***** WORKING DRAFT ******

Finite Octree Mesh Generation and Output Options

SCOREC Report # 6–1994

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June 29, 1994

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1 Introduction

Finite Octree is a fully automatic mesh generator that can mesh general non-manifold solids[1] [7]. Currently, Finite Octree supports the generation of tetrahedral solid, triangular surface and line elements.

Finite Octree interfaces directly with geometric modeling systems through a fixed set of operators which answer geometric and topological inquiries by the mesh generator. Finite Octree is available with interfaces to Parasolid™, Catia™, Shapes™, ACIS™ and SCOREC 3D geometric modelers.

This document describes the mesh generation and output options in Finite Octree. A companion document [4] describes specification of mesh control functions in Finite Octree

[1] Non-manifold objects are general combinations of wires, surfaces and solids and may have surfaces touching at an edge or a single point.

2 Mesh generation options in Finite Octree

Finite Octree supports a wide range of mesh generation options such as type of elements to be created (solid tetrahedrons, surface triangles or line elements), order of the elements (straight sided or quadratics), node renumbering, etc.,. Also supported are various formats for outputting the mesh. All these options are specified in an input file called **OCTREE.FLG**. In the absence of this file, the mesh generator assumes a default set of options.

Shown in Figure 1 is a sample **OCTREE.FLG** showing the default values of the various fields in the file. The organization of the file is such that the first column of each line sets a flag or a parameter, the second column contains a brief explanation of what the flag is and the rest of the line (where applicable) gives the possible values for the flag and what they mean. A detailed explanation of what each options follows[2].

1. Finite Octree has a procedure to eliminate poorly shaped elements by collapsing of elements whenever possible. Setting this flag to 1 will cause the application of this procedure to the mesh. (Default — On)
2. Set this option to 1 to smooth the mesh (Edge swapping to improve surface triangulation, constrained Laplacian smoothing and explicit smoothing [3]). Edge swapping attempts to improve the surface triangulation by optimizing the surface mesh topology and also performs swapping of interior mesh edges and faces to improve element shapes. Laplacian smoothing tries to improve element shapes by moving nodes to the centroid of its neighboring nodes. Explicit smoothing considers the shapes of surrounding elements to select a direction of movement of a node to improve the worst shaped element. Since elements on the interior of the mesh are well shaped, smoothing is only applied to nodes near the boundary of the model. Set this option to 2 to perform constrained Laplacian smoothing only, to 3 to perform explicit smoothing only, to 4 to perform constrained Laplacian and explicit smoothing, or to 0 to perform no smoothing. (Default — Swapping, Laplacian, and explicit)
3. Flag to turn on evaluation of geometric approximation error for chosing best surface triangulation. (Default — Off)
4. Turning this option on will create midside nodes on each finite element edge thus creating quadratic elements. (Default — Off)

[2] Programmer's note: The default settings of the various flags can be modified in the routine *gtflgs*.

Figure 1 **OCTREE.FLG** file showing the default options

1	*1*	*Invoke Drep:*		*0-No*	*1-Yes*
2.	*1*	*Smooth mesh*	*0-No*		*1-Surface,Explicit,Swapping*
			2-Surface	*3-Explicit*	*4-Surface,Explicit*
3	*1*	*Use distance criteria in triangulation*		*0-No*	*1-Yes*
4.	*0*	*Create higher order nodes*		*0-No*	*1-Yes*
5.	*0*	*Place higher order nodes on surface*	*0-No*	*1-Do not alter mesh*	*2-Alter mesh*
6.	*0*	*Reorder nodes*		*0-No*	*1-Yes*
7.	*0*	*Write SCOREC model and mesh files*		*0-No*	*1-Yes*
8.	*1*	*Create Movie BYU file*		*0-No*	*1-Yes*
9.	*1*	*Save Octree file*		*0-No*	*1-Yes*
10.		*Flag not used*			
11.		*Flag not used*			
12.		*Flag not used*			
13.		*Flag not used*			
14.	*20*	*Ratio of shortest octant side length to shortest fe edge*			
15.	*1*	*Print out mesh statistics*		*0-No*	*1-Yes*
16.		*Flag not used*			
17.	*0*	*Output file in PATRAN™ neutral file format*		*0-No*	*1-Yes*
18.	*500*	*Maximum allowable longest edge / shortest height ratio for elements*		*0-No*	*1-Yes*
19.	*2*	*Boundary or solid mesh*		*1-Boundary*	*2-Solid*
20.	*1*	*All tet, hex, or mixed*	*1-tet*	*2-hex*	*3-mixed*
21.	*0*	*Print warning messages to screen and file*		*0-No*	*1-Yes*
22.	*1*	*Check mesh after meshing and # of iterations:*		*0-No*	*1-Yes*
23.	*1*	*Aspect ratio of the universe*			

5. This flag must be on for the mesh generator to pull the midside nodes of higher order mesh edges to the surface of the model. Set this option to 1 to pull midside nodes to the model surface. Selected mesh edges will be "uncurved" if necessary to ensure valid elements. Set this option to 2 to pull midside nodes and invoke local retriangulation to reduce the number of "uncurved" edges (this setting is allowed only if small feature elimination is not performed). Note that regardless of whether this option is set to 1 or 2, some midside nodes may not be pulled to the model surface. Midside nodes are not pulled to the model if hexahedral meshes are specified. (Default — Off)
6. Set this option to 1 for reordering the nodes. (Default — Off)
7. This is an option to output the model topology and the mesh in the SCOREC model and mesh file formats [1] respectively. The respective filenames are ***modelname*.smd** and ***modelname*.sms**. (Default — Off)
8. Turning this option on creates a file called ***modelname*.MOV** containing mesh information in the CAEDOS format. This can then be imported into a visualization software such as Moviestar^{TM}[2] from Brigham Young University. If this option and the option to create higher order nodes is on, the file ***modelname*.MOV** will contain a representation of the mesh in which each curved side is split into two straight line segments. A second file, ***modelname*.mov** is created containing the corresponding straight sided mesh. (Default — On)
9. When this option is on, a binary mesh file called ***modelname*.OCT** is created. (Default — Off)
14. Maximum allowable shortest octant side length to shortest finite element edge length. (Default — 20.0)
15. Turning this option on will create mesh statistics to be written to a file called ***modelname*.STS**. (Default — On)
17. This is an option to output the mesh in Patran^{TM} neutral file format [6][5] in the file ***modelname*.NTL**. (Default — Off)
18. This sets an upper limit for the ratio of the longest finite element edge to shortest height of elements. (Default — 500.0)
19. If this option is 1, only a shell mesh is created; if it is 2 a solid mesh is created. For models with no regions the mesh generator will create a shell mesh irrespective of the value of this parameter. (Default — 2)

20. This parameter controls whether a tetrahedral or hexahedral mesh will be created. Tetrahedral meshes are created by setting this option to 1, and hexahedral meshes are created by setting it to 2. (Default — 1)
21. This flag is used to suppress or turn on the printing of warning messages to the screen and the error file. Error messages are always printed out regardless of the setting of this flag. (Default — 0)
22. Flag to make Finite Octree check the mesh and refine a local region of the mesh in which element shapes are unacceptable. (Default — On)
23. This is the aspect ratio of the root octant used to generate the octree. (Default — 1.0)

3 Finite Octree output

The output of Finite Octree can be divided into the following categories

1. Binary mesh files
2. ASCII mesh files
3. ASCII model files
4. Mesh statistics
5. Output log

A Finite Octree mesh can currently be output in three different ASCII file formats — SCOREC mesh file format, PATRAN^{TM} neutral file format and CAEDOS format. The corresponding files are called ***modelname*.sms**, ***model-name*.NTL**[6][5] and ***modelname*.MOV** respectively. The ***modelname*.sms** file is always accompanied by a file ***modelname*.smd** which describes the geometric model topology in the SCOREC model file format.

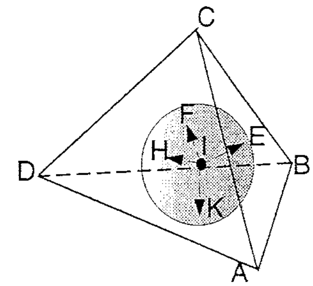
The SCOREC mesh file format is a mesh description format designed to be used with the SCOREC Mesh Database. The SCOREC Mesh Database is set of procedures which allow for easy access and manipulation of a finite element mesh [1]. SCOREC Mesh Database operators provide a simple but powerful way to manipulate meshes and using them to write translators other mesh file formats is a relatively easy task. SCOREC Mesh Database takes as its input a finite element mesh described in the SCOREC mesh file format and when available, the geometric model description in the SCOREC model file format. [1] describes the use of the SCOREC Mesh Database operators, and the SCOREC mesh and model file formats.

Mesh statistics in Finite Octree are written out in the file ***modelname*.STS**. The first block of the statistics file contains the cpu times in seconds for each phase of meshing. The second block lists the number of finite element nodes, surface triangles and tetrahedrons in the mesh.

The third block consists of a list of element characteristics as follows

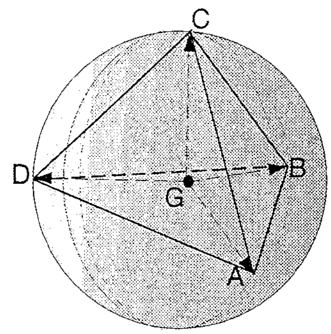
1. Worst shape $2187 * \left(V^4/(\sum A_i^2)^3\right)$ where V is the volume of the element and A_i the area of the ith face of the element. The measure is normalized so that it is 1.0 for a regular tetrahedron. The high power on this quantity produces very low values for reasonably shaped elements. The advantage of this measure is its computational efficiency.

(a)



I - Incenter of tetrahedron
IK ⊥ ACB, IE ⊥ ADB, IF ⊥ CDA, IH ⊥ BDC
IK = IE = IF = IH = r (Inradius of tetrahedron)

(b)



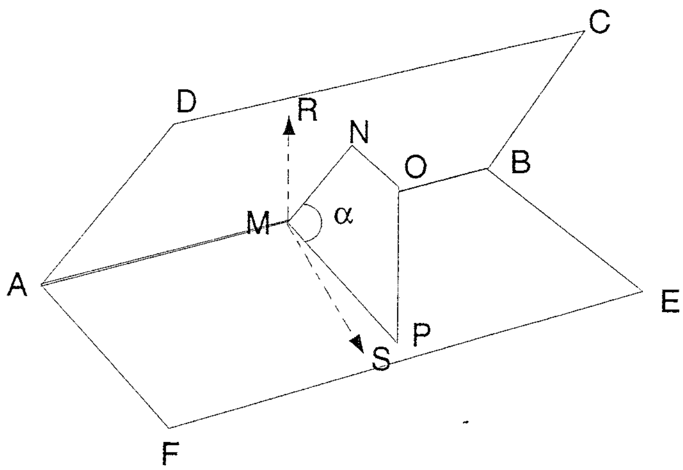
G - Circumcenter of tetrahedron
GD = GA = GB = GC = R (Circumradius of tetrahedron)

Figure 2 a) Inscribed sphere of a tetrahedron
b) Circumscribed sphere of a tetrahedron

2. Worst shape $(3r)/R$ where r is the radius of the inscribed sphere[3] and R is the radius of the circumscribed sphere[4] (See Figure 2a,b). The measure is normalized so that it is 1.0 for a regular tetrahedron.
3. Smallest dihedral angle (The dihedral angle between two intersecting faces is defined as the supplement of the angle between normals to the faces at a point on their line of intersection. In Figure 3 angle PMN is the dihedral angle between faces ABCD and ABEF. By definition, it is also the supplement of angle SMR, where MS and MR are normal to ABCD and ABEF respectively).

[3] The inscribed sphere of a tetrahedron is a unique sphere touching all four faces of a tetrahedron. Its center and radius are referred to as the incenter and the inradius respectively.

[4] The circumscribed sphere of a tetrahedron is a unqiue sphere passing through all its vertices. Its center and radius are referred to as circumcenter and circumradius respectively.



MN ⊥ AB in the plane ABCD, MP ⊥ AB in the plane ABCE
MS ⊥ ABCD at M, MR ⊥ ABEF at N
Dihedral angle - ∠PMN (α) or 180° - ∠SMR)

Figure 3 Dihedral angle between two faces

4. Largest dihedral angle
5. Largest ratio of the largest edge to shortest edge of an element
6. Largest ratio of the largest edge to shortest height (altitude) ratio

Finite Octree creates an ascii log file called ***modelname*.ERR** in which information about completion of mesh generation stages, error messages and warnings are recorded. A typical log is shown below.

```
MODEL SPECIFIER: simple
Inserting model vertices
Inserting model edges
Inserting model faces
Inserting model interior
Generating solid mesh
Improving tree representation
Smoothing model surface
Improving element shapes
Checking element shapes
```

Warnings and error messages are inserted into the log as they occur.

4 Bibliography

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