

9. Functions of GIS

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Abstract:

Geographic Information Systems (GIS) serve as powerful tools for managing, analyzing, and visualizing geographical data. At its core, GIS integrates various types of information linked to geographic locations, allowing users to comprehend, interpret, and make informed decisions based on spatial relationships and patterns.

The primary functions of GIS encompass data input, storage, analysis, and output, playing a pivotal role across multiple domains. Data collection forms the foundation of GIS, aggregating information from diverse sources such as satellite imagery, surveys, GPS, and existing databases. This amalgamation of data is organized and stored in GIS databases, maintaining spatial references crucial for accurate analysis. GIS facilitates in-depth analysis through spatial queries, overlaying different datasets, and conducting spatial analysis techniques like buffering, interpolation, and network analysis.

These functionalities enable professionals in fields like urban planning, environmental science, and public health to identify trends, assess relationships, and model scenarios for better decision-making. The applications of GIS are far-reaching, impacting disaster management, natural resource exploration, transportation planning, and more. In disaster management, GIS assists in assessing vulnerabilities, planning evacuation routes, and coordinating emergency responses. In natural resource exploration, it aids in identifying potential sites for mining, oil exploration, or renewable energy installations. Additionally, GIS supports decision-making processes by providing spatial insights. It aids in identifying suitable locations for new infrastructure, optimizing transportation routes, or analyzing demographic trends for urban development projects. In essence, GIS acts as a catalyst for informed decision-making by harnessing the power of spatial data. Its multifaceted functions empower various industries and disciplines, facilitating a deeper understanding of our world's complex geographical dynamics.

Keywords:

Spatial, GIS, Data storage, Agriculture, Climate.

8.1 Introduction:

Geographic Information Systems (GIS) serve a multitude of functions that contribute to the effective management, analysis and visualization of geospatial data. Some of the key functions of GIS include:

1. Data capture
2. Data transfer
3. Data storage
4. Querying the data
5. Analysis
6. Data Presentation

9.1 Data Capture:

Data capture in Geographic Information Systems (GIS) is the process of acquiring, collecting, and digitizing geographic data from various sources to create digital representations of the real world. This essential step forms the foundation for all GIS activities, including analysis, visualization and decision-making. Here's a detailed description of data capture in GIS:

- **Data Sources:** Data capture begins with identifying and sourcing geographic data. These sources can be diverse and include satellite imagery, aerial photographs, GPS surveys, field observations, paper maps, government databases, remote sensors and more. The data may represent features such as roads, buildings, land parcels, rivers, vegetation or any other spatial elements.
- **Data Collection:** Geographic data is collected through various means, such as field surveys, remote sensing or satellite and aerial imagery. Field surveys involve sending personnel to gather data on-site, while remote sensing captures data from a distance using sensors or instruments, like satellite or drones.
- **Data Types:** Data capture encompasses both vector and raster data. Vector data represent points, lines and polygons, suitable for features like roads, rivers and administrative boundaries. Raster data represent gridded surfaces and are used for continuous phenomena like satellite images or elevation models.
- **Data Accuracy:** Ensuring data accuracy is crucial in data capture. This involves validating data through ground truthing, verifying the precision of measurement tools, and implementing quality control checks to minimize errors.
- **Data Conversion:** In many cases, captured data needs to be converted into a digital format. This conversion may involve manual data entry, scanning and digitizing paper maps or using Optical Character Recognition (OCR) to extract information from documents.
- **Georeferencing:** Georeferencing is the process of assigning geographic coordinates (latitude and longitude) to data points. This ensures that data can be correctly placed on the Earth's surface, allowing for accurate mapping and spatial analysis.
- **Data Integration:** Data capture can involve merging data from multiple sources and formats. Integration is essential to create comprehensive and coherent GIS databases that incorporate a variety of geographic information.

- **Data Attribute Collection:** Beyond spatial coordinates, data capture includes capturing attributes or attributes associated with geographic features. For instance, in a GIS database of land parcels, attributes may include land ownership, land use and land value.
- **Data Validation:** To ensure the quality and reliability of the captured data, validation processes are applied. This includes checking for inconsistencies, completeness, and adherence to data standards. Data that does not meet quality criteria may require re-capture or correction.
- **Data Storage:** Captured data is stored in digital formats, such as shapefiles, geodatabases, or other GIS file formats. Storing data in a structured database facilitates efficient data retrieval and analysis.
- **Metadata:** Captured data is accompanied by metadata, which describes information about the data, including its source, date of capture, accuracy, and other important details. Metadata helps users understand and assess the data's quality and suitability for their needs.
- **Data Security and Privacy:** Considerations for data security and privacy are essential, especially when dealing with sensitive geographic information. Proper safeguards must be in place to protect data during capture and subsequent storage.

9.2 Data Transfer:

Data transfer in Geographic Information Systems (GIS) technology involves the movement of geographic data from one location or system to another. It is a critical component of GIS operations, as it enables the sharing, collaboration, and utilization of spatial information.

Here's a descriptive explanation of data transfer in GIS:

- **Data Sources:** GIS data can originate from a variety of sources, such as field surveys, remote sensing, satellite imagery, government agencies or online repositories. These data sources can include information on geographic features, terrain, land use, environmental parameters, and more.
- **Data Formats:** GIS data can be stored in various formats, including vector (e.g., points, lines, polygons) and raster (gridded) formats. Each format is suited for different types of data, with vector data being more suitable for representing discrete features and raster data for continuous surfaces.
- **Data Preparation:** Before transferring GIS data, it often needs to be prepared. This may involve cleaning and preprocessing to ensure data quality, consistency and compatibility. Data may need to be transformed into a common coordinate system and projection to ensure accurate overlay and analysis.
- **Data Transfer Protocols:** Various protocols and methods are used for data transfer in GIS. These include manual processes like exporting and importing data in common GIS software formats (e.g., shapefiles, geodatabases) or using data interchange standards such as Geography Markup Language (GML), Keyhole Markup Language (KML) or Web Feature Service (WFS).
- **Online Data Sources:** Many GIS applications rely on web services to access and transfer data. Web Map Services (WMS) and Web Map Tile Services (WMTS) allow users to retrieve map images, while Web Feature Services (WFS) and Web Coverage Services (WCS) provide access to vector and raster data, respectively over the internet.

- **File Transfer:** Data can be transferred as files between GIS systems. Common file formats include shapefiles, GeoJSON, and KML, which are easy to share and import into GIS software. Cloud storage services like Dropbox, Google Drive, and FTP servers are often used for file transfer.
- **Database Integration:** In enterprise GIS environments, data transfer frequently involves integrating GIS databases with other systems, such as Customer Relationship Management (CRM) or Enterprise Resource Planning (ERP) systems. This integration enables the flow of geographic information across an organization.
- **Data Sharing Platforms:** Some organizations use dedicated data sharing platforms or data portals to facilitate data transfer. These platforms provide a centralized location for storing and accessing GIS data, making it easy for multiple users or departments to collaborate.
- **Data Exchange Standards:** Standardized data formats and protocols are crucial for successful data transfer. Organizations often adhere to widely accepted GIS data exchange standards, such as those defined by the Open Geospatial Consortium (OGC), to ensure compatibility and interoperability between different GIS systems.
- **Data Security and Access Control:** Data transfer in GIS also involves considerations of data security and access control. Organizations need to implement measures to protect sensitive geographic data during transfer and ensure that only authorized individuals can access and use the information.
- **Metadata Transfer:** Metadata, which provides information about the data, should accompany the data during transfer. Metadata helps users understand the data's source, quality, and content, facilitating its effective use.

9.3 Data Storage:

Data storage in Geographic Information Systems (GIS) is a critical component that involves the organized and efficient management of geographic data. GIS data storage encompasses the physical and digital infrastructure and strategies employed to store, retrieve, and maintain spatial information.

Here's a descriptive explanation of data storage in GIS:

- **Data Types:** GIS data storage handles both vector and raster data. Vector data represent geographic features as points, lines, and polygons, while raster data store information as gridded cells. Vector data are commonly used for discrete features like roads and administrative boundaries, while raster data are suitable for continuous phenomena like satellite imagery or elevation models.
- **Data Formats:** GIS data is stored in specific formats designed for spatial data management. These formats include Shapefiles, Geodatabases (e.g., Esri File Geodatabase), GeoJSON, and many others. Raster data may be stored in formats like GeoTIFF.
- **Data Hierarchy:** GIS data storage often employs a hierarchy or structure to organize data effectively. This hierarchy can include levels such as datasets, layers, feature classes, and individual features or cells. This structure helps maintain data integrity and makes data management more straightforward.

- **Relational Databases:** For large-scale GIS projects, relational databases (e.g., PostgreSQL with PostGIS or Microsoft SQL Server) are used to store and manage spatial data efficiently. These databases allow for data integrity, data relationships, and complex querying.
- **File-Based Storage:** Smaller GIS projects may use file-based storage systems, such as shapefiles or GeoJSON files, for simplicity and ease of sharing. These formats are portable and can be easily transported and shared.
- **Geodatabases:** Geodatabases are a common choice for GIS data storage because they provide a central repository for GIS data and allow for complex data relationships, versioning, and topological integrity. They are used in Esri's ArcGIS software and come in personal, file, and enterprise geodatabase varieties.
- **Data Compression:** To save storage space, large raster datasets are often compressed. Various compression techniques like JPEG, LZW, or lossless methods are applied to raster data to reduce file sizes while maintaining data quality.
- **Data Indexing:** Data storage systems use indexing techniques to accelerate data retrieval and querying. Indexing allows for rapid access to specific geographic features or areas of interest within a dataset.
- **Data Security and Backup:** Security is a significant concern for GIS data storage. Access controls and user privileges are established to protect sensitive geographic data. Additionally, regular backups are crucial to ensure data recovery in the event of data loss or system failures.
- **Metadata:** Storing metadata, which describes the characteristics of the data (e.g., source, date, accuracy), is a standard practice in GIS data storage. Metadata provides context and helps users understand and assess the data's quality.
- **Scalability:** GIS data storage solutions must be scalable to accommodate the increasing volume of data that organizations generate over time. Scalability ensures that the system can grow and adapt to evolving GIS needs.
- **Cloud-Based Storage:** Many organizations are turning to cloud-based storage solutions like Amazon S3, Azure Blob Storage or Google Cloud Storage to store and manage GIS data. Cloud storage offers scalability, accessibility, and data redundancy benefits.

9.4 Querying the Data:

Querying data in Geographic Information Systems (GIS) is a fundamental process that allows users to retrieve specific information from spatial datasets based on their criteria.

This is crucial for spatial analysis, decision-making, and generating meaningful insights. Here's a descriptive explanation of querying data in GIS:

Data Selection:

Querying in GIS begins with selecting the dataset or layer that you want to analyze.

This could be a map layer representing features like roads, parcels, or land use, or a raster layer like a satellite image or elevation model.

Query Types: There are various types of queries in GIS

- **Attribute Queries:** These involve searching for data based on attributes or properties. For example, you might query a land parcel layer to find all parcels with a land use type of "residential."
- **Spatial Queries:** Spatial queries involve searching for features based on their spatial relationships. For example, you might query to find all hospitals within a certain distance from a major road.
- **Combined Queries:** These queries combine both attribute and spatial criteria. For example, finding all parks (attribute) within a certain neighborhood (spatial).
- **Query Expression:** Users define the query criteria using expressions. In attribute queries, expressions could involve logical operators (AND, OR), comparison operators (=, >, <), and wildcards (*, ?) to filter data. In spatial queries, you specify spatial relationships like "within," "touches," "crosses," or "contains."
- **Query Tools:** GIS software provides tools to perform queries. These tools may be in the form of dialog boxes, SQL (Structured Query Language) expressions, or visual query builders where users can define criteria through a graphical interface.
- **Query Results:** Once a query is executed, the software returns a set of features that match the specified criteria. These features are displayed on the map or presented in a tabular format. Users can visualize the results and further analyze them.
- **Selection and Highlighting:** The queried features are typically selected and highlighted in the GIS interface, making them easily distinguishable from other features. This visual representation helps users identify the specific data of interest.
- **Exporting Query Results:** Many GIS applications allow users to export the query results, either as new data layers or as tabular data. This is useful for further analysis, reporting, or sharing with others.
- **Joining Data:** In some cases, users may want to combine datasets through attribute queries. This is done by joining or relating datasets based on common attributes. For example, matching a list of customers to a list of sales territories based on a shared ZIP code.
- **Topological Queries:** GIS also supports topological queries that involve understanding the spatial relationships between features. For example, you might query to find all features that share a common boundary or do not overlap with others.
- **Buffer Queries:** Buffer queries involve creating a buffer zone around a specific geographic feature and then querying for features within that buffer zone. This is commonly used in proximity analysis.
- **Temporal Queries:** In addition to spatial and attribute queries, GIS can support temporal queries where you filter data based on time or date-related attributes. For example, you might query for all earthquake occurrences in a specific year.
- **Geospatial Analysis:** Query results can serve as inputs for further geospatial analysis, such as spatial statistics, modeling, or spatial interpolation, allowing for a deeper understanding of the data and its relationships.

9.5 Analysis:

Analysis in GIS applications refers to the process of using Geographic Information Systems (GIS) to examine and interpret spatial data to gain insights, make informed decisions, and

solve specific problems. GIS analysis involves the application of various geospatial techniques and tools to answer questions, explore relationships and extract valuable information from geographic data. Here are some common applications of GIS analysis.

- **Urban Planning:** GIS is used to analyze population growth, land use patterns, transportation networks, and infrastructure planning. It helps urban planners make informed decisions about zoning, development, and resource allocation.
- **Environmental Management:** GIS is essential for assessing and managing environmental resources. It's used to monitor deforestation, track changes in ecosystems, model climate patterns, and plan for conservation efforts.
- **Natural Resource Management:** GIS assists in the sustainable management of natural resources like forests, water, and minerals. It helps in resource inventory, monitoring, and optimizing extraction or conservation strategies.
- **Emergency Response and Disaster Management:** During disasters, GIS is crucial for locating affected areas, coordinating rescue efforts and analyzing the impact of natural or man-made disasters. It aids in decision-making and resource allocation.
- **Healthcare and Epidemiology:** GIS is used to track disease outbreaks, analyze healthcare accessibility, and map health data. It's essential for public health planning and epidemiological studies.
- **Transportation and Logistics:** GIS helps optimize transportation routes, analyze traffic patterns, and plan public transportation systems. It's used in logistics for efficient routing and delivery.
- **Business Location Analysis:** Companies use GIS to find the best locations for stores, offices, and warehouses based on factors like customer demographics, competition, and accessibility.
- **Agriculture and Precision Farming:** GIS is used for soil analysis, crop yield prediction, and resource management on farms. It helps farmers make data-driven decisions to increase productivity.
- **Archaeology and Cultural Heritage:** Archaeologists use GIS to map and analyze historical sites, uncover patterns of human settlement, and preserve cultural heritage.
- **Crime Mapping and Analysis:** Law enforcement agencies employ GIS to analyze crime patterns, allocate resources effectively, and plan crime prevention strategies.
- **Geodemographics:** GIS helps in creating geodemographic profiles of areas, enabling businesses and governments to understand the social and economic characteristics of different regions.
- **Utility Management:** Utilities like water, electricity, and telecommunications use GIS for infrastructure management, including locating pipes, cables, and assessing maintenance needs.
- **Land Use and Land Management:** GIS supports land-use planning, land parcel management, and assessing the impact of land development projects.
- **Spatial Analysis in Geography and Social Sciences:** GIS is widely used in geographic research, demographic studies, and social sciences to understand spatial relationships and patterns.
- **Environmental Impact Assessment:** Before initiating large-scale projects, such as construction or industrial development, GIS is used to assess and predict their environmental impact.

9.6 Data Presentation:

In Geographic Information Systems technology involves effectively communicating and visualizing spatial data, analysis results, and insights in a clear and understandable manner.

- **Map Creation and Visualization:** Maps are the primary medium for presenting spatial data in GIS. Users can create different types of maps, such as thematic maps, choropleth maps, heat maps and 3D maps to visualize geographic information and patterns.
- **Symbolization and Cartographic Design:** GIS software provides tools for symbolization, allowing users to choose appropriate symbols, colors, and styles to represent different types of data on maps. Effective cartographic design principles ensure clarity and readability in the presentation of information.
- **Layering and Overlay:** GIS allows for the layering and overlay of multiple datasets. Users can stack layers representing various features (e.g., roads, population density, land use) to create composite maps that show relationships and interactions between different geographic elements.
- **Interactive Maps and Applications:** Interactive maps and web-based GIS applications enhance data presentation by allowing users to interact with the data. These applications often include functionalities like zooming, panning, querying, and toggling layers for a more engaging and customizable experience.
- **Graphs, Charts and Infographics:** GIS technology enables the creation of graphs, charts, and infographics that complement maps to present additional information or analyze specific aspects of spatial data. These visual aids help in conveying complex information in a more digestible format.
- **Animation and Time-Series Visualization:** Some GIS applications support animation and time-series visualization, allowing users to show changes in geographic data over time. This is valuable for illustrating trends, temporal patterns, and dynamic phenomena.
- **3D Visualization and Flythroughs:** GIS technology includes capabilities for 3D visualization, enabling users to create three-dimensional representations of landscapes, buildings, and terrain. Flythroughs and virtual tours provide immersive experiences for presenting spatial data.
- **Story Maps and Narrative Presentations:** Story maps combine maps with multimedia elements (text, images, videos) to create compelling narratives. They guide viewers through a sequence of information, offering context and storytelling around spatial data.
- **Data Tables and Reports:** GIS software allows the creation of data tables and reports that accompany maps and visualizations. These tables summarize attribute data, statistical information, or analysis results to provide detailed insights.
- **Customization and Branding:** Users can customize the appearance and branding of maps and visualizations to align with organizational standards or personal preferences. This includes adding logos, legends, titles, and annotations.
- **Accessibility and User Experience:** Emphasis on accessibility ensures that the data presentation is understandable and usable by a wide audience. Consideration is given to color-blind friendly palettes, text sizes, and user-friendly interfaces.
- **Collaboration and Sharing:** GIS technology facilitates collaboration and sharing of presentations. Users can share maps, analysis results, and interactive applications with stakeholders, decision-makers, or the public through various platforms.

- **Effective Communication of Findings:** The ultimate goal of data presentation in GIS technology is to effectively communicate findings, insights, and analysis results. Clarity, accuracy and relevance is crucial for conveying information to the intended audience.

9.7 Future Prospects:

- **Integration and Interoperability:** Future GIS will focus on unified platforms and standardized data formats to enhance collaboration and data sharing across systems.
- **Advanced Data Capture:** Expect higher-resolution remote sensing and sensor fusion technologies, providing more detailed and multi-dimensional geospatial data.
- **Artificial Intelligence and Machine Learning:** AI-driven analytics and geospatial assistants will automate complex analysis, making GIS more accessible and efficient.
- **Real-Time and Dynamic Analysis:** GIS will support real-time data integration, dynamic modelling and instantaneous decision-making based on continuously updated information.
- **Cloud-Based and Edge Computing:** Greater reliance on cloud-based systems and edge computing will offer scalability, accessibility, and localized processing for GIS applications.
- **Augmented and Virtual Reality:** Expect immersive 3D visualization and mixed reality GIS, enabling users to explore and analyze spatial data in interactive environments.
- **Enhanced Data Privacy and Security:** Integration of blockchain technology will ensure the security and integrity of geospatial data, particularly in sensitive applications.

9.8 References:

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