GIS CERTIFICATION INSTITUTE

GISCI Geospatial Core Technical Knowledge Exam®

Official Study Guide

Version 1.1 May 2024

TABLE OF CONTENTS

INTRODUCTION

The GISCI Geospatial Core Technical Knowledge Exam is vendor and software-agnostic, based upon a job analysis of a four-year experience level, informed by the GIS&T Body of Knowledge, guided by the Geospatial Technology Competency Model (GTCM), and centered upon ten key **Knowledge Categories**. The Exam measures breadth of geospatial knowledge across **10 Content Areas**.

1. Conceptual Foundations
2. Geospatial Data Fundamentals
3. Cartography and Visualizations
4. Data Acquisitions
5. Data Manipulation
6. Analytical Methods
7. Database Design and Management
8. Application Development
9. Systems Design and Management
10. Professional Practice

This study guide is organized around the 10 Content Areas and the subtopics within each.

See **Appendix A** for the full exam blueprint.

RESOURCES

This study guide draws from several resources to provide a framework to help you prepare for the exam. Many resources are available that not only prepare for the GISP Exam but also help you develop skills in your career as a GIS Professional.

See **Appendix B** for a list of additional resources.

The University Consortium of Geographic Science GIS&T Body of Knowledge (GIS&T BoK)

"The **UCGIS** Body of Knowledge documents the domain of geographic information science and its associated technologies (GIS&T). By providing this content in a digital format, **UCGIS** aims to continue supporting the **GIS&T** higher education community and its connections with the practitioners, employers, and clients who comprise the increasingly diverse collection of **GIS&T** professionals."

Home (ucgis.org)

All Topics | GIS&T Body of Knowledge (ucgis.org)

The Geospatial Technology Competency Model (GTCM)

"The **GTCM** framework for was developed through a collaborative effort involving the Employment & Training Administration (ETA) , the GeoTech Center, and industry experts, solicited public comments to update the model to reflect the most current knowledge and skills needed by today's geospatial technology professionals. Information about the specific content, published in 2023, can be found at the CareerOneStop site:

https://www.careeronestop.org/CompetencyModel/competency-models/geospatial-technology.aspx

Open GIS Consortium (OGC)

"OGC's member-driven consensus process creates royalty free, publicly available, open geospatial standards. Existing at the cutting edge, OGC actively analyzes and anticipates emerging trends, and runs an agile Research and Development (R&D) lab – the OGC Collaborative Solutions and Innovation Program – that builds and tests innovative prototype solutions to members' use cases."

Home - Open Geospatial Consortium (ogc.org)

United States Geologic Survey (USGS)

"Created by an act of Congress in 1879, the USGS provides science for a changing world, which reflects and responds to society's continuously evolving needs. As the science arm of the Department of the Interior, the USGS brings an array of earth, water, biological, and mapping data and expertise to bear in support of decision-making on environmental, resource, and public safety issues."

USGS.gov | Science for a changing world

National Geodetic Survey (NGS)

"As part of NOAA, the NGS mission is to define, maintain and provide access to the National Spatial Reference System (NSRS) (PDF, 123 KB). The NSRS provides a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States and its territories. Additionally, the NGS supports surveyors and others with high-accuracy Global Navigation Satellite System (GNSS) data, ground control marks, models and tools, guidelines, and tutorials. Advances in technology make precise positioning available to an ever-increasing number of people. NGS is dedicated to building the technical capacity of geospatial users through a variety of training and educational resources."

Home (noaa.gov)

American Society for Photogrammetry and Remote Sensing (ASPRS)

Founded in 1934 the American Society for Photogrammetry and Remote Sensing (ASPRS) is a scientific association serving over 7,000 professional members around the world. Its mission is to advance knowledge and improve understanding of mapping sciences to promote the responsible applications of photogrammetry, remote sensing, geographic information systems (GIS) and supporting technologies.

ASPRS – IMAGING AND GEOSPATIAL SOCIETY

Geography Realm

"Geography Realm is an information site covering research and case studies about the applications of geography, geographic information systems (GIS), geospatial technologies, and cartography. Find information on Geography Realm about physical and human geography as well as guides for learning about geography and developing a career in geography. Geography Realm covers a wide range of topics, including natural landscapes, climate patterns, cultural geography, cartography, and environmental issues. GIS Lounge was merged with Geography Realm on November 28, 2023. All older GIS and geospatial articles formerly published on GISLounge.com are now archived on Geographyrealm.com."

https://www.geographyrealm.com/

EDITORS

Daniel J. Boudreau, Jr, GISP
LinkedIn Profile

Bill Hodge, GISP
LinkedIn Profile

Special thanks to the editors of the previous "Unofficial Study Guide", from which much of the outline of this document was derived. **Primary Editor**: Miklos Nadas, GISP; **Contributing Editors**: Charles Altendorf, GISP, Becca Decker, Shital Upanmanyu Dhakal, GISP, Mir Hashmi

HOW TO USE THIS STUDY GUIDE

This document is the 2nd in a three-part preparation series of what the GISP is and how it can be obtained. Please note that GISCI is not a teaching organization, and the materials provided, in and of themselves, are not intended or provided to teach GIS. They serve as a resource base for the candidate to use as a launching pad for his/her own learning pathway to approach the GISP Exam, using the terms and concepts illustrated.

If you have reached this point in reading, it is assumed that you have already read the second document in the series, the ***Pathways to GISP Certification*** (https://www.gisci.org/PreGISP/Pathways-to-GISP) and carefully reviewed the section ***"To Prepare for the Exam"*** from the GISCI web site. (https://www.gisci.org/Exam-Info/Exam-Candidate-Information)

Pathways describes the process, overall, leading to the GISP, and the section, above provides some detail on the best approach on determining your readiness to test.

A third product in this series, still under construction, will be a web site specifically dedicated to more training materials, scheduled to be utilized in an interactive environment. We hope to have that product released by early 2025.

It is STRONGLY recommended that an individual have taken two actions before starting through the Exam Study Guide.

1. Reviewed and completed the *Personal Assessment Survey* found on the GeoTech Center web site. https://www.surveymonkey.com/r/RVVP8C8
2. She/he should have taken the online Practice Exam https://www.gisci.org/Exam-Info/Practice-Exam and have that first-take score and *Practice Exam Performance Report* in hand before moving to this phase of exam preparation.

The Practice Exam Performance Score & Report (taken without prior study) will show both strengths and weaknesses in a candidate's GIS skills, provide a reasonable analysis of a Candidate's GISP Knowledge GP, and it will provide the best route to how to strengthen the weaker skills needing attention.

This document is provided to help an individual prepare for the exam portion of certification, and the candidate should start the learning pathway with the weaker skills identified in the preceding tasks.

It is important to understand that memorization of the answers either on the Practice Exam or with the exam questions provided here is NOT beneficial to moving forward with a GISP Certification, nor will it help on the exam. The GISP Exam is designed to measure knowledge in a skill area, and answer memorization is not a part of that learning process. GISCI firmly believes that a candidate cannot memorize or test their way to competence. Doing well on the exam means learning the materials, concepts, and understanding of GIS, particularly the Competency Sections upon which the exam is based. Other certifications may provide such a pathway, but the GISP does not! Investigation of the terms and concepts of each question, therefore, should be the focus of in-depth learning, not simply knowing the answer to the single question shown.

A word about GIS education is necessary at this point. While it is certainly possible to advance in knowledge on your own, the technical nature of the GIS field almost mandates that some kind of focused coursework in GIS is necessary to operate at the level of a GISP. At least 98% of current GISPs have at least a bachelor's degree, and over 50% have completed or done upper graduate work in GIS. The key to GIS competency at this level is not the degree, itself, but the number of GIS & associated courses taken along with post-education experience and training. This understanding is particularly true for those coming into GIS from another profession, without extensive training in GIS fundamentals, and those new to the profession may well benefit from starting a GIS Certificate, a 4-5 course of study that can provide a suitable foundation from which to advance.

Each section with its example questions and resources is designed to provide the candidate with the resources necessary to learn the associated skills through their own efforts. Everyone is therefore encouraged to determine her/his own best method of learning, whether by individual study, group study, reading textbooks, or taking appropriate courses, as required.

Our recommended pathway requires that the individual:

1. Determine the candidate's GISP Knowledge level.
2. Separate the identified weak knowledge areas from the stronger ones.
3. Start an appropriate study program to strengthen each weak area before moving on to the stronger

Thank you for your interest in the GISP, and we hope you find this study guide to be helpful in your pathway.

1 - CONCEPTUAL FOUNDATIONS

The foundational concepts are elementary building blocks and context setting constraints of all other entries in the Body of Knowledge. The latter encompass the philosophical and mathematical support for GIScience as well as data models, while the constituent elements include, among others, notions of scale, spatial data quality, and openness. This knowledge area is also the place to look for the origins and future of GIScience.

---

101 - UNDERSTANDING OF DATUMS, COORDINATE SYSTEMS, AND PROJECTIONS

CV-06 - Map Projections | GIS&T Body of Knowledge (ucgis.org)

DM-52 - Horizontal (Geometric) Datums | GIS&T Body of Knowledge (ucgis.org)

DM-51 - Vertical (Geopotential) Datums | GIS&T Body of Knowledge (ucgis.org)

DM-88 - Coordinate Transformations | GIS&T Body of Knowledge (ucgis.org)

DATUM - GeoTech Center

Map Projections - GeoTech Center

KEY CONCEPTS AND TERMONOLOGY

A. **Georeferencing** – associating a map (such as a pdf without spatial information) or image (such as an aerial image without spatial information) with spatial locations.
B. **Control points** – consisting of multiple points, points come in pairs that match the spatial location with a point on an unreferenced image or map.
C. **Spatial reference system (SRS) or coordinate reference system (CRS)** - a coordinate-based local, regional, or global system used to locate geographical entities.
D. **International Terrestrial Reference System (ITRS).** It is a three-dimensional coordinate system with a well-defined origin (the center of mass of the Earth) and three orthogonal coordinate axes (X,Y,Z)
E. **Map projection** - transforming coordinates from a curved earth to a flat map.
F. **Horizontal datum** - model of the earth as a spheroid (2 components, reference ellipsoid and a set of survey points both the shape of the spheroid and its position relative to the earth)
G. **Vertical datum** - reference point for elevations of surfaces and features on the Earth - could be based on tidal, seas levels, gravimetric, based on a geoid.
H. **NAVD88** - gravity based geodetic datum in North America
I. **Geodetic datum** - set of control points whose geometric relationships are known, either through measurement or calculation.
J. **WGS 84** - World Geodetic System - reference coordinate system used by the Global Positioning System (GPS)
K. **SRID integer** - spatial reference system id numbers, including EPSG codes defined by the International Association of Oil and Gas Producers
L. **4 distortions** - Distance - Direction - Shape – Area
M. **Mercator Projection** - Preserves shape and direction, area gets distorted - projecting earth onto a cylinder tangent to a meridian.
N. **Azimuthal Equidistant** - planar (tangent) - used for air route distances - distances measured from the center are true - distortion of other properties increases away from the center point.
O. **Cylindrical equal-area projections** - preserves area, shape and distance gets distorted near the upper and lower regions of the map - straight meridians and parallels - meridians are equally spaced and the parallels are unequally spaced.
P. **Conic projections** - preserves directions and areas in limited areas - distorts distances and scale except along standard parallels - generated by projecting a spherical surface onto a cone.
Q. **Choosing a projection:**

- **Latitude**: Low-latitude areas (near equator) use a conical projection; Polar regions use an Azimuthal planar projection
- **Extent**: Broad in East-West (e.g., the US) use a conical projection; Broad in North-South (e.g., Africa) use a transverse-case cylindrical projection.
- **Thematic**: If you are doing an analysis that compares different values in different locations, typically an equal-area projection will be used.

SAMPLE QUESTION

What does **georeferencing** involve in the context of spatial data?

A) Associating a map (such as a PDF without spatial information) or image (such as an aerial image without spatial information) with spatial locations.

B) Calculating the area of a geographic feature.

C) Determining the elevation of a point on the Earth's surface.

D) Converting coordinates from a flat map to a curved Earth.

Answer: A) Associating a map (such as a PDF without spatial information) or image (such as an aerial image without spatial information) with spatial locations.

Explanation: Georeferencing is the process of linking spatial data (such as maps or images) to specific geographic locations. It allows us to relate features on a map or image to their real-world positions on the Earth's surface[2].

102 - UNDERSTANDING OF REPRESENTATION OF DISCRETE FEATURES AND CONTINUOUS PHENOMENA IN GIS

DM-07 - The Raster Data Model | GIS&T Body of Knowledge (ucgis.org)

DM-13 - The topological model | GIS&T Body of Knowledge (ucgis.org)

DM-14 - Classic vector data models | GIS&T Body of Knowledge (ucgis.org)

DM-15 - The network model | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMONOLOGY

A. **Discrete features** – a feature that has a definable boundary, begins, and ends, for example a highway or lake.
B. **Continuous phenomena** – each location is a measure of something, for example elevation.
    - Measure of concentration level
    - Measure of a value in terms of a fixed point (like elevation in terms of sea level)
C. Be able to indicate if a geographic feature is either discrete or continuous.

SAMPLE QUESTION

Which of the following statements accurately describes the distinction between **discrete features** and **continuous phenomena** in GIS?

A) Discrete features have well-defined boundaries, while continuous phenomena lack clear boundaries.

B) Discrete features are represented using continuous color scales, while continuous phenomena use distinct colors or symbols.

C) Discrete features are typically represented as points, lines, or areas, while continuous phenomena are represented as polygons.

D) Continuous phenomena are mainly nouns, whereas discrete features are derived from fixed registration points.

Answer: A) Discrete features have well-defined boundaries, while continuous phenomena lack clear boundaries.

Explanation: Discrete features refer to objects with definite boundaries, such as roads, buildings, and land parcels. These features are easily represented as points, lines, or areas on maps.

Continuous phenomena, on the other hand, lack well-defined or relevant boundaries. Examples include temperature, air quality, and elevation. Continuous data is often represented using gradients or continuous color scales to visualize patterns across a range of values [12].

Understanding this distinction is crucial for effective GIS data management and analysis!

103 - KNOWLEDGE OF EARTH GEOMETRY AND ITS APPROXIMATIONS

DM-44 - Earth's Shape, Sea Level, and the Geoid | GIS&T Body of Knowledge (ucgis.org)

DM-51 - Vertical (Geopotential) Datums | GIS&T Body of Knowledge (ucgis.org)

DM-52 - Horizontal (Geometric) Datums | GIS&T Body of Knowledge (ucgis.org)

Map Projections - GeoTech Center

DATUM - GeoTech Center

KEY CONCEPTS AND TERMONOLOGY

A. **Geoid** is the shape that the surface of the oceans would take under the influence of Earth's gravitation and rotation alone, in the absence of other influences such as winds and tides. It was first defined by Carl Friedrich Gauss in 1828. Essentially, the geoid represents **the true physical shape of the Earth**. Unlike the reference ellipsoid (which is a mathematical idealized representation of the Earth as an ellipsoid), the geoid is irregular but considerably smoother than the Earth's physical surface. Its deviation from an ellipsoid ranges from +85 meters (such as in Iceland) to -106 meters (in southern India), with a total variation of less than 200 meters. In practical terms, the geoid serves as a reference coordinate surface for various vertical measurements, including orthometric heights, geopotential heights, and dynamic heights. All points on the geoid surface have the same geopotential (the sum of gravitational potential energy and centrifugal potential energy). At this surface, apart from temporary tidal fluctuations, the force of gravity acts everywhere perpendicular to the geoid, meaning that plumb lines point perpendicular and bubble levels are parallel to the geoid. In other words, the geoid corresponds to the free surface of water at rest (if only Earth's gravity and rotational acceleration were at work). This property also ensures that a ball placed on the geoid would remain at rest instead of rolling. In summary, the geoid provides a more accurate representation of the Earth's shape than a simple ellipsoid, considering the uneven distribution of mass within and on the Earth's surface. It plays a crucial role in geodesy and geophysics, especially for precise measurements and calculations related to Earth's gravitational field and topography.

B. **Reference ellipsoid** is a smoothed mathematically defined surface that approximates the geoid, the truer figure of the Earth, or other planetary body and is used as a frame of reference for geodetic calculations. It approximates the geoid by simplifying the Earth's shape into an ellipsoid (specifically, an ellipsoid of revolution).

C. **Oblate ellipsoid** is a shape that resembles a sphere but is slightly flattened at the poles. The key points about the oblate spheroid are:

- **Shape and Definition:**
  - An oblate spheroid is obtained by rotating an ellipse about its minor axis.
  - Imagine taking a sphere and gently pressing it down from the top, causing the poles to flatten slightly.
  - The result is a shape where the circumference around the poles (the shorter axis) is less than the circumference around the equator (the longer axis).
  - Shapes of this type are called **ellipsoids**.
- **Earth and Planets:**
  - The Earth and several other planets (such as Saturn) are oblate spheroids.
  - The difference between a perfect sphere and the Earth's shape is small—only about one part in 300.
  - Even an M&M candy can be considered an example of an oblate spheroid!
- **Rotation and Flattening:**
  - The amount of flattening depends on factors like density and the balance between gravitational force and centrifugal force due to rotation.
  - Gas giants like Jupiter and Saturn are even more flattened by rotation than the Earth.
  - Stars also exhibit oblate spheroidal shapes based on their rotation speed. Faster rotation leads to greater flattening.

D. **Sphere** - As can be seen from the dimensions of the Earth ellipsoid, the semi-major axis a, and the semi-minor axis b differ only by a bit more than 21 kilometers.
E. **First (direct) geodetic problem** - Given a point (in terms of its coordinates) and the direction (azimuth) and distance from that point to a second point, determine (the coordinates of) that second point.
F. **Second (inverse) geodetic problem** - Given two points, determine the azimuth and length of the line (straight line, arc or geodesic) that connects them.
G. For more information on datums, see Section 101

SAMPLE QUESTION

Which of the following statements accurately describes the difference between **geoid**, **reference ellipsoid**, and **oblate ellipsoid** in GIS?

A) The geoid represents the true physical shape of the Earth while the reference ellipsoid is a mathematical idealized representation of the Earth as an ellipsoid.

B) The reference ellipsoid represents the shape of the oceans under the influence of Earth's gravity and rotation alone, while the oblate ellipsoid is formed by rotating an ellipse about its minor axis.

C) The geoid is used to reference heights by registering ocean water levels at coastal places using tide gauges, while the reference ellipsoid is associated with land use and soils data.

D) The oblate ellipsoid is primarily used for elevation modeling, while the geoid is related to land ownership and zoning.

Answer: A) The geoid represents the true physical shape of the Earth while the reference ellipsoid is a mathematical idealized representation of the Earth as an ellipsoid. What Is Geoid In Surveying? Geoid vs Ellipsoid Comparison - Civil Stuff

104 - KNOWLEDGE OF BASIC GEOMATICS AND RELATIONSHIPS TO GIS

According to **the ISO/TC 211** series of standards, geomatics is the discipline concerned with the collection, distribution, storage, analysis, processing, and presentation of geographic data or geographic information.

In simpler terms, it involves products, services, and tools related to the integration and management of geographic (geospatial) data.

Geomatics integrates science and technology from both new and traditional disciplines:

- **Geodesy**: Precise measurement and understanding of Earth's shape, gravity field, and rotation.
- **Surveying**: Land, cadastral, aerial, mining, and engineering surveying.
- **Remote Sensing**: Collecting data from a distance (e.g., satellite imagery, LiDAR).
- **Cartography**: Creating maps and spatial representations.
- **Geographic Information Systems (GIS):** Digital tools for analyzing and visualizing geographic data.
- **Global Navigation Satellite Systems** (GPS, GLONASS, Galileo, BeiDou): Positioning and navigation technology.
- **Hydrography**: Mapping water bodies and their features.
- **Geophysics**: Studying Earth's physical properties.
- Navigation and Location-based Services

Geomatics plays a crucial role in understanding Earth and its phenomena. It enables us to explore geographic features, analyze spatial relationships, and make informed decisions. Whether it's monitoring environmental changes, creating accurate maps, or managing infrastructure, geomatics is at the heart of spatial data science.

DC-01 - Professional Land Surveying | GIS&T Body of Knowledge (ucgis.org)

National Geodetic Survey (noaa.gov)

Standards Committee – ASPRS

KEY CONCEPTS AND TERMINOLOGY

A. **Geomatics** - science and technology of gathering, analyzing, interpreting, distributing, and using geographic information (includes surveying, mapping, remote sensing, GIS, GPS)
B. **Geodesy** – is the science of measuring and representing the geometry, gravity, and spatial orientation of the earth in temporally varying 3D. It is called planetary geodesy when studying other astronomical bodies such as planets or circumplanetary systems.
C. **Global Positioning System (GPS)** - For more information on GPS, see the Section on GPS

SAMPLE QUESTION

Which of the following statements accurately describes the discipline of **geomatics** and its relationship to **Geographic Information Systems (GIS)**?

A) Geomatics involves collecting, managing, and analyzing data about Earth and its phenomena, while GIS specifically focuses on spatial data exploration.

B) Geomatics is primarily concerned with remote sensing and photogrammetry, while GIS deals with surveying and mapping.

C) Geomatics encompasses the study of land use and soils data, while GIS is limited to spatial data modeling.

D) Geomatics refers to the study of graphic representation techniques, while GIS focuses on metadata management.

Answer: A) Geomatics involves a wide range of methods and technologies for collecting, managing, and analyzing data about Earth and the phenomena arranged on and near its surface. An important component of Geomatics is Geographic Information Systems (GIS); GIS uses spatial data to explore geographic phenomena[12].

2 - GEOSPATIAL DATA FUNDAMENTALS

The core of any GIS is a database that contains representations of geographic phenomena, modeling their *geometry* (location and shape) and their *properties* or *attributes*. A GIS database may be stored in a variety of forms, such as a collection of separate data files or a single spatially-enabled relational database.

Collecting and managing these data usually constitutes the bulk of the time and financial resources of a project, far more than other aspects such as analysis and mapping.[20]

201 - UNDERSTANDING OF SPATIAL DATA MODELS AND THEIR ASSOCIATED PLANAR GEOMETRIES

Living Textbook | [DM-01-034] Conceptual Data Models | By ITC, University of Twente (ucgis.org)

Living Textbook | [DM-01-035] Logical Data Models | By ITC, University of Twente (ucgis.org)

Living Textbook | [DM-01-036] Physical Data Models | By ITC, University of Twente (ucgis.org)

Living Textbook | [DM-02-020] Entity-based Models | By ITC, University of Twente (ucgis.org)

AM-20 - Geospatial Analysis and Model Building | GIS&T Body of Knowledge (ucgis.org)

DM-23 - Fields in space and time | GIS&T Body of Knowledge (ucgis.org)

Living Textbook | [DM-02-007] The Raster Data Model | By ITC, University of Twente (ucgis.org)

DM-14 - Classic vector data models | GIS&T Body of Knowledge (ucgis.org)

DM-13 - The topological model | GIS&T Body of Knowledge (ucgis.org)

DM-15 - The network model | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Spatial model** - Basic properties and process for a set of spatial features
   a. According to Bolstad:
      - **Cartographic Models** – temporally static, combined spatial datasets, operations, and functions for problem-solving.
      - **Spatio-temporal models** – dynamics in space and time, time-driven processes
      - **Network models** - modeling of resources (flow, accumulation) as limited to networks.
   b. According to Goodchild:
      - **Data models** - entities and fields as conceptual models
      - **Static modeling** - taking inputs to transform them into outputs using sets of tools and functions.
      - **Dynamic modeling** - iterative, sets of initial conditions, apply transformations to obtain a series of predictions at time intervals.
   c. According to DeMers:
      - Based on **purpose descriptive** - passive, description of the study area prescriptive - active, imposing best solution
      - Based on **methodology stochastic** - based on statistical probabilities deterministic - based on known functional linkages and interactions
      - Based on **logic inductive** - general models based on individual data deductive - from general to specific using known factors and relationships

B. **Vector** - coordinate based data model that represents **points, lines, and polygons**.
   a. **Points** – discrete locations on the ground

- Represented by a coordinate pair.

b. **Lines** – linear features, such as rivers, roads, and transmission cables
- Composed of vertices
- Begin and end at vertices.
- Represented by an ordered list of vertices.

c. **Polygons** – form bounded areas, such as islands, land masses, and water features.
- Composed of nodes and vertices
- The start node is the same as the end node.

d. Attributes associated with each feature.

C. **Raster** - composed of rectangular arrays of regularly spaced square grid cells and each cell has a value (attribute)
- Examples include soil pH, elevation, and salinity of a water body.
- Single or multiple **bands**
- Each **cell** typically has 1 attribute value, except for multi-dimensional raster data.
- **Multidimensional raster data** represents data captured at multiple times, depths, or heights. It is commonly used in atmospheric, oceanographic, and earth sciences.

  Sources and Formats:
  - **Satellite observations**: Data collected at specific time intervals.
  - **Numerical models**: Data generated by aggregating, interpolating, or simulating from other data sources.

  Common storage formats include:
  - **netCDF**: Often used for oceanographic data.
  - **GRIB**: Commonly used for weather data.
  - **HDF**: NASA frequently uses this format for scientific data storage.
  - **Esri Cloud Raster Format (CRF):** Also supports multidimensional raster data storage.
- Raster coordinates are stored by ordering the matrix.

D. **Pixel** - smallest resolvable piece of scanned image - pixel is always a cell but a cell is not always a pixel.

E. **Geodatabase** - object oriented spatial model (feature classes, feature datasets, non-spatial tables, topology, relationship classes, geometric networks)
- Basic components include **feature classes**, **feature datasets**, **non-spatial tables**.
- Complex components include **topology**, **relationship classes**, **geometric networks**.
- Relationship classes – model real-world relationships that exist between objects such as parcels and buildings.

F. **GRID** - A grid is a structured arrangement of data points or values in equally spaced rows and columns, also known as raster data. It's commonly used to organize and analyze data, especially in fields like geography, meteorology, and computer graphics. It is often used to represent features on the Earth's surface, such as elevation, land cover, temperature, precipitation, and more. Geospatial data is typically organized into grids where each cell corresponds to a specific location.

G. **TIN** - Triangulated Irregular Network - portions vector data into contiguous, nonoverlapping triangles
- Create **Delaunay triangles**.
- Advantages of **TIN** - small areas with high precision elevation data. More efficient storage than **DEM** or contour lines
- Disadvantage of **TIN** - requires very accurate data source and costs are expensive, **TIN** production and use are very computer intensive)

H. **Topological** - features need to be connected using specific rules.

I. **Hierarchical** - database that stores related information in a tree-like structure.
- Records can be traced to parent records to a root record.

J. **Network** - collection of topologically connected network elements (edges, junctions, turns)
- Each element is associated with a collection of network attributes.

K. **Object Oriented** - data management structure stores data as objects (classes) instead of rows and tables as a relational database

- Examples include SQL Server, Oracle, PostgreSQL

SAMPLE QUESTION

Which of the following statements accurately describes the basic spatial data models and their associated planar geometries?

A) The **Cartographic Model** represents temporally static, combined spatial datasets, operations, and functions for problem-solving.

B) The **Spatio-temporal models** capture dynamics in both space and time, focusing on time-driven processes.

C) The **Network models** are used for modeling resources such as flow and accumulation but are limited to networks.

D) All of the above.

Answer: D) All of the above. The basic spatial data models include the Cartographic Model, Spatio-temporal models, and Network models, each serving different purposes and representing features using planar geometries[12].

202 - UNDERSTANDING OF SPATIAL DATA RELATIONSHIPS

Spatial data relationships refer to the way objects are arranged in relation to one another in geographic space. These relationships play a crucial role in understanding spatial patterns and interactions.

Living Textbook | [DM-01-001] Spatial Database Management Systems | By ITC, University of Twente (ucgis.org)

Living Textbook | [DM-01-003] Relational DBMS and their Spatial Extensions | By ITC, University of Twente (ucgis.org)

Attribute Relationships - GeoTech Center

KEY CONCEPTS AND TERMINOLOGY

A. **Adjacency**:
   - Adjacent features share a common boundary or touch each other.
   - For example, neighboring parcels of land or adjacent census tracts.

B. **Contiguity**:
   - Contiguous features are connected or share a border.
   - In a map, contiguity represents areas that are physically touching.
   - It's essential for analyzing connectivity, such as transportation networks or ecological habitats.

C. **Overlap**:
   - Overlapping features occupy the same space.
   - Examples include land cover classes (e.g., forest overlapping with water bodies) or administrative boundaries.

D. **Proximity**:
   - Proximity refers to how close features are to each other.
   - It's crucial for analyzing accessibility, clustering, and spatial interactions.
   - For instance, measuring the distance between hospitals or identifying nearby amenities.

E. **Spatial Joins:**
   - Spatial joins connect or join data based on their spatial relationship.
   - For instance, associating census data with administrative boundaries or linking weather stations to specific regions.

F. **Colocation Analysis:**
   - Colocation analysis examines local patterns of spatial association between two categories of point features.
   - It quantifies how often certain features occur together in proximity.

G. General types of relationships:

a. **One-to-one**: each object of the origin table can be related to 0 or 1 object of the destination table.
b. **One-to-Many:** each object in the origin table can be related to multiple objects in the destination table.
c. **Many-to-Many:** multiple objects of the origin table can be related to multiple objects of the destination table.
d. **Equals**: a = b - topologically equal
e. **Disjoint:** a ∩ b = ∅ - no point in common
f. **Intersects:** a ∩ b ≠ ∅ - some common interior points
g. **Touches**: (a ∩ b ≠ ∅) ∧ (ao ∩ bo = ∅) - a touches b, at least one boundary point in common but no interior points
h. **Contains:** a ∩ b = b - feature b is within a
i. **Covers:** ao ∩ b = b - every point of b is a point of a
j. **Covered By**: Covers(b,a) - every point of a is a point of b
k. **Within:** a ∩ b = a - a is within b
l. **Crosses**: a crosses b at some point
m. **Overlaps** - a and b have common interior points.

H. Basic Topology Rules

a. Polygon rules:
   - Must be larger than cluster tolerance.
   - Must not overlap.
   - Must not have gaps.
   - Must not overlap with
   - Must be covered by feature class of
   - Must cover each other.
   - Must be covered by
   - Boundary must be covered by
   - Area boundary must be covered by boundary of
   - Contains point.
   - Contains one point.

b. Line rules:
   - Must be larger than cluster tolerance.
   - Must not overlap.
   - Must not intersect.
   - Must not intersect with
   - Must not have dangles.
   - Must not have pseudo nodes.
   - Must not intersect or touch interior.
   - Must not intersect or touch interior with
   - Must not overlap with
   - Must be covered by feature class of
   - Must be covered by boundary of
   - Must be inside.
   - Endpoint must be covered by
   - Must not self-overlap
   - Must not self-intersect.
   - Must be single part.

c. Point rules
   - Must coincide with
   - Must be disjoint.
   - Must be covered by boundary of

- Must be properly inside.
- Must be covered by endpoint of
- Point must be covered by line.

SAMPLE QUESTION

Which of the following statements accurately describes the concept of **spatial relationships** in Geographic Information Systems (GIS)?

A) Spatial relationships refer to the way objects are arranged in relation to one another in geographic space, including concepts like adjacency, contiguity, overlap, and proximity.

B) Spatial relationships are primarily concerned with temporal dynamics and changes over time within a geographic area.

C) Spatial relationships involve the study of topographic features such as mountains, valleys, and rivers.

D) Spatial relationships focus exclusively on the physical characteristics of landforms and climate patterns.

Answer: A) Spatial relationships refer to the way objects are arranged in relation to one another in geographic space, including concepts like adjacency, contiguity, overlap, and proximity[1]. These relationships are essential for understanding how features interact and influence each other within a spatial context.

203 - UNDERSTANDING OF DATA QUALITY

Data quality is a critical aspect of Geographic Information Systems (GIS). Data quality is not a one-time task; it's a continuous process. GIS professionals must consistently validate, clean, and maintain data to achieve meaningful results and informed decision making.

KEY CONCEPTS AND TERMINOLOGY

A. **Accurate Decision Making:**
   - GIS relies on data to create maps, analyze patterns, and make informed decisions.
   - High-quality data ensures accurate conclusions and reliable results.
   - Inaccurate or incomplete data can lead to poor decisions and flawed analyses.

B. **Completeness and Consistency:**
   - Data quality involves completeness (having all necessary information) and consistency (uniformity across datasets).
   - Consistent data allows seamless integration and comparison across different layers and sources.

C. **Timeliness:**
   - Up-to-date data is crucial for real-time applications.
   - Outdated information may misrepresent current conditions (e.g., traffic flow, weather, land use).

D. **Relevance:**
   - Relevant data aligns with the specific purpose of a GIS project.
   - Irrelevant or redundant data can clutter the system and hinder analysis.

E. **Avoiding Errors**
   - Poor data quality introduces errors into spatial analyses.
   - These errors propagate through calculations, affecting subsequent results.

F. **Data Validation:**
   - Validating data ensures accuracy and completeness.

- Check for spelling errors, missing values, and inconsistencies.

G. **Data Cleaning:**
   - Cleaning data involves removing errors and standardizing formats.
   - Eliminate duplicate records and correct inaccuracies.

H. **Data Maintenance:**
   - Ongoing maintenance ensures data remains accurate over time.
   - Update data to reflect real-world changes and back up data to prevent loss.

I. **Geometric accuracy** – The closeness of a measurement to its true value

J. **Root Mean Squared Error** (RMS) – a calculation to describe the difference between the measurement and the true value.
   - This can apply to georectification.
   - RMS = the square root of the average of squared errors

K. **Thematic Accuracy** - accuracy of the non-spatial data
   - Such as, is the street name accurate on a street feature class.

L. **Resolution** – smallest separation between two coordinate values
   - For rasters this refers to the cell size

M. **Precision** – level of measurement and exactness of attribute data

N. **Fitness for use** – Does the data fulfill the needs of the project?

O. **Confusion matrix** – assesses accuracy of image classification based on additional ground truths.

P. **Quality Assurance** - process oriented and focuses on defect prevention.
   - Establishment of good quality management system and assessment of its adequacy - periodic audits - managerial tool

Q. **Quality Control** - product oriented and focuses on defect identification.
   - Finding and eliminating sources of quality problems through tools and equipment - corrective tool

R. **Imprecision** - all data is taken from a 3D globe and transferred to a 2D surface through spatial transformations (projections and datums) which causes distortions with the data.

S. **Uncertainty** - The GIS data was created/collected at a certain point of time, may already be out of date.

SAMPLE QUESTION

Which of the following statements accurately describes the key components of spatial data quality?

A) Positional accuracy

B) Temporal accuracy

C) Lineage and completeness

D) All of the above

Answer: D) All of the above. The key components of spatial data quality include positional accuracy, temporal accuracy, and lineage and completeness[12].

204 - UNDERSTANDING OF DATA RESOLUTION

Data resolution plays a crucial role in Geographic Information Systems (GIS) and impacts accuracy, analysis, aesthetics, and practical considerations in GIS. Selecting an appropriate resolution ensures effective spatial representation and informed decision-making.

KEY CONCEPTS AND TERMINOLOGY

A. **Spatial Accuracy:**
- Resolution refers to the level of detail captured by a dataset. Higher resolution means finer details.
- Accurate representation of features (e.g., roads, buildings, land cover) relies on appropriate resolution.
- Low-resolution data may overlook critical features or distort shapes.

B. **Visual Interpretation:**
- High-resolution imagery allows better visual interpretation.
- Detecting small objects (e.g., trees, utility poles) becomes feasible with finer resolution.

C. **Analysis Precision:**
- Spatial analysis (e.g., buffer zones, proximity analysis) benefits from higher resolution.
- Precise measurements and calculations depend on detailed data.

D. **Map Aesthetics:**
- Maps with high-resolution data appear more visually appealing.
- Smooth lines, clear labels, and accurate symbols enhance map quality.

E. **Scale Considerations:**
- Data resolution must match the map scale.
- Large-scale maps (e.g., city maps) require high-resolution data.
- Small-scale maps (e.g., world maps) can use coarser resolution.

F. **Data Volume and Processing Time:**
- High-resolution data increases file size and processing time.
- Balancing resolution with efficiency is essential.

G. **Remote Sensing Applications:**
- Satellite and aerial imagery provide valuable data.
- High-resolution sensors enable detailed land cover classification, change detection, and environmental monitoring.

H. **Trade-offs:**
- Choosing resolution involves trade-offs:
  - **Storage**: High-resolution data demands more storage space.
  - **Processing**: Analyzing large datasets takes longer.
  - **Cost**: Acquiring high-resolution data can be expensive.

SAMPLE QUESTION

Which of the following statements accurately describes the concept of **data resolution** for gridded data in GIS?

A) Data resolution is the smallest difference between adjacent positions that can be recorded. It is tied to the scale of a paper map.

B) Data resolution refers to the ability of a sensor to distinguish between wavelength intervals in the electromagnetic spectrum.

C) High-resolution data is typically more accurate and precise, allowing for better representation of the Earth's surface.

D) Data resolution is primarily concerned with the clarity and detail of an image, often measured in terms of dots per inch (DPI) or pixels per meter.

Answer: D) Data resolution is primarily concerned with the clarity and detail of an image, often measured in terms of dots per inch (DPI) or pixels per meter. It describes how well an image or dataset can represent features on the ground[12]. Higher resolution allows for better visualization and analysis of smaller ground objects, but it also results in larger datasets and increased storage requirements.

205 - UNDERSTANDING OF DATA VALIDATION AND UNCERTAINTY

When working with geospatial data, it's essential to consider both data validity and uncertainty. Both error and uncertainty play essential roles in modeling measurement processes. While error models focus on minimizing discrepancies, uncertainty models embrace the inherent limitations and provide a more comprehensive view of measurement results.

AM-19 - Exploratory data analysis (EDA) | GIS&T Body of Knowledge (ucgis.org)

AM-22 - Global Measures of Spatial Association | GIS&T Body of Knowledge (ucgis.org)

DC-19 - Ground Verification and Accuracy Assessment | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Error-Based Modeling:**
   - **Definition**: Error represents the difference between the obtained value and the true value. It has both magnitude and sign. The true value depends on the context of use.
   - **Focus**: Error-based models emphasize understanding and quantifying the discrepancies between measurements and the idealized true values.
   - **Application**: These models are commonly used in traditional approaches to measurement, where the goal is to minimize systematic and random errors.
   - **Example**: When calibrating an instrument, we aim to reduce systematic errors (such as bias) and random errors (such as noise).

B. **Uncertainty-Based Modeling:**
   - **Definition**: Uncertainty refers to the imprecision in a value. It acknowledges that even the best measurements cannot provide definitive and complete information.
   - **Focus**: Uncertainty-based models recognize that measurements inherently carry uncertainty due to limitations in instruments, environmental conditions, and human factors.
   - **Application**: These models are prevalent in modern metrology and scientific practice. They consider uncertainties explicitly and propagate them through calculations.
   - Example: When reporting a measurement result, we include an uncertainty range (e.g., "Length = 10.5 ± 0.2 cm").
   -

C. **Conjoint Need:**
   - **Hypotheses**:
     - The concept of the **true value** is related to the model of a measurement process.
     - The concept of **uncertainty** is related to the connection between such a model and the real world.
     - **Accuracy** is a property of measuring systems (not measurement results), while uncertainty is a property of measurement results (not measuring systems).
   - **Conclusion**: These hypotheses lead to the realization that error-based and uncertainty-based modeling are not incompatible; in fact, they are conjointly needed.
   - Why? Error models address systematic and random discrepancies, while uncertainty models explicitly account for the limitations and variability inherent in measurements.

D. **Data Validity:**
   - **Validity** refers to whether the data accurately represent the real-world phenomena they intend to describe.
   - Key considerations:
     - **Precision and Accuracy**: How specific and error-free is the data? High precision and accuracy enhance validity.
     - **Relevance:** Are the data suitable for a specific application? Data must be fit for the intended purpose.

   - **Fitness for Use**: Overall, data quality should align with the task at hand.

E. Uncertainty

- **Uncertainty** arises due to errors, limitations, and unknowns in geospatial data.
- Types of uncertainty:
   - **Measurement Uncertainty**: Errors from data collection methods (e.g., GPS accuracy).
   - **Model Uncertainty**: Inherent limitations of spatial models (e.g., interpolation).
   - **Contextual Uncertainty**: Influence of surrounding factors (e.g., land cover context).
- **Addressing uncertainty**:
   - **Sensitivity Analysis**: Assess how input variables affect results.
   - **Metadata**: Document data sources, processing steps, and assumptions.
   - **Communication**: Clearly convey uncertainty to users and decision-makers.

Responsible geospatial practice involves acknowledging and managing uncertainty,

SAMPLE QUESTION

Which of the following statements accurately describes the concept of **data validation** and **uncertainty** in GIS?

A) Data validation ensures that spatial data are accurate and complete, while uncertainty refers to the unpredictable nature of real-world phenomena.

B) Data validation involves checking the consistency and correctness of spatial data, while uncertainty relates to the precision and reliability of measurements.

C) Data validation focuses on metadata management, while uncertainty deals with spatial relationships and topology.

D) Data validation is concerned with data storage and maintenance, while uncertainty pertains to spatial analysis techniques.

Answer: B) Data validation involves checking the consistency and correctness of spatial data, ensuring that it adheres to specified rules and standards. Uncertainty, on the other hand, relates to the inherent variability and lack of perfect knowledge in spatial data due to factors like measurement errors, approximation, and model assumptions[12]. Both concepts play crucial roles in maintaining data quality and making informed decisions in GIS.

206 - UNDERSTANDING OF METADATA

Geospatial metadata (also geographic metadata) is a type of metadata applicable to geographic data and information. Such objects may be stored in a geographic information system (GIS) or may simply be documents, datasets, images or other objects, services, or related items that exist in some other native environment but whose features may be appropriate to describe in a (geographic) metadata catalog (may also be known as a data directory or data inventory).

In summary, geospatial metadata ensures proper utilization, discovery, and understanding of spatial data resources, supporting effective decision-making and analysis[1234].

DM-57 - Metadata | GIS&T Body of Knowledge (ucgis.org)

DM-60 - Spatial Data Infrastructures | GIS&T Body of Knowledge (ucgis.org)

Living Textbook | [DM-07-060] Spatial Data Infrastructures | By ITC, University of Twente (ucgis.org)

Living Textbook | [DM-07-079] U.S. National Spatial Data Infrastructure | By ITC, University of Twente (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. Documentation and Discovery:

- Like a library catalog record, metadata records document the "who, what, when, where, how, and why" of a data resource.
- Geospatial metadata describes various location-based data resources, including:
    - Maps
    - Geographic Information Systems (GIS) files
    - Imagery
    - Other spatial datasets

B. Key Components of Geospatial Metadata:

- **Title**: Descriptive name of the dataset.
- **Abstract**: Summary of the dataset's content.
- **Keywords**: Relevant terms for search and discovery.
- **Spatial Extent**: Geographic coverage (bounding coordinates).
- **Temporal Extent**: Time period covered by the data.
- **Data Format**: File format (e.g., Shapefile, GeoTIFF).
- **Data Source**: Origin of the data.
- **Accuracy and Precision**: Information about data quality.
- **Projection Information**: Coordinate system details.
- **Access Constraints**: Restrictions on data use.

C. Lifecycle Support:

- Metadata serves geospatial information resources throughout their lifecycle:
    - Creation: Documenting data during its development.
    - Management: Tracking changes and updates.
    - Access and Use: Helping users understand and utilize the data.

D. Standards and Tools:

- **ISO 191** metadata series and the **FGDC CSDGM** (Content Standard for Digital Geospatial Metadata) provide guidelines for creating consistent **metadata**.
- Tools exist to create, validate, and publish **metadata**.

SAMPLE QUESTION

What is the purpose of GIS metadata?

A) To provide a detailed description of the data, including its title, abstract, and keywords.

B) To create visual representations of spatial data on maps.

C) To analyze spatial relationships between features.

D) To measure the accuracy of elevation data.

Answer: A) To provide a detailed description of the data, including its title, abstract, and keywords. GIS metadata serves as an instruction manual for understanding how the data was created and is essential for proper data management and usage[1].

207 - KNOWLEDGE OF TEMPORAL DATA

Temporal data in Geographic Information Systems (GIS) plays a crucial role in understanding how geographic phenomena change over time.

Temporal data enriches GIS by adding the dimension of time, enabling dynamic analysis and informed spatial understanding[123]

AM-80 - Capturing Spatiotemporal Dynamics in Computational Modeling | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Definition and Examples:**
   - Temporal data represents a state at a specific moment or over a duration.
   - Examples include:
     - Land-use patterns of Hong Kong in 1990.
     - Total rainfall in Honolulu on July 1, 2009.
     - Movement patterns of ocean mammals.
     - Population increases per city.
     - Disease fatalities over time.

B. **Data Representation:**
   - Temporal data can be sampled at regular or irregular intervals.
     - Regular interval: Stream flow data collected every 15 minutes.
     - Irregular interval: Lightning or earthquake data recorded whenever an event occurs.
   - Durations of time can also be represented (e.g., start and end times for fire perimeters).

C. **Time-Aware Layers in GIS:**
   - Temporal layers are configured with attribute fields defining time extents.
   - The **time slider** allows exploration and filtering of temporal data.
   - Maps with temporal data provide additional controls to explore changes over time.

D. **Applications:**
   - Visualize trends, patterns, and variations over time.
   - Monitor environmental changes (e.g., weather, land cover).
   - Analyze historical data for decision-making.

SAMPLE QUESTION

Which of the following statements accurately describes the applications of temporal data in GIS?

A) Visualize the locations of ocean mammals to understand patterns in their movement.

B) Understand population increases per city.

C) Indicate how fatalities from a disease are increasing based on changing colors in the layer symbology.

D) View ocean temperature changes or weather patterns over time.

Answer: All the above. Temporal data in GIS allows us to explore dynamic phenomena over time, including tracking ocean mammals, monitoring population changes, visualizing disease trends, and observing climate variations[1].

208 - KNOWLEDGE OF SPATIAL DATA STANDARDS, INCLUDING ISO, FGDC, AND OGC

Living Textbook | [DM-07-079] U.S. National Spatial Data Infrastructure | By ITC, University of Twente (ucgis.org)

Geospatial Metadata Standards and Guidelines — Federal Geographic Data Committee (fgdc.gov)

Content Standard for Digital Geospatial Metadata (CSDGM) — Federal Geographic Data Committee (fgdc.gov)

Home - Open Geospatial Consortium (ogc.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Federal Geographic Data Committee (FGDC) - who, what, when, where, why, and how**
   - Include title, abstract and date, geographic extent and projection info, attribute label definitions, and domain values.

B. **Content Standard for Digital Geospatial Metadata (CSDGM)**
   - ISO 19115 - developed for documenting vector and point data and geospatial services (web-mapping, data catalogs, and data modeling applications)
   - ISO 19115-2 - adds elements to describe imagery and gridded data as well as data collected using instruments (monitoring stations and measurement devices)

C. **OGC – Open GIS Consortium**
   - Describes basic data model for holding geographic data.
   - These are data file types, such as KML.

SAMPLE QUESTION

Which of the following statements accurately describes the role of **geospatial standards** and their associated organization?

A) Geospatial standards ensure that all spatial data is stored in a single format, simplifying data management.

B) The **Federal Geographic Data Committee (FGDC)** is responsible for developing and implementing geospatial standards within the U.S. government.

C) The **Open Geospatial Consortium (OGC)** focuses on creating standards for hardware manufacturers in the geospatial industry.

D) ISO 19115-3:2016 is a standard specifically related to spatial data accuracy.

Answer: B) The **Federal Geographic Data Committee (FGDC)** is the lead entity in the U.S. government for developing, implementing, and reviewing policies, practices, and standards related to geospatial data. Geospatial standards facilitate the development, sharing, and use of geospatial data and services, benefiting both federal and non-federal agencies[1]. The FGDC collaborates with other organizations, including ISO and OGC, to ensure interoperability and consistency in geospatial data standards. ISO 19115-3:2016 is indeed a standard related to metadata implementation for fundamental concepts[2]. However, it is not the primary focus of FGDC's responsibilities.

3 - CARTOGRAPHY AND VISUALIZATION

The Cartography & Visualization section encapsulates competencies related to the design and use of maps and mapping technology. This section covers core topics of reference and thematic maps design, as well as the emerging topics of interaction design, web map design, and mobile map design. This section also covers historical and contemporary influences on cartography and evolving data and critical considerations for map design and use.

Cartography and Visualization | GIS&T Body of Knowledge (ucgis.org)

Thematic map - Wikipedia

Data Presentation: Choropleth and Isopleth Mapping Techniques (geographyfieldwork.com)

Web mapping - Wikipedia

301 - UNDERSTANDING OF GRAPHIC REPRESENTATION TECHNIQUES AND IMPLICATIONS

Thematic map - Wikipedia

KEY CONCEPTS AND TERMINOLOGY

A. **Thematic** map is a type of map especially designed to show a particular theme connected with a specific geographic area.
B. **Choropleth** - areas are shaded according to prearranged key, each shading or color type represents a range of values.
C. **Proportional Symbol** - symbol drawn proportional in size to the size of the variable being represented.
D. **Isarithmic** or **Isopleth** - lines of equal value are drawn (contour lines) or ranges of similar values are filled with similar colors or patterns.
E. **Dot** - shows distribution of phenomena where values and locations are known - place a dot where the location of variable is.
F. **Dasymetric** - alternative to choropleth - ancillary information is used to model internal distribution of the phenomenon.
G. **Multivariate displays** - putting more than two sets of data on one map (i.e. single map shows population density and annual rainfall and cancer rates)
H. **Web mapping** - process of using maps delivered by GIS - web maps are both served and consumed.

SAMPLE QUESTION

Which of the following statements about **graphic representation** techniques in GIS is true?

A) Graphic representation techniques are primarily used for aesthetic purposes in map design.

B) Graphic representation techniques have no impact on the accuracy of spatial analysis.

C) Graphic representation techniques can significantly influence how geographic data is perceived and interpreted.

D) Graphic representation techniques are only relevant for 3D visualization.

Answer: C) Graphic representation techniques can significantly influence how geographic data is perceived and interpreted.

Explanation: Graphic representation techniques play a crucial role in conveying spatial information effectively. The choice of symbols, colors, scales, and visual elements impacts how users understand and analyze geographic data. It's essential to consider these implications when creating maps and visualizations in GIS[12].

302 - UNDERSTANDING OF MAP DESIGN PRINCIPLES AND ESSENTIAL MAP ELEMENTS

All Topics | GIS&T Body of Knowledge (ucgis.org)

Living Textbook | [CV-03-005] Statistical Mapping (Enumeration, Normalization, Classification) | By ITC, University of Twente (ucgis.org)

Living Textbook | [CV-03-007] Visual Hierarchy and Layout | By ITC, University of Twente (ucgis.org)

Living Textbook | [CV-03-008] Symbolization and the Visual Variables | By ITC, University of Twente (ucgis.org)

Living Textbook | [CV-03-009] Color Theory | By ITC, University of Twente (ucgis.org)

Living Textbook | [CV-03-010] Typography | By ITC, University of Twente (ucgis.org)

Living Textbook | [CV-03-029] Design and Aesthetics | By ITC, University of Twente (ucgis.org)

Living Textbook | [CV-03-030] Map Production and Management | By ITC, University of Twente (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Map layout elements** - a title, map, legend, map scale, supporting media, north arrow, metadata (sources, currency of information, projection, copyright, authorship)

B. **Symbols** - represent things on a map.

C. **Map accuracy** - difficult to assess, all maps show a selective view of reality - instead should ask if the map is appropriate for my purposes.

D. **Map scale** - 1:100 - one inch represents 100 inches in the real world.
   - Large scale (more zoomed in) shows more detail than small scale (more zoomed out)

E. **Symbolization variables** - size, shape, orientation, pattern, hue, value

F. **Quantitative**:
   - Size – the size of the point or the thickness of a line
   - Value – the shade of the color such as dark red or light red

G. **Qualitative**:
   - Shape – for points different symbol
   - Pattern – lines having different styles such as dashed lines.
   - Hue – different colors, such as red and blue

H. **Typography** - the design of text, point size, line length, typefaces

I. **Map Scales**
   - **Verbal scale** - expresses in words a relationship between a map distance and ground distance: one inch represents 16 miles.
   - **Visual scale** - graphic scale or bar scale
   - **Representative scale** - representative fraction or ratio scale 1:24,000 - 1" = 24,000"
   - **Absolute scale** - system of measurement that begins at a minimum or zero point and progresses in only one direction.
   - **Relative scale** (arbitrary) - begins at some point selected by a person and can progress in both directions.
   - **Display vs Data** - The data is built at a certain scale/accuracy but once the data is displayed in any other format that the one it was made for, the scale gets warped. Ex: a map made as 9"x10" that is then scaled down and printed in a newspaper.
   - **Large scale** – small ratio between map units and ground units. Depict small areas such as USGS topographic maps or neighborhoods.
   - **Small scale** – large ratio between map units and ground units. Depict large areas such as countries or continents.

SAMPLE QUESTION

Which of the following design principles is most crucial for creating effective maps in cartography?

A) **Visual Contrast**: The use of colors and symbols to enhance map readability.

B) **Figure-Ground**: The arrangement of map elements in a balanced manner.

C) **Hierarchical Organization**: The inclusion of metadata for map features.

D) **Balance**: The choice of appropriate map projections.

Answer: A) Visual Contrast: Visual contrast plays a significant role in making map features stand out and ensuring legibility. It relates to how map elements contrast with each other and their background, influencing how users perceive geographic data[12].

303 - UNDERSTANDING OF SURFACE INTERPRETATION AND REPRESENTATION

Map interpretation (also known as map-reading) involves interpreting or understanding the geographic information portrayed on a map. It allows the reader to develop a mental map of the real-world information by processing the symbolized details shown on the map. Surface interpretation involves the process of understanding scale, direction, relationships, navigation and how landforms are represented and depicted in maps, both in 2D and 3D.

CV-14 - Terrain Representation | GIS&T Body of Knowledge (ucgis.org)

AM-17 - Intervisibility, Line-of-Sight, and Viewsheds | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Aerial Map Interpretation**:
- **Aerial photographs** provide detailed views of the Earth's surface from above.
- **Steps**:
  - **Patterns and Features**: Look for recognizable patterns, shapes, and features (e.g., roads, buildings, rivers).
  - **Scale Bar**: Use the scale bar to determine the size of objects on the photograph.
  - **Comparison**: Compare the aerial photograph to a traditional map to identify landmarks and features.
  - **Depth Perception**: Recognize elevation changes based on shadows and perspective.

B. **Topographic Map Interpretation**:
- Topographic maps represent the Earth's surface using contour lines and other symbols.
- Key Concepts:
  - **Contour Lines**: These imaginary lines connect points of equal elevation. Walking along a contour line keeps you on a horizontal plane.
  - **Scale**: The ratio of map distance to ground distance (expressed as a fraction).
  - **Map Orientation**: North arrow indicates geographic orientation. Magnetic declination accounts for the difference between magnetic and true north.
  - **Contour Intervals**: The vertical difference between adjacent contour lines.
  - **Quantitative Data**: Extract information like **slope**, **distance**, **elevation**, and **relief**.
  - **Planimetric vs. Topographic Maps**:
    - **Planimetric maps** show distances and directions but lack elevation information.
    - **Topographic maps** include contour lines for detailed land surface representation.

C. **Process for Reading Topographic Maps**:
- **Identify Features**:

  - Locate rivers, lakes, roads, and other landmarks.
  - Understand the map's scale and orientation.
- **Contour Lines**:
  - Interpret contour lines to visualize landforms (ridges, valleys, hills).
  - Closer contour lines indicate steeper slopes.
- **Elevation** and **Slope**:
  - Determine elevation at specific points.
  - Calculate slope by analyzing contour spacing.
- **Profiles** and **Cross-Sections**:
  - Construct topographic profiles to visualize elevation changes along a line.
  - Understand landform characteristics.

D. **Applications**:
- **Geology**: Mapping landforms, erosion, and geological features.
- **Engineering**: Assessing terrain for construction projects.
- **Forestry**, **Ecology**, and **Recreation**: Understanding landscapes.

E. Be able to read aerial and topographic maps and interpret features.

F. Be able to decide how a geographic feature should be represented in GIS.

SAMPLE QUESTION

Which of the following statements about surface interpolation in GIS is true?

A) **Surface data** represents distance values over an area, and it can be stored as cell values or deduced from a triangulated network of 3D faces.

B) **Surface models** allow you to store surface information in a GIS, approximating a surface by taking samples of values at different points and interpolating between them.

C) **Contours** are sets of lines of equal value across a surface, frequently created to represent discrete features on a map.

D) **Surface interpretation** refers to the process of converting 2D data into areas in GIS.

Answer: B) Surface models allow you to store surface information in a GIS, approximating a surface by taking samples of values at different points and interpolating between them. This representation is commonly used for visualizing terrain, elevation, and other continuous phenomena[12].

304 - UNDERSTANDING OF 2D AND 3D VISUALIZATION

Topographic Mapping | U.S. Geological Survey (usgs.gov)

Living Textbook | [CV-04-014] Terrain Representation | By ITC, University of Twente (ucgis.org)

Contour line - Wikipedia

What Is 3D Mapping? A Beginner's Guide - GIS Geography

4 Uses of 3D GIS - USC GIS Graduate Programs

3D - OpenStreetMap Wiki

AM-20 - Geospatial Analysis and Model Building | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **2D Mapping and Visualization**:

- **Definition**: 2D mapping deals with objects or images that have only two dimensions: length and width.
- **Representation**:
    - **Flat**: 2D projections appear flat on a screen or surface.
    - **Common Use**: Traditional mapping applications, such as road maps and building blueprints, rely on 2D representations.
- **Examples**:
    - **2D Shapes**: Squares, circles, triangles, and parallelograms.
    - **Mapping Elements**: Road networks, buildings, and geographical boundaries represented by lines, points, or simple shapes.
- **Applications**:
    - **Graphic Design**: Used in graphic design, animation, and video games.

B. **3D Mapping and Visualization**:

- **Definition**: 3D mapping involves objects or images with an additional dimension of depth, providing an appearance of volume and realistic representation.
- **Representation**:
    - **Depth**: 3D objects extend beyond flat surfaces, incorporating depth along with length and height.
    - **Realism**: Viewed from any angle or perspective, enhancing realism and interactivity.
- **Examples**:
    - **3D Shapes**: Cubes, cylinders, and spheres.
    - **Mapping Elements**: Spatial information, topography, and landscapes represented more accurately.
- **Applications**:
    - **Virtual Reality**: Immersive experiences.
    - **Architectural Design**: Detailed 3D modeling.
    - Movies and Video Games: Realistic visualizations.

C. **Contour Line**:

- A **contour line** is drawn on a topographic map to indicate ground elevation or depression.
- These lines connect points of the same elevation.
- They represent features such as mountains, valleys, rivers, and slopes.

D. **Contour Interval**:

- The **contour interval** refers to the **vertical distance** or **difference in elevation** between adjacent contour lines.
- It quantifies the change in elevation from one contour line to the next.
- **Index contours** (usually every fifth contour line) are bolder and serve as reference points.
- If the numbers associated with specific contour lines increase, the terrain elevation also increases. Conversely, decreasing numbers indicate a decrease in elevation.

E. **Interpreting Contour Lines**:

- **Spacing**: Closer contour lines indicate steeper slopes, while widely spaced lines suggest gentler terrain.
- **Stream Crossings**: Contour lines turn upstream as they approach streams, forming a "V" shape.
- **Ridges and Depressions**: Sharp contour points indicate ridges, while rounded contours represent flatter areas.
- **Profile Drawing**: Contour maps allow drawing terrain profiles to visualize elevation changes.3D mapping brings in z-value (e.g., elevation data)

F. An **isoline** is a line connecting points of equal value on a map, chart, or graph.

- The prefix "iso-" comes from the Greek word meaning "equal."
- **Isolines** are commonly used to represent various features, including elevation, temperature, and other variables.
- **Isobars**: Points of equal atmospheric pressure.
- **Isobaths**: Depths of water with equal depth under water.
- **Isochrones**: Points of equal time-distance from a specific location.

G. 3d mapping has also included building modeling.

SAMPLE QUESTION

Which of the following statements accurately describes the difference between **2D and 3D visualization** in GIS?

A) **2D visualization** represents features within the boundary of polygons or grid cells, while **3D visualization** uses volumes to represent features.

B) **2D visualization** is primarily used for aesthetic purposes, while **3D visualization** focuses on spatial accuracy.

C) **2D visualization** is limited to flat surfaces, while **3D visualization** can project onto three-dimensional objects.

D) **2D visualization** relies on raster data, while **3D visualization** uses vector data.

Answer: A) 2D visualization represents features within the boundary of polygons or grid cells, while 3D visualization uses volumes to represent features. In 2D, features are typically shown as flat representations, whereas 3D visualization allows for a more immersive and spatially accurate experience[12].

4 - DATA ACQUISITION

The capture of massive quantities of spatial data, able to be distributed and shared in real time, provide for an ever-increasing range of environmental and societal applications. Data capture includes the principles, methods, technologies, applications, and institutional/programmatic aspects of spatial data acquisition. Sources of data include hardcopy maps, global navigation satellite systems, satellite and aerial sensing, field surveys, land records, socioeconomic data (e.g., census), volunteered geographic information, wireless sensor networks, and unmanned aerial systems.

Data Capture | GIS&T Body of Knowledge (ucgis.org)

401 - UNDERSTANDING OF DIGITIZATION AND OTHER MANUAL DATA COLLECTION AND CONVERSION METHODS

Digitization in Geographic Information Systems (GIS) is the process of converting geographic data from hardcopy or printed material into digital form.

DC-10 - Aerial Photography: History and Georeferencing | GIS&T Body of Knowledge (ucgis.org)

DC-25 - Changes in Geospatial Data Capture Over Time: Part 1, Technological Developments | GIS&T Body of Knowledge (ucgis.org)

DC-42 - Changes in Geospatial Data Capture Over Time: Part 2, Implications and Case Studies | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Manual Digitizing**:
   - **Description:** Manual digitizing involves copying features from a physical map or image by hand to create a digital file.
   - **Method:** It is done using digitizing tablets or pucks, which are similar to computer mice.
   - **Accuracy:** Manual digitizing can achieve high accuracy.
   - **Use Case:** Useful when converting paper maps or drawings into digital format.

B. **Heads-up Digitizing**:
   - **Description**: Heads-up digitizing involves scanning paper documents (maps, drawings) into digital files.
   - **Advantages**: It avoids damage or loss of the original document.
   - **Limitations**: Cannot scan color or larger files.
   - **Organizational Benefit:** Makes paperwork more organized and reduces troubleshooting time.

C. **Automatic Digitizing**:
   - **Description**: Automatic digitizing converts raster data (images) to vector data (points, lines, polygons).
   - **Purpose**: Increases speed and efficiency of GIS data collection.
   - **Goal**: Provides up-to-date spatial data in real-time.

D. **Types of Digitizing Errors in GIS**:
   - **Geodetic Errors**: Inaccuracies due to coordinate system transformations.
   - **Dangling Nodes**: Unconnected endpoints in line features.
   - **Switchbacks, Knots & Loops**: Overlapping or tangled lines.
   - **Overshoots and Undershoots**: Features extending beyond or falling short of their intended boundaries.
   - **Silver Polygon**: A polygon with self-intersecting boundaries.

E. **Primary data** - collected specifically for the purpose of a researcher's particular study.

F. **Secondary data** - collected for another purpose by someone other than the researcher.

G. **5 types of measurement** - physical measurement, observation of behavior, archives, explicit reports, computational modeling
   - **Physical Measurement** - recording physical properties of the earth or its inhabitants - size, number, temperature, chemical makeup, moisture, etc.
   - **Observation of behavior** - observable actions or activities of individuals or groups - not thoughts, feelings, or motivations
   - **Archives** - records that have been collected primarily for non-research purposes (secondary)
   - **Explicit reports** - beliefs people express about things – survey.
   - **Computational Modeling** - models as simplified representations of portions of reality

H. **Quantitative data** - numerical values, measured on at least an ordinal level but could be on a metric level.
I. **Qualitative data** - nonnumerical or numerical (nominal) values that have no quantitative meaning.
J. **Deceptive mapping** - maps can be distorted for propaganda, military protection, or ignorance.
K. **Layer** – mechanism to display geographic datasets.
L. **Data Transfer Standards**
   - **Transfer** - follow Spatial Data Transfer Standard (SDTS) - Federal Information Processing Standard (173)- robust way of transferring GIS data between computers with no information loss, including metadata.
   - **Industry Standards** - typically do not exchange topology, only graphic info; large number of format translators.
   - **Open GIS Consortium (OGC**) – non-profit, international, voluntary consensus standards organization - created GML or Geography Markup Language - XML based encoding standard.

SAMPLE QUESTION

What is the process of **digitizing** in GIS?

A) Converting geographic data from vector to raster format.

B) Creating topographic maps from satellite imagery.

C) Converting features from a hardcopy or scanned image into vector data by tracing.

D) Generating 3D models from elevation data.

Answer: C) Converting features from a hardcopy or scanned image into vector data by tracing.

Explanation: Digitizing involves capturing geographic features by tracing them from maps or images, resulting in point, line, or polygon data in vector format. It's a fundamental step in creating accurate GIS datasets[1234].

402 - KNOWLEDGE OF FIELD DATA COLLECTION

DC-09 - Field data technologies | GIS&T Body of Knowledge (ucgis.org)

SAMPLE QUESTION

Which of the following methods is commonly used for field data collection in GIS?

A) **Adding geotagged photos** as "photos with locations" to an online web map.

B) Collecting a **GPX file** from GPS receivers and smartphone fitness apps.

C) Generating a table in **CSV or TXT format** and adding it to an online web map.

D) Using a mobile device such as a smartphone or tablet paired with a Bluetooth GNSS GPS.

Answer: D) Using a mobile device such as a smartphone or tablet paired with a Bluetooth GNSS GPS.

403 - KNOWLEDGE OF AUTOMATED DATA COLLECTION AND CONVERSION METHODS

Automated data collection and conversion takes many forms and includes the use of various methodologies, instruments or sensors, and software tools for capturing and converting data for use in GIS. Often data starts out as "non-spatial" but is "spatially enabled" during the conversion process, sometimes referred to as ETL (Extract, Translate and Load).

DC-03 - Global Positioning System | GIS&T Body of Knowledge (ucgis.org)

DC-04 - Social Media Platforms | GIS&T Body of Knowledge (ucgis.org)

DC-09 - Field data technologies | GIS&T Body of Knowledge (ucgis.org)

DC-16 - Nature of Multispectral Image Data | GIS&T Body of Knowledge (ucgis.org)

DC-26 - Remote Sensing Platforms | GIS&T Body of Knowledge (ucgis.org)

DC-27 - Light Detection and Ranging (LiDAR) | GIS&T Body of Knowledge (ucgis.org)

DC-32 - Landsat | GIS&T Body of Knowledge (ucgis.org)

DC-42 - Changes in Geospatial Data Capture Over Time: Part 2, Implications and Case Studies | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Feature Extraction**: Feature extraction refers to the process of **transforming** raw data (such as satellite imagery, LiDAR point clouds, or other geospatial data) into meaningful features that can be used for **analysis**, **visualization**, or **modeling**. Often, these features represent specific **objects**, **patterns**, or **characteristics** within the data.

- **Methods of Feature Extraction in GIS**:
  - **Manual Feature Extraction**:
    - **Description**: Human analysts manually identify and delineate features of interest.
    - **Use Cases**: Identifying building footprints, roads, rivers, or land cover types.
    - **Advantages**: High accuracy but time-consuming.
  - **Automated Feature Extraction**:
    - **Description**: Algorithms and computational techniques automatically detect and extract features.
    - **Examples**:
      Deep Learning: Neural networks analyze imagery to identify objects, classify pixels, or detect changes.
      Pattern Recognition: Algorithms recognize specific shapes or textures.
      Segmentation: Dividing an image into meaningful regions.
    - **Advantages**: Faster processing, especially for large datasets.
- **Applications of Feature Extraction**:
  - **Land Cover Classification:** Extracting land cover types (forests, urban areas, water bodies) from satellite imagery.
  - **Object Detection:** Identifying specific objects (cars, buildings, trees) in aerial photos.
  - **Change Detection:** Comparing features over time to detect alterations (urban expansion, deforestation).
  - **Terrain Modeling:** Extracting elevation contours, slope, or aspect from LiDAR data.

B. **Data or Web Scraping**:

- **Description**: This method involves **extracting** data from sources that are not intended to be accessed or read by machines.
- **Process**: Automated tools visit websites, analyze their content, and extract relevant data. It's like a digital "scraping" of information.
- **Use Cases**:

    - Collecting product prices from e-commerce websites.
    - Extracting news headlines from various news portals.
- **Advantages**:
    - Efficient for large-scale data extraction.
    - Useful for monitoring changes on websites.

C. **Using APIs (Application Programming Interfaces)**:

- **Description**: APIs allow software applications to communicate with each other.
- **Process**: Developers use APIs to retrieve specific data from online services or databases.
- **Use Cases**:
    - Fetching weather data from a weather service API.
    - Accessing social media data (e.g., Twitter API).
- **Advantages**:
    - Structured and reliable data.
    - Direct access to specific information.

D. **Remote Sensing:** process of employing and instrument to acquire information about an object or phenomenon without making physical contact with it. Unlike in situ or on-site observation, remote sensing allows us to gather data from a distance.

E. **ETL (Extract, Transform, Load):** is a fundamental data integration process used to combine data from multiple sources into a consistent format for loading into a data warehouse, data lake, or other target system.

- **Extract**:
    - During the extraction phase, raw data is copied or exported from various source locations (such as databases, CRM systems, flat files, web pages, etc.) to a staging area.
    - Data can be both **structured** (e.g., SQL databases) and **unstructured** (e.g., web pages).
    - The goal is to gather relevant data for further processing.
- **Transform**:
    - In the staging area, the raw data undergoes data processing.
    - Transformation involves:
        - **Cleaning**: Removing inconsistencies, errors, and duplicates.
        - **Sanitizing**: Ensuring data quality by standardizing formats.
        - **Aggregating**: Combining data from different sources.
        - **Enriching**: Adding additional information (e.g., calculating derived metrics).
        - The **transformed** data is now ready for its intended analytical use case.
- **Load**:
    - In this final step, the **cleaned** and **transformed** data is loaded into a target database (such as a **data warehouse**).
    - The data is organized and structured for efficient **querying** and **reporting**.
    - Loading can happen incrementally or in batch mode.

SAMPLE QUESTION

Which of the following statements accurately describes automated data collection in GIS?

A) **Automated data collection** involves manually recording empirical observations in the field.

B) **Automated collection** refers to converting legacy data into digital format.

C) **Automated data collection** includes sensor-derived data and obtaining existing data from other sources.

D) **Automated collection** primarily relies on geotagged photos.

Answer: C) Automated data collection includes sensor-derived data and obtaining existing data from other sources employing hardware and software without human intervention or manual processes. This method leverages technology and tools to efficiently collect and integrate geographic information[12].

Explanation: Automated data collection plays a crucial role in modern GIS workflows, allowing for efficient and accurate acquisition of spatial data from various sources.

404 - KNOWLEDGE OF REMOTELY SENSED DATA SOURCES AND COLLECTION METHODS

Remotely sensed data refers to information acquired from a distance using sensors on satellites and aircraft. It involves detecting and monitoring physical characteristics of an area by measuring reflected or emitted radiation without direct physical contact with the object.

Characteristics of remotely sensed data include:

Sensors: Special cameras collect remotely sensed images.

Distance: Data is acquired from a distance, typically from satellites or aircraft.

Radiation: Reflected or emitted energy (such as visible light, infrared, or microwave) is detected and recorded.

Living Textbook | [DC-02-010] Aerial Photography: History and Georeferencing | By ITC, University of Twente (ucgis.org)

Living Textbook | [DC-03-026] Remote Sensing Platforms | By ITC, University of Twente (ucgis.org)

Living Textbook | [DC-03-016] Nature of Multispectral Image Data | By ITC, University of Twente (ucgis.org)

Living Textbook | [DC-03-032] Landsat | By ITC, University of Twente (ucgis.org)

Living Textbook | [DC-03-027] Light Detection and Ranging (LiDAR) | By ITC, University of Twente (ucgis.org)

Living Textbook | [DC-03-024] Unmanned Aerial Systems (UAS) | By ITC, University of Twente (ucgis.org)

Living Textbook | [DC-02-011] Street-level Imagery | By ITC, University of Twente (ucgis.org)

Remote Sensing - GeoTech Center

Remote Sensing Imagery Resolutions - GeoTech Center

KEY CONCEPTS AND TERMINOLOGY

A. **Remote Sensing:** - 3 resolutions; **spatial**, **spectral** (electromagnetic spectrum measured), **temporal** (repeat cycle)
B. **Aerial photography** and **satellite imagery**
C. **Passive sensors**: gather radiation that is emitted from objects.
   Photography, infrared, radiometers
D. **Active sensors:** emit energy and measure the amount of energy bounced back from objects.
E. **RADAR:** acronym for radio detection and ranging; is an electromagnetic sensor system used for detecting, locating, tracking, and recognizing objects at considerable distances.
F. **LiDAR:** acronym for Light detection and ranging; is a remote-sensing technology that uses laser beams to measure precise distances and movement in an environment, in real time. It operates by targeting an object or surface with a laser and measuring the time it takes for the reflected light to return to the receiver.
G. **Multispectral scanning:** remote-sensing instrument used for Earth observation capturing data across multiple spectral bands simultaneously. The Landsat program employs these types of scanners.

H. **Infrared Imaging:** also known as thermal imaging; is a sophisticated and non-invasive technique that utilizes infrared technology to detect heat emissions from various objects.

SAMPLE QUESTION

Which of the following statements accurately describes the sources of remotely sensed data in GIS?

A) **NASA Earth Observation (NEO)** provides free satellite imagery.

B) **USGS Earth Explorer** offers access to historical aerial photographs.

C) **ESA's Sentinel data** includes radar and optical imagery.

D) All of the above.

Answer: D) All of the above. Each of these sources provide data captured by remote sensing devices such as satellites or aircraft-based imagery platforms. NEO offers a wealth of Earth observation data, including multispectral and hyperspectral imagery, which is valuable for various GIS applications[12].

Remember, these data sources play a crucial role in understanding our planet's dynamics and supporting informed decision-making!

405 - KNOWLEDGE OF ACQUISITION, USE, AND LIMITATIONS OF CROWDSOURCED AND OPEN-SOURCE DATA AND SERVICES

Crowdsourced data refers to information, opinions, or work that is collected from a large group of people. This data is typically sourced via the Internet, social media platforms, and smartphone apps.

Open-sourced data refers to information that can be freely used, re-used, and redistributed by anyone, subject only to the requirement for attribution and sharing alike. There are many sources of open data from public and private providers which can either be downloaded or directly accessed via Web Mapping Services (WMS). It is important to carefully review any open-source data to ensure its accuracy and usability. Examples of common web services open to the public are Microsoft's' **Bing Maps** Services and the USGS' **National Map** Services.

OpenStreetMap

Home - Open Geospatial Consortium (ogc.org)

10 Free GIS Data Sources: Best Global Raster and Vector Datasets - GIS Geography

KEY CONCEPTS AND TERMINOLOGY

A. **Web Mapping Service (WMS):** A WMS is a standard protocol developed by the Open Geospatial Consortium (OGC) in 1999.
B. **Web Feature Service (WFS):** A WFS provides essential tools for creating interactive maps with features like search capabilities, filtering, and sorting. Unlike **WMS**, a **WFS** gives access to **vector data** (not raster).
C. **Web Coverage Service:** Like a **WFS**, a **WCS** allows you to request multidimensional **raster data**.
D. **GeoServices REST Specification:** The GeoServices REST Specification provides an open way for web clients to communicate with GIS servers by issuing requests to the server through structured URLs. The server responds with map images, text-based geographic information, or other resources that satisfy the request.
E. **Collection Methods:**
- Crowdsourcing involves obtaining data from a diverse group of individuals who voluntarily contribute their insights or perform specific tasks.
- Examples include self-reported accident updates on traffic apps like Waze, where drivers share real-time information with other users1.

F. **Variety of Contributors**
- People involved in crowdsourcing may work as paid freelancers or contribute voluntarily.

- The crowd can consist of individuals with different skills, backgrounds, and perspectives from all over the world.

G. **Advantages**

- Cost Savings: Companies can save time and money by outsourcing work to a distributed crowd rather than maintaining in-house employees.
- Skill Diversity: Crowdsourcing allows tapping into a vast array of skills and expertise.
- Real-Time Data: Crowdsourced data can provide up-to-date information due to its dynamic nature.

H. **Limitations and drawbacks**

- **Quality and Accuracy**:
  - **Variability**: Crowdsourced data can be inconsistent in quality due to the diverse backgrounds and expertise of contributors.
  - **Misinformation**: Incorrect or biased information may spread through crowdsourcing platforms, affecting the overall accuracy of the data.
- **Bias and Representativeness**:
  - **Selection Bias**: The crowd may not represent the entire population, leading to skewed results.
  - **Demographic Bias**: Certain demographics (e.g., tech-savvy individuals) are overrepresented, while others are underrepresented.
  - **Cultural Bias**: Cultural differences can impact the interpretation of tasks or questions.
- **Privacy and Security**:
  - **Data Privacy**: Crowdsourced data often involves personal information. Ensuring privacy and protecting sensitive data can be challenging.
  - **Security Risks**: Data breaches or misuse can occur if security measures are inadequate.
- **Motivation and Incentives**:
  - **Intrinsic vs. Extrinsic Motivation**: Contributors may participate for different reasons (e.g., altruism, financial gain). Incentives can affect data quality.
  - **Free-Riding:** Some contributors may benefit without actively contributing, relying on others' efforts.
- **Task Complexity**:
  - **Complex Tasks**: **Crowdsourcing** is better suited for simple, well-defined tasks. Complex tasks may require specialized expertise that the crowd lacks.
- **Lack of Context**:
  - **Contextual Understanding**: Contributors may lack context, leading to incomplete or inaccurate responses.
  - **Ambiguity**: Ambiguous tasks can result in varied interpretations.
- **Cost and Time**:
  - **Aggregation Effort**: Curating and validating crowdsourced data can be time-consuming and costly.
  - **Revisions**: Iterative revisions may be necessary to improve data quality.

SAMPLE QUESTION

Which of the following statements accurately describes limitations of crowdsourced data?

A) **Results can be easily skewed** based on the crowd being sourced.

B) **Lack of confidentiality or ownership** of an idea.

C) **Potential to miss the best ideas, talent, or direction** and fall short of the goal or purpose.

D) **All of the above**.

Answer: D) All of the above. Crowdsourcing, while valuable, has its limitations, including potential biases, lack of confidentiality, and the risk of missing critical insights[1234].

5 – DATA MANIPULATION

Data manipulation includes the theories and techniques for managing the entire data lifecycle, from data collection to data format conversion, from data storage to data sharing and retrieval, to data provenance, data quality control and data curation for long-term data archival and preservation. Click on the link below to review various topics around the management and manipulation of geospatial data.

Management | GIS&T Body of Knowledge (ucgis.org)

---

501 - UNDERSTANDING OF GEOREFERENCING, DATA FORMAT CONVERSION, AND DATA TRANSFORMATION

DM-88 - Coordinate Transformations | GIS&T Body of Knowledge (ucgis.org)

AM-20 - Geospatial Analysis and Model Building | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Georeferencing** in Geographic Information Systems (GIS) is a crucial process that aligns spatial data, such as satellite images or scanned maps, with real-world coordinates.

B. **Transformation**: Refers to the mathematical adjustment applied to align or warp a raster dataset (such as an image) from its existing location to a spatially correct location within a map coordinate system.
   - **Types of Transformation Methods**:
     - **Affine Transformation**: includes scaling, rotation, translation, and skewing. It preserves straight lines and is commonly used for georeferencing.
     - **Polynomial Transformation**: Polynomial transformations (first-order, second order, etc.) adjust the shape of the raster more flexibly. Useful when the relationship between control points is nonlinear.
     -

C. **Control points:** Control points are known x,y coordinates that link locations on the raster dataset to real-world positions. Control points are used with a **transformation method** to shift and warp the raster to its correct location.

D. **Raster to Vector Conversion:** Is the process of transforming raster data (such as satellite imagery, scanned maps, or digital elevation models) into vector format (points, lines, polygons).

SAMPLE QUESTION

What is the purpose of georeferencing raster data in GIS?

A) To create a new coordinate system for the raster dataset.

B) To adjust the brightness and contrast of the raster image.

C) To align the raster data with known positions in a map coordinate system.

D) To convert the raster data into vector format.

Answer: C) To align the raster data with known positions in a map coordinate system.

502 - UNDERSTANDING OF SPATIAL DATA GENERALIZATION OPERATIONS AND METHODS

CV-03 - Vector Formats and Sources | GIS&T Body of Knowledge (ucgis.org)

DM-85 - Point, Line, and Area Generalization | GIS&T Body of Knowledge (ucgis.org)

DM-14 - Classic vector data models | GIS&T Body of Knowledge (ucgis.org)

DM-70 - Problems of Large Spatial Databases | GIS&T Body of Knowledge (ucgis.org)

FC-10 - GIS Data Properties | GIS&T Body of Knowledge (ucgis.org)

AM-20 - Geospatial Analysis and Model Building | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Aggregation**:
- **Description**: Aggregating smaller features into larger ones.
- **Use Case**: Grouping individual buildings into neighborhoods or merging small administrative units into larger regions.
- **Purpose**: Reduces detail while maintaining overall patterns.

B. **Smoothing**:
- **Description**: Simplifying the shape of features by removing small irregularities.
- **Methods**:
  - **Douglas-Peucker Algorithm**: Simplifies lines by retaining essential vertices.
  - **Bezier Curves**: Smooths curves by approximating them with control points.
- **Use Case**: Smoothing coastlines or river networks.

C. **Selection**:
- **Description**: Choosing relevant features for a specific map scale or purpose.
- **Example**: Displaying major roads only at small scales and including local roads at larger scales.

D. **Symbolization**:
- **Description**: Representing features with simpler symbols or icons.
- **Use Case**: Using generalized icons for cities, forests, or lakes.

E. **Simplification**:
- **Description**: Reducing the number of vertices in a line or polygon.
- **Methods**:
  - **Vertex Removal**: Eliminating unnecessary vertices.
  - **Line Generalization Algorithms**: Simplifying complex shapes.
- **Purpose**: Improves rendering performance and reduces storage.

F. **Resolution Reduction**:
- **Description**: Decreasing the spatial resolution of raster data.
- **Methods**:
  - **Resampling**: Averaging pixel values within larger cells.
  - **Pyramid Layers**: Creating lower-resolution versions of the data.
- **Use Case**: Generating overviews for large imagery datasets.

G. **Hierarchy Creation**:
- **Description**: Organizing features into hierarchical levels.
- **Example**: Grouping roads into primary, secondary, and local levels.

H. **Edge Matching**:
- **Description**: Ensuring seamless connections between adjacent map sheets or tiles.
- **Use Case**: Aligning boundaries across neighboring maps.

I. **Topological Simplification**:
- **Description**: Removing unnecessary topological details.
- **Example**: Simplifying River networks while maintaining connectivity.

J. **Scale-Dependent Rendering**:
- **Description**: Adjusting feature visibility based on the map scale.
- **Use Case**: Showing more detail at larger scales and less detail at smaller scales.

SAMPLE QUESTION

Which of the following processes is associated with **Area Generalization** in GIS?

A) Expanding and shrinking zones.

B) Smoothing zone edges.

C) Nibbling and thinning.

D) Adjusting brightness and contrast.

Answer: A) Expanding and shrinking zones[3].

503 - UNDERSTANDING OF SPATIAL FILE TYPES AND THEIR APPLICATIONS AND LIMITATIONS

Understanding the limitations of spatial file types is important when making choices about how to model and store your data. This will impact the usability, maintainability, and performance of your data in various contexts. Geographic Information Systems (GIS), spatial data comes in a variety of common formats.

KEY CONCEPTS AND TERMINOLOGY

A. **Vector Data:** represents geographic features using points, lines, and polygons (areas).
- **Shapefile (.SHP, .DBF, .SHX):** Long the industry standard for file-based vector spatial data, consisting of feature geometry, attribute data, and projection metadata. Each shapefile can only contain one type of vector data (point, line, polygon).
- **Geodatabase (File, SDE):** Object model based spatial database containing a schema and rules. It is a hybrid and can contain vector, raster, and tabular data along with topologies, file attachments and relationships among the vector and tabular data. SDE based on Oracle Spatial or SQL Server provides additional capabilities of a Relational Database Management System (RDBMS) which supports versioning and integration with other database systems.
- **GeoJSON (.GEOJSON, .JSON):** Encodes geographic structures (points, lines, polygons) using JavaScript Object Notation (JSON) and is widely used for web mapping applications.
- **Geography Markup Language (.GML, .GML):** An extension of XML, storing geographic entities in text format.
- **Google Keyhole Markup Language (KML, .KML/.KMZ):** XML-based format primarily used for Google Earth.
- **Computer Aided Design CAD (.DWG, .DXF, .DGN):** Typically generated by specific design software such as **AutoCAD** or **MicroStation** to represent 2D or 3D detailed real-world objects. Many applications can import and export CAD data formats. Typically employed in **Design**, **Engineering**, **Architecture**, **Surveying** and **Construction**.
- **Digital Terrain Model (DTM):** Like a **DEM** (often the terms are used interchangeably), a DTM provides elevation data without the influence of vegetation, buildings, or other surface features and consists of a regular or irregular array of points with defined heights, capturing features such as rivers, ridges, and breaklines.

B. **Raster Data:** is composed of a grid of pixels, where each pixel represents a value or category.
- **GeoTIFF (.TIF):** Geo-referenced raster images with embedded metadata.

- **JPEG2000 (.JP2):** Efficient compression for large imagery.
- **ArcGIS Grid (.ADF):** Proprietary format for raster datasets.
- **NetCDF (.NC):** Used for **multidimensional** scientific data (e.g., climate models).
- **HDF (.HDF):** Hierarchical Data Format for scientific data storage.
- **Digital Elevation Model (DEM):** A DEM, provides elevation data in a raster grid format, where each cell represents a specific elevation value, represents the bare ground or bare earth topographic surface of the Earth, excluding trees, buildings, and other surface objects. DEMs are created from various sources, and their purpose is to provide a detailed representation of elevation across the landscape.
- **LiDAR (LAZ, LAS):** The LAS (LIDAR Aerial Survey) file format is a widely used binary format designed to store 3D point cloud data collected by LiDAR surveying systems. Each LAS file contains a collection of individual LiDAR points, each with attributes such as X, Y, and Z coordinates, intensity values, return numbers, and classification codes. The LAZ (LASzip) file format is a compressed version of the LAS format. Developed in 2007 as an open-source solution, LAZ reduces the file size of LAS files while retaining all original data.
- **Band Interleaved by Pixel (BIP) or Band Interleaved by Line (BIL):** older raster format good at storing different brightness levels.

C. **Triangulated Irregular Network (TIN)**
- **TIN** represents **terrain surfaces** using irregularly spaced triangles.
- Commonly used for 3D modeling and visualization.

D. **General Vector Advantages:**
- Represent point, line, area very accurately.
- More efficient than raster in storage
- Supports topology.
- Interactive retrieval
- Enables map generalization.

E. **General Vector Disadvantages:**
- Less intuitively understood.
- Multiple vectors overlay is computationally intensive.
- Display and plotting vectors can be expensive.

F. **General Raster Advantages:**
- Easy to understand.
- Good to represent surfaces.
- Easy to input and output.
- Easy to draw on a screen.
- Analytical operations are easier.

G. **General Raster Disadvantages:**
- Inefficient for storage
- Compression techniques not efficient with variable data
- Large cells could potential cause information loss
- Poor at representing discrete features (points, lines, areas)
- Each cell can be owned by only one feature.
- Must include redundant or missing data.

H. **Raster to Vector** conversion is not difficult based on pixel value.

I. **Vector to Raster** conversion is very difficult because pixels may distort the lines or exact point locations and would need to be re-digitized or transformed.

SAMPLE QUESTION

Which of the following file formats is widely recognized as an industry standard for geospatial data?

A) GeoJSON

B) KML/KMZ

C) Shapefile

D) GML

Answer: C) Shapefile

Explanation: Shapefile (.SHP, .DBF, .SHX): The shapefile is the most common geospatial file type encountered. It consists of three mandatory files: SHP (feature geometry), SHX (shape index position), and DBF (attribute data). Shapefiles are widely accepted by both commercial and open-source GIS software. However, they have limitations, such as being unable to store null values, annotations, attachments, employ coded domains or network features. Field names are limited to ten characters, and shapefiles can represent only point, line, or polygon features.

504 - UNDERSTANDING OF DATA INTEGRATION

In the context of GIS, data integration combines data from different sources into a "unified environment or view" allowing it all to participate in analysis and visualization. Integration often relies on data conversion and transformation processes employing ETL (Extract, Transform and Load) tools as part of a data pipeline to combine it in a data center or data lake.

Data integration - Wikipedia

KEY CONCEPTS AND TERMINOLOGY

A. **ETL (Extract, Transform and Load):** is a fundamental data integration process used to combine data from multiple sources into a consistent format for loading into a data warehouse, data lake, or other target system. See Section 504.
B. **Data Pipeline:** Like ETL it is an end-to-end sequence of digital processes to collect, modify and deliver data.
C. **Data Warehouse:** Also known as an enterprise data warehouse or EDW, it is a system that aggregates data from different sources into a single, central, consistent data store. Its purpose is to support various data-related activities.

SAMPLE QUESTION

Which of the following is a common challenge in geospatial **data integration?**

A) **Data standardization**: Many data scientists and GIS analysts spend a significant amount of time cleaning data due to a lack of standards. Different time zones, measurement units, and adoption barriers can complicate data integration.

B) **Prohibitive cost**: Implementing GIS solutions can be expensive, hindering their adoption for research and business applications.

C) **Inconsistent data**: GIS tools often encounter inconsistent, inaccurate, or outdated data, affecting decision-making.

D) **Organizational challenges**: Aligning business processes and technical integration between GIS and other systems can pose difficulties.

Answer: A) Data standardization

Explanation:

- **Data standardization** is a critical challenge in geospatial data integration. Without consistent standards, data scientists and analysts spend a significant portion of their time cleaning and harmonizing data. Issues like varying timestamps, measurement units, and adoption barriers can hinder effective integration.
- While other challenges (such as prohibitive cost, inconsistent data, and organizational hurdles) also exist, data standardization stands out as a fundamental obstacle in GIS integration[1234].

6 - ANALYTICAL METHODS

601 - UNDERSTANDING OF DATA SELECTION QUERIES AND VIEWS

Data selection and queries are fundamental for extracting relevant information from both spatial and non-spatial datasets.

SQL Tutorial - Essential SQL For The Beginners

GIS and SQL | Geography Realm

KEY CONCEPTS AND TERMINOLOGY

A. **Data selection**:
   - Selection involves choosing a subset of features (points, lines, polygons) or records (rows) from a dataset based on specific criteria.
   - Common scenarios for data selection include:
     - **Spatial Selection**: Choosing features within a defined area (e.g., selecting all buildings within a city boundary).
     - **Attribute Selection**: Filtering features based on attribute values (e.g., selecting all roads with a speed limit above 40 mph).
   - **Tools for Data Selection**:
     - **Select by Location**: Select features based on their spatial relationship to other features (e.g., selecting all parks intersecting a river).
     - **Select by Attributes**: Choose features based on attribute conditions (e.g., selecting all parcels with a land use of "residential").
     - **Interactive Selection**: Manually select features using the mouse or touch interface.

B. **Querying in GIS**:
   - Querying involves asking questions about geographic features and their attributes.
   - Queries help retrieve specific information from a dataset.
   - **Types of Queries**:
     - **Query by Attribute**: Retrieve features based on attribute values (e.g., finding all hospitals with more than 100 beds).
     - **Query by Geography**: Retrieve features based on their spatial location (e.g., finding all rivers within a specific distance of a road).

C. **SQL Expressions in GIS:**
   - Many GIS applications such as ArcGIS and QGIS support standard SQL expressions for querying.
   - You can build WHERE clauses to filter data based on field values (e.g., STATE_NAME = 'Alabama')
   - Subqueries and compound queries are also supported.
   - Different SQL dialects are used depending on the data source (file-based, SQL Server, MS Access, ArcSDE geodatabase).

D. **Benefits of Data Selection and Queries:**

- **Efficiency**: Selecting relevant data reduces the volume of information to work with.
- **Precision**: Queries allow you to pinpoint specific features or records.
- **Analysis**: Data selection and queries support spatial analysis, visualization, and decision-making.

E. **Database View**: is a powerful construct that provides a **virtual** representation of data stored in one or more database tables. It is essentially a **named query** saved within the database that remains persistent and can be called upon when needed.

- Views encapsulate complex joins, calculations, and aggregations.
- Users can query views as if they were regular tables.
- Views ensure consistent data presentation across different applications.
- Changes to the underlying tables automatically reflect in the view results.

SAMPLE QUESTION

Which of the following SQL expressions would you use to select all roads and the fields with a speed limit greater than 40 mph from a road network dataset?

A) SELECT * FROM Roads WHERE SpeedLimit > 40

B) SELECT RoadName FROM Roads WHERE SpeedLimit = 40

C) SELECT SpeedLimit FROM Roads WHERE SpeedLimit > 40

D) SELECT RoadName, SpeedLimit FROM Roads WHERE SpeedLimit > 40

Answer: A) SELECT * FROM Roads WHERE SpeedLimit > 40

Explanation:

- Option A selects all fields (*) from the Roads table where the SpeedLimit is greater than 40 mph.
- OptionB only retrievesthe specific column (RoadName) where the SpeedLimit is equal to 40 mph.
- Option C only retrieves the specific column (SpeedLimit) where the SpeedLimit is greater than 40 mph.
- Option D only retrieves both the RoadName and SpeedLimit columns for roads meeting the condition.

Remember that SQL expressions in GIS adhere to standard SQL syntax, and the correct choice depends on the specific query requirements.

602 - UNDERSTANDING OF TECHNIQUES AND IMPLICATIONS OF DATA CLASSIFICATION

Data classification is essential for visualizing and analyzing spatial data. The choice of classification method depends on the data type/scale, distribution, visualization goals, and context of your analysis.

AM-09 - Classification and Clustering | GIS&T Body of Knowledge (ucgis.org)

AM-58 - Hot-spot and Clustering Analysis | GIS&T Body of Knowledge

(ucgis.org) Data Classification (saylordotorg.github.io)

KEY CONCEPTS AND TERMINOLOGY

A. **Manual Interval**:
- **Description**: Manually define **custom class ranges** based on your understanding of the data.
- **Use Case**: Useful when you want to tailor class breaks to specific context or domain knowledge.

B. **Defined Interval**:
- **Description**: Specify an **interval size** to create classes with equal value ranges.
- **Use Case**: Appropriate for evenly distributed data, such as temperature or elevation.

C. **Equal Interval**:
- **Description**: Divide the **attribute value range** into equal-sized subranges.
- **Use Case**: Best applied to familiar data ranges (e.g., percentages), emphasizing relative differences.

D. **Quantile**:
- **Description**: Assign an equal **number of features** to each class.
- **Use Case**: Well suited for linearly distributed data but can lead to misleading maps.

E. **Natural Breaks (Jenks):**
- **Description**: Groups data based on **natural groupings** inherent in the data.
- **Use Case**: Maximizes differences between classes, but not suitable for comparing different maps.

F. Four main types of data scales that help characterize data:
- **Nominal Scale of Measurement**:
  - **Description**: Nominal data defines the identity property of data points.
  - **Characteristics**:
    - Categories have no inherent order.
    - Examples include names, labels, and categories.
    - Nominal data can be used for grouping and categorization.
  - **Example**: Classifying animals into categories like “mammals,” “birds,” or “reptiles.”
- **Ordinal Scale of Measurement**:
  - **Description**: Ordinal data defines data placed in a specific order.
  - **Characteristics**:
    - Categories have a natural order.
    - Differences between categories are not uniform.
    - Examples include ranks, ratings, and survey responses (e.g., “strongly agree,” “agree,” “neutral,” “disagree,” “strongly disagree”).
  - **Example**: Ranking students based on their exam scores.
- **Interval Scale of Measurement**:
  - **Description**: Interval data can be **categorized**, **ranked**, and has evenly spaced **intervals**.
  - **Characteristics**:
    - **Intervals** between values are consistent.
    - Zero point is arbitrary (no true zero).
    - Examples include temperature (measured in Celsius or Fahrenheit) and calendar dates.
  - **Example**: Measuring temperature differences (e.g., 20°C to 30°C).
- **Ratio Scale of Measurement:**
  - **Description**: Ratio data has all the properties of interval data, plus a natural zero point.
  - **Characteristics**:
    - Ratios between values are meaningful.
    - True zero indicates the absence of the measured attribute.
    - Examples include height, weight, income, and time (measured in seconds).
  - **Example**: Counting the number of books on a shelf (zero books means an empty shelf).

SAMPLE QUESTION

Which of the following classification methods emphasizes natural groupings inherent in the data and maximizes differences between classes?

A) Equal Interval

B) Quantile

C) Natural Breaks (Jenks)

D) Defined Interval

Answer: C) Natural Breaks (Jenks)

Explanation: Natural breaks classification (also known as Jenks classification) groups data based on inherent patterns in the data. It sets class boundaries where there are relatively significant differences in data values. This method is data-specific and not suitable for comparing multiple maps built from different underlying information.

603 - UNDERSTANDING OF ANALYTICAL OPERATIONS AND METHODS

Analytical operations and methods in GIS allow you to extract meaningful insights from both spatial and non-spatial data. GIS analytical operations empower decision-making by revealing spatial patterns, relationships, and trends.

AM-03 - Buffers | GIS&T Body of Knowledge (ucgis.org)

AM-04 - Overlay | GIS&T Body of Knowledge (ucgis.org)

AM-07 - Point Pattern Analysis | GIS&T Body of Knowledge (ucgis.org)

AM-08 - Kernels and Density Estimation | GIS&T Body of Knowledge (ucgis.org)

AM-09 - Classification and Clustering | GIS&T Body of Knowledge (ucgis.org)

AM-29 - Kriging Interpolation | GIS&T Body of Knowledge (ucgis.org)

AM-40 - Areal Interpolation | GIS&T Body of Knowledge (ucgis.org)

AM-20 - Geospatial Analysis and Model Building | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Spatial Analysis**:
- **Description**: Spatial analysis involves studying the characteristics of places and the relationships among them.
- **Purpose**:
  - Solve complex location-oriented problems.
  - Explore and understand data from a geographic perspective.
  - Determine relationships, detect patterns, assess trends, and make predictions.
- **Capabilities**:
  - **Overlay Analysis**: Combine and compare multiple layers to identify intersections, containment, or proximity.
  - **Buffer Analysis**: Create zones around features based on a specified distance.
  - **Network Analysis**: Optimize routes, find nearest facilities, and perform service area analysis.
  - **Spatial Statistics**: Calculate statistics related to spatial patterns and distributions.

    - **Interpolation**: Estimate values at unmeasured locations based on nearby measurements.
    - **Hot Spot Analysis**: Identify statistically significant clusters of high or low values.
    - **Viewshed Analysis**: Determine visible areas from a specific location.
    - **Terrain Analysis**: Analyze elevation data for slope, aspect, and visibility.
    - **Time Series Analysis**: Study changes over time using spatiotemporal data.

B. **Geoprocessing**:
  - **Description**: Geoprocessing involves performing operations on geographic data.
  - **Purpose**:
    - Transform, analyze, and manage data.
    - Automate repetitive tasks.
  - **Tools and Techniques**:
    - **Vector Operations**: **Clip**, **dissolve**, **union**, **intersect**, and more.
    - **Raster Operations**: **Reclassify**, **resample**, **mosaic**, and **calculate**.
    - **Model Builder**: Create custom workflows by chaining geoprocessing tools.
    - **Python Scripting**: Write custom scripts for specific tasks.

C. **Raster Analysis**:
  - **Description**: Raster analysis focuses on grid-based data (e.g., elevation, satellite imagery).
  - **Capabilities**:
    - **Surface Analysis**: Calculate **slope**, **aspect**, **hillshade**, and **viewshed**.
    - **Distance Analysis**: Compute proximity, cost distance, and least-cost paths.
    - **Density Analysis**: Assess point **density**, line density, and kernel density.
    - **Change Detection**: Identify differences between raster datasets.
    - **Image Classification**: Categorize pixels based on **spectral** characteristics.

D. **Statistical Analysis**:
  - **Description**: Statistical methods help uncover patterns and relationships in spatial data.
  - **Techniques**:
    - **Descriptive Statistics**: Mean, median, standard deviation, etc.
    - **Regression Analysis**: Explore relationships between variables.
    - **Cluster Analysis**: Group similar features.
    - **Correlation Analysis**: Assess associations between variables.
    - **Spatial Autocorrelation**: Detect spatial patterns.

SAMPLE QUESTION

Which of the following spatial analysis techniques is used to identify statistically significant clusters of high or low values in a dataset?

A) Buffer Analysis

B) Natural Breaks (Jenks)

C) Viewshed Analysis

D) Hot Spot Analysis

Answer: D) Hot Spot Analysis

Explanation: Hot Spot Analysis (also known as Getis-Ord Gi) identifies statistically significant spatial clusters (hot spots or cold spots) based on attribute values. It helps detect areas with unusually high or low values compared to the overall pattern.

604 - KNOWLEDGE OF MAP ALGEBRA

Map algebra involves performing mathematical operations on raster data (gridded data) within a GIS environment. Unlike traditional algebra, which deals with scalar values, map algebra operates on entire raster datasets (individual pixels and groups of pixels). It allows you to combine, transform, and analyze raster layers using various mathematical functions.

[Map algebra - Wikipedia]

[What is Map Algebra? [Raster Math] - GIS Geography]

KEY CONCEPTS AND TERMINOLOGY

A. **Types of Map Algebra Operations**:
  - **Local Operations**:
    - Apply a function (add, subtract, multiply) to each cell in a raster independently.
    - **Examples**: addition, subtraction, multiplication, division.
  - **Global Operations**:
    - Apply a function (add, subtract, multiply) to all cells in a raster simultaneously.
    - **Examples**: rescaling, thresholding, normalization.
  - **Focal Operations**:
    - Compute an output value for each **cell** based on its **neighborhood values**.
    - **Examples**: **convolution**, **kernel filters**, moving windows.

B. **Zonal Operations**:
  - Apply a function to a group of cells within a specified zone.
  - Zones can be defined by vector or raster features.
  - **Example**: calculating average temperature within watersheds.

C. **Applications of Map Algebra**:
  - **Terrain Analysis**: Derive slope, aspect, hillshade, and viewshed.
  - **Distance Measurement**: Calculate **Euclidean distance**, **cost distance**, and **least-cost paths**.
  - **Change Detection**: Identify differences between raster datasets.
  - **Spatial Modeling**: Combine multiple layers to create new information.
  - **Image Classification**: Assign land cover classes based on spectral characteristics.

SAMPLE QUESTION

Which of the following map algebra operations involves applying a function to each cell in a raster independently?

A) Focal Operations

B) Global Operations

C) Zonal Operations

D) Local Operations

Answer: D) Local Operations

Explanation: Local operations in map algebra apply a function to each cell individually without considering neighboring cells. Examples include addition, subtraction, multiplication, and division.

605 - KNOWLEDGE OF DESCRIPTIVE AND SPATIAL STATISTICS

Descriptive statistics provide simple numeric descriptions of data, summarizing its characteristics. These statistics help us understand the central tendency, variability, and distribution of a dataset. Spatial statistics is a field of applied statistics that deals with spatial data. It involves various techniques for analyzing and understanding data with a geographic or spatial context.

Descriptive statistics - Wikipedia

Summary statistics - Wikipedia

Coefficient of determination - Wikipedia

AM-22 - Global Measures of Spatial Association | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Measures of Central Tendency**:
These statistics describe the central value around which data points tend to cluster.
Common measures include:
  - **Mean (Average):** Sum of all values divided by the number of values.
  - **Median**: Middle value when data is sorted in ascending order.
  - **Mode**: Most frequently occurring value.

B. **Measures of Dispersion (Variability)**:
These statistics quantify how spread out or dispersed the data points are.
Common measures include:
  - **Range**: Difference between the maximum and minimum values.
  - **Variance**: Average of squared differences from the mean.
  - **Standard Deviation**: Square root of the variance.

C. **Frequency Distribution**:
A table or graph showing how often each value occurs in a dataset. Useful for understanding the distribution of data.

D. **Percentiles and Quartiles**:
Percentiles divide data into equal parts. Quartiles split data into four equal parts (Q1, Q2, Q3).

E. **Skewness and Kurtosis**:
Skewness measures the asymmetry of the data distribution. Kurtosis describes the shape of the distribution (peakedness or flatness).

F. **Graphical Descriptions**:
Histograms, box plots, and scatter plots visually represent data distributions.

G. **Spatial Relationships and Patterns**:
Spatial statistics explore relationships between data points based on their spatial proximity. Techniques help identify **patterns**, **clusters**, and **trends** in spatial data.

H. **Applications of Spatial Statistics**:
  - **Geostatistics**: Analyzing spatial variability and interpolation (e.g., kriging).
  - **Point Pattern Analysis**: Studying the distribution of point features (e.g., crime incidents, tree locations).
  - **Spatial Autocorrelation**: Detecting spatial patterns (positive or negative spatial dependence).
  - **Spatial Regression**: Modeling relationships between spatial variables.
  - **Hot Spot Analysis**: Identifying statistically significant clusters (hot spots or cold spots).

SAMPLE QUESTION

Which of the following spatial statistics techniques is used to measures the spatial dependence or pattern in a dataset?

A) Geostatistics

B) Point Pattern Analysis

C) Spatial Autocorrelation

D) Hot Spot Analysis

Answer: C) Spatial Autocorrelation

Explanation: Spatial autocorrelation refers to the degree of similarity or dissimilarity between spatially adjacent data points within a geographic dataset.

7 - DATABASE DESIGN AND MANAGEMENT

701. UNDERSTANDING OF RELATIONSHIPS AMONG DATABASE OBJECTS

Database objects refer to various structures and components used to organize, store, and manipulate data. These objects play a crucial role in database management systems (DBMS).

UCGIS Bok Visualizer and Search

DM-03 - Relational DBMS and their Spatial Extensions | GIS&T Body of Knowledge (ucgis.org)

DM-04 - Object-oriented DBMS | GIS&T Body of Knowledge (ucgis.org)

DM-28 - Topological relationships | GIS&T Body of Knowledge (ucgis.org)

DM-34 - Conceptual Data Models | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Schema**: structure or design of the database or database object (table, view, index, stored procedure, trigger) - defines the tables, fields in each table, relationships between fields - a schema will include information on which fields have domains and what those domains are.
B. **Data dictionary:** catalog or table containing information about the datasets stored in a database.
C. **Domain**: the range of values for a particular metadata element
D. **Attribute domain**: enforces data integrity, identify what values are allowed in a field in a feature class.
E. **Coded value domain**: attribute domain that defines a set of permissible values for an attribute in a geodatabase - it has a code and its equivalent value.
F. **Range domain**: type of attribute domain that defines the range of permissible values for a numeric attribute.
G. **Spatial domain**: allowable range for x, y coordinates and for m, z values.
H. **Tables**: collection of related data held in structured format within a database, contains fields and rows
I. **Views**: result set of a stored query on the data - users can query - virtual table computed dynamically from data when the view is accessed.
J. **Sequences**: ordered collection of objects in which repetitions are allowed (finite or infinite) number of elements is the length of the sequence.
K. **Synonyms**: Alias or alternate name for a table, view, sequence, or other object.

L. **Indexes**: data structure that improves the speed of data retrieval operations in a database table.
   - Causes more storage space and additional writes.
   - Quickly locate data in the database
   - Indexes can be on multiple columns.

M. **Clusters**: Can either be:
   - Multiple servers share one storage - this is typically used to handle user load balancing.
   - Databases **distributed** to different servers using **replication** - this is typically used if you have multiple users utilizing the same data in different physical locations. There is a master database that the replica databases sync between.

N. **Database Links**: data stored in a different database but accessible by to the database currently being accessed.

O. **Snapshot**: state of a system at a particular point in time - can be a backup.

P. **Procedure**: sometimes referred to as a “stored procedure”, is a subroutine available to applications that access a relational database system (data validation, access control mechanisms).

Q. **Trigger**: procedural code automatically executed in response to certain events on a particular table or view in a database

R. **Functions (subroutine):** sequence of program instructions that perform a specific task.

S. **Package**: built from source with one of the available package management systems

T. **Non-schema objects**: users, roles, contexts, directory objects

---

SAMPLE QUESTION

Which of the following database objects is used to improve query performance by allowing faster data retrieval?

A) Tables

B) Indexes

C) Views

D) Sequences

Answer: B) Indexes

Explanation: Indexes are database objects that improve query performance by allowing faster data retrieval based on indexed columns. They provide efficient access to specific rows within a table.

702. UNDERSTANDING OF DATABASE DESIGN

The database design process is significant and involves creating a well-structured and efficient database to store and manage data. This is one of the most important roles of a senior GIS professional as all organizations depend on accurate, reliable, and well-performing databases for managing assets, resources and supporting all manner of operations and activities. Generally, the process is outlined as followed:

1. **Determine the Purpose of Your Database**
   - Understand the goals and requirements for your database.
   - Consider the users, data sources, and anticipated queries.
2. **Find and Organize the Information Required**
   - Gather all the types of information you want to record in the database.
   - Identify the entities (objects or concepts) relevant to your domain.
   - Define the attributes (fields) for each entity.
3. **Divide the Information into Feature Classes and Tables**
   - Each feature class or table represents an entity or a relationship between entities.
   - Tables should be normalized to minimize redundancy and improve data integrity.
4. **Specify Primary Keys and Analyze Relationships**
   - Choose a primary key for each feature class and table (a unique identifier).
   - Define relationships (one-to-one, one-to-many, many-to-many) between tables.
5. **Design the Feature Classes, Tables and Fields**
   - Determine what features need to be captured, stored and what type of geometry is required (points, lines, polygons, images etc.). Will features need to be modeled for different scales?
   - Determine the data types for each field (e.g., text, number, date).
   - Set any constraints (such as required fields or unique values).
   - Identify coded value domains.
6. **Create Views and Indexes**
   - Create views to simplify complex queries or restrict access to sensitive data.
   - Define indexes to improve query performance.
7. **Implement Data Integrity and Security Measures**
   - Set up constraints (such as foreign keys) to maintain data integrity.
   - Define security rules to control access to data.
   - Determine if versioning is required.
8. **Test and Refine the Design**
   - Populate the feature classes, tables with sample data.
   - Test queries, views, and data manipulation operations.
   - Refine the design based on feedback and testing.
9. **Document the Database Design**
   - Create a data dictionary describing each table, field, and relationship.
   - Document any business rules or assumptions.
10. **Implement the Database**
    - Create the actual database using a Database Management System (DBMS).
    - Set up tables, relationships, views, and indexes.
    - Prepare for backups and disaster recovery.

DM-67 - NoSQL Databases | GIS&T Body of Knowledge (ucgis.org)

DM-81 - Array Databases | GIS&T Body of Knowledge (ucgis.org)

[DM-01 - Spatial Database Management Systems | GIS&T Body of Knowledge (ucgis.org)]

[DM-03 - Relational DBMS and their Spatial Extensions | GIS&T Body of Knowledge (ucgis.org)]

KEY CONCEPTS AND TERMINOLOGY

A. **Database design**: process of producing a detailed data model of a database.

B. **Design process**:
   - **Conceptual schema** - Determine where relationships and dependency are within the data.
   - **Logical Data Model** - Arrange data in a logical structure that can be mapped into the storage objects supported by the database management system.
   - **Physical database design**
     - Physical configuration of the database on the storage media
     - Detailed specification of data elements, data types, indexing options, and other parameters residing in the DBMS data dictionary
     - Modules, hardware, software

C. **Field Types**: the proper field type will secure data and make databases more efficient.
   - **Short integer** - between -32768 and 32768
   - **Long integer** - between -2,147,483,648 and 2147483647
   - **Float** - single-precision floating-point numbers
   - **Double**- double-precision floating-point numbers
   - **Text** - could be a coded value - assign to an integer through a domain.
   - **Dates** – a calendar date and sometimes a time is associated.
   - **BLOBs** - data stored as a long sequence of binary numbers - ArcGIS stores annotation and dimensions as BLOBs - images, multimedia, bits of code.
   - **Object Identifiers** - Unique IDs and FIDs
   - **Global Identifiers** - Global ID and GUID - data types store registry style strings consisting of 36 characters enclosed in curly brackets.
   - **Raster field types** - raster can be stored within the geodatabase.
   - **Geometry** - point, line, polygon, multipoint, multipatch.

SAMPLE QUESTION

What is the full form of **DBMS**?

A) Data of a Binary Management System

B) Database Management System

C) Database Management Service

D) Data Backup Management System

Answer: b) **Database Management System**

703. KNOWLEDGE OF DATABASE MANAGEMENT AND ADMINISTRATION

Database management and administration play crucial roles in ensuring efficient and secure handling of data within organizations, providing for:

- **Organization and Accessibility**
- **Integrity and Quality**
- **Security and Privacy**
- **Performance Optimization**
- **Backup and Recovery**
- **Scalability and Growth**
- **Business Intelligence and Analytics**
- **Cost Efficiency**

UCGIS Bok Visualizer and Search

DM-62 - Database Administration | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Basic tasks**:
   - **Backup and recovery of databases** - Regularly creating and storing database backups in a separate location helps keep the system operational after natural disasters, cyber-attacks, or other issues.
   - **Database security** - prevent hackers, **design**, and employ **security models**, tasks - **authentication**, **authorization**, **auditing** (making sure the right people have the right access)
   - **Storage and capacity planning** - disk storage is needed and monitor disk space and watch growth trends.
   - **Performance monitoring and tuning** - identify **bottlenecks**, **tuning** (**indexing**, **queries** on speed of return, right **monitoring** tools, **capacity** of server hardware)
   - **Troubleshooting** - quickly ascertain problem, root causes, correct it and take measures to prevent a reoccurrence.
   - **High availability** - ensures that a system remains operational with minimal interruption to end users, even in the face of hardware or software failures, power outages, or other disruptions.
     - **Data Backup and Recovery**
     - **Data Replication** - Continuously copying data from one database to another ensures system operability even if one database fails.
     - **Clustering** - Multiple nodes collaborate to provide data access, ensuring system continuity even if one node fails.
     - **Load Balancing** - Distributing requests evenly across multiple database servers maintains operability even if one server fails.
     - **Automated Failover** - Automatically switching to a backup server when the primary server fails minimizes downtime.
     - **High Availability Clusters** - Also known as failover clusters, these groups of interconnected servers work together to keep applications or services available to users. Redundancy and failover mechanisms ensure that if one server fails or goes offline, another server seamlessly takes over its workload.
   - **ETL functions** - data extraction, transformation, and loading.

B. **Archiving**: involves selectively removing specific records from active databases and storing them in an archive often capturing, managing, and analyzing data changes.
   - Most often done with geodatabases
   - These archived records can be managed and retrieved if needed, even though they are no longer part of the active dataset.
   - **Reasons for archiving**:

   - **Cost Reduction**: By shifting data to low-cost storage repositories, organizations can reduce expenses associated with warm storage.
   - **Regulatory Compliance**: Retaining old data is essential for compliance with regulations.
   - **Future Reference and Analysis**: Some historical data may be needed for future research or analysis.

C. **Retrieval**: extracting data from a backup due to data loss or data corruption

SAMPLE QUESTION

Which of the following is **not a critical task** in database administration?

A) Database Backup and Recovery

B) Data Archiving

C) Database Indexing

D) Database Query Optimization

Answer: C) Database Indexing

Explanation: Indexes are database objects that improve query performance by allowing faster data retrieval based on indexed columns. While they provide efficient access to specific rows within a table, indexing itself is not a critical database administration task.

704. KNOWLEDGE OF DATA SECURITY

Database security is a multifaceted endeavor that balances usability with protection. It's essential to safeguard not only the data but also the DBMS, associated applications, and the underlying infrastructure. Security provides controls for the confidentiality, integrity, and availability of data within databases.

Database Security: An Essential Guide | IBM

What is Database Security | Threats & Best Practices | Imperva

KEY CONCEPTS AND TERMINOLOGY

A. **Administrative Controls**:
   - **Installation, Change, and Configuration Management**: Govern the setup, modifications, and configuration changes to the database system.
   - **User Administration**: Manage user accounts, profiles, password policies, privileges, and roles.
   - **Security Architecture**: Design and implement security measures at the architectural level.
   - **Operating System Security Principles**: Secure the underlying operating system to prevent unauthorized access.
   - **Database Application Security Models**: Define access controls and permissions for applications interacting with the database.
   -

B. **Preventative Controls**:
   - **Access Controls**: Restrict access to authorized **users** and **roles**.
   - **Encryption**: Encrypt sensitive data to prevent **unauthorized** reading.
   - **Tokenization and Masking**: Tokenize or mask data to protect sensitive information.

- **Organized Data Structure**: Configure the database management system (DBMS) for optimal security.
- **Permissions and Access Controls**: Set fine-grained permissions for users and roles.

C. **Detective Controls**:
- **Database Activity Monitoring**: Continuously monitor database activity for suspicious behavior.
- **Data Loss Prevention Tools**: Identify and prevent unauthorized data transfers or leaks.

D. **Data Owner**: user with administrative privileges who creates tables, feature classes own those datasets.

E. **User Access Roles**:
- **Administrator** - Full control of the database, can read, create, update, delete features. Can create and delete feature classes, tables, and other database items as well as modify the database schema.
- **Editor** - can read, update, create, and delete features in existing tables.
- **Reader** – can only view data shared with them.
- **Creator** - can create additional feature classes, tables, as well as read, update, create, and delete features.

F. **Authentication**: database checks the list of users to make sure a user is allowed to make a connection.

G. **Operating System (OS) authentication** - refers to the process by which an operating system verifies the identity of a user or program attempting to access its resources.

H. **Database Authentication** - is the process of confirming that a user attempting to log in to a database is authorized to do so and has the rights to perform specific activities within that database. Access controls are stored within the database.

SAMPLE QUESTION

Which of the following is **not** a critical approach to ensure data security?

A) Authentication
B) Access control
C) Encryption
D) Database queries

Answer: D) Database queries.

8 - APPLICATION DEVELOPMENT

Geographic Information Systems (GIS) play a crucial role in various domains, and application development within this context involves creating software that leverages spatial data and tools.

Key components and considerations of GIS Application Development:

- **Data Collection**: Gather spatial data from various sources (e.g., GPS, aerial surveys, sensors).
- **Data Storage**: Organize data in databases (e.g., PostgreSQL with PostGIS, Oracle Spatial).
- **Data Processing**: Perform spatial operations (e.g., buffering, overlay, routing).
- **Visualization**: Create maps, charts, and interactive interfaces.
- **Analysis**: Extract insights (e.g., proximity analysis, hotspot detection).
- **Integration**: Combine GIS with other systems (e.g., web services, mobile apps).

Key GIS Development Tools and Techniques:

- **Programming Languages**: **Python** (with libraries like GeoPandas, Fiona, ArcPy), **JavaScript** (for web-based GIS), Java, C#.
- **GIS Libraries and APIs**: OpenLayers, Leaflet, ArcGIS API for JavaScript, Google Maps API.
- **Spatial Databases**: PostGIS, Oracle Spatial, SQLite/SpatiaLite.
- **Web Mapping Frameworks**: Mapbox, Carto, Esri ArcGIS Online.
- **Desktop GIS Software**: QGIS, Esri ArcGIS.

Important Considerations and Challenges:

- **Data Quality**: Ensure accurate and up-to-date spatial data.
- **Performance**: Efficiently handle large datasets.
- **User Experience**: Design intuitive interfaces for map interaction.
- **Security**: Protect sensitive location information.

801 - KNOWLEDGE OF DATA TRANSFER PROTOCOLS

File Transfer Protocol - Wikipedia

Comparison of file transfer protocols - Wikipedia

Data Transfer Protocol - an overview | ScienceDirect Topics

KEY CONCEPTS AND TERMINOLOGY

A. **Data exchange procedures** - transfer constructs (based on data models):
   (1) logical constructs solely pertaining to this standard,
   (2) constructs relating to the implementation method, and
   (3) constructs solely pertaining to the transfer media.
   - **File based transfer** - data is in a structured file format.
   - **Application Programming Interface (API)** - data is accessed and exchanged as needed between software systems.
   - **Web services** - data is accessed and exchanged over networks and the internet between software components, using http and other web-based protocols.

B. Transfer of data between a **client server** and an **end user**
C. **SSL** – secure sockets layer
D. **TLS** – transport layer security (latest version of SSL)
E. **SSL** and **TSL** are used to encrypt data.
F. **Network transport protocols**:

- Communication **packet** is constructed at different **intervals**.
    - **Transmission Control Protocol** – header package for the data at the transport layer
    - **Internet Protocol** – header is added at the internet layer.
    - **Media Access Control (MAC) address** – added at the physical network layer.
    - Transferred from the **host** to the **receiver**.

G. **Network File Services** (**NFS**) - is a distributed file system protocol originally developed by Sun Microsystems in 1984. It allows users on client computers to access files over a computer network, much like local storage is accessed.

H. **Common Internet File System** (**CIFS**) - is a file-sharing protocol that provides an open and cross-platform mechanism for requesting network server files and services. CIFS facilitates seamless file sharing and resource access across networks, making it valuable for collaborative work and data exchange.

I. **HTTP/HTTPS Protocols** – Hypertext Transfer Protocol – standard web transmission protocol that uses the SSL/TLS protocol for encryption– a way for delivering map images or map data to web browsers.

SAMPLE QUESTION

Which protocol is commonly used for secure communication between a web browser and a website?

A) HTTP

B) FTP

C) SMTP

D) HTTPS

Answer: D) HTTPS

Explanation: HTTPS (Hypertext Transfer Protocol Secure) ensures encrypted and secure communication over the internet, protecting sensitive data during transmission. The other options (HTTP, FTP, and SMTP) do not provide the same level of security.

802 - KNOWLEDGE OF CODING, SCRIPTING, AND MODELING BASICS

Scripting in GIS is a powerful way to employ programming languages to automate tasks, customize existing tools, and create new functionalities and tools within geospatial systems and combine GIS with other systems.

Object-oriented programming - Wikipedia

Extensibility - Wikipedia

PY4E - Python for Everybody

KEY CONCEPTS AND TERMINOLOGY

A. **Scripting** – involves using programming languages to automate tasks, customize existing tools, and create new functionalities within geospatial systems. A script is interpreted by the software and computer rather than compiled like a program.
- Used to manipulate, customize, and automate existing processes and software.
- Allows tailoring a GIS tool to your specific needs.
- Repetitive tasks can be automated, saving time and effort.
- **Scripts** can be employed to handle large and complex **data manipulation**, **analysis,** and **visualization**.
- Scripts can be used to combine GIS with other systems or web services.

B. **Common Scripting and Programming Languages is GIS**:
- **Python**: Widely used due to its simplicity, readability, and extensive libraries (e.g., GeoPandas, Fiona). Typically employed for data processing, analysis, and modeling. Often combined with JavaScript for creating interactive web maps.
- **R**: Popular for statistical analysis and data visualization in GIS. Typically employed for data processing, analysis, and modeling.
- **JavaScript**: Essential for web mapping (e.g., Mapbox, Leaflet). Often combined with Python for creating interactive web maps.
- **SQL**: Used for geospatial databases (e.g., PostgreSQL with PostGIS).
- **Java, C#, and C++:** Relevant for Map Servers and custom GIS applications.

C. **Object oriented programming (OOP)** - programming paradigm based on concept of "objects" which are data structures that contain data in the form of fields (aka attributes) and code in the form of procedures (aka methods) - most common are class based.

D. **Extensibility** - system design principle where the implementation takes future growth into consideration - level of effort to extend the system and implement the extension.

E. **Query expressions** – select a subset of features or records for use in a process or calculation.

SAMPLE QUESTION

Which programming language is commonly used for automating geospatial tasks and customizing GIS workflows?

A) Java

B) R

C) HTML

D) Python

Answer: D) Python

Explanation: Python is widely used in GIS for automating data processing, creating custom tools, and integrating with other geospatial libraries. While other languages (such as Java, R, and HTML) have their applications, Python's simplicity and extensive libraries make it a popular choice for GIS scripting.

803 - AWARENESS OF BASIC APPLICATION DEVELOPMENT METHODS

Application development is an iterative process for creating software applications to solve specific problems or meet needs.

Software development process - Wikipedia

Top 4 Software Development Methodologies | Synopsys Blog

KEY CONCEPTS AND TERMINOLOGY

A. Types of application development methods:
- **Agile** – a flexible and iterative approach to creating software. It emphasizes collaboration, adaptability, and delivering value to users. Software is developed in mini-increments and adding of the new functionality – i.e., 2-week sprints. Agile methodologies include **Scrum**, **Extreme Programming (XP)**, **Kanban**, and others. These approaches share common values and principles, such as collaboration, adaptability, and delivering working software frequently.

- **Agile process includes**:
  - **Requirements Analysis** - Agile teams work closely with **stakeholders** to understand user needs and define **requirements**. Instead of detailed upfront planning, they focus on creating a **high-level vision**.
  - **Design** - Design decisions are made incrementally as the project progresses. The goal is to create a simple and effective solution that meets user needs.
  - **Development** - Teams build the software **incrementally**, adding features in short cycles (usually 1-4 weeks). Developers collaborate closely, and the code is continuously integrated and tested.
  - **Testing** - Testing is an integral part of Agile. **Automated tests** are written alongside code, ensuring that new features don't break existing functionality.
  - **Deployment** - Working software is deployed frequently (often daily or weekly). This allows users to provide feedback early and helps identify issues sooner.
  - **Review** - Regular reviews with stakeholders ensure that the project stays aligned with user needs. Adjustments are made based on feedback.
- **DevOps** – is a methodology in the software development and IT industry. Used as a set of practices and tools, DevOps integrates and automates the work of software development (Dev) and IT operations (Ops) as a means for improving and shortening the systems development life cycle.
- **Waterfall** – Rigid linear model that contains phases similar to Agile but are sequential (requirements, design, implementation, verification, maintenance) – each phase must be complete before moving to the next phase.
- **Rapid application development (RAD**) – condensed development process that produces high quality system with low investment costs.
- **Spiral development** – combination of waterfall and RAD – combines the advantages of top-down and bottom-up concepts.

SAMPLE QUESTION

Which of the following best describes the **Agile** application development method?

A) A sequential and linear approach to software development, emphasizing thorough planning and documentation.

B) A flexible and iterative approach that values customer collaboration, adaptability, and responding to change.

C) A method that focuses on creating detailed design specifications before writing any code.

D) A process that relies heavily on formal testing and quality assurance.

Answer: B) A flexible and iterative approach that values customer collaboration, adaptability, and responding to change.

Explanation: The Agile methodology emphasizes incremental development, frequent feedback, and the ability to adapt to changing requirements. It encourages close collaboration with stakeholders and prioritizes working software over extensive documentation[12].

9 - SYSTEMS DESIGN AND MANAGEMENT

901. KNOWLEDGE OF SYSTEMS ARCHITECTURE AND DESIGN, INCLUDING VARIOUS GIS SOFTWARES, PLATFORMS, AND ENVIRONMENTS

System Design & Management (SDM) is an interdisciplinary field that addresses complex challenges by viewing elements as dynamic, interconnected systems.

Distributed GIS - Wikipedia

Virtualization - Wikipedia

KEY CONCEPTS AND TERMINOLOGY

A. **Architecture design**:
   - **Requirements Phase** - user needs assessment and workflow loads analysis (baseline and peak traffic)
   - **Design Phase** - Infrastructure requirements, network communication capacity, hardware and software procurement, software development and data acquisition must be identified.
   - **Construction Phase** - system procurement, data acquisition and database design, authorization for application design and development, prototype testing
   - **Implementation Phase** - Initial deployment and operational testing, final system delivery, user training, system maintenance operations
   - **Capacity Planning Tool** (**CPT**) - developed as a framework to promote successful GIS system design and implementation.

B. **Enterprise environments**:
   - **Enterprise GIS Environment** - broad spectrum of integrated enterprise technologies connected by local area networks, wide area networks, internet communications, and file systems.
   - **Enterprise technologies** - database servers, storage area networks, windows terminal servers, web servers, map servers, desktop clients
   - **Virtualization**: typically refers to hardware virtualization which refers to the creation of a **virtual machine** that acts like a real computer with an operating system. Software executed on these virtual machines is separated from the underlying hardware resources. In hardware virtualization, the **host machine** is the machine that is used by the virtualization and the **guest machine** is the virtual machine. The words host and guest are used to distinguish the software that runs on the physical machine from the software that runs on the virtual machine. The software or **firmware** that creates a virtual machine on the host hardware is called a **hypervisor** or **virtual machine monitor**.
   - **Distributed Files Systems (DFS)**: a powerful approach that spans multiple machines or nodes in a network, allowing seamless access to files and shared resources. DFS is a data storage and management scheme that enables users or applications to access various types of files (such as PDFs, Word documents, images, videos, and audio files) from shared storage across multiple networked servers, which can be separated geographically.

C. Platforms:
   - **Desktop** - individual user on a computer, make maps, data analysis, data creation.
   - **Server** - bring geospatial capabilities and data into hands of everyone in organization, allows access to web GIS, control of GIS data on your own infrastructure, control over how GIS platform is deployed, maintained, secured, and used.
   - **Hosted (cloud)** - ability to discover, use, make, and share maps with any device anywhere, anytime - access other users maps and data - connect more people outside of organization and share latest maps, data, and ideas.

- **Enterprise GIS** - integrated through entire organization so that many users can manage, share, and use spatial data and related information in a common environment to address a variety of needs, including data creation, modification, visualization, analysis, dissemination.
- **Enterprise GIS** can utilize both hosted (cloud) and on-premises servers in a **hybrid** or **distributed deployment**.

D. **Software**: The software employed in the system will vary depending on the hardware types and purposes.

- **Centralized Servers** – Operating systems like Microsoft Windows Server, Relational Database Management Systems (RDMS) like SQL Server or Oracle.
- **Desktop Machines** - XXX

E. **GIS Software**:

- GRASS
- Esri
- QGIS
- MapInfo
- Smallworld

SAMPLE QUESTION

What are key factors to consider when designing an efficient system architecture for GIS?

A) Whether users will work on-premises or be remote

B) Data integrity and consistency

C) Capacity for system scaling

D) All of the above

Answer: D) All of the above

902. KNOWLEDGE OF SYSTEMS AND APPLICATION SECURITY

Systems and Application Security encompasses measures to safeguard both software systems and individual applications.

Application security - Wikipedia

What is application security? A process and tools for securing software | CSO Online

GIS and Security Applications | Geography Realm

KEY CONCEPTS AND TERMINOLOGY

A. **Application security** - Making applications more secure by finding, fixing, and enhancing the security.

B. **Application security** is important because it will help keep the data safe.

C. **Continuous deployment and integration** cause security fixes to be deployed constantly (daily or hourly)

D. **Security testing**:

- **Static testing** – analyzes code at fixed points.
- **Dynamic testing** – analyzes running code and can simulate an attack.
- **Interactive testing** – combines static and dynamic testing.
- **Mobile testing** – designed to examine how an attacker can attack mobile apps.

E. Methods to prevent **unauthorized access** to **data** and **metadata**.

- Define who has access.
- Employ other software to enforce these policies.
- Identify management systems to check the credentials of users.
- Data authenticity verification

SAMPLE QUESTION

Which of the following best describes **SQL injection**?

A) A technique used to bypass firewalls and gain unauthorized access to a network.

B) A type of malware that spreads through email attachments.

C) A vulnerability that allows an attacker to manipulate database queries by injecting malicious SQL code.

D) A cryptographic algorithm used for secure data transmission.

Answer: C) A vulnerability that allows an attacker to manipulate database queries by injecting malicious SQL code.

Explanation: SQL injection occurs when an attacker inserts **malicious SQL statements** into an application's **input fields**. This can lead to unauthorized access, data leakage, or even complete control over the database. Proper **input validation** and **parameterized queries** are essential to prevent SQL injection attacks.

903. AWARENESS OF TRENDS IN GEOSPATIAL TECHNOLOGY

Staying abreast of trends in GIS and technology, skills and professional practice is critical as a GIS Professional as technology expands and evolves constantly. Below are some examples of organizational websites for tracking GIS trends.

Home - Open Geospatial Consortium (ogc.org)

100 Best GIS Blogs and Websites To Follow in 2024 (feedspot.com)

Geographic Information Systems (gis) Conferences 2024/2025/2026 (conferenceindex.org)

ArcNews | News for GIS Users (esri.com)

ArcGIS Blog | Get Insider Info from the Esri Product Teams

Professional GIS Education and Training - Urban and Regional Information Systems Association (urisa.org)

KEY CONCEPTS AND TERMINOLOGY

A. **Strategies for maintaining awareness of trends**:
    - Read blogs.
    - Attend conferences.
    - Attend webinars.
    - Join local and online GIS groups.
    - Monitor job postings to stay abreast of important and marketable skills desired by employers.

B. **Examples of important current trends and technologies relevant for GIS Professionals**:
    - Artificial Intelligence (AI)
    - Machine Learning (ML)
    - Internet of things (IoT)
    - Unmanned Aerial Vehicles (UAV)

- Mobile Technologies

SAMPLE QUESTION

What is a good approach for staying abreast of trends in geospatial technology?

A) Read blogs.
B) Attend conferences.
C) Join local and online GIS groups.
D) All the above

Answer: D) All the above

10 - PROFESSIONAL PRACTICE

Professional practice encompasses a rich and multifaceted notion that remains elusive for many practitioners, researchers, policy makers, and administrators. However, dimensions of it include:

Diverse Understandings:

- Practice is a complex concept, often underestimated by researchers who view it from narrow perspectives.
- It involves both **individual** and **extra-individual** features.
- **Theoretical density** surrounds a "practice", making it challenging to fully grasp.

Professional Practice:

- Professional practice specifically refers to the **actions** and **behaviors** of individuals within their **work context,** often referred to as "**Standards of Practice**."
- It extends beyond mere **technical skills** and includes **ethical conduct**, **decision**-**making**, and **interactions** with others.
- Professionals apply their **knowledge** and **expertise** to **real-world situations**.

Extra-Individual Features:

- Practice is not solely about **individual practitioners**; it also involves **broader elements**.
- These features include **organizational structures**, **cultural norms**, **historical context**, and **societal expectations**.
- Understanding practice requires considering these external influences.

Context Matters:

- **Professional practice** varies across **domains** (e.g., education, healthcare, engineering, design).
- It adapts to specific contexts, such as **legal**, **ethical**, and **cultural frameworks**.
- Effective **professional practice** aligns with the **values** and **norms** of the **profession**.

In summary, professional practice goes beyond technical competence, encompassing ethical behavior, contextual awareness, and the interplay of individual and collective factors.

What Is Professional Practice? Recognizing and Respecting Diversity in Understandings of Practice | SpringerLink

What is Professional Practice? - National Design Academy (nda.ac.uk)

1001. UNDERSTANDING OF APPROPRIATE INTERPRETATION OF WORK-RELATED POLICIES AND PROCEDURES

Each organization has different **policies** and **procedures** for editing, storing, and archiving data, and those policies should be understood and followed. They are essential **guidelines** within an organization that shape how employees **conduct** themselves and **interact** with their work environment. These documents not only set expectations but also reflect the organization's values and professionalism.

KEY CONCEPTS AND TERMINOLOGY

A. **Policies**:
   - Policies are overarching **principles** that outline the organization's **approach** to specific issues.
   - They connect the organization's **vision**, **values**, and **day-to-day operations**.
   - For instance, a policy might address **workplace conduct**, **anti-discrimination**, or **data security**.

B. **Procedures**:

- Procedures provide specific **action plans** for implementing policies.
- They guide employees on how to **handle various situations**.
- For example, a procedure might detail steps for reporting incidents, requesting time off, or handling customer complaints1.

C. **Importance**:

- Clear policies and procedures enhance **workplace efficiency** and **culture**.
- They prevent **trial-and-error decision-making** and **micromanagement**.
- Well-documented **guidelines** save **time**, **reduce stress**, and **ensure compliance with regulations**.

SAMPLE QUESTION

Which of the following best describes the significance of **workplace policies** and **procedures**?

A) A bureaucratic burden that hinders employee creativity.

B) A set of rigid rules that restrict employee autonomy.

C) Essential guidelines that ensure consistent operations, compliance with laws, and efficient resource utilization.

D) Optional suggestions for employees to follow.

Answer: C) Essential guidelines that ensure consistent operations, compliance with laws, and efficient resource utilization.

Explanation: Workplace policies and procedures provide a roadmap for day-to-day operations. They maintain consistency, enhance service quality, and create a safer workplace. Compliance with policies benefits both employees and the organization as a whole.

1003. KNOWLEDGE OF MANAGING, DOCUMENTING, AND COMMUNICATING GIS WORK

Managing, documenting, and communicating GIS work involves a systematic approach to ensure efficiency, accuracy, and effective collaboration. Effective management, documentation, and communication enhance GIS strategies, programs and project outcomes and facilitate collaboration across teams.

10.2: GIS Project Management Tools and Techniques - Geosciences LibreTexts

Building Sustainable GIS Management with URISA's GIS Capability Maturity Model | ArcNews | Spring 2015 (esri.com)

KE-12 - GIS&T Project Planning and Management | GIS&T Body of Knowledge (ucgis.org)

KEY CONCEPTS AND TERMINOLOGY

A. **GIS Strategic Plan**:

- **Purpose and Vision**:
  - Clearly define the **purpose** of the **GIS program** within the organization.
  - Establish a **vision** for how GIS will contribute to overall success.
- **Goals and Objectives**:
  - Identify specific **goals** related to geospatial technology.
  - Set **measurable objectives** that **align** with organizational **priorities**.
- **Scope and Priorities**:
  - Determine the **scope** of GIS activities (e.g., data management, analysis, visualization).
  - Prioritize **initiatives** based on their **impact** and **feasibility**.

B. **Critical Path**: The longest path through a project or to a defined milestone. The critical path is made up of a set of related linked tasks that lead to the conclusion of the project or milestone.
C. **Gantt Chart**: One view of a project plan or status report in which horizontally arranged linear bars depict start and end points of project tasks.
D. **GIS Program**: An ongoing effort or initiative established by an organization using GIS&T to support its mission and business requirements.
E. **Data Governance**: a systematic approach that ensures the availability, quality, security, and proper utilization of an organization's data.
F. **GIS Project**: A temporary endeavor undertaken using GIS&T to create a unique product or service.
G. **Pilot Project**: A planned, limited activity that includes many attributes of a full project, which is designed as a demonstration or a trial of a **project scope**, **specifications**, or **methodology**. The pilot project is undertaken to answer questions and provide an opportunity to adjust the plan and specifications before proceeding with the full project.
H. **Process Group**: Related and mutually supporting sets of activities that help ensure a successful project. Defined by the Project Management Institute as an overall structure for project planning and management.
I. **Project Charter**: A document that officially authorizes a project, and it includes statements of project objectives, participation, and approval and commitment of resources by managers of stakeholder departments.
J. **Project Management**: The application of knowledge, skills, tools, and techniques to project activities to meet requirements.
K. **Project Manager**: An individual who has formal responsibility for directing and executing a project, its team and stakeholders, and the project deliverables and results.
L. **Project Management Knowledge Areas**: A framework that addresses critical concerns and practices that must be considered in project planning and execution.
M. **Project Portfolio Management**: A management approach based on a set of practices that view multiple projects as being interrelated and contributing together to overall program and organizational goals.
N. **Resources**: Tangible commodities that enable project work to be carried out. Resources include people, money, equipment, materials, and the organizations that are the sources of these commodities.
O. **Stakeholder**: Individuals, groups, or organizational entities that have some interest, participation, or role in a project or program, or which may be affected by its development and operation.
P. **Task Predecessor:** A defined attribute of a task that indicates the timing relationship of the task with another task. Also referred to as task "linkages," predecessors describe how the timing of one task is influenced by or related to another.
Q. **Work Breakdown Structure (WBS):** A hierarchical format for presenting tasks in a project

SAMPLE QUESTION

Which of the following best describes the importance of documenting and communicating GIS work within an organization?

A) It's an optional step that doesn't significantly impact project outcomes.

B) Proper documentation ensures that only technical staff can understand the work.

C) Clear documentation facilitates knowledge sharing, collaboration, and project continuity.

D) Communication about GIS work is limited to internal team members only.

Answer: C) Clear documentation facilitates knowledge sharing, collaboration, and project continuity.

Explanation: Documenting GIS work ensures that processes, data, and decisions are well-documented for future reference. Effective communication about GIS work extends beyond the team, benefiting stakeholders and organizational learning. Proper documentation and communication enhance efficiency, reduce errors, and promote best practices.

1004. AWARENESS OF HOW GIS IS USED ACROSS OTHER PROFESSIONS

While GIS skills and jobs vary between subject matter areas, professions, companies, and industries, they also overlap in many significant ways. As a GIS professional it is important to maintain an awareness of how GIS is employed across various domains to continue broadening and deepening your knowledge and skills.

KEY CONCEPTS AND TERMINOLOGY

A. Read other LinkedIn profiles to get a sense of what skills others have in GIS.
B. Make new connections in LinkedIn to expand your network of peers and colleagues.
C. Attend conferences and webinars.
D. Join a local group and discuss with other GIS professionals what tools they use and what kind of work they perform.
E. Make time to monitor and read blogs and social networking post from other GIS Professionals.

1005. AWARENESS OF GIS-RELATED PROFESSIONAL ORGANIZATIONS AND CERTIFICATION

GIS Organizations - Geography Realm

Ten Things You Need to Know about GIS Certification (directionsmag.com)

A – EXAM BLUEPRINT

GISCI Geospatial Core Technical Exam ® Knowledge Categories

Knowledge Categories	Weight
1. Conceptual Foundations	10%
2. Geospatial Data Fundamentals	15%
3. Cartography and Visualization	10%
4. Data Acquisition	11%
5. Data Manipulation	11%
6. Analytical Methods	11%
7. Database Design and Management	10%
8. Application Development	7%
9. Systems Design and Management	7%
10. Professional Practice	8%
Total	*100%*

Knowledge, Skills & Ability Areas

	1. Conceptual Foundations
101	Understanding of datums, coordinate systems, and projections
102	Understanding of representation of discrete features and continuous phenomena in GIS
103	Knowledge of earth geometry and its approximations
104	Knowledge of basic geomatics and relationships to GIS

	2. Geospatial Data Fundamentals
201	Understanding of spatial data models and their associated planar geometries
202	Understanding of spatial data relationships
203	Understanding of data quality
204	Understanding of data resolution
205	Understanding of data validation and uncertainty
206	Understanding of metadata
207	Knowledge of temporal data
208	Knowledge of spatial data standards, including ISO, FGDC, and OGC

	3. Cartography and Visualization
301	Understanding of graphic representation techniques and implications
302	Understanding of map design principles and essential map elements
303	Understanding of surface interpretation and representation
304	Understanding of 2D and 3D visualization

	4. Data Acquisition
401	Understanding of digitization and other manual data collection and conversion methods
402	Knowledge of field data collection
403	Knowledge of automated data collection and conversion methods
404	Knowledge of remotely sensed data sources and collection methods
405	Knowledge of acquisition, use, and limitations of crowdsourced and open source data and services

	5. Data Manipulation
501	Understanding of georeferencing, data format conversion, and data transformation
502	Understanding of spatial data generalization operations and methods
503	Understanding of spatial file types and their applications and limitations
504	Understanding of data integration

	6. Analytical Methods
601	Understanding of data selection queries and views
602	Understanding of techniques and implications of data classification
603	Understanding of analytical operations and methods
604	Knowledge of map algebra
605	Knowledge of descriptive and spatial statistics

	7. Database Design and Management
701	Understanding of relationships among database objects
702	Understanding of database design
703	Knowledge of database management and administration
704	Knowledge of data security

	8. Application Development
801	Knowledge of data transfer protocols
802	Knowledge of coding, scripting, and modeling basics

803	Awareness of basic application development methods

	9. Systems Design and Management
901	Knowledge of systems architecture and design, including various GIS softwares, platforms, and environments
902	Knowledge of systems and application security
903	Awareness of trends in geospatial technology

	10. Professional Practice
1001	Understanding of appropriate interpretation of work-related policies and procedures
1002	Understanding of ethics related to technical GIS work
1003	Knowledge of managing, documenting, and communicating GIS work
1004	Awareness of how GIS is used across other professions
1005	Awareness of GIS-related professional organizations and certification

B – REFERENCES

Below are some specific resources that include textbooks, websites, and other references from which some exam questions are developed. While the exam is software agnostic the list below contains some books published by Esri as they contain useful guidance on GIS concepts and approaches. This list is by no means exhaustive but is a representative sample. Many worthwhile textbooks are available that cover the fundamentals addressed in the exam and are part of many academic programs. It is recommended that candidates become familiar with these and other resources and when possible, add them to your personal library.

- ***Geographic Information Science and Technology Body of Knowledge***
  ISBN-13: 9780892912674
  ISBN-10: 0892912677

  Website

- ***Mapping, Society, and Technology*** *(Steven Manson)*

  Website

- ***GIS Fundamentals: A First Text on Geographic Information Systems – 5th Edition*** *(Bolstad and Manson)*
  ISBN-13: 9781506695877
  ISBN-10: 1506695876

- ***Geographic Information Science and Systems*** *(Longley, Goodchild, Maguire, and Rhind)*
  ISBN-13: 9781118676950
  ISBN-10: 1118676955

- ***Python for Geospatial Data Analysis: Theory, Tools, and Practice for Location Intelligence*** *(Bonny McClain)*
  ISBN-13: 9781098104795
  ISBN-10: 109810479X

- ***Python for ArcGIS*** *(Laura Tateosian)*
  ISBN-13: 9783319183978
  ISBN-10: 3319183974

- ***Discovering GIS and ArcGIS Pro*** *(Bradley A. Shellito - 3rd edition)*
  ISBN-13: 9781319230753
  ISBN-10: 131923075X

- ***GIS Research Methods: Incorporating Spatial Perspectives*** *(Sheila L. Steinberg and Steven J. Steinberg)*
  ISBN-13: 9781589483781
  ISBN-10: 1589483782

- ***Spatial Database Systems: Design, Implementation, and Project Management*** *(Albert K.W. Yeung and Brent G. Hall)*
  ISBN-13: 9781402053931
  ISBN-10: 1402053932

- ***Databases: A Beginner's Guide*** *(Andy Oppel)*
  ISBN-13: 9780071608466
  ISBN-10: 007160846X

- ***Getting to Know Web GIS*** *(PindeFu)*
  ISBN-13: 9781589487277
  ISBN-10: 1589487273

- ***Open resource: Essentials of Geographic Information Systems*** *(Campbell and Shin)*

Website

Notes: Website for the book with summary text and downloadable PDF.

- ***Digital Elevation Model Technologies and Applications: The DEM User's Manual*** *– (Maune, David F.)*
  ISBN-13: 9781570830648
  ISBN-10: 1570830649

- ***The Design and Implementation of Geographic Information Systems –****(John E. Harmon, Steven J. Anderson)*
  ISBN-13: 9780471204886
  ISBN-10: 0471204889

- ***GIS Fundamentals: A First Text on Geographic Information Systems, 6th Edition*** *– (Bolstad, Paul)*
  ISBN-13: 9781593995522
  ISBN-10: 1593995520

- ***Elements of Cartography*** *– (Robinson, Arthur H. - Morrison, Joel L. - Muehrcke, Phillip C. - Kimerling, A. Jon - Guptill, Stephen C.)*
  ISBN-13: 9780471555797
  ISBN-10: 0471555797

- ***Learning Geospatial Analysis with Python*** *– (Lawhead, Joel)*
  ISBN-13: 9781789959277
  ISBN-10: 1789959276

- ***Programming Logic & Design, Comprehensive 9th Edition*** *– (Farrell, Joyce)*
  ISBN-13: 9781337685689
  ISBN-10: 1337685682

- ***Remote Sensing and Image Interpretation*** *– (Thomas Lillesand, Ralph W. Kiefer, Jonathan Chapman)*
  ISBN-13: 9780470052457
  ISBN-10: 0470052457
- ***Manual of Airborne Topographic LiDAR*** *– (Renslow, Michael)*
  ISBN-13: 9781570830976
  ISBN-10: 1570830975

- ***Fundamentals of Geographic Information Systems, 4th Edition*** *– (Demers, Michael)*

- ***A to Z GIS: An Illustrated Dictionary of Geographic Information Systems*** *– (Wade, Tasha and Sommer, Shelly)*

  ISBN-13: 9781589481404

  ISBN-10: 1589481402