Software Tool Development for Higher Education on Geospatial Technology
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Abstract
People who have knowledge on Geospatial Information Standards are not enough, even though the Spatial Data Infrastructure (SDI) is constructed widely in the world. One of reasons is that only a few educational organizations open courses on the related knowledge in Japan. We should consider a development of the educational tools to improve such a situation. This paper aims to propose the design of the introductory course, course materials and the open software tool on Geospatial technology based on the knowledge behind Geographic Information Standards.

Keywords: GIS education, Geographic Information Standard, open educational tool

1. INTRODUCTION
Today, the construction and utilization of global, international, national, and sub-national SDIs are promoted rapidly. We can point out at least three reasons. The first is the natural resource depletion caused by the world population growth. The second is the escalation of disasters and environmental issues. The third is the social demand to make spatial data interoperable. ISO/TC211, OGC and other related organizations provide Geographic Information Standards to realize the spatial data interoperability. EU published INSPIRE Directive in order to establish an infrastructure for Spatial Information in the member countries (European Union, 2007). Japanese government enacted “Basic Act on the Advancement of Utilizing Geospatial Information” in the same year (Murakami, 2008). Also the US Ministry of Labor identifies the Geospatial Industry as the high growth industry (US Ministry of Labor, 2010).

Meanwhile, UCGIS published GIS&T Body of Knowledge (BoK) in 2006 (DiBiase et al., 2006), and an education initiative in the Association of Geographic Information Laboratories in Europe (AGILE) is investigating BoK and education, qualification, and certification systems. In Japan, the initiative on a GIS&T BoK was undertaken by the research project “Development of geographic information science curricula and sustainable web library systems for serving their contents” [Chair: Atsuyuki Okabe, The University of Tokyo] from 2005 up to 2007 (Ota et al., 2008). Also the research project “Geographic Information Sciences Education and Spatial Thinking” [Chair: Yasushi Asami, The University of Tokyo] is running from 2009 to 2013. The Japan Society for the Promotion of Science (JSPS) funds both projects. International Conference on Spatial Thinking and Geographic Information Science to promote the later research activity was held from September 14 to 16, Tokyo (Asami, 2011).

The author is a member of both projects and developing teaching aids for the introductory course of Geospatial Technology on the viewpoint of the dissemination of Geographic Information Standards (Ota, 2010). There are two reasons to emphasize GI Standards. One is that there are few educational tools to learn knowledge behind SDI in Japan, even though the SDI construction and its utilization are urgent issues. The other is that GI Standards can be seen as a gateway to the knowledge of Geospatial Technology. For example, ISO 19107 - Spatial schema (ISO, 2003) provides well-structured spatial geometry and topology.
This paper will focus on designing of the lecture notes (slides) and the software tool for a semester course brought for undergraduate students and beginners in the GIS industry. At first, we will discuss designing the introductory course on Geospatial Technology. At second, the software tool called “GeoPack” will be reported in preliminary fashion as it is still under development. And finally, we will remark the future works and the schedule of the development.

2. DESIGNING OF THE COURSE ON GEOSPATIAL TECHNOLOGY

We will discuss the purpose, constraints, topics, and syllabus of the semester course for undergraduate students and for beginners working in GIS industry in this section.

2.1. Purpose

Purpose of the course is that students will have an overview of Geospatial Technology, the role of each knowledge unit in the BoK of Geospatial Technology, and how to acquire, store, analyse, exchange and represent geospatial data. Furthermore, we have a plan so that the students will be able to get tips on the geospatial software development, if they ask for.

2.2. Constraints

We have to accept several constraints before designing the course. There are time limitation, volume of knowledge that students can learn, and prerequisites. Standard lecture hours are 22.5 hours as 15 lectures (1 credit) in Japan. In addition, students are expected to study 22.5 hours before and after lectures. It means that the total length for students is 45 hours and it is divided over 15 lectures. Thus, appropriate volume of lecture notes (slides) for teachers and aids for self-learning are required. We cannot request long list of prerequisites to students, as long as they are beginners of this research field. However, we expect they have knowledge of high school level mathematics (In case of Japan, it may happen that students who did not select mathematics as the subject of entrance examination are included in the class), because they will learn geometric attributes (point, curve and surface) of geographic features, basic idea of coordinate reference system and fundamental algorithm (distance, centre, point in polygon, etc.) of spatial analysis.

2.3. Topics

In accordance with the scope of ISO/TC211 (http://www.isotc211.org/scope.htm), standards provided by TC211 may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. Meanwhile, GIS&T BoK (DiBiase et al., 2006 on page 5-6) defines Geospatial Technology as it supports a wide variety of uses, from data acquisition (e.g., aerial imaging, remote sensing, land surveying, and global navigation satellite systems), to data storage and manipulation (e.g., GIS, image processing, and database management software), to data analysis (e.g., software for statistical analysis and modeling) to display and output (e.g., geovisualization software and imaging devices).
In this paper, Geospatial Technology (in other words, Geomatics, or Geographic Information Science and Technology) is defined as a discipline of modelling, acquisition, management, analysis, exchange and representation of geospatial data. Each element of Geospatial Technology can be seen as a knowledge unit of the BoK on this research field.

2.3.1. Modelling

Modelling is a process to describe "feature" as an abstraction of the real world phenomena. An abstraction process is called modelling. A structural cluster of models is constructed in the human brain by assimilation and accommodation. However, to think of digital data acquisition following the model, it is impossible to get well-structured data, if the model contains ambiguity. It means that data acquisition is not possible without formal description of model, in other words the schema. Therefore, the schema description language such as UML is important to achieve un-ambiguity.

Geospatial data is a special type of data as it relates to the position/location on the earth. So, we need the restrictions to the schema. General Feature Model (GFM) defined in ISO 19109 (ISO, 2005) provides them as a meta-model for the formal description of feature and association between them. GFM includes rules how to define attributes and operations of a feature and an association. The author simplified the GFM defined in ISO 19109 for the elemental education (Figure 1).

Figure 1. General Feature Model (GFM) for the elemental education of Geospatial Technology.

Attributes are classified as spatial, temporal, thematic and location. The schema made in compliance with GFM is called an application schema. In case of the semester course, spatial attributes are limited up to two topological dimensions. It means that geometric primitives are point, curve and surface. But a coordinate can be three-dimensional. Temporal primitives are zero-dimensional instant and one-dimensional period. Thematic attributes are for example, character string, number, image and movie. Location is a place on the earth identifying indirectly.
Operation is a function to get characteristics of a feature processing by an application. It returns a result of operation by input attributes as arguments. Association is a connection between features. The strong association is called composition. “Strong” means if a feature is eliminated, connected features are also eliminated. As long as an association is a real world phenomenon, association is a feature.

2.3.2. Acquisition

Acquisition is a production process of spatial data, in other words a set of feature instances. This knowledge unit contains not only methods but also spatial and temporal reference systems and data quality. Actually the scope of this knowledge unit is huge. For example, paper map digitizing, ground survey, GPS survey, photogrammetry, remote sensing, hydrographical survey, geological survey, meteorological investigation are all acquisition technologies. However, it is impossible to teach them in the limited time. Thus the lecture is limited to paper map digitizing, spatial/temporal reference systems and data quality. Because, students can experience paper map digitizing rather easier than other acquisitions, and concepts of reference system and data quality are important for almost all acquisition process.

2.3.3. Management

Management, in this case, means the action to store, access, and transfer data files (e.g., a set of feature instances, application schema and metadata). Metadata is defined as "data about data" (ISO, 2003). The actual metadata used in clearinghouses is complicated as it was designed for general purpose. However for the fundamental education, we need at least what is it and how it works. Therefore, enough elements of metadata for basic education could be title, overview, responsible party, geographic extent, temporal extent and publication date.

2.3.4. Spatial Analysis

Huge variety of spatial analysis methods is developed for different research fields. Therefore, it is impossible for students to get whole image of spatial analysis in this course. We recommend learning the basic computational geometry, for example, showing below, because we presume computational geometry is the most fundamental knowledge of spatial analysis.

Centre – gravity centre, centroid
Algorithm to judge “point in polygon”
Distance – Euclid, Manhattan
Fundamental algorithm of the shortest path
Algorithm to judge “point in line buffer”
Introduction to Voronoi diagram
Introduction to 9 intersections
Allen’s temporal relationships

2.3.5. Representation

Representation is a process to make information from data. For example, map is information produced by visualization of geospatial data. People may find the meaning from maps but may not from geospatial data, as it is just a sequence of codes.
Structure of maps and portrayal schemas selected from the basic knowledge of Cartography are introduced in the lecture. A map consists of content (symbols and labels), title, subtitle, legends, scale, orientation, inset maps and illustrations, frames and neat lines, description of producer, resource, lineage and date of publication. Meanwhile, portrayal schema defines the structure of symbols and labels by using UML. Students will learn how to illustrate these elements on maps.

2.3.6. Exchange

Data exchange is defined as data transfer from one system to another. If the style of data management is different, then a sender encodes data from internal to standardized external format, and a receiver decode data to its own format. To achieve encode and decode, the rules to describe standardized data shall be required. ISO/TC211 and OGC standards adopt XML as a common rule. For example, a coordinate is defined by a sequence of number and dimension. It can be described as follows. Component is a sequence of coordinate elements, while dimension is a number of coordinate elements.

<Coordinate component="575.8,278.2" dimension="2"/>

We exchange spatial data but also application schema, metadata, portrayal schema, etc.

2.4. Syllabus

The author has got an opportunity to teach a semester course of Geospatial Technology at University of Tokyo from 2008 to 2010 (Ota et al., 2009). The topics and volume the students can learn during a half-year became clear through this experience. Table 1 shows topics for the course. As long as SDI is the means to assemble geographic information that describes the arrangement and attributes of features and phenomena on the Earth (National Research Council, 1993) and its overriding objective is to facilitate access to geographic information assets, modelling (the real world recognition and its formal description) and exchange, in other word data sharing are both important subjects in Geospatial Technology.

Table 1. Topics for semester course “Introduction to Spatial Technology”

<table>
<thead>
<tr>
<th>Classes</th>
<th>Topics</th>
<th>Knowledge Units</th>
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<tbody>
<tr>
<td>1. Introduction (Geospatial Technology and Society)</td>
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<td></td>
<td>· Maps and Images on the Web</td>
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<td>· Augmented reality in SF Movies/Animations and mobile-phones</td>
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<td>· Official geospatial applications and information sharing</td>
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<td></td>
<td>· Crisis mapping and disaster response</td>
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<td></td>
<td>· The definition of Geospatial Technology</td>
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<tr>
<td>2. Spatial Thinking and Modelling</td>
<td>Modelling</td>
<td></td>
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<tr>
<td></td>
<td>· Spatial thinking - cognition, reasoning and discovery</td>
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<td></td>
<td>· Cognition - equilibration and three mountain task by Jean Piaget, conceptual modelling</td>
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<td></td>
<td>· Spatial cognition - The Image of the City by Kevin Lynch, etc.</td>
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<td></td>
<td>· Reasoning - deduction, induction and abduction, the first law of geography by W. Tobler</td>
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<tr>
<td>3. Formal Description of Models</td>
<td>Modelling</td>
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<td></td>
<td>· Model and meta-model, and consensus making</td>
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<td></td>
<td>· The definition of a feature</td>
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<td></td>
<td>· UML as a schema language</td>
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</tbody>
</table>
3. GEOPACK

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- Class diagram and its notation

4. General Feature Model and Application Schema
  - General feature model
  - Application schema and its design process

5. Formal Description of Feature Instances
  - How to describe feature instance following application schema in XML

6. Spatial Schema
  - 2D geometric primitives - point, curve and surface
  - 2D geometric complex

8. Temporal Schema
  - Time in our dairy life
  - Temporal primitives
  - Feature succession as temporal association between features
  - How to describe "change" on attribute level and feature level

9. Reference Systems and Place
  - Spatial referencing by coordinate
  - Spatial referencing by geographic identifier
  - Temporal reference system - calendar and clock, ordinal time
  - Position, location and place

10. Coverage
    - Object view and field view
    - Coverage - point, curve, surface
    - Coverage - discrete, contiguous
    - Coverage schema and algorithm to get value at the given position

11. Spatial Data Acquisition
    - Spatial data acquisition and its process
    - Acquisition methods
    - Data product specification

12. Conformance and Quality
    - Conformance of application schema
    - Data quality - completeness, positional and temporal accuracy, logical consistency, and thematic accuracy

13. Spatial Data Management and Exchange
    - Metadata and clearinghouse
    - Encoding - application schema, spatial data, etc.

14. Spatial Analysis
    - Introduction to spatial analysis
    - Computational geometry as spatial analysis method

15. Representation
    - Separation of visual data from spatial data
    - Portrayal schema and portrayal dictionary
    - Map design
In this section, we introduce how the student will experience and learn through exercises. GeoPack is software as a teaching aid for exercises on Geospatial Technology. Each knowledge unit corresponds with each module of GeoPack as shown in Figure 2. The module "Application schema designer" corresponds with the knowledge unit "Modelling" and it allows the students to design the schema through definitions of feature types and association types. Students will be able to understand how people recognize the real world, what modelling means and how to describe schemas for his/her universe of discourse.

3.1. Modelling

Application Schema Designer is used to compose a formal conceptual model. Application schema has two components. One is Feature Type Designer and the other is Association Type Designer. People who share the universe of discourse should use the same application schema. In the exercise, students design application schema independently at first. Then, they will work to build consensus through the group discussion.

3.2. Acquisition

In GeoPack, data acquisition is realized as digitizing geometry on the base map, inputting texts and attaching photos and/or movies on a feature instance. The sequence of exercise for data acquisition will be as follows.
1) Prepare the base map for digitizing geometric attribute and texts, photos and/or, movies for thematic attributes of features.
2) Select the application schema on the Acquisition module.
3) Set parameters
   - Coordinate reference system and projection
   - Portrayal dictionary
4) Create feature instance, digitize geometry, and input or select temporal, thematic and location attributes
5) Store a “kit”, a set of feature instances, application schema, and default symbol dictionary.

![Acquisition Manager](a) ![Geometry Editor](b)

Figure 3. Acquisition Manager (a) and Geometry Editor (b)

### 3.3. Management

Data Management is the act of receiving, storing, accessing and sending data. In case of GepPack, we can manage spatial data using metadata. The sequence of exercise is as follows.

1) Describe metadata for the kit. Metadata elements for GeoPack are:
   - Title
   - Overview
   - Responsible party
   - Publication date
   - Geographic extent
   - Temporal extent
   - Keywords.

2) Find a kit through narrow down of metadata in the selected folder by restricting element values.
3) Update or analyze feature instances in the kit.

Kits are stored in the folder of user's PC, as GeoPack is desktop software. It means that this exercise is not the experience to use public clearinghouse or catalogue service. However, the student can understand how to manage and access the spatial data by using metadata.
3.4. Analysis

The operation defined during feature type design analyses the feature instance. The result of analysis is stored in the feature instance as an attribute value. For example, imagine spatial attributes “shape: SG_Surface”, “centerPosition:SG_Point” (SG means Spatial Geometry), and an operation “getCentroid (surface:SG_Surface):SG_Point” is declared in a feature type “Building”. The declaration “an argument surface responds to an attribute shape” allows “getCentroid” active. To push “run” button on the module, “getCentroid” will run using the shape of building and the result will be stored in “centerPosition”. Anyone will be able to add new operations, because we are planning to publish GeoPack as open source software.

3.5. Representation

This module will have sub-modules for designing symbols and labels, designing maps, displaying maps on the screen, and printing out on the paper. However, we realized only the symbol designer at the moment of writing this paper. The sequence of symbol design is as follows.
1) Design line symbol: Select colour, thickness, transparency, caps, joints and interpolation method
2) Design area symbol: Select filling pattern and borderline
3) Design point symbol: Set the size. Digitize lines and areas after selecting line symbol and area symbol

3.6. Exchange

This module simply encodes and decodes data. Target data are, application schema, symbol style schema, kit, and metadata. In GeoPack, interior data format is Action Message Format (AMF), because the program is written in ActionScript V3.0. The sequence of the typical exercise is as follows.
1) Encode a kit to XML document.
2) View the XML document on the text editor
3) Change an attribute value (for example, text, colour and coordinate value)
4) Decode the XML document into inner format
5) Confirm the change on the screen

4. FINAL REMARKS

We have a schedule to publish lecture slides and GeoPack around the end of 2012. However, GeoPack is still under-developing at the moment writing this paper, we need to add the consistency between lecture slides and GeoPack. We also need to add the manual of GeoPack.

5. ACKNOWLEDGEMENTS

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BIBLIOGRAPHY