MINING GEOLOGY 2004

Innovations in Coal and Metalliferous Mining Geology
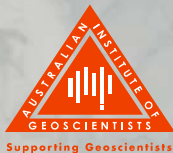
EXTENDED ABSTRACTS

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Leapfrog's implicit drawing tool: a new way of drawing geological objects of any shape rapidly in 3D

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INTRODUCTION

Leapfrog ™ software was released to the resource market in December 2003, and has been gaining in popularity with explorers and mine operators of metalliferous deposits, principally in Western Australia. Leapfrog's main strength is its ability to 3D contour grade data straight from desurveyed drillhole data without the need for creating block models. This 3D capability has allowed exploration geologists who have traditionally used 2D GIS-based products to review regional distribution of grades to view their grade trends in 3D space. Leapfrog is also popular with property evaluators of mining companies who require an objective view when inspecting deposits that are on the market.

We are about to release an upgrade of the software (version 1.5), which will contain some powerful enhancements including lithological boundary modelling. The other major highlight of the upgrade is Leapfrog's free-form 3D drawing tool. The ability of this drawing tool is unlike any other software tool that is available in the resource market, as we rely on a new modelling paradigm to allow geologists to rapidly create 3D objects of any shape (Figure 1).

Existing software methods to quickly construct surfaces can work only on line-of-sight sampled data (eg. lithological contact points in drillhole data). Line-of-sight data can simply be modeled with 2D or $F(x,y)$ interpolation techniques. Two-dimensional interpolation, however, does not allow non line-of-sight data such as overturned folds or more complex 3D shapes such as intrusions to be modelled. Leapfrog's tools works on true three dimensional data ($F(x,y,z)$) but the process is as easy as 2D interpolation and this is the main distinguishing feature of Leapfrog's drawing tool.

A BRIEF HISTORY OF IMPLICIT MODELLING

The modelling paradigm that the Leapfrog drawing tool is based on is referred to in the graphics literature as ***implicit modelling*** (Bloomenthal 1997). The name is derived from the fact that the modelled surfaces, such as lithological contacts, sketched fault surfaces or isograde surfaces, represent iso-potentials of continuous volumetric functions. The surface that is modelled therefore is not explicitly defined by way of digitizing every triangulation vertices, but the existence of the surface is *implied* in the volumetric function which is usually only defined by only a small amount of control points. The iso-potentials are simply evaluated and saved as triangulations from this volume function.

Implicit modelling technique can be traced back to the computer graphics literature in the 1980s where iso-distance potentials generated from primitive geometric objects, such as spaces curves and spheres, were blended together to form complex objects. Since these objects can be expressed as algebraic equations (Blinn 1982), the shapes could be animated readily and were used in special effects for motion pictures. An example of such an animation can be seen in *Star Trek VI: The Undiscovered Country* (Paramount Pictures, 1991) where a character in the film is shot by a laser beam and blood flows out from the body into zero gravity. Implicit surfaces that morphed into various shapes realistically simulated blood globules floating in space.

Useful as it may have been in the movie industry, the implicit modelling technique could not be developed as a general 3D modelling tool because the technique relied on generating the shapes from fixed distances from the primitives. That is, the control points had to be positioned away from the actual surface to be constructed; therefore this technique was

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unsuitable for most geological modelling applications, and as well unsuitable as a general surface drawing tool.

The implicit modelling method only recently become a practical methodology for modelling natural data when the technique was combined with rapid 3D interpolation (Carr et al. 2001). The method outlined by Carr et al. (2001) allows the control points to be located on the surface to be modelled, and together with the fact that there is no limit placed on the number of control points (other than hardware limitation) makes this a very practical technique for geological modelling.

THE ADVANTAGES OF LEAPFROG'S IMPLICIT FREE-FORM DRAWING TOOL

Unlike traditional software tools available in the resource industry, the input data to Leapfrog, such as assay values, lithological codes and drawn polylines, are converted to a volume function ($f(x,y,z)$) within Leapfrog software by way of spatial interpolation of the point attributes (*cf.* Cowan et al. 2003). We use a volumetric spline interpolation to fit the data (or more specifically referred to as ***bi-harmonic radial basis function***), but effectively any interpolation function can be used to fit the data into a volumetric function, including Kriging.

The free-form drawing tool that utilises the volumetric spline function has attributes that are ideally suited for geological modelling, and these are:

1. Results in the smoothest surface that goes through the control points. This characteristic is ideal for geological modelling, as the boundaries between drillholes are invariably manually smoothed by the geologists who model with traditional 3D modelling software.

2. The drawing can be done using the drawn control points and polyline contours, but can incorporate any contact points that are extracted from the drillhole database.

3. Incorporating contact points of several thousand points into a drawn object surface takes only tens of seconds to process.

4. The volumetric spline can be either fitted with, or without, a noise factor that may better represent the surface roughness of a geological contact (equivalent to a nugget value). That is, the control points can be digitally snapped to, or an average smooth surface can be fitted through rough contact data. A boundary fitted with a nugget value would ideally be used if there is some uncertainty in its position.

5. Three-dimensional shapes of any geometry can be drawn simply with a standard three-button mouse without the need for non-standard input tools, such as a haptic device.

6. It can rapidly draw any shape, including objects that are branched, but there is no need to use tie-lines, as required in traditional software to create 3D objects.

7. Although the input control points are drawn in sections as contours or points, the sections do not necessarily have to be parallel to each other and can be drawn in arbitrary sections (Figure 1).

8. There is no need to draw closed contours when trying to construct a closed object, such as an intrusion, as required by traditional software. The polylines can be defined where the geologist is confident of the boundary position (eg. close to drillholes) and the rest is interpolated smoothly by the volumetric spline interpolator.

9. Object editing is done by modifying the control contours and points and reinterpolating, rather than editing the object mesh (Figure 1).

10. The drawn 3D objects are saved as continuous functions, therefore, the objects can be generated at any desired resolution.

11. Functional representation of geological objects such as strata or faults requires no editing if these features terminate against each other. Boolean operations are conducted with the functions, rather than the computed mesh surfaces.
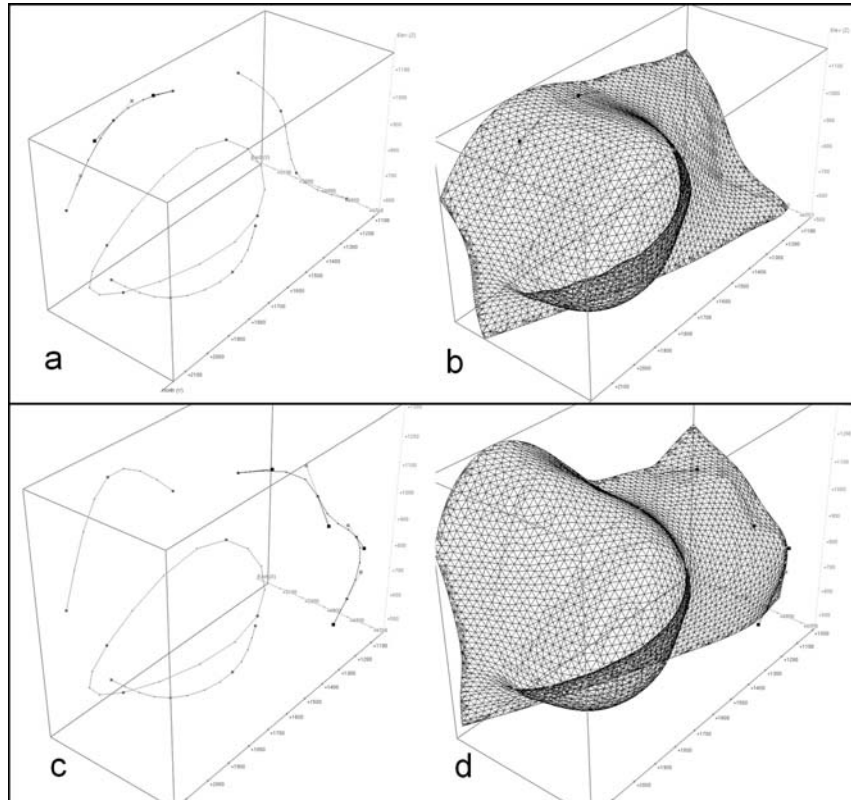
Figure 1. a) Mixture of closed and open polylines are drawn in four non-parallel sections. Note the absence of tie-lines; b) Implicit surface smoothly fitted through the control lines; c) Two of the original control lines are quickly edited, and d) shows the resulting implicit surface after polyline editing. The surface generation takes seconds, and mesh resolution can be changed by the user.

CONCLUSIONS

Leapfrog's free-form drawing tool makes the creation of 3D geological objects a simple process and this is only possible because Leapfrog works with a new modelling paradigm. What is impossible with 2D interpolation becomes simple in 3D interpolation. Leapfrog does not require the operator to be experienced in mining 3D modelling software, and indeed, many users of Leapfrog cite the ease of use as being one of the main attractions of Leapfrog. A mere three hours is the average to become proficient at creating complex 3D objects that take many weeks to create in traditional software that requires extensive manual digitization. For more information on Leapfrog visit URL www.leapfrog3d.com.

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