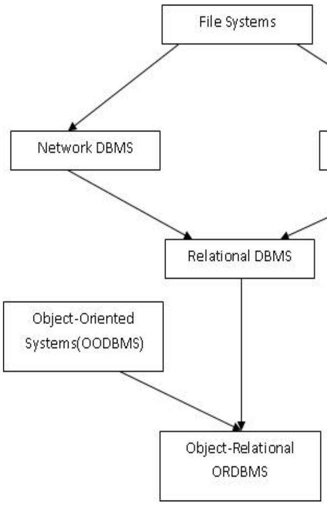


Fig. 1. Evolution of Spatial Database

## III. FEATURES OF SPATIAL DATABASE

1) Spatial Measurements
length of lines, area of polygon, the distance between geometries etc. can be measured easily in spatial database.

2) Spatial Functions
Modify existing features to create new ones, for example, intersecting features, etc.

3) Spatial Predicates:
Allows true/false queries about spatial relationships between geometries.

4) Geometry Constructors
Helps in creating new geometrics by specifying the vertices (points or nodes) which define the shape.

5) Volume
The size of spatial data are larger. It contains multidimensional data that require more storage space. Spatial database are more suited for multidimensional data.

## IV. GEOGRAPHIC INFORMATION SYSTEM(GIS) AND SPATIAL DATA

Geographic Information System(GIS)[4] is a technology for visualization and analysis of geographical data. It is the very basic principle behind the implementation of Spatial Database Management System. A GIS can be built as the front-end for any Spatial Database Management System. GIS applications consists of tools that allow users to create interactive queries (user-created searches), analysing spatial information, editing data of maps, and presenting the results of all these operations. Example of GIS Application are ArcGIS Online, CartoDB, GoogleMaps, TeraData.

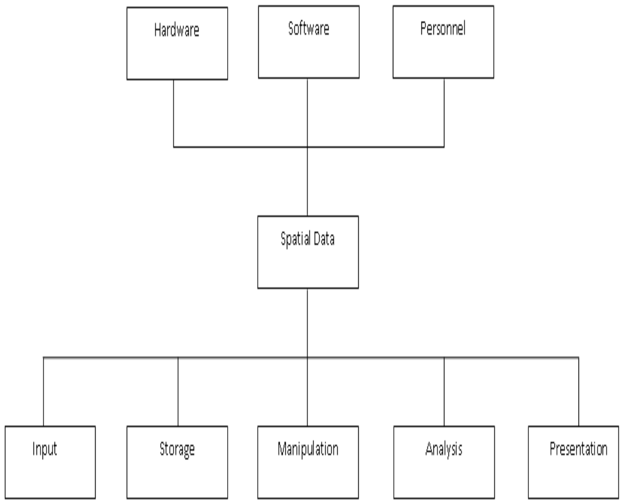


Fig. 2: GIS System

## V. ARCHITECTURE OF SPATIAL DATABASE

The architecture of Spatial Database Management System is three layer architecture.

***1) The top layer*:** The top layer comprises of the Spatial Data Application through which user communicate directly with the database. These Application includes GIS(Geographic Information System), MMIS(Multimedia Information System) or CAD(Computer Aided Design). These can be used for capturing, storing, manipulating, analysing, managing and presenting all types of spatial or geographical data.

***2) The middle layer:*** The middle layer is the spatial database where all of the domain knowledge are encapsulated. The Spatial Data Application Communicates directly with this layer. This layer interacts directly with both Application layer and database server. This layer has three parts:

A. Interface to Spatial Application

- Abstract Data Types: Spatial data types provides fundamental abstraction for modelling the geometrical structure of objects in space, relationships among them, their properties and their operations. It includes point, line, region, partitions and graphs (networks).

- Data Model: Traditionally we store and present spatial data in the form of a map. There are three basic types of spatial data models for storing geographic data digitally. They are[5]:

  a) Raster Model: Raster data models use grid-cell data structures where the geographic area is divided into cells identified by row and column. This data structure is commonly called raster.

  b) Vector Model: Vector storage implies the use of vectors (directional lines) for representing a geographic feature. Vector data is defined by the use of sequential points or vertices to make a linear segment. Every vertex is made up of an X coordinate and a Y coordinate.

  c) Image Model: Image data is used for the representation of graphical or pictorial data. that differs significantly from raster data.

- Interpretation of Spatial Data: It involves searching of useful object in the given collection of pixels data. It is used in Image Analysis and uses supervised and unsupervised approaches for interpretation[6].

- Networks: Spatial Networks are the graphs[7] in which geometric object are connected to each other by help of edges and vertices.

- Data Volume: The growing production of data[8] everyday has exponentially increased the data volume which are required to be managed and processed efficiently.

- Visualization: Information visualization [9] technique is used to present the data in a visual form allow users to derive insights from the data, and support user interactions.

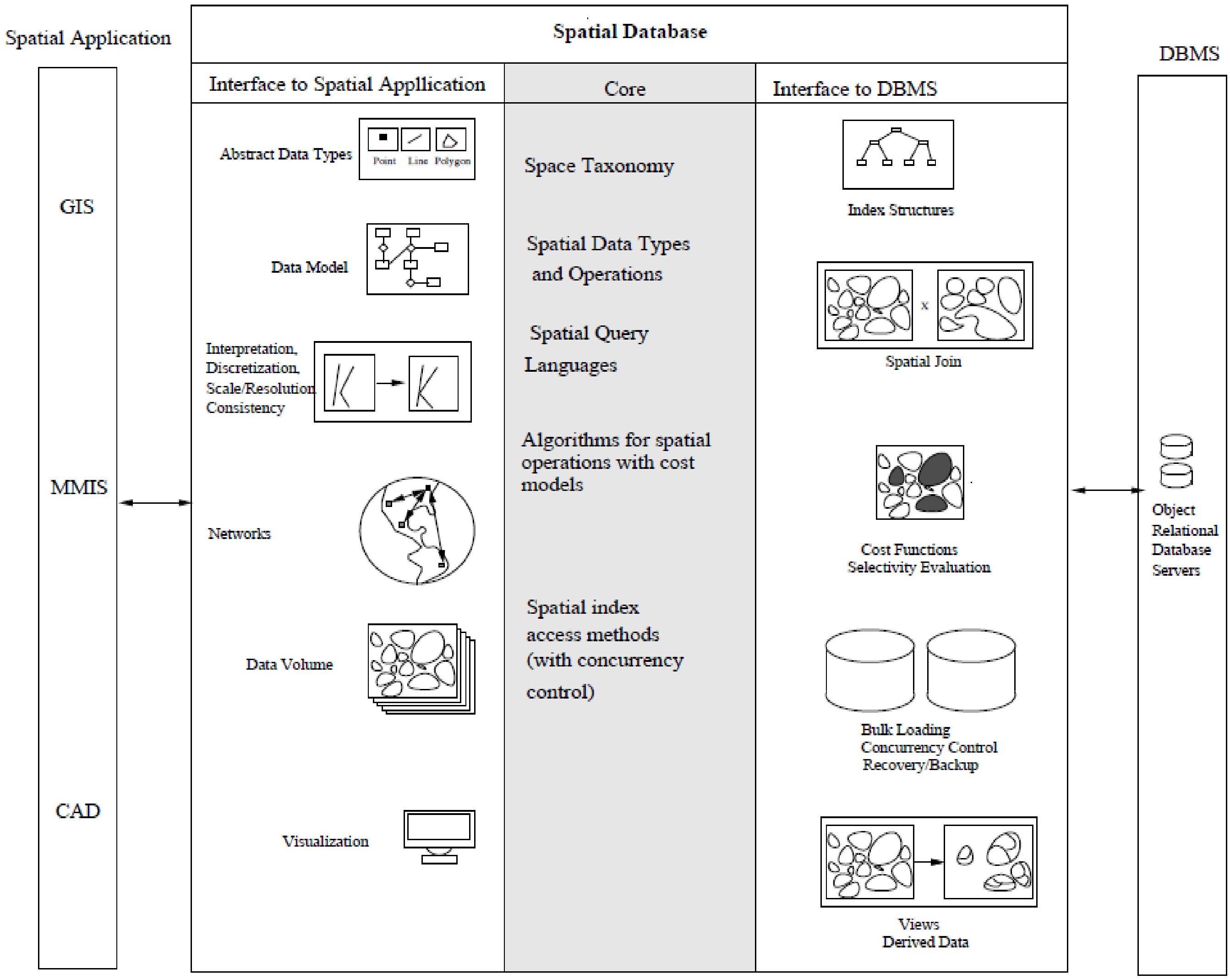


Fig. 2 : Three Layer Architecture Of Spatial Database

B. Core

Most of the domain knowledge is encapsulated in core. The core comprise of following :

- Space Taxonomy: It refers to multitude of description that are available to organise space[10]. These spaces can be Topological, Network, Directional, Euclidian.
- Spatial Data Types and Operations: Spatial data types[11] or geometric data types provide an abstraction by modelling the geometric structure of objects in space as well as their relationships, properties, and operations. Spatial Data Operations allow the storage of input data, their analysis and obtaining new data as output information[ 12]. Spatial Operation include Spatial Fig.3: Three Layer Architecture of SD
- Overlay, Spatial Search, Buffer Operation etc.
- Spatial Query Language: The spatial query language[13] has been designed as an extension of SQL and represent SQL concepts for spatial object and the integration of spatial operations and relationships.
- Spatial Index: Spatial indexing[14] is an important mechanism that helps to improve the spatial database information processing and information management.

C. Interface to DBMS

Interface to DBMS forms the lower layer of Spatial database and interact with the database. It has following components:

- Index Structure: Traditional Database uses B-tree for indexing and data storage but for multidimensional data single indexing is not suitable. So, R-tree are used for Spatial database indexing[15].
- Spatial Join: A Spatial join is a GIS operation that join data from one feature layer's attribute table to another from a spatial perspective. Spatial joins works by choosing a target feature and then comparing it spatially to other feature layers. The target features will inherit the attributes of other features if and only if these two features share the same spatial reference. Spatial join provides a way so that information of one feature class can be added to another feature class.
- Cost Functions Selectivity Evaluation: For efficient query optimization[17] it is important to select highly accurate but efficient cost effective mechanism for query processing.
- Bulk Loading: As massive amount of data are being saved in the Spatial Database. There requires a management for smooth and concurrent loading of data.

**3)** *Bottom Level:* This layer contains the Object Relational Database Server that stores the data. It supports both object oriented database model and relational database model. Object-relational DBMS's i capable of dealing with very large data volumes with great complexity.

## VI. APPLICATION OF SPATIAL DATABASE

1) Urban Planning

Urban planning requires analysis of long historical data using computer for modelling and simulation. A database management tool ,GIS, offers forward data mapping functions that can be used for displaying geographical information and at backhand data retrieval functions for 'querying' maps. These front-end and backend operations helps analysts and planners for better management. These analysis help in transportation analysis , land use analysis, pollution analysis etc. Analysing these type types of data we can plan for better use of resources and services.[18]

2) Military Operations

Spatial data holds crucial importance to the Military Commander in the battle field as it helps in decision-making in the planning and development of a state's growth. Use of GIS in the management of military bases facilitates maintenance of all stores which may be found on the base. "GIS allows military land and facilities managers to reduce base operation and maintenance costs, improve mission effectiveness, provide rapid modelling capabilities for analysing alternative strategies, and improve communication and to store institutional knowledge."[19]

3) Farming

Geographic Information Systems is helpful in being able to map and present current and future changes in rainfall, temperature, crop production and more. By mapping the geographical and geological features of current (and potential) farmlands scientists and farmers could work together in creating more effective and efficient farming techniques; this would increase production of food in different parts of the world that are facing problems in producing enough food for the people around them. GIS helps analysing soil data which combines with historical farming practices to determine which crops are best to plant, where they should be planted and how to maintain the nutrition level of soil to best benefit the plants.[20]

4) Disaster and Emergency

All phases of managing diaster and emergencies depends on data from various sources. The relevant data has to be collected, organized and displayed logically to determine the area (size) and scope of emergency management programs. By the use of GIS, all departments could share information through a database on computer-generated map in one location. Without this capability, emergency workers must must need to have access to a number of department managers, its unique maps and its unique data. Most emergencies do not provide time to gather these resources. This results in emergency responders having to guess, estimate, or make decisions without adequate information.[21].

5) Weather Forecasting

GIS is the key component in weather processing systems which allows instantaneous plotting, interpolation and animation of weather data across any isobaric level of the atmosphere. GIS has facilitated the incorporation of numerical weather model output into weather processing systems, upon which the satellite images and topography can be superimposed; an approach which greatly aids the skill of the weather forecaster.[22]

## VII. CONCLUSION

In this paper we aimed to provide guidance regarding the evolution of Spatial Database Management System, its architecture, characteristics and applications. The paper presents an abstract idea how the data related to space are stored, managed and implemented. Today in this fast changing world there is a need to utilize the resources efficiently and spatial data can help us do it in many ways. The applications that are mentioned in the paper are its real world implementation. It has helped in cost reduction and increased resource utilization.

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