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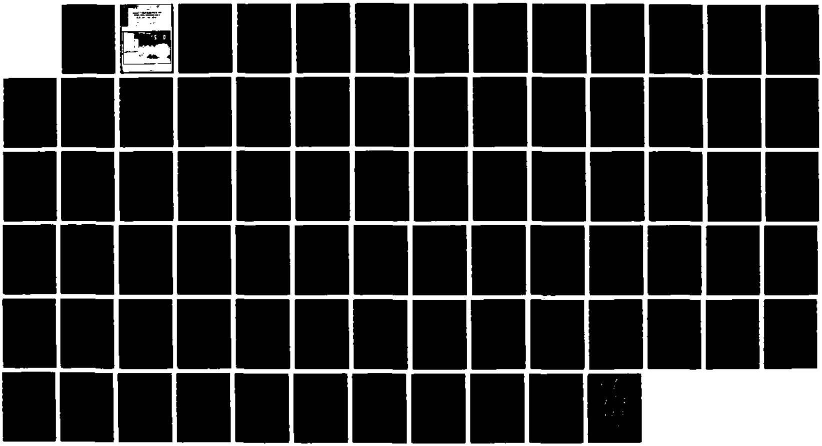

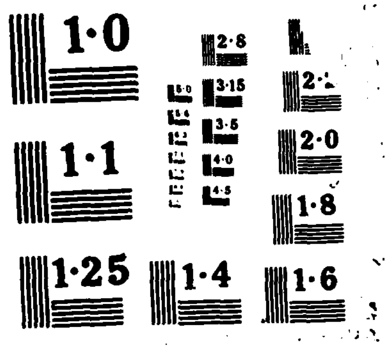
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SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS

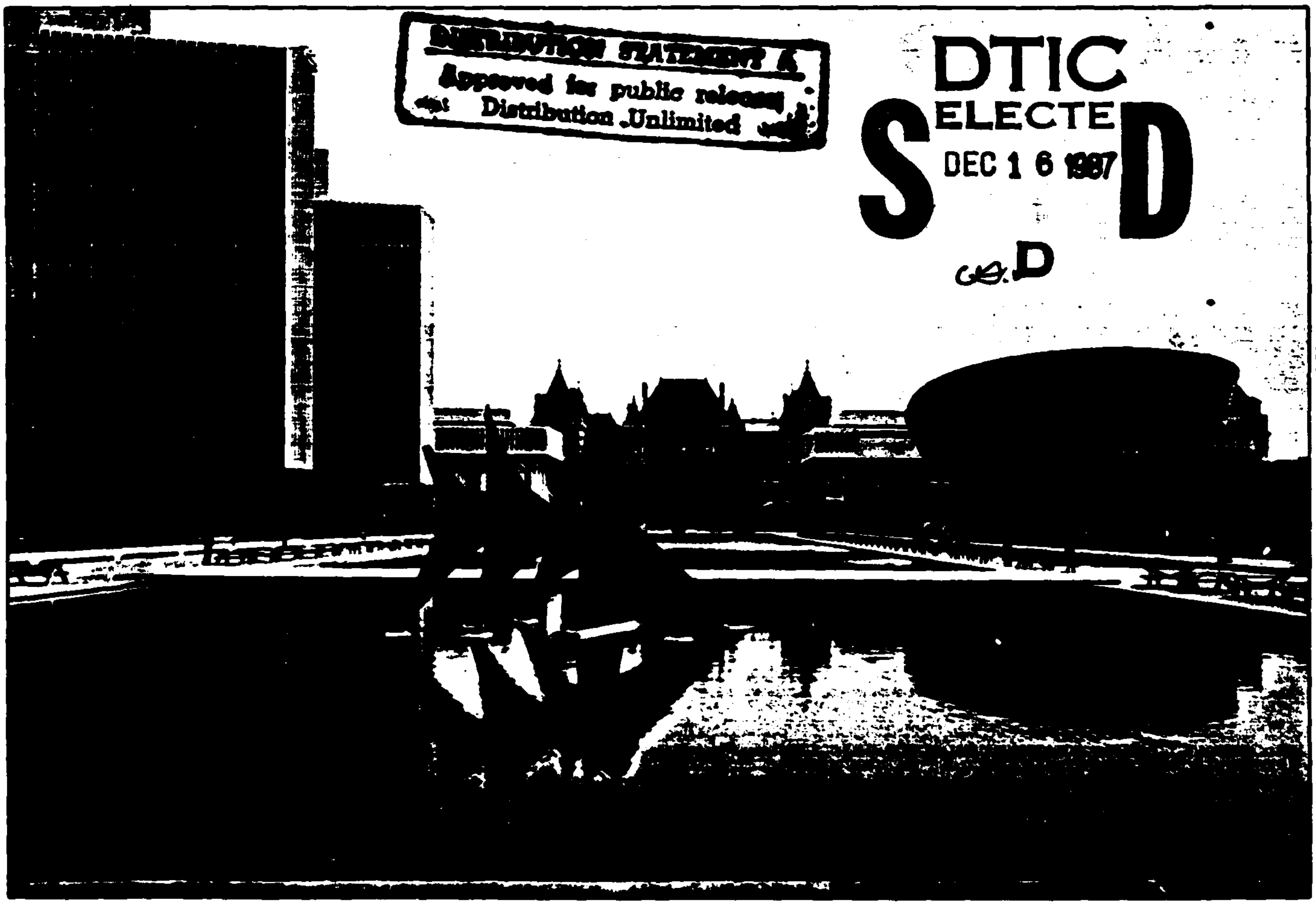
Final Program

SIAM CONFERENCE ON APPLIED GEOMETRY July 20–24, 1987

with the cosponsorship of Rensselaer Polytechnic Institute

and Short Course on Uses of Surfaces in Industry: Geometric Modeling, Machine Vision, and Motion Planning July 19, 1987

Hilton Hotel • Albany, New York



- Image Processing
- Surfaces
- Mathematical Methods and Design
- Packing and Tiling
- Mesh Generation
- Graphics
- Computational Geometry
- Robotics
- Solids
- Modeling for Manufacturing

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Applied Geometry, Geometry Processing, Geometry, Computational Geometry, Digital Geometry

19. ABSTRACT

This conference was organized to bring together researchers and practitioners working in several geometry-based disciplines. Because of the theoretical needs of several of the applications areas, input was sought from "pure" mathematicians whose research and general background knowledge was believed to impact on certain stalled applications efforts. In that regard the conference was successful. The communication between the pure and applied camps was good.

In summary, the conference revealed that some of the subdisciplines of applied geometry, are becoming more and more dependent on carefully laid mathematical foundations. It was difficult to miss the fact that most of the practitioners are lacking in the relevant mathematical background, and the theoretical mathematicians have missed some important applications-motivated theoretical questions. It is with anticipation that we watch the next two years for important mathematical development in applied geometry, and its transfer to the engineering community. The week in Albany is viewed as a catalyst.

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Final Technical Report

SIAM Conference on Applied Geometry
July 20-24, 1987 - Albany, New York

This conference was organized to bring together researchers and practitioners working in several geometry-based disciplines. Because of the theoretical needs of several of the applications areas, input was sought from "pure" mathematicians whose research and general background knowledge was believed to impact on certain stalled applications efforts. In that regard the conference was successful. The communication between the pure and applied camps was good.

As happened two years ago at the predecessor to this conference, the roughly 400 participants were split, about half from academia and half from industry and government laboratories. The two groups spoke easily to each other, with the academics having the opportunity to learn about the major implementation efforts required at the making-mathematics-work stage. The practitioners had the opportunity to become exposed to some of the relevant mathematical building blocks.

The core of the conference was twelve invited presentations.

Jacob T. Schwartz, Courant Institute of the Mathematical Sciences
"Geometric Issues and Algorithms Related to Robot Motions"

Andrew Yao, Princeton University
"Geometric Approaches to Computational Problems"

Branko Grunbaum, University of Washington
"The Generation and Uses of Aperiodic Tilings"

John K. Hinds, General Electric Corporate Research and Development
"Solid Modeling and Manufacturing Applications"

Thomas W. Sederberg, Brigham Young University
"Free-Form Modeling with Cubic Algebraic Surfaces"

Tomas Lozano-Perez, Massachusetts Institute of Technology
"Robot Systems That Sense, Plan and Manipulate"

Bruno Buchberger, Johannes Kepler University
"Grobner Bases: An Algorithmic Algebraic Method for Nonlinear Geometry"

Shreeram S. Abhyankar, Purdue University
"Implicitization and Parametrization of Curves and Surfaces"

Joseph L. Mundy, General Electric Corporate Research and Development Center
"The Application of Geometric Reasoning to Vision and Robotics

Carl de Boor, University of Wisconsin, Madison
"Subdivision Algorithms for Curves and Surfaces"

John Hopcroft, Cornell University
"Computer Modeling and Simulation"

Malcolm Sabin, Finite Element Graphics System, Ltd., Cambridge, England
"Semiparametric Surfaces"

There were sixteen minisymposia which are listed below with their organizers:

- **Geometry Processing**, Gerald Farin, Arizona State University
- **Algebraic Methods in Geometry**, Bruno Buchberger, Johannes Kepler University, Linz, Austria
- **Geometric Tolerancing**, Vijay Srinivasan, IBM T. J. Watson Research Center
- **Geometric Continuity**, Wolfgang Boehm, Technical University of Braunschweig, Federal Republic of Germany
- **Visual Multidimensional Geometry with Applications**, Alfred Inselberg, IBM Scientific Center
- **Blending Surfaces**, Christoph Hoffmann, Purdue University
- **Motion Planning**, Michael Wesley, IBM T. J. Watson Research Center
- **Non-Tensor Product Surfaces**, David R. Ferguson, Boeing Computer Services
- **Probabilistic Approaches to CAGD (Computer-Aided Geometric Design)**, Ronald N. Goldman, Control Data Corporation
- **Algebraic Geometry in Geometric Modeling**, Miriam Lucian, Boeing Commercial Airplane Company
- **Computational Geometry**, W. Randolph Franklin, Rensselaer Polytechnic Institute
- **Mesh Generation**, David A. Field, General Motors Research Laboratories
- **Data Reduction for Splines and Its Applications**, Tom Lyche, University of Oslo
- **Digital Geometry**, Robert A. Melter, Long Island University
- **Parallel Methods in Geometry**, Harry McLaughlin, Rensselaer Polytechnic Institute
- **Shape Control in Surface Design**, David R. Ferguson, Boeing Computer Services

In addition there were some 130 contributed papers and a poster session.

In summary, the conference revealed that some of the subdisciplines of applied geometry, are becoming more and more dependent on carefully laid mathematical foundations. It was difficult to miss the fact that most of the practitioners are lacking in the relevant mathematical background, and the theoretical mathematicians have missed some important applications-motivated theoretical questions. It is with anticipation that we watch the next two years for important mathematical development in applied geometry, and its transfer to the engineering community. The week in Albany is viewed as a catalyst.

Harry W. McLaughlin
Conference Chairman

SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS
117 South 17th Street
14th Floor
Philadelphia, PA 19103

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ORGANIZING COMMITTEE

Harry McLaughlin, Chair Rensselaer Polytechnic Institute

Carl de Boor, University of Wisconsin, Madison

David R. Ferguson, Boeing Computer Services

John Hopcroft, Cornell University

Leon Seitelman, Pratt & Whitney Aircraft Co.

Ramon Sarraga, General Motors Research Laboratories

Michael Wozny, National Science Foundation (on leave from Rensselaer Polytechnic Institute)

FUNDING SOURCES

SIAM is conducting this conference with the partial support of the Army Research Office, the Department of Energy and the National Science Foundation.

SHORT COURSE

Short Course on Uses of Surfaces in Industry: Geometric Modeling, Machine Vision, and Motion Planning
Sunday, July 19
Albany Hilton, Ballroom A-B

This course will focus on the various aspects of mathematical representations of surfaces with emphasis on their actual or potential use for solving industrial problems.

Speakers: Paul Besl, General Motors Research Laboratories; Rida Farouki, IBM T. J. Watson Research Center; Gordon Wilfong, AT&T Bell Laboratories; Ramon Sarraga (Organizer), General Motors Research Laboratories.

The course will provide a fairly broad introduction to both fundamental mathematical problems and engineering applications.

Themes

- Motion Planning around Polyhedral Obstacles
- Role of Surfaces in Computer Vision
- Boundary Evaluation in CAD/CAM Solid Modeling Systems
- Surface Modeling Problems

There will be a panel question-and-answer period at the end of the program. Preprints of the lecture materials will be distributed upon check-in.

PROGRAM

8:30 AM	**Motion Planning** Gordon Wilfong
10:00 AM	Coffee
10:30 AM	**Surfaces in Computer Vision** Paul Besl
12:00 PM	Lunch
1:30 PM	**Computational Issues in Solid Boundary Evaluation** Rida Farouki
3:00 PM	Coffee
3:30 PM	**G-1 Bézier Patching of Irregular Surface Shapes** Ramon Sarraga
5:15 PM	**Program Adjourns**

Registration Fees

	SIAM Member	Non-Member	Student Member	Student Non-Member
Advance	$75	$ 90	$30	$40
On-Site	$90	$105	$40	$50

* Registration fee includes preprints and lunch

MEETING HIGHLIGHTS

Invited Presentations

Monday, July 20, 9:00 AM
Invited Presentation 1
Geometric Issues and Algorithms Related to Robot Motions

Studies of robot motions planning have made use of increasingly sophisticated algorithmic ideas in geometry. The speaker will review some of the techniques that have been employed with emphasis on the use of so-called Davenport-Schinzel sequences. Other ideas drawn from algebraic topology will also be reviewed and experimental implementations of some of the algorithms described.

Jacob T. Schwartz
Courant Institute of the Mathematical Sciences
New York University

Monday, July 20, 9:45 AM
Invited Presentation 2
Geometric Approaches to Computational Problems

In recent years the geometric approach has been applied, often in unexpected ways, to solve computational problems in various contexts. In many cases combinatorial problems need to be embedded in Euclidean space before significant progress can be made with tools in geometry. For example, there are discrete combinatorial problems for which computationally efficient methods have been discovered by viewing problems geometrically and applying linear-programming style algorithms; there are also discrete problems whose complexity has been determined by examining the properties of the geometric complexes associated with the original combinatorial structures.

In this talk we will discuss the state of development along these lines, presenting paradigms from application areas including communications, combinatorial algorithms, and proving lower bounds in computational complexity. We will also discuss the directions in which future progress can be expected.

Andrew Yao
Princeton University

Tuesday, July 21, 9:00 AM
Invited Presentation 3
The Generation and Uses of Aperiodic Tilings

Tilings are complete coverings of the plane, without gaps or overlappings, using one or more sets each of which consists of infinitely many identical geometric shapes. Certain devices or shapes lead to periodic tilings where one basic arrangement repeats itself infinitely many times in two more fixed directions.

A tiling is "aperiodic" if no translation is a symmetry of the tiling itself, or of any other tiling possible with the same tiles. Aperiodic tilings first arose in decision theory and in recreational mathematics; recently they have attracted wide attention through their relations to "quasicrystals"—solid state phenomena which contradict traditional crystallographic ideas (in particular, violate the "crystallographic restriction"). Most attempts to describe the aperiodic tilings relevant to quasicrystals are based on reducing high-dimensional periodic tilings to three (or two) dimensions by suitable projections or other operations. These methods will be explained and compared to more direct methods based on relations between neighboring tiles and not needing higher dimensions.

Branko Grünbaum
University of Washington

Tuesday, July 21, 9:45 AM
Invited Presentation 4
Solid Modeling and Manufacturing Applications

Here is a presentation about a hybrid method of solid modeling with boolean operations and open ended primitives based on parametric rational n-dimensional mathematics. The unique features derived from this mathematical base are the range of part shapes included and the degree of automation that can be achieved in machining of parts and tooling. Complex part shapes are modeled by combinations of splines and meshes, transformational sweeps, dimensional contractions, offset primitives and constructive solid geometry operations.

Machining is automated by careful selection of reliable algorithms which can be implemented for this unified mathematical base. A prototype software system implementation of the method (called TRUCE (for tri-dimensional rational unified cubic engine) has been developed by General Electric and applied to industrial problems involving geometric complexity in design and tooling.

John K. Hinds
General Electric Corporate Reseach and Development

Tuesday, July 21, 2:00 PM
Invited Presentation 5
Free-Form Modeling with Cubic Algebraic Surfaces

Geometric modeling of free-form shape has traditionally been accomplished using parametric surface patches, most commonly by cubic patches. An alternate method for defining a surface is by using an implicit equation. An advantage of implicitly defined surfaces is that their algebraic degree is lower than that of comparable parametric surfaces. For example, bi-cubic patches generally have an algebraic degree of eighteen, whereas cubic algebraic surfaces are of degree three.

Recently, a technique was developed for controlling the shape of a cubic surface and for fitting together a piece-wise collection of bounded cubic surface patches with tangent continuity. These techniques will be presented, along with algorithms for parametrizing cubic algebraic surfaces.

Thomas W. Sederberg
Brigham Young University

Wednesday, July 22, 9:00 AM
Invited Presentation 6
Robot Systems That Sense, Plan and Manipulate

An intelligent robot should have three generic capabilities:

- The ability to perceive its environment and to locate objects of interest.
- The ability to act on its environment.
- The ability to plan actions to achieve its goals.

Many robot systems have exhibited subsets of these capabilities but, surprisingly, very few systems (aside from some mobile robots) have ever embodied all of these capabilities in non-trivial form.

A new integrated robot system, HANDEY, that combines these three capabilities is now under development at MIT. It consists of six major modules: geometric modeling system, laser-range finder, model-based object localizer, collision-free path planner, grasp planner, and robot trajectory-control system. Its domain is that of assembly of planar-faced polyhedra, both convex and nonconvex. The user starts by building accurate geometric models for all the objects to be manipulated, and then specifies a sequence of MOVE commands that specify an object and its destination. HANDEY locates each part on its worktable, grasps it, and takes it to the destination while avoiding collisions. The unique features of HANDEY are its ability to operate on a wide class of objects and to operate in a cluttered environment.

The speaker will review the computational problems that must be solved to achieve the integration of the three generic capabilities and describe HANDEY.

Tomas Lozano-Perez
Massachusetts Institute of Technology

Wednesday, July 22, 9:45 AM
Invited Presentation 7
Gröbner Bases: An Algorithmic Algebraic Method for Non-Linear Geometry

Gröbner bases are certain standard forms for systems of multivariate polynomial equations. The Gröbner basis form of polynomial systems can be obtained by a general algorithm. In the talk this algorithm will be explained and various applications of Gröbner bases in non-linear computational geometry will be presented: inverse robot kinematics, geometrical theorem proving, solid modeling, geometrical decomposition and determination of global properties of geometrical objects, for example, dimension.

Bruno Buchberger
Johannes Kepler University

Meeting Highlights

Wednesday, July 22, 11:00 AM
Invited Presentation 8
Implicitization and Parametrization of Curves and Surfaces

Geometric modeling is largely concerned with representations of curves and surfaces. A plane curve may be described either by one bivariate implicit equation or a pair of univariate parametric equations. Likewise, a surface in space is described either by a trivariate implicit equation or a triad of bivariate parametric equations. From the computational viewpoint, it is important to be able to go back and forth between these two modes of description.

Algorithms are being developed for rational and polynomial parametrizations of both curves and surfaces. An algorithmic irreducibility criterion has been designed to decide when a rationally parametrizable curve is actually polynomially parametrizable. The reverse process of implicitization leads to problems of generalizing the Sylvester resultant. This may be attacked by the symbolic method of classical invariant theory. It is hoped that a greater understanding of the underlying mathematics will facilitate the development of useful algorithms.

The algorithmic irreducibility criterion and the resultant problem both have a bearing on the Jacobian conjecture in algebraic geometry. Thus, the interplay between computational algorithms and the underlying mathematics is clearly mutually beneficial.

Shreeram S. Abhyankar
Purdue University

Wednesday, July 22, 11:45 AM
Invited Presentation 9
The Application of Geometric Reasoning to Vision and Robotics

Robotics requires the use of formal procedures which are characterized as decision trees. Well-known approaches include the Grobner basis, Collins' method of cylindrical decomposition, and Wu's method, a fairly common theoretical approach.

The central problem that the speaker will address is to decide the consistency of a given two-dimensional view with the three dimensional object, which is given algebraically. Use is made of methods for planning robot paths. In the time-dependent case, the hand-off problem between two robots can also be dealt with.

Recently, some new methods for decision procedures in geometry problems have been developed. These methods provide a new way for looking at solid models as algebraic relations versus the classical approach that employs face-edge-vertex (topologically-oriented, boundary) models.

The speaker will apply these methods to problems in model-based vision and robot geometry.

Joseph L. Mundy
General Electric Corporate Research and Development Center

Thursday, July 23, 2:00 PM
Invited Presentation 10
Subdivision Algorithms for Curves and Surfaces

Various algorithms in use in computer-aided geometric design can be interpreted as corner-cutting or "whittling" algorithms, i.e., as generating a sequence of broken lines, each of which is obtained from its predecessors by cutting off one or more of the corners. The first of these to be developed is probably de Rham's trisection algorithm; the best known are Chaikin's algorithm, degree-raising for the Bernstein-Bezier form, and knot insertion for splines.

A survey is given for the current state of such algorithms with special emphasis on their generalization to surfaces.

Carl de Boor
University of Wisconsin, Madison

Thursday, July 23, 2:45 PM
Invited Presentation 11
Computer Modeling and Simulation

The modeling and simulation of objects will play a vital role in computer-aided design and off-line robot programming. Currently, solid modeling systems are capable of modeling rigid solids, computing their volume and inertial properties, calculating offset surfaces, and testing for interference between two parts. Simulation systems tend to be ad hoc and a general purpose model driven simulation system is nonexistent.

The ability to represent physical objects in multiple domains and to carry out model driven simulations will have far reaching consequences. Today, researchers are beginning to develop the software systems that will allow easy construction of models and simulations. The speaker will discuss the science base needed to support software systems capable of representing, manipulation and reasoning about physical objects.

John Hopcroft
Cornell University

Friday, July 24, 9:00 AM
Invited Presentation 12
Semiparametric Surfaces

Over the last twenty years, computer-based surface description software has become an essential tool in the automotive, aircraft and shipbuilding industries. Such software uses primarily the parametric surface description. Consideration is being given to the use of "algebraic surface description."

Two examples have been encountered recently of surfaces which do not fit either mould by definition. These are the "blend" which is generated by intersections of offset algebraic surfaces, and the "developable". In each case there is a natural parametrization in one direction, but not in the other.

The speaker will discuss how such surfaces might be converted to more conventional descriptions and how they might be interrogated directly.

Malcolm Sabin
Finite Element Graphics System, Ltd.
Cambridge, England

Minisymposia

1. **Geometry Processing**
   Gerald Farin, Arizona State University
2. **Algebraic Methods in Geometry**
   Bruno Buchberger
   Johannes Kepler University
   Linz, Austria
3. **Geometric Tolerancing**
   Vijay Srinivasan, IBM-T.J. Watson Research Center
4. **Geometric Continuity**
   Wolfgang Boehm
   Technical University of Braunschweig
   Federal Republic of Germany
5. **Visual Multi-Dimensional Geometry with Applications**
   Alfred Inselberg, IBM Scientific Center
6. **Blending Surfaces**
   Christoph Hoffmann, Purdue University
7. **Motion Planning**
   Michael Wesley, IBM-T.J. Watson Research Center
8. **Non-Tensor Product Surfaces**
   David R. Ferguson, Boeing Computer Services
9. **Probabilistic Approaches to CAGD (Computer-Aided Geometric Design)**
   Ronald N. Goldman
   Control Data Corporation
10. **Algebraic Geometry in Geometric Modeling**
    Miriam Lucian, Boeing Commercial Airplane Company
11. **Computational Geometry**
    W. Randolph Franklin, Rensselaer Polytechnic Institute
12. **Mesh Generation**
    David A. Field, General Motors Research Laboratories
13. **Data Reduction for Splines and Its Applications**
    Tom Lyche, University of Oslo
14. **Digital Geometry**
    Robert A. Melter, Long Island University
15. **Parallel Methods in Geometry**
    Harry McLauglin, Rensselaer Polytechnic Institute
16. **Shape Control in Surface Design**
    David R. Ferguson, Boeing Computer Services

PROGRAM-AT-A-GLANCE

Saturday, July 18/PM

5:00 PM/Prefunction Area, Ballroom Level
Registration opens for Short Course

10:00 PM
Registration Closes

Sunday, July 19/AM

Short Course on Uses of Surfaces in Industry: Geometric Modeling, Machine Vision, and Motion Planning

7:00 AM/Prefunction Area, Ballroom Level
Registration opens for Short Course

8:30 AM/Ballroom A-B
Motion Planning
Gordon Wilfong
AT&T Bell Laboratories

10:00 AM/Prefunction Area, Ballroom Level
Coffee

10:30 AM/Ballroom A-B
Surfaces in Computer Vision
Paul Besl
General Motors Research Laboratories

Sunday, July 19/PM

12:00 PM/Ballroom C-D
Lunch

1:30 PM/Ballroom A-B
Computational Issues in Solid Boundary Evaluation
Rida Farouki
IBM-T.J. Watson Research Center

3:00 PM/Prefunction Area
Coffee

3:30 PM/Ballroom A-B
G-1 Bézier Patching of Irregular Surface Shapes
Ramon Sarraga
General Motors Research Laboratories

5:00 PM/Prefunction Area
Registration Opens for Conference

8:00 PM/Prefunction Area
Welcoming Reception
Cash Bar

10:00 PM
Registration Closes

Monday, July 20/AM

7:30 AM/Prefunction Area, Ballroom Level
Registration Opens

8:45 AM/Ballroom A-B
Opening Remarks

9:00 AM/Ballroom A-B
Invited Presentations 1 and 2
Chair: Carl de Boor
University of Wisconsin, Madison

9:00 AM/Ballroom A-B
Geometric Issues and Algorithms Related to Robot Motions
Jacob T. Schwartz
Courant Institute of Mathematical Sciences
New York University

9:45 AM/Ballroom A-B
Geometric Approaches to Computational Problems
Andrew Yao
Princeton University

10:30 AM/Prefunction Area
Coffee

11:00 AM/CONCURRENT SESSIONS

Minisymposium 1/Ballroom A-B
Geometry Processing
Chair: Gerald Farin
Arizona State University

Minisymposium 2/Ballroom C
Algebraic Methods in Geometry
Chair: Bruno Buchberger
Johannes Kepler University
Linz, Austria

Minisymposium 3/Ballroom E
Geometric Tolerancing
Chair: Vijay Srinivasan
IBM-T.J. Watson Research Center

Monday, July 20/PM

12:30 PM/**Lunch**

2:00 PM/CONCURRENT SESSIONS

Minisymposium 4/Ballroom A-B
Geometric Continuity
Chair: Wolfgang Boehm
Technical University of Braunschweig
Federal Republic of Germany

Minisymposium 5/Ballroom C
Visual Multi-Dimensional Geometry with Applications
Chair: Alfred Inselberg
IBM Scientific Center

Minisymposium 6/Ballroom E
Blending Surfaces
Chair: Christoph Hoffmann
Purdue University

3:30 PM/Prefunction Area
Coffee

4:00 PM/CONCURRENT SESSIONS

Contributed Presentations 1/Ballroom D
Surface Methods
Chair: C. N. Shen
Rensselaer Polytechnic Institute

Contributed Presentations 2/Ballroom A-B
Solid Modeling
Chair: Donald P. Peterson
Sandia National Laboratories

Contributed Presentations 3/Ballroom E
Computational Geometry 1
Chair: Yves de Montaudouin
Lehigh University

Contributed Presentations 4/Ballroom C
General Topics 1
Chair: Subhas Desa
Carnegie Mellon University

6:15 PM/Prefunction Area
Beer Party

Tuesday, July 21/AM

9:00 AM/Ballroom A-B
Invited Presentations 3 and 4
Chair: Ramon Sarraga
General Motors Research Laboratories

9:00 AM/Ballroom A-B
The Generation and Uses of Aperiodic Tilings
Branko Grünbaum
University of Washington

9:45 AM/Ballroom A-B
Solid Modeling and Manufacturing Applications
John K. Hinds
General Electric Corporate Research and Development Center

10:30 AM/Prefunction Area
Coffee

11:00 AM/CONCURRENT SESSIONS

Minisymposium 7/Ballroom E
(11:00 AM–1:15 PM)
Motion Planning
Chair: Michael Wesley
IBM-T.J. Watson Research Center

Minisymposium 8/Ballroom C
Non-Tensor Product Surfaces
Chair: David R. Ferguson
Boeing Computer Services

Minisymposium 9/Ballroom A-B
Probabilistic Approaches to Computer-Aided Geometric Design (CAGD)
Chair: Ronald N. Goldman
Control Data Corporation

Tuesday, July 21/PM

12:30 PM/**Lunch**

2:00 PM/Ballroom A-B
Invited Presentation 5
Chair: Leon Seitelman
Pratt & Whitney Aircraft Co.

Free-Form Modeling with Cubic Algebraic Surfaces
Thomas W. Sederberg
Brigham Young University

2:45 PM/Prefunction Area
Coffee

3:15 PM/CONCURRENT SESSIONS

Contributed Presentations 5/Ballroom E
Mathematical Methods 1
Chair: Mladen Luksic
University of Texas at San Antonio

Contributed Presentations 6/Ballroom D
Robot Path Planning 1
Chair: Daniel Koditschek
Yale University

Contributed Presentations 7/Ballroom C
General Topics 2
Chair: Seymour Haber
National Bureau of Standards

Contributed Presentations 8/Ballroom A-B
Computational Geometry 2
Chair: Don J. Orser
National Bureau of Standards

Poster Session
Beverwyck Room

Program-At-A-Glance

Wednesday, July 22/AM

9:00 AM/Ballroom A-B
Invited Presentations 6 and 7
Chair: Michael Wozny
Rensselaer Polytechnic Institute

9:00 AM
Robot Systems That Sense, Plan and Manipulate
Tomas Lozano-Perez
Massachusetts Institute of Technology

9:45 AM
Gröbner Bases: An Algorithmic Algebraic Method for Non-Linear Geometry
Bruno Buchberger
Johannes Kepler University

10:30 AM/Prefunction Area
Coffee

11:00 AM/Ballroom A-B
Invited Presentations 8 and 9
Chair: Wolfgang Boehm
Technical University of Braunschweig
Federal Republic of Germany

11:00 AM
Implicitization and Parametrization of Curves and Surfaces
Shreeram S. Abhyankar
Purdue University

11:45 AM
The Application of Geometric Reasoning to Vision and Robotics
Joseph L. Mundy
General Electric Corporate Research and Development Center

Wednesday, July 22/PM

12:30 PM/**Lunch**

2:00 PM/CONCURRENT SESSIONS

Contributed Presentations 9/Ballroom E
Surface Applications
Chair: Nelson Max
Lawrence Livermore National Laboratory

Contributed Presentations 10/Ballroom D
Image Processing
Chair: Y. J. Tejwani
Southern Illinois University

Contributed Presentations 11/Ballroom C
Robot Path Planning 2
Chair: Vassilios D. Tourassis
University of Rochester

Contributed Presentations 12
Ballroom A-B
Algebraic Curves and Surfaces
Chair: Miriam L. Lucian
Boeing Commercial Airplane Co.

Contributed Presentations 12a/Beverwyck Room
General Topics 3
Chair: Matthew Hejna
Rensselaer Polytechnic Institute

3:30 PM/Prefunction Area
Coffee

5:00 PM/Saratoga Performing Arts Center
Dinner & Ballet

Thursday, July 23/AM

8:45 AM/CONCURRENT SESSIONS

Minisymposium 10/Ballroom C
Algebraic Geometry in Geometric Modeling
Chair: Miriam Lucian
Boeing Commercial Airplane Company

Minisymposium 11/Ballroom A-B
Computational Geometry
Chair: W. Randolph Franklin
Rensselaer Polytechnic Institute

Minisymposium 12/Ballroom E
Mesh Generation
Chair: David A. Field
General Motors Research Laboratories

10:15 AM/Prefunction Area
Coffee

10:45 AM/CONCURRENT SESSIONS

Contributed Presentations 13
Ballroom A-B
Computational Geometry 3
Chair: Paula Beaty
Colorado State University

Contributed Presentations 14/Ballroom C
Robot Path Planning 3
Chair: Jaroslaw R. Rossignac
IBM-T.J. Watson Research Center

Contributed Presentations 15/Ballroom D
Curves
Chair: John A. Roulier
University of Connecticut, Storrs

Contributed Presentations 16/Ballroom E
Graphics and Image Processing
Chair: Peter Waksman
University of Rochester

Thursday, July 23/PM

12:30 PM/**Lunch**

2:00 PM/Ballroom A-B
Invited Presentations 10 and 11
Chair: Harry McLaughlin
Rensselaer Polytechnic Institute

2:00 PM
Subdivision Algorithms for Curves and Surfaces
Carl de Boor
University of Wisconsin, Madison

2:45 PM
Computer Modeling and Simulation
John Hopcroft
Cornell University

3:30 PM/Prefunction Area
Coffee

4:00 PM/CONCURRENT SESSIONS

Contributed Presentations 17
Ballroom A-B
Mesh Generation
Chair: R. E. LaBarre
United Technologies Research Center

Contributed Presentations 18/Ballroom C
Computational Geometry 4
Chair: Howard B. Wilson
University of Alabama

Contributed Presentations 19
Beverwyck Room
Applications and Implementations
Chair: Wayne D. Smith
Mississippi State University

Contributed Presentations 20/Ballroom D
Mathematical Methods 2
Chair: Michael O'Connor
IBM-T.J. Watson Research Center

Contributed Presentations 21/Ballroom E
Path Planning Plus Geometric Modeling
Chair: Boris Aronov
Courant Institute of Mathematical Sciences

Friday, July 24/AM

9:00 AM/Ballroom A-B
Invited Presentation 12
Chair: David R. Ferguson
Boeing Computer Services

Semiparametric Surfaces
Malcolm Sabin
Finite Element Graphic System, Ltd.
Cambridge, England

9:45 AM/"Summing Up"
Michael Wesley
IBM-T.J. Watson Research Center

10:15 AM/Prefunction Area
Coffee

10:30 AM/CONCURRENT SESSIONS

Minisymposium 13/Ballroom E
Data Reduction for Splines and Its Applications
Chair: Tom Lyche
University of Oslo

Minisymposium 14/Ballroom C
Digital Geometry
Chair: Robert A. Melter
Long Island University

Minisymposium 15/Ballroom A-B
Parallel Methods in Geometry
Chair: Harry McLaughlin
Rensselaer Polytechnic Institute

Minisypmosium 16/Ballroom D
Shape Control in Surface Design
Chair: David R. Ferguson
Boeing Computer Services

12:00 PM/Conference Adjourns

Special Notice to Contributed Presentation Authors and Chairmen of Contributed Presentation Sessions:

Fifteen minutes are allowed for each contributed presentation. Presenters are requested to spend a maximum of 12 minutes for their presentation, and 3 minutes for questions and answers.

Please note:

For presentations with more than one author, an underlineation is used to denote the author who will present the paper.

GENERAL PROGRAM

Saturday, July 18/PM

5:00 PM/Prefunction Area, Ballroom Level
Registration opens for Short Course

10:00 PM
Registration Closes

Sunday, July 19/AM

Short Course on Uses of Surfaces in Industry: Geometric Modeling, Machine Vision, and Motion Planning

7:00 AM/Prefunction Area, Ballroom Level
Registration opens for Short Course

8:30 AM/Ballroom A-B
Motion Planning
Gordon Wilfong
AT&T Bell Laboratories

10:00 AM/Prefunction Area, Ballroom Level
Coffee

10:30 AM/Ballroom A-B
Surfaces in Computer Vision
Paul Besl
General Motors Research Laboratories

Sunday, July 19/PM

12:00 PM/Ballroom C-D
Lunch

1:30 PM/Ballroom A-B
Computational Issues in Solid Boundary Evaluation
Rida Farouki
IBM-T.J. Watson Research Center

3:00 PM/Prefunction Area
Coffee

3:30 PM/Ballroom A-B
G-1 Bézier Patching of Irregular Surface Shapes
Ramon Sarraga
General Motors Research Laboratories

5:00 PM/Prefunction Area
Registration Opens for Conference

8:00 PM/Prefunction Area
Welcoming Reception
Cash Bar

10:00 PM
Registration Closes

Monday, July 20/AM

7:30 AM/Prefunction Area, Ballroom Level
Registration Opens

8:45 AM/Ballroom A-B
Opening Remarks

9:00 AM/Ballroom A-B
Invited Presentations 1 and 2
Chair: Carl de Boor
University of Wisconsin, Madison

9:00 AM/Ballroom A-B
Geometric Issues and Algorithms Related to Robot Motions
Jacob T. Schwartz
Courant Institute of Mathematical Sciences
New York University

9:45 AM/Ballroom A-B
Geometric Approaches to Computational Problems
Andrew Yao
Princeton University

10:30 AM/Prefunction Area
Coffee

11:00 AM/*CONCURRENT SESSIONS*

Monday, July 20/11:00 AM – 12:30 PM
Minisymposium 1/Ballroom A-B
GEOMETRY PROCESSING

Much effort in geometric modeling is spent on "Geometry Generation", examples being the generation of a curve from data points or the fitting of a surface through a curve network. However, in order to produce a final product, the initial geometry has to be processed further: instances of such "Geometry Processing" are intersections, offsets, blends, or a ray traced image of an object. Geometry processing is often much more complicated than geometry generation and is just beginning to emerge as a discipline in its own right.

CHAIR AND ORGANIZER
Gerald Farin
Arizona State University
Tempe, AZ

11:00/M1/A1
Surface/Surface Intersections
R. E. Barnhill
Arizona State University
Tempe, AZ

11:30/M2/A1
Imprecise Geometric Computation
R. T. Farouki and V. T. Rajan
IBM T. J. Watson Research Center
Yorktown Heights, NY

12:00/M3/A1
An Improved Penalty Function for Implicit Blending of Multiple Surfaces
Alyn P. Rockwood
Evans & Sutherland Computer Corp.
Salt Lake City, UT

Monday, July 20/11:00 AM – 12:30 PM
Minisymposium 2/Ballroom C
ALGEBRAIC METHODS IN GEOMETRY

Two algorithmic methods for solving large classes of problems in real and complex algebraic geometry will be presented: Collins' method of "Cylindrical Algebraic Decomposition" and applications of Buchberger's method to "Geometrical Theorem Proving". In the two lectures, together with the plenary lecture of Buchberger, recent applications in robot programming (path finding, collision detection, inverse kinematics), geometrical theorem proving, solid modeling and global analysis of nonlinear geometrical objects will be given. Existing software for the two methods will be described.

CHAIR AND ORGANIZER
Bruno Buchberger
Johannes Kepler University
Linz, Austria

11:00/M4/A2
Cylindrical Algebraic Decomposition: A Universal Algorithmic Algebraic Method for Real Geometry
George E. Collins
Ohio State University
Columbus, OH

12:00/M5/A2
Geometrical Theorem Proving Based on Polynomial Ideal Theory
Bernhard Kutzler
Johannes Kepler University
Linz, Austria

Monday, July 20/11:00 AM – 12:30 PM
Minisymposium 3/Ballroom E
GEOMETRIC TOLERANCING

Geometric tolerancing is an area that deals with representing and processing information about the allowable variation in a product geometry. Note that this is not an area that addresses issues of numerical "tolerances" that are associated with imprecise arithmetic calculations in a computer. More specifically, we are interested only in the tolerances that engineers specify on a product. The purpose of this minisymposium is to bring together some of the state-of-the-art research that has been going on in the area of geometric tolerancing, and provide a forum for discussion on this topic. Three talks are scheduled on the mathematical and computational issues of geometric tolerancing.

CHAIR AND ORGANIZER
Vijay Srinivasan
IBM T. J. Watson Research Center
Yorktown Heights, NY

11:00/M6/A2
A Vector Space Approach to Mathematical Representation of Tolerances
Joshua Turner
IBM Data Systems Division
Poughkeepsie, NY

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

11:30/M7/A3
A Formal View of Some Functional Requirements in Mechanical Design
Rangarajan Jayaraman and V. Srinivasan
IBM T. J. Watson Research Center
Yorktown Heights, NY

12:00/M8/A3
Geometric Tolerances and Mathematical Programming
V. Thomas Rajan
IBM T. J. Watson Research Center
Yorktown Heights, NY

Monday, July 20/PM

*12:30 PM/***Lunch**

2:00 PM/CONCURRENT SESSIONS

Monday, July 20/2:00–3:30 PM
Minisymposium 4/Ballroom A-B
GEOMETRIC CONTINUITY

The seeds of visual continuity were first sewn by Greg Nielson in 1974 while considering so-called Nu-splines. In the last six years the interest in "visual continuity" of curves and surfaces has been growing: In 1981 Barsky started his work with the use of a special B-spline like function over uniform knots, having two so-called "shape parameters". Nearly at the same time, a simple Euclidean construction of curvature continuous splines was given by Farin. In 1985, W. Boehm generalized the construction of the Bézier points of a cubic spline curve or surface to curvature continuous cubics and to torsion continuous quartics. Nearly at the same time, T. Goodman and K. Unsworth developed a Mansfield-like recursion for the evaluation of generalized β-B-splines [Goodman, Unsworth '85]. Some more theoretical aspects were considered in 1985 by Dyn, Micchelli and others.

CHAIR AND ORGANIZER
Wolfgang Boehm
Technical University Braunschweig
Braunschweig, W. Germany

2:00/M9/A3
Geometric Continuity for Triangular Bézier Patches
Bruce Piper
University of Utah
Salt Lake City, UT

2:30/M10/A3
Nu-Spline Fractals
Gregory M. Nielson
Arizona State University
Tempe, AZ

3:00/M11/A4
Surfaces with Geometric Continuity
Hans Hagen
Technical University of Braunschweig
Braunschweig, W. Germany

Monday, July 20/2:00–3:30 PM
Minisymposium 5/Ballroom C
VISUAL MULTI-DIMENSIONAL GEOMETRY WITH APPLICATIONS

A non-projective mapping $R^N \rightarrow R^2$ for any positive integer N is obtained from new system of parallel coordinates. Relations in N variables are portrayed as planar "graphs" having certain properties analogous to the corresponding hypersurface in R^N. In the plane a point $\leftarrow\rightarrow$ line duality leads to efficient algorithms for convex merge and intersection of convex sets. A line in R^N is represented by $N-1$ planar points and a hyperplane by $N-1$ vertical lines. These enable some geometrical constructions and the representation of polyhedra in R^N. The representation of a class of more general convex and nonconvex hypersurfaces is known. There is an algorithm for constructing and displaying any point interior, exterior or on a hypersurface belonging to these classes. Computer graphics implementations will be shown of: 1) the representations; 2) algorithms; 3) the phase-space in N variables; 4) application to exploratory data analysis in statistics; and 5) a new air traffic control system (i.e. R^4) where the time and space trajectory information is displayed and used in collision avoidance (proximity) and routing.

CHAIRS AND ORGANIZERS
Alfred Inselberg
IBM Scientific Center
Los Angeles, CA
and
Bernard Dimsdale
University of California
Los Angeles, CA

2:00/M12/A4
Visual Multidimensional Geometry with Applications
Alfred Inselberg
IBM Scientific Center
Los Angeles, CA
and B. Dimsdale
University of California
Los Angeles

2:30/M13/A4
Application of Multidimensional Graphics to Phase Space
J. Rivero
IBM Scientific Center
Los Angeles, CA

3:00/M14/A4
Application of Parallel Coordinates to Complex System Design and Operation
J. Helly
The Aerospace Corp.
Los Angeles, CA

Monday, July 20/2:00–3:30 PM
Minisymposium 6/Ballroom E
BLENDING SURFACES

Blending surfaces are found on virtually all manufactured objects. Technically, they are surface elements intended to round or fill edges and corners. They are also useful for fairing. Efficient methods exist for deriving blending surfaces automatically for edges and for corners of limited complexity. This minisymposium describes recent research perfecting these techniques and developing a comprehensive theory assessing the scope of the method.

CHAIR AND ORGANIZER
Christoph Hoffmann
Purdue University
West Lafayette, IN

2:00/M16/A5
Issues in Implicit Blending
(to be presented by the chair)

2:30/M17/A5
Piecewise Quadric Blending of Implicitly Defined Surfaces
Lasse Holmstrom
Laboratory of Information Processing Science
Helsinki, Finland

3:00/M18/A5
Construction of Low Degree Blending Surfaces
Joe Warren
Rice University
Houston, TX

*3:30 PM/*Prefunction Area
Coffee

4:00 PM/CONCURRENT SESSIONS

Monday, July 20/4:00–5:30 PM
Contributed Presentations 1/Ballroom D
SURFACE METHODS

Chair: C.N. Shen, Rensselaer Polytechnic Institute

4:00/12/A14
Recursive Surface Smoothing for Random Grid Displacements of Discrete Measurements
Roy Ho and C. N. Shen, Rensselaer Polytechnic Institute, Troy, NY

4:15/46/A14
Interpolation to Large Data Sets Using Bezier Curves and Surfaces
Ardeshir Goshtasby, University of Kentucky, Lexington, KY

4:30/97/A14
A Trivariate Powell-Sabin Interpolant
Andrew J. Worsey, University of North Carolina at Wilmington, Wilmington, NC

4:45/102/A15
An Improved Monotone Bivariate Interpolation Algorithm
F. N. Fritsch and R. E. Carlson, Lawrence Livermore National Laboratory, Livermore, CA

5:00/4/A15
An Efficient Algorithm for Computing the Geometric Features of Parametrized Surfaces
Su-shing Chen, University of North Carolina, Charlotte, NC and Michael Penna, Purdue University, Indianapolis, IN

5:15/75/A15
Application of Diparabolic Interpolation to Surface Modeling
Edward L. Copeland, Rockwell International, Houston, TX

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

General Program

Monday, July 20/4:00 - 5:45 PM
Contributed Presentations 2/Ballroom A-B
SOLID MODELING

Chair: Donald P. Peterson, Sandia National Laboratories

4:00/28/A15
Halfspace Representation of 2½ D Parts
Donald P. Peterson, Sandia National Laboratories, Albuquerque, NM

4:15/11/A16
Solid Modeling with Ruled Surfaces
Per-Olof Fjällström, IBM Svenska AB, Stockholm, Sweden

4:30/50/A16
Constructive Solid Geometry with Surface-Constraint
Yasumasa Kawashima, Tomotoshi Ishida and Shinji Tokumasu, Hitachi Research Laboratory, Ibaraki-ken, Japan

4:45/41/A16
High Level Representations and Algorithms for Extended Geometrical Modelling
Jaroslaw R. Rossignac and Michael A. O'Connor, IBM-T.J. Watson Research Center, Yorktown Heights, NY

5:00/9/A16
Solid Modeling for Automated Tolerance Analysis
Joshua U. Turner, IBM Corporation, Poughkeepsie, NY and Michael J. Wozny, Rensselaer Polytechnic Institute, Troy, NY

5:15/27/A16
Automated Constant-Radius Blending in a Boundary-Representation Solid Modeler
Mark Mummy, Boeing Computer Services, Seattle, WA

5:30/6/A17
Solids by Blending Parametric Contours
U. G. Gujar, V. C. Bhavsar, and N. N. Datar, University of New Brunswick, Fredericton, Canada

Monday, July 20/4:00 - 5:30 PM
Contributed Presentations 3/Ballroom E
COMPUTATIONAL GEOMETRY 1

Chair: Yves de Montaudouin, Lehigh University

4:00/49/A17
Voronoi Diagrams on the Sphere
John Dolan and Richard Weiss, University of Massachusetts, Amherst, MA

4:15/114/A17
Conjugate Indicator Algorithms for Two and Three Dimensional Delaunay Triangulation
Charles Edward Buckley, Integrated Systems Laboratory, ETH-Zurich, Switzerland

4:30/30/A17
A New Data Structure for Nearest Neighbor Searching
Owen Murphy, University of Vermont, Burlington, VT and Stanley Selkow, Worcester Polytechnic Institute, Worcester, MA

4:45/111/A18
Detecting and Computing the Intersection of Convex Objects
David P. Dobkin, Princeton University, Princeton, NJ and Diane L. Souvaine, Rutgers University, New Brunswick, NJ

5:00/23/A18
Algorithm for the Surface/Surface Intersection Problem
Yves de Montaudouin, Lehigh University, Bethlehem, PA

5:15/55/A18
Intersection Problems in Polygon Overlay
Jose Armando Guevara, Environmental Systems Research Institute, Redlands, CA

Monday, July 20/4:00 - 5:30 PM
Contributed Presentations 4/Ballroom C
GENERAL TOPICS 1

Chair: Subhas Desa, Carnegie-Mellon University

4:00/77/A19
The Geometry of Form Closure
Xanthippi Markenscoff, University of California, Santa Barbara, CA, Luqun Ni, Institute of Mathematics, Beijing, China and Christos H. Papadimitriou, Stanford University, Stanford, CA

4:15/117/A19
Interactive Design with Rational Overhauser Curves
Jeffrey J. Jortner and John A. Brewer, III, Louisiana State University, Baton Rouge, LA

4:30/128/A19
On the Global Properties of Motion of Kinematics
Subhas Desa, Carnegie Mellon University, Pittsburgh, PA

4:45/131/A19
EZ-SURF Package for Sculptured Surface Fit and Numerically Controlled Machining
Lena Fishman and Prashant Kurdukar Bridgeport Machines Inc., Willow Grove, PA

5:00/133/A24
Simplifying Polygonal Curves
Michael Werman, Brown University, Providence, RI

5:15/L-7/A48
Non-Rectangular Surface Patches Using Rectangular Transfinite Interpolation
Alan K. Jones, Boeing Computer Services, Seattle, WA

6:15 PM/Prefunction Area
Beer Party

Tuesday, July 21/AM

9:00 AM/Ballroom A-B
Invited Presentations 3 and 4
Chair: Ramon Sarraga
General Motors Research Laboratories

9:00 AM/Ballroom A-B
The Generation and Uses of Aperiodic Tilings
Branko Grünbaum
University of Washington

9:45 AM/Ballroom A-B
Solid Modeling and Manufacturing Applications
John K. Hinds
General Electric Corporate Research and Development Center

10:30 AM/Prefunction Area
Coffee

11:00 AM/CONCURRENT SESSIONS

Tuesday, July 21/11:00 AM - 1:15 PM
Minisymposium 7/Ballroom E
MOTION PLANNING

Motion planning has been studied as an example of geometric reasoning since the earliest days of computer-based robotics. In this tutorial session, four speakers cover the subject from theoretical, algorithmic, and practical points of view. The first speaker (Lozano-Perez) will give an overview of the subject and cover the topic of collision-free motion planning and controlled-collision fine motion planning. The second speaker (Yap) will address the computational complexity issues in geometric motion planning. The third speaker (Kanade) will cover the integration of sensory information, particularly vision, into the motion planning process. The final speaker (Khatib) will present a potential field approach to practical low level motion planning in the context of a layered system.

CHAIR AND ORGANIZER
Michael Wesley
IBM T. J. Watson Research Center
Yorktown Heights, NY

11:00/M19/A6
An Overview of Motion Planning
Tomas Lozano-Perez
Massachusetts Institute of Technology
Cambridge, MA

11:30/M20/A6
Theoretical Advances in Algorithmic Motion Planning
Chee Yap
Courant Institute of Mathematical Sciences, New York University
New York, NY

12:00/M21/A6
Sensor Integration for Robot Mobility
Takeo Kanade
Carnegie-Mellon University
Pittsburgh, PA

12:30/M22/A6
Toward Multi-Level Robot Collision Avoidance: The Artificial Potential Field Concept
Oussama Khatib
Stanford University
Stanford, CA

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

Tuesday, July 21/11:00 AM–12:30 PM
Minisymposium 8/Ballroom C
NON-TENSOR PRODUCT SURFACES

Tensor product surfaces have proven to be extremely valuable in many areas of surface design. However, there are many significant areas where tensor product surfaces are inappropriate, e.g., scattered data approximation. The next step in surface methods will involve developing models which are not based on tensor products. Investigators have begun to concentrate on piecewise polynomial surfaces with a view toward understanding them and their usefulness for applications. Difficult mathematical problems concerning the structure of these surfaces and their applicability to engineering problems remain. This minisymposium will present overviews of this area including problems, recent work and applications.

CHAIR AND ORGANIZER
David R. Ferguson
Boeing Computer Services
Seattle, WA

11:00/M23/A7
Multivariate Splines
Peter Alfeld
University of Utah
Salt Lake City, UT

11:30/M24/A7
Convex Approximations to Multivariate Scattered Data
Thomas Grandine
Boeing Computer Services
Seattle, WA

12:00/M24a/A7
An Interpolatory Surface Under Tension with Automatic Selection of Tension
Robert J. Renka
North Texas State University
Denton, TX

Tuesday, July 21/11:00 AM–12:30 PM
Minisymposium 9/Ballroom A-B
PROBABILISTIC APPROACHES TO COMPUTER-AIDED GEOMETRIC DESIGN (CAGD)

Many of the blending functions of Computer Aided Geometric Design (CAGD)—including Bernstein polynomials, B-splines, Catmul-Rom splines and even Lagrange polynomials—can be used to model simple stochastic processes. Therefore the geometric properties of the corresponding curves and surfaces can be derived largely from probabilistic considerations. In this minisymposium, the speakers will: explain why probability and geometry are so closely linked in CAGD; give several examples of properties of curves and surfaces which can be derived from simple probabilistic arguments; discuss some additional geometric properties for which a probabilistic interpretation has yet to be found; illustrate the duality between Polya's urn model and B-splines; and introduce a general multiprocessor hardware for extremely fast computation of points on curves and surfaces based upon the recursive formulas satisfied by all urn models.

CHAIR AND ORGANIZER
Ronald A. Goldman
Control Data Corporation
Arden Hills, MN

11:00/M25/A7
Introduction to the Probabilistic Approaches to CAGD
(to be presented by the chair)

11:30/M26/A8
Urn Models on CAGD
Phillip J. Barry
University of Utah
Salt Lake City, UT

12:00/M27/A8
Using Urn Models for Fast Curves and Surface Generation
Tony D. DeRose
University of Washington
Seattle, WA

Tuesday, July 21/PM

12:30 PM/**Lunch**

2:00 PM/Ballroom A-B
Invited Presentation 5
Chair: Leon Seitelman
Pratt & Whitney Aircraft Co.

Free-Form Modeling with Cubic Algebraic Surfaces
Thomas W. Sederberg
Brigham Young University

2:45 PM/Prefunction Area
Coffee

3:15 PM/***CONCURRENT SESSIONS***

Tuesday, July 21/3:15–4:45 PM
Contributed Presentations 5/Ballroom E
MATHEMATICAL METHODS 1

Chair: Mladin Luksic, University of Texas, San Antonio

3:15/54/A20
On Some Topological Problems in Robotics Motion Planning
Mladen Luksic, The University of Texas at San Antonio, San Antonio, TX

3:30/103/A20
Polyharmonic Cardinal Splines
W. R. Madych, University of Connecticut, Storrs, CT and S. A. Nelson, Iowa State University, Ames, IA

3:45/78/A20
Hermite Interpolation by C^1 Piecewise Polynomials on Triangulations
Edmond Nadler, IBM-T.J. Watson Research Center, Yorktown Heights, NY

4:00/94/A20
Free-Form Curve Modeling by Polycurve Codes
Chang Y. Choo, Worcester Polytechnic Institute, Worcester, MA

4:15/86/A21
The Unit Circle as the Mathematical Model for the Space and Time Measurements of Special Relativity Theory
Herbert J. Nichol, (retired) Drexel University, Philadelphia, PA

4:30/129/A21
Elastically Deformable Geometric Models
Demetri Terzopoulos, Schlumberger Palo Alto Research, Palo Alto, CA, John Platt and Alkan Barr, California Institute of Technology, Pasadena, CA and Kurt Fleisher, Schlumberger Palo Alto Research, Palo Alto, CA

Tuesday, July 21/3:15–4:45 PM
Contributed Presentations 6/Ballroom D
ROBOT PATH PLANNING 1

Chair: Daniel Koditschek, Yale University

3:15/72/A21
Optimal Path Planning by Cost Wave Propagation in Configuration Space
Leo Dorst, Philips Laboratories, Briarcliff Manor, NY

3:30/83/A22
Polar Morse Functions and Exact Robot Navigation
Daniel E. Koditschek, Yale University, New Haven, CT

3:45/84/A22
Path Planning for Mobile Robots in Unexplored Terrain
Baba Prasad S. Chikballapur and S. K. Mohapatra, University of Hyderabad, Hyderabad, India

4:00/110/A22
Manipulator Workspace Geometry By the Monte Carlo Method
David Perel and Jahangir S. Rastegar, Manhattan College, Riverdale, NY

4:15/31/A22
A Probabilistic Approach to the Design of Robot Arms
Jahangir S. Rastegar and Behruz Fardanesh, Manhattan College, Riverdale, NY

4:30/20/A23
The Application of Quintic Splines to Kinematic Design Problems
Bartholomew MacCarthy, Oxford University Computing Laboratory, UK

Tuesday, July 21/3:15–4:45 PM
Contributed Presentations 7/Ballroom C
GENERAL TOPICS 2

Chair: Seymour Haber, National Bureau of Standards

3:15/85/A23
A Characterization of Octree Behavior
Donald T. Kasper, Northrop Advanced Systems Division, Pico Rivera, CA

3:30/100/A23
A Pattern-Theoretic Formulation of Shape
Ulf Grenander and Daniel MacRae Keenan, Brown University, Providence, RI

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

General Program

3:45/64/A23
A Construction of Non-Periodic Tilings
Seymour Haber and James F. Lawrence, National Bureau of Standards Gaithersburg, MD

4:00/22/A24
On A Class of Geometric Packing Problems
R. Chandrasekaran, University of Texas at Dallas, Richardson, TX and Santosh N. Kabadi, University of New Brunswick, New Brunswick, Canada

4:15/119/A24
Identification of Industrial Objects from Video Images Based on Their B-Rep Solid Models
Farhad Towfiq, R. Curt Grove and H. R. Keshavan, Northrop Research and Technology Center, Palos Verdes Peninsula, CA

4:30/130/A24
Graphics Representation of Implicitly Defined Surfaces
Timothy S. Norfolk and Phillip H. Schmidt, The University of Akron, Akron, OH

Tuesday, July 21/3:15–4:30 PM
Contributed Presentations 8/Ballroom A-B
COMPUTATIONAL GEOMETRY 2

Chair: Don J. Orser, National Bureau of Standards

3:15/118/A25
A Calculus for Reasoning about Polygons, Polyhedra and Complexes Made from Them
Don J. Orser, National Bureau of Standards, Gaithersburg, MD

3:30/124/A25
On the External Contour of the Union of a Set of Polygons and Applications
Jean Daniel Boissonnat, INRIA, Valbonne, France

3:45/126/A25
Using Prolog For Gometric Intersection
Peter Y. F. Wu, Rensselaer Polytechnic Institute, Troy, NY

4:00/127/A25
An Optimal Visibility Algorithm for a Simple Polygon with Star Shaped Holes
Esther M. Arkin and Joseph S. B. Mitchell, Cornell University, Ithaca, NY

4:15/L-5/A48
Number-Theoretic Properties of Two-Dimensional Lattices
Roger V. Jean, University of Quebec, Rimouski

Tuesday, July 21/3:15–4:45 PM
Poster Session/Beverwyck Room

44/A45
General Curvature Formulae for Implicit Surfaces
Mark A. Stuff, Environmental Research Institute of Michigan, Ann Arbor, MI

57/A45
Surface Model for Laser Ranging System
Jacques Lemordant, Grenoble University, St. Martin d'Heres, France

92/A45
Spline Curve Fitting for Interactive Design
Christine Potier and Christine Vercken, Ecole National Superieure des Telecommunications, Paris-Cedex, France

98/A46
Romboy Homotopy and Etruscan Venus: An Experiment in Computer Topology
George K. Francis, Donna J. Cox and Ray L. Idaszak, University of Illinois, Urbana, IL

101/A46
Analytic Functions of Conic Sections in a Computer-Aided Design System
Joshua Zev Levin, Design System, Pacer Systems Inc, Horsham, PA

L-9/A46
Dimensioning and Tolerancing of Engineering Components Using Constructive Solid Geometry
Laurence P. Wickens, University of Leeds, Great Britain

Wednesday, July 22/AM

9:00 AM/Ballroom A-B
Invited Presentations 6 and 7
Chair: Michael Wozny
Rensselaer Polytechnic Institute

9:00 AM
Robot Systems That Sense, Plan and Manipulate
Tomas Lozano-Perez
Massachusetts Institute of Technology

9:45 AM
Gröbner Bases: An Algorithmic Algebraic Method for Non-Linear Geometry
Bruno Buchberger
Johannes Kepler University

10:30 AM/Prefunction Area
Coffee

11:00 AM/Ballroom A-B
Invited Presentations 8 and 9
Chair: Wolfgang Boehm
Technical University of Braunschweig
Federal Republic of Germany

11:00 AM
Implicitization and Parametrization of Curves and Surfaces
Shreeram S. Abhyankar
Purdue University

11:45 AM
The Application of Geometric Reasoning to Vision and Robotics
Joseph L. Mundy
General Electric Corporate Research and Development Center

Wednesday, July 22/PM

12:30 PM/**Lunch**

2:00 PM/***CONCURRENT SESSIONS***

Wednesday, July 22/2:00–3:45 PM
Contributed Presentations 9/Ballroom E
SURFACE APPLICATIONS

Chair: Nelson Max, Lawrence Livermore National Laboratory

2:00/76/A26
Approximating Molecular Surfaces by Spherical Harmonics
Nelson L. Max, Lawrence Livermore National Laboratory, Livermore, CA

2:15/89/A26
Geometric Modeling of Complex Surfaces in Turbomachines
B. Ozell and R. Camarero, Ecole Polytechnique, Montreal, Canada

2:30/24/A26
Surface Geometry Requirements for Finite-Difference Aerodynamic Calculations
G. David Kerlick, Sterling Software Inc., Moffett Field, CA

2:45/66/A26
Probing Convex Polygons with X-rays
Herbert Edelsbrunner and Steven S. Skiena, University of Illinois, Urbana, IL

3:00/21/A27
The Use of Tensor Product Splines for the Approximation of The Sea Bed Surface
D. C. Handscomb and B. L. MacCarthy, Oxford University Computing Laboratory, UK

3:15/60/A27
Fast Frontal and Drag Area Computations in Space Vehicle Design and Analysis
Vish Dixit, Rockwell International, Downey, CA

3:30/38/A27
Geometrical Analysis of Gastric Emptying
R. Ech, A. Abutaleb, Z. Delalic and J. Siegel, Temple University, Philadelphia, PA

Wednesday, July 22/2:00–3:30 PM
Contributed Presentations 10/Ballroom D
IMAGE PROCESSING

Chair: Y.J. Tejwani, Southern Illinois University

2:00/34/A27
The Gray-Scale Version of the Matheron Representation Theorem for Tau-openings
Edward R. Dougherty, Fairleigh Dickinson University, Teaneck, NJ

2:15/33/A28
Gray-Scale Morphology as an Extension of Matheron-Hadwiger Two-valued Theory
Edward R. Dougherty, Fairleigh Dickinson University, Teaneck, NJ and Charles R. Giardina, The Singer Company-Kearfott Division, Little Falls, NJ

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

2:30/81/A28
A Gaussian Localized Image Processing Model
Joseph Shu, NYNEX Corporation, White Plains, NY

2:45/96/A28
Minimal Curves in Image Segmentation
Jayant M. Shah, Northeastern University, Boston, MA

3:00/1/A28
An Integral Measure Signature for Recognition of Plane Curves and Surfaces Using Cylindrical Multivalued Transform
Y. J. Tejwani, Southern Illinois University, Carbondale, IL

3:15/35/A28
Determining Object Posture from Dense Range Maps
B. C. Vemuri and J. K. Aggarwal, The University of Texas at Austin, Austin, TX

Wednesday, July 22/2:00–3:30 PM
Contributed Presentations 11/Ballroom C
ROBOT PATH PLANNING 2

Chair: Vassilios D. Tourassis, University of Rochester

2:00/107/A29
Real-Time Adaptive Motion Planning
Bruce G. Hartleben, MTS Systems Corporation, Minneapolis, MN

2:15/87/A29
Parallel Processing: The Road to Autonomy
Bruce Moxon, BBN Advanced Computers, Inc, Cambridge, MA

2:30/62/A29
Towards a Global Navigation and Positioning System for Mobile Robots
Wayne D. Smith, Mississippi State University, Mississippi State, MS

2:45/112/A29
Robot Kinematics Based Upon Simple Applied Geometric Notions
Vassilios D. Tourassis, University of Rochester, Rochester, NY

3:00/73/A30
Forward and Inverse Synthesis for a Robot with Three Degrees of Freedom
A. H. Shirkhodaie and A. H. Soni, Oklahoma State University, Stillwater, OK

3:15/120/A30
Using Fiducial Marks for Tracking a Robot Arm
Aram Falsafi, Lester A. Gerhardt and George Nagy, Rensselaer Polytechnic Institute, Troy, NY and Leila De Floriani, National Research Council, Genova, Italy

Wednesday, July 22/2:00–3:30 PM
Contributed Presentations 12/Ballroom A-B
ALGEBRAIC CURVES AND SURFACES

Chair: Miriam L. Lucian, Boeing Commercial Airplane Co.

2:00/109/A30
An Algorithm for Computing and Plotting on Implicitly Defined Surface
Stefan Gnutzmann, University of the Federal Armed Forces, Hamburg, W. Germany

2:15/113/A30
Genus Is a Birational Invariant: Parameterizing Rational Space Curves
S. S. Abhyankar and C. Bajaj, Purdue University, West Lafayette, IN

2:30/56/A31
Algebraic Varieties, Path-Following Methods and Stopping Times
Richard Wongkew, University of California at Berkeley, Berkeley, CA

2:45/18/A31
Polynomially Parametrizable Planar Algebraic Curves
Miriam L. Lucian, Boeing Commercial Airplane Co., Seattle, WA

3:00/36/A31
Finding the Defining Equation for a Rationally Parametrized Surface
Arthur J. Schwartz, University of Michigan, Ann Arbor, MI and Charles M. Stanton, Indiana University at South Bend, South Bend, IN

3:15/67/A31
Convex Decompositions and Gaussian Approximations of Objects Bounded by Piecewise Algebraic Curves
Chanderjit Bajaj and Myung-Soo Kim, Purdue University, West Lafayette, IN

Wednesday, July 22/2:00–3:30 PM
Contributed Presentations 12a/Beverwyck Room
GENERAL TOPICS 3 *(Abstracts submitted after deadline)*

Chair: Matthew Hejna, Rensselaer Polytechnic Institute

2:00/L-1/A47
Coordinated Activation of Multijointed Artificial Limbs
Jozsef Laczko, Hungarian Academy of Sciences, Budapest, Hungary

2:15/L-2/A47
Experiences in Integrating Sculptured Surfaces in Boundary Structure Volume Modellers
Tor Dokken, Center for Industrial Research, Oslo, Norway; and Magdy Imam, Technical University of Berlin, Berlin, W. Germany

2:30/L-3/A47
Analysis of Geometric Tolerances in CAD and CAM
Peter Hoffmann, Computer Applications and Service Co., Budapest, Hungary

2:45/L-4/A48
A Geometric Condition for Smoothness Between Adjacent Bézier Surface Patches
Liu Dingyuan, Fudan University, Shanghai, China

3:00/L-6/A48
Reconstruction of Systems of Overlapping Sets
Wolfgang Weil, University of Karlsruhe, W. Germany

3:15/L-8/A48
The System INDUSURF for Automatic Measurement of Car Body Surfaces
Wolfgang Förstner, Universitat Stuttgart, W. Germany

3:30 PM/Prefunction Area
Coffee

5:00 PM/Saratoga Performing Arts Center
Dinner & Ballet

Thursday, July 23/AM

8:45 AM/***CONCURRENT SESSIONS***

Thursday, July 23/8:45–10:15 AM
Minisymposium 10/Ballroom C
ALGEBRAIC GEOMETRY IN GEOMETRIC MODELING

Presentations in this minisymposium will encompass both general methods and their applications. "Geometric Reasoning with Logic and Algebra" and "Elimination Methods for Systems of Polynomial Equations in Several Variables" will present algebraic geometry methods applicable in modeling; "C^1 Rational Finite Elements" and "Parametric Cubics as Algebraic Curves" will be applications of such methods. We hope this symposium will be of interest both to specialists and to people getting into the field.

CHAIR AND ORGANIZER
Miriam L. Lucian
Boeing Commercial Airplane Co.
Seattle, WA

8:45/M28/A8
C^1 Rational Finite Elements
Eugene Wachspress
University of Tennessee
Knoxville, TN

9:05/M29/A8
Geometric Reasoning with Logic and Algebra
Dennis Arnon
Xerox Research Center
Palo Alto, CA

9:25/M30/A9
Elimination Methods for Systems of Polynomial Equations in Several Variables
Andrew Neff
IBM T. J. Watson Research Center
Yorktown Heights, NY

9:45/M31/A9
Parametric Cubics as Algebraic Curves
Richard Patterson
Indiana University — Purdue University
Indianapolis, IN

Thursday, July 23/8:45–10:15 AM
Minisymposium 11/Ballroom A-B
COMPUTATIONAL GEOMETRY

Implications of present and future properties of computation such as roundoff and parallel processors are considered in the session. Robust computation of subdivisions in the presence of finite precision computations is presented. Next a systematic method of exploiting parallel architectures in algorithms such as convex hull determination is given. Finally, new data

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

General Program

structures that are stable and minimize the number of special cases in operations such as polygon overlay are presented.

CHAIR AND ORGANIZER
W. Randolph Franklin
Rensselaer Polytechnic Institute
Troy, NY

8:45/M32/A9
On Parallel Algorithms in Computational Geometry
Minsoo Suk and S. J. Oh
Syracuse University
Syracuse, NY

9:15/M33/A9
Verifiable Geometric Computations Using Finite Precision Arithmetic
Victor J. Milenkovic
Carnegie-Mellon University

9:45/M34/A9
Polygon Properties Calculated From the Vertex Neighborhoods
(to be presented by the Chair)

Thursday, July 23/8:45-10:15 AM
Minisymposium 12/Ballroom E
MESH GENERATION

Much development of transfinite interpolation techniques occurred at GM in the 60's. Today automatic 3-D mesh generation at GM has incorporated these techniques along with recent developments based on mathematical properties of Delaunay triangulations. This background serves to unify the first two presentation topics; recent mesh generation developments at GM, and powerful new mesh generation codes based upon transfinite interpolation and solutions to elliptic partial differential equations encountered in aerospace engineering. Also included in this minisymposium is research supported by GM on a totally different mesh generation approach motivated by octree's, an extremely efficient data structure for digital computers. Introductory and concluding remarks will be given by the minisymposium chairperson.

CHAIR AND ORGANIZER
David A. Field
General Motors Research Laboratories
Warren, MI

8:45/M35/A10
A New Automatic Node Placement Strategy for Graded Triangular Meshes
William H. Frey
General Motors Research Laboratories
Warren, MI

9:10/M36/A10
Automated Grid Generation for General 3D Regions
Joe F. Thompson
Mississippi State University
Mississippi State, MS

9:35/M37/A10
Mesh Generation by the Finite Octree Technique
Mark S. Shephard
Rensselaer Polytechnic Institute
Troy, NY

*10:15 AM/*Prefunction Area
Coffee

10:45 AM/CONCURRENT SESSIONS

Thursday, July 23/10:45-11:45 AM
Contributed Presentations 13/Ballroom A-B
COMPUTATIONAL GEOMETRY 3

Chair: Paula Beaty, Colorado State University

10:45/95/A32
d-Neighbourhoods of Simple Externally Visible Polygons
Dolores Lodares and Manuel Abellanas, Universidad Politecnica de Madrid, Madrid, Spain

11:00/7/A32
Application of 2-n Sorting in Computational Geometry
Jeffrey L. Posdamer, Washington University, St. Louis, MO

11:15/15/A32
Scheduling Pattern of Points or Intervals on a Circle Line
Peter J. Brucker, Universitat Osnabrueck, W. Germany

11:30/43/A32
On the Complexity of 3D Variational Geometry
Paula Beaty and Patrick Fitzhorn, Colorado State University, Ft. Collins, CO

Thursday, July 23/10:45 AM-12:15 PM
Contributed Presentations 14/Ballroom C
ROBOT PATH PLANNING 3

Chair: Jaroslaw R. Rossignac, IBM T.J. Watson Research Center

10:45/63/A33
A General Path Planning Algorithm for Kinematically Redundant Robots Using a Selective Mapping of Configuration Space
Pierre E. Dupont, and Stephen Derby, Rensselaer Polytechnic Institute, Troy, NY

11:00/2/A33
Path Planning for Mobile Robots: An Elastic Band Approach
S. K. Mohapatra and Baba Prasad S. Chikballapur, University of Hyderabad, Hyderabad, India

11:15/58/A33
Euclidean Shortest Path through Horizontal and Vertical Line Barriers in O(n log n) Time
Man-Tak Shing, University of California at Santa Barbara, Santa Barbara, CA

11:30/40/A33
Active Zones in Constructive Solid Geometry for Redundancy and Interference Detection
Jaroslaw R. Rossignac, IBM-Thomas Watson Research Center, Yorktown Heights, NY and Herbert B. Voelcker, Cornell University, Ithaca, NY

11:45/99/A34
Collision Avoiding Paths for Robots
Prabhakar M. Ghare, Northern Virginia Graduate Center, Falls Church, VA

12:00/71/A34
Separability and Order
Ivan Rival, University of Ottawa, Ottawa, Canada

Thursday, July 23/10:45 AM-12:15 PM
Contributed Presentations 15/Ballroom D
CURVES

Chair: John A. Roulier, University of Connecticut, Storrs

10:45/5/A34
Computing Approximating Spline Curves with Few Pieces
Michael Kallay, University of California, Davis, CA

11:00/32/A34
The Sorting of Points on a Curve
John K. Johnstone, Cornell University, Ithaca, NY

11:15/14/A34
Interpolatory Curves which Preserve the Sign of Curvature
John A. Roulier, University of Connecticut, Storrs, CT

11:30/13/A35
A Heuristic Method for Data Parametrization
E. T. Y. Lee, Boeing Commercial Airplane Co., Seattle, WA

11:45/48/A35
An Algorithm for Constrained Approximation
Lars-Erik Andersson, Linkoping University, Linkoping, Sweden

12:00/42/A35
A 4-Point Interpolatory Subdivision Scheme for Curve Design
N. Dyn, Tel Aviv University, Tel-Aviv, Israel, J. Gregory, Brunel University, Middlesex, UK and D. Levin, Tel Aviv University, Tel-Aviv, Israel

Thursday, July 23/10:45 AM-12:15 PM
Contributed Presentations 16/Ballroom E
GRAPHICS AND IMAGE PROCESSING

Chair: Peter Waksman, University of Rochester

10:45/8/A35
Circle Averages and Probabilities in the Hexagonal Lattice
Peter Waksman, University of Rochester, Rochester, NY

11:00/51/A36
Boundary Tracking in Multidimensions and Some Discrete Topologic Problems
Jayaram K. Udupa, Hospital of the University of Pennsylvania, Philadelphia, PA

11:15/47/A36
Ray Intercept Determination and Characterization Using Linear Programming and Convex Polyhedra
H. Ric Blacksten, Human Resources Research Organization, Alexandria, VA

11:30/74/A36
Ray-Tracing Fractal Surfaces
David L. Wells, Texas Instruments, Dallas, TX and Stephen L. Stepoway, Southern Methodist University, Dallas, TX

11:45/104/A36
Codes for Straight Lines in N-Space
Jerome Rothstein, Ohio State University, Columbus, OH

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

12:00/91/A37
A New Model of Texture Based on Substitution Sequences
Pierre Michel, Universite de Bretagne Occidentale, Brest Cedex, France, Christian Roux, and Moncef Daoud, Ecole National Superieure des Telecommunications de Bretagne, Brest Cedex, France

Thursday, July 23/PM

12:30 PM/**Lunch**

2:00 PM/Ballroom A-B
Invited Presentations 10 and 11
Chair: Harry McLaughlin
Rensselaer Polytechnic Institute

2:00 PM
Subdivision Algorithms for Curves and Surfaces
Carl de Boor
University of Wisconsin, Madison

2:45 PM
Computer Modeling and Simulation
John Hopcroft
Cornell University

3:30 PM/Prefunction Area
Coffee

4:00 PM/***CONCURRENT SESSIONS***

Thursday, July 23/4:00 - 5:30 PM
Contributed Presentations 17
Ballroom A-B
MESH GENERATION

Chair: R.E. LaBarre, United Technologies Research Center

4:00/108/A37
Finite Element Mesh Optimization Using Distributive Lattice Processing
Joseph M. Juarez, OAO Corporation El Segundo, CA

4:15/70/A37
Algebraic Grid Generation in Patched Mesh Systems
Raymond Ching-Chung Luh and C. K. Lombard, PEDA Corporation, Palo Alto, CA

4:30/82/A38
An Algorithm for the Automatic Decomposition of Octal Cells Into Finite Elements
Mukul Saxena and Renato Perucchio, University of Rochester, Rochester, NY

4:45/37/A38
Vertex Planting in Solid Finite Element Mesh Generation
Timothy Thomasma, University of Michigan, Dearborn, MI

5:00/29/A38
Refining Simplicial Meshes for Finite Element Problems
Woody Lichtenstein, Culler Scientific Systems Corporation, Goleta, CA

5:15/3/A38
Mesh Generation for Arbitrarily Shaped Regions
R. E. LaBarre and B. J. McCartin, United Technologies Research Center, East Hartford, CT

Thursday, July 23/4:00 - 5:30 P.M.
Contributed Presentations 18/Ballroom C
COMPUTATIONAL GEOMETRY 4

Chair: Howard B. Wilson, University of Alabama

4:00/10/A39
Line Integral Computation of Geometrical Properties of Plane Faces and Polyhedra
Howard B. Wilson, University of Alabama, Tuscaloosa, AL

4:15/68/A39
Graph Based Scheme for Recognition of Polyhedral Features From a 3-D Solid Model
Sanjay Joshi, T. C. Chang and Vijaya Chandru, Purdue University, West Lafayette, IN

4:30/106/A39
Tetrahedral Recursive Decomposition of Free-Space from Boundary Points
Stephane Aubry and Vincent Hayward, McGill University, Montreal, Canada

4:45/93/A39
Medial Axis Transform Using Ridge Following
R. Mark Volkmann, University of Missouri, Rolla, MO and Karl G. Kempf, FMC Corporation, Santa Clara, CA

5:00/19/A40
Vectorized Conjugate Gradient Projection Methods
Ron S. Dembo and Patrick Henaff, Goldman, Sachs & Co. New York, NY

5:15/69/A40
A Sympletic Approach to Graph Theory
Max Garzon, Memphis State University, Memphis, TN

Thursday, July 23/4:00 - 5:30 PM
Contributed Presentations 19/Beverwyck Room
APPLICATIONS AND IMPLEMENTATIONS

Chair: Wayne D. Smith, Mississippi State University

4:00/25/A40
Applications of Differential Geometry to Structural Mechanics
Philip Samuels, Hatfield Polytechnic, England

4:15/16/A40
Metal Die Design Using Orthogonal Volume Preserving Coordinates in R^3
Maija Kuusela, Helsinki University of Technology, Finland

4:30/61/A41
Application of the CORDIC Algorithm to Robot Navigational Computations
Wayne D. Smith, Mississippi State University, Mississippi State, MS

4:45/79/A41
Robochess the Intelligent Robot Chess Player
A. R. Nekovei and M. T. Musavi, University of Maine, Orono, ME

5:00/80/A41
A Central Computer Scheme for Controlling Several Small Educational Robots
A. R. Nekovei, M. T. Musavi and M. T. Noori, University of Maine, Orono, ME

5:15/90/A41
Applications of Mathematical Logic to Robotics and Automation
Paul P. Botosani, Bridgeport Engineering Institute, Bridgeport, CT

Thursday, July 23/4:00 - 5:30 PM
Contributed Presentations 20/Ballroom D
MATHEMATICAL METHODS 2

Chair: Michael O'Connor, IBM T.J. Watson Research Center

4:00/26/A42
Geometric Encounters of the Bayesian Kind: What is Likely to be Seen
Richard A. Vitale, Claremont Graduate School, Claremont, CA

4:15/45/A42
Symbolic Management of Solid Modeling For Hidden Surface Removal: The Chieng-Hoeltzel Algorithm
Wei-Hua Chieng and David A. Hoeltzel, Columbia University, New York, NY

4:30/39/A42
Robust Utilities for Geometric Modelling with Natural Quadrics
Michael A. O'Connor and Jaroslaw R. Rossignac, IBM-Thomas J. Watson Research Center, Yorktown Heights, NY

4:45/88/A42
Closed Curves, Regions and Boundaries in Integer and Digital Spaces
Efim Khalimsky, City University of New York, Staten Island, NY

5:00/52/A43
Jordan Pushing and Pulling
Pierre Rosenstiehl, Ecole des Hautes Etudes en Sciences Sociales Paris Cedex, France

5:15/53/A43
Integration Constraints in Parametric Design of Physical Objects
Alberto Paoluzzi, Universita di Roma La Sapienza, Rome, Italy

Thursday, July 23/4:00 - 5:30 PM
Contributed Presentations 21/Ballroom E
PATH PLANNING PLUS GEOMETRIC MODELING

Chair: Boris Aronov, Courant Institute of Mathematical Sciences

4:00/115/A43
Two-Dimensional Robot Arm Motion Planning
Boris Aronov and Colm O'Dunlaing, Courant Institute, New York, NY

4:15/116/A43
Minimum Speed Motions
Boris Aronov, Courant Institute, New York, NY, Steven Fortune and Gordon Wilfong, AT&T Bell Laboratories, Murray Hill, NJ

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

General Program

4:30/121/A44
An Uniform Approach to Geometric Modeling
Ming-ming Wang and Shui-Sheng Chern, Tufts University, Medford, MA

4:45/122/A44
Solid Modelling in C
Eugene Loch and Shui-Sheng Chern, Tufts University, Medford, MA

5:00/123/A44
Geometric Representation of Swept Volumes for Polyhedral Objects
John D. Weld and Ming C. Leu, Cornell University, Ithaca, NY

5:15/132/A44
Collision-free Trajectory Planning: Computational Geometry and Splines in Space-Time
Kamal Kant and Steven W. Zucker, McGill University, Montreal, Canada

Friday, July 24/AM

9:00 AM/Ballroom A-B
Invited Presentation 12
Chair: David R. Ferguson
Boeing Computer Services

Semiparametric Surfaces
Malcolm Sabin
Finite Element Graphic System, Ltd.
Cambridge, England

9:45 AM/"Summing Up"
Michael Wesley
IBM-T.J. Watson Research Center

10:15 AM/Prefunction Area
Coffee

10:30 AM/CONCURRENT SESSIONS

Friday, July 24/10:30 AM - 12:00 Noon
Minisymposium 13/Ballroom E
DATA REDUCTION FOR SPLINES AND ITS APPLICATIONS

The number of coefficients used when describing a curve or surface in B-spline format, is often much greater than necessary. The computation time and storage requirements for the manipulation of such an overrepresented curve or surface, would be greatly reduced if an approximation with fewer parameters was used instead. A method for accomplishing such a data reduction, without perturbing the curve or surface more than a given tolerance, has been developed. Both the theoretical and practical aspects of this method will be described, and illustrated with industrial examples.

CHAIR AND ORGANIZER
Tom Lyche
University of Oslo
Oslo, Norway

10:30/M38/A10
Data Reduction for Splines
(to be presented by the chair)

11:00/M39/A11
Data Reduction Combined with Recursion and Iteration in Intersections
Tor Dokken
Center for Industrial Research
Oslo, Norway

11:30/M40/A11
Knotline Removal on Box-Spline Surfaces
Morten Daehlen
Center for Industrial Research
Oslo, Norway

Friday, July 24/10:30 AM - 12:00 Noon
Minisymposium 14/Ballroom C
DIGITAL GEOMETRY

Digital geometry can be described as the study of geometric properties of subsets of digital images. It has proved to be an important tool in computer vision. Among the general concepts which intervene in this investigation are connectedness, curvature and convexity. Of continuing interest has been the problem of characterizing digital straight lines. The generalization of certain theorems from the plane to three-dimensional space remains an open question. Specialization of the classical program of distance geometry, e.g., the determination of metric bases, to the digital case yields results of mathematical interest.

CHAIR AND ORGANIZER
Robert A. Melter
Long Island University
Southampton, NY

10:30/M41/A11
Digital Geometry: A Survey
Azriel Rosenfeld
University of Maryland
College Park, MD

10:50/M42/A11
Continuous Representations of a Digital Image
Chung-Nim Lee
The University of Michigan
Ann Arbor, MI
and
Azriel Rosenfield
University of Maryland
College Park, MD

11:10/M43/A12
On Digital Topology and Thinning Algorithms
T. Yung Kong
Ohio University
Athens, OH

11:30/M44/A12
Metrics in Digital Geometry
(to be presented by the chair)

Friday, July 24/10:30 AM - 12:00 Noon
Minisymposium 15/Ballroom A-B
PARALLEL METHODS IN GEOMETRY

The availability of parallel processors has prompted several questions about geometric modeling, two of which are: (1) are commonly used mathematical models appropriate for parallel processing? and (2) is there an opportunity to develop new modeling techniques which are implementable on, and can take advantage of, parallel machines? Both of these questions will be discussed.

CHAIR AND ORGANIZER
Harry W. McLaughlin
Rensselaer Polytechnic Institute
Troy, NY

10:30/M45/A12
Affine Maps and Parallel Methods
Craig Shelly
Rensselaer Polytechnic Institute
Troy, NY

11:00/M46/A12
Evaluating β-Splines and Computing Least Squares Approximations on Parallel Processors
Richard Mastro
Boeing Computer Services
Seattle, WA

11:30/M47/A13
Mathematical Morphology
Michael M. Skolnick
Rensselaer Polytechnic Institute
Troy, NY

Friday, July 24/10:30 AM - 12:00 Noon
Minisymposium 16/Ballroom D
SHAPE CONTROL IN SURFACE DESIGN

The shape of surfaces representing geometric models or measured data is often more important than proximity to particular points. For example, when modeling an airfoil cross section or when modeling drag characteristics of aircraft, the shape (convexity or monotonicity) is more important than fidelity to the defining data. Similar problems arise with higher dimensional surfaces. This minisymposium will present three views on the problem of controllir [illegible] while still reasonably reproduci[illegible]. One presentation will concentr[illegible] constructing convex surface[illegible]er will discuss problems in mo[illegible]data and the third will cover meth[illegible] on smoothing shape.

CHAIR AND ORGANIZER
David R. Ferguson
Boeing Computer Services
Seattle, WA

10:30/M48/A13
The Automatic Generation of Convex Surfaces
Roger Andersson, Erik Andersson, Mats Boman, Tony Elmroth
Volvo Data, AD
Goteborg, Sweden
and
Bjorn E. J. Dahlberg, Bo Johansson
University of Goteborg and
Chalmers University of Technology

11:00/M49/A13
Modeling Multivariate Data Using Shape Control
(to be presented by the chair)

11:30/M50/A13
Surface Interpolation and Shape Control Using Tension Parameters
Thomas Foley
Arizona State University
Tempe, AZ

12:00 PM/Conference Adjourns

Note: The numbers that follow the individual times for each presentation represent the numerical order and page number of the abstract.

GENERAL INFORMATION

Special Functions

Welcoming Reception
Sunday, July 19, 8:00 PM
Prefunction Area, Ballroom Level
Cash Bar

Beer Party
Monday, July 20, 6:15 PM
Prefunction Area, Ballroom Level
$10.00

Dinner and Ballet
Wednesday, July 22, 5:15 PM
Saratoga Performing Arts Center
$34.00

Coppelia, performed by the New York City Ballet, music by Leo Delibes and choreographed by Balanchine and Danilova, coupled with the delightful choices of a dinner buffet (Shrimp, Chilled Scallops, Baked Blue Fish, Chicken Divan, Steak tips with Mushrooms, Pasta Primavera, Carved Roast Beef, Baked Ocean White Fish, Garden Vegetables) can only promise to be the makings of a memorable evening. Therefore, SIAM has purchased a limited number of tickets (covered) which are available on a first come, first served basis at the beautiful outdoor Saratoga Performing Arts Center. The entire evening including dinner, performance, wine and transportation all for $34.00.

Book Exhibits

The book exhibits will be in the Prefunction Area — Ballroom Level of the Hilton Hotel. The exhibit times are 9:00 AM to 5:00 PM, Monday to Thursday, July 20–23; 9:00 AM–11:00 AM, Friday, July 24.

Special Notice To: All Conference Participants

SIAM requests participants to refrain from smoking in the session rooms during lectures. Thank you.

UPCOMING CONFERENCES

October 12–15, 1987
SIAM Annual Meeting and 35th Anniversary
Marriott Hotel — City Center
Denver, CO

December 1–4, 1987
Third SIAM Conference on Parallel Processing for Scientific Computing
The Westin Bonaventure Hotel
Los Angeles, CA

May 23–26, 1988
Third SIAM Conference on Linear Algebra
The Concourse Hotel
Madison, WI

June 13–16, 1988
Fourth SIAM Conference on Discrete Mathematics
Cathedral Hill Hotel
San Francisco, CA

REGISTRATION INFORMATION

The registration desk will be located in the Prefunction Area on the Ballroom Level of the hotel and will be open as listed below:

Saturday, July 18/5:00 PM–10:00 PM
Sunday, July 19/7:00 AM–10:00 PM
Monday, July 20/7:00 AM–6:00 PM
Tuesday, July 21–Thursday, July 23/8:00 AM–6:00 PM
Friday, July 24/8:00 AM–12:00 NOON

		SIAM Member	Non Member	Student Member	Student Non-Member
Short Course Fees	Advance	$ 75	$ 90	$30	$40
	On-site	$90	$105	$40	$50
Conference Fees	Advance	$110	$140	$20	$30
	On-site	$135	$165	$20	$30

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Special Note

There will be no prorated fees. No refunds will be issued once the conference has started.

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MONDAY, JULY 20

11:00 AM - 12:30 PM
Ballroom A-B

Minisymposium 1
GEOMETRY PROCESSING

#M1/11:00 AM
Surface/Surface Intersections

Geometric modelling utilizes the approximation of surfaces and solids by simpler forms. One resulting difficulty is that intersections of the simpler forms are usually not themselves simple. This talk discusses one of the most often needed geometric processes, surface/surface intersection. A robust algorithm for the SSI of rectangular patches is given and illustrated.

R. E. Barnhill
Computer Science Department
Arizona State University
Tempe, AZ 85287

#M2/11:30 AM
Imprecise Geometric Computation

We describe preliminary results in a theory of imprecise geometric computation, which attempts to incorporate awareness of the consequences of finite precision arithmetic in geometric algorithms. The focus is on algebraic geometry representations and the systems of polynomial equations arising in their intersection. Running error analyses are formulated for several basic polynomial procedures, and theoretical arguments are used to demonstrate the enhanced conditioning of the Bernstein basis formulation. The performance of several root isolation algorithms is assessed (including the inherently ill-conditioned problem of determining multiple roots), and the coupling of error monitoring into the decision structure of a geometric algorithm is briefly discussed.

R.T. Farouki and V.T. Rajan
IBM Thomas J. Watson Research Center,
P.O. Box 218,
Yorktown Heights, N.Y. 10598.

#M3/12:00 Noon
An Improved Penalty Function for Implicit Blending of Multiple Surfaces

Several methods have recently been developed which define blending surfaces as implicit functions and are used (primarily in solid modelling) to create smooth transitions between other surfaces. Although diverse, the approaches ultimately rely on a penalty function which measures distance from a point to a surface. It is shown that for blending multiple surfaces the currently accepted penalty functions may permit discontinuities or other unacceptable results in the blend. A new penalty function, with better properties of distance measure and continuity, is investigated. Numerical reliability of given evaluation techniques is also discussed.

Alyn P. Rockwood
Evans & Sutherland Computer Corp.
580 Arapeen Drive
P.O. Box 8700
Salt Lake City, Utah 84108

* Minisymposium abstract numbers are preceded by an M.

MONDAY, JULY 20

11:00 AM - 12:30 PM
Ballroom C

Minisymposium 2
ALGEBRAIC METHODS IN GEOMETRY

#M4/11:00 AM

Cylindrical Algebraic Decomposition: A Universal Algorithmic Algebraic Method for Real Geometry

Cylindrical algebraic decomposition provides an effective method, implemented in the SAC-2 computer algebra system, for real quantifier elimination and for solution of many geometrical problems in Euclidean spaces, including robot motion problems such as collision detection, inverse kinematics and path planning. This talk will briefly describe the method, its implementation, its application, and present examples.

George E. Collins
Dept. of Computer and Information
Ohio State University
2036 Neil Avenue Mall
Columbus, Ohio 43210-1277

#M5/12:00 Noon

Geometrical Theorem Proving Based on Polynomial Ideal Theory

In recent years, automated geometry theorem proving has gained a lot of attention. Using Buchberger's method of Groebner bases, "incompletely specified" geometry theorems that can be formulated in terms of polynomial equations can be proved mechanically. By "incompletely specified" we mean, that the non-degeneracy conditions are not specified but found by the procedure. Three variants how to use Buchberger's algorithm are discussed in detail. Finally, a computing time statistics based on an implementation of all three methods in the computer algebra system SCRATCHPAD II is presented.

Bernhard A. Kutzler
Research Institute for Symbolic Computation (RISC)
Johannes Kepler University
A-4040 Linz
Austria (Europe)

MONDAY, JULY 20

11:00 AM - 12:30 PM
Ballroom E

Minisymposium 3
GEOMETRIC TOLERANCING

#M6/11:00 AM

A Vector Space Approach to the Mathematical Representation of Tolerances

Standards exist for the specification of tolerances on mechanical parts. However to compute with tolerances, a rigorous mathematical interpretation is necessary. This paper develops a theory in which instances of in-tolerance parts are associated with points in a normed vector space over the real numbers. This permits the use of a distance metric to establish a correspondence between a tolerance specification and an "in-tolerance" region of the vector space. The exploration of examples drawn from both geometric and dimensional (plus-minus) tolerancing practice, leads to a number of computationally significant insights.

Joshua U. Turner
IBM Corporation
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P.O. Box 390
Poughkeepsie, N.Y. 12602

#M7/11:30 AM

A Formal View of Some Geometric Functional Requirements in Mechanical Design

Integration of geometric tolerances into solid models is critical to reasoning about mechanical products and assemblies for process planning and other purposes. We approach this problem from the perspective of two classes of functional requirements. Both are directly relatable to the geometry of mechanical parts. One is concerned with positioning of parts with respect to each other in an assembly; the other is concerned with maintaining material bulk in critical portions of parts. Through a number of examples, we show that these requirements can be captured in the form of geometrical tolerance specifications that we refer to as virtual boundary requirements. We develop a formalism for precise statement of virtual boundary requirements, and point out that the only formalism for tolerances in solid models proposed in the literature is inadequate for the purpose.

Rangarajan Jayaraman
Vijay Srinivasan

Manufacturing Research Department
IBM Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights
New York 10598

#M8/12:00 Noon

Geometric Tolerances and Mathematical Programming

Some geometric tolerances are a set of constraints on the variables specifying the geometry of an object. Mathematically, these tolerances are a set of inequalities. Determining the maximum allowed variations of variables then reduces to a problem in mathematical programming. If the constraints are linear and there is only one degree of freedom (one axis) then this reduces to a problem in linear programming. As the number of degrees of freedom increases, the allowed region for the variables become a polytope in a higher dimensional space, and the complexity of the problem increases rapidly.

V.T.Rajan
IBM Corp.
T.J. Watson Research Centre
P.O. Box 218
Yorktown Heights, NY 10598

MONDAY, JULY 20

2:00 - 3:30 PM
Ballroom A-B

Minisymposium 4
GEOMETRIC CONTINUITY

#M9/2:00 PM

Geometric Continuity For Triangular Bézier Patches

We consider joining two triangular Bézier patches and enforcing geometric continuity. This is one of the fundamental problems in the construction of smooth surfaces with triangular patches. General conditions for the composite surface to have tangent plane continuity are stated and an investigation is made into the various free parameters available and how best to choose these. We also give results on the necessary degrees of the Bézier patches in order to interpolate to positions and tangents.

Bruce Piper
Dept. of Mathematics
University of Utah
Salt Lake City, UT 84112

#M10/2:30 PM

Nu-Spline Fractals

We use some of the techniques of nu-splines for stochastic modeling of natural terrains. The input to the model consists of a relatively small number of control points with associated tension values. High tension values lead to very rough and jagged areas whereas small tension values lead to smooth regions. We have developed our techniques for a wide variety of topologies including visually continuous curves, a rectangular network of nu-splines and a triangular network of visually continuous curves. This last application area utilizes a newly developed six parameter G^1 patch for triangles which we will discuss.

Gregory Morris Nielson, 1348 West Mountain View Drive, Mesa, AZ 85201

Arizona State University
Engineering & Applied Sciences
Computer Science Department (252 G)
Tempe, AZ 85287

#M11/3:00 PM

Surfaces with geometric continuity

The methods of CAGD have arisen from the need of efficient computer representation of practical curves and surfaces used in engineering design. Two major problems of free-form surface design based on surface patch definition are twist incompatibilities and appropriate continuity conditions between adjacent patches. The purpose of the talk ist to present new methods for interpolating not only to function values and to derivatives but also to curvature values given along the boundaries of arbitrary triangular and rectangular patches. To avoid twist constraints, the mixed partial derivatives are replaced by the product of a convex combination of curvature functions and the normal vectors.

Prof. Dr. H. Hagen
Abteilung Computergraphik
Technische Universität Braunschweig
Gauss-Strasse 12
D-3300 Braunschweig
FEDERAL REPUBLIC OF GERMANY

MONDAY, JULY 20

2:00 - 3:30 PM
Ballroom C

Minisymposium 5
VISUAL MULTI-DIMENSIONAL GEOMETRY
WITH APPLICATIONS

#M12/2:00 PM

VISUAL MULTI-DIMENSIONAL GEOMETRY WITH APPLICATIONS

By means of a Multi-Dimensional system of *Parallel Coordinates*, a subset of R^N is represented by (i.e. mapped non-projectively onto) a subset of R^2. A duality between *point* ←→ *line*, and a *new duality for convex sets* are induced for N = 2 giving rise to some optimal algorithms for convex-hull construction and convex merge and intersections of convex sets. For any N a line in R^N is represented by $N-1$ planar points and a hyperplane by $N-1$ vertical lines together with a polygonal line (representing one of its points), enabling some geometrical constructions and the representation of polyhedra in R^N. The representation of certain convex and non-convex hypersurfaces is known. There is an algorithm for constructing and displaying interior/exterior or surface points (together with proximity information) for this class of hypersurfaces. An application to *Air Traffic Control* is given where the trajectory of an aircraft is a function of time T and three space variables. It provides a display from which proximities, velocities and other properties can be visualized and computed. In turn, this yields efficient *Collision Avoidance and Routing algorithms.*

Alfred Inselberg * # & Bernard Dimsdale*

* *IBM Scientific Center*
11601 Wilshire Boulevard
Los Angeles, CA 90025-1738
••••• & •••••
#University of California
Department of Computer Science
Los Angeles, CA 90024

#M13/2:30 PM

Application of Multidimensional Graphics to Phase Space

The phase space of a dynamical system is easily represented in parallel coordinates. It is possible to view the whole of phase space without resorting to projections or cross sections. Examples are given of familiar phenomena, such as fixed points, bifurcation diagrams, and periodic orbits; both for maps and for systems of nonlinear differential equations. A modification of the Lorenz equations is analyzed both in conventional and parallel coordinate representations. Several interesting features of the trajectory, difficult to see in projection, are easily seen in the parallel coordinate representation. Finally, an application to meteorological modeling is presented.

Juan Rivero
IBM Scientific Center
11601 Willshire Boule ard
Los Angeles, CA 90025

#M14/3:00 PM
Application of Parallel Coordinates to Complex System Design and Operation

Data display using parallel coordinates offers unique advantages to the design and operation of complex systems. The uniqueness is achieved through the ability to simultaneously display arbitrary numbers of variables. It is also possible to augment any parallel coordinate display by additional variables without altering either the representation or interpretation of prior set of displayed variables. These features are particularly useful to the architect/engineer with a need to investigate relationships between system variables or information from one phase of the system life-cycle to a succeeding phases. This capability enables engineers to visualize the relationship(s) between requirements and performance during system definition and testing as well as during system operation. The parallel coordinate approach makes it possible to display data at a level of integration that connot be achieved in the conventional Cartesian representation. Examples of this approach are given.

J.J. Helly
The Aerospace Corporation - M5/642, P.O. Box 92957, Los Angeles, California 90009

MONDAY, JULY 20

2:00 - 3:30 PM
Ballroom E

Minisymposium 6
BLENDING SURFACES

#M16/2:00 PM
Issues in Implicit Blending

We will summarize techniques for blending implicit algebraic surfaces and how they might apply to the parametric surface domain. We will also clarify what problems are currently open and what might be needed to solve them.

Christoph M. Hoffmann
Purdue University
West Lafayette, Indiana 47907

#M17/2:30 PM
Piecewise Quadratic Blending of Implicitly Defined Surfaces

We present a method to blend a corner where arbitrarily many implicitly defined surfaces meet. The blending surface consists of several implicitly defined pieces each piece being defined by a quadratic combination of a certain subcollection of the functions defining the original surfaces. The range of the blending is flexible and the shape is controlled by a real parameter. The blending surface lies in the intersection of the non-negative halfspaces defined by the original functions. Therefore the corner to be blended must be "convex". However, at least in the case of three surfaces, the presented method naturally generalizes to non-convex situations as well.

Lasse Holmstrom
Helsinki University of Technology
Laboratory of Information Processing Science
Otakaari 1 A, SF-02150 Espoo, Finland

#M18/3:00 PM
Construction of Low Degree Blending Surfaces

Several recent works have presented algorithms for constructing blending surfaces. A blending surface is a surface that smoothly joins a collection of surfaces or smooths their edges of intersection. Given a pair of algebraic surfaces, we derive general methods for both smoothly joining the surfaces along predefined curves and smoothing the edge of intersection of the surfaces. Both these methods are formulated in terms of an algebraic construct known as the ideal. Using techniques from algebraic geometry, we then show that these methods derive blending surfaces of the lowest possible degree.

Joe Warren
Department of Computer Science
Rice University
P.O. Box 1892
Houston, TX 77251

TUESDAY, JULY 21

11:00 AM - 1:15 PM
Ballroom E

Minisymposium 7
MOTION PLANNING

#M19/11:00 AM

An Overview of Motion Planning

Research in motion planning is aimed at developing algorithms that can be used to plan the motions necessary for a robot to achieve tasks in its environment. Motion planning spans the range topics from planning collision-free paths in a known or partly known environment, through the choice of grasp point on a part, through the specification of compliant motions for assembly, through the planning of sensorless alignment strategies. A common set of themes cut across this range of topics, notably, the representation of geometric and physical constraints, modeling the effect of uncertainty, and understanding the information from sensors. This talk surveys the major problem areas in motion planning and identifies some of the basic approaches to their solution.

Tomas Lozano-Perez
Massachusetts Institute of Technology
The Artificial Intelligence Laboratory
545 Technology Square
Cambridge, MA 02139

#M20/11:30 AM

Theoretical Advances in Algorithmic Motion Planning

Motion planning is one of the first areas of robotics to be studied from the complexity theoretic point of view and remains the most advanced in this sense. We will briefly review the past highlights and describe some interesting new directions. This includes the use of Morse theory, the introduction of sensing or probing, and the introduction of kinematics, dynamics and friction.

Chee Keng Yap
New York University
Dept. of Computer Science Courant Institute for Mathematic Sciences
251 Mercer Street
New York, NY 10012

#M21/12:00 Noon

Sensor Integration for Robot Mobility

Quite a few algorithms for motion planning, such as trajectory generation and obstacle avoidance, have been developed. In order for a mobile robot to actually perform such motion planning, however, it must construct, by using sensors, a certain spatial and contextual description of the local environment with in which it operates. The necessary information to be contained in the description includes naviagable areas, obstacles (location, shape, and size),vehicle positions relative to other objects,etc. Some pieces of information come from sensors, whereas others from other knowledge sources like maps. Information obtained from a single source may be partial or even erroneous. A consistent description is obtained by integrating information from multiple sensors over time. The talk will discuss techniques and issues of sensor integration for mobile robots by using actual examples drawn from our effort on the CMU Navlab System which autonomously navigates in the outdoor scene.

Takeo Kanade
Department of Computer Science
Carnegie-Mellon University
Pittsburgh, PA 15213

#M22/12:30 PM

Toward a Multi-Level Robot Collision Avoidance: The Artificial Potential Field Concept

Robot collision avoidance has been generally treated as a high level planning problem, and the function of low-level control has been perceived as limited to the execution of elementary operations for which motions are precisely specified. Paced by the relatively slow time-cycle of high-level control, the robot's interaction with its environment is restricted. This limits the robot's ability to carry out fast and interactive operations in a cluttered and evolving environment. The "artificial potential field" concept is proposed as a means for the expansion of the function of low-level control to include local real-time obstacle avoidance. In this framework, robot collision avoidance is distributed between different levels of control associated with different levels of environment sensory feedback.

Oussama Khatib
Artificial Intelligence Laboratory
Stanford University
Stanford, C.A. 94305

TUESDAY, JULY 21

11:00 AM 12:30 PM
Ballroom C

Minisymposium 8
NON-TENSOR PRODUCT SURFACES

#M23/11:00 AM

Multivariate Splines

Piecewise polynomial functions are used almost invariably in solving univariate problems in Computer Aided Design. It is natural to contemplate the use of similar functions in problems involving two independent variables. For example, one might consider piecewise polynomial functions of fixed degree on each triangle in a triangulation which are globally differentiable. However, this approach leads to difficult problems concerning the most fundamental questions about spline spaces. Such questions include: What is the dimension of a given space? Is there a local basis? Can functions in the space be used to solve certain interpolation problems? In this talk, some recent results in this area will be described.

Peter Alfeld
Department of Mathematics
University of Utah
Salt Lake City, Utah, 84112

#M24/11:30

Convex Approximations to Multivariate Scattered Data

In many data fitting applications, it is just as important to control the shape of the fitted surface as it is to control the closeness of the fit. This paper presents a method for generating convex piecewise polynomial functions over a triangulation of the data. The method requires the solution of a large, sparse quadratic programming problem. Because of the special structure of this optimization problem, a fast, highly specialized, iterative method for solving it is presented.

Thomas A. Grandine
Applied Mathematics Staff
Engineering Technology Applications Division
Boeing Computer Services Company
P.O. Box 24346, MS 7L-21
Seattle, WA 98124-0346

#M24a/12:00 Noon

An Interpolatory Surface Under Tension with Automatic Selection of Tension

A triangle-based surface interpolation method for scattered data is extended to a surface under tension by a generalization of the univariate spline under tension. Tension factors associated with triangulation edges are automatically selected to satisfy local properties such as monotonicity and convexity. A user can thus suppress the overshoot and undershoot caused by steep gradients and, more generally, control the shape of the surface. A software package is available from the presenter.

Robert J. Renka
Department of Computer Science
North Texas State University
P. O. Box 13886
Denton, TX 76203

TUESDAY, JULY 21

11:00 AM - 12:30 PM
Ballroom A-B

Minisymposium 9
PROBABILISTIC APPROACHES TO COMPUTER-AIDED GEOMETRIC DESIGN (CAGD)

#M25/11:00 AM

Introduction to the Probabilistic Approaches to Computer-Aided Geometric Design (CAGD)

The speaker will explain why probability and geometry are so closely linked in CAGD.

Ronald A. Goldman
Control Data Corporation
4105 North Lexington Avenue
AHS-225
Arden Hills, MN 55126

#M26/11:30 AM
Urn Models on CAGD

A class of curve schemes which generalize Bézier curves is generated from simple probabilistic models. These curve schemes retain many of the properties which make Bézier curves so suitable for CAGD (computer-aided geometric design). In particular they are characterized by always having a de Casteljau-like evaluation algorithm. Certain known schemes (e.g. B-splines) are shown to be in this class. Generalizations to surfaces are also discussed.

Phillip J. Barry
Dept. of Mathematics
University of Utah
Salt Lake City, UT 84112

#M27/12:00 Noon
Using Urn Models for Fast Curves and Surface Generation

In this minisymposium, the architecture and operation of the Triangle, a pipelined, parallel multiprocessor architecture for the computation and rendering of line segments, conic sections (i.e., circles, ellipses, etc.), spline curves, and tensor product surfaces will be described. Based on discrete probablistic description of polynomial curves known as urn models, the Triangle can be used as an accelerator to dramatically enhance the performance of standard graphics workstations. Using the custom VLSI Triangle that we are currently desigining, we estimate that it will be possible to completely recompute and display up to 65 bicubic patches at real-time rates, at a density of 1,000 points per patch.

Professor Tony D. DeRose
Department of Computer Science FR-35
University of Washington
Seattle, WA 98195

THURSDAY, JULY 23

8:45 - 10:15 AM
Ballroom C

Minisymposium 10
ALGEBRAIC GEOMETRY IN GEOMETRIC MODELING

#M28/8:45 AM
C^1 Rational Finite Elements

Classical algebraic geometry provided the theoretical foundation for construction of rational basis functions to achieve globally C^0 patchwork approximation of any prescribed polynomial degree over any regular algebraic reticulation of a planar region. This constructive theory has now been generalized from C^0 to C^1. In this note rational basis functions are developed for patchwork degree-three globally C^1 approximation over a convex quadrilateral partitioning. A numerical procedure for solving discrete finite element equations derived with this C^1 rational basis is also described. Although isoparametric C^0 bases enjoy certain advantages over the rational C^0 bases, no C^1 isoparametric element is currently known.

Eugene L. Wachspress
Department of Mathematics
Ayres Hall, Room 18B
The University of Tennessee
Knoxville, TN 37996-1300

#M29/9:05 AM
Geometric Reasoning with Logic and Algebra

Geometric Reasoning is concerned with (geometric) objects that typically are definable by formulas of the language of the first-order theory of the real numbers. A variety of GR problems can be cast into one of the following forms: query problem - does a certain collection of objects possess a certain (first-order) property; constraint problem - given a quantified formula defining an object, find an equivalent definition by a quantifier-free formula; display problem - describe an object, e.g., specify its topology, or render it. In the last fifteen years, feasible algorithms for the exact solution of these problems have been discovered, implemented, and used to solve nontrivial problems. We give examples.

Dennis S. Arnon
Xerox Palo Alto Research Center
Computer Science Laboratory
3333 Coyote Hill Road
Palo Alto, CA 94304

#M30/9:25 AM
Elimination Methods for Systems of Polynomial Equations in Several Variables

When finding the common zeros of a system of polynomials in several variable, often the method used is to compute the resultant of successive pairs of polynomials until a single polynomial in one variable is produced. Unfortunately, when the number of variables involved is greater than two this method produces many extraneous solutions, which results in much wasted effort checked for actual solutions, and worse, the univariate polynomial which must be solved has degree several times greater than necessary. A procedure which avoids these problems will be presented.

Andrew C. Neff
IBM T.J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598

#M31/9:45 AM
Parametric Cubics as Algebraic Curves

Some classical and not-so-classical algorithms of algebraic curve theory will be presented in the context of planar parametric cubic curves. These algorithms relate to finding singular points, detecting degeneracy, finding inflection points, comparing parametrizations, and finding implicit equations.

Richard R. Patterson
Dept. of Mathematical Sciences
Indiana University Purdue University
P. O. Box 647
Indianapolis, IN 46223

THURSDAY, JULY 23
8:45 - 10:15 AM
Ballroom A-B

Minisymposium 11
COMPUTATIONAL GEOMETRY

#M32/8:45 AM
On Parallel Algorithms in Computational Geometry

A systematic methodology for developing parallel algorithms for the problems in computational geometry is proposed. A data structure and its mapped problem solving technique are chosen based on the analysis of a given problem, then basic operations are extracted both at large-grain and fine-grain levels. A suitable abstract parallel machine for those operations is selected, and algorithmic processes on this abstract parallel machine are developed. The algorithmic processes are checked whether all of the user constraints can be met to determine any additional features to the model. A new O(log n) parallel algorithm for the convex hull problem has been developed by following this approach.

Minsoo Suk
S. J. Oh
Department of Electrical and Computer Engineering
Syracuse University
Syracuse, New York 13244-1240

#M33/9:15 AM
Verifiable Geometric Computations Using Finite Precision Arithmetic

This paper presents algorithms which, using standard single precision arithmetic, determine how n lines or conic sections subdivide a plane. All calculations are carried out to the same degree of accuracy as that used to specify the inputs. Other line subdivision algorithms require twice as many bits of precision; other conic section algorithms require even more. The worst case time of the algorithms presented here has not yet been determined, but the line algorithm is $O(n^2 * \log(n))$ on typical inputs (n^2 is a trivial lower bound). These results are part of ongoing research into robust geometric computation in the presence of round-off error.

Victor J. Milenkovic
Department of Computer Science
Carnegie Mellon University
Pittsburgh, PA 15213

#M34/9:45 AM
Polygon Properties Calculated From The Vertex Neighborhoods

Calculating properties of polyhedra given only the set of the locations and neighborhoods of the vertices is easy. Possible properties include volume, surface area, and point containment testing. No global topological information at all is explicitly needed (although the complete global topology could be recovered). The neighborhood of the vertex means the directions of the edges and faces on it but not their extents. These vertex-based formulae are dual to the usual formulae that use the faces. Alternative data structures and formulae for polyhedron calculation are important since special cases are a function partly of the data structure, and because different methods have different numerical accuracy and error detection properties.

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THURSDAY, JULY 23

8:45 - 10:15 AM
Ballroom E

Minisymposium 12
MESH GENERATION

#M35/8:45 AM
A New Automatic Node Placement Strategy for Graded Triangular Meshes

Automating triangular finite element mesh generation involves two interrelated tasks: generating a distribution of well-placed nodes on the boundary and in the interior of the domain, and constructing a triangulation of these nodes. The Delaunay triangulation usually gives a suitable mesh for a given distribution of nodes, and Watson's algorithm provides a flexible means of constructing it. In this presentation, a new method is described for automating node placement in a Delaunay triangulation. The boundary nodes are triangulated first, and the resulting mesh is selectively refined until a given explicit or implicit spacing function is satisfied.

William H. Frey
Mathematics Department
General Motors Research Laboratories
Warren, MI 48090-9055

#M36/9:10 AM
Automated Grid Generation for General 3D Regions

Codes are now available that can generate hexahedral meshes in arbitrary 3D regions. These meshes are composite grids formed by patching together six-sided subregions of the region with complete continuity. Grid line spacing is controlled automatically from the boundary point distributions. The generation procedures used are transfinite interpolation and the solution of a certain set of elliptic partial differential equations. These structured grids can serve as the basis for finite-difference or finite-element solutions of partial differential equations on regions of arbitrary geometry.

Joe F. Thompson
Department of Aerospace Engineering
Mississippi State University
Drawer A
Mississippi State, MS 39762

#M37/9:35 AM
Mesh Generation by the Finite Octree Technique

The finite octree is the basis of an automatic mesh generator for general three-dimensional domains. The presentation will concentrate on the algorithmic procedures that make up this mesh generator indicating how they address the complexities of automatically discretizing any geometry into a valid finite element mesh that reflects the desired mesh gradations. Specific consideration will be given to the construction of the finite octree which is carried out by the hierarchic insertion of the boundary information into the tree via geometric communication operators. The importance of maintaining topologic consistency to insure validity, reduce computational effort and aid in controlling possible numerical difficulties as the element mesh is defined from the finite octree will also be discussed.

Mark S. Shephard
Center for Interactive Computer Graphics
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

FRIDAY, JULY 24

10:30 AM - 12:00 Noon
Ballroom E

Minisymposium 13
DATA REDUCTION FOR SPLINES AND ITS APPLICATIONS

#M38/10:30 AM
DATA REDUCTION FOR SPLINES

We present an overall strategy for reducing the number of discontinuous derivatives at the knots of a given B-spline function without perturbing the spline more than a given tolerance. This amounts to removing some or all of the knots of the spline. The number an location of the remaining knots is determined automatically. Knot removal can be used succesfully to fit a spline to functions and data. We also show how this data reduction technique can be applied to parametric curves and tensor product surfaces. The usefulness of data reduction is illustrated with several examples.

Professor Tom Lyche
Institute of Informatics
University of Oslo
P.O. Box 1080, Blindern
0316 OSLO 3
Norway

#M39/11:00 AM

DATA REDUCTION COMBINED WITH RECURSION AND ITERATION IN INTERSECTIONS

When implementing intersections of B-spline represented geometries, we are faced with the problems of calculation speed, finding all solutions, and the amount of data necessary for representing resulting curves. By combining one or more of the components: data reduction on the geometries to be intersected, recursion for finding all intersection branches/points, iteration to calculate the intersections within the user specified tolerance, and data reduction on the intersection curves produced, a number of different intersection cases for B-spline curves and surfaces have been implemented.

Tor Dokken
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Forskningsveien 1
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Norway

#M40/11:30 AM

KNOTLINE REMOVAL ON BOX-SPLINE SURFACES

We give a method for removing knotlines from a parametric box-spline surface. More specifically, given a box-spline surface S and a tolerance ϵ, an algotithm to determine a box-spline approximation S' to S with error less than ϵ is given. The approximation is such that the knotlines of S' form a subset of the knotlines of S.

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FRIDAY, JULY 24

10:30 AM - 12:00 NOON
Ballroom C

Minisymposium 14
DIGITAL GEOMETRY

#M41/10:30 AM

Digital Geometry: A Survey

Digital geometry is the study of geometric properties of finite sets of lattice points in Euclidean n-space, where usually n = 2 or 3. Such sets of points are assumed to be "digital" representations of bounded n-dimensional objects, and digital geometry is concerned with how properties of these representations are related to properties of the objects. Concepts surveyed in this paper include connectedness; arcs, curves, and borders; area and perimeter; distance, diameter, and geodesics; straightness and convexity; and continuity.

Azriel Rosenfeld
Center for Automation Research
University of Maryland
College Park, MD 20742-3411

#M42/10:50 AM

Continuous Representation of a Digital Image

Connectivity analysis of a digital image is normallybased on the space occupancy representation in the past. However, it met with severe restriction in developing a digital surface theory. Appearant difficulty being the incorrect topology of the boundary of the represented region, we propose here a modified version of the space occupancy representation whose continuous topology yields the correct topology on the digital image as well as its boundary. Our idea is derived from a technique of resolving sigularities in algebraic geometry. Using this new representation, we can establish a number of results which are difficult to prove directly from digital geometry. Comparison with other continuous representations will be also discussed.

Chung-Nim Lee
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The University of Michigan
Ann Arbor, MI 48109

Azriel Rosenfeld
Center for Automation Research
University of Maryland
College Park, MD 20742

#M43/11:10 AM
On Digital Topology and Thinning Algorithms

The talk will begin with an account of some simple concepts of digital topology, including the "fundamental groups" of a digital picture and the notion of a continuous analog.

A result that is useful in designing two-dimensional thinning algorithms was published by Rosenfeld in [Inf. Control 29, 1975, 286 - 291]. It gives sufficient conditions on a set of 1's in a two-dimensional binary digital picture for the "topology" of the picture to be preserved when those 1's are changed to 0's. The second half of the talk will describe work by the speaker and others to obtain a three-dimensional version of this result.

T. Yung Kong
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#M44/11:30 AM
Metrics in Digital Geometry

The analysis of a digitized image usually presupposes the definition of a metric on the set of lattice points. In addition to the Euclidean distance, the two most commonly used metrics are those referred to by the names "checkerboard" and "city block". These functions can be characterized in a number of ways, in particular as members of a family of path-generated digital metrics. Interesting results are obtained when the classical program of distance geometry is specialized to the digital case.

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FRIDAY, JULY 24

10:30 - 12:00 Noon
Ballroom A-B

Minisymposium 15
PARALLEL METHODS IN GEOMETRY

#M45/10:30 AM
Affine Maps and Parallel Methods

A key observation is that any one segment of a polynomial curve or surface is the affine image of any other segment. This allows one to construct, in a parallel mode, many segments of a curve or surface, each of which is the affine image of a prototype. When the curve or surface is given as a linear combination of control points, the affine map corresponding to each segment is determined by the placement of the control points alone. Such constructions allow for some computationally intensive curves and surfaces to be built with less costs.

Craig Shelly
Department of Computer Science
Rensselaer Polytechnic Institute
Troy, NY 12180

#M46/11:00 AM
Evaluating B-splines and Computing Least Squares Approximations on Parallel Processors

Experiments were conducted in order to determine the usefulness of parallel processors for evaluating B-splines and computing least squares approximations with splines. The parallel processors used were the Intel Hypercube, which is a distributive memory machine, the Sequent Balance 21000, and the Alliant FX/8, which are shared memory machines. A function partitioning algorithm for B-spline evaluation was implemented on the Hypercube. Data partitioning algorithms for B-spline evaluation and least squares approximations to univariate and multivariate gridded data were implemented on the shared memory machines. The results of these experiments will be presented.

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#M47/11:30 AM

Mathematical Morphology

Mathematical morphology is a geometric approach to image processing that is based upon the use of a restricted class of cellular automata transformations. These transformations provide a decomposition of global geometric objects into a well defined sequence of local neighborhood transformations. This ability to construct geometric objects is useful in image processing - to detect and filter features on images - and may be of use in computer graphics and computational geometry.

Dr. Michael M. Skolnick
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FRIDAY, JULY 24

10:30 - 12:00 Noon
Ballroom D

Minisymposium 16
SHAPE CONTROL IN SURFACE DESIGN

#M48/10:30 AM

The Automatic Generation of Convex Surfaces

In this talk, an almost automatic process will be described to create convex surfaces with prescribed smoothness whose distance to a set of measure points is less than a prescribed tolerance.

In the first part of the procedure, a preliminary surface with the desired smoothness is created from a network of curves. Both the network and the patch topology are determined from the set of ordered measure points.

In the next part, the preliminary surface is turned into a convex one by transversal modifications. By a suitable linearization of the normal curvature, the problem is turned into a sequence of linear programming problems. These are solved by an implementation of the Karmarkar algorithm.

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Mats Boman, Tony Elmroth
Department of Applied Mathematics and Statistics
Volvo Data AB
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Björn E. J. Dahlberg, Bo Johansson
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University of Göteborg and
Chalmers University of Technology
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#M49/11:00 AM

Modeling Multivariate Data using Shape Control

Constraining a geometric model to a particular shape is an important requirement of curve and surface design, and because of this need, a wide variety of methods for controlling shape have been developed. Shape constraints are also important in modeling multivariate data. However, methods for imposing shape constraints when many independent variables are involved are not as well developed as in the case of curve and surface construction. In this talk we will discuss our experiences in fitting multivariate data and in imposing shape constraints on the models. The emphasis will be on automatic methods of shape constraint.

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#M50/11:30 AM

Surface Interpolation with Shape Control Using Tension Parameters

A brief survey is given of some methods that use tension parameters to control the shape of interpolating curves and surfaces. A new surface interpolant to network curves is introduced which generalizes the spline blending method of Gordon. The cardinal bases of the network curves are used to define a surface interpolant with shape control parameters. The new method uses blending functions that are of the same type as the network curves, whereas the spline blending techniques uses blending functions that are possibly of a different type than the network curves.

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MONDAY, JULY 20

4:00 - 5:30 PM
Ballroom D

Contributed Presentations 1
SURFACE METHODS

#12/4:00 PM

Recursive Surface Smoothing for Random Grid Displacements of Discrete Measurements

A smoothed approximation of unknown shape of a surface is found for the case having random displacements to the discrete measurements of the surface. The displacement noise is modeled by movement of the measurement node points using zero mean, random sequences. It is solved by optimally fitting the data with approximating function written as linear combination of the *Bi-cubic B-spline basis. The* calculations required to solve for the coefficient matrix can become unreasonably large. A recursive algorithm was developed to remedy the above-mentioned problems in which the number of calculations increased only linearly with the numbers of data points.

Re[illegible] He and C. N. Shen
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Rensselaer Polytechnic Institute
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#46/4:15 PM

Interpolation to Large Data Sets Using Bezier Curves and Surfaces

This presentation covers two main issues. One, the traditional formulas for Bezier curves and surfaces become unstable as the number of data points increases. A localization method is proposed that uses local data to determine Bezier curves and surfaces fitting large sets of data with a guaranteed accuracy. Two, data interpolation requires determination of control vertices of Bezier curves and surfaces that fit the data. This inverse computation involves solution of a system of equations which become unstable as the data points grow. Here, an iterative algorithm is described that determines the control vertices of such curves and surfaces without solving a system of equations and still provides the required accuracy.

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#97/4:30 PM

A Trivariate Powell-Sabin Interpolant

We consider the problem of producing a piecewise quadratic, C^1 interpolant to positional and gradient information at the vertices of a tessellation in R^3 of tetrahedra. The value of such an interpolant is that it is easy to contour. By splitting each tetrahedron in an appropriate way, we show how the problem may be solved. The solution does rely upon the fact that certain geometric constraints must be satisfied. We consider these and examine how they can be met through the splitting process which is a generalization of that for the bivariate Powell-Sabin interpolant.

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* All contributed abstracts are numbered in the order that they were received at the SIAM office.

#102/4:45 PM

An Improved Monotone Bivariate Interpolation Algorithm*

In [*Computer Aided Geometric Design* 2 (1985), 117-121] the authors outlined a five-step algorithm for monotone piecewise bicubic interpolation to monotonic data on a rectangular mesh. Here we describe a new approach to steps 3 and 4 that makes the algorithm easier to implement and analyze. A simple modification produces a method that is symmetric in the independent variables. Evidence that step 3 is generally not needed will be provided, and extensions to piecewise monotonic data will be discussed.

* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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#4/5:00 PM

An efficient algorithm for computing the geometric features of parametrized surfaces

The geometric features of a surface have the potential to provide a basis for geometric subsystems in computer aided design, geometric modeling, computer vision and image understanding environments. A fundamental barrier to implementing such subsystems, however, is inefficiency in computing these features for complex realistic objects. We present an efficient algorithm for computing the geometric features for surfaces (such as Bezier surfaces) whose shape is specified by a set of control points. For each such surface we compute 6 (constant) matrices that contain information about the geometric features at ech point of the surface. We compute the geometric features at each point by using an evaluation map to determine data that is used in standard formulas for the geometric features.

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Michael Penna, Department of Mathematical Sciences, Purdue University at Indianapolis, Indianapolis, Indiana 46223

#75/5:15 PM

Application of Diparabolic Interpolation to Surface Modeling

Because of the unique properties of Diparabolic Interpolation an extension to surface modeling was developed. Diparabolic Interpolation is a 4 point, 5th order interpolation which satisfies certain spline conditions along with slope continuity and at the same time eliminates unwanted curvature reversals. These properties are perserved in the generalization to surfaces. The equations are presented along with a brief overview of their origin. Example surface plots are presented and their continuity and smoothness are discussed.

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MONDAY, JULY 20

4:00 - 5:45 PM
Ballroom A-B

Contributed Presentations 2
SOLID MODELING

#28/4:00 PM

Halfspace Representation of 2-1/2 D Parts

A closed profile curve comprised of both straight and curved segments is often used as input to define 2-1/2 D (extruded) parts. A simple halfspace representation of such an object, subject to modest restrictions, has previously been shown by the speaker to exist if the vertices of the profile curve define a simple polygon. The speaker will discuss new results that extend the class of profile curves that have a simple halfspace representation to include many whose vertices do not define a simple polygon.

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#11/4:15 PM

Solid Modeling with Ruled Surfaces

Set operations on predefined primitives are typical ways to create and modify solid models. In general, it is also desirable to smooth sharp edges and corners with blend surfaces.
However, even when the main surfaces are fairly simple, the corresponding intersection curves and blend surfaces can be quite complex.
In this paper these problems are investigated in the context of a solid modeler where the main surfaces are ruled. Ruled surfaces are more restricted than general free-form surfaces but are important in many practical applications. Planes, cylinders, cones and tabulated cylinders are all examples of ruled surfaces.

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SWEDEN

#50/4:30 PM

Constructive Solid Geometry with Surface-Constraint

A new method is discussed for solid modelling, named "Constructive Solid Geometry with Surface-Constraint (CSG/SC)", which has aptitudes for a model used in mechanical design or geometric simulation. The CSG/SC is based on CSG in order to manage the geometric characteristics symbolically. The SC is the symbolic information, about how the boundary surfaces are located relative to the others, e.g. "parallel", "coaxial", and so on. It's specified by the designer's request in order to describe the priority and the geometric relations of the boundary surfaces explicitly. Applying CSG/SC to the editor of CSG, two features can be achieved i.e. (1) the primitives of CSG are located automatically by the declarations of the SC, (2) re-dimensioning for one primitive induces that of all the ones related to it by the SC.

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#41/4:45 PM

High Level Representations and Algorithms for Extended Geometrical Modelling

Specific applications in manufacturing require that capabilities of currently available geometric modellers be extended to model objects of mixed dimensions that are subsets of a sub-manifold of $\mathbb{R}^n$ and need not be closed or open. To meet this need we propose a new class of objects represented by mixed dimensional collections of disjoint open cells. We present dimension-independent high-level algorithms that operate on these objects and can be combined to perform regularized Boolean, set theoretic, and other user-defined operations. Examples of practical applications will be given.

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Michael A. O'Connor

#9/5:00 PM

Solid Modeling for Automated Tolerance Analysis

Correctly tolerancing the size and shape of parts in an assembly is currently a cumbersome manual task. Solid modeling technology holds promise for automating the tolerance analysis activity, resulting in improved product quality and cost. This paper presents a new approach developed at Rensselaer Polytechnic Institute (RPI) that uses geometric information to assess the effect of each possible part variation on the design objectives of the assembly. Both Monte Carlo and linear programming algorithms are available. This approach is shown to be effective in automatically identifying improperly toleranced designs.

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#27/5:15 PM

Automated Constant-Radius Blending in a Boundary-Representation Solid Modeler

We present a methodology for automated constant-radius blending in a boundary-rep solid modeler. The modeler is based on sculptured surfaces, represented in rational B-spline form. The blending is automated in the sense that required user input is limited to the specification of a radius and the selection of edges to be filleted. Based on this input, all necessary fillets and corner-blending surfaces are constructed, and the blending surfaces are automatically integrated into the boundary-rep of the blended object via surface trim-and-join operations.

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#6/5:30 PM

Solids by Blending Parametric Contours

Two parametrically defined contours are blended together in a linear or non-linear fashion to generate solids. The concept of interpolation is extended for this purpose. Various factors such as number of points, choice of points, intra-contour and inter-contour connectivity techniques and connectivity selection criteria, affecting the shape of the object are identified and parameterized. The concept of modifying function is introduced for global shape control. Various solids generated include goblets with square base and circular top, vase with elliptical top and star shaped base, variations of chess pawns, pipe connectors for a square and a circular pipe and odd shaped funnels.

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MONDAY, JULY 20

4:00 - 5:30 PM
Ballroom E

Contributed Presentations 3
COMPUTATIONAL GEOMETRY 1

#49/4:00 PM

Voronoi Diagrams on the Sphere

At the present time there is no closed form solution to the problem of reconstructing convex polyhedra from their extended gaussian images (EGI's). This problem has led us to define Delaunay triangulations and Voronoi diagrams on the sphere. We present an O(n log n) algorithm for producing Delaunay triangulations on the sphere, which is an extension of the Guibas/Stolfi algorithm. Additionally, we define a "weighted Voronoi diagram" on the sphere such that the area of each Voronoi polygon is adjusted by weights associated with the corresponding Voronoi point and those of its neighbors. Finally, we suggest how these constructions might be used in the solution of the EGI problem.

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#114/4:15 PM

Conjugate Indicator Algorithms for Two and Three Dimensional Delaunay Triangulation

Most published three-dimensional Delaunay triangulation algorithms have quadratic time complexity. However, two-dimensional algorithms with O(n log n) time complexity have been reported.

In this work, this bound is extended to three dimensions, using the relationship between Delaunay triangulations and containing space convex hulls. The algorithm presented is based entirely on conjugate indicator functions, but is intuitively appealing and easy to program. An interesting new structure for three-dimensional space subdivision, developed as a by-product of the research, is also described.

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#30/4:30 PM

A New Data Structure for Nearest Neighbor Searching

Given a file of N points in k-dimensional space and a query expressed as an additional point in the space, the nearest neighbor problem deals with locating a point in the file that is closest to the query according to some metric. This paper presents a new method for finding nearest neighbors in any bounded region. The algorithm employs a variation of the Voronoi tessellation to allow nearest neighbor retrievals to be performed in expected constant time and is of particular theoretical interest since the expected number of records examined can be decreased as the amount of storage is increased. Under the assumption that the points in the file are uniformly distributed, it is shown that as the amount of storage increases, the expected number of records examined will approach 1.

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Stanley Selkow
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#111/4:45 PM

Detecting and Computing the Intersection of Convex Objects

Numerous applications require intersection detection and/or computation. For convex polygons, it is known that O(log n) and O(n) operations, respectively, are necessary and sufficient to detect and compute the intersection. We extend these results to convex splinegons. A splinegon is a generalized polygon with curves replacing the straight edges. The bounds remain unchanged except that "operations" now include manipulations on curved edges (e.g. finding intersections). We refine the bound for intersection detection to O(log n) simple operations and O(k(n)) curved operations, where k(n) depends on problem instance, never exceeds O(log n) and is constant for a wide class of instances. We discuss implementations of these algorithms in both the polygon and splinegon cases.

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Diane L. Souvaine
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#23/5:00 PM

Algorithm for the Surface/Surface Intersection Problem

The surface/surface intersection problem in geometric modeling demands simplification rather than an exhaustive search for singularities. Still the class of problem treated has to be sufficiently "generic" to be of interest for technology. We give a finite, terminating algorithm to find a complete set of starting points for the intersection loci. This is indeed the last significant problem since good stepping techniques are known. All formulas for the new aspects of the algorithm are given.

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#55/5:15 PM

Intersection Problems in Polygon Overlay

A Geographic Information System (GIS) is a computer aided information system used to capture, store, refine/verify, analyze/model, and display geographic data. A Geographic Information System Procedure is an abstract (implementation independent) algorithmic function of a GIS that allows one to select, process, and update elements from a spatial data structure and/or spatial data base.

A GISP key to all GIS is that of polygon overlay, the process of taking two different representations of the same geographic space, and creating a composite network of polygons whose identities relate to the original polygons from which they were formed.

In this paper, the author will discuss two basic issues related to polygon overlay: 1) given a set of digital lines which is an appropriate primitive data component for efficient intersection detection and reporting, and 2) given the problems associated with exact intersection, what sort of problems are encountered when using the fuzzy intersection concept. This paper presents an empirical experiment made to determine an appropriate data primitive representation for polygon overlay, as well as some of the problems in the implementation of the fuzzy intersection concept.

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MONDAY, JULY 20

4:00 - 5:30 PM
Ballroom C

Contributed Presentations 4
GENERAL TOPICS 1

#77/4:00 PM

The Geometry Of Form Closure

A form closure of an object is a set F of forces applied on it, with the property that any other force can be balanced by a positive combination of F. It has been pointed out by K. Lakshminarayana that form closure requires at least four forces in two dimensions, and seven forces in three. It was also conjectured that these numbers can be achieved by forces normal to the surface of the object (called fingers). In this paper we prove this conjecture. For three dimensions we prove that form closure of any object with piecewise smooth boundary can be achieved with twelve fingers if and only if the object does not have a rotational symmetry; furthermore, under very general conditions seven fingers are enough.

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Luqun Ni, Institute of Mathematics, Academia Sinica, Beijing, China.

Christos H. Papadimitriou, Departments of Computer Science and Operations Research, Stanford University, Stanford, CA 94305.

#117/4:15 PM

Interactive Design with Rational Overhauser Curves

Interactive design using a recently developed rational interpolating cubic curve which implicitly maintains first order geometric continuity in splines is explored. The curve is formed by blending two rational quadratic curves. Since the blending method used was originally introduced by Overhauser, this curve is called the Rational Overhauser (Rover) curve. The use of Rover's four shape factors to provide control of the curve is demonstrated. The geometrical interpretation of these shape factors and their relationship to each other is discussed. The interactive definition of conic sections and the advantages of mapping between the Rover curve and rational forms of the Hermite, Bezier, and B-Spline curves are also explored.

Jeffrey J. Jortner and John A. Brewer, III
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#128/4:30 PM

On The Global Properties of Motion in Kinematics

The planar motion of a rigid body E with respect to another rigid body Σ is determined by three generalized coordinates. The set of positions corresponding to the motion of E with respect to Σ can therefore be mapped into a three-dimensional space called the image space of the motion. A continuous planar motion is mapped into a curve in the image space. In this paper we show how the concept of kinematic mappings can be used to classify planar motion, study the global properties of motion and derive new theorems. The basic geometrical tools which will be used are algebraic and projective geometry.

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#131/4:45 PM

EZ-SURF Package for Sculptured Surface Fit and Numerically Controlled Machining.

EZ-SURF is one of a series of software packages comprising Bridgeport Machines' EZ-CAM: personal computer based interactive part programming system. EZ-SURF constructs a smooth composite surface through a user-defined network of curves. The part program to machine this surface is then generated automatically. The first version of the EZ-SURF package utilized a well known tensor product patch representation. The speaker will discuss the merits of this technique. He will emphasize many pratical cases where it fails to maintain gradient continuity across patch boundaries. An alternate approach based on the rational Coons patch will also be discussed.

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TUESDAY, JULY 21

3:15 - 4:45 PM
Ballroom E

Contributed Presentations 5
MATHEMATICAL METHODS 1

#54/3:15 PM

On Some Topological Problems in Robotics Motion Planning

It has been demonstrated that $R^3 \times SO_3$, the configuration space of six degree-of-freedom manipulator, opens many opportunities for topological research. This presentation will concentrate on some aspects concerning the construction of chains of intersection manifolds in relation to free space path generation, and existence of bijective correspondence between such chains and connected Voronoi manifold chains. The methods will be primarily topological. Some issues concerning complexity of corresponding construction algorithms will also be addressed.

Mladen Luksic
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#103/3:30 PM

Polyharmonic Cardinal Splines

If k is a positive integer such that $2k \geq n+1$ then we define a k-harmonic cardinal spline on R^n to be a tempered distribution f which is in $C^{2k-n-1}(R^n)$ and satisfies $\Delta^k f=0$ on $R^n \setminus Z^n$. (Here Δ denotes the Laplace operator and Δ^k its k-th iterate.) These splines enjoy many of the properties of univariate polynomial splines of odd order. For example, if $\{v_j\}_{j \in Z^n}$ is a sequence of polynomial growth then the corresponding k-harmonic cardinal spline interpolation problem has a unique solution; the corresponding L splines have exponential decay at infinity. Furthermore k-harmonic splines have representations in terms of simple basic functions which reduce to the familiar B-splines in the univariate case.

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#78/3:45 PM

Hermite Interpolation by C^1 Piecewise Polynomials on Triangulations

Interpolation by simple bivariate C^1 piecewise polynomials to function value and gradient data at the vertices of an arbitrary triangulation is considered. Considerations of the dimension of such spline spaces show that piecewise quartics are likely to solve the problem. Using the Bernstein-Bézier representation of a piecewise polynomial, the problem is isolated, in a sense, to regions surrounding each vertex of the triangulation. For all triangulations without a certain unlikely geometric degeneracy, it can indeed be done with piecewise quartics, and a constructive solution is given.

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#94/4:00 PM

Free-Form Curve Modeling by Polycurve Codes

This paper presents a free-form curve modeling scheme, called the polycurve code, which is based on Freeman's generalized chain code. When the curves placed on a square grid are approximated by a systematic procedure similar to that of generalized chain codes, polycurve codes use as approximators pre-defined circular-arc segments as well as line segments. Polycurve codes enable fast extraction of labeled higher-level segments suitable for efficient feature calculation of the curves. We show that polycurve codes improve modeling performance, e.g., compactness and encoding time, over other schemes such as the chain code and the generalized chain code.

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#86/4:15 PM

The Unit Circle as the Mathematical Model for Special Relativity Theory

When parametric equations for points on the unit circle are written with the slope of the vector from the center of the circle to points on the circle as parameter, the resulting equations provide the geometric analog of the Lorentz-Einstein equations.

Thus, an isomorphism between the geometric structure of the unit circle and space-time measurements may be created to establish the unit circle as a mathematical model for Special Relativity.

This model differs in physically significant ways from the geometric model current among physicists, and provides new deductive consequences in addition to well-known results.

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#129/4:30 PM

Elastically Deformable Geometric Models

We develop an approach to modeling which incorporates the dynamics of idealized deformable materials. This approach extends the purely geometric models which have been used traditionally to represent the instantaneous shapes of objects. Our deformable models unify the description of shape with the description of nonrigid motion. Such modeling power is needed both in computer vision and in computer graphics. We propose variational principle formulations for elastically deformable curves, surfaces, and solids. In several applications, we demonstrate the numerical solution of the associated partial differential equations of motion under the influence of external forces simulating gravity, wind, collisions with impenetrable objects, as well as diverse shaping forces applied by the user.

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TUESDAY, JULY 21

3:15 - 4:45 PM
Ballroom D

Contributed Presentations 6
ROBOT PATH PLANNING 1

#72/3:15 PM

Optimal Path Planning by Cost Wave Propagation in Configuration Space

An algorithm for optimal path planning and obstacle avoidance is presented that is applicable to arbitrary robots and obstacles, for a wide range of optimality criteria. It is based on the propagation of cost waves through the discretized configuration space, endowed with an appropriate metric. There is some freedom in actually implementing the basic idea, allowing for trade-off between time and storage space. In the straightforward implementation discussed, the time required is not worse than linearly dependent on the number of obstacles, storage space is exponential with the desired accuracy. The algorithm can be parallelized, and is well suited for implementation in hardware.

Leo Dorst
Robotics & Flexible Automation
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345 Scarborough Road
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#83/ 3:30 PM

Polar Morse Equations and Exact Robot Navigation

A formulation of robot navigation tasks in terms of feedback control algorithms based upon potential functions leads to the following general problem. Given a completely specified configuration space, $\mathcal{W}$ — an analytic manifold with boundary — and a desired "destination" point, $p \in \mathcal{W}$, construct an analytic scalar valued map of $\mathcal{W}$ onto some closed real interval, $\varphi \in C^{\omega}[\mathcal{W}, [0, \eta]]$, with the properties: i) non-degenerate critical points; ii) unique minimum at the destination point, and iii) "admissible" with respect to the configuration space, i.e. $\partial\mathcal{W} = \varphi^{-1}[\eta]$. Motivated by elementary results of algebraic and differential topology, the author has constructed such "admissible analytic polar Morse functions" for a very restricted class of configuration manifolds, $\mathcal{W}$. On the other hand, a twenty-five year old theorem of Marston Morse asserts the existence of a "smooth polar Morse function" (properties i and ii) over any C^{∞} manifold. This talk will discuss the implications of these results for practical problems of robot motion planning.

Daniel E. Koditschek
Center for Systems Science
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Department of Electrical Engineering
P. O. Box 2157, Yale Station
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#84/ 3:45 PM

Path Planning for Mobile Robots in Unexplored Terrain

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[illegible] S. [illegible]ikballapur and S. K. Mohapatra
Robotics Lab.
School of Mathematics and Computer Science
University of Hyderabad, Hyderabad - 500 134 INDIA

#110/4:00 PM

MANIPULATOR WORKSPACE GEOMETRY BY THE MONTE CARLO METHOD

A new technique, based on the Monte Carlo Method, for determining the workspace geometry for a general nR manipulator, where n is any integer between 2 and 6, will be presented. This method avoids the difficulties encountered when attempting to determine workspace geometry in the usual fashion, which involves the repeated solution of systems of nonlinear algebraic equations to find points at which the Jacobian is zero, a problem which is computationally very difficult.

David Perel
Jahangir S. Rastegar

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Manhattan College
Manhattan College Parkway
Riverdale, N.Y. 10471

#31/4:15 PM

A PROBABILISTIC APPROACH TO THE DESIGN OF ROBOT ARMS

The geometric design of robot arms is a subject of great interest in the field of robotics, with most of the important questions still remaining to be answered. In their presentation, the speakers will discuss a novel probabilistic approach to the optimum geometric design of manipulators. The method developed can be used to determine the manipulator with minimum total link length that would cover a specified working space. The method will be shown to be very efficient and simple to apply, and capable of accomodating very complex working spaces.

Jahangir S. Rastegar
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Behruz Fardanesh
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#20/4:30 PM

The Application of Quintic Splines to Kinematic Design Problems

The specification of motion curves is a fundamental problem in many engineering disciplines, including mechanism design, robotics and highway design. These problems require interpolating motion curves which impart acceptable dynamic characteristics to the system. It is often difficult to satisfy these constraints with standard kinematic curves - in particular controlling acceleration. Spline functions posess many characteristics which make them suitable for kinematic design. The quintic spline may provide the optimum solution for many problems. This paper will emphasize the most flexible construction of quintic splines using a B-spline basis, discussing: (i) the imposition of derivative boundary conditions - vital for controlled motion; (ii) the use of knot positions as design parameters to control acceleration; (iii) computational aspects - the ease and accuracy of evaluation and differentiation using B-splines. Practical examples will be presented.

B. L. MacCarthy
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England

TUESDAY, JULY 21

3:15 - 4:45 PM
Ballroom C

Contributed Presentations 7
GENERAL TOPICS 2

#85/3:15 PM

A Characterization of Octree Behavior

Several experiments were conducted on the behavior of the Octree data structure in terms of its efficiency in storing thin-shelled and sparse objects while varying their size, position, and amount of concavity. Objects of this type are a worst-case empirical measure of Octree storage efficiency. Metrics included several measures of the number of nodes used in the tree structure to store each object. Results confirm that octrees exhibit linear storage in relationship to object surface area while also exhibiting harmonic effects that result from the successive division of space used in the construction of the tree structure.

Donald T. Kasper
Northrop Advanced Systems Division
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#100/3:30 PM

A Pattern-Theoretic Formulation of Shape

The concept of shape has been a fundamental idea in the development of geometry, the shapes being the figures obtainable in the geometry. For the modern technologies of image processing and computer vision one needs geometries which lie in between the too-restrictive Similarity group and the too-relaxed Diffeomorphism group on $\mathbf{R}^3$. What the appropriate geometry is will depend upon what one feels are the important characteristics to be captured as invariants. This talk will discuss one approach to some of these questions.

Ulf Grenander
Daniel MacRae Keenan
Division of Applied Mathematics
Brown University
Providence, Rhode Island 02912

#64/3:45 PM

A Construction of Non-Periodic Tilings

N. G. de Bruyn's algebraic construction of Penrose's tiling of the plane, has a natural generalization that is referred to as "the projection method". We give an alternative description of this generalized construction, which may be of interest in itself, and lends itself to analysis. In our method a k-dimensional subspace S of R^n determines a certain periodic tiling of R^n. The intersections of translates of S with this tiling give tilings of R^k that are in general non-periodic. The periodic tiling of R^n has period 1 in each coordinate direction, so it can be thought of as a decomposition of the torus T^n into a finite set of polytopes; the tilings of R^k are obtained by wrapping an image of R^k around T^n via reduction modulo one.

Seymour Haber
James F. Lawrence
Mathematical Analysis Division
National Bureau of Standards
Gaithersburg, Maryland 20899

TUESDAY, JULY 21
3:15 - 4:45 PM
Ballroom E

Contributed Presentations 5
MATHEMATICAL METHODS 1

#54/3:15 PM

On Some Topological Problems in Robotics Motion Planning

It has been demonstrated that $R^3 \times SO_3$, the configuration space of six degree-of-freedom manipulator, opens many opportunities for topological research. This presentation will concentrate on some aspects concerning the construction of chains of intersection manifolds in relation to free space path generation, and existence of bijective correspondence between such chains and connected Voronoi manifold chains. The methods will be primarily topological. Some issues concerning complexity of corresponding construction algorithms will also be addressed.

Mladen Luksic
Division of Mathematics, Computer Science, and Systems Design
The University of Texas at San Antonio
San Antonio, Texas 78285

#103/3:30 PM

Polyharmonic Cardinal Splines

If k is a positive integer such that $2k \geq n+1$ then we define a k-harmonic cardinal spline on R^n to be a tempered distribution f which is in $C^{2k-n-1}(R^n)$ and satisfies $\Delta^k f=0$ on $R^n \setminus Z^n$. (Here Δ denotes the Laplace operator and Δ^k its k-th iterate.) These splines enjoy many of the properties of univariate polynomial splines of odd order. For example, if $\{v_j\}_{j \in Z^n}$ is a sequence of polynomial growth then the corresponding k-harmonic cardinal spline interpolation problem has a unique solution; the corresponding L splines have exponential decay at infinity. Furthermore k-harmonic splines have representations in terms of simple basic functions which reduce to the familiar B-splines in the univariate case.

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Storrs, CT 06268
and
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Dept. of Mathematics
Iowa State University
Ames, IA 50011

#78/3:45 PM

Hermite Interpolation by C^1 Piecewise Polynomials on Triangulations

Interpolation by simple bivariate C^1 piecewise polynomials to function value and gradient data at the vertices of an arbitrary triangulation is considered. Considerations of the dimension of such spline spaces show that piecewise quartics are likely to solve the problem. Using the Bernstein-Bézier representation of a piecewise polynomial, the problem is isolated, in a sense, to regions surrounding each vertex of the triangulation. For all triangulations without a certain unlikely geometric degeneracy, it can indeed be done with piecewise quartics, and a constructive solution is given.

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#94/4:00 PM

Free-Form Curve Modeling by Polycurve Codes

This paper presents a free-form curve modeling scheme, called the polycurve code, which is based on Freeman's generalized chain code. When the curves placed on a square grid are approximated by a systematic procedure similar to that of generalized chain codes, polycurve codes use as approximators pre-defined circular-arc segments as well as line segments. Polycurve codes enable fast extraction of labeled higher-level segments suitable for efficient feature calculation of the curves. We show that polycurve codes improve modeling performance, e.g., compactness and encoding time, over other schemes such as the chain code and the generalized chain code.

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#86/4:15 PM

The Unit Circle as the Mathematical Model for Special Relativity Theory

When parametric equations for points on the unit circle are written with the slope of the vector from the center of the circle to points on the circle as parameter, the resulting equations provide the geometric analog of the Lorentz-Einstein equations.

Thus, an isomorphism between the geometric structure of the unit circle and space-time measurements may be created to establish the unit circle as a mathematical model for Special Relativity.

This model differs in physically significant ways from the geometric model current among physicists, and provides new deductive consequences in addition to well-known results.

Herbert J. [illegible], Retired
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[illegible], Pa., [illegible]

#129/4:30 PM

Elastically Deformable Geometric Models

We develop an approach to modeling which incorporates the dynamics of idealized deformable materials. This approach extends the purely geometric models which have been used traditionally to represent the instantaneous shapes of objects. Our deformable models unify the description of shape with the description of nonrigid motion. Such modeling power is needed both in computer vision and in computer graphics. We propose variational principle formulations for elastically deformable curves, surfaces, and solids. In several applications, we demonstrate the numerical solution of the associated partial differential equations of motion under the influence of external forces simulating gravity, wind, collisions with impenetrable objects, as well as diverse shaping forces applied by the user.

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John Platt‡
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Kurt Fleischer†

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Palo Alto, CA 94304

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California Institute of Technology
Pasadena, CA 91125

TUESDAY, JULY 21
3:15 - 4:45 PM
Ballroom D

Contributed Presentations 6
ROBOT PATH PLANNING 1

#72/3:15 PM

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#83/ 3:30 PM

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Baba Prasad S. Chikballapur and S. K. Mohapatra
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#110/4:00 PM

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Jahangir S. Rastegar

Department of Mechanical Engineering
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#31/4:15 PM

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#20/4:30 PM

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B. L. MacCarthy
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TUESDAY, JULY 21

3:15 - 4:45 PM
Ballroom C

Contributed Presentations 7
GENERAL TOPICS 2

#85/3:15 PM

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#100/3:30 PM

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Daniel MacRae Keenan
Division of Applied Mathematics
Brown University
Providence, Rhode Island 02912

#64/3:45 PM

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Seymour Haber
James F. Lawrence
Mathematical Analysis Division
National Bureau of Standards
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#22/4:00 PM

On a Class of Geometric Packing Problems

We consider the problem of disjoint packing of trapezoids of a given width "h" into a strip of width "h", so as to minimize the total length "L" of the strip. Various modifications of the problem, in which we allow different types of rotations, are considered and o(nlogn) algorithms are developed in each of the cases. Also, given weights to the trapezoids and given a strip of fixed length "L", the problem of finding a maximum weight packing is considered. Interesting applications in Computer Science are presented.

(1) Prof. R. Chandrasekaran
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#119/4:15 PM

Identification of Industrial Objects from Video Images Based on Their B-Rep Solid Models

We present a method for finding the correspondence (matching) between video image and B-Rep solid models of an industrial object. This method will be used in a CAD-driven vision system for identifying parts and their location and orientation. Our approach is to extract image features from image data and match them to boundary primitives from B-Rep solid models in order to generate and test hypotheses that identify the objects. The correspondence between image features and boundary primitives of models are statistically characterized to obtain criteria for testing the matching hypotheses. Experimental results for objects with planar and quadratic surfaces are presented.

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#130/4:30 PM

Graphics Representation of Implicitly Defined Surfaces

A surface consisting of points which satisfy the equation $F(x,y,z)=0$ may be approximated by a piecewise linear surface which can be constructed using only one point on the surface and function value information. This construction is described and enhancements of the piecewise linear surface to better represent the original surface are discussed.

Timothy S. Norfolk and
Phillip H. Schmidt

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Moved to Session 4, Mon. July 20, Ballroom C

#133/5:00 PM

Simplifying Polygonal Curves

A distance between convex polygonal curves is defined. It is shown how to compute a constrained version of a given polygonal curve that minimizes this distance. The constraints can be number of sides or allowed angles between sides and the curves themselves can be either open or closed. Experiments indicate that the approximating curve visually resembles the original. This procedure is shown to have uses in pattern recognition and graphics.

Michael Werman
Division of Applied Mathematics
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TUESDAY, JULY 21

3:15 - 4:30 PM
Ballroom A-B

CONTRIBUTED PRESENTATIONS 8
COMPUTATIONAL GEOMETRY 2

#118/3:15 PM

A Calculus for Reasoning about Polygons, Polyhedra and Complexes Made from Them

It is well known that the topological elements, i. e., vertices, edges, faces, cells etc., making up a particular polygon, polyhedron, or more generally, a polytope or polytope complex, has the structure of a mathematical lattice. We describe here a new method of modeling such a complex by explicitly storing this lattice. Corresponding to each topologically distinct polytope or polytope complex there is a unique family of sets whose elements correspond to the vertices, edges, faces etc. of the polytope. In this *incidence calculus* the lattice partial order is modeled by the subset relation and the join and meet by set intersections. This calculus provides both a space and time efficient method for a computer to store the incidencies between the polytopes' elements in support of processing algorithms. A remarkable mathematical fact is that the full incidence calculus may be generated from certain subsets of itself. An algorithm exploiting this fact, based on knowing just which highest dimensional elements are are incident on each vertex, is described. The application of the incidence calculus to qualitative visual reasoning and to configuration space will be discussed.

Don J. Orser
Center for Manufacturing Engineering
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#124/3:30 PM

ON THE EXTERNAL CONTOUR OF THE UNION OF A SET OF POLYGONS AND APPLICATIONS

Let $P_1,..P_k$ be k simple polygons with a total number of N edges. We prove that the external contour of the union of the P_i (i=1...k) is O(N) (though the contour of the union may be $O(N^2)$). An efficient algorithm is presented that Computes this external contour.

Two applications are presented in the field of robotics : planing of a collision free movement when only translations are allowed and representing obstacles from measurements.

BOISSONNAT Jean Daniel
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06560 VALBONNE

#126/3:45 PM

Using Prolog For Gometric Intersection

We present a logic programming approach in Prolog to polygon intersection problems. Instances of geometric entities and their relationships are represented as facts, and rules encoding geometry algorithms perform data processing. Apart from relational data structuring and the general high level nature of Prolog, we describe specifically two features in our strategy: rational arithmetic and the adaptive grid. Operator overloading in Prolog provides for the modular installation of a different arithmetic domain. Rational arithmetic guarantees numerical accuracy and thus topological consistency, and tangential situations can be properly handled. The adaptive grid sorts out potentially intersecting elements which share the same vicinity. The approach is based on local processing and set-based operations which are obviously easy in Prolog.

Peter Y.F. Wu
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Rensselaer Polytechnic Institute
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#127/4:00 PM

An Optimal Visibility Algorithm for a Simple Polygon with Star Shaped Holes

A well studied problem is that of finding the visibility polygon from a point inside a simple polygon. This can be done in optimal O(n) time where n is the number of vertices describing the scene. Also the problem in which there are a collection of m disjoint simple polygonal "holes" has been studied, and there exist algorithms achieving O(n log m) time, whereas the known lower bound is $\Omega(n + m \log m)$. We present an algorithm that achieves this bound in the special case of star shaped holes, thus extending a similar result for convex holes.

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School of Operations Research and Industrial Engineering
Cornell University
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WEDNESDAY, JULY 22

2:00 - 3:45 PM
Ballroom E

Contributed Presentations 9
SURFACE APPLICATIONS

#76/2:00 PM

Approximating Molecular Surfaces by Spherical Harmonics

Smoothed molecular surfaces can be used to analyze the general shapes of proteins, and as reference surfaces for locating clefts and projections. The radius of the surface in a given direction is defined by a polynomial or spherical harmonic function on the unit sphere. Starting with equally spaced points on a solvent-accessible molecular surface, generated by an algorithm of Connolley, we can either evaluate the spherical harmonic coefficients by a summation over the surface points, or by the "QR" least squares algorithm. The resulting surface can be drawing with randomly spaced dots, or by ray tracing after conversion to an implicit polynomial equation.

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48

#89/2:15 PM

GEOMETRIC MODELING OF COMPLEX SURFACES IN TURBOMACHINES

The simulation of the flow in a turbomachine, by solving Navier-Stokes equations, requires the geometric definition of its wetted surfaces. For a turbine, the parts that need to be modeled are the spiral casing, the guide vanes, the assembly of the hub, shroud, and blades, and the diffuser. These are intricate 3D shapes that the hydraulic designer must be able to define and modify easily. In this paper, we describe a practical method for the geometric modeling of the wetted surfaces. The constituent parts of a turbomachine are each characterized by a spine along which, laws of thickness, orientation, and shape are applied. These laws are normalized continuous 2D curves that the designer can interactively edit. A set of layered "supports", such as surfaces of revolution, or planes, intersecting the spine, are then defined. The value of the different laws at the intersection point, are used to calculate directly on the support, the curves describing the actual boundaries of the wetted surfaces. Convenient mapping projections of the curves lying on these supports into the screen, are also presented. A special attention is given to the manner whereby the designer is then able to extract meaningful geometric parameters and information about the turbomachine.

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#24/2:30 PM

Surface Geometry Requirements for Finite-Difference Aerodynamic Calculations

The modelling of aerodynamic surfaces for realistic simulation of viscous flow at high Reynolds number presents stringent requirements on the geometric representation of the surface, and its approximation by a finite-difference grid. Requirements on these doubly curved surfaces include accuracy within a thin boundary layer, monotonicity, and geometric continuity. This paper will present current progress and problems associated with the geometrical representation of a complete F-16 aircraft used in a transonic Navier-Stokes simulation.

G. David Kerlick
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Applied Computational Fluids Branch
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#66/2:45 PM

Probing Convex Polygons with X-rays

An *x-ray probe* through a polygon measures the length of intersection between a line and the polygon. We consider the properties of various classes of x-ray probes, and show how they interact to give finite strategies for completely describing convex n-gons. It is shown that $(3n/2)+6$ probes are sufficient to verify a specified n-gon, while for determining convex polygons $(3n-1)/2$ x-ray probes are necessary and $5n+O(1)$ sufficient, with $3n+O(1)$ sufficient given that a lower bound on the size of the smallest edge of P is known.

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Steven S. Skiena
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#21/3:00 PM

The Use of Tensor Product Splines for the Approximation of the Sea Bed Surface

An economical and accurate representation of the sea bed surface from discrete hydrographic survey data, for use in real time navigation, provides a challenging problem in surface approximation. Recent work by the present authors indicates that an approach based on tensor product B-spline surfaces may be very useful. The paper will outline the advantages of this representation with respect to computation, data reduction and recovery of values and derivatives. Two approaches will be discussed:

(i) the use of least squares approximation to scattered data
(ii) the use of a two-stage process involving interpolation to data on a grid.

Practical examples will be shown.

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#60/3:15 PM

Fast Frontal and Drag Area Computations in Space Vehicle Design and Analysis

A fast $O((N+k)\log N)$ algorithm for the Boolean Masking problem is developed in the context of space vehicle design and analysis. The objects are geometric regions. The boundary of a region is specified by a set of equations of the form: $f(x) + by = 0$. The algorithm evaluates a Boolean expression over the objects. Frontal and drag areas are two critical factors in the structural design of a space vehicle which can be written as Boolean expressions over the projections of the vehicle components. The algorithm makes the exact computations of these two factors possible in a reasonable amount of time and hence accelerating the iterative design process.

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#38/3:30 PM

Geometrical Analysis of Gastric Emptying

The objective of this report is to study the geometrical properties of the stomach during gastric emptying. This will enable us to identify the abnormalities in the digestion process, if there are any. A typical approach in gastric study is to administer the patients with radioactive materials immediately following ingestion of the labeled meal, the patient is positioned for imaging on a digital gamma camera equipped with a medium energy collimator and interfaced to a nuclear medicine computer system. Images are obtained at 15 minutes intervals.

Geometricals properties can be represented using, for example, Fourier descriptors, radius of curvature, or the method of moments. In this study we used the method of moments because it is more powerful in providing indices that are invariant to scaling, rotation, and translation. Eventually, we were able to get a more accurate representation of the stomach mobility, and a potential index that can differentiate between normal and abnormal emptying modalties.

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WEDNESDAY, JULY 22
2:00 - 3:30 PM
Ballroom D

Contributed Presentations 10
IMAGE PROCESSING

#34/2:00 PM

The Gray-scale Version of the Matheron Representation Theorem for Tau-openings

The morphological filtering of images is based upon the relationship between the local geometry of an image and the global geometry of a structuring element. The original Matheron representation expresses every tau-opening, in the two-valued setting, in terms of elementary openings. The present result extends the representation to the gray-scale case by employing a two-value filter that is induced, via the umbra transform, by the original gray-scale filter. The expansion gives the filter as an extended supremum of openings of the image by elements taken from a base for the invariant class of the filter. In the digital case, the expansion takes the form of an EXTMAX operation, EXTMAX being a basis operator in the general image algebra.

Edward R. Dougherty
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Fairleigh Dickinson University
Teaneck, NJ 07666

#33/2:15 PM

Gray-scale Morphology as an Extension of Matheron-Hadwiger Two-valued Theory

Numerous approaches have been employed to apply the two-valued morphological method, which extracts geometric information from a black-and-white image, to gray-scale images. The present theory satisfies four criteria important to any such generalization: (1) The original theory is a special case of the gray-scale theory. (2) The original Matheron representation theorems for general morphological filters and tau-openings possess gray-scale extensions. (3) The digital theory is fully expressible within the general image algebra. (4) For practical classes of filters, such as order statistic filters and low-pass moving average filters with total mask weight one, the general representation theorem reduces to a finite expansion over the basis for the filter.

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Charles R. Giardina
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#81/2:30 PM

A Gaussian Localized Image Processing Model

This paper describes a new Gaussian localized image processing model for improving image processing results in a variety of computer vision applications such as image enhancement, segmentation, as well as pattern recognition. Because traditional image processing techniques are based on global information over an entire input image, the empirical results are poor if the input image has spatially dependent heuristics. The Gaussian localized image processing is based on local image heuristics. It processes an input image by the following steps: 1) divide the image into subimages based on an overlay image division scheme, 2) process these subimages based on local image heuristics, 3) recombine subimages into one image using the Gaussian overlay recombination scheme which eliminates the defects of connecting these independently processed subimages. Experimental results and a comparison between the global image process and the Gaussian localized image process are given.

Joseph Shu
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#96/2:45 PM

Minimal Curves in Image Segmentation

One of the ways to obtain a robust algorithm for segmenting an image is to formulate it as a minimization problem. One formulates an energy functional which reflects the properties that one would expect of any segmenting scheme. The problem of finding minimizing curves which segment a given image then becomes analogous to the problem of determining geodesics. The speaker will illustrate this with the analysis of a specific case. The curves qualitatively behave like geodesics in a Lorentzian space.

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#1/3:00 PM

An Integral Measure Signature for Recognition of Plane Curves and Surfaces Using Cylindrical Multivalued Transform

In this paper the use of Cylindrical Multivalued Transform CMLT for defining an Integral Transform Measure Signature for curves and surfaces is examined. This Integral Measure is robust to the effect of noise and quantization errors. These signatures are used as low level primitives in computer vision system for the purpose of recognizing curves and surfaces. The evaluation and the properties of these signatures are discussed.

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#35/3:15 PM

Determining Object Posture from Dense Range Maps

In this paper, we present a new method for determining object posture from dense range maps that is based on matching object surface descriptions with model surface descriptions. The objects and models are represented by regions that are a collection of surface patches homogeneous in certain intrinsic surface properties. The technique for determining the posture requires that correspondence be established exactly, between one point on the object surface and one on the model surface. Once the single point correspondence is specified, closed form solutions are given for determining the attitude of the unknown view of the object in 3 space with respect to the model.

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WEDNESDAY, JULY 22

2:00 - 3:30 PM
Ballroom C

Contributed Presentations 11
ROBOT PATH PLANNING 2

#107/2:00 PM

Real-Time Adaptive Motion Planning

This is a discussion of approaches used in robotics systems that require real-time definition and alteration of their motion plans. In adaptive robot systems that have on-line feedback, there is a need to modify or redefine the motion plan as it is being executed due to anomolies encountered by vision systems, tracking sensors, etc. Through the use of a parallel processing environment, these approaches were successfully implemented without affecting the speed of the robot control loops. The speaker will discuss the proven techniques in recent robotics systems, and the direction of current work.

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#87/2:15 PM

Parallel Processing: the Road to Autonomy

The fusion of information from multiple sensing modalities can be used to reduce or eliminate ambiguity introduced by the perceptual process, providing autonomous systems with the ability to successfully react to and interact with their environments. Computationally intense data acquisition and analysis tasks, symbolic abstraction of raw data, and subsequent knowledge based interpretation and correlation are all employed to build consistent world models used in the planning and control of autonomous systems. Powerful multiprocessor computer architectures, such as the Butterfly™ Parallel Processor, provide both the computational capabilities and the organizational framework required to support the development of these autonomous systems.

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#62/2:30 PM

Towards a Global Navigation and Positioning System for Mobile Robots

This paper reports on the initial results of a project directed towards finding methods for determining and maintaining positional information on mobile robots. This project is limited to systems not involving vision, and restricts the motion of the robot to single planar surface. Techniques investigated include inertial navigation and external beacons. The beacon types include radio, laser, sonar and other types. Systems of beacon navigation investigated are rho/theta, rho/rho and theta/theta systems. Techniques for reducing external inputs to positional information are discussed, with emphasis on speed, efficiency and small error values.

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#112/2:45 PM

Robot Kinematics Based Upon Simple Applied Geometric Notions

Robot kinematics is concerned with the geometry of robot motion (as a function of time) with respect to a fixed reference coordinate frame, without the consideration of the forces and torques that cause the motion. Real-time robot planning requires efficient kinematic transformations to relate the temporal evolution of the joint coordinates to the motion of the end-effector. The development of a new kinematic algorithm based upon simple geometric notions is the theme of this paper. The algorithm, which is applicable to serial (open-chain) manipulators with arbitrary axes of motion, can accommodate both forward and inverse kinematic transformations.

Vassilios D. Tourassis
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#73/3:00 PM

Forward and Inverse Synthesis for a Robot with Three Degrees of Freedom

Planar algebraic curves (polynomial, parametric type) are frequently required to be generated to manufacture specific geometric surface characteristics of the machine parts.Precision, accuracy, and speed are in general prime requisites. However, flexibility also becomes mandatory in today's industry environment. A planar three degree of freedom robot is designed and fabricated with a built in forward and inverse kinematic algorithm. The robot may programmed to generate planar enveloping curves where in the generator (*tool*) is an infinite line. Forward and inverse design of this particular planar robot for generation of algebraic curves will be illustrated.

A. H. Shirkhodaie and A. H. Soni
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#120/3:15 PM

Using Fiducial Marks for Tracking a Robot Arm

Distinguishable fiducial marks etched on several facets of a robot hand or tool and viewed by a fixed digitizing camera can be used for low-cost, accurate closed-loop control. Marks are located and identified in the digitized image, and vertices are determined from edge intersections. Then the camera coordinate system is mapped into the robot-centered system. The marks consist of polygons against a contrasting background. We consider the problem of determining shapes that minimize the number of edges (for fast computation), maximize the length of the edges (for accurate direction determination with a low-resolution camera), and avoid near-collinearities. The shape of the marks should yield a well-conditioned transformation matrix for the six coordinates of the manipulator.

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WEDNESDAY, JULY 22

2:00 -3:30 PM
Ballroom A-B

Contributed Presentations 12
ALGEBRAIC CURVES AND SURFACES

#109/2:00 PM

An Algorithm for Computing and Plotting an Implicitly Defined Surface

Implicitly defined surfaces $H(x,y,z) = 0$ are plotted with the help of this new algorithm. It starts at a known zero-point (x_o,y_o,z_o) of H and generates a sequence of points (x_i,y_i,z_i) on the 2-dimensional manifold. The selection of the next search direction and an examination of the already generated part of the surface are efficiently dealt with by a triangulation of the $\mathbb{R}^3$.

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#113/2:15 PM

GENUS IS A BIRATIONAL INVARIANT: Parameterizing Rational Space Curves

Consider an irreducible algebraic space curve C which is the intersection of two algebraic surfaces $f(x,y,z) = 0$ and $g(x,y,z) = 0$. There always exists a birational correspondence between the points of C and the points of an irreducible plane curve P whose genus is the same as that of C. Thus C is rational iff the genus of P is zero. When f and g are not tangent along C we present a method of obtaining a projected plane curve P whose points are in birational correspondence with C. Algorithms to obtain parameterizations of rational curves are presented and these involve solving systems of homogeneous linear equations and the computation of resultants.

S.S. ABHYANKAR
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#56/2:30 PM

Algebraic Varieties, Path-Following Methods and Stopping Times

Let ρ represent a small positive constant and P a map from a Banach space B into itself. In this talk we will provide a geometric analysis of certain path-following algorithms that are designed to solve the inequality $|P(\cdot)| \leq \rho$. Strong geometric understanding is obtained when B is finite dimensional and P is chosen from the family of d^{th} degree polynomials. In this case there is an intermingling of the classical Newton-Kantorovich arguments and the "Elimination Theory" of Algebraic Geometry.

Richard Wongkew
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#18/2:45 PM

Polynomially Parametrizable Planar Algebraic Curves

As is well known, a planar algebraic curve is rationally parametrizable just in case it has genus 0. The problem of parametrization by polynomials, not being projectively invariant, did not seem to interest previous investigators; however, with the advent of computer graphics systems having as basic canonical forms piecewise polynomial curves, the problem becomes relevant. In this paper we offer a necessary and sufficient characterization of such curves.

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#36/3:00 PM

Finding the Defining Equation for a Rationally Parametrized Surface.

In this paper we extend the use of Sylvester's resultant via a method of Kronecker to show the existence of a polynomial $F(x,y,z)$ which determines the rationally parametrized surface

$$\sum : x = p(u)/k(u),\ y = q(u)/k(u),\ z = r(u)/k(u)$$
$$u = (u_1, u_2, u_3)$$

via the equation $F(x,y,z) = 0$. We employ the Weierstrass preparation theorem and some elementary (algebraic) field theory to establish the correctness of the method. We find a bound and the degree of $F(x,y,z)$ by applying a weak form of Bezout's theorem. We analyze the real torus and compare its rational parametric and implicit definition.

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Charles M. Stanton
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#67/3:15 PM

Convex Decompositions and Gaussian Approximations of Objects Bounded by Piecewise Algebraic Curves

In various applications dealing with arbitrary shaped geometric objects, convex shape simplifications and polygonal approximations often lead to simpler and faster solutions. With this in mind, we present an algorithm to decompose an arbitrary shaped object bounded by piecewise algebraic curves into the union and difference of convex objects with algebraic curve boundaries. We also describe how to obtain a polygonal approximation of an object bounded by piecewise algebraic curves. The polygonal approximation (termed Gaussian approximation) is curvature dependent with independent refinement control points, one for each convex or concave edge on the object boundary. A collection of techniques from computational algebraic geometry and numerical methods are used.

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Myung-Soo Kim

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THURSDAY, JULY 23

10:45 AM - 11:45 AM
Ballroom A-B

Contributed Presentations 13
COMPUTATIONAL GEOMETRY 3

#95/10:45 AM

d-Neighbourhoods of Simple Externally Visible Polygons

It is well known that a *d-neighbourhood* of a set S in R^n is the set of points in R^n with distance to S less or equal to d. We define a simple externally visible (s.e.v.) polygon as a polygon such that for every component D_i of its convex deficiency there exists a point at infinity p_i such that D_i is contained in the visibility polygon of p_i with respect to the polygon. We give algorithms to known if a polygon is s.e.v. and to construct the d-neighbourhood of a s.e.v. polygon. Some applications to robotics are given.

Dolores Lodares
Manuel Abellanas

Facultad de Informática
Universidad Politecnica de Madrid
Ctra de Valencia Km.7
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#7/11:00 AM

Application of 2-n Sorting in Computational Geometry

The recursive division of space used in 2-n tree solid modelling suggests a similar approach to preprocessing points in real n-dimensional space. The resultant process generates an n-dimensional sort. The steps of: selection of a region; choice of subdivision point; recursive termination rule; and, recursive ascent recombination algorithm each can be varied. By appropriate choices of such procedures an n-dimensional sort, a cluster finding procedure, a surface mesh generator and ray-tracing preprocessor can be specified. Various results are demonstrated.

Jeffrey L. Posdamer
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#15/11:15 AM

Scheduling pattern of points or intervals on a circle line

Consider n polygons with vertices on a circle line. How should the polygons moved relative to each other to minimize (maximize) the maximum (minimum) distance between vertices on the circle line?

In a second type of problems the vertices of each polygon are replaced by nonoverlapping intervals. How should these pattern of intervals to be moved relative to each other such that the maximal overlapping of intervals of different pattern is minimized?

For the case of two pattern efficient algorithms for solving these problems are presented. For the n pattern case enumerative procedures are derived.

Peter J. Brucker
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#43/11:30 AM

On the Complexity of 3D Variational Geometry

Three dimensional variational geometry, when used to generate typically complex engineering solids of interest, can quickly subsume normal computing resources. This is due to the inherent nature of variational geometry since it enumerates object geometry as sets of functional constraints rather than nominal cartesion elements. The complexity issue then arises concerning the solution of these potentially large equation sets to derive the geometry of a single object, or small set of objects. This paper discusses a vectorized implementation paradigm for variational geometry that exploits the vector processing capabilities of the Cray/ETA class supercomputers. It then discusses potential exploitation of temporal and spatial coherence to reduce the problem complexity.

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THURSDAY, JULY 23

10:45 AM - 12:15 PM
Ballroom C

Contributed Presentations 14

ROBOT PATH PLANNING 3

#63/10:45 AM

A General Path Planning Algorithm for Kinematically Redundant Robots Using a Selective Mapping of Configuration Space

In this talk, a path planning algorithm for kinematically redundant robots is discussed. The algorithm selectively maps joint space in search of a collision free path. This differs from prior configuration space methods which generally map all of joint space. A complete mapping usually proves intractable for robots with more than three joints unless constraints are imposed on the allowable types of robots and obstacles. The algorithm which will be discussed avoids an exhaustive mapping in most cases and consequently is quite general. It cannot guarantee an optimal solution, but rather attempts to find a "good" solution while mapping a minimal amount of joint space. The algorithm also takes advantage of the multiple goal configurations available as a result of redundancy. The implementation of this algorithm for robots with seven joints is discussed.

Pierre E. Dupont, Research Assistant
Stephen Derby, Associate Professor

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#2/11:00 AM

Path Planning for Mobile Robots : An Elastic Band Approach

Recent advances in mobile robot application in industry have led to a new field of research in optimal collision-free path planning. A few algorithms have been proposed to derive optimal collision-free paths in unknown environments, e.g., shopfloors. We propose a novel approach which evolves optimal collision-free paths among all kinds of obstacles (e.g. convex, concavo-convex polyhedrals and irregular-shaped objects). This approach offers the additional advantage of drastically reducing the computational overhead. This advantage is amply manifested in a many obstacle environment.

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&
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INDIA

#58/11:15 AM

Euclidean Shortest Path through Horizontal and Vertical Line Barriers in O(n log n) Time

The problem of finding the shortest Euclidean path amongst obstacles may be stated as follows: Given a set of obstacles and two points (s and t) in the plane, find the shortest Euclidean path from s to t which avoids all obstacles. In this paper, we study the Euclidean shortest path problem for the case where the obstacles are n disjoint line segments that are either vertical or horizontal, and present an O(n log n) time algorithm for finding such a path.

Man-Tak Shing
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University of California, Santa Barbara
California, 93106

#40/11:30 AM

Active Zones in Constructive Solid Geometry for Redundancy and Interference Detection

Solids are represented in Constructive Solid Geometry (CSG) as Boolean combinations (binary trees) of simple primitives. CSG representations are not unique, and may contain primitives that are redundant, i.e. may be removed without altering the represented solid. Null (empty) solids, important in collision detection, provide blatant examples of elaborate representations where all primitives are redundant. We associate with each primitive an active zone that represents the region of space where changes to the primitive affect the represented solid. Properties of active zones lead to efficient tests for redundance and to significant improvements of null object detection and other algorithms central to many important applications of CSG.

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IBM - T. J. Watson Research Center
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Herbert B. Voelcker
The Sibley School of Mechanical and Aerospace Eng.
Upson Hall, Cornell University
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#99/11:45 AM

Collision Avoiding Paths for Robots

This paper presents an analysis of the possibility of collision on the path of a Robot. Two operating policies are considered i) Simultaneous motion of all elements and ii) Sequential motions of one element at a time. The collision possibility may involve any element of the Robot. The other side of the collision may involve either a free-moving or a stationary object. The analysis is based on differing "perceptions" of "distance" between two points; one for the Robot and second for the free-moving object. The analysis is limited to Robots with fixed bases and revolute joints except at end-effectors.

Prabhakar M. Ghare
Program Director, Engineering Administration
Northern Virginia Graduate Center, Virginia Tech
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#71/12:00 PM

Separability and Order

How may a robot arm be moved to pick up an object from a crowded shelf without unwanted collisions? This is an instance of the problem known in computational geometry as the "separability problem". We present a computational model based on ordered sets.

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THURSDAY, JULY 23

10:45 AM - 12:15 PM
Ballroom D

CONTRIBUTED PRESENTATIONS 15
CURVES

#5/10:45 AM

Computing Approximating Spline Curves with Few Pieces

A given piecewise cubic curve may be approximated by another cubic with fewer pieces. Computing such an approximating curve is needed for efficient shape modelling. The method described here is based on merging pairs of adjacent cubic pieces. It has been implemented, and some good results are presented here.

Michael Kallay
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#32/11:00 AM

The Sorting of Points on a Curve

The sorting of points on a curve is an important problem in geometric modeling. For example, the algorithm for computing the intersection of two models requires curve sorting. The two most obvious methods of sorting--using a parameterization of the curve and crawling along the curve using Newton's method--are not always adequate. The former method will be slow when the degree of the parameterization is high and when the parameterization is not rational, and it can be difficult to find a parameterization at all for high degree curves. The latter method is too slow and only works on nonsingular segments of the curve. We propose a third method which is the method of choice in many situations. This new method is motivated by the observation that points on a convex segment of a curve can be sorted easily.The relative merits of the three methods are discussed.

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#14/11:15 AM

Interpolatory Curves which Preserve the Sign of Curvature

Conditions on the control points of nth degree Bezier curves which guarantee that the resulting curve has positive curvature are given. In the case of curves of degree three, the conditions are necessary and sufficient. These results may be used to produce piecewise parametric interpolatory curves which preserve local sign of curvature and satisfy additional constraints as well.

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#13/11:30 AM

A Heuristic Method for
Data Parametrization

In designing a parametric polynomial or a spline through an ordered set of data points in the plane, the choice of the interpolating nodes makes a great deal of difference in the resulting curve. It is generally recognized that the choice of uniform nodes is unsatisfactory. But the oft recommended choice based on cumulative chord distances may also lead to wild curves. In *this talk, based on a pseudo-physical analogy,* we obtain a simple formula for node assignment, which almost invariably results in much "fairer" or more "pleasing" curves than are obtained by the chord length parametrization.

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#48/11:45 AM

An Algorithm for Constrained Approximation.

The problem of least squares (including interpolation) fitting of a function, defined on an interval of the real line, to measured data is considered. The fitting is done under convexity and/or concavity constraints over the whole or parts of the interval.This models a situation where the underlying function is known to posess certain shape properties, which are important to keep in the approximant. The problem is formulated as a constrained smoothing spline problem and a characterization result enables the use of a Newton type algorithm for computing the approximant.

Lars-Erik Andersson
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#42/12:00 PM

A 4-Point Interpolatory Subdivision Scheme For Curve Design

A 4-point interpolatory subdivision scheme with a tension parameter is analysed. It is shown that for a certain range of the tension parameter the resulting curve is C^1. The role of the tension parameter is demonstrated by few examples. The application to surfaces and some further potential generalizations are discussed.

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THURSDAY, JULY 23

10:45 AM - 12:15 PM
Ballroom E

Contributed Presentations 16
GRAPHICS AND IMAGE PROCESSING

#8/10:45 AM

Circle Averages and Probabilities in the Hexagonal Lattice

In a lattice-defined image the grey level of a point can be replaced by the average grey-level on a "circle" of neighboring points. The texture of the image can be studied in terms of the question: what is the probability of observing a given circle average? Here, the circle radius is allowed to vary as a parameter and we consider basic mathematical problems such as the relation between locally and globally computed probabilities, the inverse problem of determining the image given global probabilities, and consider applications of these ideas to image enhancement and modelling the retina.

Waksman, Peter
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#51/11:00 AM

Boundary Tracking in Multidimensions and Some Discrete Topologic Problems

In medical imaging, 3D digital images of internal human structures are routinely generated by devices such as CT scanners. An important step in visualizing structures from such images is the formation of the boundary surface(s) of the objects of interest. In a clinical software package called 3D98 (used worldwide), prior to surface formation a 3D binary image is obtained; the problem of surface formation then is to determine the boundary surface between certain subsets of 1- and 0-voxels of the binary image. A 4D version of this problem aries in the case of dynamic organs like the heart. Previous algorithms for 2D,3D,and 4D boundary tracking have been ad hoc in nature and dimensionality dependent. The speaker will outline a unified approach (based on graph theory) that leads to algorithms, each of which can track boundaries in images of arbitrary (but finite) dimensions, some of them being more efficient than the existing algorithms. Some open mathematical problems will also be outlined.

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#47/11:15 AM

Ray Intercept Determination and Characterization Using Linear Programming and Convex Polyhedra

Areas ranging from computer generated graphics to weapon effects analysis require determination of the intercept of a ray with a structure defined as a collection of convex polyhedra, and the characterization of that intercept in terms of angle of incidence and orientation of the intercepted surface with respect to a global coordinate system. The intercept problem can be formulated as a linear programming problem and solved accordingly. Three vertices defining a convex polyhedron face intercepted are identified in the solution tableau, and may be used to characterize the intercept. Applications and extensions are illustrated.

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#74/11:30 AM

Ray-Tracing Fractal Surfaces

One technique for modeling terrain in computer graphics is the use of stochastic or fractal surfaces having dimensions between 2.0 and 2.5. To ray-trace such a surface we must compute the intersection of a ray and the fractal surface. A technique is described here which reduces the problem from a 3-D intersection to a 2-D one. This intersection is found by an iterative algorithm which probabilistically computes a bounding envelope for the fractal surface. Regions of the envelope with a low probability of containing the ray-surface intersection are iteratively discarded until the remaining region is sufficiently small. The performance of the algorithm can be tuned by varying the accuracy of the rendering.

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#104/11:45 AM

Codes for Straight Lines in N-Space

The finite binary codes for lines of rational slope in the plane (J. Rothstein and CFR Weiman, Computer Graphics and Image Processing 5, 106-24 (1976)) is inductively generalized to lines in Euclidean n-space. The codes are amenable to parallel processing. Affine transformations with fixed origin and line translations correspond to simple character string manipulations; no matrix operations are needed. Higher dimensional subspaces are inductively definable as bundles of lines. Applications to pattern recognition and computer graphics, as well as to computational geometry and group theory will be mentioned.

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#91/12:00 PM
A new model of texture based on substitution sequences

We propose an original model for textured images based on one dimensional symbol substitution sequences that are mapped in the bidimensional space of the image. On one hand, it allows to synthesize highly structured textured images that are periodical or pseudoperiodical. On the other hand, suitable substitution sequences have an asymptotical property of randomness and may be used to model pseudorandom textures. Implementation is easy and fast, as it does not require any algebraic computing, nor random numbers generation. Elements of characterization mainly based on the image cooccurrence matrices are given on several examples of synthesized textures.

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THURSDAY, JULY 23

4:00 - 5:30 PM
Ballroom A-B

Contributed Presentations 17
MESH GENERATION

#108/4:00 PM
Finite Element Mesh Optimization Using Distributive Lattice Processing

Finite element mesh optimization implies selecting an objective function that results in an accurate and stable solution given a mesh layout. Here our objective function guarantees a constant geometric mesh layout interior to the boundary. This strategy is used to avoid finite element distortions during the nonlinear solution process. After each solution step, the finite element result calculated at the gauss points are extrapolated across mesh boundaries using a distributive lattice approximation. Two numerical examples are presented using the nonlinear finite element code ADINA in a distributive lattice based closed loop pre and post processor control program.

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#70/4:15 PM
Algebraic Grid Generation in Patched Mesh Systems

An interactive graphics based multiple step procedure is presented to generate 2-D and 3-D finite difference meshes by the algebraic method. The procedure is applied in a patched mesh system where any complex grid domain can be represented by a number of simple topologically quadrilateral patches or blocks. Continuity at the patch boundaries is enforced where desired. The patching strategy based in local geometric scales on which the problem is regular together with the use of the algebraic method with a parametric cubic polynomial and the use of blending and stretching functions allows for precise control of grid properties and results in smooth high quality meshes.

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#82/4:30 PM

An Algorithm for the Automatic Decomposition of Octal Cells into Finite Elements

Recursive spatial decomposition schemes have been found to offer an efficient avenue for automatic finite element mesh generation from solid models. In this paper, we discuss a two-stage meshing scheme based on the octal decomposition of a solid domain described by a Constructive Solid Geometry (CSG) modeller. Using the CSG classification algorithms the domain is boxed and recursively decomposed into octal cells that are classified as inside, outside, or neither-in-nor-out (NIO). Finite element topologies are inserted in the subdomains represented by the intersection of each NIO cell and the original solid via the combined use of templates and finite element extractors that operate on the boundary representation of each subdomain.

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(* Research Assistant and Assistant Professor & Director, respectively)

#37/4:45 PM

Vertex Planting in Solid Finite Element Mesh Generation

An attractive approach for developing an algorithm for automatic finite element mesh generation in solids is to first place vertices or node points in the solid and then connect them in order to form tetrahedra. The speaker will show that no mesh generation algorithm for solid polyhedra that forms tetrahedra using only the solid's vertices can succeed in all cases. Any reliable mesh generation algorithm must be able to plant new vertices in the solid. A simple method will be presented for inserting new vertices as the need for them is encountered in the course of forming tetrahedra from existing vertices.

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#29/5:00 PM

Refining Simplicial Meshes for Finite Element Problems

An n-simplex which is a fundamental domain for a reflection group can be subdivided into 2^n congruent simplices which are all similar to the original simplex. Therefore meshes built out of simplices can be arbitrarily refined without changing the angles between faces. Nested dissection type orderings are described for the solution of the finite element equations arising from such simplicial meshes.

Woody Lichtenstein
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#3/5:15 PM

Mesh Generation for Arbitrarily Shaped Regions

Traditional tensor product meshes are exceedingly difficult to work with in the face of geometric generality, suchas non-convexity or multiple connectedness. A mesh triangulation scheme, employing Watson's algorithm, is discussed and methods to allow for non-convexity and multiple connectedness are explained. Additionally, this mesh technique has been used in conjunction with solutions to nonlinear systems of PDE's. The control area approximation solution technique was shown to exhibit a second order convergence history with these triangular meshes.

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THURSDAY, JULY 23

4:00 - 5:30 PM
Ballroom C

Contributed Presentations 18
COMPUTATIONAL GEOMETRY 4

#10/4:00 PM

Line Integral Computation of Geometrical Properties of Plane Faces and Polyhedra

Surface integrals arising during computation of geometrical properties of volumes are studied. Line integrals are formulated which give the contributions of a general plane surface area. These integrals are evaluated to provide more concise exact formulas for the geometrical properties of polyhedra than have been obtained previously. A forty statement APL program is presented which implements the method.

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#68/4:15 PM

Graph Based Scheme for Recognition of Polyhedral Features From a 3-D Solid Model

One of the outstanding problems in Automated Process Planning is the recognition of machined features automatically from the 3-D part description. Features in this context are regions of the part to which manufacturing significance can be attached. This paper proposes algorithms based on an Attributed Adjacency Graph to recognize some primitive polyhedral features such as step, slot, pocket, blind step, blind slot, and hole from a boundary representation. The algorithms have been extended to recognize certain classes of interacting features. The algorithms have been implemented and computational results will be presented.

Sanjay Joshi
T. C. Chang
Vijaya Chandru

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West Lafayette, IN 47907

#106/4:30 PM

Tetrahedral Recursive Decomposition of Free-Space from Boundary Points

Because of the exponential nature of robotic path-planning and collision detection, there has been an increasing trend to approach the problem from a representational point of view as much as from an algorithmic one. This contribution presents a conversion scheme to obtain a volumetric recursive tetrahedral decomposition of the free-space starting from the obstacles surface points. The aim of the representation is similar to that of the octree: search efficiency, compactness, and parallelism. However, thanks to the absence of an arbitrary reference frame and of preferred primitive sizes, the final representation is intrinsic to the solid (free space) being modeled.

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#93/4:45 PM

Medial Axis Transform Using Ridge Following

The medial axis transform (MAT) is an invertible, object-centered, 2-D shape representation defined as the collection of the centers of disks contained in the shape but not in any other such disk. Its uses include feature extraction and shape smoothing. MAT-generating algorithms include brushfire, which suffers from digitization inaccuracy, Voronoi diagrams, which are potentially inefficient (particularly for curved shapes), and ridge following. Ridge following overcomes these deficiencies although it has been inadequately implemented in the past. The speaker will describe an improved implementation. The presentation will include proofs of MAT invertibility and connectivity along with experimental results on several shapes.

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Karl G. Kempf
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Central Engineering Laboratory
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#19/5:00 PM

Vectorized Conjugate Gradient Projection Methods

Conjugate gradient methods lend themselves to vectorization because most of the computation involves vector dot products and matrix-vector multiplications. We report on an effort to vectorize a family of conjugate gradient projection methods for solving box-constrained quadratic programming problems. Conclusions are two-fold:

- By a combination of careful coding and choice of appropriate data structure, one is able to achieve significant gains in computational speed.

- The evaluation of algorithmic options, in particular the respective advantages of subspace minimization vs. conjugate projection methods is dramatically altered on a vector processor, because a larger portion of the computation can be vectorized when subspace minimization is used.

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Patrick Henaff
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#69/5:15 PM

A Sympletic Approach to Graph Theory

The question of the existence of "analytical geometry" in the study of graph problems is considered. Such an encoding would allow uniform representation of graphs and a reduction of graph theoretic problems to solving (not necessarily trivial) "numerical" equations. Graphical coordinate systems are introduced so that every graph becomes a subset of a vector space V endowed with alternating bilinear form over a field. This encoding allows the use of sympletic geometry to solve graph-theoretic problems. For instance, classical results on the decomposition of isometries by a bounded number of transvections in a sympletic space naturally lead to a new general graph isomorphism test. The complexity of this test and the solution of other graph theoretic problems will be discussed.

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THURSDAY, JULY 23

4:00 - 5:30 PM
Beverwyck Room

Contributed Presentations 19
APPLICATIONS AND IMPLEMENTATIONS

#25/4:00 PM

Applications of Differential Geometry to Structural Mechanics

We investigate the postbuckling behaviour of elastic structures buckling simultaneously in $n \geq 2$ modes via the differential geometry of its associated energy manifold. In normalised coordinates the buckling point, taken as the origin, becomes an umbilic point of the energy manifold of the perfect system. We show that the projections of the lines of curvature through the umbilic point coincide with the perfect postbuckling path projections and that the behaviour of lines of curvature local to the umbilic distinguishes different types of imperfect system behaviour. Using also the Euler characteristic a complete classification is given for $n = 2,3$.

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#16/4:15 PM

Metal Die Design Using Orthogonal Volume Preserving Coordinates in R^3

We consider a special case of rigid/perfectly plastic flow for metals, namely ideal flow. It is defined for steady state processes by requiring the coincidense of streamlines and major principal stress lines. Since ideal flow produces homogeneous deformations without redundant work it is desirable for the design of dies for metal extrusion or drawing. One can introduce an orthogonal volume preserving material coordinate system. The equations of plastic flow can be solved using these coordinates. This leads to the geometric problem of finding such coordinates in R^3. Solving a hyperbolic equation with suitable boundary conditions yields the desired die shapes.

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SF-[illegible] Espoo 15
Finland

#61/4:30 PM

Application of the CORDIC Algorithm to Robot Navigational Computations.

In performing navigational computations for mobile robots, coordinate conversions between polar and rectangular systems are likely to be required. The CORDIC algorithm, first developed for aircraft navigation systems by Jack E. Volder offers a fast and efficient technique for performing such conversions. Both rectangular-to-polar and polar-to-rectangular conversions can be accomplished without trigonometric functions by using just add, shift, and a single multiply operation. This paper analyzes methods for implementing the CORDIC algorithm on microcomputers such as the Motorola 6808 as found in the Hero-1 robot. High speed machine language techniques for both binary and decimal bases are covered. Both types of conversions are discussed. An elementary analysis of error bounds is also covered.

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#79/4:45 PM

Robochess The Intelligent Robot Chess Player

This paper describes ROBOCHESS, an intelligent robot chess player, which employs a mechanical robot, a computer vision system, and an Artificial Intelligence (AI) program in an integrated operation. ROBOCHESS is capable of realizing different chess configurations, understanding the moves, and moving its own pieces to appropriate locations. Therefore, it is able to play against a human or another robot chess player. A vision system is used to provide the robot with the visual information about the chess board and location of different pieces. A computer chess program is used to calculate the moves, and a robot is used to implement the move. Finally the overall system is coordinated by an AI program.

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University of Maine
Orono, Maine 04469

#80/5:00 PM

A Central Computer Scheme for Controlling Several Small Educational Robots

This paper describes the Maine Educational Robotics System (MERS)at the University of Maine. The paper focuses on a general interconnected robotics laboratory set-up based on a central computer. The MERS system that has been described as an example of such a system consists of four robot workstations and will use a VAXstation* as the central computer. Each workstation consists of a regular terminal, an educational robot, and associated hardware and software. Contrary to the isolated robot work stations, the system explained in this paper is expandable for future development work. Also, because of the availability of different CAD software for a central computer a CAD/CAM work station can be easily developed around such a system.

*VAXstation is a registered trademark of Digital Equipment Corp.

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#90/5:15 PM

Applications of Mathematical Logic to Robotics and Automation

Here is described and analyzed the applications of mathematical logic to industrial logic control systems, the most versatile and widely used tools in manufacturing automation today. These systems, called "programmable controllers", (PCs) are even used as controllers for industrial robots themselves. The PCs apply the mathematical logic concepts as: decisions by attributes and by variables, truth tables, Boolean algebra, etc. combined with logic networks, ladder logic diagrams, timers and sequencers, time-line diagrams, etc.

The speaker will discuss the current and the future applications of mathematical logic in PCs which are the heart of systems integration of the factory automation.

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THURSDAY, JULY 23

4:00 - 5:30 PM
Ballroom D

Contributed Presentations 20
MATHEMATICAL METHODS 2

#26/4:00 PM

Geometric Encounters of the Bayesian Kind: what is Likely to be Seen?

The talk will discuss the problem of quantifying how likely it is that various shapes will be encountered. A recent technique departs from ad hoc methods by incorporating a "first-principles" dynamic. The output is a set of prior probabilities which can be used for Bayesian updating and decision-making.

Richard A. Vitale, Department of Mathematics, The Claremont Graduate School, Claremont, CA 91711

#45/4:15 PM

Symbolic Management of Solid Modeling For Hidden Surface Removal: The Chieng-Hoeltzel Algorithm

This research introduces an efficient, symbolically managed, object-space, hidden surface removal algorithm. Based on the Weiler-Atherton Algorithm and aided by symbolic reasoning processes, the Chieng-Hoeltzel Algorithm has been designed to minimize redundant and time consuming numerical calculations, such as "inside" vertex testing. The procedures incorporated within this algorithm include: 1) intersecting-and-encoding (vertex and edge numbering), 2) decoding-and-sorting, 3) tracing-and-symbolic-merging and 4) information-sorting. While differing from purely numerical solid modeling operations, this symbolically managed algorithm is designed to concentrate more on the attributes of an object's surfaces. The theoretical basis of the algorithm as well as its application in mechanical CAD are discussed.

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Graduate Research Assistant

David A. Hoeltzel
Assistant Professor

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#39/4:30 PM

Robust Utilities for Geometric Modelling with Natural Quadrics

Geometric modelling applicatons are based on fundamental algorithms that compute geometric representations based on intersections of surfaces, and evaluate numerical or discrete properties of such representations. The robustness of these applications is heavily dependent upon topological validity of the reprentations which in singular cases is difficult or impossible to obtain by approximate methods. Using symbol manipulation, we provide representations that are complete and exact, and several key algorithms involving space curve intersections. These algorithms, explicitly designed to handle all singularities, compute correct answers to topological queries, and therefore can be used as fundamental and reliable building blocks in a variety of geometric applications.

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Jaroslaw R. Rossignac

#88/4:45 PM

Closed Curves, Regions and Boundaries in Integer and Digital Spaces

Integer and digital spaces are playing significant role in digital image processing, computer graphics, computer tomography, robot vision and many other fields, where we have deal with finitely or countably many objects. Such spaces are among the least developed in topology, and it does not satisfy the requirements of applied sciences. For example, there are many boundary finding algorithms without definition of boundary itself. Existing combinatorial definitions of curves, arcs and others cannot completely replace topological.

Here we give topological definitions of digital arc, curve, boundaryand region. Some results obtained topologicaly. For example: In digital plane boundary of a region, which does not intersect with the conture of the plane, is a digital curve. In real plane a boundary of a bounded region is not a curve, ingeneral. Digital Jordan curve theorem is proven.

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#52/5:00 PM

Jordan pushing and pulling

A set of Jordan arcs monotonic with respect to the Y-axis is called the objects, and a set of Jordan arcs monotonic with respect to the X-axis is called the pushers. Each pusher is incident by one end with the upper side of a first object and incident by the other end with the lower side of a second object, and consequently oriented. The objects are pairwise disjoint, and any pusher is disjoint from the objects except by its two incidences ; and whenever two pushers cross, they are both oriented in the positive direction of the Y-axis. The theorem proved is that the pushing relation between the objects is acyclic. Consequences appear about tentative stretching of pseudo lines of a pattern and, practically, while improving the automatic design of electrical networks, which the author has implemented. A set of potential inequalities is involved.

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#53/5:15 PM

Integration Constraints in Parametric Design of Physical Objects

The paper addresses the topic of incorporating in CAD systems integration constraints concerning object's mass and inertia.In particular, we deal with conformally parameterized polyhedral objects. In such representation inertial constraints can be expressed as non-linear polynomials in the object parameters. Hence, in looking for the existence of feasible or optimum design, a symbolic expression for the partial derivatives of constraints is necessary. We show that such derivatives are closely linked to the topology of the solid, and are expressable as integrals over domains of lower geometrical dimension than the original solid. First, second and third derivatives, when non-zero, are proportional to: a surface integral over a face of the solid; a line integral over an edge; the function evaluated on a vertex. This result gives a very simple way for arranging symbolic expressions for domain-derivatives. It holds for the integral of any sectionally continuous function over a polyhedral domain. (*)The work was done while the author was visiting the Robotics Group at the Department of Computer Science at Cornell University.

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THURSDAY, JULY 23

4:00 - 5:30 PM
Ballroom E

Contributed Presentations 21
PATH PLANNING PLUS GEOMETRIC MODELING

#115/4:00 PM

Two-Dimensional Robot Arm Motion Planning

Consider a two-link robot with a telescoping upper arm and a fixed-length forearm. Given a collection of polygonal obstacles in the plane and the desired initial and final configurations for the robot arm in terms of placement and orientation of the forearm, determine whether it is possible to move the robot continuously from the initial to the final configuration in such a way that neither link intersects the obstacles. We present a partitioning algorithm that produces a graph representation of the configuration space of the robot which reduces the motion planning problem to graph searching.

Boris Aronov and Colm O'Dunlaing
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251 Mercer Street
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#116/4:15 PM

Minimum Speed Motions

Consider an object X confined to move along a one-dimensional "corridor", such as a car on a one lane road or a train on a track. There are certain times when X is restricted from particular sections of the corridor. For example, a traffic light prohibits a car from crossing an intersection during certain periods of time. Other objects may cross the corridor and obstruct a portion of it for a given span of time. We present an algorithm for planning motions of X that avoid the restricted regions and such that the maximum speed that X attains is minimized.

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Steven Fortune
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Gordon Wilfong
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#121/4:30 PM

An Uniform Approach To Geometric Modelling

Computer modelling of the geometry of objects on the basis of computational geometry is a powerful tool for engineering design and manufacture. While the superiority of geometric modelling approach has been widely recognized, it is used far less often than the drafting approach on the basis of descriptive geometry. The major reason for this lag is not so much the lack of good geometric modelling systems, but rather the training with which designers adopt from engineering design education. This paper describes an uniform approach to geometric modelling for engineering design without drastically changing their traditional design practices. This new approach provides a uniform way to deal with 2-D drafting, 3-D modelling and 4-D moving of objects.

Ming-ming Wang and Shui-Sheng Chern
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#122/4:45 PM

Solid Modelling in C

Solid modelling technology, aimed at the unambiguous, consistent, and complete representation of geometric models, has been well recognized as a powerful tool for engineering design and manufacture. C programming language which features economy of expression, modern control flow, efficient data structure, and a rich set of operators, has been widely used as a structured language for many applications. The combination of solid modelling technique into C has the potential to revolutionize academic design education and enhance industrial design practice. This paper describes the concept and methodology of extending C language to accomodate geometric shape manipulation for supporting engineering design.

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#123/5:00 PM

Geometric Representation of Swept Volumes for Polyhedral Objects

A theory of swept volumes for compact n-dimensional manifolds in $\mathbf{R}^n$ is presented with application to polyhedral objects in $\mathbf{R}^3$. It is shown that the swept volume for a compact n-manifold in $\mathbf{R}^n$ is equal to the swept volume for its boundary. This fact is significant in that the swept volume for an object can be generated using only the swept volumes for the surfaces of its boundary. This theory is applied to polyhedral objects in $\mathbf{R}^3$. The swept volume for a polyhedral object is generated from only the swept volumes for all of its bounding polygonal faces.

John D. Weld and Ming C. Leu
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#132/5:15 PM

Collision-free Trajectory Planning: Computational Geometry and Splines in Space-time

We consider the problem of planning the velocity of a robot along a given path such that it avoids collision with moving obstacles by considering time as an additional dimension. 2D computational geometric techniques may then be applied in the path-time space with additional constraints from time-monotonicity and maxima for the robot's velocity and acceleration. Finally, spline techniques are used to develop an algorithm for finding a C^0 collision-free velocity profile that passes *through the «middle»* of the free path-time space and satisfies the maximum velocity constraint.

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TUESDAY, JULY 21

3: 15 - 4:45 PM
Beverwyck Room

Poster Presentations

#44

General Curvature Formlae for Implicit Surfaces

Principal curvatures and directions are derived for implicitly defined surfaces, without defining coordinate patches. Results are given by explicit algebraic formulae involving the first and second partials of the implicit function(s). This avoids the need to solve for any of the spatial variables explicitly, and prevents defining several patches for a complex surface, hence preventing discontinuous (due to finite precision) at patch boundaries. The curvature data is used in synthetic aperture radar simulations, allowing accurate estimates of scattered power to be propagated through the ray tracing of complex scenes.

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#57

Surface Model for Laser Ranging System

A spherical perspective projection can be used to model a laser ranging system. The laser is located at the sphere center and the Range Image is formed on the unit sphere: a range (depth) value is associated with each point of the unit sphere. If several values are associated with each point of the sphere, we have a Multi-Valued Range Image. MVRI is a natural structure for the integration of the information issued from different view-point dependant RI. The decomposition of the scene by the one parameter family of planes (corresponding to the laser sheet of light) make us able, to compute a MVRI from distinct RI and object properties (curvature and normals), by fast 1D operations.

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France

#92

Spline Curve Fitting For Interactive Design

In many graphical applications, it is necessary to build a geometrical curve model by fitting an ordered set of data points. We developped on a microcomputer an interactive spline smoothing method, efficient when the data set is large.

Once the user has chosen the order of the curve and the data parametrization, a spline curve, with as few control points as possible, is automatically fitted by using a smoothing criterion. To handle the curve, the B-spline representation is associated to a hierarchical data structure reflecting an adaptative polygonal approximation of the curve. This structure, obtained by generating the Bézier points and subdividing the corresponding Bézier segments, is efficiently used to display the curve, select it when it is pointed with the mouse and determine curves intersections.

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#98

Romboy Homotopy and Etruscan Venus: An Experiment in Computer Topology

A collaboration between a descriptive topologist, a computer artist and graphics programmer at the National Center for Supercomputing Applications gave birth to a series of beautiful surfaces together with a computationally inexpensive technique for rendering them. They are generated by a variable ellipse moving in space. François Apéry, a student of the great topological visualizer, Bernard Morin of Strasbourg, used such "ovalesques" for a homotopy from Steiner's Roman surface to Boy's surface, Adv. Math. 60(1986) 185-266. Exploring how his Romboy homotopy cancels the 6 Whitney umbrellas we found that Apéry's desingularization technique generalizes to a vast class of visually pleasing surfaces and their wonderful deformations.

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Donna J. Cox
Electronic Imaging Laboratory
Ray L. Idaszak
National Center for Supercomputing Applications
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#101

Analytic Functions of Conic Sections in a Computer-Aided Design System

The AYCAD Computer-Aided Design System used polynomial-based algorithms for finding Normals, Tangents, and Intersections of Conic Sections, and Circular Tangents of Points, Lines, Circular Arcs and Circles. This is done by representing conic sections as rational polynomial functions. This paper discusses these algorithms, and how to avoid such pitfalls as singular denominators. The paper also discusses methods of solving polynomials with high precision.

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#L-9/Poster Session/Tue. 3:15 PM

Dimensioning and Tolerancing of Engineering Components using Constructive Solid Geometry

Constructive Solid Geometry (CSG) has been applied successfully to the description of nominal shapes for evaluating various representations used for graphical presentation and extraction of manufacturing data. Real engineering components are, however, imperfect and described in terms of permitted variance from the nominal (tolerances). Various representations have been considered for representing dimensions and tolerances for different applications: engineering drawings, tolerance analysis and synthesis, manufacturing and inspection. The speaker will discuss a representation which satisfies the requirements of many of these applications and can be created directly from a CSG description. The presentation will include examples of implementations in Fortran, Pascal and Ada.

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ADDENDUM

(Abstracts submitted after deadline)

#L-1/2:00 PM Wed., Cont. Presentations 12a

Coordinated Activation of Multijointed Artificial Limbs

Multidimensional geometric representation of neural systems has been developed recently /Tensor Network Theory by A.J.Pellionisz and R.Llinás/. Here this paradigm is applied to the control of multijointed limbs or robot arms. This is a possibility to describe the function of biological and man-made apparatus using the same principle. The problem is that an intended movement specified in 3D Cartesian coordinates must be converted into angular change for each joint. Thus the intention must be expressed in an overcomplete frame of reference, which is defined by the geometry of the examined limb. Computer programs and films will be presented.

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#L-2/2:15 PM Wed., Cont. Presentations 12a

Experiences in intergrating sculptured surfaces in boundary structure volume modellers.

In the German/Norwegian CAD/CAM Project Advanced Production Systems (APS), the sculptured surface modeller APS-SS has been intergrated into the German volume modeller COMPAC. The existing data structures have been changed so that the original modellers can run stand alone or as an intergrated modeller. Methods and advantages of intergrating sculptured surfaces into volume modellers will be discussed. Results and some applications will be presented.

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#L-3/2:30 PM Wed., Cont. Presentations 12a

Analysis of Geometric Tolerances in CAD and CAM

An experimental system has been developed which, based on 1D tolerances (constraints, imposed on distances between point pairs form a set of collinear points), solves the following problems

- find the resulting variation of distance between any two points,
- allocate correct tolerances to elements of an alternative tolerancing scheme (worst case and probabilistic approach, allocation of equal tolerances or tolerance classes).

This self-contained system can be used to allocate tolerances to component dimensions of an assembly and also to to allocate tolerances (permitted variabilities) to machining steps of producing a part.
A major enhancement is described which extends this system to 2D tolerancing problems.
A method is described of integrating the system into an the framework of an existing CAD/CAM system.

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#L-4/2:45 PM Wed., Cont. Presentations 12a

A Geometric Condition for Smoothness Between Adjacent Bézier Surface Patches

A necessary and sufficient condition is obtained which ensures tangent plane continuity (geometric C^1 or visual C^1 continuity) between adjacent mxn and lxs degree Bézier surface patches. This condition is also effective for partial adjacent Bézier patches.

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#L-5/4:15 PM Tue., Cont. Presentations 8

Number-Theoretic Properties of Two-Dimensional Lattices

The notion visible point in a lattice is extended to the notion of visible pair of points in a two-dimensional infinite lattice, normalized as a vertical strip of width 1, centered at the origin. The pair (m,n) is shown to be visible iff |m(nd) - n(md)| = 1, where (x) is the integer nearest to x, d (a value between 0 and ½) is the abscissa of point 1, while xd - (xd) is that of point x. A general characterization of the visible and opposed pairs (with respect to the vertical axis of the lattice) will be put forward. Geometrical and computational algorithms delivering all the visible pairs for any value of d will be presented. The biological meanings of these an other results will be mentionned.

Roger V. JEAN
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University of Quebec
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#L-6/3:00 PM Wed., Cont. Presentations 12a

Reconstruction of Systems of Overlapping Sets

The investigation of systems of overlapping, non-distinguishable particles in two or three dimensions is a frequently occuring problem in Image Analysis and Stereology. If the particles are randomly distributed according to a Poisson process with suitable invariance properties, a number of geometric quantities of the system (number density, mean (surface) area, mean volume) can be reconstructed from measurements of the union set. If the distribution of the particles is not isotropic, the reconstruction problem involves mixed volumes.

Wolfgang Weil
Mathematical Institute II
University of Karlsruhe
D - 7500 Karlsruhe
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#L-7/5:15 PM Mon., Cont. Presentations 4

Non-Rectangular Surface Patches Using Rectangular Transfinite Interpolation

General conditions are exhibited which ensure tangent and curvature continuity between adjacent rectangular surface patches in the absence of parametric smoothness. We use these to construct geometrically continuous n-sided assemblages of rectangular patches, for odd n, satisfying arbitrary boundary data. No rational correction terms are required at the common vertex. The resulting patches are suitable for modelling topological singularities in a CAGD system which supports only rectangular data types. For example, a C^1 bicubic grid can be matched with piecewise biquintic polygonal regions. Piecewise binonic polygons allow curvature continuity.

Alan K. Jones
Engineering Technology Applications Division
Boeing Computer Services Company
P.O. Box 24346, MS 7L-21
Seattle, WA 98124-0346

#L-8/3:15 PM Wed., Cont. Presentations 12a

The System INDUSURF for Automatic Measurement of Car Body Surfaces

The paper presents the concept of a system for the *automatic measurement of surfaces*. The system consists of a photogrammetric measuring device with CCD-Cameras, a texture projector and the software package SURF. Except for an initialization phase the system is able to automatically measure 3D-coordinates of sections of the object with an arbitrary set of given planes using image matching techniques. The achieved accuracy is 1 : 50 000. The system has been developed in cooperation with Zeiss Company and since 1986 is used by Volkswagen Company for measuring surfaces of car bodies and other parts as input to their CAD/CAM system VWSURF.

Wolfgang Förstner
Institut fur Photogrammetrie
Universitat Stuttgart
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Stuttgart, W. Germany

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Penna, Michael	Mon. PM	5:00	5:15	C/P 1	A15	Ballroom D
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Rastegar, J. S.	Tue. PM	4:15	4:30	C/P 6	A22	Ballroom D
Renka, Robert	Tue. PM	12:00	12:30	M/S 8	A7	Ballroom C
Rival, Ivan	Thur. PM	12:00	12:15	C/P 14	A34	Ballroom C
Rivero, Juan	Mon. PM	2:30	3:00	M/S 5	A4	Ballroom C
Rockwood, Alyn	Mon. PM	12:00	12:30	M/S 1	A1	Ballroom A-B
Rosenfeld, Azriel	Fri. AM	10:30	10:50	M/S 14	A11	Ballroom C
Rosensthiehl, P.	Thur. PM	5:00	5:15	C/P 20	A43	Ballroom D
Rossignac, J. R.	Mon. PM	4:45	5:00	C/P 2	A16	Ballroom A-B
Rossignac, J. R.	Thur. AM	11:30	11:45	C/P 14	A33	Ballroom C
Rossignac, J. R.	Thur. PM	4:30	4:45	C/P 20	A42	Ballroom D
Rothstein, Jerome	Thur. AM	11:45	12:00	C/P 16	A36	Ballroom E
Roulier, John	Thur. AM	11:15	11:30	C/P 15	A34	Ballroom D
Roux, Christian	Thur. PM	12:00	12:15	C/P 16	A37	Ballroom E
Sabin, Malcolm	Fri. AM	09:00	09:45	I/P 12	3	Ballroom A-B
Samuels, Philip	Thur. PM	4:00	4:15	C/P 19	A40	Beverwyck Room
Saxena, Mukul	Thur. PM	4:30	4:45	C/P 17	A38	Ballroom A-B
Schimdt, Phillip	Tue. PM	4:30	4:45	C/P 7	A24	Ballroom C
Schwartz, Arthur	Wed. PM	3:00	3:15	C/P 12	A31	Ballroom A-B
Schwartz, Jacob	Mon. AM	09:00	09:45	I/P 1	2	Ballroom A-B
Sederberg, Thomas	Tue. PM	2:00	2:45	I/P 5	2	Ballroom A-B
Selkow, Stanley	Mon. PM	4:30	4:45	C/P 3	A17	Ballroom E
Shah, Jayant	Wed. PM	2:45	3:00	C/P 10	A28	Ballroom D
Shelly, Craig	Fri. AM	10:30	11:00	M/S 15	A12	Ballroom A-B
Shen, C. N.	Mon. PM	4:00	4:15	C/P 1	A14	Ballroom D
Shephard, Mark	Thur. AM	09:35	10:00	M/S 12	A10	Ballroom E
Shing, Man-Tak	Thur. AM	11:15	11:30	C/P 14	A33	Ballroom C
Shirkhodaie, A. H.	Wed. PM	3:00	3:15	C/P 11	A30	Ballroom C
Shu, Joseph	Wed. PM	2:30	2:45	C/P 10	A28	Ballroom D
Siegel, J.	Wed. PM	3:30	3:45	C/P 9	A27	Ballroom E
Skiena, Steven	Wed. PM	2:45	3:00	C/P 9	A26	Ballroom E
Skolnick, Michael	Fri. AM	11:30	12:00	M/S 15	A13	Ballroom A-B
Smith, Wayne	Wed. PM	2:30	2:45	C/P 11	A29	Ballroom C
Smith, Wayne	Thur. PM	4:30	4:45	C/P 19	A41	Beverwyck Room
Soni, A. H.	Wed. PM	3:00	3:15	C/P 11	A30	Ballroom C

*C/P = Contributed Presentation
I/P = Invited Presentation
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Name	Day	Time	End-Time	Session*	Abst.Page	Room
Souvaine, Diane	Mon. PM	4:45	5:00	C/P 3	A18	Ballroom E
Srinivasan, Vijay	Mon. AM	11:30	12:00	M/S 3	A3	Ballroom E
Stanton, Charles	Wed. PM	3:00	3:15	C/P 12	A31	Ballroom A-B
Stepoway, Stephen	Thur. AM	11:30	11:45	C/P 16	A36	Ballroom E
Stuff, Mark	Tue. PM	3:15	4:45	Poster	A45	Beverwyck Room
Suk, Minsoo	Thur. AM	08:45	09:15	M/S 11	A9	Ballroom A-B
Tejwani, Y. J.	Wed. PM	3:00	3:15	C/P 10	A28	Ballroom D
Terzopoulos, D.	Tue. PM	4:30	4:45	C/P 5	A21	Ballroom E
Thomasma, Timothy	Thur. PM	4:45	5:00	C/P 17	A38	Ballroom A-B
Thompson, Joe	Thur. AM	09:10	09:35	M/S 12	A10	Ballroom E
Tokumasu, Shinji	Mon. PM	4:30	4:45	C/P 2	A16	Ballroom A-B
Tourassis, V. D.	Wed. PM	2:45	3:00	C/P 11	A29	Ballroom C
Towfiq,, Farhad	Tue. PM	4:15	4:30	C/P 7	A24	Ballroom C
Turner, Joshua	Mon. AM	11:00	11:30	M/S 3	A2	Ballroom E
Turner, Joshua	Mon. PM	5:00	5:15	C/P 2	A16	Ballroom A-B
Udupa, Jayaram	Thur. AM	11:00	11:15	C/P 16	A36	Ballroom E
Vemuri, B. C.	Wed. PM	3:15	3:30	C/P 10	A28	Ballroom D
Vercken, Christine	Tue. PM	3:15	4:45	Poster	A45	Beverwyck Room
Vitale, Richard A.	Thur. PM	4:00	4:15	C/P 20	A42	Ballroom D
Voelcker, Herbert	Thur. AM	11:30	11:45	C/P 14	A33	Ballroom C
Volkmann, R. Mark	Thur. PM	4:45	5:00	C/P 18	A39	Ballroom C
Wachspress, Eugene	Thur. AM	08:45	09:05	M/S 10	A8	Ballroom C
Waksman, Peter	Thur. AM	10:45	11:00	C/P 16	A35	Ballroom E
Wang, Ming-ming	Thur. PM	4:30	4:45	C/P 21	A44	Ballroom E
Warren, Joe	Mon. PM	3:00	3:30	M/S 6	A5	Ballroom E
Weil, Wolfgang	Wed. PM	3:00	3:15	C/P 12a	A48	Beverwyck Room
Weiss, Richard	Mon. PM	4:00	4:15	C/P 3	A17	Ballroom E
Weld, John	Thur. PM	5:00	5:15	C/P 21	A44	Ballroom E
Wells, David	Thur. AM	11:30	11:45	C/P 16	A36	Ballroom E
Werman, Michael	Mon. PM	5:00	5:15	C/P 4	A24	Ballroom C
Wickens, Laurence	Tue. PM	3:15	4:45	Poster	A46	Beverwyck Room
Wilfong, Gordon	Thur. PM	4:15	4:30	C/P 21	A43	Ballroom E
Wilson, Howard	Thur. PM	4:00	4:15	C/P 18	A39	Ballroom C
Wongkew, Richard	Wed. PM	2:30	2:45	C/P 12	A31	Ballroom A-B
Worsey, Andrew	Mon. PM	4:30	4:45	C/P 1	A14	Ballroom D
Wozny, Michael	Mon. PM	5:00	5:15	C/P 2	A16	Ballroom A-B
Wu, Peter Y. F.	Tue. PM	3:45	4:00	C/P 8	A25	Ballroom A-B
Yao, Andrew	Mon. AM	09:45	10:30	I/P 2	2	Ballroom A-B
Yap, Chee Keng	Tue. AM	11:30	12:00	M/S 7	A6	Ballroom E
Zucker, Steven	Thur.PM	5:15	5:30	C/P 21	A44	Ballroom E

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