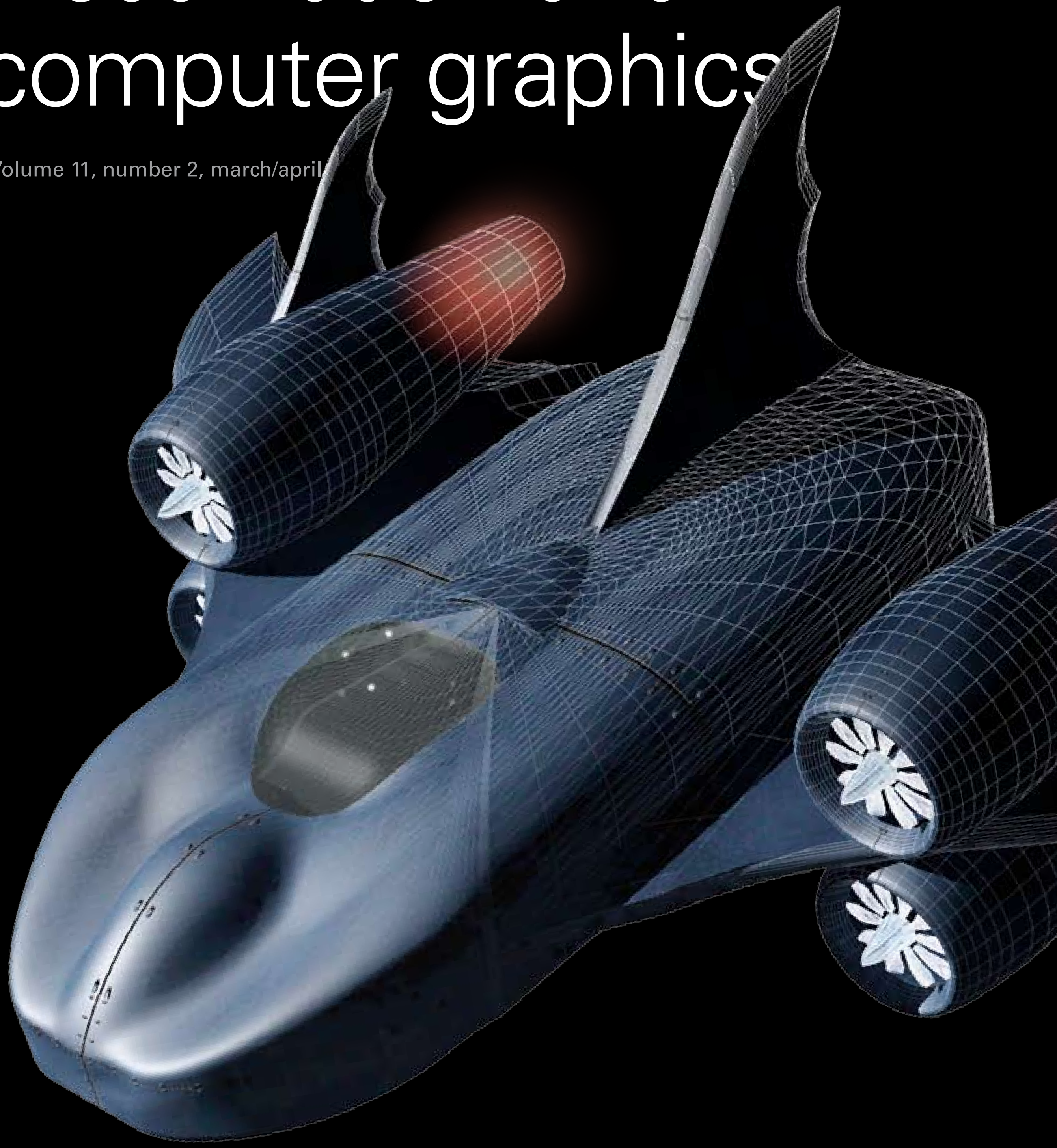
IEEE transactions on visualization and computer graphics · volume 11, number 12, march/april 2005

12

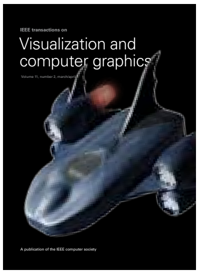
IEEE transactions on

Visualization and computer graphics

Volume 11, number 2, march/april



A publication of the IEEE computer society



IEEE transactions on
Visualization and
computer graphics
Volume 11, number 2, march/april

A publication of the IEEE computer society

IEEE transactions on

Visualization and computer graphics

Editor-in-chief

David S. Ebert
School of electrical and computer engineering
1285 EE building
Purdue University
West Lafayette, IN 47906
+765 494 9064 / +765 494 6905 (fax)
ebertd@purdue.edu

Associate editor-in-chief

Charles D. Hansen
School of computing
University of Utah
50 S. Central campus drive, 3190 MEB
Salt Lake City, Utah 84112
(801) 581-3154
hansen@cs.utah.edu

Editorial board

Georges-Pierre Bonneau
Lab. Gravir
Georges-Pierre.
Bonneau@imag.fr

Leila De Floriani
universita' di Genova
deflo@disi.unige.it

Julie Dorsey
Yale University
dorsey@cs.yale.edu

Thomas Ertl
University of Stuttgart
Thomas.Ertl@informatik.
uni-stuttgart.de

Rond Fedkiw
Stanford University
fedkiw@cs.stanford.edu

Michael Gleicher
University of Wisconsin
gleicher@cs.wisc.edu

Eduard Gröller
Vienna University
of Technology
groeller@cg.tuwien.ac.at

Baining Guo
Microsoft research Asia
bainguo@microsoft.com

Ken Joy
University of
California at Davis
joy@cs.ucdavis.edu

David Kao
NASA Ames research center
davidkao@nas.nasa.gov

David Laidlaw
Brown University
dhl@cs.brown.edu

Anselmo Lastra
University of North
carolina at Chapel Hill
Lastra@cs.unc.edu

Ming C. Lin
University of North Carolina
lin@cs.unc.edu

Alex Pang
University of California,
Santa Cruz
pang@cse.ucsc.edu

Rick Parent
Ohio State University
parent@cis.ohio-state.edu

Hanspeter Pfister
Mitsubishi electrical
research laboratories
pfister@merl.com

Steven Roth
Maya viz
roth@maya.com

Hans-Peter Seidel
MPI Informatik
hpseidel@mpi-sb.mpg.de

Chris Shaw
Georgia institute
of technology
cdshaw@cc.gatech.edu

Claudio Silva
OGI
csilva@cse.ogi.edu

John Stasko
Georgia institute
of technology
stasko@cc.gatech.edu

Rüdiger Westerman
Technische Universität
München
westermann@in.tum.de

Advisory board

Henry Fuchs
Univ. of North Carolina,
Chapel Hill
fuchs@cs.unc.edu

Hans Hagen
University of Kaiserlautern
hagen@informatik.uni-kl.de

Patrick Hanrahan
Stanford University
hanrahan@phot.stanford.edu

Arie E. Kaufman
State Uiv. of New York
at Stony Brook
ari@cs.sunysb.edu

Gregory M. Nielson
Arizona State University
nielson@asu.edu

Lawrence J. Rosenblum
rosenblum@ait.nrl.navy.mil

Manuscript submission / status inquiries – For information on submitting a manuscript or on a paper awaiting publication, please contact: Transactions assistan TVCG, IEEE Computer Society, 10662 Los Vaqueros Circle, PO Box 3014, Los Alamitos, CA 90720-1314 USA; email: tvcg@computer.org, phone: +1 714 821 8380; fax +1 714 821 9975.

About the cover image – Hairstyles produced by the constraint-based styler. Image adapted from figure supplied by Byoungwon Choe and Hyeong-Seok Ko, School of electrical and computer science, Seoul National University, Korea. See article, page 160.

Papers

Sharpen & bend: Recovering curved sharp edges in triangle meshes produced by feature-insensitive sampling

Marco Attene, Bianca Falcidieno, Jarek Rossignac and Michela Spagnuolo

Abstract — Various acquisition, analysis, visualization, and compression approaches sample surfaces of 3D shapes in a uniform fashion without any attempt to align the samples with sharp edges or to adapt the sampling density to the surface curvature.

Consequently, triangle meshes that interpolate these samples usually chamfer sharp features and exhibit a relatively large error in their vicinity. We present two new filters that improve the quality of these resampled models. EdgeSharpener restores the sharp edges by splitting the chamfer edges and forcing the new vertices to lie on intersections of planes extending the smooth surfaces incident upon these chamfers. Bender refines the resulting triangle mesh using an interpolating subdivision scheme that preserves the sharpness of the recovered sharp edges while bending their polyline approximations into smooth curves. A combined Sharpen&Bend postprocessing significantly reduces the error produced by feature-insensitive sampling processes. For example, we have observed that the mean-squared distortion introduced by the SwingWrapper remeshing-based compressor can often be reduced by 80 percent executing EdgeSherpener alone after decompression. For models with curved regions, this error may be further reduced by an additional 60 percent if we follow the EdgeSharpening phase by Bender.

Index Terms — Computer graphics, computational geometry and object modeling, boundary representations, geometric algorithms, languages and systems.

1 INTRODUCTION

The surfaces of 3D models are often represented by approximating triangle meshes. Their triangles are the simplest form of interpolant between surface samples, which may have been acquired with a laser scanner [21, [3], [181, computed from a 3D scalar field resolved on a regular grid [8], [32], or identified on slices of medical data [101, [12]. Most acquisition techniques restrict each sample to lie on a specific line or curve whose position is completely defined by a preestablished pattern. For example, a laser-scanner measures distances along a family of parallel or concentric rays that form a regular pattern or grid. One may also argue that an isosurface extraction uses three such patterns, aligned with the three principal directions. Because the pattern of these rays or stabbing curves is not adjusted to hit the sharp edges and corners of the model, almost none of the samples lie on such sharp features. Therefore, the sharp edges and corners of the original shape are removed by the sampling process and replaced by irregularly triangulated chamfers. The error between the original shape and the approximating triangle mesh may be decreased by using a finer sampling step. But, oversampling will significantly increase the number of vertices and, thus, the associated transmission and processing cost. Furthermore, as observed by Kobbelt

Manuscript received 23 Mar. 2004; revised 7 Oct. 2004; accepted 12 Oct. 1004; published online 13 Jan. 2005. For information on obtaining reprints of this article, please send e-mail to. tvcg@compnter.org, and reference IEEECS Log Nnmber TVCG-0031-0304.

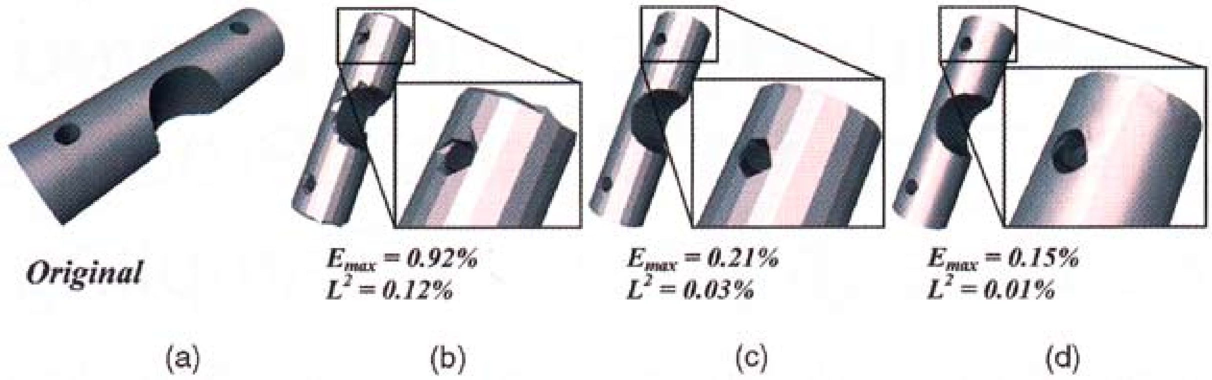


Fig. 1. An original model (a) was remeshed through a feature-insensitive algorithm (b). The sharp edges and corners were restored by EdgeSharpener (c). Then, Bender faired the smooth regions without rounding off the sharp features reconstructed by EdgeSharpener (d). For each model, the maximum distance from the original surface (Emar) and the mean-squared distortion (L2) are reported. All the values are percent of the bounding-box diagonal.

et al. [29], the associated aliasing problem will not be solved by oversampling since the surface normals in the reconstructed model will not converge to the normal field of the original object. Similar aliasing artifacts can be observed on models produced by surface remeshing, which is the basis of three of the most effective compression techniques published recently [5], [20], [1]. All three methods create a new mesh that approximates the original one. Vertices of the new mesh are placed on the original surface or at quantized locations near the surface so that their position can be predicted more accurately and encoded with fewer bits. To reduce the encoding of each vertex to a single parameter, the vertices of the resampled mesh are restricted to each lie on a specific curve, which is completely defined by previously processed neighboring vertices. Unfortunately, almost none of the new vertices fall on sharp edges or corners. As a consequence, the sharp features are not captured in the new mesh and a significant error between the original surface and its approximating triangle mesh occurs near these sharp features. To reduce this error, one may choose to use a feature-sensitive remeshing process [30], which attempts to place the samples on the sharp edges and comers of the original model. Unfortunately, this solution requires a more verbose representation of the samples, which are no longer restricted to each lie on a specific curve and, hence, must be encoded using three coordinates each.

In order to retain the compactness of a feature-insensitive retiling while reducing the approximation error, we have developed the EdgeSharpener approach. It automatically identifies the chamfers and replaces them with refined portions of the mesh that more accurately approximate the original shape, restoring a piecewise linear approximation of the sharp edges. After the sharp edges have been restored by EdgeSharpener, the error between the triangle mesh and the original model is distributed more uniformly and accounts for the difference between the original curved surface and its piecewise-linear approximation. When the original surface is smooth everywhere, the error may be further reduced by subdividing the approximating triangle mesh.

An interpolating subdivision process [14], [44] may be used to refine the triangle mesh globally, bending the triangles to smooth the surface at the edges and vertices. Unfortunately, when the original model contains sharp edges, such a bending process would round or blend the sharp edges restored by EdgeSharpener and, hence, would increase the error, annihilating the benefits achieved by EdgeSharpener. Considering sharp edges as if they were boundaries, as suggested in [44], is not sufficient for retaining corners and sharp edges with dead-ends. Thus, we introduce here a new approach, called Bender, which preserves the sharpness of the features restored by EdgeSharpener, while bending them so that they form smooth curves between sharp corners. For edges that are not sharp and not adjacent to a sharp edge, Bender performs a modified Butterfly subdivision [43], [44]. For other edges, we introduce new subdivision rules, which make it possible to properly refine sharp corners, sharp edges, and also smooth edges that connect to sharp features. The benefits of combining Edge-Sharpener and Bender (into a filter that we call Sharpen&Bend) are illustrated in Fig. 1.

A significant number of publications have been focused on identifying sharp features in a 3D model [24], [251, even in the presence of noise. More recently, solutions were proposed for maintaining sharp features during remeshing [29], [41]. In both cases, the features to be extracted or preserved are present in the model. In contrast to this body of previous work, our solution recovers sharp features in an aliased model from which they have been removed by feature-insensitive retiling. Our edge-sharpening process works well for meshes generated through a variety of uniform sampling schemes and does not introduce undesirable side effects away from sharp features.

The above considerations reveal the importance of Sharpen&Bend for postprocessing laser-digitized models. Most surface reconstruction approaches, in fact, are not able to correctly reconstruct sharp features. Moreover, while sufficient sampling conditions have been studied for smooth 3D objects [21, a guaranteed-quality reconstruction of surfaces with sharp features has remained a challenge, even in the 2D case [13].

1.1 Original Contributions

A preliminary description of EdgeSharpener was first introduced in a conference publication [4]. In this paper, however, a more thorough analysis of the state of the art is presented, along with a deeper investigation of the results and limitations of the method. Moreover, extensions to the original algorithm are introduced in order to tag sharp edges while reconstructing them. For nonadaptively sampled surfaces, this approach is more accurate than typical methods based on a threshold of the dihedral angle. Here, we also introduce Bender, which uses novel rules to maintain the sharpness of tagged edges while subdividing the mesh. We show that, to properly handle sharp edges which are not closed 1-manifold curves, it is not sufficient to treat them as if they were boundary curves and, hence, we introduce novel special rules. Most important, this paper proposes a new all-in-one black box to improve nonadaptively (re)sampled meshes. We show that, for a variety of popular remeshed models, Sharpen&Bend significantly decreases their distortion with respect to the corresponding original shapes.

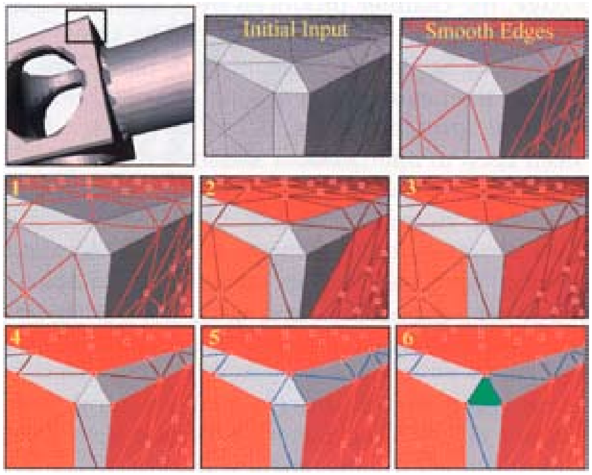


Fig. 1. An original model (a) was remeshed through a feature-insensitive algorithm (b). The sharp edges and corners were restored by EdgeSharpener (c). Then, Bender faired the smooth regions without rounding off the sharp features reconstructed by EdgeSharpener (d). For each model, the maximum distance from the original surface (Emar) and the mean-squared distortion (L2) are reported. All the values are percent of the bounding-box diagonal.

2 RELATED WORK

Here, we successively discuss approaches to identify features in unstructured data (scattered points), partially structured data (contours or profiles), and structured data (polygonal meshes). Then, we discuss feature-sensitive polygonization, retiling, smoothing, and subdivision approaches that preserve sharp features.

2.1 Identifying Sharp Features in Unstructured Point Clouds

When a scattered point sampling of a surface is sufficiently dense, sharp features may be inferred by analyzing the neighborhood of each point. This analysis may be performed after a triangle mesh has been reconstructed [1] or directly from a point cloud [19] by first organizing it through a neighbor graph, then evaluating the flatness of the neighbors of each point, and, finally, extracting an optimized subgraph spanning nonflat vertices. Even after pruning, the edges of that subgraph often form zig-zag patterns because they connect input samples on opposite sides of sharp features. Gumhold et al. propose smoothing the zig-zags by fitting low degree splines [19]. The resulting curves are likely to lie on chamfers, rather than on the intersections of extrapolated surfaces. For instance, if the original solid had a convex sharp edge, the chamfer produced by a feature-insensitive sampling would cut through the solid. The spline approximation would lie on the chamfer and, hence, inside the solid, rather than close to the original sharp edge. Perceptual grouping rules, based on surface normals, have been used to infer smooth surface patches [21]. Sharp features are recovered as intersections of adjacent patches. When surface normals are not provided, the method estimates them at each sample from the locations of neighboring samples. Hence, normals at samples near sharp features are polluted

REFERENCES

[1] **U. Adamy, J. Giesen, and M. John,** «New Techniques for Topologically Correct Surface Reconstruction». Proc. w, 373–380, 2000.

[2] **N. Amenta, S. Choi, and R. Kolluri,** «The Power Crust». Proc. Sixth ACM Symp. Solid Modeling and Applications, 249–260, 2001.

[3] **M. Attene and M. Spagnuolo,** «Automatic Surface Reconstruction from Point Sets in Space». Computer Graphics Forum (Proc. Eurographics '00), vol. 19, no. 3, 457–465, 2000.

[4] **M. Attene, B. Falcidieno, J. Rossignac, and M. Spagnuolo,** «EdgeSharpener: Recovering Sharp Features in Triangulations of NonAdaptively Re-Meshed Surfaces». Proc. First Eurographics Symp. Geometry Processing, 63–72, 2003.

[5] **M. Attene, B. Falcidieno, M. Spagnuolo, and J. Rossinac,** «SwingWrapper: Retiling Triangle Meshes for Better EdgeBreaker Compression». ACM Trans. Graphics, 22, no. 4,982–996, 2003.

[6] **S. Biasotti, M. Mortara, and M. Spagnuolo,** «Surface Compression and Reconstruction Using Reeb Graphs and Shape Analysis». Proc. Spring Conf. Computer Graphics (SCCG '00), 174–185, 2000.

[7] **H. Bierniarm, I.M. Martin, D. Zorin, and F. Bernardini,** «Sharp Features on Multiresolution Subdivision Surfaces». Proc. Pacific Graphics '01, 140–149, 2001.

[8] **J. Bloomenthal,** «Polygonization of Implicit Surfaces». Computer Aided Geometric Design, 5, 341–355, 1988.

[9] **M. Botsch and L.P. Kobbelt,** «A Robust Procedure to Eliminate Degenerate Faces from Triangle Meshes». Proc. Vision, Modeling and Visualization (VMV '01), 2001.

[10] **S.W. Cheng and T.K. Dey,** «Improved Construction of Delaunay Based Contour Surfaces». Proc. ACM Symp. Solid Modeling and Applications, 322–323, 1999.

[33] **P. Cignoni, C. Rocchini, and R. Scopigno,** «Metro: Measuring Error on Simplified Surfaces». Computer Graphics Forum (Proc. Eurographics '98), 17, no. 2, 167–l74, 1998.

[12] **G. Cong and B. Parving,** «Robust and Efficient Surface Reconstruction from Contours». The Visual Computer, 17, 199–208, 2001.

[13] **T.K. Dey and R. Wenger,** «Reconstructing Curves with Sharp Corners». Computational Geometry Theory Applications, 19, 89–99, 2001.

[14] **N. Dyn, J. Gregory, and D. Levitt,** «A Butterfly Subdivision Scheme for Surface Interpolation with Tension Control». ACM Trans. Graphics, 9, no. 2, 160–169, 1990.

[15] **N. Dyn, J. Gregory, and D. Levin,** «A Four-Point Interpolatory Subdivision Scheme for Curve Design». Computer Aided Geometric Design, 4, 257–268, 1987.

[16] **5. Fleishman, I. Drori, and D. Cohen-Or,** «Bilateral Mesh Denoising». Proc. ACM SIGGRAPH '03, 950–953, 2003.

[17] **M. Garland and P.S. Heckbert,** «Surface Simplification Using Quadric Error Metrics». Proc. ACM SIGGRAPH '97, 209–216, 1997.

[18] **J. Giesen and M. John,** «Surface Reconstruction Based on a Dynamical System». Computer Graphics Forum (Proc. Furographics '02), 21, no. 3, 363–371, 2002.

[19] **5. Gumhold, X. Wang, and R. Macleod,** «Feature Extraction from Point Clouds». Proc. 10th Int'l Meshing Roundtable, 293–305, 2001.

[20] **I. Guskov, K. Vidimce, W. Sweldens, and P. Schröder,** «Normal Meshes». Proc. ACM SIGGRAPH '00, 95–102, 2000.

[21] **G. Guy and G. Medioni,** «Inference of Surfaces, 3D Curves and junctions from Sparse, Noisy, 3D Data». IEEE Trans. Pattern Analysis and Machine Intelligence, 19, no. 11, 1265–1277, Nov. 1997.

[22] **H. Hoppe,** «Progressive Meshes». Proc. AM SIGGRAPH '96, 99–108, 1996.

[23] **H. Hoppe, T. Derose, T. Duchamp, M. Halstead, I-I. Jin, J. Mcdonald, J. Schweitzer, and W. Stuetzlc,** «Picccwise Smooth Surface Reconstruction». Proc. ACM SIGGF.APt-I '94, 295–302, 1994.

[24] **A. Hubeli and M.H. Gross,** «Multiresolution Feature Extraction from Unstructured Meshes». Proc. IEEE Visualization '01, 1625,2001.

[25] **A. Hubcli, K. Meyer, and M.H. Gross,** «Mesh Edge Detection». Proc. Workshop Lake Tahoe, 2000.

[26] **T. Jones, F. Durand, and M. Desbrun,** «Non-Iterarive, Feature Preserving Mesh Smoothing». Proc. ACM SIGGRAPH '03, 943–949, 2003.

[27] **T. Ju, F. Losasso, S. Schaefer, and J. Warren,** «Dual Contouring of Hermite Data». Proc. ACM SIGGRAPH '02, 339–346, 2002.

[28] **A. Khodakovsky, P. Schröder, and W. Sweldens,** «Progressive Geometry Compression». Proc. ACM SIGGRAPH '00, 271–278, 2000.

[29] **L.P. Kobbelt, M. Botsch, U. Schwanecke, and H-P. Seidel,** «Feature Sensitive Surface Extraction from Volume Data». Proc. ACM SIGGRAPH '01, 57–66, 2001.

[30] **A. Lee, W. Sweldens, P. Schröder, L. Cowsar, and D.Dobkin,** «MAPS: Multiresolution Adaptive Parameterization of Surfaces». Proc. ACM SIGGRAPH '98, 95–104, 1998.

[31] **A. Loop,** «Smooth Subdivision Surfaces Based on Triangles». master's thesis, Dept. of Math., Univ. of Utah, 1987.

[32] **W. Lorensen and H. Cline,** «Marching Cubes: A High Resolution 3D Surface Construction Algorithm». Proc. ACM SIGGRAPH '87, 163–169, 1987.

[33] **F. Mokhatarian, N. Khalili, and P. Yuen,** «Multi-Scale 3-D FreeForm Surface Smoothing». Proc. British Machine Vision Conf, 730–739, 1998.

[34] **Y. Ohtake and A.G. Belyaev,** «Dual/Primal Mesh Optimization for Polygonized Implicit Surfaces». Proc. ACM Symp. Solid Modeling and Applications, 171–178, 2002.

[35] **Y. Ohtake, AG. Belyaev, and A. Pasko,** «Dynamic Meshes for Accurate Polygonization of Implicit Surfaces with Sharp Features». Proc. Shape Modeling Int'l (SMI '03), 74–81, 2001.

[36] **G. Patané and M. Spagnuolo,** «Multi-Resolution and SliceOriented Feature Extraction and Segmentation of Digitized Data». Proc. ACM Symp. Solid Modeling and Applications, 305–312, 2002.

[37] **C. Roechini, P. Cignoni, F. Ganovelli, C. Montani, P. Pingi, and R. Scopigno,** «Marching Intersections: An Efficient Resampling Algorithm for Surface Management». Proc. Shape Modeling Int'l (SMI '01), 296–305, 2001.

[38] **J. Rossignac,** «Edgebreaker: Connectivity Compression For Triangle Meshes». IEEE Trans. Visualization and Computer Graph's, 5, no. 1, 47–61, Jan-Mar. 1999.

[39] **J. Rossignac,** «3D Compression Made Simple: EdgeBreaker with Wrap&Zip on a Corner-Table». Proc. Shape Modeling Int'l (SMl '01), 278–283, 2001.

[40] **A. Szymczak, D. King, and J. Rossignac,** «Piecewise Regular Meshes». Graphical Models, 64, nos. 3-4, 183–198, 2002.

[41] **J. Vorsatz, C. Rössl, L.P. Kobbelt, and H.P. Seidel,** «Feature Sensitive Remeshing». Computer Graphics Forum (Proc. Eurographics '01), 20, no. 2, 393–401, 2001.

[42] **K. Watanabe and AG. Belyaev,** «Detection of Salient

Executive committee

President
Gerald L. Engel*
Computer Science
& Engineering
Univ. of Connecticut,
Stanford
1 University Place
Stanford, CT 06901-2315
Phone: +1 203 251 8431
Fax: +1 203 251 8592
g.engel@ computer.org

President elect
Deborah M. Cooper*

Past president
Carl K. Chang*

VP, publications
Michael R. Williams (1st VP)*

VP electronic products and services
James W. Moore (2nd VP)*

VP, chapters activities
Christina M. Schober*

VP, conferences and tutorials
Yervant Zorian†

VP, educational activities
Murali Varanasi†

VP, standards activities
Susan K. Land*

VP, technical activities
Stephanie M. White†

Secretary
Stephen B. Seidman†

Treasurer
Rangachar Kasturi†

Computer editor in chief
Doris L. Carver†

Executive director
David W. Hennage†

2004–2005IEEE division v. director
Gene F. Hoffnagle†

2005 2006 IEEE division VIII director
Stephen L. Diamond†

2005 IEEE division v. director elect
Oscar N. Garcia*

* voting member of the board of Governors

† nonvoting member of the board of Governors

IEEE officers

President and CEO
W. Cleon Anderson

President elect
Michael R. Lightner

Past president
Arthur W. Winston

Secretary
Mohamed El-Hawary

Treasurer
Joseph V. Lillie

VP, educational activities
Moshe Kam

VP, publication servises and products
Leah H. Jamieson

VP, regional activities
Marc T. Apter

V P, standards association
James T. Carlo

VP, technical activities
Ralph W. Wyndrum Jr.

IEEE division v. director
Gene F. Hoffnagle

Executive staff

Executive director
David W. Hennage

Asses. executive direct
Anne Marie Kelly

Publislisher
Angela Burgess

Assistant publisher
Dick Price
Director, administration
Violet S. Doan

Director, information tehcnology & services
Robert G. Care

Director, business & product development
Peter Turner

Board of governors

Term expiring 2005
Oscar N. Garcia
Michel Israel
Stephen B. Seidman
Kathleen M. Swigger
Makoto Takizawa

Term expiring 2006
Mark Christensen
Alan Clements
Annie Combelles
Ann Q. Gates
James D. Isaak
Susan A. Mengel

Term expiring 2007
Richard A. Kemmerer
Brian M. O'Connell,
Christina M. Schober

Next board meeting
7 March 2005, Portland, OR

Computer society offices

Headquarters office
1730 Massachusetts Ave. NW
Washington, DC 20036-1992
Phone: +1 202 371 0101
• Fax: +1 202 728 9614
E- mail: hq.ofc@
computer.org

Publications office
10662 Las Vaqueros
Cir., PO Box 3014
Los Alamitos, CA 01720-1314
Phone: +1 714 8213380
E-mail: help@computer.org
Membership Orders
Phone: +1 800 272 6657
Fax: +1 714 821 4641
E- mails: help@computer.org

Asia/Pacific office
Walanabe Building
1-4-2 Minami-Aoyama,
Mnato-ku,Tokyo
107-0062, T4as
Phone: 81334083/18
Fax: 813 3408 3 553
E -mail: tokyo.ofc@
computer.org

IEEE computer society

IEEE computer society

Purpose
The IEEE Computer Society is the world's latest association of computing professionals, and is the leading provider of technical information in the field.

Membership
Members receive the monthly magazine Computer, discounts, , and opportunities to serve (all activities are led by volunteer members). Membership is open to all IEEE members, affiliate society members, and others interested in the computer field.

Computer society web site
The IEEE Composer Society's Web site, at www.computer.org, offers information and samples from the society's publications and conferences, as well as a broad range of information about technical committees, standards, student activities, and more.

Ombudsman
Members experiencing problems magazine delivery, membership status, or unresolved complaints-may write to the ombudsman at the Publications Office or send an e-mail to help@computer.org.

Chapters
Regular at-id Student chapters worldwide provide the opportunity to interact with colleagues, hear technical experts, and serve the local professional community.

Available information
To obtain more information on any of the following, contact the Publications Office:

- Membership applications
- Publications catalog
- Draft standards and order forms
- Technical committee list
- Technical committee application
- Chapter start up proced ures
- Student scholarship information
- Volunteer leaders/ staff directors
- IEEE senior member grade application (requires 10 years practice and significant performance in five of those 10)

To check membership status or report a change of address, call the IEEE toll-free number, +1800 678 4333. Direct all other Computer Society -related questions to use Publica tions Office.

Publications and activities

COMPUTER
The flagship publication of the IEEE Computer Society, Computer publishes peer-reviewed technical content that covers all aspects of computer science, computer engineering, technology, and applications.

PERIODICALS
The society publishes 15 magazines and 11 research transactions. Refer to membership application or request information as noted at left.

CONFERENCE PROCEEDINGS, TUTORIAL TEXTS, STANDARDS DOCUMENTS
The IEEE Computer Society Conference Publishing Services publishes more than 175 tides ever year.

STANDARDS WORKING GROUPS
More than 150 groups produce IEEE standards used throughout the world.

TECHNICAL COMMITTEES
TCs provide professional interaction in over 30 technical areas and directly influence computer engineering conferences and publications.

CONFERENCES/ EDUCATION
The society holds about 130 conferences each year and sponsors mans educational activities, including computing science accreditation.