**PACKAGE ID -** 001353MLTPL00 OPT-MS

**KWIC TITLE -** Local, Optimization-based Simplicial Mesh Smoothing

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**LIMITATION CODE -**COPY **AUDIENCE CODE -** UNL

**COMPLETION DATE -** 07/01/1999 **PUBLICATION DATE -** 07/01/1999

**DESCRIPTION -** OPT-MS is a C software package for the improvement and untangling of simplicial meshes (triangles in 2D, tetrahedra in 3D). Overall mesh quality is improved by iterating over the mesh vertices and adjusting their position to optimize some measure of mesh quality, such as element angle or aspect ratio. Several solution techniques (including Laplacian smoothing, "Smart" Laplacian smoothing, optimization-based smoothing and several combinations thereof) and objective functions (for example, element angle, sin (angle), and aspect ratio) are available to the user for both two and three-dimensional meshes. If the mesh contains invalid elements (those with negative area) a different optimization algorithm for mesh untangling is provided.

**PACKAGE CONTENTS -** Media Directory; Software Abstract; Media Includes Source Code, Sample Problem Input and Output Data, Make Files;

**SOURCE CODE INCLUDED? -** Yes

**MEDIA QUANTITY -** 1 CD Rom

**METHOD OF SOLUTION -** The optimization-based smoothing problem is formulated as max min_m q(x), where min_m q(x) is a non smooth composite function whose components, q(x), are nonlinear, smooth, and continuously differentiable functions of the free vertex position. This non smooth optimization problem is solved using an analogue of the steepest descent method for smooth functions. The search direction, s, at each step is the steepest descent direction derived from all possible convex linear combinations of the gradients in the active set. The line search subproblem along s is solved by predicting the points at which the active set will change. These points are found by computing the intersection of the projection of a current active function in the search direction with the linear approximation of each function given by the first-order Taylor series approximation. The distance to the nearest intersection point from the current location gives the initial step length. The initial step is accepted if the actual improvement achieved by moving the free vertex exceeds 90% of the estimated improvement or the subsequent step results in a smaller function improvement. Otherwise, the step length is halved recursively until a step is accepted, or if fails below some minimum step length tolerance. The optimization based untangling

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**METHOD OF SOLUTION -(CONT)** problem is formulated using the objective function max min Area (volume) of the simplices in the local submesh. This objective function is linear in the free vertex position and the simplex method is used to solve the resulting linear program. Noting that certain cases of this problem are degenerate, the following well-posed conditions are assumed: (1) the vertices of the submesh do not all lie in a lower-dimensional subspace than the original problem and (2) none of the vertices are co-located at the same point in space. Mesh untangling often results in poor quality meshes because the technique has no motivation to create good quality elements; in fact, this technique can distort small equilateral elements in an effort to increase their volume. In practice, meshes untangled using this procedure often contain elements with angles as small as 10 to the minus 3rd degrees, and this technique must be followed by one or more of the mesh improvement techniques discussed previously.

**COMPUTER -** MLT-PLTFM

**OPERATING SYSTEMS -** sunOs, solaris, IRIX 6.4 and 6.5

**PROGRAMMING LANGUAGES -** C

**SOFTWARE LIMITATIONS -** 1) works only with simplicial meshes (triangle in 2D and tetrahedra in 3D). Ongoing research is planned to extend the algorithms to hexahedral and mixed element meshes. 2) works only with 2D planar surfaces and 3D volume meshes. Non-planar surfaces must be smoothed by projecting them to a planar surface and then snapping the resulting new location of the free vertex back to the curved surface. 3) the optimization routine works to improve the worst quality element in the mesh, and, as a result, can sacrifice average mesh quality. The combined approaches somewhat mitigate this effect by using Laplacian smoothing everywhere to improve average quality and optimization only in the worst quality elements. 4) the optimization technique is guaranteed to converge only for objective functions with convex level sets so user experimentation with non-concave functions may lead to meshes of worse quality than the original mesh. 5) works only with a priori improvement based on geometric information. There are no mechanisms in place for posteriori improvement based on solution accuracy measures.

**SOURCE CODE AVAILABLE (Y/N) -** Y

**UNIQUE FEATURES -** The use of the non-smooth optimization algorithm for local mesh improvement and the linear programming approach for mesh untangling are new. The application interface is very simple, and the software package can be used with only three calls to the Opt-MS library. The required input is straightforward for any mesh generation software to create.

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**RELATED SOFTWARE -** BLAS and LAPACK

**HARDWARE REQS -** 10 Mbytes storage for the initial source code and approximately 4 additional Mbytes for each compiled library instantiation.

**TIME REQUIREMENTS -** The time required varies with the size of the mesh and the technique chosen. In computational experiments performed, the following time requirements per mesh grid point were found for the different techniques on a SPARC10 workstation: Smart Laplacian Smoothing .440 ms, Optimization based smoothing 2.08 ms, Default Combined Technique .936 ms, Untangling Technique .256 ms.

**ABSTRACT STATUS -** Released AS-IS 10/2/2000

**SUBJECT CLASS CODE -** Z

**KEYWORDS -**
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O CODES
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**EDB SUBJECT CATEGORIES -**
990200

**SPONSOR -** DOE

**PACKAGE TYPE -** AS - IS