Development of Visualization Tool for Geologic Information on GRASS GIS

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ABSTRACT

Generally, geological maps on Geographic Information Systems (GIS) are intended for use both by geoscience professionals and general public. The geological map contains graphical elements such as line symbols, point symbols, and colored or patterned areas to represent geological information such as the dip and strike of a strata, fault, axis of fold, as well as the geometry, orientation and character of the geological structures that have deformed them. On the other hand, the three dimensional geological information such as borehole data is also necessary for geological mapping. However, it is difficult to express many symbols of the geological map and borehole data in general purpose GIS.

The present paper discusses the implementation of 3D visualization and geological map symbology in the Open Source GRASS GIS environment.

1 INTRODUCTION

The geological maps are drawn as a result of estimation of the three-dimensional distribution of the geological units based on the relationship and structure of each geologic layers derived from the field observation data. As for the geological map, relation of geology is more important than the geologic units distribution. Various information were expressed in the geological map of paper sheet, so that it can be read as four-dimensional geologic information such as the geological history, three-dimensional structure and relationship of the geologic units.

Recently, geological maps and other digital information related to earthscience have come to be used widely in GIS for disaster reduction, the exploration of the mineral resources and the assessment of the environment. There are many kinds of geological maps such as the geology distribution maps, the geological structural maps and hazard maps. It is necessary to express geologic attribute, symbols, and so on with the distribution of the geology units and the location of faults in these geologic maps. GIS visualization tools that can express various geological information are also necessary for these geological maps.

Some proprietary GIS and software tools exclusive meant for a geological data, support use of geological rendering symbols and three dimensional visualization. But, there was no such function in GRASS which is the most popular free and open source GIS. The newly developed GRASS tools in the present research can display some geological attribute symbols. Further, this developed program can visualize three-dimensional borehole data using Nviz environment.

2 GEOLOGIC MAP SYMBOLS

2.1 Geologic features and symbols

The geological map contains graphical elements such as line symbols, point symbols, and colored or patterned areas to represent geological information. There are many geological features that require to be expressed as symbols in a geological map. They are as follows;

Contacts: Conformable contact, Unconformable contact.

Faults: Normal fault, Reverse fault, Strike-slip fault, Oblique-slip fault, Thrust fault, Lineament, Joint.

Folds: Anticline, Syncline, Antiform, Synform, Flexure, Monocline.

Bedding: Inclined (Strike and dip), Horizontal, Vertical, Cleavage, Foliation, Lineation, Landslide features, Natural resources, and Geohydrologic features.

These geological symbols can be classified into 4 types according to the data format and drawing algorithm.

Type 1. Symmetric line symbol element

These line symbol elements do not have to distinguish the left or the right of a line. These elements included the axis of surfaces such as fold axis. The vector data of line and the code corresponding to the geologic feature are required to express using GIS environment.

Type 2. Asymmetric line symbol element

These line symbol elements have to distinguish the left and the right of line. These line elements include the axis of surfaces such as flexure axis. The identified information of right and left of the line element is necessary, as well as the data of Type 1 above.

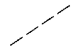
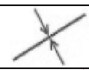
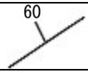
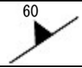
Type 3. Directional point symbol element

These point symbol elements have to express the direction of the surface or the line. The vector point data of the site, the code corresponding to the geological feature and the direction data of the geological trend are required.

Type 4. Non-directional point symbol element

These point symbol elements have to express the only point of the geological element. The vector point data of the site and the code corresponding to the geological feature are required.

Table 1. Examples of symbol for geologic feature.

Types	Geologic features	Line elements	Symbols
1	Fault	Estimated fault line (unspecified sense of slip)	
	Fold	Anticline axis	
	Fold	Syncline axis	
2	Fault	Normal fault line	
	Fold	Flexure axis	
	Landslide	Head or main scarp of landslide	
3	Bedding	Inclined bedding (showing strike and dip)	
	Foliation	Inclined Metamorphic Foliation	
	Lineation	Inclined lineation (showing bearing and plunge)	
4	Natural Resource	Mining and Mineral exploration	
	Natural Resource	Oil and Gas well	
	Geohydrologic	Spring	

The levels of confidence and location accuracy are shown by the line pattern, line width and color of symbols. The following examples show the level of location accuracy of contact of geological units (FDGC, 2006).

———————— Identity and existence certain, location accurate.

— — — — — — Identity and existence certain, location approximate.

– – – – – – – – – – Identity and existence certain, location inferred.

------------------ Identity and existence certain, location concealed.

Also, the line patterns are used for identification of the activity (e.g. active fault, inactive fault and general).

2.2 Data set of geologic map symbols

Current vector data structure of GIS can be used for expression of the Type 1 and 4 geological elements. Because the present information of GIS is insufficient for the Type 2 and 3, new definition of data or additional new data format is necessary. The sense of deformation or movement can be defined by directionality of the line for the Type 2. For example, in the case of normal fault, the footwall belongs to the right side of a line direction from initial to terminal point. For the Type 3 geological elements, it is necessary to express the attitude (or orientation) of the surface (or lineation) at the outcrop. There is no standard format to define these data. For example, in the case of bedding, there are several standard methods of reporting strikes (e.g. degrees from north to clockwise: 120° or degrees from north to west or east: N30°E). It is easy to convert one to the other, but a program is required to define the standard format.

2.3 Command for geologic symbols

The following new display commands of GRASS GIS have been developed to present the geologic feature elements. The development of digital symbol patterns for *d.vect* command is necessary instead of new commands for the Type 4 geological elements. Examples of these commands are shown in Figure 1.

d.geologic.1: Vector line display command for the Type 1 geological elements.
Parameters: map(= vector layer file name), legend(= color table file name), size(= size of symbol), interval(= interval of symbol).

d.geologic.2: Vector line display command for the Type 2.

d.geologic.3: Vector point display command for the Type 4.

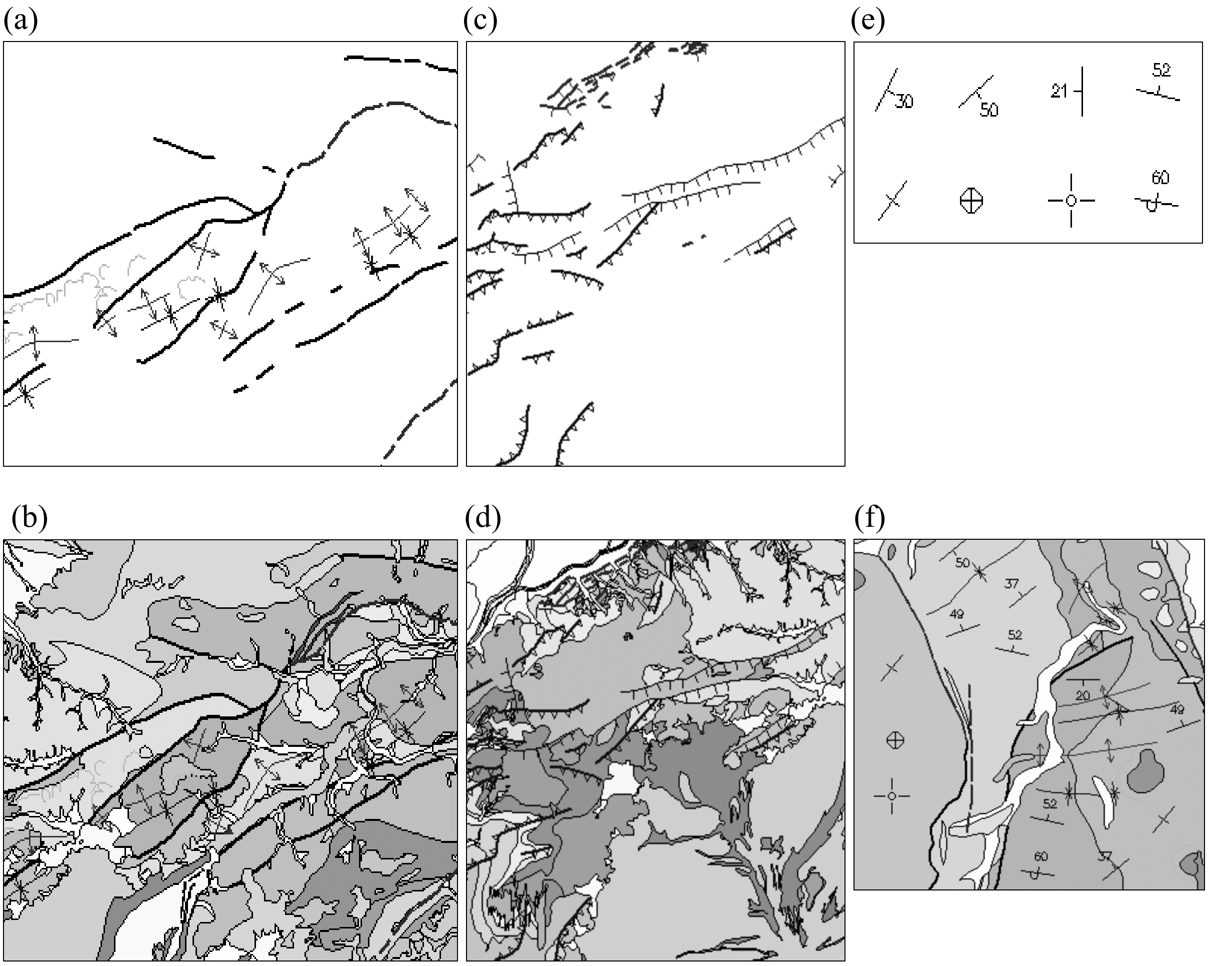


Figure 1. Examples of geologic features using developed new command of GRASS. (a) symmetric line symbol (Type 1), (b) geologic map of Type 1, (c) asymmetric line symbol (Type 2), (d) geologic map of Type 2, (e) directional point symbol (Type 3) and (f) geologic map of Type 3.

3 THREE DIMENSIONAL VISUALIZATON OF BOREHOLE DATA

The geological tools for Nviz of GRASS have been developed for three dimensional visualization of borehole information. The borehole data were converted to vector segment data according to the geological feature using the developed programs. The borehole data can be expressed to line or columnar form of Nviz. The example of three dimensional borehole images is demonstrated in Figure 2. The surfaces displayed in Figure 2 were estimated by the surface interpolation program (Nonogaki *et al.*, 2006) which can create high-density surface (DEM) using various geological information.

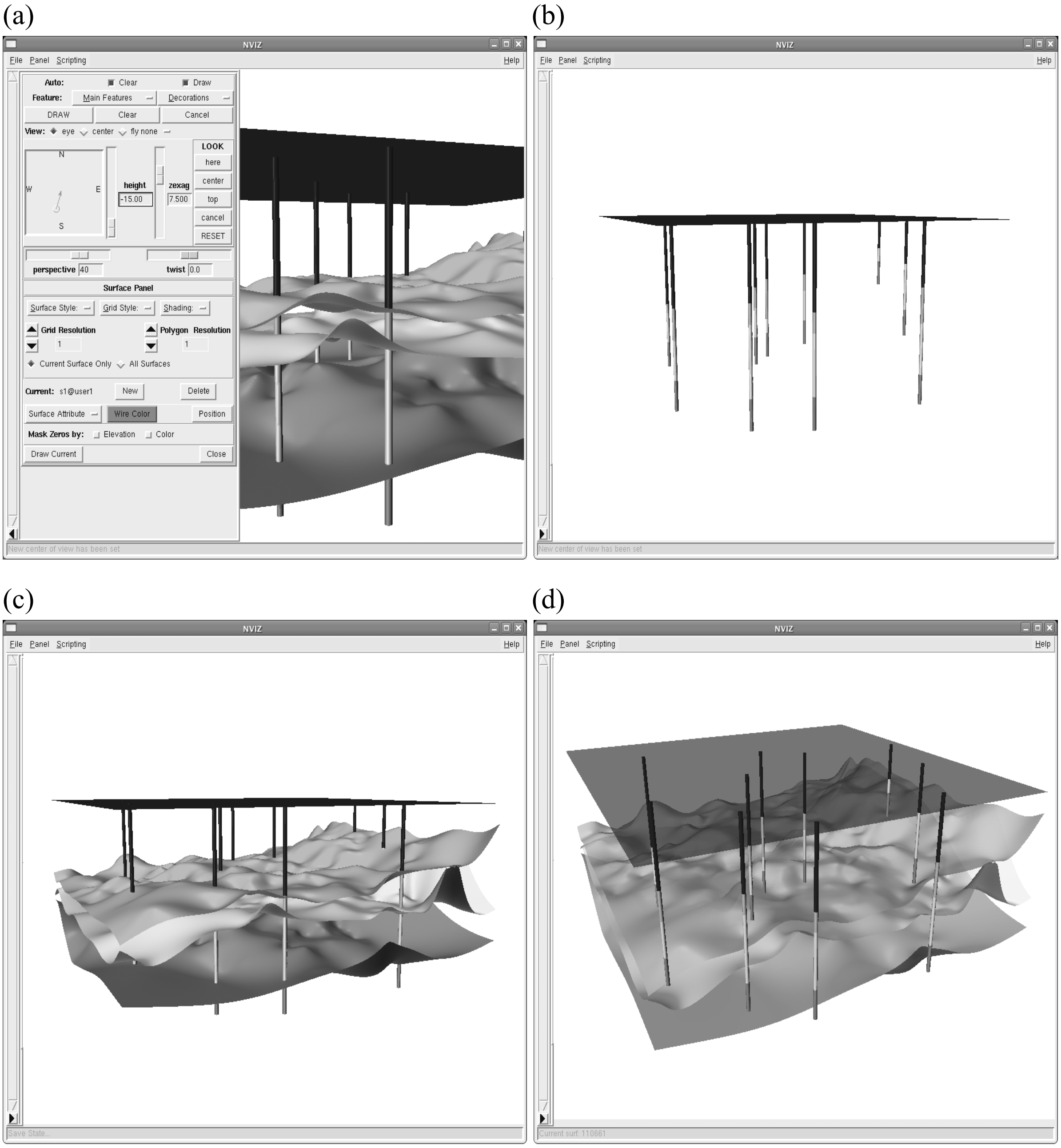


Figure 2. Example images of borehole data using Nviz of GRASS. (a) Control panel and surface panel of Nviz, (b) borehole images in columnar form, (c) borehole images with estimated geologic surfaces and (d) borehole images with high transparency surface.

4 CONCLUSIONS

The visualization tools for geological information are still in the making. The geological symbols and definition of geological features are slightly different in every country. Development of symbols and adjusting database corresponding to each country are necessary in the next step.

GRASS6 will be able to handle the three dimensional vector data (Neteler and Mitasova, 2002) and make it possible to display geological features more effectively. Three dimensional geological modeling using GRASS has already been discussed in our previous work (Masumoto *et al.*, 2004). In the future, all geological elements from field observation to three dimensional modeling can be processed on GRASS GIS.

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