DEVELOPMENT OF PROTOTYPE SYSTEM FOR THREE DIMENSIONAL GEOLOGIC MODELING BASED ON WEB-GIS

Shinji Masumoto[1], Susumu Nonogaki[1], Sarawut Ninsawat[2], Satomi Iwamura[1], Kenichi Sakurai[1], Venkatesh Raghavan[2], Tatsuya Nemoto[3] and Kiyoji Shiono[1]

[1]Department of Geosciences, Graduate School of Science, Osaka City University,
3-3-138 Sugimoto, Sumiyoshi-ku, Osaka 558-8585, Japan
Email: masumoto@sci.osaka-cu.ac.jp
[2]Graduate School for Creative Cities, Osaka City University
3-3-138 Sugimoto, Sumiyoshi-ku, Osaka 558-8585, Japan
Email: sarawut@ninsawat.com
[3]National Institute of Advanced Industrial Science and Technology
Tsukuba Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan
Email: nemoto-tatsuya@aist.go.jp

ABSTRACT

The purpose of the present study is to develop a three dimensional geologic modeling system on Web-GIS for sharing, integrating, processing, and disseminating geologic information. The prototype system has been developed to perform acquisition of the field survey data, construction of the models, and visualization of the results on Web.

The base system is constructed by the integration of Web-GIS Engine, GIS and relational database to support for WPS (Web Processing Service), WMS (Web Map Service), and WFS (Web Feature Service) using the typical FOSS4G (Free and Open Source Software for Geoinformatics) products such as MapServer, GRASS and PostgreSQL. The main system of the geologic modeling is composed by nine functional modules as follows: 1. Data acquisition module, 2. stratigraphic correlation module, 3.classify and arrange module, 4. logical modeling module, 5. surface estimation module, 6. geologic function module, 7. database management module, 8. visualization module, and 9. standardization module.

1. INTRODUCTION

Recently there are many problems such as environmental pollution, mitigation and prevention of natural disasters and geological disposal of radioactive wastes, etc., which should be carefully considered using geologic information. For the solution of these problems, it is necessary to provide the geologic information accurately and effectively.

The geologic maps and three dimensional geologic models are the geologic information generated as a result of geological analysis based on the fundamental field data and the knowledge of the geologist. But the quantity and quality of the basic data, theory and assumption of geological process are not known for the user of geologic maps or models. Therefore, it is important to actively provide the following information in addition to the geologic maps and models.

1. Basic data (field survey data, borehole data, topographical data, etc.).
2. Logical model (sequence, stratigraphy, structure, assumption, etc.).
3. Geological mapping and modeling process.

The above information enable user to evaluate accuracy, resolution and reliability of the geologic maps and models.

The providing of these information can be realized by the construction of geological model as the logical model. For this purpose, the basic theory for three dimensional modeling has been developed (Shiono *et al*. 1994, Shiono *et al*., 1998). The methodology and algorithms implemented for visualization of geologic model have been developed using the Open Source GRASS GIS environment (Masumoto *et al*., 1997, Masumoto *et al*., 2004). Further, with the aim of providing an easy to use interface and also to provide remote access possibly from field sites, an online Spatial Information System for Geologic Modeling (SISGeM) incorporating the algorithms and methods used in the standalone system has been developed (Raghavan *et al*., 2000, Nemoto *et al*., 2003). However, the SISGeM is unable to perform the function for sharing and distributed processing of the GIS information due to the lack of interoperability of main system.

The Geo-Processing Service on the Web-GIS became possible through the development of theory and techniques. In this paper, we have developed the prototype Web-GIS system for three dimensional geologic modeling to perform acquisition of the field survey data, construction of the models and visualization of the results.

2. SYSTEM CONFIGURATION AND FUNCTION

The three dimensional geologic modeling system has been constructed from Web-GIS base system and the functional modules.

2.1 Base system

The base system is constructed by the integration of Web-GIS engine, Web-GIS client, GIS and relational database to support the function for WMS (Web Mapping Service), WFS (Web Feature Service), and WPS (Web Processing Service) using the typical FOSS4G (Free and Open Source Software for Geoinformatics) products (Ninsawat *et al*., 2008). The software configuration of this base system is shown in Table 1. These software systems except OS and Database are supported by OSGeo (The Open Source Geospatial) Foundation.

Table 1. Software configuration of the base system.

Software System		Download Site of Software
Operating System	Mandriva Linux	http://www.mandriva.com/
Mapping Engine	MapServer	http://mapserver.gis.umn.edu/
Web-GIS Client	OpenLayers	http://openlayers.org/
GIS	GRASS GIS	http://grass.osgeo.org/
DataBase	PostgreSQL/PostGIS	http://www.postgresql.org/
Tools/Library	GDAL/OGR	http://www.gdal.org/

2.2 Modules for geologic modeling

The main system of the geologic modeling is composed of six function modules ranging from the field survey input data to the construction of three dimensional models. In addition to these modules, there are three function modules that enable sharing, providing and visualizing of all the data in standard format of Web and Web-GIS. Figure 1 shows the relationship of the nine modules and the data flow of the system. The outlines of these functional modules are as follows.

Data acquisition module

This module imports various basic data files such as the filed survey data, the borehole data, and the elevation data from offline or online database into the relational database of the system.

Stratigraphic correlation module

This module supports stratigraphic correlation of the geologic data establishing the stratigraphic classification and geologic structure on Web-GIS. The result of the correlation and the established stratigraphy are stored into the database. During this time, the module focuses on the borehole data and there is a limit to the data type that can be handled on the Web (Sakurai *et al*., 2008).

Classify and arrange module

This module performs the classification and arrangement of the basic data according to the established stratigraphy using inference engine. Also, this module checks the consistency of the results logically and generates the location data and the event sequence (Iwamura *et al*., 2008).

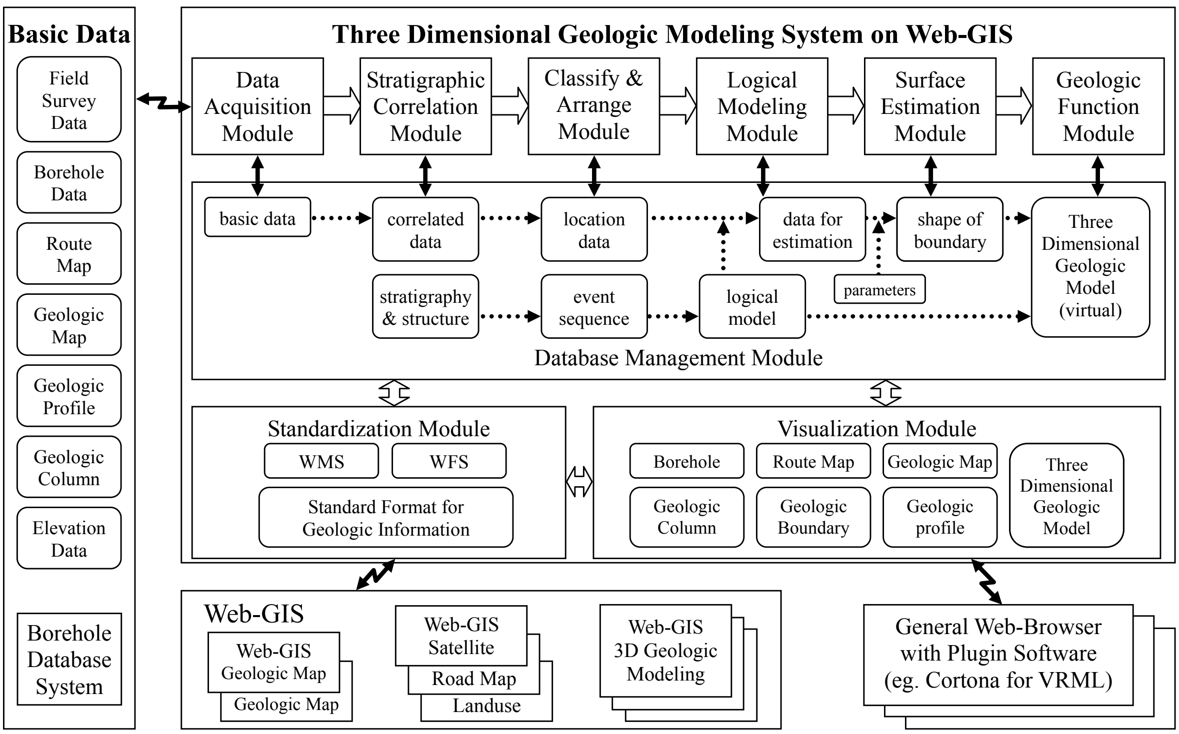

Figure 1. The relationships of the modules and the data flow of the three dimensional geologic modeling system on Web-GIS.

Logical modeling module

This module creates the logical model of geologic structure and arranges the data set for the estimation of the geologic boundary. The logical model showing the hierarchical relationship between the boundary surfaces and geologic units can be automatically generated based on the event sequence and knowledge of geologic structures.

Surface estimation module

This module generates the geologic boundary surfaces estimated from the data set arranged by the logical modeling module using bi-cubic spline function. These surfaces including the parameter for estimation are store in the database (Nonogaki et al., 2008).

Geologic function module

This module defines the geologic function that expresses the rule to assign the unique geologic unit to every point in the objective three dimensional space. Three dimensional geologic models are constructed virtually by implementing the geologic function from the boundary surfaces of geologic units and the logical model of geologic structure.

Database management module

This module manages all data of the database stored by the modules for geologic modeling. The basic data, the results of stratigraphic correlation, the event sequence, the logical model of geologic structure, estimated surface, and the parameter of estimation can be queried and updated according to demand from the modules.

Visualization module

This module exports the data and the model to the visualizing format in two or three dimension. For three dimensional visualization, X3D (eXtensible 3D; formerly known as VRML (Virtual Reality Modeling Language) next generation) format is used for Web plug-in viewer (e.g.: SwirlX3D for X3D, Cortna for VRML), and GRASS format is as an auxiliary method for NVIZ visualization tool of GRASS.

Standardization module

This module transfers the data and the elements of the model to standard format of Web-GIS. WMS and WFS define the (raster) images and the vector features by the Open Geospatial Consortium (OGC). These standards can be used for the geologic elements. But, there is no standardized format for geologic model. In the near feature, it is necessary to define the world standard format for sharing and practical use of geologic model information.

Figure 2 shows the example image of the stratigraphic correlation module. The visualization examples of the three dimensional geologic model and the borehole data using GRASS GIS and X3D (VRML) are shown in Figure 3 and Figure 4 respectively.

3. CONCLUSIONS

This System can, not only share and provide general geographical information (road network, digital elevation model, and satellite image, etc.) but also basic information for geologic modeling using WMS and WFS function can be obtained. Further, the system can process large area virtual model can be constructed by combining several smaller geologic models in different field localities.

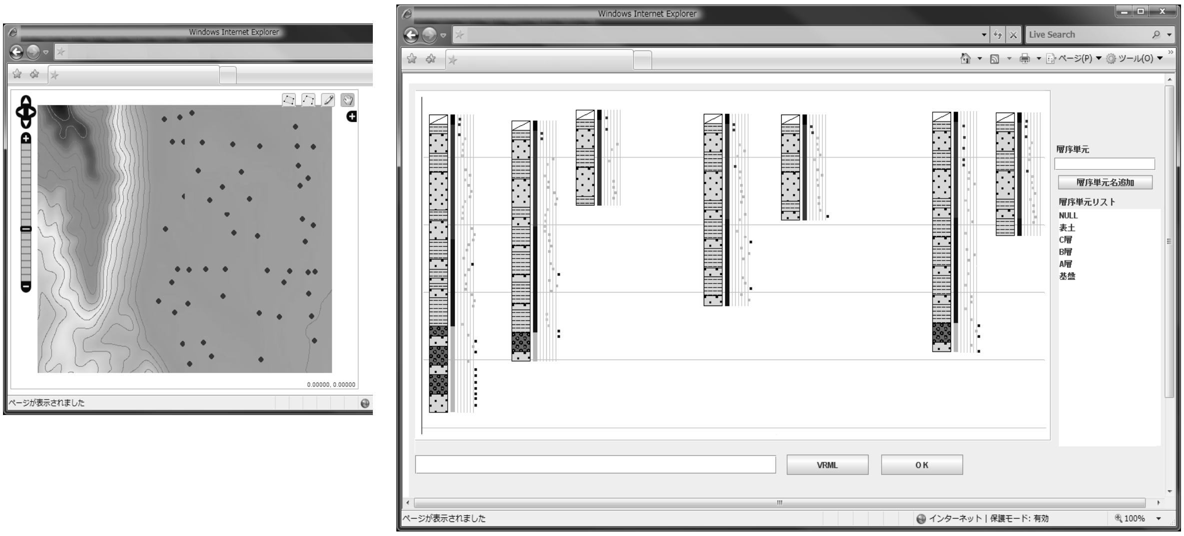

Figure 2. Example images of the stratigraphic correlation module.

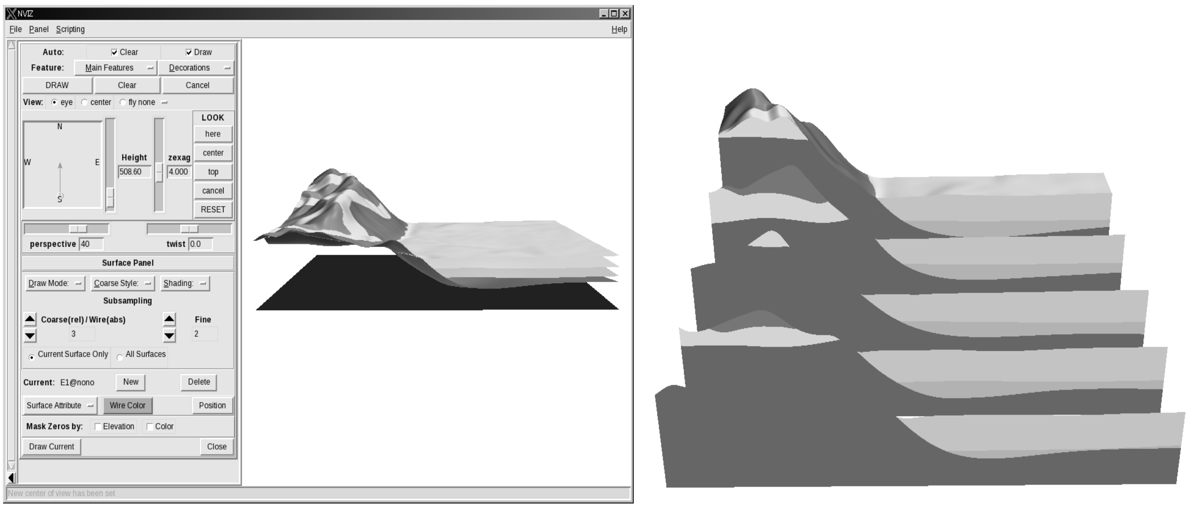

Figure 3. The examples of the three dimensional geologic model using NVIZ of GRASS.

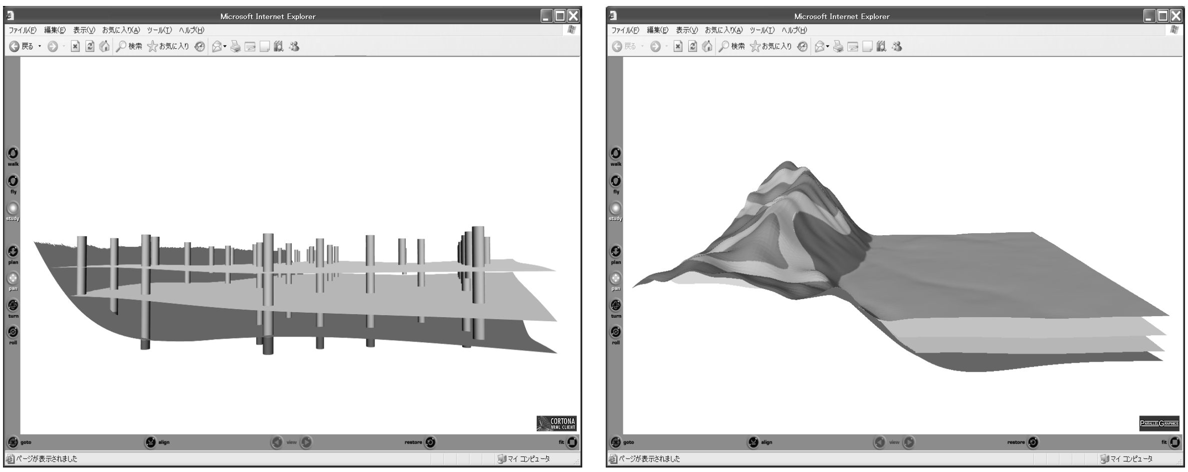

Figure 4. The examples of the borehole data and the three dimensional geologic model using X3D (VRML).

Presently, the system of three dimensional geologic modeling is almost complete at least theoretically and is in the improvement stage for practical application. On the other hand, some new idea (theory, algorithm and technique) related with three dimensional geologic modeling have been developed. The mathematical expression of geologic boundary based on the neighborhood function (Nemoto *et al*., 2005) and an algorithm for extraction of geomorphological characteristics based on a mathematical function derived from BS-Horizon (Nonogaki *et al*., 2008) are examples of new algorithm that a vastly different from the conventional method. In the future, it is necessary to investigate a new generation theory of geologic modeling incorporating these algorithms and mathematical expressions.

4. ACKNOWLEDGEMENT

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