Destroying the Distinction Between Explicit and Implicit Geological Modelling

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Abstract

Mathematically and topologically there is a clear distinction between the terms explicit and implicit surface modelling. In the mining and financial industries, however, these terms have come to represent something else. To some people, they represent a divide, a division, a hard boundary (to use a geostatistical term) that is considered the border between good and evil. The misconception that a geological model made with the assistance of a so-called implicit modelling tool is either better or worse than a model made with a so-called traditional or explicit tool or methodology needs to be destroyed.

The same divide existed during the change over from sectional pencil and paper modelling to sectional computer-based modelling and that was overcome (eventually). The same divide also existed (and still exists in some places) around the use of ordinary kriging instead of inverse distance for block estimation.

Implicit models require significant amounts of “manual" input before they are fit for use and the same levels of geological, volumetric and statistical validation. They also require peer review. The primary advantage of implicit modelling methods is speed, not accuracy, not unbiasedness, not detail, but speed. Speed leads to the ability to test multiple scenarios and models and allows for modelling by trial and error. Think – model – examine – accept / reject – modify – repeat until happy.

This presentation examines some history of methods of geological modelling, the origin of the term “implicit” in this context and proposes that there is not much that is implicit about “implicit” modelling.

Introduction

Computerised geological volume modelling in a 3D graphical environment has been around for approximately 30 years. For the first 15 years or so, the basis of the vast majority of geological volume models were created with some variant of polygon sectional interpretations joined up manually or semi automatically and edited to form closed surface volume wireframes. A few people were playing with the idea of modelling surfaces from block models or 3D point grids but without much success. Then along came this wonderful little “blob generator” that came to be known as implicit modelling. At first nobody really believed it could produce realistic and useful shapes, but it was an awful lot of fun to play with. Then slowly it got better and many of us became believers. But there was a problem, some very bad implicit models made it into the public domain and implicit models were tarnished forever after. It’s time for the industry as a whole to get over this and understand that modelling methods in themselves are not the problem.

Implicit vs Explicit

This section examines definitions of the terms implicit and explicit in general use, mathematical use and what they have come to mean in the mining industry.

In general use, the term explicit is variously defined as; stated clearly and in detail, leaving no room for confusion or doubt; very specific clear or detailed; disentangled (from Latin “explicitus”); fully and clearly expressed or demonstrated; leaving nothing merely implied; unequivocal; and clearly developed or formulated.

The term implicit, in general use, is variously defined as; suggested though not directly expressed; always to be found in; essentially connected with; entangled; and implied indirectly.

Mathematically, an implicit surface is defined by a continuous volume function \( F(x,y,z) = 0 \) at an infinite level of detail. The surface is implied to exist within the mathematical function. The surface is said to be implicit in that the equation is not solved for \( x, y \) and \( z \). The surface becomes explicit when the equation is solved and an approximation of that surface at a specified resolution is rendered as, for example, a triangulated wireframe.

The origin of the use of the terms “implicit” and “explicit” as they are now used in the mining industry is the paper presented at the 5th International Mining Geology Conference in Bendigo Victoria in 2003 (Cowan 2003). The specific passage from the paper is given below.

“Traditional method of explicitly defining three-dimensional (3D) ore-waste and geological boundaries relies heavily on a time-consuming process of manual digitisation. This method of modelling can be best described as surface modelling, as complex surface geometry is built up by digitising points that lie on the surface. With the advent of fast 3D interpolation methods, however, construction of geological surfaces using volume
functions is now a practical alternative to explicit modelling of surfaces. Unlike explicit modelling, surfaces contained in volume functions are not explicitly defined or digitised. Instead the existence of surfaces in the volume function is implicit, thus the process of modelling surfaces from volume function is called ‘implicit modelling’.

A model produced via the use of some variant of Fast Radial Basis Functions (RBF) to generate an underlying volume function from either categorical (e.g. lithology) and/or grade data, and subsequently render a wireframe volume, is called an implicit model (Figure 1). Any model produced by sets of 2D and/or 3D polyline interpretations and somehow stitched together to create a wireframe has become known as an explicit model (Figure 2).

Evolution of Geological Volume Modelling

Below is a very rough timeline of improvements in the geological volume modelling process:

- 30-100 years ago - hand drawn polygonal sections on A0 sheets of paper. “You’ll never be able to do that on a tiny computer screen.” Extrapolated parallel halfway between sections to calculate volumes.
- 30 years ago – direct block modelling unconstrained by any limiting shells (short lived). (e.g. Cram and Duke 1989).
- 20-30 years ago – still hand drawn polygons on paper but digitised into 2D "strings" and located in 3D for wireframing (2.5D).
- 15-20 years ago - strings snapped directly to drill holes on screen in pseudo 3D and connected by triangles.
- 10-15 years ago - simultaneous 3D wireframing from plan and sectional interpretations.
15 years ago - RBF adapted to the mining industry (Cowan 2003) with progressive improvements (isotropic grade shells, anisotropic grade shells, trend model grade shells, indicator shells and seamless multiple lithology models).

A selection of quotes, below, from various geological modelling papers over these years makes interesting reading:

**McKinstry 1948**

“A more common and adaptable method of calculation, however, is to draw up a series of cross sections through parallel rows of holes calculating the area and average grade of ore shown in each cross section. This method can be used even if the rows are not equal distances apart with holes uniformly spaced along them. ……….. A set of cross sections drawn at right angles to the first set gives a good means of checking the result. Volumes are computed by averaging the areas of each pair of adjoining sections and multiplying by the distance between them. Extensions beyond the extreme end-sections are assumed or omitted depending on the probable shape of the ore-boundary.”

**Cram and Duke 1989**

“Computer based geological modelling techniques have evolved dramatically in the last five years from computer controlled simple cubic block modelling with an unconstrained spherical search pattern, to the almost complete control given to the geologist via such techniques as wire framed structural control, and dynamic anisotropic search……..Unfortunately there have been a number of failures in computer based grade estimation projects in the past. Case failures, however, can normally be traced to inability of the geologist to impose geological control on the estimation procedure combined with the lack of display facilities to validate the model.”

**Johnson 1995**

“With 3D ore shape modelling, it is also possible to use non-planar ore outlines, with the interpreted ore shape passing through the drillholes. This approach has the advantage that the errors from off-section orebody intersections are avoided.……..The geologists must form a geometry which matches the conceptual view of the ore occurrence and ensure that they understand how the computer system used calculates the volumes. If the underlying assumptions inherent in the method conflict in any way with the conceptual model visualised for the ore occurrence, then that method must not be used.”

**Archibald 1997**

“3D computer modelling of geology and orebody delineation is still largely in its infancy. Two current and significant drawbacks to the routine use of computer modelling of geology in both mining and exploration are the tedious and time consuming modelling process and the lack of seamless interaction between 3D computer aided drafting (CAD) software and geographical information systems (GIS) which are largely 2D in their data treatment. There is an urgent need for a 3D spatial information system (e.g. 3D GIS) with intelligent and rapid modelling functionality.”

**Cowan 2003**

“Based on recent advances in fast scattered data interpolation methods, implicit modelling first defines a continuous three-dimensional function that describes the grade or rock distribution. This volumetric function is interrogated for a grade value, or a geological surface, thus allowing the extraction of the 3D object to be automated and eliminating the need to manually digitise surfaces. Since the function is continuous throughout space and does not depend on a mesh or grid for its definition, the extracted geological or grade wireframes can be constructed at any desired resolution in the specific volume of interest.”

**Knight 2006**

“The overall results of this study find that the MineSight® and LeapfrogTM solid mode accuracies are virtually the same, and that their volume, cross-sectional area, and surface differences are comparable. This study concludes that the implicit modelling technique generates accurate solid models that can be used in place of explicit models as ore shells for resource estimation in certain circumstances.”

**Cowan 2011**

“Implicit modelling is a quick way to generate wireframes of any shape that honour drill hole data. What is generally not known is that wireframe triangulation solids produced from implicit modelling are derived from the 3D function created by the interpolation process………..Although implicit modelling has successfully generated geologically realistic wireframes (e.g. Knight, 2006), a more efficient use of implicit models is to directly output a block model from the interpolation functions (referred herein as ‘direct to block’ method of implicit modelling). This ‘direct to block’ method produces block models and skips the production of wireframes that require validation.”

**Barnes and Gossage 2014**
“Implicit models are, however, often just as prone to the generation of 3D artefacts as a pseudo two-dimensional (2D) manual digitising exercise. It is possible to minimise the generation of unintended artefacts by careful adjustment of the 3D shape-generation parameters within the software package. These 3D artefacts are generally caused by the irregular nature of many drilling patterns wherein bounding data does not exist or is sporadic and the shape modelling algorithm encounters difficulties in ‘closing off’ a 3D isosurface. Often the optimum approach might be one of modelling and testing hypotheses using implicit modelling, with ‘final’ wireframes built [explicitly] using the implicit models as a guide. The speed of implicit modelling is its primary advantage, wherein a complex 3D model can be developed, reviewed and validated in hours rather than the weeks that a complex model might take to digitise using explicit modelling.”

Aside: One thing that is apparent on reviewing many papers on the history of geological modelling is the ongoing confusion and lack of distinction between strictly geological models and strictly grade models. Loosely speaking grade modelling is typically done post geological modelling. The geological model as a surface defining the absolute limits of the volume and the grade model filling the space within the volume with some form of spatial interpolator, usually a block model of sorts. But these methods can also be flipped around. Implicit models actually use a spatial interpolator from which a selected “geological” surface is extracted. Cowan (2011) revives the concept of skipping the surface creation step altogether and Stuart (2014) lays out, very well, the case for utilising RBF directly as a block grade estimator.

Misconceptions
From the author’s observations there are two commonly expressed, but opposite, misconceptions that have taken hold in certain sections of the mining and mining finance industries:

1. That an implicit model somehow “knows” what the “true” grade/geological surface is therefore better than an explicit model.
2. That implicit models are an uncontrolled mathematical fantasy and create models that bear no relationship to geological reality.

While the first misconception is a completely false statement, the second has a rather large grain of truth in it that requires some further discussion. Even so, implicit modelling is just another modelling method and, as the saying goes, all models are wrong, but some are useful.

Discussion
There is no unique solution to either the geological volume modelling problem or the grade estimation problem and we must rely on models which are simply a single outcome (or a limited range of models in the case of simulation) from an infinite range of possible models. The term implicit in the mining industry now seems to carry with it a sense that an implicit model is somehow objective rather than subjective. Each individual implicit volume model in software such as LeapfrogTM now requires around 50 parameters to be explicitly specified in order to create and/or reproduce it. That is 50 subjective decisions by the modeller (These are at least all recorded whereas with explicit sectional wire framing the position of every single sectional polyline vertex is a subjective decision by the modeller, the definition of which is not recorded). However, the concept that implicit models are somehow objective and identically reproducible by an independent modeller is nonsense. In the authors direct experience, implicit modelling of the same dataset by two geologists can still lead to very different models. The grain of truth in the second misconception stems from a number of implicit geological models that made it into the public domain in the relatively early days of implicit modelling which were clearly never validated or peer reviewed and did, in the light of further drilling and/or better modelling, in fact turn out to bear no relationship to geological reality. The thing is that for anyone with even a little geological modelling experience, the issues were fairly easy to spot if any pictures of the models were provided in the associated reports or public releases. The counter to this is that, in the authors direct experience of technical review and due diligence of many projects, there are even more, totally inappropriate models, generated by explicit methods. It is just that the industry takes these in its stride and lays any blame on the Competent Person, rather than on the modelling method. Why should it not be the same with implicit models?

Why Destroy the Distinction?
Just because a geological volume model is constructed entirely or partially with an implicit modelling tool does not mean that is any better or worse than a geological volume model created with any other modelling tools. Both explicit models and implicit models can be useful models. Both require geological thought to be applied to their construction. Both require validation. Both are subject to uncertainty. Both can also be very wrong if created by inexperienced and unsupervised modelers. During technical review or due diligence work, to
immediately dismiss or degrade a model on either basis is incorrect. There should be no distinction or discrimination on the basis of modelling method alone.

**Alternatives / the Future of Geological Volume Modelling**

Some alternatives to either explicit or implicit modelling are; pluri-gaussian simulation (Le Lac’h 1997), potential fields (Renard 2013); direct to block implicit modelling (Cowan 2011). New work on multi-Gaussian transforms (Talebi 2019) is also investigating the possibility that in some specific cases (internal) boundary definition may not even be required.

**Conclusions**

Implicit modelling, whatever you call it, is here to stay. In Clayton Deutsch’s words “That ship has sailed” (2017, verbal quote from presentation, IAMG Perth, 2017). The mining and financial industries need to understand that geological models are just models and the tools we use to build them are just tools.

The quality and accuracy of any model is reliant on the underlying data used to provide the framework, on the accumulated knowledge and skills of the people who gather the data and make the models, on the time available, and on the rigour of the validation methods used.

The underlying mathematics of the generation of implicit models is still implicit in the mathematical sense. However, the models themselves now have so many additional parameters, that are necessary for creation of geologically realistic shapes, that there is no longer much that is implicit about implicit models.

The primary advantage of implicit modelling methods is speed, not accuracy, not unbiasedness, not detail, but speed. With speed comes the ability to iterate, to try different assumptions, to alter the numerous parameters to form the best model that the combined experience of the modelling team instinctively expects. With speed also comes the ability, which can often be a trap, to include more detailed, higher resolution models where data is available. Conversely there is a temptation to include detail that is not supported by the data.

Just because a geological volume model is constructed entirely or partially with an implicit modelling tool does not mean that is any better or worse than a geological volume model created with any other modelling tools. During technical review or due diligence work, to immediately dismiss or degrade a model on either basis is incorrect. What matters firstly is that any model honours the data, secondly that it makes geological sense and thirdly that it has been subject to some sort of validation and peer review process. There should be no distinction or discrimination on the basis of modelling method alone.

**References**


