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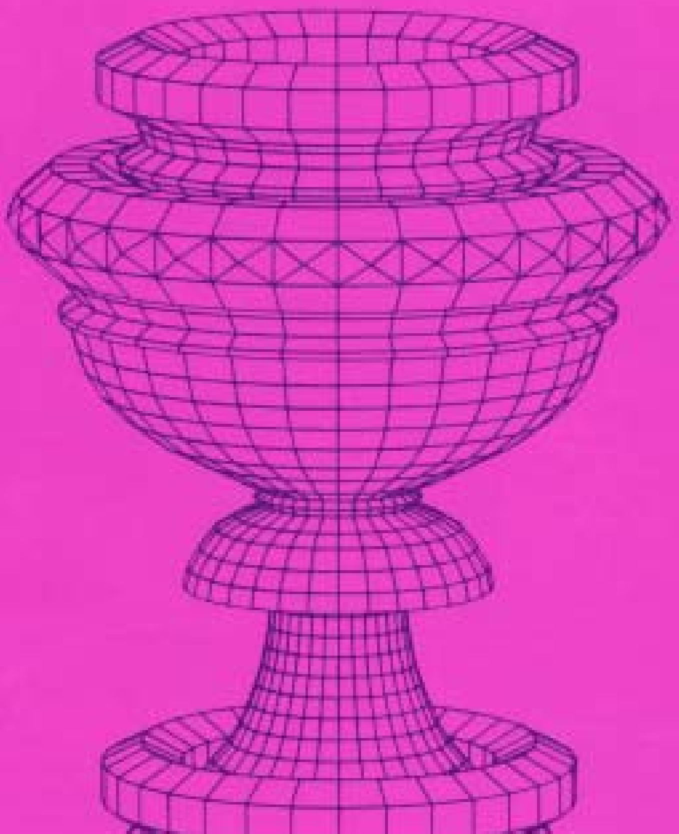

SPECIAL ISSUE: GRID GENERATION, FINITE ELEMENTS, AND GEOMETRIC DESIGN

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CONTENTS

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Computer Aided Geometric Design 12 (1995) 647-649

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Preface

Grid Generation, Finite Elements, and Geometric Design

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This special issue developed from a proposal to the Society for Industrial and Applied Mathematics (SIAM) to illustrate, in a book of contributed papers, the mutual influences that exist among the areas of finite elements (FE), grid generation, and computer aided geometric design (CAGD). For example, a major goal was to show the usefulness of geometric design concepts when developing FE and grid generation methods. The plan to edit a collection of papers from these fields originated during the Third SIAM Conference on Geometric Design, which was held during the first week of November, 1993, in Tempe, Arizona.

For various reasons, the book proposal did not come to fruition, and we turned to CAGD to publish the papers submitted to us. Because of space limitations, we could not publish all the papers accepted for the book in a single issue of CAGD. As a result, the papers that fit well within the scope of CAGD have been dispersed in several issues of the journal, while those that pertain to FE, grid generation, and related subjects are presented in this special issue.

The special issue contains one review paper and five current research articles. The survey article (by David Field) provides some background for the CAGD reader who is not familiar with FE methods and grid generation. The special issue provides a blend of papers from surface grid generation, volume grid generation, grid optimization, and potential applications of homology theory to the generation of FE grids and FE systems of equations. The similar underlying concepts will help propagate research among disciplines and, hopefully, increase the interest in FE and grid generation problems in the CAGD community.

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The special issue emphasizes the variety of fields for which discretization of three-dimensional geometries is essential. Most authors are, or were, practitioners from industry or members of multidisciplinary research institutions, such as the NSF Engineering Research Center for Computational Field Simulation at Mississippi State University. As a result, most authors address practical engineering problems.

David Field, in his overview paper "The legacy of automatic mesh generation", reviews early efforts to automatically create FE meshes from solid models. Parametrically defined blocks of FEs initially dominated mesh generation, but the creation of more complex solids forced mesh generation away from the direct use of parametrizations. The review emphasizes the earliest and most important techniques for mesh generation that relied on solid modeling and includes the more recent advancing front technique. Current developments and directions in automatic mesh generation are outlined.

Bharat Soni and Shaochen Yang ("NURBS based surface grid redistribution and remapping algorithms") present algorithms to redistribute, refine, remap, and optimize structured surface grids for computational fluid dynamics (CFD) applications involving complex regimes. Non-uniform rational B-splines (NURBS) are used for the representation of parametric surfaces. A semi-automatic remapping algorithm is discussed leading to a simplified surface grid generation process that reduces the time required for grid generation for complicated surfaces involving holes, gaps, and interior objects. Transfinite interpolation and elliptic generation schemes are enhanced for the optimization process considering grid line orthogonality and smoothness.

The paper "Automatic generation of hexahedral finite element meshes" by Robert Schneiders and Rolf Bünten discusses a new method for the generation of FE meshes consisting of quadrilateral or hexahedral elements for the simulation of metal forming. The objective is the reduction of mesh distortion, and the algorithm is demonstrated for the simulation of a complex forging process.

A solution-adaptive FE procedure for simulating complex flow fields about complicated aerospace configurations is presented in the paper "Aerospace applications of solution adaptive finite element analysis" by David Marcum and Nigel Weatherill. A new adaptive grid generation method based on the Delaunay triangulation combined with adaptation sources is discussed. The method allows the generation of high-quality solution-adapted grids. Adaptation sources are identified automatically. The sources are placed in regions with complicated flow field features.

The next two papers are included here in an attempt to "look over the horizon" of current CAGD, FE, and grid generation, which are based mainly on numerical analysis, to geometric modeling work of a non-numerical nature. We believe that non-numerical tools most likely will be combined with CAGD, FE, and grid generation in the engineering software of the future. The two examples presented here involve applications of algebraic topology.

Richard Palmer ("Chain models and finite element analysis: An executable CHAINS formulation of plane stress") uses algebraic-topological k-chains for the definition of a computer language, called "CHAINS", whose basic data types are cells, cell complexes, and k-chains. The goal of CHAINS, in applications, is formal generation of FE systems of equations. More fundamentally, CHAINS is a step towards the goal of automating the process of creating software for scientific computing by raising the semantic level at which physical systems are specified.

The paper "An incremental algorithm for Betti numbers of simplicial complexes on the 3-sphere" by Jose Delfinado and Herbert Edelsbrunner presents an improved algorithm for computing Betti numbers in the context of alpha shapes. Roughly speaking, the Betti number is an algebraic measure of the "number of holes" in a triangulated polyhedral object. Alpha shapes are sequentially refined representations of suitably triangulated finite point sets in two and three dimensions. These representations are simplicial complexes containing progressively more proximity information about the underlying point set. The representation at any given level is a subcomplex of the representation at the next (higher) level. Alpha shapes facilitate detailed cluster analysis of point data and are therefore useful in model discretization for analysis and visualization.

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