RECENT TRENDS IN COMPUTER CONTOURING

The contour map is, by far, the most common display mode for geophysical and geological data. With the increasing use of computers in geophysical data analysis, the demand for computer contoured maps is rapidly growing. Computer contouring has been available on a fairly routine basis for about ten years (see, for example, Dayhoff, 1963), but in spite of this, much programming effort (and money) is still being devoted to the research and development of new contouring programs. The main reason for this continuing research is the failure of previous effort to establish an interpolation technique for irregularly spaced data which gives consistently "good" results, under whatever definition of "good" is applied. The purpose of this note is to describe the directions of some recent research into the contouring problem, and hopefully to suggest in which direction the ultimate solution may lie.

Most of the literature on interpolation and contouring, up to the middle of 1969 has recently been reviewed (Crain, 1970). The review indicates that the majority of successfully used programs for interpolation are characterized by a certain "patchiness"; they are usually combinations of various methods which, on their own, are unsatisfactory. Others, are highly specialized and restricted to a certain type or style of data. Considering the vast literature on one-dimensional interpolation (e.g. Ralston, 1956), little theoretical work has been done on the smoothness, continuity or spectral properties of any of the two dimensional methods. A very recent paper by Naidu (1970) is one of the few to approach this problem.

As pointed out by Anderssen (1970) the main considerations in the past have been strictly numerical. Methods have been chosen on their ease of calculation rather than through knowledge of the underlying physics or statistics of the surface. Anderssen insists, in the first place, that all measurements do have some observational error. This swing from a deterministic to a stochastic approach is probably the most important new trend in the field at present. (The trend is also apparent in Geology; see Mann, 1970). One problem is this philosophy implies that all data points need not be 'validated', a violation of traditional contouring practice. This is no minor problem. One geologist I know, insists on interpolating <u>exactly</u> linearly , using proportional dividers, between adjacent data points, as if straight lines were somehow more 'correct' than any other smooth curve. In any event, Anderssen's plan of action is to <u>first</u> determine the error structure, whether it be normal, log-normal, exponential, or whatever, and <u>then</u> minimize the error in any of the customary senses such as least-squares or minimax. Such an approach has yet to be applied. Obviously the error structure of various types of data will differ, perhaps explaining why most present interpolation methods fail to be universal.

Another current trend in interpolation is towards the treatment of the surface as a whole. Attempts to produce a single (complicated) function to interpolate a large area have failed due to numerical problems, and the arbitrary and unrealistic nature of the chosen function (Crain, 1970). The new approach, however, is to produce a purely numerical surface, each point of which depends on all the available data points to some extent. The arbitrary choice of a functional form of the surface can be disregarded, and instead, the <u>properties</u> of the surface in terms of smoothness, continuity, etc. are specified based on knowledge of the true surface. Usually, this amounts to performing a numerical solution, by iterative techniques, to a differential equation. For instance, if you want a surface which is smooth and continuous everywhere except at the data points, and has maxima and minima only at the data points, you solve Laplace's equation. A fourth order equation can be used to generate the surface of maximum smoothness which passes through the data points (I.Briggs, 1970, pers. comm.). (A two dimensional equivalent to spline interpolation, Alberg et. al., 1967.) It should also be possible to add constraints of various kinds on the surface.

The other part of the contouring problem, that of actually drawing the contour lines from a square grid of points, can perhaps be declared "solved". Recent research has concentrated on increased sophistication and efficiency (e.g. Palmer, 1970). Contouring programs which produce drafting quality maps are now fairly common, with labelled contours (with line following lables), periodic reinforced contours, omitted contours on steep gradients, and even hatchures around depressions.

One recent paper has approached the contouring problem without the intermediate square grid (Lodwick and Whittle, 1970). The advantage is that the contour line segments are no longer bounded by a fixed grid and can be short where necessary and lengthened in smooth areas. This should provide for contour generation and plotting efficiency. An obvious disadvantage is the lack of a grid which is often a desired by-product for use in other types of processing such as spatial filtering and continuation.

Looking to the future then, it might be seen that within a few years we might be able, when attempting computer interpolation, to specify that we want "the smoothest possible surface, with no gradients greater than 'x', which minimizes in a least-squares sense a log-normal error", or any other combination appropriate to the data.

It should be remembered, however, that we usually have more information available than simply the data points, in the form of geological trends, known structures, or the knowledge that certain structures are impossible. Some attempts have been made to incorporate this type of information, such as Smith (1968), with varying success. The inclusion of this type of information in contouring programs is relatively unexplored and is likely to receive considerable attention in the future.

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