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A Strategic Framework of GIS Web Applications: Structure and Contents

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Abstract

The rapid development of internet-based applications has led to the appearance of a new kind of GIS Web applications, new technologies and fast growing geospatial data acquired from many sources. Therefore, to improve the GIS Web decision-making abilities and performance, a suitable architectural structure is needed to well understand, manage and maintain the spatial big data, GIS components, and complex interrelations among them. In GIS Web application, the optimal visualization is required to minimize of spatial amount of data that is transferred over the network media, and well-administrate sharing data on the servers. In GIS Web application, software design and data design are very important tasks and they are considered as challenging problems that face the software developers and database administrators. This paper describes the architecture design guidelines for modular GIS software and shared data models to manage high-level of interrelationships among large number of distributed GIS components. The design concentrates on the modular quality attributes of efficient, low-coupling and high-cohesion. This paper also presents a generic and comprehensive methodology to store a generalized geographic data and eliminate geospatial data redundancy on the server-side. It will play an important role to reduce the storage space by avoiding redundant data to achieve relatively good quality of the image and enhance the in general the response time. The representation of internal stored data structures and the suitable selection of application software architecture, which uses the spatial data and non-spatial and to provide fast access to spatial data, are crucial issues. Hence, the design guidelines and implementation issues are discussed for GIS Web-based Application.

1. Introduction

Geographic Information System (GIS) faces a new number of developments and trends in changing industry world and new trends of spatial (or geographical) data acquired from many sources. The sources of spatial data are digital maps, aerial photographs, high resolution satellite images, textual data, statistical data or any other related documents. Internet technology helps to make Web GIS cheap and to spread geospatial data to become widely accessible and increasingly available. The users of Web GIS software can visually interact and interpret the geospatial data [1].

In general, Web GIS is a distributed information systems that consists of hardware devices, software application components, geospatial data and end-users [2]. It is constructed from the web technology and the GIS, which is mainly composed of spatial data to handle storage, recovery, management and analysis. Web GIS is different slightly from Internet GIS, where the Internet GIS supports many services and the Web GIS is one of these services, as it is shown in figure 1.

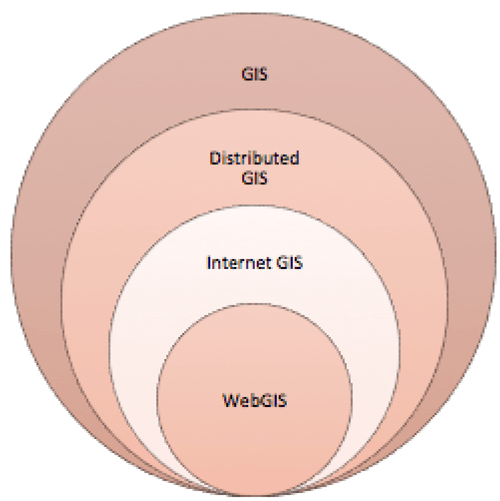

Figure 1 internet GIS and web GIS comparison [2]

Web GIS integrate interrelated set of software programs for creating, altering, manipulating, controlling, analyzing, reasoning and displaying data both in digital text and graphic forms. GIS supports spatial analysis and modeling. To achieve better results and well-understanding and interpreting, different group of layers of information about a place are combined together to compose a map. The group of layers depends on the user's perspective and purposes, and the user can switch between layers whenever necessary. Each layer represents particular side of map's attributes and characteristics [3]. One layer can represent the roads in a particular area; another layer can represent the location of medical facilities and the number of patients they served; or represent the rivers in the same area. To well-chosen a level of layer accuracy, each layer is placed on top of the other layers to create a stack of information related to a particular area. These connections among stored GIS maps and their data patterns are what distinguish Web GIS from other information systems. The efficiency of implementing the spatial data structure is measured by: reducing the storage of data, increasing the geometrical processing performance and reducing the execution time. For these reasons, the representation of internal stored data structures and the application software architecture, which uses the spatial data to provide fast access to spatial data, are crucial issues.

GIS is a combination of software modules, spatial and textual data, and different hardware components. It is called a GIS application. Sometimes GIS application is defined as the software modules while others defined it as the combination of both software and hardware components [4], [5]. GISs require four general categories of hardware components according to specific tasks of the system to solve complex problems: data acquisition, data analysis, data modeling, data output presentation, manipulation and data management [4], [*6*].

There is an exponentially increasing growth in the number of Web sites that contain geographical information. Currently, most of Web-based GIS users are ordinary GIS users (i.e. no GIS skills are required) rather than being domain experts [7], [8]. Users and organizations use the data in different range of applications such as, emergency response and management, architecture engineering urban planning, and the application of combining GIS and artificial intelligence for solving transportation planning problems [6], [9]. They search GIS databases for many purposes such as analyzing tasks, finding businesses, routing directions, browsing maps, downloading maps, etc. This will lead to a new significant GIS Web services, and may change GIS requirements [10]. GIS Web-based developers will focus in their work on service-delivery model rather than traditional data-distribution model, besides the implementation of traditional design issues such as performance, reliability, coordination, scalability, interoperability and security. They face a challenge to integrate GIS Web-based services with location-based information and mobile applications to transmit extremely large volumes of geospatial data over the Internet and wireless environments.

There are many challenges that may influence negatively the design phase and the development of GIS Web-base application and make them difficult tasks:

- Quality of geospatial data are not always formally described especially for some GIS Web-based services.
- The application may need large-scale GIS domain knowledge that requires intensive computational process of Geospatial queries;
- The initial cost of preparing, designing, storing spatial data in a database and distribute it, is 5-10 times higher than the cost of software and hardware [11].
- The Speed is one of the major problems of Web GIS and heavy usage of maps and graphics
- Geospatial data input is a main cost and difficult situation in implementing GIS Web application, which may affect negatively users' decision making or the execution take long time.
- The image can have more disorganized and unnecessary data than desired
- The features are not well extracted and described; it is difficult to accurately discover the effects of the features.
- The complexity of design and implement Web GIS, where for the development of large Web GISs there is no proper methodology for the development of large GISs.

To overcome these problems, we propose a framework for the designing a multi-tier client-server architecture that support the implementation of large Web GIS, which will focus on interacting with well-structure of data model and data structures**.** The design of Web GIS is absolutely necessary to implement software applications efficiently and consistently, since they are related to the computational methods used to extract map features and reduce the search space.

The contributions of this research are summarized in the following four aspects:

i. Spatial data representation models and data structures are presented and discussed how to select the most suitable data representation model and structure.
ii. We investigate the factors that affect the design of data representation models and application components, and propose, when it is possible, the methods that reduce their influence.
iii. The design guidelines of GIS Web-based application, implementation, and deployment are discussed for GIS Web-based Application.
iv. We propose a framework for GIS Web-based applications that is based on modular software architecture, shared data models and distributed GIS components. The interactive GIS Web-based System Architecture is explained.

The paper is organized as follow: Section 2 gives an overview of GIS Web-based applications. Section 3 the proposed framework is presented, which gives a description of GIS Web-based application architecture design and main design issues. In Section 4, the spatial representation data models and data structures are presented. Based on this, in Section 5, the methodology for multi-layer query answering is discussed. Finally, the paper ends with concluding remarks in section 6

2. Literature Review

Unlike software engineering, where developers have a number of methodologies from which to choose, there is no true methodology for the development of large Web GISs. Web GIS focuses on how to manage large spatial datasets in server-side if client-server model, and how to develop techniques to enhance system performance [12]. The recursive parallel object-oriented model for GIS provides a process framework for the creation of large GISs, with a focus on reusability, reliability, and communication [13].

Because of the extensive GIS applications use in many different aspects of our lives and many of the early GIS software systems did not continue and failed. Some of the reasons for the failure are that the developers don't understand the purpose for creating these systems, they have not a good understanding of what the requirements of the system are, or the designers were not properly designed and inevitably faced problems [14], [15]. Therefore, the analysis, design and implementation of these software systems have become very important. Like most software, the more information contained in these systems, the larger they are, and the more expensive to create and implement.

In many different GIS Web-based applications or GIS Web; such as (www.mapquest.com) and (www.mapsonus.com), the clients have only standard Web browsers to access remote spatial database servers to retrieve the maps data that satisfied dependably the client's queries with acceptable response time and throughput. All image services operations are performed on the server-side applications. The results of the queries are transferred to the clients, where the client's site manages the clients' interactions [16].

Many design principles are not applicable in designing Web GIS services, while they are work well in another distributed systems. Jay Ratcliff et al discussed the design strategies regarding the transactional mode to enhance the services performance of Web GIS. Hey explained the design decisions related to the service granularity, the communication manners, and the transmission formats. The success of GIS Web services requires reducing the synchronous transactions, the callback design patterns can be used to transform synchronous transactions into asynchronous, where, the client can work on other operations and not interrupted by computation time on the server side. the remote users have the same database accessing power and servers provide a collection of map features [17].

GIS Web is provided a service of distributing the interactive maps and other geospatial data amongst different computers in different locations that can be shared and made publicly accessible [18]. It involves preparing data, categorizing the content, and designing the web site, configuring the servers, and improving using the users' feedback. Since MS-Access is not suitable to store geospatial data and process it efficiently and effectively, an integrated GIS model can combine multi-representation databases, which is based on the mathematical computation to represent the relations of the three different types of relations: intra-resolution, inter-resolution and up-date. [19]. When the GIS Web users request the map for a certain scale, several datasets for each predefined scale of an existing map are created and displayed using vector-based geographic data. This is called a Multiple Representation Data Bases (MRDB). Since this approach uses a number of static predefined map resolutions, there is no way to render the maps' data into a required scale. Only the closest scale to the required one is selected and then displayed. Another difficulty related to this vector-based geographic data is maintaining the redundant data, which required complex updating process and large-sized memory. Raster data hierarchies can be represented using the quad-tree structure that was encoded using encodes as a tree structures and pointers, where each leaf node is represented by its locational code and the collection of leaves represented as a binary tree, but this method produced coarse quality image and computationally expensive [20]. GIS can take features from the map and communicate them to a grid coordination system, which is used to represent both the features located on the map and attribute data that describe these features. These features can be drawn in any required scale with more flexible computational mapping than standard maps. GISs also have spatial analysis capabilities for map features [13].

In raster data, the image is presented in a coarse quality to be plotted quickly and then refined the view keeping the same map resolution. Discrete Wavelet Transform (DWT) integrated embedding block coding is used to achieve fast content reduction using image coding standard JPEG2000 to display the relevant image content relatively fast [21], [22]. The three different techniques, which are used in large raster image transmission in mobile environments; bit-stream compression, transmission and decoding-and-browsing, are combined together into one adapted approach.

3. The Proposed Framework

The large-scale distributed GIS Web-based systems make them more difficult to understand, design, implement, and test because of the complex interactions among system components and the infrastructure. Therefore, GIS Web-based systems are preferred to be developed and delivered using incremental model to get users' feedback of clients' requirements. It is structured into several logical layers (i.e Tiers) with clear predefined interactions between functionally logical layers [14].

3.1 GIS Design Issues

After determining the basic visualization functions: zooming-in, zooming-out, spatial query, etc, and determining and collecting the required data: geospatial data, map attributes and document data, the design phase is adopted to customize the servers for application. In order to make the GIS Web Application widely applicable and used, the data design and application design must be standard and follow the general design guidelines that satisfy: transparency, supporting interoperability using standard protocols of distributed systems, scalability of throughput specifications, Security policies, Quality of service (QoS) specifications, and failure management that deals with the failures detecting and repairing.

3.2 GIS Web-based Application Architecture Design

The general architecture of GIS Web-based application is similar to three-tier client-server architecture. High-level of interrelationships among large number of distributed GIS components require modular software architecture and shared data models, through assuring cohesion and coupling as a software structural quality. GIS Web-based software is modeled as a set of services that are provided by distributed servers and a set of associated clients can access these different services on servers and present the information results to the users. The clients and the servers are distributed process [23]. Figure 2 is shown the GIS web-base system components.

To overcome the limitations of thin-client architecture; where the integrated Web server and GIS map server manage the centralized large-volume of data (no vector data used) resources in slow response time, or fat-client architecture; where the client side needs additional display generator software to make the user interface has more interactive capabilities and to handle vector data [16], [24], the medium-client architecture is proposed instead.

- The proposed architecture design can be used as a logical model to structure and integrate the distributed GIS Web-based system components. The architecture is designed in a way that can optimize data transferring between the web server and the database servers.
- The large volume of data from multiple sources is integrated and the documents of information about various maps, data, and services are stored in the metadata. It is preferred to add temporal attribute as a timestamp in the quad-tree leaf node to refer to data that is last accessed.
- All the spatial servers for maps are linked together and communicate with a Web Browser. Web Server can gather the user requests from Web browser and present the corresponding results graphically or documents from the GIS spatial server to the

Web browser then to the clients. The internet GIS map server makes Web server interface easily access the spatial data.

- The main activities of the development model are proposed in figure 3. The model consists of two major parts, according to their purposes, components and tasks. The left part represents "the cartographers' side, a number of different geospatial data types are collected, maintained, classified and represented suitably as geospatial data and attributes in data repositories in a way that is suitable for browser. Data collection, access, and dissemination have high impacts on the quality of decision-making. The geospatial data and non-spatial data records are accessed and acquired by any GIS Web. In the second part, retrieve the required data from the repository according to the user's query and the map is generated and presented on the user. The accuracy of displayed results is highly dependent on the validity and accuracy of the spatial data and different formats disseminated among Web GIS applications.

4. Spatial Representation Data Models And Data Structures

The quality of a Web GIS application is challenged by different key elements: data collection, data representation, data storage data access, large volume of transferred data, user friendly of transformed data in real-time, data analysis, and geo-visualization**.**

The spatial data representation model and data structure are needed to describe the spatial shape, location, attributes and characteristics for processing and managing geographic information.

4.1 High-level Spatial Representation Data Models

To formalize spatial data, several data models are developed and each has its features, capabilities and deficiencies when users implement them. Understanding the required spatial data model help to design the spatial concepts that will be used and manipulated symbolically by computers according to mathematical formal rules [11]. GIS data models use spatial variable that describe locations, and attribute variables that describes the characteristics of the locations. Each data model has different data types, specification and scales. Thus, the GIS data models objective is to extract and transfer the complex and infinite information about geographic maps into more manageable information that is suitable for processing and managing.

To understand the certain parts of GIS from the users' perspective, the concepts usage is independent of the actual implementation aspects. The role of the spatial data model is similar to the conceptual schema in three-schema database management systems, which separates logical schema from physical schema [25]. The commonly defined approach of modeling spatial attributes is to separate the users' perception from the implementation operations into geometrical data attributes and non-geometrical data attributes.

At a first stage, Area of Interest (AoI) is determined. The geospatial data are collected extracted, transformed and to be utilized in different GIS functions. The data of the maps, the map-related features and the attached metadata for a given area may be stored in many interrelated different database [13]. Metadata is the descriptive documentation needed to describe all aspects of geospatial dataset about the covered area, dataset producer, data set purpose, data set forms. It can include the description of:

- Spatial Data (observation data) of absolute and relative geographic features. It is the digitized form of a known location on earth.
- Attribute or Thematic Data of the spatial features depending on the specific content of the data. The statistics and locational variables linked to the geographic features.
- Topology of how geographic features are combined and related to one another
- Data Layers that combine attribute data to spatial location, where the same area can have different maps that can be viewed as transparency layers one on the top of others and each layer has a specific type of data
- Layer Types of how the spatial and attribute information are connected; vector and raster are two major layer types, as it they are shown in figure 4.

GIS spatial data is stored and managed using different representations, where each representation model has some advantages and disadvantages features. The high-level spatial data models can be [27]:

1. Raster conceptual data model: two dimensional arrays forming sets of thematic layers, where each element in the matrix is carrying the value of a single attribute

2. Vector conceptual data model: represents an entity as point, line and area. It is structured as a set of thematic layers
3. Object-oriented data model: is a discrete model using an object-based approach that has both physical attributes and geometric characteristics.

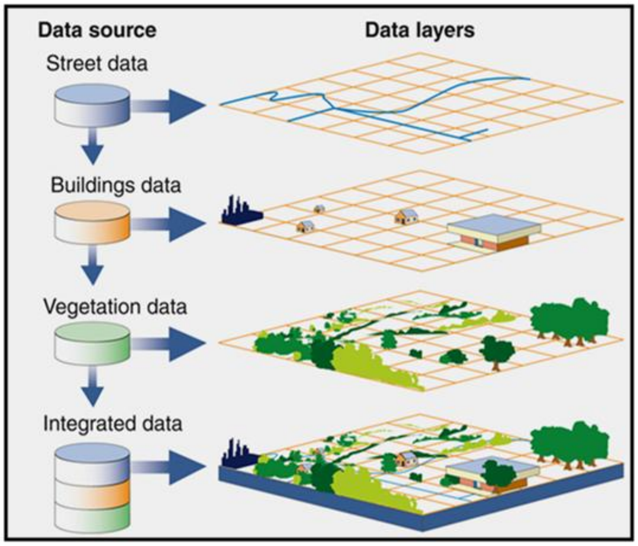

Figure 4. GIS data layers or themes [26]

4.2 Low-level Spatial Data Structure

Low-level spatial data structure must follow the properties defined in the corresponding high-level spatial data representation models. The user can implement several spatial data structures using one spatial data model. The objectives of techniques to structure the spatial data are:

- To conceptually differentiate the physical storage, conceptual, and user's (or logical) perceptions. The distinction of data independency is useful in changing on one model will not lead to changing or affecting other models. This conceptual differentiation needs well-defined interfaces among these levels. To perform geometric user's queries, where searching and determining the results depends on the selecting of a special data structure
- To design a schema and construct spatial database management systems, since there is different data abstraction. A differentiation also occurs between data structures and data models; the high-level and low-level spatial data structures, under common interface.

To represent the maps, we need to explore the input data set through determining the domain and type of problems, required time to receive the results of user's request, and the quality of GIS-based application system. There are three map representation techniques, where the GIS-based software must correspond to the users' needs and skills.

1. Static maps are produced by converting the maps into images. It was the oldest technique. The whole image is accessed and served at once. The users can interpret the map easily but cannot make zoom-in or zoom-out interaction with these sorts of maps. The implementation performance will be degraded when the number of geographically referenced areas to be displayed is increased. Defining geospatial data as maps is more powerful than defining them using numeric values [28].
2. Vector data structure is composed of geometric primitive information to represent most of the objects on the maps using [29]. It is represented in a coordination form of pair of numbers, triplet numbers or n-numbers expressing the n-dimensional of location. Figure 5 shows as vector data representation.
   It can be implemented as a database table and used to define:
   - Nodes (point): is defined by coordinates.
   - Edges (lines): is defined by a series of line segments with start and end points.
   - Areas (polygon): is defined by sequential edges of area boundaries appeared in each GIS layer; and each layer is represented by a record of values in a table.

The representation elements have interrelationships; called topological relationships, to represent location, shape, and attribute information

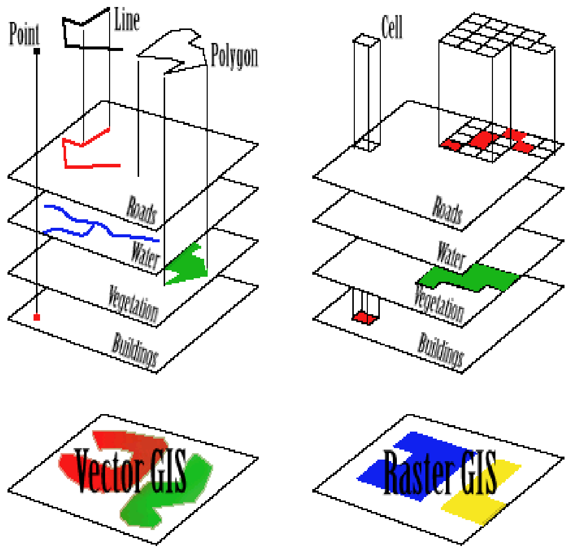

Figure 5 Spatial Data Representation [30]

3. Raster data structures or the tile-based data structures: the map is decomposed into small equally-sized square cells or spaced grids. It is also called a raster GIS. The raster representation is shown in figure 5 and figure 6.

It is most widely used map representation technique in environmental applications of GIS. The user can access and load up quickly only the required cells of specific parts of the map (instead of loading all the cells of the map) and then combine them at client side. Based on user's requests, the cells are changed dynamically. In comparison to static map representation, raster data structure will reduce the amount of memory space and processing time in the server and client sides, but needs a large disk space to store all the required cells on the client site.

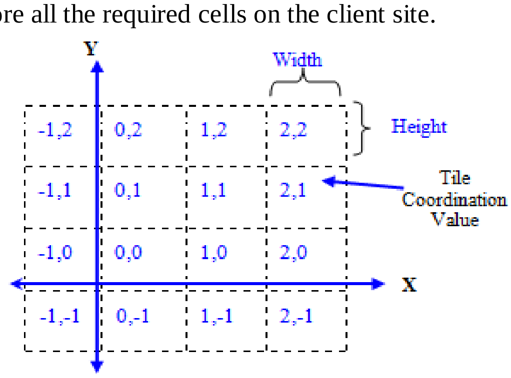

Figure 6 Raster GIS data structure

The process of converting vector data into raster data is called Rasterization; it is easier to transform raster data into vector data. The cell in the table stores a value and a count of cells with that value.

4.3 DBMS Choosing

The designer can select GIS or a DBMS to store the application data [31]. The storing/retrieving records in GIS Web-based applications are influenced by the database and the storage requirements of geographically referenced data. Database plays an important part of GIS Web-based applications. The predefined format of geospatial data can be stored in database files as: binary, XML, string etc in secure way for multi-users [31].

Once the geospatial data are stored directly in database (known as geodatabase) using extension software to handle spatial objects, they can be indexed, searched, retrieved and displayed for data query in response to different user requests in the form of maps [31]. Thus the performance of the GIS Web-based application is influenced by the performance of a database. There are a number of different database management systems available; in addition there are a number of database tuning techniques available to enhance the performance of databases. There are different numbers of object relational database management systems (ORDBMSs) that can define data structure, which is modeled by Entity-Relationship (ER) model, and store the data values efficiently in flat tables and objects. The DBMS act as a centralized data repository for spatial data and thematic or attribute data that is accessible by multiple users at the same time. DBMS supports the retrieving, storing, retrieving, manipulating, analyzing, and map production. For GIS Web-based applications, Oracle spatial, PostgreSQL and SQL Server the most appropriate relational database management systems [32]. They support spatial indexing scheme called Size Separation Indexing (SSI) based on a size separation technique [33], grid computing, confidentiality of spatial data records and parallel execution of processes, while MS-Access and MySQL are not suitable, as ORDBMS, because they are not appropriate to handle a huge volume of data. Also, there are number of tuning techniques that can be used to enhance the performance of database. Progressively the Object-Oriented Database management systems are incorporated (ODBMS) in GIS Web-based applications.

5. Methodology For Multi-Layer Query Answering

5.1. Data Retrieving and Query Answering

Using medium client server technique, the problem solver facilitates spatial and textual data retrieval, and display. It includes HTML interface, internet interface, and computational software to provide GIS functionalities and accessing GIS databases and servers. For answering a particular query or performing a task that depends on geographical image or spatial data, it is needed to discover the most relevant GIS data sources on the web. Data retrieval is based on the DBMS structure that maintains the data attributes and on command interfaces that are provided with the GIS Web-based application. Most GIS Web applications are provided with programming subroutine libraries. Thus, it allows the user to write their specific retrieval routines.

The propagation of huge number of high quality GIS data sources has led to a significant challenge to search and find out the GIS source data. There are little efforts in making the GIS databases searchable on the Web [6]. Consequently, the challenge is to build a search engine for processing a user query on large geospatial repositories, with a restricted small response time as a key requirement. The results are produced by retrieving the geographic data sets; i.e. can only be retrieved partially, and combining the data from different GIS databases. In geographic Information Retrieval (GIR) System, the requested data are retrieved from spatial databases in one of the following two ways:

i. *Using* text-based *search engines*: Most GIS data sources describe the data source with keywords metadata. Metadata includes information about schema, information about the data content, data types, data format, and the spatial indicators of the data sources. The keyword-based search engine extracts the keywords from queries and implements index of the metadata to discover the relevant sources. Keywords do not capture spatial semantics. It depends on textual-based matching; therefore, it will not find out the semantically relevant data and will miss the most relevant sources on the web [6].

ii. *Using specialized geographical data, where* an index is created for the data sources based on metadata information that is linked with the graphical data. This technique will overcome the difficulties of using keyword-based matching techniques by explaining the semantics of geographical data of maps. *The specialized geographical data* contains only textual metadata summaries at a very coarse level, did not have the geospatial characteristics, and is created by humans and therefore, it is considered as a main limitation of this technique that affects significantly the retrieval quality.

Hence, the GIS retrieval systems should concentrate on GIS contents of both textual and spatial data descriptions, instead of relying on the metadata.

iii. Using *filter and refine* methods are useful in retrieving and answering processes. A filtering method produces a set of solution candidates, set of *'N'* feasible solutions, which is a superset of the objects satisfying user's query. A filtering method objective is used to narrow the search space. Then, a refinement method will examine each solution candidate and check the query joint conditions. It is preferred to use an objective function to refine the results.

5.2. Performance Evaluation of Retrieving

To evaluate search strategy, precision, recall and F are the most used l criteria based on the results of the retrieval process [32],[33].

- Precision (P) is a measure of a system to display only relevant items. It is the ratio of the total number of relevant retrieved data to the sum of documents retrieved.

$$P = \frac{\sum \text{the relevant items retrieved}}{\sum \text{items retrieved}} \quad ...(1)$$

- Recall (R) is the measure of system to retrieve and displayed all relevant records in the GIS database. It is measured as a ratio of all relevant records to the total number of relevant

$$R = \frac{\sum \text{the relevant items retrieved}}{\sum \text{Relevant items}} \quad ...(2)$$

- *F*-measure combines the precision and recall measures with an equal weight of the precision (P) and the recall (R), (i.e. balanced F-score), and it is calculated as:

$$F(P,R) = 2 \times \frac{P \times R}{P + R} \quad ...(3)$$

Where:
P = Precision
R = Recall

5.3. Transform Results to the User and Map-Data Output

The user can generate graphical-data, normally maps, textual or tabular reports representation, which express spatial relationships derived from spatial DBMS map information [5]. The results can be: Graphical display, interpretation of the Graphical display result, displaying selected objects within graphical representations, Scale selection, or displaying and describing the query answering related to a particular area. A GIS can be viewed in three ways and are used at varying levels in all GIS applications [26]:

1. The Database View: presenting static maps in the forms of images using different vector data format. This presentation type does not allow user interaction and hence it is simple and easy way.
2. The Map View: divides the map into a number of zoom-level maps and each level has the same number of tiles, therefore, this geo-visualization technique is widely used and is dynamic and fast to load.
3. The Model View: uses mathematical calculations based on vector images to preserve the accurate shape with less distortion.

6. Conclusion

The rapid development of internet-based applications has led to the appearance of a new kind of GIS Web applications, new technologies and fast growing geospatial data acquired from many sources. Therefore, to improve the GIS Web decision-making abilities and performance, a suitable architectural structure is needed to well understand, manage and maintain the spatial big data, GIS components, and complex interrelations among them. This paper studies requirement analysis to explore the needed functions and explains the range of technical issues involved in designing and developing a Web-based GIS. It proposes the architecture design issues of GIS Web-based application. In GIS Web application, the optimal visualization is required to minimize of spatial amount of data that is transferred over the network media, and well-administrate sharing data on the servers. In GIS Web application, software design and data design are very important tasks and they are considered as challenging problems that face the software developers and database administrators. This paper describes the architecture design guidelines for modular GIS software and shared data models to manage high-level of interrelationships among large number of distributed GIS components. The interoperable GIS Web service components were suggested during the software design architecture of the proposed model, together with the geospatial data models and structures for applications using these components. The design concentrates on the modular quality attributes of efficient, low-coupling and high-cohesion. This paper also presents a generic and comprehensive methodology to store a generalized geographic data and eliminate geospatial data size on the server-side. It will play an important role to reduce the storage space by avoiding redundant data to achieve relatively good quality of the image and enhance the in general the response time.

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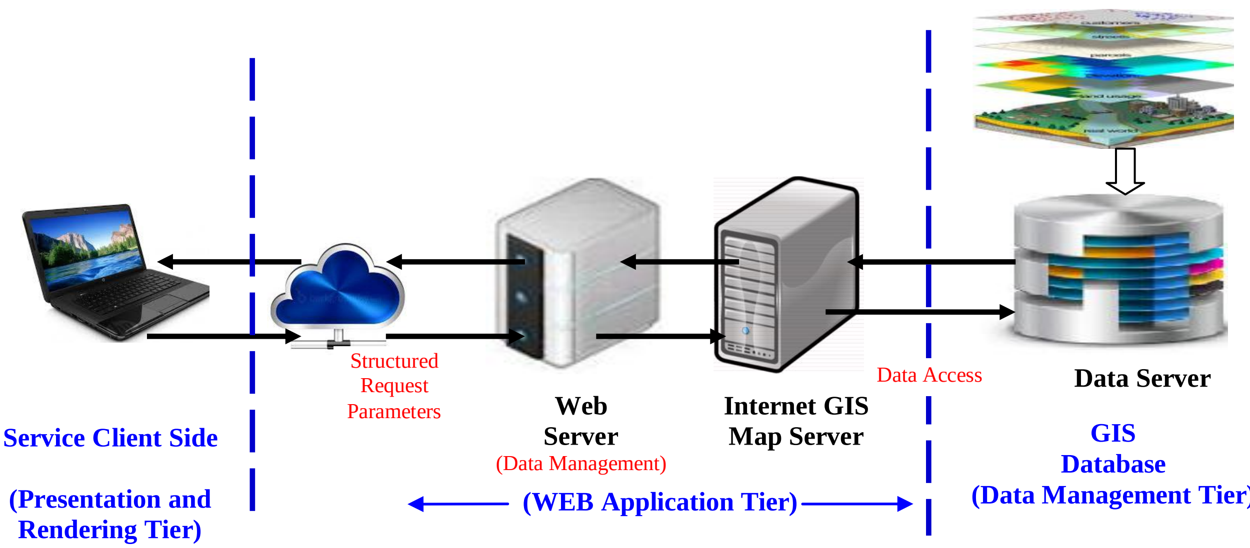

Figure2. Interactive multi-tier GIS Web-based System

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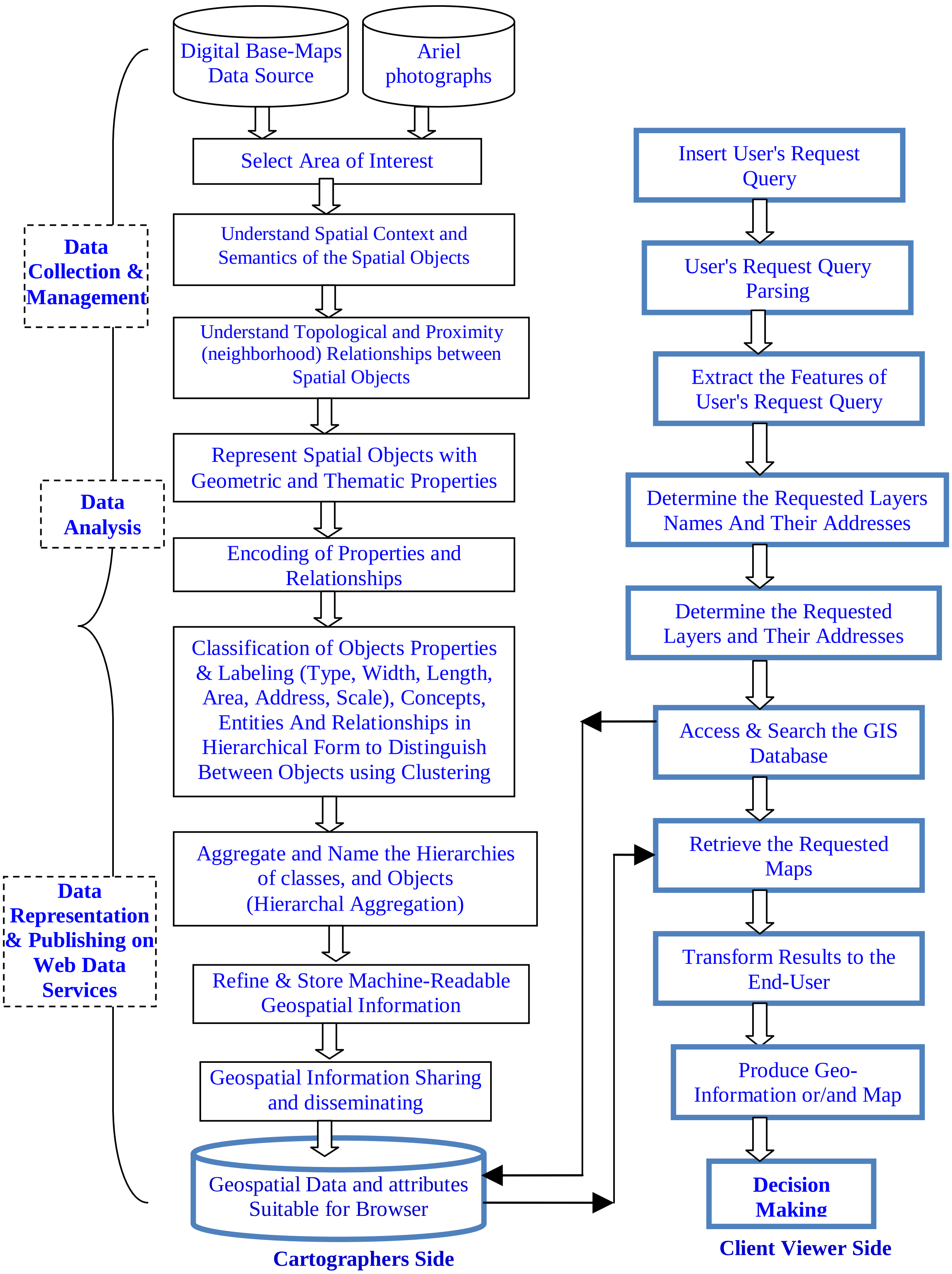

Figure 3. Interactive GIS Web-based System Architecture