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Spatial Databases, Implementation of Spatial Data Analysis and Geoprocessing Techniques in Construction Domain Context

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Abstract

Along with the fast development and application of geographic information science and technology, has become very important the research on the spatial databases to address the growing spatial data management and to enhance the spatial analysis and geoproccesing. Geographical Information System (GIS) contains heterogeneous data from multidisciplinary sources in different formats and the spatial databases are repositories of these spatial / GIS data, presenting the spatial attributes with respect to the location. In this paper is presented an overview of the spatial databases with their functionalities to store spatial features, display them, and perform spatial processing and analysis. Through a rich set of spatial techniques are presented the spatial analysis and are proposed geoprocessing techniques to perform on the construction domain in Tirana, Albania.

Keywords: GIS, Spatial Databases, Spatial Data Analysis, Geoprocessing, decision support

INTRODUCTION

GIS has advanced as a new emerging field to enhance the information and communication technologies based on the spatial data implementations and in this regard, the spatial databases have an important role. GIS through the newly integrated technologies and with growing researches on the spatial databases have advanced greatly to address spatial data management, geoprocessing techniques and spatial data analysis.

The field of research in this paper consists in providing an overview of the spatial databases, which allow advanced visualization of the spatial data, selecting or searching for geographic data, performing spatial processing and implementing analysis on spatial data.

The Geoinformation on GIS has become indispensable and used in many application fields and multidisciplinary areas to manage information in relation to position. In this paper are presented and proposed related to the construction domain, the spatial data analysis and geoprocessing techniques performed on the spatial database with geographic data of capital city of Albania, Tirana. These results aims to give a status of the construction domain and will also support on further researches and spatial data analysis related to urban planning field.

SPATIAL DATABASES AND SPATIAL DATA ANALYSIS

Spatial database research has progressed and has continued to advance greatly for more over several decades, addressing the growing data management and analysis needs of spatial applications. Geospatial information has been indispensable for many application fields, including traffic planning, urban planning, energy management etc. Geospatial data are mainly stored in relational databases, that have been developed for many geographic information systems.

A spatial database is a database that is optimized for storing and querying data representing objects defined in a geometric space. Most spatial databases allow the representation of simple geometric objects such as points, lines and polygons. (Wikipedia Spatial Databases, 2021) A spatial database is also known as geodatabase and geospatial database, which represents a database of geographic data or spatial data.

A spatial database allows us to store features, display them, or perform geoprocessing and analysis through a rich set of spatial functions. (Gary E. Sherman, 2010) Some of the advantages of storing data in a spatial database are as the attributes and geometry of features are stored together; spatial indexing makes drawing faster at larger scales; spatial queries provide the ability to explore features and their relationships; better data management.

A spatial database is nothing more than a regular database with support for geometry data types. It typically contains functions to manipulate the geometries and perform spatial queries. In a spatial database, a table represents a layer, a row is a feature, and a spatial column contains the geometry of the feature. (Gary E. Sherman, 2010) A spatial database system 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 spatial join methods. (Ralf Hartmut Güting, 1994) Spatial database systems offer the underlying database technology for geographic information systems and other applications.

A spatial query is a special type of database query supported by spatial databases, including geodatabases. The queries differ from non-spatial SQL queries in several important ways. Two of the most important are that they allow for the use of geometry data types such as points, lines and polygons and that these queries consider the spatial relationship between these geometries. (Wikipedia Spatial Databases, 2021)

DBMS spatial methods and querying GIS data for performing spatial analysis are fundamental in retrieving pertinent data and discovering new spatial relationships.

Spatial analysis in GIS based on the respective spatial databases consists in the geoprocessing techniques and DBMS spatial queries/methods, which allows to turn data into information and create new data as derivative datasets by manipulating these existing spatial features and their related attributes.

SPATIAL PROCESSING ON GEODATABASES

Fundamentals of geodatabases

The geodatabase is a collection of geographic datasets of various types. A key geodatabase concept is the dataset. It is the primary mechanism used to organize and use geographic information in ArcGIS. The geodatabase contains three primary dataset types such as feature classes, raster datasets, tables. (Esri. Fundamentals of the geodatabase, 2020) Creating a collection of these dataset types is the first step in designing and building a geodatabase and typically is started by building a number of these fundamental dataset types.

A Geodatabase is a collection of geographic datasets of various types held in a common file system folder, or a multiuser relational database management system (such as Oracle, Microsoft SQL Server, PostgreSQL, IBM Informix, or IBM Db2). Geodatabases come in many sizes, have varying numbers of users and can scale from small, single-user databases built on files up to larger workgroup, department, and enterprise geodatabases accessed by many users. (Esri. What is a geodatabase, 2020)

It can be stated that a geodatabase is more than a collection of datasets and the term geodatabase has multiple meanings in ArcGIS:

- The geodatabase is the native data structure for ArcGIS and is the primary data format used for editing and data management.
- The geodatabase is the physical store of geographic information or the spatial data, primarily using a database management system or file system.
- Geodatabases have a comprehensive information model for representing and managing geographic information, which is implemented as a series of tables holding feature classes, raster datasets, and attributes.
- Geodatabase software logic provides the common application logic used throughout ArcGIS for accessing and working with all geographic data in a variety of files and formats.
- Geodatabases have a transaction model for managing GIS data workflows.

Related to the architecture of a geodatabase, we can state that is object relational as it is implemented using the same multitier application architecture found in other advanced database management system applications. This multitier architecture of the geodatabase is sometimes referred to as an object-relational model. The geodatabase objects persist as rows in database tables that have identity, and the behaviour is supplied through the geodatabase application logic. (Esri. The architecture of a geodatabase, 2020)

The geodatabase storage model is based on essential relational database concepts and leverages the strengths of the underlying database management system. The model for storing and working with spatial data is based on tables and well-defined attribute types, which are used to store the schema, rule, base, and spatial attribute data for each geographic dataset. Structured query language (SQL) can be used to create, modify, and query tables and their data elements.

At the core of the geodatabase is a standard relational database schema as a series of standard database tables, column types, indexes, and other database objects. The schema is a collection of geodatabase system tables in the DBMS that defines the integrity and behaviour of the geographic information.

The three primary datasets in the geodatabase the feature classes, attribute tables, and raster datasets, as well as other geodatabase elements, are stored using tables. The spatial representations in geographic datasets are stored as either vector features or rasters and these geometries are stored and managed in attribute columns along with traditional tabular attribute fields. [4] (Esri. A quick tour of the geodatabase, 2020) In Fig. 1 is shown a feature class with the buildings of Tirana, which is stored as a table.

Buildings

OBJECTID *	Shape *	EMRI_RRUGE	KODI_POSTA	KODI_RRUGE	Area	Shape_Length	Shape_Area	Adm_Unit
13218	Polygon	DËSHMORËT E 4 SHKURTIT	1001	234	1850.655814	209.263322	1850.655814	TR/275
15827	Polygon	BLV. DËSHMORËT E KOMBIT	1001	197	2358.015229	260.83923	2358.015229	TR/10
15846	Polygon	MURAT TOPTANI	1001	774	378.998999	101.522729	378.998999	TR/10
15825	Polygon	SHESHI FAN STILIAN NOLI	1001	3004	553.349648	101.95667	553.349648	TR/10
15826	Polygon	SHESHI FAN STILIAN NOLI	1001	3004	537.557014	106.605611	537.557014	TR/10
15828	Polygon	BLV. ZHANË D'ARK	1001	199	1905.766595	324.930625	1905.766595	TR/10
15829	Polygon	BLV. ZHANË D'ARK	1001	199	433.715672	99.260186	433.715672	TR/10
15830	Polygon	BLV. ZHANË D'ARK	1001	199	653.735763	120.27639	653.735763	TR/10
15831	Polygon	BLV. ZHANË D'ARK	1001	199	352.622644	81.565889	352.622644	TR/10

Fig. 1 Feature class stored as a table

Basically, geodatabase holds a collection of datasets and there are three types: [5] (Esri. Types of geodatabases, 2020)

- File geodatabases, which is stored as folders in a file system and each dataset is held as a file;
- Personal geodatabases—All datasets are stored within a Microsoft Access data file
- Enterprise geodatabases—Also known as multiuser geodatabases, they can be unlimited in size and numbers of users. Stored in a relational database using Oracle, Microsoft SQL Server, IBM DB2, IBM Informix, or PostgreSQL.

Case study: Implementing spatial analysis in geodatabase with spatial data of Tirana

Based on spatial data of Tirana city, capital of Albania, is created the geodatabase considering for spatial analysis the data related to the construction domain. In this case study a spatial analysis is performed to find the percentage of construction area in administrative and structural units of Tirana. Based on these analysis and results of this case study, the urban planning field will be subject for further enhancement on the spatial data analysis and geoprocessing. The geodatabase created to implement spatial analysis and geoprocessing contains the feature classes / tables as shown in the layers the map in Fig. 2.

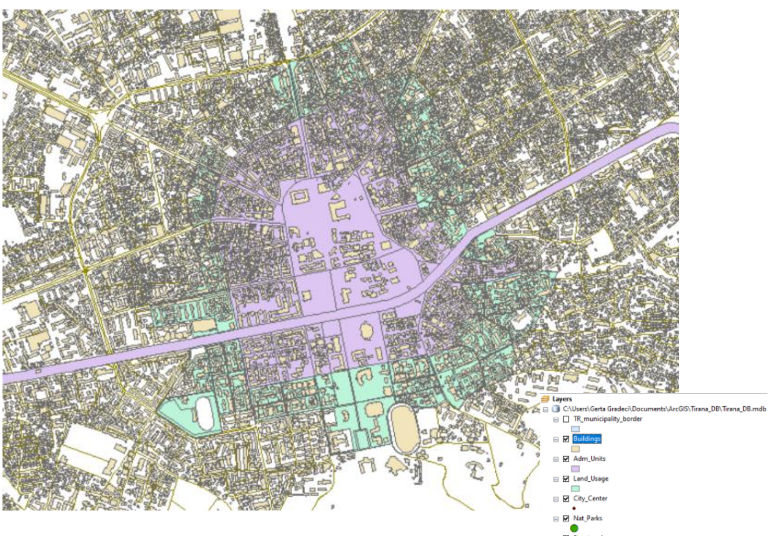

Fig. 2 Map of Tirana with respective geodatabase spatial data

A geoprocessing on the buildings feature class is implemented, to summarize the buildings area by administration units. The results of this geoprocessing are saved in a table containing the summarized area of the buildings by administrative units.

These results on geoprocessing of summarizing the buildings area per administration units are joined to administration unit feature class, realizing so a joint field for this feature class. The python script is shown in the Fig.3, which joins the contents of a table to another table based on a common attribute field (in_field, join_field). The input table is updated to contain the fields from the join table and we can select which fields from the join table will be added to the input table. The records in the Input Table are matched to the records in the Join Table based on the values of Input Join Field and the Output Join Field.

```
Python
>>> # Replace a layer/table view name with a path
 to a dataset (which can be a layer file) or
 create the layer/table view within the script
... # The following inputs are layers or table
 views: "Adm_Units", "Sum_AreaBuild_Unit"
... arcpy.JoinField_management
 (in_data="Adm_Units",
 in_field="Njesite_Strukturore_njesia",
 join_table="Sum_AreaBuild_Unit",
 join_field="Adm_Unit", fields="Sum_Area_Build")
```

Fig. 3 Python script to implement joining between spatial tables

In the results of the output spatial table (Adm_Units) are included the area of each feature (shape column holds the polygon geometry for each feature), and also the summarized area for all the buildings for each administrative unit, as shown in Fig.4. So, in these results are shown the area of construction for each administrative unit of Tirana. On these spatial data is performed further geoprocessing to define the percentage of the construction in an administrative unit of Tirana.

Adm_Units

nenkategor	label	njesia	Bashkia	shape_Leng	Shape_Length	Shape_Area	Area_Adm_Unit	Sum_Area_Build	Percentage_Build_Area
AR.P	SHA.Aktivitete Shoqerore & Argetimi	TR/1	Tiranë	798.750035	1949.149887	233098.239453	233098.24	44046.32	18.9
	S+A+IS+AR	TR/10	Tiranë	17.273106	1336.109787	103162.085175	103162.09	15537.23	15.06
	S+A+IS+AR	TR/275	Tiranë	236.181451	823.238283	41568.309687	41568.31	1850.66	4.45

Fig. 4 Table containing the area of the feature, summarized area of construction by administrative unit and percentage of construction area per administrative unit

In Fig. 5 is shown the script to generate the percentage of the construction per administration units

```
Python
>>> # Replace a layer/table view name with a path
 to a dataset (which can be a layer file) or
 create the layer/table view within the script
... # The following inputs are layers or table
 views: "Adm_Units"
... arcpy.CalculateField_management
 (in_table="Adm_Units",
 field="Percentage_Build_Area", expression="!
 Sum_Area_Build! / !Area_Adm_Unit! *100",
 expression_type="PYTHON_9.3", code_block=""))
```

Fig.5 Python script for calculating the percentage of construction area per administrative unit

The results based on the geoprocessing for the calculation of percentage of construction area per administrative unit are shown in Fig.6.

In this map are selected three of the administrative units in the center of the city of Tirana. The results for each of these features are shown as pie charts based on the values of the total area of the administrative units and the construction/buildings area, reflecting also the percentage of the area constructed within the respective administrative unit.

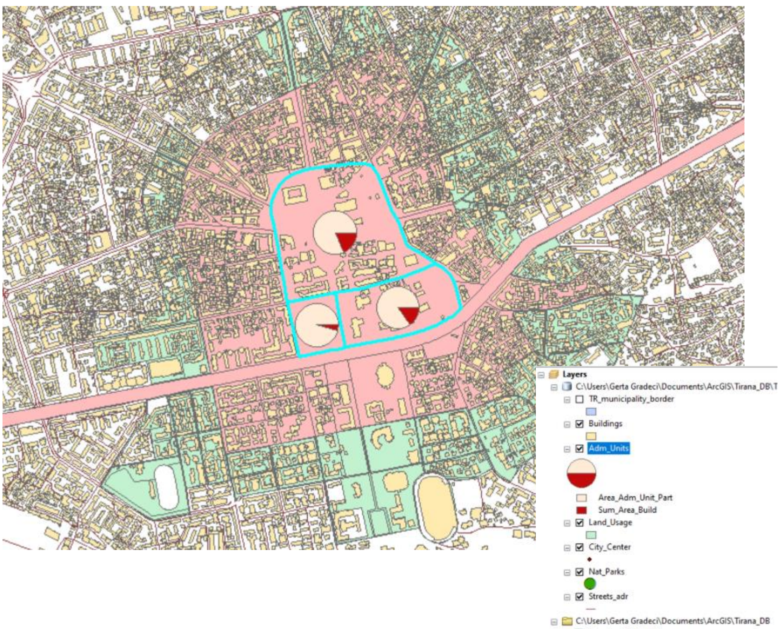

Fig. 6 Results of the construction area within the respective selected administrative units

CONCLUSIONS

In this paper, we discussed related to the spatial databases as databases optimized for spatial data management for storing and querying spatial objects defined in a geometric space. So, the spatial databases allows to store spatial features, display them and perform geoprocessing and spatial analysis through a rich set of spatial functions. Some of the advantages of storing data in a spatial database are as the attributes and geometry of features are stored together; spatial indexing makes drawing and processing faster at larger scales;

spatial queries provide the ability to explore features and their relationships; better data management.

In addition, spatial analysis and geoprocessing techniques are performed on the spatial database of Tirana in the contexts of the construction domain. The results of these spatial analyses aim to have a general overview of the status of the construction for the administrative and structural units of Tirana/Albania. These results will be used for future work that will consist in further enhancement of the spatial processing and analyzing techniques on the urban planning field.

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