Wire-Frame Approximation of Surface from Contour Data by GA

Letter

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1. Introduction

Surface approximation by triangulation is treated as a combination problem of triangular elements in a polygon approximation with the original data as the point set. In geographical information processing approximating the original surface from contour line data information can be achieved through triangulation. Since geographical contour line data are continuous curves, it is necessary to make a polygon approximation of the contours before triangulation. An approximation technique as proposed in [1] could be used. The triangulation is then done between points on adjacent contour lines. Various contour triangulation schemes have been reported, for example[2][3]. These techniques ascribe to one or more of the following; 1). Deterministic sequential processing, 2). Evaluation based on local divisions, 3). Sequential division evaluation. The authors attempt to counter inadequacies in the above conventional methods in proposing a general yet simple contour line data triangulation scheme that is relatively technique independent and carries out the processing in a parallel manner[4]. In this study the authors use a Genetic Algorithm (GA) to triangulate digitized contour line data from a geographical map.

2. System Overview

In the proposed method, unlike the conventional methods, the evaluation of the triangulation is not patch by patch but global. Evaluation is done on the whole triangulation at each layer of contour and results in parallel instead of sequential triangulation. Because this kind of processing can make triangulation decisions independently at individual contour height levels, simultaneous processing of all contour levels becomes possible. However for now the levels are processed sequentially. The resultant triangulation is judged primarily on the evaluation score and visually by observing the 3D wire-frame model from the triangulation.

In this study a triangular division's degree of similarity to an equilateral triangle is adopted as the measure of fitness. GA is used to vary the combinations in the triangulation to minimize the total error. The overall evaluation is best when all the triangles in the triangulation approach an equilateral

triangle[5]. For each pair of adjacent lines we solve the problem of optimization for different combinations of patch lines. Suppose the angles in a triangle existing between two adjacent contour lines are θ_j ($j=1, 2, 3$) radians, the fidelity (E) is then given by

$$E = \left\{ - \sum_{j=1}^3 \left| \theta_j - \frac{\pi}{3} \right| \right\} + P \quad (1)$$

and if the number of triangles composed by synthesis at any one time at some arbitrary contour level is N , the fidelity becomes

$$E_{all} = \left\{ - \sum_{i=1}^N \sum_{j=1}^3 \left| \theta_{ij} - \frac{\pi}{3} \right| + P \right\} \quad (2)$$

where P is a penalty incurred by a patch line crossing either another patch line or a contour line and is defined as

$$P = \begin{cases} \alpha & : \text{if \{crossing occurs\}} \\ 0 & : \text{otherwise} \end{cases} ; (\alpha < 0).$$

The combination of patch lines for which E_{all} is a maximum gives the best triangulation of the contour data. For more natural 3D models the height component of the data points is included in the angle calculations.

It is necessary to encode the state of the triangulation into a gene for manipulation by GA. In this study, the problem is simplified by considering each contour line to form a closed loop. Generality is not lost since open loop contour lines can be adapted to form closed contour loop by preprocessing[6]. Each synthesized triangle has one side as a segment of a contour line and we use an assignment coding of $\{0, 1\}$ to distinguish between an upper contour and the lower contour. Figure 1 illustrates the effect. Genes are therefore made up of a row of bits having the values $\{0, 1\}$ the number of bits being equal to the number of patch lines to be determined. The result of triangulation was displayed in a three-dimensional wire-frame model for visual evaluation.

Figure 1

3. Simulation

To confirm the performance of this technique, contour line data was obtained and triangulation simulation done. In the experiment, we opted to use data that did not require any preprocessing and the originating contour lines were assumed to have undergone polygon approximation beforehand. Sample results of triangulation are shown in Figures 2. No hidden line processing is done for the three dimensional display wire-frame. Varying the inter-contour height at times leads to a change in the overall triangulation since the height is a factor in the evaluation. In the three dimensional display, the triangular patch forms seen in side view are closer to equilateral triangles though the two dimensional view may sometimes indicate otherwise.

4. Conclusion

A method of triangulation of contour line data approximated by a polygon and a general method of evaluation were proposed and their validity confirmed by simulation. Since a processing system using simple GA is adopted to search for a pseudo-optimal solution, the implementation of the whole system in hardware is expected to be simple. This study is considered a stepping stone to application to more complex topographical maps and to general triangulation problems. The essential limitation of GA is that it is difficult to prevent it from locking onto a local optimum solution and also that the processing time is long compared with the sequential triangulation methods. These are the major shortcomings that need to be improved on.

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Figure 2