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Linear and Rotary Displacement in Finite Element Sensitivity Computation
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Abstract. This paper presents a new parametrised mesh generator for sensitivity computation in finite element optimization. The generator allows repeated solutions with iterated meshes so that it can be employed in a first order optimization strategy exploiting its faster convergence rates.

1. Parameterization for Optimization

Parameterization renders the finite element mesh generation process easy for repeated studies. Thus to study the effect of, say, the size of a part, the finite element problem can be defined by a parametric description of the dimensions of that part and repeatedly studied for different values of those dimensions. Such a facility is available with many commercial codes such as Flux [1]. These mesh generators are useful for zeroth order optimization studies where object functions can be computed under post-processing.

For higher order optimization purposes, however, parameterization must follow certain rules [2] or C1 continuity will be lost and mesh induced minima will be seen as local minima by the optimization process. A second elastic deformation accompanied by a structural mapping has been employed to enforce the required rules with meshes, but the process is time consuming and involves repeatedly solving a larger structural problem than the electromagnetic field problem at hand [3]. Elastically deforming meshes within selected domains has been done. Here we give a general mesh generator.

2. The rule

Several kinds of movements are possible with parameters. We give the general equations for linear and rotary motion (other kinds of motion will be left for the full paper. The basic rule is that connectivity between nodes is to be preserved.

3. Selecting parametrized box or Rectangular boundary

Any node in a mesh topology can be allowed to move with parameters on either side of the mesh boundary. For a given problem, the boundary for moving nodes has to be selected. Here, the nodes are considered to move either in the horizontal (X) or Vertical (Y) direction. The corresponding left and right most limits in the direction X are denoted X_l and X_r respectively. Similarly top and bottom most limits in the Y direction are denoted by Y_t and Y_b respectively. These limits can be decided with respect to the given problem and it gives the Parametrized box or Rectangular Boundary for moving nodes.

4. Determining ratio of nodal divisions

Let P be a variable point on the material interface and Q be an arbitrary point in the selected rectangle moving boundary. The selected boundary can be divided into four quadrants by drawing horizontal and vertical lines through the point P . Hence the point Q can be seen in one of the four quadrants of the rectangular boundary. Now let the x-y coordinates of points P and Q are denoted by Px, Qx, Py, Qy respectively.

The ratio of nodal divisions R can be determined from the location of nodes. It varies with respect to the moving directions. The moving ratio can be calculated as given in the algorithm as follows:

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if (P=Q) then R = 1
  else if (Qx = Px) then
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            if (Qy >= Py) then
              R = (Yu - Qy)/(Yt - Py);
            else
              R = (Qy - Yb)/(Py - Yb);
    else if (Qx > Px) then
            R1 = (Xr - Qx)/(Xr - Px);
            if (Qy >=Py) then
              R2 = (Yt - Qy)/(Yt - Py);
            else
            R2 = (Qy - Yb)/(Py - Yb);
            R=R1*R2;
    else
            R1 = (Xl - Qx)/(Xl - Px);
            if (Qy >=Py) then
              R2 = (Yt - Qy)/(Yt - Py);
            else
            R2 = (Qy - Yb)/(Py - Yb);
            R = R1*R2;
    end if
```

5. Results

The mesh of Fig. 1 shows the movement of lines. The vertical line lengths below the jagged dark contour are parameters. The dark jagged line is a material boundary and defines the shape of the pole face. As a line length parameter changes, all nodes on it are moved preserving the ratio of nodal divisions on the line while the same automatically happens to the vertical part above the contour. Fig.2 shows part of the principle behind the generator for nodal coordinate parameters. The circled nodes (on an optimized boundary) are moved elastically to their new positions. Such changes preserve derivative continuity. The derivatives may be computed very easily through readily implemented algorithms.

6. Conclusions

A flexible parametrised mesh generator for optimization has been demonstrated to model moving (i.e., optimized) shapes. The applicable equations will be in the full paper.

7. Acknowledgements

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8. References

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[3] [3] K. Weeber and S.R.H. Hoole, "A Structural Mapping Technique for Geometric Parametrization in the Synthesis of Magnetic Devices," Int. J. Num. Meth. Eng. Vol. 33, pp. 2145-79, July 15, 1992

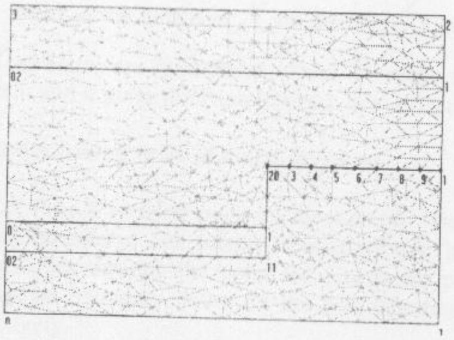

Fig.1: Movement of lines

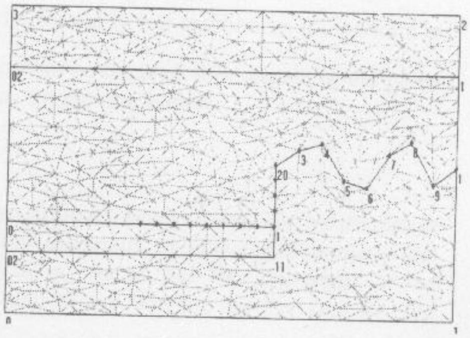

Fig 2: Circled Nodes move elastically pulling the mesh