Quadrilateral Mesh Smoothing Using a Steady State Genetic Algorithm

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Abstract. This paper investigates the use of a steady state genetic algorithm (GA) to perform quadrilateral finite element mesh smoothing. GAS short for genetic algorithm smoother moves one to 64 nodes at the same time. GAs smooth as well as untangle (removing twisted and inverted elements), which has been a separate operation in the past.

1 Introduction

A common use of finite elements analysis (FEA) is to determine displacements and stresses of a structure. Automeshers fill the model with finite elements establishing connectivity between the element nodes; it is the objective of mesh smoothers to insure the quality of the mesh once connectivity has been established. Poorly shaped finite elements result in incorrect results. This paper compares a GA smoothing tool with the Laplace smoothing method.

2 Finite Element Smoothing with a GA

FlexGA, the genetic algorithm engine used in this paper, is written in MATLAB and was developed by Dr. K. K. Kumar, The Flexible Intelligence Group, Tuscaloosa, AL. The objective function created by Alan Oddy, at Carleton University in Ottawa, Canada was written in C and interfaced with MATLAB using CMEX, the MATLAB/C interface code [1].

The GA works on a family of chromosomes that in this problem represents the X/Y coordinates of each element node. The distortion metric was augmented with penalty functions. There are penalty functions that check for quadrilateral interior angles being equal to 90 degrees; aspect ratios equal to one and twisted or inverted element. The angular penalty function is

$$pf = \sum_{i=1}^{4} \frac{(\varphi_i - 90)^2}{SF}$$

GAS-N moves all of the element nodes at a time. An upper limit of about 64 nodes was run using GAS-N. A rectangle with a cutout was created to fool the Laplace smoother to see how the GA would perform using movable boundary nodes. (See Figure (a)).

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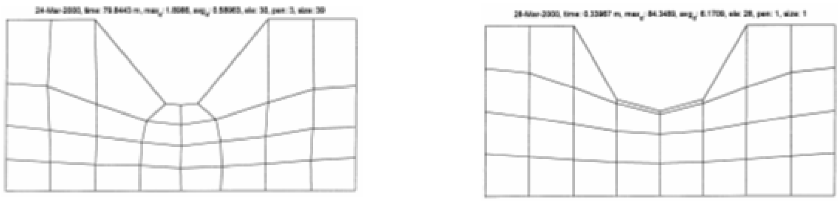
3 Results

For simple meshes, the Laplace smoother outperformed the GAS-N smoother when both accuracy and computational time were considered. However, GAS-N usually outperformed the Laplace method in terms of accuracy when complex geometries were encountered. An example can be seen in the rectangle shown in Figure (a) with a semicircular cutout. Figure (b) presents this mesh smoothed with the Laplace method (maximum distortion of 84.3) with Figure 1 giving the mesh smoothed with GAS-N using movable boundary nodes (maximum distortion of 1.9).



(a) GAS-smoothed with movable boundary nodes

(b) Laplace-smoothed

Using a series of square "checker board" models ranging in size from and 8x8 mesh to a 3x3 mesh, it was determined that 64 X/Y node coordinates can be successfully manipulated at a time. A more reasonable upper limit is 35 active nodes. It was also determined that 16 movable nodes is the controllable limit of GAS-N without the use of feasible circles to limit the individual nodal search areas.

In conclusion, GAS-N's ability to move small groups of nodes simultaneously during the smoothing process makes it potentially an effective tool for smoothing large meshes.

References

1. Holder, E. M., (2001). Quadrilateral Mesh Smoothing Using a Genetic Algorithm, Doctoral Dissertation, University of Alabama.