

DEVELOPMENT OF AN ONLINE SYSTEM FOR 3D GEOLOGIC MODELING

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ABSTRACT

We have developed a prototype Spatial Information System for Geologic Modeling (SISGeM). SISGeM has been successfully implemented by integrating the GIS and relational database management system (RDBMS) with the Internet. The spatial data management is carried out using Geographic Resource Analysis Support System (GRASS) GIS. Online access to GRASS functions has been enabled using the basic framework of GRASSLinks interface. Several additional modules were incorporated into web interface to tailor the system for its present needs. RDBMS manage data that is recorded in a field outcrop or derived by digitizing hardcopy geologic maps. The system is capable of managing geologic data, generating 3D geologic models and visualizing horizontal sections at user-defined depths.

1. INTRODUCTION

GIS can be readily used to manage and analyze 2D information and also afford 3D visualization of surface features. However, general-purpose GIS packages do not offer capabilities for constructing or visualizing 3D geologic models. GIS tools must, therefore, be appropriately tailored to handle geologic data and accommodate the special spatial analysis needs of geologic information. Since 3D geologic information consists of both spatial and relational components, integration of GIS and RDBMS into a common environment is necessary to facilitate efficient handling of geologic data. Further, the fact being that both GIS and RDBMS tools require specialized training, it is desirable that a user-friendly interface that hides the underlying complexities of GIS and RDBMS is also designed.

We have developed a prototype Spatial Information System for Geologic Modeling (SISGeM). SISGeM has been successfully implemented by integrating GIS and RDBMS with Internet. The system is capable of generating 3D geologic models using data that is recorded in a field outcrop or derived by digitizing hardcopy geologic maps and visualizing horizontal sections at user-defined depths. In this study, we present functions of SISGeM and an example of generating 3D geologic model using actual geologic data derived from geological survey.

2. SYSTEM REQUIREMENT

SISGeM was implemented on a personal computer based Web server environment. Linux was selected as the development environment but the system can be implemented on any UNIX platform. An outline of the system is shown in Figure 1. All of software components used for implementing the system is available as free packages that can be downloaded over the Internet.

A GIS provides the core component for visualization, analysis and management of spatial data sets. The Geographic Resource Analysis Support System (GRASS; Byars and Clamons, 1997) was used to serve as the GIS environment. GRASS GIS was originally developed at the US Army, Construction Engineering Research Laboratory, but recently the development is coordinated by the GRASS Development Team (Refer GRASS URL for details). Online access to GRASS functions has been enabled using the basic framework of GRASSLinks interface (Huse, 1995). Several additional modules were incorporated into web interface to tailor the system for its present needs.

GRASS; <http://wgrass.media.osaka-cu.ac.jp/grassh/index2.html>

GRASSLinks; <http://www.regis.berkeley.edu/sue/phd/>

A Relational DataBase Management System (RDBMS) was used to manage data that is recorded in a field outcrop or derived by digitizing hardcopy geologic maps. The PostgreSQL RDBMS which is supported under GRASS was used. The front-end for online access to the RDBMS was coded using the Hypertext Preprocessor (PHP).

PostgreSQL; <http://www.postgres.org/>

PHP; <http://www.php.net/>

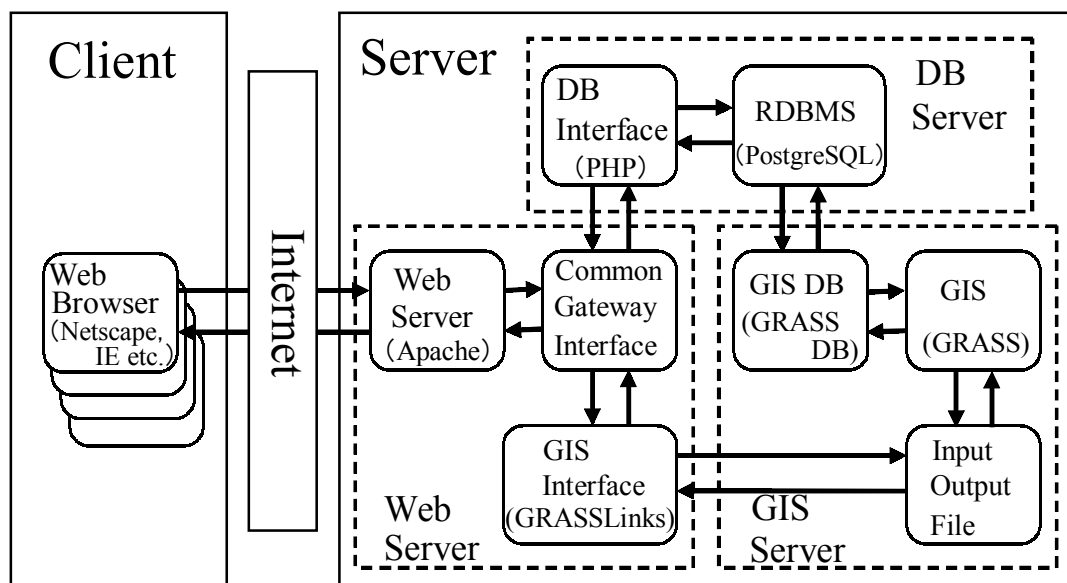


Figure 1. An outline of the system.

3. DATA PREPARATION

In order to demonstrate the working of the SISGeM, we have selected test area (425×600m) in Kishiwada district of Osaka prefecture, Western Japan (Fig. 2). The area consists of Cretaceous sediments. Each sediment has a conformity relationships with its surroundings.

Data requirements for generating 3D geologic model using the SISGeM include geologic data (coordinates, geologic unit and strike-dip) and Digital Elevation Model (DEM). The geologic data was derived from geological survey. Geologic data of 102 points including 14 strike-dip records were utilized. DEM data of 2.5m grid-size estimated by utilizing of inter-contour information of the topographic maps (Noumi *et al.*, 1999) was used (Fig. 3). DEM was incorporated into the GRASS database georeferenced on UTM coordinate system.

4. GENERATING 3D GEOLOGIC MODELS

In SISGeM, a process of generating 3D geologic model is based on Masumoto *et al.* (1999). The actual estimation of geologic boundary surfaces is done using the “Horizon2000” program (Shiono *et al.*, 2001). “Horizon2000” has been included as an independent routine into the SISGeM. The generation of input data for “Horizon2000” is facilitated by creating two RDBMS tables. For the sake of clarity, we refer to these tables as “Geodata” and “Relation” respectively. A record of “Geodata” table stores the spatial coordinates (x, y and Elevation), name of the geologic unit, and strike-dip values (trend and dip angle) corresponding to the spatial location. The “Relation” table is a matrix denoting the relationship between geologic bodies and geologic surfaces that define the geologic unit. “Relation” table of the test area is shown in Table 1. “+1” and “-1” mean space that lie above and below the surface respectively, and “0” means no specific relation with the surface. For example, a body b_2 that lies above surface S_1 , below surface S_2 and S_4 , and has no direct relation with surface S_3 is expressed in Table 1.

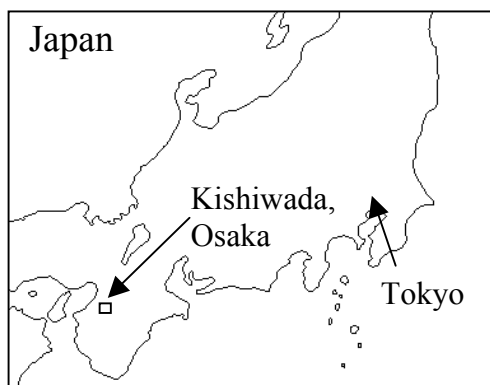


Figure 2. Location map.

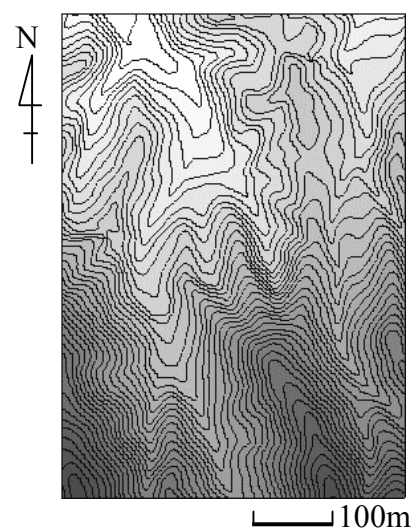


Figure 3. Digital Elevation Model.

Table 1. “Relation” table.

	Surface S_1	Surface S_2	Surface S_3	Surface S_4
Body b_1	-1	0	0	-1
Body b_2	+1	-1	0	-1
Body b_3	+1	+1	-1	-1
Body b_4	+1	+1	+1	-1
α (air)	0	0	0	+1

Similarly, the relationships for other geologic bodies can also be defined. The data for populating “Relation” table is derived from the knowledge of stratigraphy of a given area.

Having incorporated DEM into the GRASS database and defined the structure for the RDBMS tables, subsequent operations can be performed online using the various functions available in SISGeM. Various options that can be selected from the SISGeM’s menu page are listed below.

- Input data option allows the user to input geologic data using a “clickable” basemap.
- Reclass option can be used to interactively reduce or combine the categories that are available in the original geologic map. This is useful when the user just wishes to experiment by combining different categories.
- Upload option allows the user to populate the RDBMS “Geodata” table after inputting geologic data.
- Define Relation option can be used for populating the RDBMS “Relation” table so as to define the relationships between geologic bodies and boundary surfaces.
- Extract data option prepares the input file for the “Horizon2000” program by extracting data from the “Geodata” and “Relation” tables.
- Create Surface option is used to actually execute the “Horizon2000” program and create the geologic surfaces.
- Interpolate Surface option is used to generate finer resolution raster image from a coarse resolution input data. A grid-to-grid interpolation is performed using a bi-cubic spline function. The present version of the “Horizon2000” that is used in SISGeM is a memory and CPU intensive routine, therefore, its ability to process large arrays of data is limited. The solution that we have adopted is to use “Horizon2000” to create surfaces of relatively coarser resolution. This trade-off of between resolution and processing time is balanced by applying the grid-to-grid interpolation to produce raster image of a finer resolution so as to enable better visualization.

- Horizontal Section option can be used for generating an image depicting disposition of geologic units at user-defined depths.
- Display option can be used to visualize raster layers in 2D. Vector and site data can also be superimposed over the raster maps.
- Ftp option can be used for downloading the files generated by the user via Ftp (File transfer protocol). Recently, SISGeM does not offer online access to the NVIZ visualization tool that is useful for generating vertical sections or animated sequences. Relevant data needs be downloaded using this option and NVIZ must be executed locally on the client machine.

Surface geologic map and horizontal section generated by SISGeM are shown in Figs. 4 and 5 respectively. Examples of vertical sections drawn using NVIZ are presented in Fig. 6.

5. CONCLUSIONS

SISGeM, an online system for 3D geologic modeling has been developed. The system has been successfully implemented by integrating the GIS and RDBMS with the Internet. It is capable of generating 3D geologic model using data that is recorded in a field outcrop or derived by digitizing hardcopy geologic maps and visualizing horizontal sections at user-defined depths.

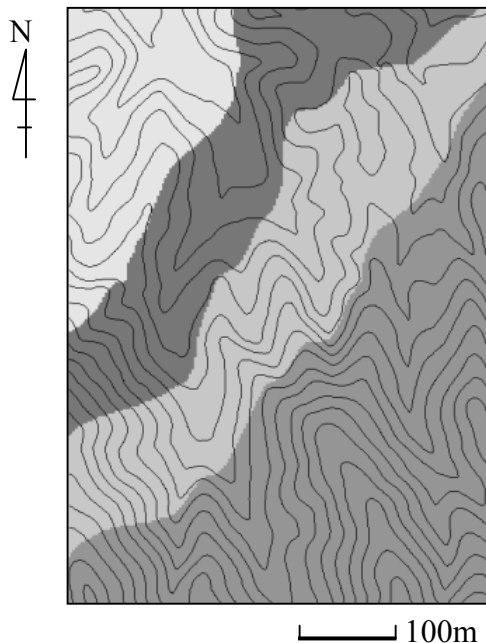


Figure 4. Surface geologic map.

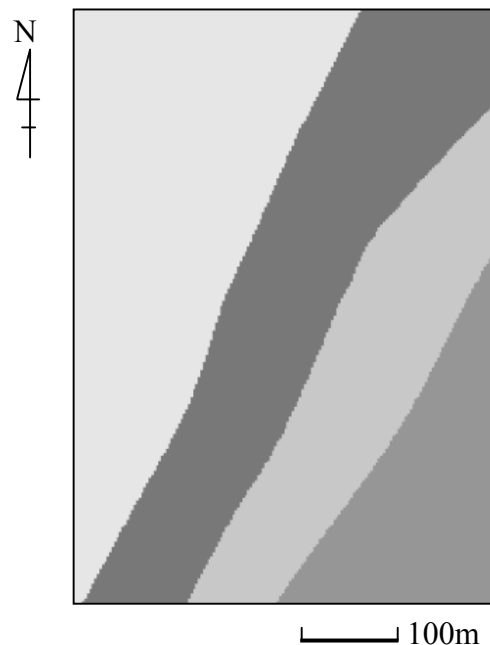


Figure 5. Horizontal sections (200m).

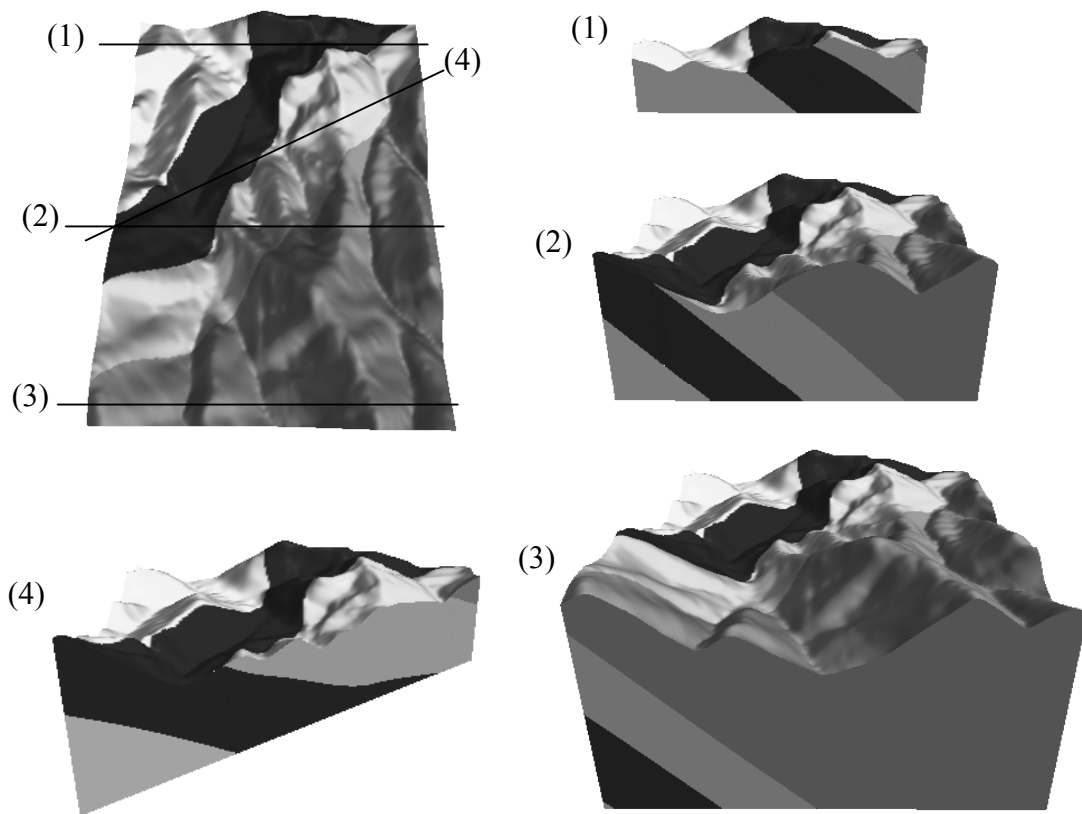


Figure 6. Examples of vertical sections drawn using NVIZ.

6. REFERENCES

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