Leapfrog™: new software for faster and better 3D geological modelling

Paul Hodkiewicz, Principal Consultant (Geology), SRK Consulting, 10 Richardson Street, West Perth WA 6005, Australia, phodkiewicz@srk.com.au

Abstract

Leapfrog software is a powerful tool for geologists that dramatically reduces the amount of time required to interpret drill hole data, in an easy-to-use 3D environment. It allows geologists to use all available data to better interpret trends in mineralisation, improve exploration and near-mine targeting, and rapidly construct domains for resource estimation. Leapfrog outputs include valid and closed wireframe models of lithology, alteration and mineralization, which can be readily imported into other mining software packages. Existing maps and cross-sections can also be viewed in Leapfrog’s 3D environment to guide interpretations.

Leapfrog software (www.leapfrog3d.com) was developed by SRK Consulting and Applied Research Associates of New Zealand (ARANZ) for 3D modelling of drill hole data and for the rapid construction of wireframe models. Leapfrog models highlight the 3D geometry of mineralisation and assist in the interpretation of ore controls at a variety of scales.

The main benefits of Leapfrog, compared to other mining software packages, include the following:

1. It is easy to learn and use. Training for beginners can be completed in a few days.
2. All historic data can be used in 3D, including scanned images of maps and sections.
3. Large drill hole datasets are easy to import and view.
4. Fast results mean that multiple interpretations can be modelled and tested.
5. Models are easy to update as new data become available.

This paper presents Leapfrog modelling results from a variety of different deposits and mineralization styles.
Introduction

Leapfrog is 3D geological modelling software that allows rapid construction of geological wireframes directly from scattered drill hole data without the need for manual digitizing.

Some unique features and benefits are:

1. Leapfrog is the first software that allows the construction of geological models using 3D interpolation technology. This new method of geological modelling is termed implicit modelling.
2. Implicit modelling, in contrast to traditional explicit modelling (i.e., digitizing), does not require time-consuming manual creation and manipulation of polylines and polygons. This reduces the time required for modelling from days (or weeks) to hours.
3. Leapfrog uses a recently developed rapid 3D interpolation engine (FastRBF™) to construct 3D boundary models from drill hole data and to solve geological modelling problems.
4. Leapfrog was designed and developed specifically for mining and exploration geologists.
5. Leapfrog’s streamlined workflow is simple to understand, learn, and operate.
6. New users can learn most Leapfrog modelling techniques in a few days.

Why Leapfrog?

The simplest way to describe Leapfrog’s capability is 3D contouring of drill hole data. This capability is significant because the continuity of mineralisation in most ore deposits is controlled by structural features (e.g., faults and vein sets) that focused hydrothermal fluid flow during deposit formation. Therefore, 3D contours of assay data can be used to highlight structural controls on fluid flow and the orientation of mineralised domains (Figure 1). A better understanding of these controls improves exploration drill targeting and resource estimation.

![Figure 1](image.png)

Figure 1. Plan view of Au mineralization along a curved shear zone (grey surface). Drill holes are shown in blue, with high-grade Au intervals in red. Leapfrog models at 2 ppm (yellow) and 4 ppm (red) highlight the main structural control on hydrothermal fluid flow in this deposit.
Leapfrog’s ability to **rapidly** model and wireframe all types of drill hole data (including lithology and alteration codes) in 3D also distinguishes it from other modelling software packages, which usually require time-consuming manual creation and manipulation (digitizing) of polylines in order to construct wireframes from drill holes. For example, a large dataset of approximately 100,000 drill hole intervals can usually be modelled in Leapfrog in a few hours. Therefore, it is much easier to produce multiple or alternative geological interpretations, which can then be tested and refined as drilling or mining progresses and knowledge of controls on mineralization improves.

**Radial Basis Functions**

The interpolation algorithm behind Leapfrog is the Radial Basis Function or RBF. FastRBF™ was developed by Applied Research Associates New Zealand (ARANZ) and it allows scattered 3D data sets to be described by a single mathematical function. Isosurfaces of the function (represented as wireframes) can then be created for any value and at any resolution. RBFs are a natural way to interpolate scattered data, particularly when the data points do not lie on a regular grid and when the sampling density varies. This is why RBF interpolations are ideal for drill hole data.

The ability to fit an RBF to large data sets has previously been considered impractical for data consisting of more than a few thousand points. FastRBF™ overcomes these computational limitations and allows millions of measurements to be modelled by a single RBF on a desktop PC.

**Modelling Mineralization**

This section shows several examples of Leapfrog models based on assay data, which highlight structural controls on hydrothermal fluid flow.

Orogenic lode-gold deposits are usually associated with shear zones and commonly have high-grade plunging shoots that form as a result of preferential hydrothermal fluid flow along linear structural features such as intersection lineations or fold hinges (Figure 2). Surrounding lower grade mineralization generally occurs with disseminated sulfides related to hydrothermal alteration along the margins of the shear zone. These lower grade domains are associated with zones of less-focussed fluid flow and may not have the same structural controls on grade continuity as the high-grade shoots (Figure 3). Leapfrog allows these different grade domains to be modelled independently, in order to highlight the different structural controls.
Figure 2. Leapfrog model of gold mineralization in a Western Australian lode-gold deposit. Cross section view through open pit and underground mine openings shows drill holes in blue and steeply plunging shoots of high-grade (>5 ppm Au) mineralization in yellow. This model is based on approximately 10,000 two-metre composites and was completed in less than 30 minutes.

Figure 3. Long section view of gold mineralization in a lode-gold deposit in Ghana. The broad domain of low grade (1 ppm Au) mineralization is shown in yellow. Internal high-grade shoots (>5 ppm Au in red) plunge towards the right.
Mineralization in Cu-Au porphyry deposits is controlled by magmatic-hydrothermal fluid flow associated with porphyry intrusions. Continuous zones of economic mineralization generally occur in stockwork vein arrays and disseminations along the upper margins and flanks of the intrusions (Figure 4).

Figure 4. Two Cu-Au porphyry deposits: Top image is a cross section through topography (grey) and a pink intrusion, with +0.5% Cu intervals in drill holes shown in red and a Leapfrog model of 0.5% Cu in green along the upper margin of the intrusion. Bottom image shows Leapfrog models of 0.4% Cu (green) and 0.4 ppm Au (yellow) along the margin of the porphyry intrusion in pink. Drill holes show lithology. Both models are based on approximately 20,000 two-metre composites and were completed in less than one hour.
Modelling Lithology and Alteration Data

Leapfrog can also be used to model any coded drill hole data (e.g., lithology, alteration codes) as shown in Figure 5 and Figure 6.

Figure 5. Top image shows a model of the base-of-oxidation surface, based on ‘OX’ codes from drill holes, shown in red. Bottom image shows a model of a steeply dipping quartz porphyry intrusion, based on ‘QZP’ codes from drill holes, shown in green. The QZP model has been clipped below the oxidation surface. These models were created in approximately 10 minutes without digitizing any polylines.
Figure 6. Quartz vein model. Top image shows red quartz vein based on lithology code in drill holes and clipped below topography. Bottom image shows vein clipped within a 40 metre buffer around drill holes. Buffers can be built quickly in Leapfrog and used to constrain models, for example within variogram ranges for resource classification. These models were created in approximately 15 minutes without digitizing any polylines.
Structural Trends

Leapfrog’s ability to use folded contacts and fault surfaces to model mineralization is especially important for building domains for resource estimation in structurally complex deposits. Wireframe surfaces can be used as ‘structural trends’ in Leapfrog to guide interpolations in non-planar or non-linear directions (Figure 7). The ability to model along complex trends is a distinct advantage compared to other geological modelling software packages.

Figure 7. Section views of lithology and iron mineralization in a folded stratigraphic sequence. Top image shows a folded iron formation unit based on yellow lithology codes from drilling. Bottom image shows models of Fe ≥ 55% in red, based on composites selected within the iron formation (red ≥ 55% Fe and white < 55% Fe). The folded contacts were used as ‘structural trends’ to model Fe along the fold limbs.
Workflow

There are four main steps in the Leapfrog workflow for modelling drill hole data.

1. Data import and preparation
   a. Leapfrog imports collar, survey, assay and geology (lithology, alteration, etc) drill hole data files in csv format.
   b. As the drill hole data files are being imported, Leapfrog completes a thorough drill hole validation routine. Error reports are automatically produced for use by database managers. Alternatively, errors can be fixed interactively within Leapfrog to produce a clean database.
   c. A compositing routine prepares composites of any length from the assay intervals.
   d. Existing wireframes (e.g., topography, open pit and UG mines, fault surfaces, geological models) in a variety of formats (dxf, Surpac, Gemcom, Datamine, Vulcan and GOCAD) can also be imported.
   e. Maps, images and cross sections in jpg, png and tif formats can be geo-referenced and imported in 3D. This is important because it allows previous or historic interpretations, usually completed in 2D plan and section, to be viewed in 3D and compared to the new Leapfrog models.

2. Interpolation (modelling) of data
   a. Leapfrog interpolation uses a Radial Basis Function, which allows scattered 3D data points to be described by a single mathematical function.
   b. Models can be isotropic, meaning without any trends or directional bias, or anisotropic, based on planar, linear or more complex structural trends.
   c. Assays and any coded drill hole data, such as lithology and alteration, can be interpolated.

3. Viewing and interpretation of results
   a. Isosurfaces, or wireframes, can be built at any assay value and at any resolution.
   b. In addition to wireframes, interpolation results can be viewed (evaluated) on surfaces and within a grid of points, similar to a block model.

4. Exporting results
   a. Leapfrog wireframes can be exported in a variety of formats, including dxf, Surpac, Gemcom, Datamine, Vulcan, Micromine and GOCAD
   b. Leapfrog Scenes can be saved and viewed in the Leapfrog Viewer, which is free to download from www.leapfrog3d.com.

Summary

Leapfrog provides significant advantages compared to most existing geological modelling software packages. Its innovative application of new interpolation and modelling techniques allows exploration and mine geologists to rapidly view, model and interpret lithology, alteration and assay data from drill holes. Leapfrog models highlight structural controls on the continuity of mineralization and can be used to improve near-mine and exploration drill targeting, as well as domain construction for resource estimation.