POTENTIAL FIELD WAVELETS AS A TOOL IN EXPLORATION

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Potential field surveys represent some of the cheapest forms of geophysical exploration. The use of airborne surveying techniques enables relatively easy exploration of remote or inaccessible areas. Accordingly, potential field methods have been the subject of extensive research.

Broadly speaking, the techniques used in analysing potential fields divide into two classes. The first class is represented by the visual inspection of aeromagnetic or gravity maps by geoscientists. More or less sophisticated image processing tools and different kinds of enhancements (first/second derivatives, sun-angle illumination, map colouring) are used in order to allow human analysts to better discriminate geometrical features present in the data. This approach has some of the flavour of an art and requires specific training and experience. As such, it has the disadvantage of being partly subjective. The second class of analysis might be described generically as inversion. Here, more or less sophisticated algorithms are employed in order to determine the geological setting(s) that may be responsible for a particular data set. The target of this kind of analysis is typically the location and depth extension of major geological bodies.

We developed a technique that attempts to unify the visual and inversion approach mentioned above into a single procedure by the use of wavelet analysis. Wavelets are well suited for the analysis of potential field data. With the choice of an appropriate wavelet, the potential field fundamental equations have a very elegant and compact form in the wavelet domain. Also the detection of wavelet multiscale maxima (or edges) allows the automatic production of the type of map commonly called a 'worm diagram' or skeletonisation in geological jargon, without the subjectivity implicit in human interpretation. These edges are of fundamental importance both from an image processing and a physical point of view. They can give quantitative information about the depth and characteristics of causative bodies, and can therefore be used in an inversion procedure. Other applications, such as data compression, de-noising, enhancement/elimination of specific features and interpolation, also fit within this single rigorous framework.

The automatic edge detection algorithm has been applied to aeromagnetic data shown in Figure 1. Here the edges produced at different scales are stacked one upon the other and the amplitude of the wavelet maxima is mapped as greyscale. This representation of the multiscale edges overlies the 3-D relief rendering of the magnetic map. We see some strong magnetic anomalies emerging from a mostly flat background in which structure cannot easily be discriminated. Not only are the major features in the data well defined by the edges, but the algorithm is also able to detect features in the flat background that are not easily seen in the original image. This clearly helps the interpretation of the aeromagnetic image. Similar images have already been produced for exploration purposes in other areas of Australia and the reaction of experienced interpreters has been positive.

The information contained in the multiscale wavelet maxima is often sufficient to reconstruct the original image. This feature can be exploited in image processing. Specific features in the data can be enhanced or eliminated by appropriately manipulating the correspondent edges. This image processing approach offers advantages compared to traditional ones, such as Fourier techniques, since it allows the selection and specific manipulation of local features without affecting the global appearance of the image.

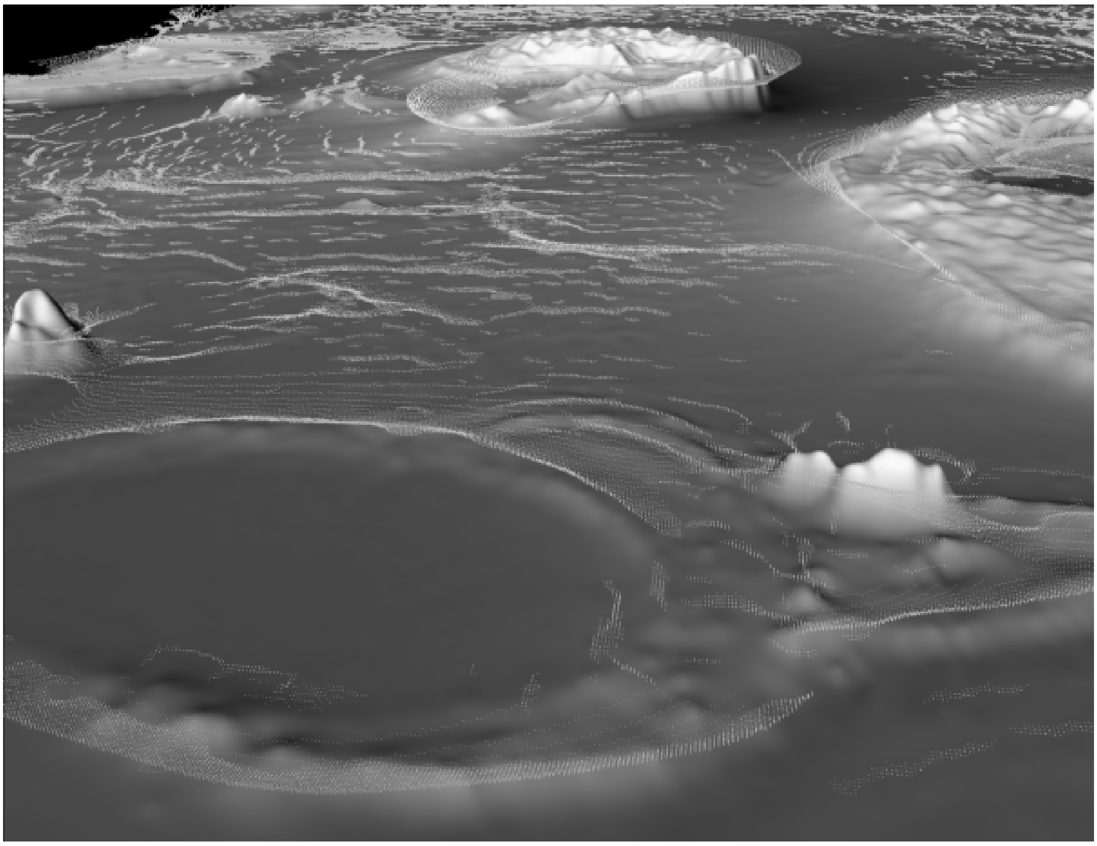

Figure 1 Perspective relief view of aeromagnetic data for a region near St Arnaud, Victoria, Australia, (courtesy of the Geological Survey of Victoria) with the multiscale edges suspended in the space above the image. Increasing height above the image represents increased scale in the wavelet analysis. The amplitude of the multiscale edge has been mapped to greyscale.

Eventually, it can be shown that the information contained in the evolution of the edges amplitude at different scales can be used to estimate the depth and type of causative sources in an inversion approach. The inversion problem is well known to be non-unique. However, the wavelet representation offers a possibility here, since the source singularity information gleaned from the multiscale edges (that is, edges in the source) could conceivably be used to set a priori likelihood on the location of the sources boundaries. For example, penalising variations in the source intensity at points in space not associated with edges, would amount to a (soft) constraint tending to make the source variation piecewise constant.

We believe that the main advantage of this approach is that it works in a framework ('worm diagram') that is in common use for geoscientists and consequently is easily interpretable from a geological point of view. It also allows a fast, fine-resolution analysis of maps many orders of magnitude larger than is possible for traditional, voxel based, inversion algorithms. Under the framework of an ongoing collaboration with Fractal Graphics, the algorithm will form the basis of both an interactive visualisation environment designed for hands-on use by field geologists and geophysicists and a 3-D full inversion procedure.