National Centers of Academic Excellence in Geospatial Sciences Knowledge Units

Core Knowledge Units

Knowledge Unit title: Geo-referencing Systems

Knowledge Unit description: Skills and knowledge of datums, coordinate systems, map projections, coordinate transformation, registration, and rectification

Requirement satisfaction: This KU is satisfied when all six (6) Topics and any seven (7) Learning Objectives are met.

Topics:
- Geoid and ellipsoid, geometry, and WGS84
- Geographic and planar coordinate systems, horizontal and vertical datums
- Earth coordinate systems and associated transformations: Earth Centered Inertial (ECI), Earth Centered Frame (ECF), spherical, ellipsoidal, and 2D and 3D coordinate transformations
- Map projections
- Registration
- Rectification

Learning objective(s):
1. Distinguish between a geoid, an ellipsoid, a sphere, and the terrain surface
2. Explain the angular measurements represented by latitude and longitude coordinates
3. Explain why plane coordinates are sometimes preferable to geographic coordinates
4. Explain what Universal Transverse Mercator (UTM), State Place Coordinates (SPC) eastings and northings, and the Military Grid Reference System (MGRS) represent
5. Describe an application in which a linear referencing system is particularly useful
6. Distinguish how the datum associated with a linear referencing system differs from a horizontal or vertical datum
7. Define horizontal datum in terms of the relationship between a coordinate systems and an approximation of the Earth's surface
8. Illustrate the difference between a vertical datum and a geoid
9. Define the four geometric properties of the globe that may be preserved or lost in projected coordinates
10. Explain the mathematical basis for how latitude/longitude coordinates are projected into X/Y coordinate space
11. Discuss the methods used for coordinate transformations and map projection

12. Apply data transforms among datums coordinate systems, and map projections
13. Explain the rectification processes for originally collected digital data and for scanned and digitized data layers
14. Explain the advantages and challenges of the Web Mercator projection
15. Recognize the distortions (shape, area, and distance) inherent to map projections
16. Demonstrate the ability to determine proper map projections for different applications

Knowledge Unit title: Spatial Data Fundamentals

Knowledge Unit description: Skills and knowledge required to understand geospatial data and the techniques and methods needed for effective data management

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Challenges in vector-to-raster and raster-to-vector conversions
- Conflation of data from different sources--or for different uses--as it relates to mapping
- Data schemas and data models
- Data quality using Quality Assurance/Quality Control (QA/QC) methods
- Concepts of geospatial data types (vector, raster, TIN, DEM, image, point cloud, object based, etc.) and their use
- Concepts of geospatial file structures on the web (XML, KML, GML, GeoJSON, RDF, and OWL) and their use
- Data storage (e.g. RDBMS, NOSQL, etc.)
- Extract, Transform and Load (ETL) operations for geospatial data: managing content
- Points, lines and polygons
- Topology
- Networks
- Linear referencing
- Grid cell, image, pyramid, quadtree, lidar (las), Logarithm of Odds (LoDs)
- Object-based feature models
- Scale and resolution (or “level of data”)

Learning objective(s):

1. Describe methods for data storage related to database options to include pros/cons of each approach
2. Recognize the concepts of data modeling: (conceptual, logical, and physical) and the relationship of data models to data schemas
3. Identify current tools for conflation of data and how data conflation operations are performed and the role of business rules and business logic in guiding conflation
4. Explain methods of Quality Control and Quality Assurance and the differences between QA and QC.
5. Describe the process for precision and accuracy assessment in QA/QC, tradeoffs in spatial representation, and the affects on analysis
6. Discuss geospatial data types (vector, raster, TIN, DEM, image, point cloud, object, etc.) and how each is used in cartographic production

7. Describe geospatial file structures on the web (XML, KML, GML, GeoJSON, RDF, and OWL) and the use of each
8. Explain and demonstrate the basic data and content management principles of extract, transform, and load operations.
9. Discuss how to access data from a database, exploit data using commercial GIS tools, and return data to a “gold data” repository
10. Identify basic spatial data models
11. Apply conversions among spatial data models
12. Recognize the basic elements and structures of each data model
13. Discuss the limitations imposed by the data model on data processing
14. Evaluate the assumptions that are made when representing the world as points, lines, or polygons
15. Explain how uncertainty affects spatial representation.
16. Define terms related to topology, and illustrate a topological relationship
17. Evaluate the positive and negative impact of the shift from integrated topological models
18. Discuss the impact of early prototype data models (e.g. POLYVRT, GBF/DIME) on contemporary vector formats
19. List definitions of networks that apply to specific applications or industries
20. Demonstrate how attributes of networks can be used to represent cost, time, distance, or many other measures
21. Construct a data structure to contain point or linear geometry for database record events that are referenced by their position along a linear feature
22. Describe the architectures of various object-relational spatial data models, including spatial extensions of DBMS, proprietary object-based data models from GIS vendors, and open source and standards-based efforts
23. Recognize how scale affects the type of data that can be used and how this affects aggregated data sets (e.g. the generalization of aggregated data sources from multiple scales)
24. Describe multiple measurement techniques

Knowledge Unit title: Remote Sensing Fundamentals

Knowledge Unit description: Skills and knowledge required to broadly understand remote sensing systems and applications—an introduction to the theory of remote sensing, basic phenomenology, imaging systems, image analysis applications, and techniques.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:

- Electromagnetic radiation/material interaction basics (reflection, absorption, transmission, and scattering)
- Basics of atmospheric contributions to remotely sensed signals
- Basic differences in spectral regimes (reflective vs. emissive remote sensing)
- Passive imaging system fundamentals (EO, IR, MSI, HIS)
  - Types of camera models and their parameters (frame, linear, whiskbroom)
- Active imaging system fundamentals (radar and lidar)
- Impacts of resolution dimensions (spatial, spectral, radiometric, temporal) and how they inform sensor design
- Impacts of resolution dimensions (spatial, spectral, radiometric, temporal) and how they inform data analysis
- Characteristics of commercial/civil satellite, and airborne systems
- Basics of atmospheric compensation (radiance vs. reflectance)
- Fundamentals of basic quantitative image analysis (classification, spectral analysis, thermal analysis)
- Basic concepts of remote sensing including spatial, spectral, radiometric and temporal resolution, spectral signatures, and creation and use of composite images

Learning objective(s):

1. Explain light matter interactions and impacts on observable phenomenology
2. Discuss how sensors are designed and how images are formed
3. Identify existing and planned remote sensing systems and their characteristics
4. Express the basic premises behind the quantitative analysis of remotely sensed data

Knowledge Unit title: Spatial Data Management

Knowledge Unit description: Skills and knowledge required to store, manage and maintain geospatial data, to include topological relationships

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Basic storage and retrieval structures
- Basics of database management systems
- Relational and object-oriented databases
- Feature-based DBMS, object oriented DBMS, non-SQL DBMS.
- Management of crowd-sourced, VGI, and other non-traditional data types
- Managing topology, distance, adjacency, and connectivity in spatial data (points, lines, polygons, pixels, raster data)
- Database modeling
- Managing geometric relationships among features (distances and lengths; direction, shape, and area; proximity and distance decay; adjacency and connectivity)

Learning objective(s):

1. Define basic data structure terminology (e.g., records, field, parent/child, nodes, pointers, topology)
2. Differentiate among data models, data structures, and file structures
3. Discuss the advantages and disadvantages of different data structures (e.g., arrays, linked lists, binary trees) in storing geospatial data
4. Analyze the relative storage efficiency of each of the basic data structures
5. Employ algorithms that store geospatial data to a range of data structures
6. Compare and contrast direct and indirect access search and retrieval methods
7. Employ algorithms that retrieve geospatial data from a range of data structures
8. Describe the advantages and disadvantages of different compression techniques relative to geographic data representation
9. Demonstrate how DBMS are currently used in conjunction with GIS
10. Explain why some of the older DBMS are now of limited use within GIS
11. Diagram hierarchical DBMS architecture
12. Diagram network DBMS architecture
13. Differentiate among network, hierarchical and relational database structures, and their uses and limitations for geographic data storage and processing
14. Describe the geo-relational model (or dual architecture) approach to GIS DBMS
15. Explain the use of non-traditional database management systems (e.g. non-SQL) for spatial data management

16. Explain management approaches to non-traditional data types (e.g. crowd-sourced VGI, open GIS platforms/portals, web portal, cloud spatial data management
17. Discuss spatial query and indexing to include metadata tagging
18. Restate approaches to managing proximity, distance, adjacency, topology and connectivity in spatial data (e.g. points, lines, polygons, pixels, raster data) using data management systems
19. Describe several different measures of distance between two points (e.g. Euclidean, Manhattan, network, spherical, time, social, cost)
20. Describe operations that can be performed on qualitative representations of direction
21. Explain why an object’s shape might be important in analysis
22. Explain how variations in the calculation of area may have real-world implications (e.g. when calculating density)
23. Explain the rationale behind the use of different forms of distance decay functions
24. Demonstrate how adjacency and connectivity can be recorded into matrices

Knowledge Unit title: Geospatial Data Standards

Knowledge Unit description: Skills and knowledge required to understand the processes and application of standards in geospatial science

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Standards bodies (national, international, commercial, non-profit)
- The importance of standards and how they are developed
- Open standards vs proprietary standards
- Fundamentals of data standards
- Fundamentals of metadata
- Fundamentals of Web Service Standards and how they are used
- Service-enabling data
- Fundamentals of ontology

Learning objective(s):

1. Discuss the history and mission of critical standard bodies and coordination activities to include (e.g. ISO, IHO, DGIWG, OGC, ANSI, FGDC, WC3, Spatial Data Infrastructure (SDI), etc.)
2. Describe the role played by standards in cartographic activities
3. Examine the principles of open vs. proprietary standards and the pros and cons of each
4. Describe the fundamentals of data standards and how they are used in data/content management and the production of cartographic outputs
5. Discuss basic metadata concepts. What metadata is; Primary uses; Importance in data discovery; Enabling of service catalog functions. Types of metadata (e.g. record level, feature/attribute level, service metadata, etc.)
6. Discuss the major dimensions of web service standards to include:
   WMS, WCS, WFS, WPS, REST, WSC; How these standards are developed; What they are used for; Differences between each; REST vs. OGC/SOAP
7. Employ and employee concepts of standards to enable data for web services
8. Explain the role of ontology in spatial data standards

Knowledge Unit title: Effective Visual Communications of Spatio-temporal Information

Knowledge Unit description: Skills and knowledge required to convey information and facilitate the presentation of knowledge in visual and multi-media form.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:

- Graphic depiction precision and certainty
- Introduce, define, and display a variety of visualization methodologies
- Graphic and visual depiction techniques for spatial data to support analytic or technical understanding, to include (traditional visual graphics and displays), virtual and immersive environments
- Today's media and the use of infographic-type visualizations
- Multi-media style reporting
- Advantages and disadvantages of virtual tools and technology with on data and imagery applications emphasis
- Appropriate use of scale in visual presentations
- Appropriate use of graphic vs. image-based representation of information
- Cartographic representation of data
- Geospatial representation of non-spatial data

Learning objective(s):

1. Demonstrate the ability to organize, prepare and display visual images and graphics
2. Demonstrate the ability to tell a story through static, motion, and multi-dimensional images and graphics
3. Organize a persuasive argument using visual images and graphics
4. List virtual and immersive environments appropriate to the applications of geospatial data and imagery
5. List data required to create imagery-based graphics, and the advantages and disadvantages of creating a variety of imagery-based products
6. Explain the use of multi-media used in graphic depictions
7. Discuss the need for graphic spatial depictions to communicate information effectively, and discuss the impact of timeliness, data sets, and how the information will be disseminated

Knowledge Unit title: Professional Ethics in Geospatial Information Science and Technology

Knowledge Unit description: Skills and knowledge—including but not limited to codes of ethics—that govern work with geospatial technologies used to track people and things (e.g., Global Positioning Systems [GPS], satellite remote sensing, GIS).

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Components of professionalism including care, attention and discipline, fiduciary responsibility, and mentoring
- Keeping current as a professional (familiarity, tools, skills, legal and professional framework as well as the ability to self-assess and computer fluency)
- Professional certifications and codes of ethics, conduct, and practice, (e.g. ASPRS, GISCI, USGIF and international societies)
- Accountability, responsibility and liability (e.g. data and software correctness, reliability and safety, as well as ethical confidentiality of geospatial professionals)
- Maintaining awareness of consequences
- Ethical dissent and whistle-blowing
- Potential misuse of geospatial technologies (e.g. geoslavery, infringement of privacy, proper conducts and etiquette when working with indigenous communities, etc.), examples of misuses and consequences
- Acceptable use policies for workplace computing

Learning objective(s):

1. Identify ethical issues that arise in software development and determine how to address them technically and ethically.
2. Recognize the ethical responsibility of ensuring software and data correctness, reliability and safety.
3. Describe the mechanisms that typically exist for a professional to keep up-to-date.
4. Describe the strengths and weaknesses of relevant professional codes as expressions of professionalism and guides to decision-making.
5. Analyze a global geospatial issue, observing the role of professionals and government officials in managing this problem.
6. Evaluate the professional codes of ethics from the ASPRS, GISCI, and other organizations.
7. Describe the consequences of inappropriate professional behavior.
8. Identify the progressive stages of a whistle-blowing incident.
9. Investigate forms of harassment and discrimination and avenues of assistance
10. Examine various forms of professional credentialing

11. Develop a computer usage/acceptable use policy that includes enforcement measures.
12. Describe issues associated with industries' push to focus on time to market vs. enforcing quality professional standards

Knowledge Unit title: Geospatial Analysis

Knowledge Unit description: Skills and knowledge required to conduct basic geospatial analysis; this KU can be applied to a broad range of spatial problems.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Buffers and overlays
- Neighborhoods
- Raster/map algebra
- Least-cost analysis
- Error analysis/matrices
- Point pattern analysis and density estimation
- Cluster analysis
- Multi-criteria evaluation
- Spatial process models

Learning objective(s):

1. Outline circumstances where buffering around an object is useful in analysis
2. Demonstrate how the geometric operations of intersection and overlay can be implemented in a GIS
3. Demonstrate methods that can be used to establish non-overlapping neighborhoods of similarity in raster datasets
4. Explain the categories of map algebra operations (e.g. focal, local, zonal, and global functions)
5. Perform basic error analysis, understanding errors of commission/omission
6. Create density maps from point datasets using kernels and density estimation techniques using standard software
7. Discuss the characteristics of the various cluster detection techniques
8. Perform a cluster detection analysis to detect hot spots in a point pattern
9. Compare and contrast the terms multi-criteria evaluation, weighted linear combination, and site suitability analysis
10. Differentiate between contributing factors and constraints in a multi-criteria application
11. Discuss the relationship between spatial processes and spatial patterns

12. Differentiate between deterministic and stochastic spatial process models

Knowledge Unit title: Errors in Geospatial Information

Knowledge Unit description: Skills and knowledge required to identify and correct various forms of inaccurate or corrupted geospatial data

Requirement satisfaction: This KU is satisfied when all Topics and Learning Objectives are met.

Topics:
- Common ways that error is introduced into geospatial analysis and information
- Methods to detect corrupted data/information
- Methods for correcting inaccurate or incorrect geospatial information
- Using quality management systems in geospatial information production
- Error inherent in scale

Learning objective(s):
1. Describe common ways in which geospatial data and information is corrupted primarily through data collection, human communication, and error propagation through analysis processes
2. Identify corrupted geospatial information in various forms.
3. Recognize the criticality of providing precise, accurate and valid/correct geospatial information to various end consumers (e.g. the military, scientists, disaster responders)
4. Explain the value and utility of employing a rigorous, industry-accepted (e.g. ISO) Quality Management System in geospatial information production
5. Describe the effect of scale in precision and accuracy of map data

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Knowledge Units

Optional Knowledge Units

Geospatial Analysis Focus Area

Knowledge Unit title: Geospatial Analytic Reasoning and Problem Solving Fundamentals

Knowledge Unit description: Cognitive/social skills and knowledge required to understand and apply analytic reasoning and problem solving methods

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:
- Perception and cognition associated with analytic reasoning and problem solving
- Understanding meta-cognition and socio-cultural thought foundations
- Geographic and cultural influences that lead to analytic bias
- Analytical constraints associated with collective memory
- Establishing appropriate analytic queries related to problem-solving and reporting requirements
- Making insightful judgments through sound analytical objectivity, healthy skepticism, and realistic pattern considerations
- Translating requirements into appropriate analytic questions
- Solving complex analytics questions through right-sizing project scope

Learning objective(s):
1. Discuss analytic bias as it relates to situational awareness, experience, and cultural differences
2. Identify common biases regarded as the main reasons for judgment errors in analysis
3. Describe the impact of social media, collective memory, and false information on creating sound analytical interpretations and judgment
4. Identify information and sources for checking analytical relevance and accuracy
5. Recognize the difference between assumptions and inferences
6. Identify viewpoints and sources of judgment that serve self-interests
7. Solve a problem applying spatial analytic techniques
8. List common approaches used to identify project scope and management

Knowledge Unit title: Foundations of Spatial Thinking

Knowledge Unit description: Skills and knowledge required to understand historical, personal, and social perceptions of geographic information.

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Geography as a foundation for GIS
- Common-sense geographies
- The cultural and political influences affecting the perception and understanding of geographic information and phenomena
- Tobler's first law of geography
- Geographic contextualization and constraints for analysis and interpretations

Learning objective(s):

1. Define the properties that make a phenomenon geographic
2. Explore the history of geography and its role in Geospatial Information Sciences and Technology
3. Discuss the differing denotations and connotations of the terms spatial, geographic, and geospatial
4. Describe the ways in which the elements of culture may influence the understanding and use of geographic information
5. Recognize the impact of one's social background on one's own geographic worldview and perceptions, and how it influences one's use of GIS
6. Evaluate the influences of political ideologies on the understanding of geographic information

Knowledge Unit title: Geometric Measures

Knowledge Unit description: Skills and knowledge required to use measurements to extract meaning from geospatial datasets or to derive new data for further analysis

Requirement satisfaction: This KU is satisfied when all Topics and seven (7) Learning Objectives are met.

Topics:
- Distances and lengths
- Direction, shape, area, volume, and time
- Proximity and distance decay
- Adjacency and connectivity

Learning objective(s):
1. Describe several different measures of distance between two points (e.g. Euclidean, Manhattan, network, spherical, time, social, cost)
2. Describe operations that can be performed on qualitative representations of direction
3. Explain why the shape of an object might be important in analysis
4. Explain how variations in the calculation of area may have real-world implications (e.g. when calculating density
5. Explain the rationale behind the use of different forms of distance decay functions
6. Demonstrate how adjacency and connectivity can be recorded into matrices
7. Explain how different map projections can introduce errors in measurement of distance, direction or area.
8. Explain how topology relates to adjacency and connectivity.

Knowledge Unit title: Analysis of Workflow in Project Management

Knowledge Unit description: Skills and knowledge required to design a workflow of GIS procedures and data to implement mathematical, geographical, statistical, and other analytic models

Requirement satisfaction: This KU is satisfied when the Topic and all Learning Objectives are met.

Topics:

- Applying the scientific method to projects using geospatial and remote sensing data

Learning objective(s):

1. Discuss the scientific and algorithmic approaches to frame research questions and develop projects
2. Deconstruct a scientific hypothesis to identify possible strategies for testing
3. Identify the sequence of operations and statistical/mathematical methods appropriate for a specific application
4. Develop a planned analytical procedure to solve a new unstructured problem
5. Compare and contrast the relative merits of various tools and methods for procedure design, including flowcharting and pseudocode
6. Select the appropriate environment (e.g. GIS software, software development environment) for implementing an analytical procedure

Knowledge Unit title: Analysis of Topographic or Field-based Data

Knowledge Unit description: Skills and knowledge required to conduct analysis with continuous surface data

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Digital Elevation Models (DEMs)
- Triangulated irregular networks (TINs)
- DEM-derived surface calculations (e.g. slope, aspect, visibility)
- Interpolation
- Friction surfaces

Learning objective(s):
1. Explain why the properties of spatial continuity are characteristic of spatial surfaces
2. Outline methods for calculating slope and aspect from a DEM
3. Outline methods for calculating slope and aspect from a TIN
4. Explain why different interpolation methods (e.g. inverse distance weighted, bi-cubic spline fitting, kriging) produce different results, and suggest ways that they can be evaluated in the context of a specific problem
5. Perform siting analyses using specified visibility, slope, and other surface-related constraints
6. Explain how friction surfaces are enhanced by the use of impedance and barriers
7. Apply the principles of friction surfaces in the calculation of least-cost paths

Knowledge Unit title: Geostatistics and Spatial Econometrics

Knowledge Unit description: Skills and knowledge required to analyze continuous data by understanding the concept of semi-variograms and their use in spatial prediction.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Regionalized variable theory
- Spatial sampling for statistical analysis
- Principles of semi-variogram construction and modeling
- Weighted least squares method
- Principles of kriging and different types of kriging
- Spatial trend analysis
- Mathematical operations allowed at each level
- Spatial econometrics
- Spatial regression analysis and geographically weighted regression (GWR)
- Spatial filtering

Learning objective(s):

1. Create spatial samples under a variety of requirements (e.g. coverage, randomness, and transects)
2. Construct a semi-variogram and illustrate with a semi-variogram cloud
3. Apply the method of weighted least squares and maximum likelihood to fit semi-variogram models to datasets
4. Conduct a spatial interpolation process using kriging from data description to final error map
5. Apply kriging to appropriate datasets, and interpret the results
6. Identify geospatial trends within datasets
7. Explain and know how to test for spatial autocorrelation
8. Discuss statistical levels and the operations allowed at each level
9. Apply appropriate levels to data types
10. Describe the metric content of the levels and know how to change among levels
11. Discuss how the statistical data level affects geospatial manipulations
12. Describe the general types of spatial econometric models
13. Demonstrate how the spatial weights matrix is fundamental in spatial econometrics models
14. Justify the choice of a particular spatial autoregressive model for a given application
15. Apply a spatial autoregressive model to estimate spatial lags and spatial interactions among variables.
16. Identify modeling situations when and what spatial filtering will be useful.

17. Explain the principles of Geographically Weighted Regression (GWR), and discuss what kinds of problems are most suited or not suited for GWR to model spatial relationships.
18. Perform an analysis using the GWR technique

Knowledge Unit title: Network Analysis

Knowledge Unit description: Skills and knowledge required to examine phenomena that can be modeled in the form of connected sets of edges and vertices.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Defining a network: geospatial networks and social networks
- Graph theory
- Network metrics that describe connections, distributions, and segmentation
- Methods of modeling networks (least-cost path, flow modeling, accessibility modeling)
- Networks (e.g. hydrologic, transportation, telecommunications, transmission patterns of infectious diseases, social networks, natural disasters, etc.) used to define specific applications or industries
- Understanding the inter-connectedness of networks, communities, patterns of behavior, etc. in analysis through defining and identifying network relationships
- Demonstrations of practical situations in which network fundamentals help define the analytical picture through relationship discovery

Learning objective(s):

1. Describe terminology related to network analysis
2. Demonstrate how networks can be measured using the number of elements in the network, the distances along network edges, and the network's level of connectivity in a network
3. Compute the optimum path between two points through a network using Dijkstra's algorithm
4. Apply a maximum flow algorithm to calculate the largest flow from a source to a sink
5. Explain how the classic transportation problem can be structured as a linear program
6. Explain several classic problems to which network analysis is applied
7. Discuss methods for measuring different kinds of accessibility on a network
8. Define how exploiting networks and network relationships can be applied to address complex analysis problems
9. Demonstrate how network analysis tools deepen analytic capabilities and enhance product outputs

Knowledge Unit title: Optimization and Location-allocation Modeling

Knowledge Unit description: Skills and knowledge required to enable the optimization of spatial decision support for business and government applications

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Location modeling
- Linear and non-linear programming
- Integer programming
- Critical Path Method (CPM)
- Location-allocation modeling
- Spatial Optimization

Learning objective(s):

1. Compare and contrast the concepts of discrete vs. continuous location problems
2. Describe the structure of linear programs
3. Implement linear programs for spatial allocation problems
4. Assess the outcome of location-allocation models using other spatial analysis techniques
5. Use location-allocation software to find service facilities that meet given sets of constraints
6. Create working models to locate new or existing facilities for allocating resources
7. Define optimal alternative methods, and the trade-offs among solutions

Knowledge Unit title: Spatial Data Integration

Knowledge Unit description: Skills and knowledge required to integrate disparate types of data that vary in data model, geometry, resolution, accuracy and temporarily

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Spatial integration (geometric integration, edge-matching, horizontal integration, vertical integration, data fusion)
- Attribute and semantic integration
- Temporal integration (time conversion, temporal lineage)

Learning objective(s):
1. Describe the methods used for data integration.
2. Provide methods for vertical and horizontal data integration
3. Appraise when geometric and semantic integration are possible
4. Discuss the practical limits of data integration based on data attribution, resolution, and accuracy.

Cartographic Sciences and Geo-visualization Focus Area

Knowledge Unit title: Foundations of Cartography

Knowledge Unit description: Skills and knowledge required to understand change in the motives for mapping, the history of exploration, printing technologies, data collection technologies, design technologies, the scientific understanding of map use, visual analysis of graphic displays, application domains, and creative design innovations

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- History of cartography
- Understanding audience and purpose of a map
- Technological trends and transformations
- Map elements (legends, insets, neatlines, etc.), map scale, and map design
- Source materials for mapping, and scale of measurement
- Reference maps and thematic maps (and types of thematic maps: choroplethic maps, dasymetric maps, contour maps, etc.)
- Data abstraction, classification, selection, generalization, symbolization
- Map reading and induction
- Projection as a map design issue
- Visual variables
- Color theory

Learning objective(s):

1. Describe how symbolization methods used in map-making affect viewer interpretation of the information being presented
2. Discuss the impact that Web mapping via applications such as Google Earth has had on the practice of cartography
3. Explain how emerging technologies in related fields (e.g., the stereoplotter, aerial and satellite imagery, GPS and lidar, the World Wide Web, immersive and virtual environments) have advanced cartography and visualization methods
4. Explain how technological changes have affected cartographic design and production
5. Evaluate the advantages and limitations of various technological approaches to mapping
6. Select new technologies in related fields that have the most potential for use in cartography and visualization
7. Explain the impact of advances in visualization methods on the evolution of cartography

8. Describe how compilation, production, and distribution methods used in map-making have evolved
9. Identify the map projections commonly used for specific types of maps
10. Identify the most salient projection property of various generic mapping goals and proper use of different types of thematic maps (e.g., choropleth map, navigation chart, flow map)
11. Explain why certain map projection properties have been associated with specific map types
12. Select appropriate projections for world or regional scales that are suited to specific map purposes and phenomena with specific directional orientations or thematic areal aggregations
13. Determine the parameters needed to optimize the pattern of scale distortion that is associated with a given map projection for a particular mapping goal and area of interest
14. Diagnose an inappropriate projection choice for a given map and suggest an alternative
15. Construct a map projection suited to a given purpose and geographic location; re-create the same map using a different projection and describe what the different views communicate
16. Identify the criteria used in the selection of data to be represented on a map.
17. Apply the concepts of classification, selection, and generalization of data for portrayal on a map.
18. Describe map projections in general, the types of projections, the distortions inherent to each type and how this relates to map design.

Knowledge Unit title: Mapping and Design Principles

Knowledge Unit description: Skills and knowledge required to produce and reproduce maps, and understand the computation issues relating to these workflows. Capabilities for map and product distribution methods are also included.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:
- Raster and vector formats
- Modern and historic map production methods
- Map preparation (standard and custom products)
- Typography and placement principles
- Data distribution methods
- Collaborative map design
- Information visualization techniques applied to geographic information
- Developing animated and interactive maps
- “Mapping mashup” construction and programming
- Sources of dynamic geographic information use
- Usability of dynamic maps

Learning objective(s):
1. Distinguish between raster and vector formats and how each is used in the production of mapping and geospatial products
2. Describe historical map production methods
3. Discuss the principles of map preparation and production to include projections, cartographic license and displacement, rules for typography placement,
4. Explain modern and historic map production methods
5. Prepare maps for standard and custom products
6. Describe the impacts of conversion on practical use and visualization
7. Discuss questions of locational and attribute accuracy
8. Explain projection changes (forward and inverse)
9. Discuss appropriate algorithms and questions of data loss
10. Explain methods used to distribute/disseminate map products and outputs (e.g. interactive and on-line distribution, hand help devices, web services, social media sites such as Map Story)
11. Describe the principals for collaborative map design (e.g. VGI, Map Story, Wiki Maps)

Knowledge Unit title: Extraction and Generalization of Geospatial Data for Geographic Visualization and Cartography

Knowledge Unit description: Skills and knowledge required to extract data from primary imagery sources to include commercial sources that represent varying degrees of resolution and spectral characteristics (e.g. panchromatic, multi-spectral, hyper-spectral, etc.)

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Imagery types and their characteristics
- Proper selection and use of imagery to produce maps and geospatial products
- Techniques for data extraction from imagery source
- Classification (per pixel)
- Object-based image analysis
- Neural networks and learning classifiers
- Fuzzy maps

Learning objective(s):
1. Discuss imagery types
2. Describe proper use of imagery types to support a range of mapping applications
3. Demonstrate the capability to extract content from an imagery source to support mapping outputs
4. Explain the role of content specifications and standards in data extraction

Knowledge Unit title: Integration of Geospatial Information Sources

Knowledge Unit description: Skills and knowledge required to integrate geospatial content, using modern methods to acquire and update data from non-traditional sources.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:

- Emerging geospatial information sources (social media, open sources, VGI)
- Data crowdsourcing fundamentals
- Pros/cons of using open source and social media data in mapping applications
- Sources and methods for evaluating and incorporating open source and VGI
- Data transaction and update methods from hand-held and mobile devices
- Emerging techniques for integrating non-traditional geospatial data and content for cartographic use.
- CAD to GIS conversion, data interoperability in cartography
- Integrating floor plans/CAD diagrams into maps (Building Information Modeling (BIM))

Learning objective(s):

1. Describe non-traditional and emerging data types and their applicability to mapping and product generation
2. Explain the principles of crowdsourcing data (methods, pros/cons, the crowd to self-police content)
3. Examine methods for crowd ranking. (employing manual and automated techniques to understand the validity of open source data, applying automated methods for continuous crowd ranking to support the updating of geospatial data)
4. Explore methods for incorporating data from mobile devices into larger geospatial activities in near real-time (e.g. how to take data from Twitter feeds and media reports and incorporate to rapidly update geospatial data to support Humanitarian Assistance and Disaster Relief (HADR) missions)
5. Describe the limitations of using open source data and issues of data quality
6. Develop fit for use products from open, community, and crowd-sourced data

Remote Sensing/Imagery Science Focus Area

Knowledge Unit title: Remote Sensing Collection Platforms

Knowledge Unit description: Skills and knowledge required to describe and understand remote sensing collection platforms and applying this knowledge to solving spatio-temporal problems

Requirement satisfaction: This KU is satisfied when seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Basics of aerial photography
- High altitude and low altitude airborne platforms
- Basics of aircraft position / orientation measurement (i.e., GPS and Inertial Navigation Systems (INS))
- Basic relationships between aircraft operation (i.e., flight speed) and collection parameters (i.e., sensor integration time)
- Using aerial photography in geospatial information and production problem solving
- US imaging satellite constellation
- Non-US imaging satellites constellation
- Imaging satellite orbits (e.g. geosynchronous, sun synchronous, etc.)
- Using imaging satellite types and orbits in geospatial information and production problem solving
- Basic UAV aviation and safety
- UAV mission planning
- UAV data collection and processing

Learning objective(s):

1. Describe the basic theories of aerial photography
2. Describe common applications for remote sensing using aerial photography
3. Describe the basic terms related to aircraft flight path and image parameters: Field of View (FOV), Instantaneous FOV (IFOV), Ground Instantaneous FOV (GIFOV) and their relationship
4. Describe the differences between roll, pitch, and yaw and their impact on resulting imagery
5. Describe how platform speed and collection parameters influence image quality (i.e., blur, resolution, etc.)
6. Describe the difference between nadir-looking and "agile" satellites (i.e., Worldview-2)

7. Describe the full constellation of imaging satellites (US and non-US) in space, to include their uplink and downlink architectures
8. Describe how a satellites orbit can affect when and what type of data can be collected.
9. Apply the knowledge of the global satellite constellation to solving geospatial problems such as disaster response/humanitarian relief, military operations support, global disease surveillance, crop surveillance, earth sciences (e.g. earthquakes, volcanoes, ice melt) and other areas
10. Describe UAV imagery collection and its applications ranging from precision agriculture, to disaster response/humanitarian relief/search and rescue, and homeland security and military applications

Knowledge Unit title: Radiometry

Knowledge Unit description: Skills and knowledge required to comprehend the quantitative measurement of electromagnetic energy and its application to simple imaging systems

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Basic radiometric and photometric terms.
- Derivation of source propagation and sensor output equations
- How / why do specific materials detect photons at various wavelengths
- Ways to characterize radiometric performance of detectors
- Sensor calibration

Learning objective(s):

1. Comprehend the quantitative measurement of electromagnetic energy and how it is applied to simple imaging systems.
2. Discuss radiometric and photometric terms
3. Describe basic characteristics of detector materials and figures of merit
4. Explain basic principles and approaches to radiometric sensor calibration.

Knowledge Unit title: Electro-optical (EO) Sensor Science

Knowledge Unit description: Skills and basic knowledge required to comprehend passive visible and infrared phenomenology, theory, and design.

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Basic focal-plane and detector applications in remote sensing sensors
- Visible, shortwave-, midwave- and longwave- infrared measurement theory and techniques
- Accounting for reflected and emitted energy as described in spectral signatures
- Atmospheric interactions, windows and absorption regions/bands
- Basic theory, application, and design of a broad range of sensors
- Basic passive EO systems and types.

Learning objective(s):
1. At a fundamental level, explain the process of passive EO signal generation, (propagation, target interaction, signal receipt and recording)
2. Discuss atmospheric effects on passive EO collections
3. Describe reflected and emitted energy and spectral signature generation.
4. Explain sensor theory and application as specifically associated with passive EO imaging

Knowledge Unit title: Thermal Remote Sensing

Knowledge Unit description: Skills and basic knowledge required to comprehend concepts, issues and applications relating to thermal imaging systems

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:
- Principles of thermal remote sensing (Planck function, black body radiation)
- Atmospheric effects
- Spectral emissivity and kinetic temperature
- Factors affecting kinetic temperature
- Radiant temperature
- Solar heating, longwave upwelling and downwelling radiation
- Daytime vs. night-time acquisition
- Thermal data applications
- Measured radiance as a function of observed material temperature and emissivity
- Methods to separate temperature and emissivity
- Thermal hyperpectral systems

Learning objective(s):
1. Describe the principles of thermal imaging systems and factors to consider when processing thermal data
2. Identify tools, processing techniques, and applications of thermal data
3. Recognize thermal data benefits and limitations

Knowledge Unit title: Basic Radar Science

Knowledge Unit description: Skills and basic knowledge required to comprehend radar phenomenology, theory, and design.

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Wave-guiding and radiation as applicable to microwave antennas.
- Radio Frequency/microwave measurement theory and techniques
- Basic theory, application, and design of a broad range of antennas
- Basic radar systems and types.

Learning objective(s):

1. At a fundamental level, explain the process of radar operation from signal generation, to propagation, target interaction, signal receipt and recording.
2. Discuss atmospheric effects on radar operation
3. Describe the use and purpose of signal chirping.
4. Explain antenna theory and application as specifically associated with radar imaging

Knowledge Unit title: Lidar data collection and processing

Knowledge Unit description: Skills and basic knowledge of how lidar data is collected and processed

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and seven (7) Learning Objectives are met.

Topics:

- Lidar data ingest/manipulation in 3D viewer
- Basic analysis of lidar data
- Lidar data quality
- Types of lidar sensors
- Different forms of lidar data (multiple point returns, intensity data, waveform data)
- Introduction to lidar data analysis tools, principles, and applications (viewshed/line of sight analysis, DEM/DSM estimation)
- Lidar classification
- Application of lidar to real-world missions
- Lidar systems for military applications

Learning objective(s):

1. Use lidar data in at least one software package
2. Perform basic point cloud and raster based analysis
3. Recognize basic lidar artifacts and the limitations of lidar data
4. Describe the fundamental physics behind lidar collections
5. Discuss the limitations of lidar collection (e.g. altitude, weather, dust)
6. Identify different lidar modalities (e.g. airborne, terrestrial, atmospheric)
7. Explain scientific, military, homeland security uses for lidar data
8. Describe lidar systems employed by the military (e.g. the Buckeye System)

Knowledge Unit title: Remote Sensing Data Analysis

Knowledge Unit description: Introduction to the basic applications of quantitative remote sensing data analysis and the mathematical tools used for data exploitation

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Remote Sensing applications (classification, spectral signature analysis, change detection, anomaly detection, target detection, spectral unmixing)
- Mathematical frameworks for algorithm development (multivariate statistics, linear algebra and subspace geometry, spectral linear mixture model, basic signal detection theory)
- Spectral Classification Algorithms (supervised and unsupervised, minimum distance to the mean, Mahalanobis distance, Gaussian maximum likelihood)
- Spectral signature analysis algorithms (band ratio analysis such as NDVI, NDWI), geologic mineral analysis
- Spectral Detection algorithms (anomaly detection such as RX, change detection such as chronocrome, covariance equalization), target detection such as GLRT, spectral matched filtr, ACE, CEM)
- Linear spectral unmixing

Learning objective(s):

1. Explain the (semi-) automated applications of quantitative remote sensing image analysis
2. Describe the mathematical principles behind quantitative remote sensing image analysis
3. Discuss the basics of spectral signature analysis
4. Identify the limitations of quantitative remote sensing image analysis

Knowledge Unit title: Digital Image Processing
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Knowledge Unit description: Skills and knowledge required to process of remote sensing images.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:
- Radiometric and geometric correction
- Histogram manipulation, image enhancement and restoration
- Spatial and morphological filtering
- Image transformation and data/feature dimensionality reduction
- Basics of image/data compression
- Image classification and segmentation
- Basics of image storage format and representations
- Image processing algorithms and techniques to support image enhancement; image filtering, resampling, interpolation
- Automatic and assisted feature recognition algorithms and their limitations
- Point and feature matching algorithms

Learning objective(s):
1. Describe the steps necessary to prepare raster images for analysis
2. Apply various forms of pixel and histogram manipulation to extract information from image
3. Apply methods to classify an image into various features and classes
4. Explain the concepts of digital counts, image histogram processing, and compression
5. Demonstrate basic proficiency in the computational manipulation of imagery

Knowledge Unit title: Computational Radiometry

Knowledge Unit description: Skills and knowledge required to develop, generate, and apply synthetic scenes

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Understanding of imaging system modeling (e.g. NIIRS, general image quality equation)
- Understanding of material and optical properties
- Understanding of atmospheric modeling
- Scene construction basics and geometry modeling

Learning objective(s):

1. Explain the process to produce synthetic imagery covering various regions of the electromagnetic spectrum
2. Use synthetic scenes to test image system designs
3. Use synthetic scenes to evaluate image exploitation algorithms

Knowledge Unit title: Imagery Time Series Analysis

Knowledge Unit description: Skills and basic knowledge required to conduct temporal analysis of pixel-wise observations over space and time

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- Understanding of basic temporal signal analysis methods such as Harmonic Analysis of Time Series (HANTS) and Savitsky-Golay Filter, to include
  - Using the Iterative Fourier transform to model pixel-wise observations
  - Decomposing complex temporal signals into series of simple sinusoidal waves
  - Replacing outliers and noisy data with values from the Fourier series
  - Appling least-squares polynomial regression and fitting successive subsets of adjacent data points
  - Understanding various time scales of phenomenology in remotely sensed imagery, such as daily vs. annual (i.e., seasonal) cycles
  - Understanding various time scales of remote sensing systems, such as video rate vs. daily observation vs. Landsat revisit rate

Learning objective(s):

1. Describe the algorithms used for temporal signal decomposition.
2. Explain the various timescales of interest in remote sensing systems
3. Explain the observable phenomenologies in temporal remote sensing systems

Photogrammetry Focus Area

Knowledge Unit title: Photogrammetric Theory

Knowledge Unit description: Skills and knowledge of photogrammetry concepts and theory.

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:

- The importance of photogrammetry in geospatial applications
- Photogrammetric interior orientation (focal length, principal point, image coordinate systems, transformations, and fiducials)
- Photogrammetric exterior orientation (location, orientation, and transformations)
- Photogrammetric optics, ray tracing, lens/telescope design and lens distortion modeling
- Camera, sensor and platform coordinate systems and associated transformations for satellite, airborne, and UAV platforms
- Sensor models (modeling ground to image and image to ground projections for various sensors and platforms and colinearity equations)
- Rigorous vs. replacement sensor models, generic sensor models, and community sensor model (CSM)
- Approximations to sensor models (polynomial [RPC, RSM], DLT, orthographic and accuracy/performance characteristics)
- Single image resection to recover camera model
- Relative orientation, multi-image intersection
- Camera calibration
- Perspective geometry
- Block adjustment/triangulation of multiple photos to recover imaging and ground parameters, including interior and exterior orientations
- Stereoscopy, parallax, and relief displacement

Learning objective(s):

1. Discuss sensor modeling and accuracy characterization
2. Explain how to determine interior and exterior orientation of sensors on satellite, airborne and UAV platforms and how they are used in photogrammetric operations
3. Describe a variety of multi-image photogrammetric techniques and their application to camera calibration, exterior orientation, and image exploitation
4. Discuss optics theory and application
5. Compare and contrast the similarities and differences among the photogrammetric exploitation of imagery data from satellite, airborne and UAV platforms

Knowledge Unit title: Photogrammetric Application

Knowledge Unit description: Skills and knowledge to apply photogrammetry to spatial problems

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:
- Image measurement techniques and autocorrelation
- Monoscopic ray intersection
- Stereoscopic/multiscopic ray intersection
- Triangulation, single sensor and multi-sensor block adjustment,
- Perspective, orthographic, and epipolar rectification
- Terrain/surface/object models (types, formats, how constructed, how to use, accuracy)
- Automated and manual terrain extraction techniques
- Line of sight extractions from multiscopic imagery
- Image registration
- Algorithms and techniques for measuring object properties from imagery (dimensions, shape, locations, orientation)
- Algorithms, techniques and limitations of using solar information for measuring object properties from imagery
- Algorithms, techniques and limitations of using shadow information for measuring object properties from imagery
- CAD modeling and fusing CAD models with imagery to include draping imagery over urban 3D models
- Image simulation techniques

Learning objective(s):
1. Discuss algorithms to generate terrain models and their various formats
2. Explain how image rays can be used to determine object dimensions and orientations
3. Describe how to build CAD models of objects and project them into imagery for multiple types of terrain (e.g. earth surface, urban areas, etc.)
4. Explain the theory and application of rectification

Knowledge Unit title: Close Range Photogrammetry

Knowledge Unit description: Skills and knowledge to apply close-range photogrammetry to GEOINT problems

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:

- Characteristics of handheld cameras (point and click, single lens reflex, and mobile devices)
- Close-range camera calibration
- Perspective geometry and single photo perspective photogrammetric techniques.
- Recovering camera model from vanishing perspective
- Block adjustment/triangulation of multiple photos to recover imaging and ground parameters, including interior and exterior orientations
- Stereoscopy, parallax, and relief displacement
- Algorithms and techniques for measuring object properties from close-range imagery (dimensions, shape, locations, orientation)
- Algorithms, techniques and limitations of using solar information for measuring object properties from close-range imagery
- Incorporation of photogrammetric results into 3D visualization products, e.g., point clouds, surface models, and engineering models.
- Perspective geometry and characteristics of immersive imagery (e.g. digital street view images, Google Earth,)

Learning objective(s):

1. Describe the characteristics of close-range cameras
2. Explain how image rays can be used to determine object dimensions and orientations
3. Discuss perspective geometry and how to use it in building camera models
4. Apply relevant techniques of computer vision to close-range photogrammetry
5. Apply relevant techniques of measurement to determine object dimensions and orientations in immersive imagery (e.g. digital street view images, Google Earth)

Knowledge Unit title: Mathematics, Statistics and Optimization for Imagery Applications

Knowledge Unit description: Skills and knowledge in statistics and optimization theory for photogrammetric applications

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:
- Understanding statements of absolute and relative accuracy for geopositioning, distance, azimuth, and various object properties
- Error propagation theory and its application to geopositioning, relative mensuration, and measured object properties
- Statistical representation and analysis of sensor or image product absolute and relative accuracy performance
- Optimization theory using least squares techniques (general least squares, constrained, unified least squares, sequential, least squares filtering)
- Linear algebra (matrix representation, linear transformations, equation solution)
- Numerical analysis (numerical considerations, iteration, numerical approximation)
- Projective geometry

Learning objective(s):
1. Identify general concepts of statistics and their application to spatial information
2. Discuss statistical graphing and analysis of absolute and relative accuracy performance for sensors and their derived products.
3. Explain theory and application of least squares optimization techniques
4. Describe how to model 3D space

Knowledge Unit title: Digital Photogrammetry

Knowledge Unit description: Skills and knowledge to understand algorithms and practices in image processing and computer vision and their application to image exploitation

Requirement satisfaction: This KU is satisfied when at least seven (7) Topics and all Learning Objectives are met.

Topics:

- Image processing algorithms and techniques to support image enhancement (image filtering, resampling, interpolation)
- Automatic and assisted feature recognition algorithms and their limitations
- Point and feature-matching algorithms
- Computer vision (camera calibration, image formation, 3D shape reconstruction, object recognition, feature detection, motion estimation, feature matching, transformations, computational photography)
- Digital signal processing
- Digital scanning algorithms, techniques, and accuracy
- Incorporation of photogrammetric results into 3D visualization products (e.g., point clouds, surface models, engineering models)
- Implications for photogrammetry in immersive 3D environments (e.g. Oculus Rift, holograms, first-person video, anaglyphs)

Learning objective(s):

1. Identify overall image processing algorithms for remotes sensing applications
2. Describe theory and algorithms of computer vision and apply them to photogrammetric problems
3. Describe theory and algorithms of immersive 3D technologies such as Oculus Rift, holograms, first person video, anaglyphs, etc. and apply them to photogrammetric problems

Information Science Focus Area

Knowledge Unit title: Spatial Applications of Big Data

Knowledge Unit description: Skills and knowledge relating to techniques and concepts for employing data science and big data analytic methods to cartographic activities

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Big data for spatial applications
- Big data analytics for spatial applications
- Methods for spatial data analysis in big data
- Using data science principles in cartographic design
- Application of data science principles to cartography
- Future and emerging areas of data science inquiry for spatial applications
- QA/QC of geospatial data in big data applications

Learning objective(s):
1. Explain the concepts and principles of big data analytics for spatial applications (meaning, methods, outcomes)
2. Demonstrate the use of big data analytics concepts in geospatial analysis
3. Describe QA/QC methods for geospatial data in big data applications and discuss the implications for analysis and analytics results
4. Describe the future directions for big data analytics in geospatial applications.
5. Discuss approaches to geospatial metadata/data tagging in big data applications, why metadata/data tagging is important and challenges to managing geospatial data in big data applications.

Knowledge Unit title: Advanced Spatial Analysis Through Programming

Knowledge Unit description: Skills and knowledge required to expand existing data processing functionality and develop new applications for geospatial analysis, spatial statistics, remote sensing applications, etc. using common programming languages.

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Common scripting languages for spatial applications (e.g. Python, etc.)
- Common programming languages for spatial applications (e.g. IDL, C++/JAVA, ERDAS Imagine Spatial Modeler)
- Cloud-based programming for spatial applications
- Creating spatial applications for mobile and web-based platforms

Learning objective(s):
1. Describe the basics of scripting and programming languages used for spatial applications (desktop, mobile, web-based applications)
2. Explain the basics of programming and coding algorithmic routines in expanding existing applications and/or developing new functionality and capabilities to address hard-problem challenges with niche solutions.
3. Discuss the basics of how programming and scripting languages are used with common geospatial software packages (e.g. ENVI, ESRI, ERDAS Imagine)
4. Demonstrate the applied application of programming for spatial applications (e.g. automate the QC of 40 maps)
5. Demonstrate the applied use of cloud-based technologies (e.g. MapReduce, Hadoop) for geospatial applications

Knowledge Unit title: Spatial Query Operations and Query Languages

Knowledge Unit description: Skills and knowledge required to conduct basic data queries

Requirement satisfaction: This KU is satisfied when at all Topics and all Learning Objectives are met.

Topics:

- Set theory
- Application of query operations/query languages to GIS and spatial data analysis (e.g. Structured Query Language (SQL), non-SQL, SPARQL, JSON, JAVA, HTML)
- Attribute queries vs. spatial queries

Learning objective(s):

1. Explain how set theory relates to spatial queries
2. Perform a logic (set theoretic) query using GIS software
3. Define basic terms of query processing (e.g. SQL, primary and foreign keys, table join)
4. Demonstrate multiple query language techniques (e.g. SQL, non-SQL, SPARQL, JSON, JAVA, HTML) to retrieve elements from a GIS
5. Compare and contrast attribute queries and spatial queries
6. Construct a query statement to search for a specific spatial or temporal relationship; compare/contrast the use of different query languages for spatio-temporal data searches and describe when to choose one language over another

Aeronautical Analysis Focus Area

Knowledge Unit title: Airspace Analysis

Knowledge Unit description: Skills and knowledge required to determine aeronautical accuracy, validity and/or safety of domestic and foreign airspace data and information

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Domestic airspace boundary formulation, limitations and characteristics
- Foreign airspace boundary formulation, limitations and characteristics
- International airspace structures, regulations and policy
- Domestic and international piloting procedures in airspace of the world

Learning objective(s):
1. Identify the various types and characteristics of worldwide airspace structures.
2. Describe US military mission requirements in using worldwide airspace structures.
3. Determine if, how, and when domestic/international airspace is safe for US military use.

Knowledge Unit title: Airway Analysis

Knowledge Unit description: Skills and knowledge required to determine aeronautical accuracy, validity and/or safety of domestic and foreign airway data and information

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Domestic airway limitations and characteristics
- Foreign airway limitations and characteristics
- International airway structures, regulations and policy
- Domestic and international piloting procedures on airways of the world

Learning objective(s):
1. Identify the various types and characteristics of worldwide airway structures.
2. Describe US military mission requirements in using worldwide airway structures.
3. Determine if, how and when a domestic/international airway is safe for US military use.

Knowledge Unit title: Airfield Analysis

Knowledge Unit description: Skills and knowledge required to analyze and determine various airfield characteristics

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Airfields logistics
- Airfield infrastructure
- US military aircraft usage of domestics/international airfield services
- Common signs of airfield upgrades and expansion

Learning objective(s):
1. Identify common and uncommon forms of domestic and international airfield infrastructure
2. Describe the variety and complexity of US military mission requirements in using worldwide airfields
3. Determine if, how and when domestic/international airfields are safe and/or suitable for US military use.

Knowledge Unit title: Flight Procedure Analysis

Knowledge Unit description: Skills and knowledge required to determine aeronautical accuracy, validity and/or safety of domestic and foreign flight procedures

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Domestic flight procedure limitations and characteristics
- Foreign flight procedure limitations and characteristics
- International flight procedure formulation, regulations and policy
- Domestic and international piloting procedures of the world

Learning objective(s):
1. Discuss the various worldwide flight procedures
2. Describe US military mission requirements in using worldwide flight procedures
3. Determine if, how and when domestic/international flight procedures are safe for US military use.

Navigation and Location Focus Area

Knowledge Unit title: Geodesy

Knowledge Unit description: Skills and knowledge relating to the theory and application of geodesy to photogrammetric applications

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:
- Geometric geodesy (ellipsoid characteristics, geometry, WGS84)
- Gravity modeling and earth gravity models; the geoid and geoid separation, mean sea level approximation.
- Earth coordinate systems and associated transformations (ECI, ECF, spherical, ellipsoidal)
- Local coordinate systems and associated transformations (spherical, ENU, geographic projection systems [UTM, state plane])
- Absolute and relative survey coordinate and accuracy information
- Ellipsoid height, geoid height, and orthographic height
- Universal time and earth orientation parameters

Learning objective(s):
1. Discuss the general theory of geodesy and gravity modeling (relations of gravitational models and geoid, the effects of gravitational distribution on the height datum problem)
2. Identify the various spatial coordinate systems and how to transform between them
3. Explain what the geoid is, and how it relates to mean sea level
4. Discuss the importance of ground survey information and the use of the word “control” to describe a surveyed point or feature.
5. Describe the differences between ellipsoid height, geoid height, msl height, and orthographic heights

Knowledge Unit title: Fundamentals of the Global Positioning System (GPS) and the Global Navigation Satellite System (GNSS)

Knowledge Unit description: Skills and knowledge relating to how GPS and GNSS work and the diverse range of uses for satellite navigation

Requirement satisfaction: This KU is satisfied when all Topics and all Learning Objectives are met.

Topics:

- How GPS works
- Orbits and signals
- Accuracy and error analysis
- GPS modernization and GNSS
- GNSS today and the into the future

Learning objective(s):

1. Describe a GNSS system (hardware, software and control of system) and relate it to GPS
2. Describe a plan for collecting GPS data (hardware, software, process) for different types of applications.
3. Describe what can affect the accuracy or cause errors for data collected by a GPS
4. Demonstrate how to collect accurate GPS data useful in different applications
5. Discuss the historic development of GNSS and describe possible future uses and trends.