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Development of GIS Core Curricula: A Curriculum Draft, Chapters 1 and 2

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GIS Association of Japan Working Group on GIS Education Curricula

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Chapter 1
Geographic Information Systems (GIS) Core Curriculum Overview

The Board of Directors of the GIS Association of Japan (GISA) formed a working group to study GIS education curricula (C-WG) on October 22, 2002. This report presents the C-WG's proposed GIS core curriculum content items and their systems that are used to form the basis of GIS instruction at universities. The working group is currently comprised of Atsuyuki Okabe (Director), Takashi Oguchi (Vice-director), Hiroyuki Kohsaka, Yuji Murayama, and Mizuki Kawabata. Members will be added as necessary.

The proposed GIS core curricula are to be developed in four stages. In Stage 1, material was arranged from November 2002 through September 2003, and a plan of core curriculum items was drafted. The work was quite voluminous and time-consuming, so was completed mainly by Kawabata, Oguchi, and Okabe. References used in Stage 1 were: the NCGIA core curriculum, UCGIS's Strawman Report of the model undergraduate curricula for Geographic Information Science & Technology, and major GIS textbooks in English (see Kawabata et al., 2003). In Stage 2, C-WG added two new members, Hiroyuki Kohsaka and Yuji Murayama. The group revised the draft plan in response to comments from the faculty at the Center for Spatial Information Science at the University of Tokyo. The curriculum draft plan proposed by this report is this Stage 2 plan. C-WG members will continue to be added and the Stage 2 plan will be improved to develop into the Stage 3 plan. The Stage 3 plan will be shared with GISA members and a Stage 4 plan that reflects comments from members will be developed. The Stage 4 plan will become the GISA curriculum plan and will be shared with other organizations.

This report consists of GIS curriculum content items, explanations of the items, and material. Chapter 1 presents an overview of the GIS core curricula. Next, Chapter 2 describes core curriculum content items, and Chapter 3 summarizes the explanations of individual content items. The explanations are material that serve as references for each content item.

1.1 GIS Education

We use the term 'GIS education' not to mean instruction in GIS software operations but rather instruction in scientific knowledge that is based on the creation of GIS. In that sense, 'GIS education' can be referred to as instruction in Geographic Information Science, or Spatial Information Science. In other words, it does not mean education in statistical software operations but education in statistics.

1.2 Education Environment Assumed by Curricula

There are very few undergraduate and graduate schools that offer a GIS-centric education. Many treat teaching secondarily and their education environments vary. The curricula proposed herein do not assume a structured education environment. Therefore, in practice, it is assumed that defining undergraduate and graduate levels is merely the beginning and these curricula may be adjusted according to different educational environments and objectives.

1.3 Core Curriculum

These curricula are intended to propose absolutely basic content items in GIS education. Therefore, the curricula proposed here may be referred to as core curricula. However, because it is difficult to definitively prescribe fundamental contents, breadth is offered and two levels, Levels 1 and 2, are considered. Level 1 is assigned to items that appear in over two-thirds of 16 standard textbooks (14 textbooks and two reports by NCGIA and UCGIS, listed in Kawabata et al., 2003) or that cannot be omitted in light of the logical consistency of overall curricula. Level 2 is assigned to items that appear in more than half of 16 standard textbooks or that should be considered in light of the logical consistency of overall curricula.

1.4 Item Order and Education Order of Curricula

The order of curriculum content items presented in Chapter 2 is not necessarily appropriate to teaching practice. When teaching in practice, the order may be re-arranged in accordance to the education contents in each academic field. Order may also be re-arranged to meet students' interests.

1.5 Term Consistency

GIS is relevant to a number of academic fields and terms are currently not used consistently. This report aims for consistency in term use, but there are terms for which it is premature to assign a single term. In those cases, we explain that multiple terms may apply, and the one used may be determined by each education environment.

1.6 Overall Consistency

A purpose of the curricula is to coordinate all individual items. However, as there are a number of items derived from a variety of fields, we do not suppose that this coordination is complete. The consistency of the structure overall is at this time loose.

Chapter 2 GIS Core Curriculum Content Items

2.1 Introduction

This section presents a curriculum overview and deals with background items before going into the details.

* Structure of curriculum content items
  - Summary of each section (content structure of Geographic Information Science)

* Definitions of GIS and related minimal and basic terms (Level 1)
  - Geographic information, geographic data, spatial information, spatial data
  - Geographic Information Science, Spatial Information Science
  - Geographic Information Systems

* Uses and application fields of GIS (Level 1)
  - Overview of academic applications
  - Overview of real world applications

* GIS-related academic fields (Level 2)
  - Geography, cartography, information science, remote sensing, etc.

* History of GIS (Level 2)
  - Canada GIS
  - SYMAP
  - TIGER
  - DIME
  - History of GIS research organizations (e.g., Laboratory for Computer Graphics and Spatial Analysis at Harvard University, NCGIA, URISA, RRL in the U.K.)

2.2 Conceptual Modeling and Basic Concepts of the Real World

Based on a certain viewpoint and with computer processing in mind, this section deals with methods to develop conceptual models of the real world by abstracting the real world, and also deals with formal conceptual modeling. Note that this section does not deal with conceptual models of the real world themselves but deals with conceptual modeling; in other words, the methodology of conceptual model development.

* Epistemology and cognition theory of the real world (Level 2)
  - Spatial epistemology, spatial cognition theory
  - Object-oriented spatial epistemology
  - Spatial ontology

* Conceptual modeling of the real world (Level 1)
  - Methods to define viewpoints and subjects of conceptual modeling

  - Decomposing the real world into entities
    Creating features from entities
    Methods to handle discrete entities and continuous entities
    Methods to handle ambiguous entities
    Spatial division of the real world (regionalization)

  - Conceptualizing nature of spatial entities
    Conceptualizing spatial nature (methodology of defining ‘spatial attributes’)
    Conceptualizing non-spatial nature
    Linking spatial nature and non-spatial nature

  - Conceptualizing spatial relationships
    Conceptualizing qualitative spatial relationships
      Neighborhood, contiguous, surrounding, etc.
    Conceptualizing quantitative spatial relationships
      Distance, direction, spatial correlation, etc.

* Methodology of spatial references (Level 1)
  - Spatial referencing based on coordinates
  - Spatial referencing based on geographic identifiers
  - Spatial referencing based on spatial division (e.g., grid), etc.

* Methodology of defining scale and spatial units (Level 1)

- Scale theory, spatial unit theory
- Conceptualizing space depending on scale and spatial unit

  Generalization, MAUP, etc.

* Formal modeling of spatial conceptual models (Level 1)

Methodology of defining formal modeling of conceptual models assuming computer processing.

- Geometric formal modeling of spatial nature and relationships

  Euclidean formal modeling

  Topological (graph theoretical) formal modeling

- Formal modeling of non-spatial nature and relationships

  Tabular formal modeling

- Formal modeling of logical structure of spatial conceptual models

  Formal modeling of logical structure consisting of spatial and non-spatial nature and relationships

* Formal conceptual modeling language (Level 2; Level 1 when emphasizing system implementation)

- Formal modeling by Unified Modeling Language (UML)

* Geographic basic concepts (Level 1)

- Location (e.g., distribution, disposition, relation, density)
- Landscape (e.g., openness, direction, relief, bird’s-eye view)
- Region (e.g., substantial region, formal region, homogeneity, heterogeneity, connectivity, functionality)

2.3 Spatial Data Models

This section deals with the representation of formalized models that are systematically conceptualized using a given method through data models that can be processed by computers.

* Spatial referencing of spatial data (Level 1)
  - Spatial referencing based on coordinates
    - Earth ellipsoid
    - Latitude and longitude
    - Map projections and coordinate systems
  - Spatial referencing based on geographic identifiers (Level 1)
    - Address, zip code, etc.
    - Address matching, geocoding
  - Spatial attribute and non-spatial attribute data (Level 1)
    - Methods to define spatial attribute data
    - Methods to define non-spatial attribute data
    - Methods to link spatial attribute data and non-spatial attribute data

* Spatial data models (Level 1)
  - General theory of spatial data models
    - Discrete spatial data models
    - Continuous spatial data models
    - Discrete and continuous spatial data models
  - Raster models
  - Spatial tessellation models (e.g., mesh, grid)
  - Vector models
  - 2.5-dimension models (e.g., DTM/DEM, TIN)
  - Spatio-temporal models (Level 2)

* Spatial metadata (Level 1)
  - Metadata items
  - Clearinghouse functions

Note: Spatial database systems are described in section 2.8.

2.4 Acquisition of Spatial Data

This section deals with methods to acquire spatial data.

* Surveying (Level 1)
  - Basic surveying methods
    Positioning, measuring angle, measuring distance, etc.
  - Surveying methods using satellites (e.g., use of GPS)

* Methods of spatial data acquisition in field work (Level 1)

* Spatial data sampling (Level 2)
  - Sampling methods
  - Sample size
  - Estimation methods from samples

* Remote sensing and image measurements (Level 1)
  - Platforms (airplanes, satellites)
  - Sensors

  Note: Data processing and measurement methods and precision testing methods are presented in section 2.5.

* Making spatial data from existing maps (Level 1)
  - Digitizing
  - Scanning
  - Attaching coordinates

  Note: Processing methods are described in the subsequent section.

* Making spatial data from existing statistics (Level 1)
  - Making spatial data from census data
  - Making spatial data from other statistics

  Note: Specific statistics are dealt in accordance with specific fields.

* Acquisition of existing spatial data (Level 1)
  - Search and acquisition using clearinghouse
  - Acquisition of data on the market (e.g., digital maps)
  - Acquisition using the Internet

* Distribution using spatial data transfer (Level 1)
    - Spatial data transfer standards
    - Interoperability

2.5 Editing Spatial Data

This section deals with methods to edit acquired spatial data.

* Spatial data transformations (Level 1)
  - Raster and vector conversions
  - Projection changes, coordinate transformations
  - Aggregation, generalization
  - Data compression

* Linking between spatial attribute data and non-spatial attribute data (Level 1)

* Merging methods (Level 1)
  - Conflation
  - Rubber sheeting

* Editing vector data and raster data (Level 1)
  - Editing vector data such as edge matching
  - Editing remote sensing data (Level 2)

* Quality of spatial data (Level 1)
  - Quantitative quality

    Completeness, logical consistency, location precision, temporal precision, thematic precision
  - Non-quantitative quality
  - Quality evaluation

* Methods to handle data with errors and uncertainty (Level 1)
  - Methods to detect and edit errors
  - Methods to handle uncertainty with fuzzy logic

2.6 Spatial Data Analysis

This section deals with analytical methods using spatial data.

* Basic operations for spatial data analysis (Level 1)
    - Classification, reclassification, integration, and algebraic operations based on attributes
    - Neighborhood operations (e.g., buffer, Voronoi)
    - Operations on geometric quantities (e.g., distance, area)
    - Geometric logical operations (e.g., overlay)
    - Spatial queries, selections, extractions
    - Spatial filtering (Level 2)

* Point data analysis (Level 1)
    - Basic patterns of point distributions (e.g., random, condensation, uniformity)
    - Quadrat methods, nearest neighbor distance methods, K-function methods
    - Kernel methods

* Network data analysis (Level 1)
    - Connectivity analysis (e.g., Kansky measures)
    - Shortest-distance path
    - Accessibility analysis

* Area data analysis (Level 1)
    - Descriptive statistical analysis
    - Spatial correlation, spatial autocorrelation, correlogram
    - Spatial regression analysis

* Analysis of spatially continuous data (Level 1)
    - Spatial interpolation (e.g., kriging)
    - Terrain analysis (DEM/DTM)
    - Watershed analysis
    - Viewshed analysis
    - Regional trend surface analysis

* Spatial pattern analysis (combined analysis of above analyses)
    - Classic spatial pattern analysis (e.g., concentric circle, sector, multinuclear)
    - Central place analysis

- Local pattern and global pattern analysis
- Cognitive spatial pattern analysis

* Analysis using spatial models (Level 2)
  - Location-allocation models
  - Spatial interaction models
  - Spatial diffusion and propagation models

* Spatial planning based on spatial analysis
  - Spatial decision making support systems

2.7 Visual Communication of Spatial Data

This section deals with visualization of spatial data and results from spatial analysis.

* Basics of visual communication (Level 1)
    - Visual communication theory
    - Design theory

* Selection of representation methods (Level 1)
    - Data nature
    - Classification of representation methods
    - Map types

* Graphic design (Level 1)
    - Arrangement of descriptive information
    - Spatial scale
    - Creation of base maps
    - Symbolization methods
    - Map readability

* Communication and use of results
    - Creation of output maps (Level 1)
    - Mapping in interactive environments (Level 2)
    - Evaluation of communicability (Level 2)

2.8 GIS System Establishment

This section deals with system establishment for actual GIS uses.

* GIS hardware (Level 1)
    - Computers
    - Peripheral devices such as digitizers and scanners
    - Network-related devices

* GIS software (Level 1)
    - General theory of database systems
    - Spatial databases
    - Spatial database management systems
    - Spatial database languages
    - Network GIS

* Introduction and management of GIS (Level 2)
    - GIS design (Level 1)
    - Making system plans
    - System install
    - Operation and management

2.9 GIS and Society

This section deals with social activities and issues related to GIS.

* Engagement with GIS by governments, local public organizations, and NPOs (Level 1)
    - National spatial data infrastructure
    - Integrated GIS
    - Approaches by advanced nations

* GIS industry (Level 1)

* GIS and organizations (Level 1)

* Standardization (Level 1)
    - ISO/TC211
    - OpenGIS
    - Geographic information standards

* Legal issues of GIS (Level 2)
    - Information disclosure
    - Ownership

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