3-D Visualization of complicated rock in hydropower Engineering

Honghu Wei[1],Jianfeng Wang[2] and Wei Yang [3]

[1]the College of Architecture Engineering, Beijing University of Technology
100 Pingleyuan, Beijing 100022
Tel: +86-10-67391650
Fax: +86-10-67392772
Email:whh888@bjut.edu.cn
[2]Institute of Mechanics, Chinese Academy of Sciences
15# Zhongguancun Road,Haidian,Beijing 100080
Tel:+86-10-62537649
Email:JFWang@sina.com.cn
[3]Linfen Water Resource Bureau
2# Shuita Road, Linfen 041000,Shanxi
Tel:+86-357-2685391

Abstract

Folds,faults and soft layers are main constructions which influens strongly rock's mechanics and the safety of hydropower engineering construction. More higher accurate techniques of 3-D visualization techniques will be needed in hydropower enginnering to describe the statra and constuctures. Basing on Gemcom's production of 3-D visualization,The paper analyzes a method with many mutual functions to realize figuring of spa tial distribution and crossing of structures and constructures.

Discussions are made for constructing complicated structures such as faults, folds(expecially for upturn folds) and thin soft layers. And finally the technique is applied for 3-D modeling of geological bodies in actual hydropower engineerings.

The paper puts forward some techniques for modeling complicated structures and constructions with the help of Gemcom Desktop Edition. The application of the techniques will be more significent to the 3-D visualization of hydropower engineering.

1. Introduction

Hydropower development is very important for a country rich of waterpower resources. The plan of a hydropower engineering should be carried out under the complete understanding of geological conditions. Though engineering prospecting is the main means of obtaining geologica l information, effective measure should be adopted to process and display the information in order to understand fully the distribution in space of rock structures, and 3-D visualization is the mainmethod. 3-D visualization of rock structures and constructures is an effective way to realize figuring of space distribution, mutual restriction and crossing of rock structures and constructures.

Underground media consists of neither a series of surfaces, profiles or block, nor continous bodies. Every geological unit is an irregular block with distinctive characteristic. Noncontinuities usually occur at the boundaries and will be much complicated by the action of foldings,faulting and weathering. In addition,soft layers will make change largely of rock's mechanical qualities(for example rock stress and elastic modules). Although soft layers are usually thin(maybe less than $n \times 10cm$), they can weaken rock's shear strength, this would affect extremely the safety of hydropower engineering. These thin layers must be modeled accurately in space. Therefore more higher accuracy of 3-D visualization techniques will be needed in hydropower enginnering to figure the rock structures in hydropower engineering than in other large scale rock engineerings.

There are several methods in use of 3-D visualizations for underground rock mass at present. Basing on specified algorithms and functions,the techniques describe the space distribution of structures and constructures [1-5]. It is difficult to model completely the structures in terms of functional relation. Some method with more interaction functions is needed for modeling the complicated constructions.

Basing on the Gemcom Desktop Edition, a product of Gemcom Software International Inc. with many intersecting functions, the paper analyzes the technique of modeling complex geological constructures such as fault, folds(Particularly for upturn folds) and thin weak layers.Finally the technique is applied for 3-D modeling of geological bodies and constructures in actual hydropower project. The result of application shows that it is more easier and more accurate to model complicated constructures with this technique than with other products.

2. 3-D spatial data management

2.1 Digitization of geological information

There are two kinds of 3-D interface data available for an underground engineering: one is the engineering geological section diagrams,and the other is digitalized geological section in CAD. As to the geological section diagram, it is converted to image firstly by means of scanning , and then the image is digitalized to sector information with CAD or other utilities. Direct collection can be adopted to pick up layer boundary lines from a CAD's geological section. With this means all information relative to strata and constructures can be obtained to form a vector section.

2.2 Vector Section transformed to space distribution

The vector information obtained by digitalizing has only 2D coodinates, and it has to be transformed into 3-D messages before it can be used for modeling.The transformation can be done with the coodinates of the two ends of the section line and the distance from the beginning end of the section to the sampling point. Specific colour property is endowed to every interface boundary line to distinguish from other lines. All of the sections' interface lines are put together to form the space information of the strata and constructures(shown in Figure 1),which can be used to generate the geological and constructural models.

3． 3-D Modeling of Complex constructures

3.1 Fault modeling

The crustal movement intensely causes the cracks of the strata. The strata along the two sides of the fault plane move reversely, which results in incontinuity of strata interfaces. When crushed the fault still has thickness. It is very dificult to express in a computer this kind of complex structure with ordinary functional relation, unless with strong iteraction function.

Figure1 space distribution of strata interface lines

It can be divided into several steps to model a fault：

(1) Fabricating strata boundary line to keep the lines continous along the two sides of the fault

First extract all the lines that belong to some strata interface, and it can be seen that the lines of the two sides of the fault are discontinous because of the malposition of the upper and lower walls of the fault(shown in Figure 2). Some lines are fabricated to keep the lines continous along the fault(Shown in Figure 3).

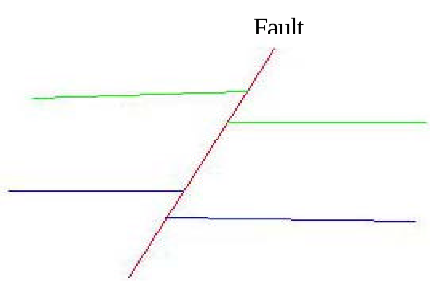

Fig.2 Model of Fault

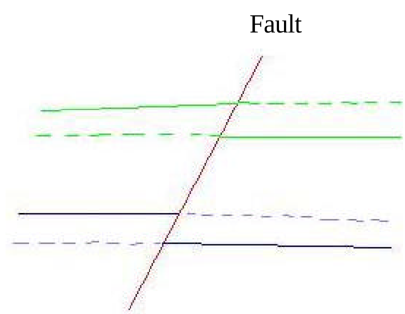

Figure 3 actual and fabricated interface lines

(2) Generating grid surface of some interface

Because of the fabricated lines, there are four surfaces, namely S_1, S_2, S_3 and S_4, needed to be generated for each stratum, each surface consists of two parts: one is actual and the other is fabricated. The right parts of S_1 and S_2 and the left parts of S_3 and S_4 are fabricated(shown as in Figure 3). The aim to do so is to keep the sharp change of interface along the two sides of the fault.

(3) Generating strata

Gemcom Desktop Edition supplies the function of generating a volume with two unintersected interfaces. With this function two volumes, namely V_1 and V_2, are needed to be generated for each strata: one generated with S_1 and S_2, and the other with S_3 and S_4.

(4) Intersecting and compounding of volumes

First of all intersecting V_1 into two parts with generated surface and the left wing of the stratum can be obtained by discarding the right wing. Similarly the right part of V_2 is kept by intersecting V_2 with the fault surface and discarding the left part of V_2. Finally the strata along with the two sides of the fault can be obtained by compounding the two parts left(shown in Figure 4)

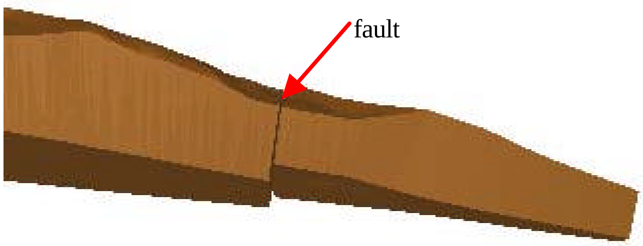

Figure 4 strata along both sides of a fault

3.2 Modeling of upturn folds

Upturn fold is one of the most complex structure formsin strata.It is very hard to describe a upturn fold with mathimatical function in computer because of its complicated distribution in space, therefore direct modeling of the structure can hardly be done based on its space partern. According to 3-D modeling in computer, the projection of a upturn fold to any direction may result in overlapping. Indirect method including intersection and iteraction functions of Gemcom Desktop Edition should be used to construct the model.

Decomposition of section boundary lines is used to model the structure by dividing complicated boundary line pattern into several simple shape ones. Each part is modelled with different methods to form a volume. A sample line is shown in Figure 5 which is an upturn fold pattern. The pattern can be divided into two parts by adding a dotted line: the main line changes slightly along the distance and stored in the form of status line, and the other is constructed as a closed ring and stored in form of closed ring.

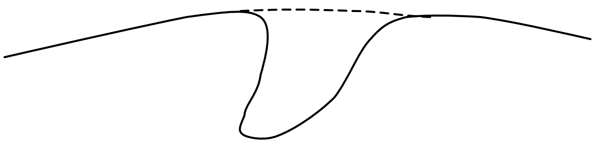

Figure 5 model of upturn fold

Steps of modeling upturn fold are shown as following:

(1) Generating volumes

All the status lines belonging to the same interface are selected to form a grid surface, and then the main volume V_1 of a stratum is created with two nabouring surfaces. And the volume V_2 inside the closed ring is created by function of expanding tied rings into a solid.

(2) Intersecting and compounding of volumes

The volume V_1 is cut with V_2 and the part taken by V_2 in V_1 is taken away. Finally the empty is filled with V_2 and the pattern of upturn fold is formed. The same proccess is applied to other strata to obtain the complete structure of a multi-layer upturn fold model.

3.3 Modeling of thin feeble double layer

The feeble double layer is one of significent layers with mechanics characteristics important to the safety of underground engineering.The feature of its spatial distribution is large scale and small thickness, hence it is comparatively more difficult completely to construct such part of the body pattern.

Because of the thickness of the layer and data density in some of the area, the two interfaces created of feeble double layer may be intersecting at some positions. And a volume created with the two interfaces will be invalidity and can not be used for further application.

Based on the function supplied by Gemcom Desktop Edition to create volume with two unintersecting surfaces, the feeble double layer can be created by the following steps. Firstly one of the two surfaces is moved away from the other to ensure that thw two surfaces will not be intersecting at any position, then a volume is created with these two unintersecting surfaces. Finally the volume is cut with the interface before moving and the model with validity feature of the feeble double layer can be obtained(shown in Figure 6).

Figure 6 Model of feeble double layer

4. 3-D geological Modeling applied to Actual project

The project, a project of hydropower construction, locates at a sector uncovered with bedrock. The main dam stretches across the canyon, with sharp undulation of relief along the two sides of it(shown in Figure 7).The bedrock consists of lower Trias series such as limestone and dolomite, and upper Trias series namely mudstone, silicate stone and silt sandstone. Additionally there are 4 faults crisscrossing among the strata(shown in Figure 8) and 7 feeble double layers. Total layers to be modelled

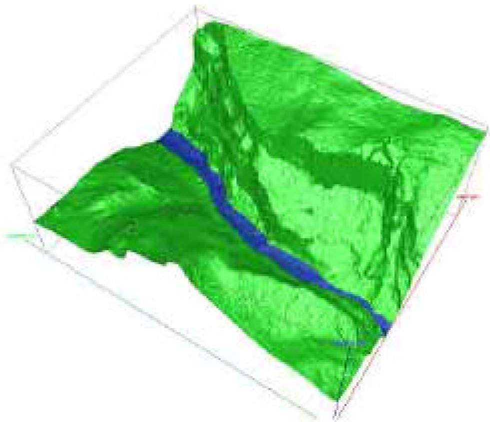

Figure 7 The topography of the project

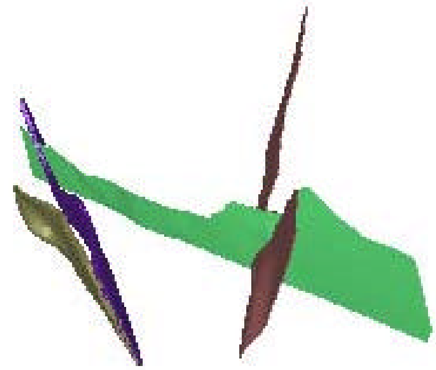

Figure 8 faults in the strata

is 12.

The construction of the model is divided into three parts: strata, faults and feeble double layers. All the information used for the construction comes from 23 engineering geological sections, one engineering geological plane diagram and contour lines of the area.

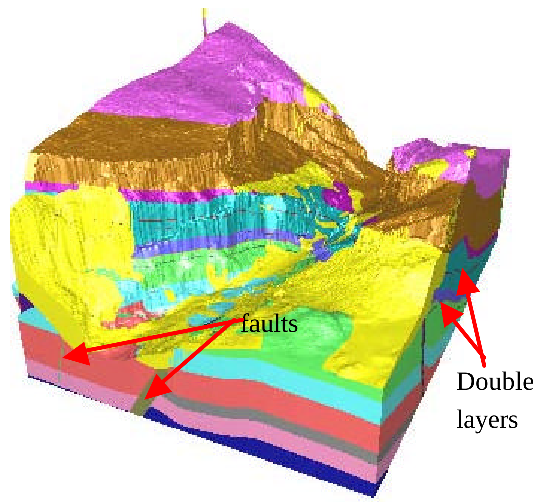

Figure 9 the complete model of the project

First of all the strata, faults and feeble double layers are constructed respectively, then the strata are cut with the faults and feeble double layers. At the same time each of the strata, the faults and the feeble double layers is intersected with the topographic surface created. Finally the intersected strata, the feeble double layers and the faults are compounded to form the model of the project(shown in Figure 9).

5. Conclusions

With the functions supplied by Gemcom Desktop Edition, much complex patterns of geological bodies can be constructed easily and accurately. Constructures such as faults, upturn folds, which can not be expressed in terms of some mathematical functions, can be modelled by the way of decomposition. The way to obtain a 3-D model of any complicated geological bodies becomes more important to hydropower engineering and any other underground engineering construction.

6. References

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