Computational Geometry – 99102

Michael Goodrich (Johns Hopkins) Rolf Klein (Hagen)
Raimund Seidel (Saarbrücken)

07.03.1999 to 12.03.1999

Abstract

Geometric computing is creeping into virtually every corner of science and engineering, from design and manufacturing to astrophysics and cartography. This report describes presentations made at a workshop focused on recent advances in this computational geometry field.

Previous Dagstuhl workshops on computational geometry dealt mostly with theoretical issues: the development of provably efficient algorithms for various geometric problems on point sets, arrangements of curves and surfaces, triangulations and other sets of objects; proving various combinatorial results on sets of geomtric objects, which usually have implications on the performance of performance guarantees of geometric algorithms; describing the intrinsic computational complexity of various geometric problems.

This workshop continued some of this tradition, but as one more point there was a strong emphasis on the exchange of ideas regarding carrying the many theoretical findings of the last years into computational practice. There were presentations about the recent development of software libraries such as CGAL, LEDA, JDSL, VEGA, and TPIE, and also some experimentation with them. These libraries should help to simplify the realization of abstractly conceived geometric algorithms as actually executable software.

The participants and organizers of this workshop would like to thank the Dagstuhl office and the local personnel for the engaged and competent support in all matters. The cordial atmosphere provided for an unusually successful and enjoyable workshop.

Computational Geometry

Program - Monday, 8 March 1999

9.00-9.30: Marc Van Kreveld, Utrecht University
Six CG Problems from Cartographic Generalization
9.30-10.00: Rolf Klein, FernUniversität Hagen
Optimal Strategy for Walking an Unknown Street

10.00-10.45 COFFEE BREAK

10.45-11.15: Subhash Suri, Washington University
Analysis of a Bounding Box Heuristic
11.15-11.45: Ferran Hurtado, Univ. Politec. de Catalunya - Barcelona
On the minimum size of visibility graphs
11.45-12.15: Sergey Bespamyatnikh, University of British Columbia
Generalizing Ham Sandwich Cuts to Equitable Subdivisions

12.15-14.00: LUNCH

14.00-15.30: Breakout time

15.30-16.00: COFFEE BREAK

16.00-16.30: Klara Kedem, Ben Gurion University
Metrics for Detecting Substructures in Proteins
16.30-17.00: Kurt Mehlhorn, MPI - Saarbrücken
Curve Reconstruction
17.00-17.30: Michel Pocchiola, ENS - Paris
On Topological Sweeping
17.30-18.00: Emo Welzl, ETH Zürich
Y-Facets

18.00: DINNER

Computational Geometry

Program - Tuesday, 9 March 1999

9.00-9.25: Stefan Näher, Universität Halle
LEDA
9.30-9.55: Stefan Schirra, MPI - Saarbrücken
CGAL

10.00-10.45 COFFEE BREAK

10.45-11.10: Michael Goodrich, Johns Hopkins Univ. - Baltimore
JDSL
11.15-11.40: Christoph A. Bröcker, Universität Freiburg
VEGA
11.45-12.10: Lars Arge, Duke University - Durham
TPIE

12.15-14.00: LUNCH

14.00-15.30: Breakout time

15.30-16.00: COFFEE BREAK

16.00-16.25: Leonidas Guibas, Stanford University
Kinetic Collision Detection
16.30-16.55: Dan Halperin, Tel Aviv University
Experiments with Arrangements
17.00-17.25: Jack Snoeyink, University of British Columbia
CG and GIS: Theory and Practice
17.30-17.55: Elmar Schömer, Universität Saarbrücken
Collision Detection and Response

18.00: DINNER

20:00: Open Problem Session - Lecture Hall
(Please bring an open problem for others to enjoy and an open bottle for yourself to enjoy)

Computational Geometry

Program - Wednesday, 10 March 1999

9.00-9.25: Oswin Aichholzer, TU Graz
The Path of a Triangulation
9.30-9.55: Jonathan Shewchuk, Univ. California - Berkeley
Arbitrary-Dimensional Constrained Delaunay Triangulations

10.00-10.45 COFFEE BREAK

10.45-11.10: Jörg-Rüdiger Sack, Carleton University - Ottawa
An Isotropic Shortest Path
11.15-11.40: Bernd Gärtner, ETH Zürich
Pseudo-Random Matrices
11.45-12.10: Tetsuo Asano, JAIST - Ishikawa
Geometric Approaches to Computer Vision

12.15-14.00: LUNCH

14.00-18.00: HIKE and free time

18.00: DINNER

Computational Geometry

Program - Thursday, 11 March 1999

9.00-9.55: Pankaj Kumar Agarwal, Duke University - Durham, **Micha Sharir**, Tel Aviv University
Cylinders, Cigars, and Greblah

10.00-10.45 COFFEE BREAK

10.45-11.10: Michiel Smid, Universität Magdeburg
Protecting Facets in Layered Manufacturing
11.15-11.40: Helmut Alt, FU Berlin
L-infinity Nearest Neighbors in Higher Dimensions
11.45-12.10: Komei Fukuda, ETH Zürich
On Orientation Reconstruction Problems in Arrangements and Oriented Matroids

12.15-14.00: LUNCH

14.00-15.30: Breakout time

15.30-16.00: COFFEE BREAK

16.00-16.25: Lars Arge, Duke University - Durham
I/O-Efficient Dynamic Point Location in monotone Planar Subdivisions
16.30-16.55: Jefferey S. Vitter, Duke University - Durham
Topics in I/O Computation
17.00-17.25: Rephael Wenger, Ohio State University
Constructing PL-Homeomorphisms and Planar Graph Embedding
17.30-17.55: Vera Rosta Fukuda, Webster Univ. - Genève
Generalized and Geometric Ramsey Numbers

18.00: DINNER

Computational Geometry

Program - Friday, 12 March 1999

9.00-9.25: John E. Hershberger, Mentor Graphics - Wilsonville
Connectivity of Moving Rectangles
9.30-9.55: Franz Aurenhammer, TU Graz
Edge Operations on Spanning Trees

10.00-10.45 COFFEE BREAK

10.45-11.10: Peter Widmayer, ETH Zürich
Antenna Placement on Terrains
11.15-11.40: Matya Katz, Ben Gurion University
Walking Around Fat Objects
11.45-12.10: David G. Kirkpatrick, University of British Columbia
Reconstructing Polygons from their Complex Moments

12.15-14.00: LUNCH

Adjourn

Six Computational Geometry Problems from Cartographic Generalization

Marc van Kreveld, Utrecht University

Map generalization is making a map suitable for display at a reduced map scale. This is done by removing objects, simplifying them, combining them into larger ones, and so on. Automated cartographic generalization is a source of many interesting problems for computational geometers. In the talk six examples were given. For example, when two polygons are too close for the map scale, how does one change their shape to guarantee a minimum separation? What is the minimum total amount of area carved out from the two polygons to assure this? As a second example, consider rivers that are wide at some sections and narrow at others. On detailed maps rivers are shown as polygons, but at smaller map scale the narrow parts will be collapsed to polylines or curves, while the wide parts will appear as lakes. (At even smaller scales these are also collapsed.) Given two thresholds W1 and W2, suppose collapse must be performed where the river is more narrow than W1 but may not be performed when it is more wide than W2. Compute the partly collapsed river while minimizing the number of alternations in collapse and not collapse. In case of the same numbers, collapse as much as possible without making the lakes too small in size. These problems were presented with the hope of stimulating research during this workshop.

An Optimal Strategy for Walking an Unknown Street

Rolf Klein, FernUniversität Hagen

Let P denote a simple polygon with two distinguished vertices, s and t. We call (P, s, t) a *street* if the two boundary chains from s to t are mutually weakly visible (equivalently, if from each s-to-t path inside P the whole polygon P is visible). It has been known since 1991 that a mobile robot equipped with an onboard-vision system that starts from s in an unknown street can find the target vertex t, on a path at most 5.71 times as long as the shortest path from s to t. This is in contrast to general simple polygons, where no constant ratio can be achieved for the searching problem.

Over the years, many papers have appeared that improved on the upper bound. We provide an optimal search strategy for streets that guarantees a competitive ratio of $\sqrt{2}$, thus matching the lower bound known before.

This work has been done jointly with Ch. Icking and E. Langetepe, Hagen. The same strategy has been discovered independently, and at the same time, by I. Semrau and S. Schuierer, Freiburg.

Analysis of a Bounding Box Heuristic

Subhash Suri, Washington University

Bounding boxes are commonly used in computer graphics and other fields to improve the performance of algorithms that should process only the intersecting objects. A bounding box heuristic avoids unnecessary intersection processing by eliminating pairs whose bounding boxes are disjoint.

We analyze the performance of bounding box heuristics in terms of two natural parameters: aspect ratio α and scale factor σ.

Let $K_b(S)$ be the number of pairs of bounding boxes for a set S of n objects and let $K_o(S)$ be the nunmber of intersecting object pairs. Then the performance of bounding box heuristic can be related by the ratio

$$\rho(S) = \frac{K_b(S)}{n + K_o(S)}$$

.

Let $\rho(n) = max_{S,|S|=n}\rho(S)$

Main result:

$$\rho(n) = O(\alpha_{avg}^{2/3} \cdot \sigma^{1/2} \cdot n^{1/3}).$$

On the minimum size of visibility graphs

Ferrran Hurtado, Universitat Politècnica de Catalunya

The minimum size of the visibility graph of a set S of n segments in the plane is known to be $5n-4$, which is tight: $|E(VG(S)| \geq 5n-4$.

The contracted visibility graph of S has minimum size $n-1$, and the bound is achievable: $|E(CVG(S)| \geq n-1$.

The example giving the tightness of these bounds had chords (a segment is a chord when it has both endpoints on the convex hull, but it is not an edge on the hull).

The absence of chords is equivalent to $VG(S)$ being 3-connected and to $CVG(S)$ being 2-connected. In this work we prove that in this situation

$$|E(VG(S)| \geq 6n-6 \text{ and } |E(CVG(S)| \geq 2n-3,$$

and both bounds are tight.

When $VG(S)$ is 4-connected, the tight lower bound is still $6n-6$, and when $CVG(S)$ is 3-connected, the lower bound for its size goes up to $2n-2$, which is tight.

(Joint work with Alfredo García, Marc Noy and Javier Tejel)

Generalizing Ham Sandwich Cuts to Equitable Subdivisions

Sergey Bespamyatnikh, Univ. of British Columbia

We prove the following generalization of Ham Sandwich Theorems. For any gn red and gm blue points in the plane in general position, $g, n, m \in N$ there exists a convex subdivision of the plane into g convex polygonal regions such that each region contains n red and m blue points. We present an $O(N^{4/3} log^2 N \log g)$ time algorithm to construct such a subdivision, where $N = g(n+m)$ is the total size of input.

Metrics for Detecting Substructures in Proteins

Klara Kedem, Ben Gurion Univ.

Given the proteins by the $3d$ coordinates of their alpha-carbons, we devise a tool to find large matching contignoms substructures. The URMS-unit vector RMS computes the RMS distance between the unit vector representations of the proteins.

It is advantageous compared to the standard coordinates RMS. Moreover, its properties allow us to output all matching substructures in time $O(n \log n)$.

(Joint work with Chew, Huttenlocher, Kleinberg).

Curve Reconstruction

Kurt Mehlhorn, MPI – Saarbrücken

We present a curve reconstruction algorithm (joint work with T. Dey and E. Ramos) that for a point set S outputs a graph G with vertex set S and a collection Γ of open and closed curves with the following properties. If γ is any curve such that S is a dense sample for γ then any two points of S adjacent on γ are connected by an edge of G. Also S is a dense sample of Γ and points are connected by an edge of G iff they are adjacent on Γ.

On the topological sweep method

Michel Pocchiola, ENS – Paris

We describe a new method to implement, in constant amortized time, the flip operation of the so-called 'Greedy Flip Algorithm', a topological sweep algorithm for tangent visibility graphs/visibility complexes of pairwise disjoint convex sets. The method uses only primitive data structures and only one geometric predicate: the relative orientation of three convex sets. It matchs the so-called 'Topological Sweep Method' of Edelsbrunner and Guibas in the case where the convex sets are reduced to points. The analysis relies on two horizon theorems (Joint work with Pierre Angelier).

Entering & Leaving j-facets

Emo Welzl, ETH – Zürich

We review some basic properties and concepts of/for polytopes (h-vector, Dehn-Sommerville Relations, Generalized Lower Bound Theorem) in the setting of j-facets, with a conclusion to the number of $(\leq j)$-facets in 3-space.

LEDA

Stefan Näher, Universität Halle

In the first part we report on the state of the geometric part of LEDA. For further information on the geometric algorithms provided and the geometry kernels available in LEDA we refer to the forthcoming book on LEDA to appear by Cambridge University Press.

In the second part we present GeoWin, a new tool for the animation of geometric algorithms, similar to the GraphWin tool that was already available. GeoWin uses LEDA and works well with LEDA geometry but is not bound to LEDA. It works well with CGAL geomtry, too.

CGAL

Stefan Schirra, MPI – Saarbrücken

In the first part of the talk we briefly report on the state of the CGAL library which is developed in ESPRIT LTR IV projects CGAL and GALIA. An online documentation of the functionality of the current release of CGAL can be found at http://www.cs.uu.nl/CGAL/Information/doc_html. In the second part we show that CGAL is a beautiful framework for geometric computing. We report on case studies on the cost of geometric computing. Thanks to the parameterization CGAL provides a unique framework for studying the influence of data representation, programming techniques like reference counting, programming style, and the choice of arithmetic on the performance of an algorithm. Concerning arithmetic, there are several techniques applicable to enable exact geometric computation (for different types of problems). The most powerful option is using CGAL with the number type `leda_real` from LEDA. For most problems, this provides a user with an "implementation of the real RAM". Thus a user don't need to worry about robustness problems anymore, when this combination is used. We present the number type `leda_real` and report on experiments using number type `leda_real` in CGAL.

JDSL

Michael Goodrich, Johns Hopkins University

We outline the basic architecture of the Data Structures Library in Java (JDSL). It includes the fundamental data structures, including stacks, queues, sequences, trees, priority queues, dictionaries, and graphs, as well as several object-oriented design patterns for using these structures. We also describe a new spatial decomposition data structure called the Balanced Aspect Ratio (BAR) Tree. This data structure is a binary space partition tree such that all its regions are convex, have bounded aspect ratio, and are defined so that the depth of the tree is $O(\log n)$.

Vega - Visualization environment for geometric algorithms

Christoph A. Broecker and Sven Schuierer, Univ. Freiburg

We present a new approach to the distributed visualization of geometric algorithms that emphasizes the position of the end user. Concepts are introduced that enable a more flexible usage of visualized geometric algorithms, while keeping the task of adapting existing algorithms to the new scheme as simple as possible.

A main proposition is that interactivity should not be built into the visualized *algorithm*, but into the visualizing *system*. With this in mind, we devise a visualization model for geometric algorithms that incorporates strong algorithm execution control, flexible manipulation of geometric input/output data and adjustable view attributes. The new visualization model is implemented in the *Vega* system. Vega offers distributed visualization of geometric algorithms based on source code annotation and supports the standard libraries LEDA and CGAL.

More information about *Vega* is available at the following web location: `http://ad.informatik.uni-freiburg.de/Vega`.

TPIE

Lars Arge, Duke Univ.

We present the TPIE system (Transparent Parallel I/O Environment) developed at Duke University. TPIE (see `http://www.cs.duke.edu/TPIE`) is a software package that allows for simple, efficient, and portable implementation of I/O-efficient algorithms. We describe the main components of the system, implementation done so far, as well as planned future work. We also demonstrate the efficiency of TPIE by presenting some recent practical results on red-blue rectangle intersection. This problem is one of the key components in what in spatial databases are called "spatial join" ("map-overlay").

Kinetic Collision Detection

Leonidas Guibas, Stanford Univ.

Suppose we have two moving simple polygons P and Q in the plane and wish to detect collisions between them. In this talk we exhibit a tiling for the free space outside the polygons which deforms and occasionally changes combinatorially as the polygons move. We argue that with this tiling detecting collisions and the need for combinatorial changes is easy, and that – under some assumptions on the polygon motion – the total number of combinatorial changes to the tiling is small.

Experiments with Arrangements

Dan Halperin, Tel Aviv University

Arrangements are the underlying structures of many algorithmic solutions to geometric problems. In my talk I'll report on experimental work with arrangements done recently at Tel Aviv University. I will describe:

(1) A package for handling planar maps and arrangements which is robust and efficient and allows for fast point location into arbitrary subdivisions (part of the CGAL library) • Algorithms for computing the Minkowski sum of two polygonal sets built on top of the subdivision package (with Eyal Flato, Iddo Hanniel and Oren Nechushtan).

(2) A space sweep algorithm that constructs an arrangement of triangles in three-space and produces two decompositions of the arrangement: the standard vertical decomposition and a sparser subdivision (adding fewer extra faces) that is more efficient in certain respects. • A preprocessor that perturbs a collection of polyhedral surfaces (or triangles) such that their arrangement can be manipulated robustly using floating point arithmetic (with Sigal Raab and Hayim Shaul).

(3) Algorithms for on-line construction of the zone of a curve in a planar arrangement of lines that were designed and implemented as part of a software contest. I'll describe the winning algorithm of the contest and two variants of it that attempt at improving it (with Sariel Har-Peled and Chaim Linhart).

CG in GIS: theory in PRACTICE

Jack Snoeyink, UBC Computer Science

We described some lessons from learned from applying Computational geometry in practical implementations in Geographic Information Systems. We used work with Michael McAllister on computing all watersheds in a region, and work with Christopher Gold on the crust algorithm as examples.

Collision Detection and Response

Elmar Schömer, Univ. Saarbrücken

Collision Detection and Response

Detecting collisions and calculating physically correct collision responses play an important role when simulating the dynamics of colliding rigid bodies. Virtual reality applications such as virtual assembly planning and ergonomy studies can especially profit from advances in these directions, because they enable an interactive and intuitive manipulation of objects in virtual environments. This talk presents new algorithms for the real-time simulation of multi-body systems with unilateral contacts. The algorithms for dynamic collision detection and for the calculation of contact forces are part of the software library SILVIA, a simulation library for virtual reality applications. See http://www-hotz.cs.uni-sb.de/~schoemer

The Path of a Triangulation

Oswin Aichholzer, TU Graz

For a planar point set S let T be a triangulation of S and l a line properly intersecting T. We show that there always exists a unique path in T with certain properties with respect to l. This path is then generalized to (non triangulated) point sets restricted to the interior of simple polygons. This so-called triangulation path enables us to treat several triangulation problems on planar point sets in a divide & conquer-like manner. For example, we give the first algorithm for counting triangulations of a planar point set which is observed to run in time sublinear in the number of triangulations. Moreover, the triangulation path proves to be useful for the computation of optimal triangulations.

Arbitrary-Dimensional Constrained Delaunay Triangulations

Jonathan Shewchuk, Univ. California – Berkeley

Constrained Delaunay triangulations (CDTs) are useful for mesh generation and function interpolation. In dimensions higher than two, CDTs do not exist for all inputs, but they exist for inputs that satisfy conditions that are straightforward to maintain in three dimensions.

I discuss four gift-wrapping algorithms for constructing CDTs, which work on any input that has a CDT. The naive algorithm runs in $O(n_v n_f n_s)$ time, where n_v is the number of vertices, n_f is the number of constraining $(d-1)$-faces, and n_s is the number of d-simplices in the output (where d is the dimension).

A practical sweep algorithm improves the running time to $O(n_v n_s)$, and is likely to run yet more quickly in many circumstances encountered in practice. A sweep algorithm employing small-dimensional linear programming runs in $O(n_v^2 n_f + n_s \log n_v)$ time, which is faster if the output size n_s is significantly larger than $n_v n_f$. These two sweep algorithms come in both sweep hyperplane and sweep hypersphere variants. Finally, another sweep hypersphere algorithm deletes a vertex from a CDT in $O(n_s \log n_v)$ time.

Shortest Anisotropic Paths on Terrains

Jörg-Rüdiger Sack, School of Computer Science, Carleton University

We discuss the problem of computing shortest an-isotropic paths on terrains. Anisotropic path costs take into account the length of the path traveled, possibly weighted, and the direction of travel along the faces of the terrain. Considering faces to be weighted has added realism to the study of (pure) Euclidean shortest paths. Parameters such as the varied nature of the terrain, friction, or slope of each face, can be captured via face weights. Anisotropic paths add further realism by taking into consideration the direction of travel on each face thereby e.g., eliminating paths that are too steep for vehicles to travel and preventing the vehicles from turning over. Prior to this work an $O(n^n)$ time algorithm due to Rowe and Ross was known for computing anisotropic paths. Here we present the first polynomial time approximation algorithm for computing shortest anisotropic paths. Our algorithm is simple to implement and allows for the computation of shortest anisotropic paths within a desired accuracy.

(Joint with Mark Lanthier, Anil Maheshwari. Research supported in part by NSERC.)

Pitfalls with Pseudorandom Matrices

Bernd Gärtner, ETH – Zürich

We review a known phenomenon encountered in generating random matrices using the linear congruential method: the determinant of such a matrix is divisible by a large power of the generators's modulus. This leads to several potential pitfalls when using such matrices and their determinants for testing geometric algorithms. In many cases, an overestimation of the algorithms' performance might result.

Geometric Approach to Computer Vision

Tetsuo Asano, JAIST, Japan

A common representation of an image is a matrix with intensity levels as its elements. Regarding intensity levels of pixels as height at corresponding locations, an image can be viewed as a terrain map which is usually represented by a set of contour lines. In this talk it is described how this contour representation is applied to image processing.

There is an algorithm for enumerating all the contours in an output sensitive manner. However, the total length of the contour lines could be quadratic in the image size (number of pixels). Thus, it is not reasonable to store the whole collection of those contour lines.

One of the applications is natural zooming in which an image should be enlarged withour introducing jaggies. For this problem we propse a method as follows: First we compute a contour line. Then, every time we extract a contour line, we approximate it by a smoother curve and then enlarge it. Then, we put some information on the output image by following the enlarged contour. The problem here is how to approximate a contour line by a smoother curve without violating the inclusion relationship among contour lines. Finally some experimental results are shown for comparison with the conventional method.

Pipes, Cigars, and Kreplach

Pankaj K. Agarwal, Duke University, and Micha Sharir, Tel Aviv University

We show that the combinatorial complexity of the boundary of the union of the Minkowski sums of a ball with a collection of n pairwise-disjoint triangles in R^3 is $O(n^{2+\varepsilon})$ for any $\varepsilon > 0$. In other words, the combinatorial complexity of the free configuration space of a ball moving amid the given triangles is $O(n^{2+\varepsilon})$. If the triangles "degenerate" to infinite lines, the Minkowski sums are 'pipes' — infinite congurent cylinders (so their union has near-quadratic complexity). Cigars are obtained from line segements, and kreplach arise in the general case.

Protecting Facets in Layered Manufacturing

Michiel Smid, Univ. Magdeburg

In Layered Manufacturing, a three-dimensional polyhedral object is built by slicing its (virtual) CAD model, and manufacturing the slices successively. During this process, support structures are used to prop up overhangs. An important issue is choosing the build direction, as it affects the support structures, which in turn impact process speed and part finish. Algorithms are given that (i) compute a description of all build directions for which a fixed facet is not in contact with supports, and (ii) compute a description of all build directions for which the total area of all facets that are not in contact with supports is minimum. The first algorithm is worst-case optimal. A simplified version of the first algorithm has been implemented, and test results on models obtained from industry are given. Finally, a heuristic is proposed for computing a build direction that approximates the minimal area of all parts of the model that are in contact with supports.

(Joint work with: Jörg Schwerdt, Ravi Janardan, Eric Johnson, Jayanth Majhi.)

L_∞ Nearest Neighbor Search in High Dimensions

Helmut Alt, FU Berlin

Two ideas are presented leading to very simple algorithms to determine the L_∞-nearest neighbor in highdimensional space which are on the average significantly faster than the brute-foce method. We assume that the sites are n randomly chosen points in the d-dimensional unit cube.

The first idea is to precompute a box around the given query point whose side length is chosen such that the expected number of sites within the box is small. Points are scanned coordinate by coordinate and are removed as soon as it turns out that they lie outside the box.

The second idea is to start with a box of sidelength 1 and to keep decreasing it according to the points found so far. Points are processed as in the first method.

A detailed analysis shows that both ideas speed up the brute force search by a factor of $\ln n$. They also can be combined into one algorithm which, in experiments, is by a factor of about 5 faster than the brute force method for reasonable values of n and d.

(Joint work with Ulrich Hoffmann)

On orientation reconstruction problems in arrangements and oriented matroids

Komei Fukuda, Dept. of Mathematics, ETH-Zentrum

Consider a central arrangement A of m hyperplanes in R^d. Let $FL(A)$ be the face lattice of A (with an artificial greatest element added). There are two graphs associated with A, namely, the *graph* $G(A)$ (i.e. 1-skeleton) of A and the *cell graph* $G^*(A)$ (i.e. the dual 1-skeleton) of A. We assume that all three structures $FL(A)$, $G(A)$ and $G(A)$ are purely combinatorial objects and do not contain any geometric (i.e. coordinate) information on A. Therefore, the two graphs are substructures of the face lattice. We consider two reconstruction problems: one is to reconstruct $FL(A)$ from $G(A)$ and the other to do the same from $G^*(A)$. These can be variations of the problem for simple polytopes studied by Kalai: given the graph of a simple convex polytope, construct its lattice.

The latter problem admits a polynomial-time algorithm, and this was first shown by Fukuda, Tamura and Saito in 1991. In this talk we present old and new results on the former problem, due to Cordovil-KF-Guedes de Olveira and Finschi-KF-Lüthi. In particular, we show the problem is not well-defined unless an extra information is also given, and we present polynomial algorithms for slightly modified problems.

I/O-Efficient Dynamic Point Location in Monotone Subdivisions

Lars Arge, Duke University

We present an efficient external-memory dynamic data structure for point location in monotone planar subdivisions. Our data structure uses $O(N/B)$ disk blocks to store a monotone subdivision of size N, where B is the size of a disk block. It supports queries in $O(\log_B^2 N)$ I/Os (worst-case) and updates in $O(\log_B^2 N)$ I/Os (amortized). We also propose a new variant of B-trees, called *level-balanced B-trees*, which allow insert, delete, merge, and split operations in $O((1 + \frac{b}{B} \log_{M/B} \frac{N}{B}) \log_b N)$ I/Os (amortized), $2 \leq b \leq B/2$, even if each node stores a pointer to its parent. Here M is the size of main memory. Besides being essential to our point-location data structure, we believe that *level-balanced B-trees* are of significant independent interest. They can, for example, be used to dynamically maintain a planar st-graph using $O((1 + \frac{b}{B} \log_{M/B} \frac{N}{B}) \log_b N) = O(\log_B^2 N)$ I/Os (amortized) per update, so that reachability queries can be answered in $O(\log_B N)$ I/Os (worst case).

Point location in external memory and level-balanced B-trees

Jeffrey Vitter, Duke Univ.

As part II of the talk, we present a dynamic external memory data structure called *level-balanced B-trees* that maintains parent pointers and supports search and order queries in $O(\log_b N)$ I/Os and splice, merge, insert, and delete operations in $O((log_b N)\frac{b}{B}\log_{M/B}(N/B))$ I/Os amortized, where b is a tunable parameter in the range $1 \leq b \leq B$, B is the disk block size, N is the number of items stored, and M is the internal memory size. With the choice $b = B/\log B$, we get the bounds $O(\log_B N)$ and $O((\log_B N)^2)$, respectively. The data structure uses a global rather than local balancing constraint. It can be used in support of reachability in planar s, t-graphs and point location in monotone subdivisions.

Constructing PL-Homeomorphisms and Planar Graph Embeddings

Rephael Wenger, Ohio State Univ.

Let P and Q be two polygons, possibly with holes, and let $\{p_1, ..., p_n\}$ and $\{q_1, ..., q_n\}$ be the vertex sets of P and dff$Q$, respectively. We describe a general method of constructing PL-homeomorphisms from P to Q and mapping p_i to q_i. $O(n^2)$ triangles are sufficient and sometimes necessary to construct such homeomorphisms. We also describe a simple greedy algorithm for the related problem of constructing k pairwise disjoint polygonal paths in a simple polygon using $O(M \log k)$ line segments where M is the size of the optimal solution (the fewest required.) Finally, let $\{p_1, ..., p_n\}$ be a set of n points in the plane and let G be a planar graph with vertex set $\{v_1, ..., v_n\}$. We show how to give a planar embedding of G mapping v_i to p_i and using a total of $O(n^2)$ line segments.

(Joint work with Mark Babikov, Janos Pach, Diane Souvaine and Himanshu Gupta.)

Geometric ideas related to Ramsey theory

Vera Rosta, Webster University

In a recent paper with Gy. Karolyi we show that $R_G(C_k, P_l) = (k-1)(l-1)+1$, that is, in any 2-coloring of the $\binom{n}{2}$ line segments determined by $n \geq (k-1)(l-1)+1$ points in the plane, one of the color classes contains a non-crossing cycle of length k or the other color class contains a non-crossing path of length l. This result is best possible. These cycles and paths can be found by an $O(n^3)$ time algorithm. Similarly $(k-1)(l-1)+1 \leq R_G(C_k, C_l) \leq (k-1)(l-2)+(k-2)(l-1)+2$. We compare these so called Geometric Ramsey numbers to the Generalized Ramsey numbers for cycles, paths, trees etc. where we consider simple graphs and the non-crossing constraint is dropped. We also present a simple new proof for an earlier theorem on $R(C_k, C_l)$ in simple, non-geometric graphs.

Gy. Elekes conjectured that if the edges of a simple graph on n vertices, $n > n_0(k)$, are colored with cn colors so that no two adjacent edges have the same color then there is an alternating two colored path of length k. If this is true, Szemeredi's famous theorem would follow from it. A simple, geometric counterexample can be constructed to Elekes's conjecture using hypercube graph.

Kinetic Connectivity of Rectangles

John Hershberger, Mentor Graphics

We develop a kinetic data structure (KDS) for maintaining the connectivity of a set of axis-aligned rectangles moving in the plane. In the kinetic framework, each rectangle is assumed to travel along a low-degree algebraic path, specified by a flight plan—if the flight plan changes, the data structure is informed about it. The connectivity of rectangles changes only at discrete moments, given by the times when the order of rectangles along either axis changes. Our main result is a kinetic data structure of size $O(n \log n)$ that requires $O(\log^2 n)$ amortized time for each update, and answers connectivity queries in worst-case time $O(\log n / \log \log n)$.

(Joint work with Subhash Suri.)

Edge Operations on Spanning Trees

Franz Aurenhammer, TU Graz

Let S be a set of n points in R^2 , and let T be a spanning tree of S. Sliding an edge $e \in T$ means moving one endpoint of e along a neighbored edge so that no crossings among edges are introduced. We show that each non-crossing spanning tree T_1 can be transformed into any other one by a sequence of slidings. The proof strongly relies on triangulating the trees.

In trying to prove a better upper bound on the number of slides, we encountered the following result. If a spanning tree T is the minimum spanning tree of its own constrained Delaunay triangulation, then T has to be the (global) minimum spanning tree of the point set S.

Antenna Placement on Terrains

Peter Widmayer, ETH Zürich

We study the problem of placing a smallest number of antennas at a fixed height above a terrain (given as a triangulated irregular network) such that each point on the terrain sees one of the antennas. This problem is motivated by plans of telecommunications companies in Switzerland to place balloons at fixed positions in the air, where they serve as antennas for mobile phones. We show that this problem is not only NP-hard, but that an optimum solution even cannot be approximated within a ratio of $\frac{1-\epsilon}{28} \ln n$, for any $\epsilon > 0$, where n is the number of vertices of the terrain. This inapproximability bound follows by a reduction of the result by Feige that proves that SET COVER cannot be approximated within a factor of $(1-\epsilon)\ln n$. Furthermore, we propose an approximation algorithm that achieves an $O(\log n)$ ratio and runs in polynomial time. In a practical prototype, we tried various heuristics, and the greedy heuristics based on SET COVER turned out to give reasonably looking results.

Walking Around Fat Obstacles

Matthew J. Katz, Ben Gurion Univ.

We prove that if an object O is convex and fat then, for any two points a and b on its boundary, there exists a path along the boundary, from a to b, whose length is bounded by the length of the line segment $\overline{ab}$ times some constant β.

This constant is a function of the fatness-constant and the dimension d. We prove bounds for β and show how to efficiently find paths on the boundary of O whose lengths are within these bounds. As an application of this result, we present a method for computing short paths among convex, fat obstacles in $\mathbb{R}^d$ by applying de Berg's method for producing a linear-size subdivision of the space. Given a start site and a destination site in the free space, a standard obstacle-avoiding "straight-line" path that is at most some multiplicative constant factor longer than the length of the segment between the sites can be computed efficiently.

(join work with L. Paul Chew, Haggai David and Klara Kedem)

Reconstructing polygons from their complex moments

David Kirkpatrick, Univ. British Columbia

Building on results of Motzkin and Schoenberg in the early 50's and Philip Davis in the early 60's, Milafar et al. [IEEE Trans. on Signal Processing, Feb. '95] showed that the vertices of any polygon P are uniquely determined by the first $2n-3$ complex moments of P (ie. $\int\int_p z^k dxdy, k = 1, 2, \cdots 2n-3$).

Very recently Golub et al. have shown how to overcome some of the numerical difficulties with the reconstruction. They also show how the moments can be used to provide partial informations about the connections (edges) joining the reconstructed vertices. This gives rise to an interesting combinatorial/geometric problem: how to efficiently construct polygons consistent with the given moment informations (in highly degenerate cases there may be exceptionally many such "solutions").

This talk presents the background along with some of our progress (both theoretical and experimental) on this problem.

(Joint work with S. Durocher and J. Varah, UBC.)

List of Participants - Dagstuhl Seminar 99102 23.07.98

Date: 07.03.1999 - 12.03.1999

Title: Computational Geometry

Pankaj Kumar Agarwal
Duke University
Computer Science Dept.
Box 90129
NC 27708-0129 Durham
USA
phone: +1-919-660-6540
fax: +1-919-660-6519
e-mail: pankaj@cs.duke.edu
url: www.cs.duke.edu/~pankaj

Oswin Aichholzer
TU Graz
Institut fur Grundlagen der Informationsverarbeitung
Klosterwiesgasse 32
A-8010 Graz
AUSTRIA
phone: +43-316-873-5841
fax: +43-316-873-5805
e-mail: oaich@igi.tu-graz.ac.at
url: www.cis.tu-graz.ac.at/igi/oaich/

Helmut Alt
Freie Universitat Berlin
FB Mathematik und Informatik
Takustr. 9
D-14195 Berlin
GERMANY
phone: +49-30-83875160
fax: +49-30-83875109
e-mail: alt@inf.fu-berlin.de
url: www.inf.fu-berlin.de/inst/theo/tcs

Lars Arge
Duke University
Computer Science Dept.
D205 LSRC
Box 90129
Durham, NC 27708-0129
USA
phone: +1-919-660-6557
fax: +1-919-660-6519
e-mail: large@cs.duke.edu
url: www.cs.duke.edu/~large

Boris Aronov
Polytechnic University
Computer & Information Science Dept.
6 Metrotech Center
Brooklyn, New York 11201

USA
phone: +1-718-260-3092
e-mail: aronov@ziggy.poly.edu

Tetsuo Asano
Japan Adance Institute for Science and Technology
School of Information Science
Asahidai - Tatsunokuchi
923-1292 Ishikawa
JAPAN
phone: +81-761-51-1205
fax: +81-761-51-1149
e-mail: t-asano@jaist.ac.jp

Franz Aurenhammer
TU Graz
Institut fur Grundlagen der Informationsverarbeitung
Klosterwiesgasse 32
A-8010 Graz
AUSTRIA
phone: +43-316-873-5844
fax: +43-316-873-5805
e-mail: auren@igi.tu-graz.ac.at

Gill Barequet
Technion
Dept. of Computer Science
IL-32000 Haifa
ISRAEL
phone: +972-4-829-3219
fax: +972-4-822-1128
e-mail: barequet@cs.technion.ac.il
url: www.cs.technion.ac.il/~barequet/

Sergey Bespamyatnikh
University of British Columbia
Dept. of Computer Science
201-2366 Main Mall
V6T 1Z4 Vancouver
CANADA
phone: +1-604-822-3123
e-mail: besp@cs.ubc.ca
url: www.cs.ubc.ca/spider/besp/

Christoph A. Brocker
Universitat Freiburg
Institut fur Informatik
Geb. 51, Am Flugplatz 10
D-79110 Freiburg
GERMANY
phone: +49-761-203-8168
fax: +49-761-203-8162
e-mail: hipke@informatik.uni-freiburg.de
url: ad.informatik.uni-freiburg.de/~hipke/

Scot Drysdale
Dept. of Computer Science, 6211 Sudikoff Lab.
Dartmouth College
Hanover, NH 03755-3510
USA
phone: +1-603-646-2101
fax: +1-603-646-1672
e-mail: scot@cs.dartmouth.edu

Alon Efrat
Stanford University
Dept. of Computer Science
Gates 375
353 Serra Mall
Stanford, CA 94305-9045
USA
fax: +1-650-723-0033
e-mail: alon@cs.stanford.edu

Jeff Erickson
The University of Illinois
Dept. of Computer Science
1304 West Springfield Avenue
Urbana, IL 61801
USA
phone: +1-217-333-6769
e-mail: jeffe@cs.uiuc.edu
url: compgeom.cs.uiuc.edu/~jeffe/

William Evans
University of Arizona
Dept. of Computer Science
1040 E. Fourth Street
Tucson, AZ 85721
USA
fax: +1-520-621-4246
e-mail: will@cs.arizona.edu

Komei Fukuda
ETH Zurich
Institut fur Unternehmensforschung (Operations Research)
CH-8092 Zurich
SWITZERLAND
phone: +41-1-632-4023
fax: +41-1-632-1025
e-mail: fukuda@ifor.math.ethz.ch
url: www.ifor.math.ethz.ch/staff/fukuda

Michael Goodrich
Johns Hopkins University
Computer Science Dept.
3400 N. Charles Street
Baltimore, MD 21218

USA
phone: +1-410-516-7708
fax: +1-410-516-6134
e-mail: goodrich@cs.jhu.edu
url: www.cs.jhu.edu/~goodrich/

Leonidas Guibas
Stanford University
Computer Systems Laboratory
Stanford, CA 94305-9040
USA
phone: +1-650-723-0304
fax: +1-650-723-0033
e-mail: guibas@cs.stanford.edu
url: graphics.stanford.edu/~guibas

Bernd Gartner
ETH Zurich
Institut fur Informatik
CH-8092 Zurich
SWITZERLAND
phone: +41-1-632-6986
e-mail: gaertner@inf.ethz.ch
url: www.inf.ethz.ch/personal/gaertner

Dan Halperin
Tel Aviv University
Computer Science Dept.
69978 Tel-Aviv
ISRAEL
phone: +972-3-6406478
fax: +972-3-640-9357
e-mail: halperin@math.tau.ac.il
url: www.math.tau.ac.il/~halperin

John E. Hershberger
Mentor Graphics Corp.
Interconnectix Business Unit
8005 SW Boeckman Road
Wilsonville, OR 97070
USA
phone: +1-503-685-0723
fax: +1-503-685-4897
e-mail: john_hershberger@mentor.com

Ferran Hurtado
Universitat Politecnica de Catalunya
Dept. de Matematica Aplicada II
Pau Gargallo 5
E-08028 Barcelona
SPAIN
phone: +34-93 4017280
fax: +34-93 4017284
e-mail: hurtado@ma2.upc.es

url: www-ma2.upc.es/~hurtado/ferran.html

Matya Katz
Ben Gurion University
Dept. of Mathematics & Computer Science
84105 Beer Sheva
ISRAEL
phone: +972-7-6461628
fax: +972-7-6472909
e-mail: matya@cs.bgu.ac.il
url: www.cs.gbu.ac.il/~matya

Klara Kedem
Ben Gurion University
Dept. of Mathematics & Computer Science
Box 653
84105 Beer Sheva
ISRAEL
phone: +972-7-6461-628
fax: +972-7-6472-909
e-mail: klara@cs.bgu.ac.il
url: www.cs.bgu.ac.il/~klara

David G. Kirkpatrick
University of British Columbia
Dept. of Computer Science
201-2366 Main Mall
V6T 1Z4 Vancouver
CANADA
fax: +1-604-822-5485
e-mail: kirk@cs.ubc.ca

Rolf Klein
FernUniversitat-GH-Hagen
Praktische Informatik IV
Informatikzentrum
D-58084 Hagen
GERMANY
phone: +49-2331-987-327
fax: +49-2331-987-4896
e-mail: rolf.klein@fernuni-hagen.de

Kurt Mehlhorn
MPI fur Informatik
Im Stadtwald
D-66123 Saarbrucken
GERMANY
phone: +49-681-9325 100
fax: +49-681-9325 199
e-mail: mehlhorn@mpi-sb.mpg.de
url: www.mpi-sb.mpg.de/~mehlhorn

Stefan Naher
Universitat Halle

FB Mathematik und Informatik
Kurt-Mothes-Str. 1
D-06099 Halle
GERMANY
phone: +49-345-552-47 12
fax: +49-345-552-70 09
e-mail: naeher@informatik.uni-halle.de
url: www-informatik.uni-halle/~naeher

Michel Pocchiola
Ecole Normale Superieure
Departement de Mathematiques
45 Rue d'Ulm
F-75230 Paris
FRANCE
phone: +33-1-44 32 20 42
fax: +33-1-44 32 20 80
e-mail: pocchiola@dmi.ens.fr

Vera Rosta Fukuda
Webster University
Mathematique & Computer Science
15 Route de Collex
CH-1293 Geneve
SWITZERLAND
phone: +41-21-617-76 89 87
e-mail: rosta@masg22.epfl.ch

Gunter Rote
TU Graz
Institut fur Mathematik
Steyrergasse 30
A-8010 Graz
AUSTRIAN
phone: +43-316-873-5355
fax: +43-316-873-5369
e-mail: rote@opt.math.tu-graz.ac.at
url: www.tu-graz.ac.at/rote

Jorg-Rudiger Sack
Carleton University
School of Computer Science
ON-K1S 5B6 Ottawa
CANADA
phone: +1-613-520-43 61
fax: +1-613-520-43 34
e-mail: sack@scs.carleton.ca
url: www.scs.carleton.ca/people/faculty/sack.html

Stefan Schirra
MPI fur Informatik
Im Stadtwald
D-66123 Saarbrucken
GERMANY

phone: +49-681-9325-106
fax: +49-681-9325-199
e-mail: stschirr@mpi-sb.mpg.de
url: www.mpi-sb.mpg.de/~stschirr/

Raimund Seidel
Universitat des Saarlandes
FB 14 - Informatik
PF 15 11 50
D-66041 Saarbrucken
GERMANY
phone: +49-681-302-4513
fax: +49-681-302-5576
e-mail: seidel@cs.uni-sb.de

Micha Sharir
Tel Aviv University
School of Mathematical Sciences
69978 Tel-Aviv
ISRAEL
fax: +972-3-6409357
e-mail: sharir@math.tau.ac.il

Jonathan Shewchuk
University of California at Berkeley
Computer Science Division
625 Soda Hall
CA 94720-1776 Berkeley
USA
USA
phone: +1-510-642-3936
fax: +1-510-642-3962
e-mail: jrs@cs.berkeley.edu
url: www.cs.berkeley.edu/~jrs

Michiel Smid
Universitat Magdeburg
Fakultat fur Informatik
Universitatsplatz 2
D-39106 Magdeburg
GERMANY
phone: +49-391-67-18557
fax: +49-391-67-11164
e-mail: michiel@isg.cs.uni-magdeburg.de

Jack Snoeyink
University of British Columbia
Dept. of Computer Science
201-2366 Main Mall
V6T 1Z4 Vancouver
CANADA
phone: +1-604-822-8169
fax: +1-604-822-5485
e-mail: snoeyink@cs.ubc.ca

url: www.cs.ubc.ca/spider/snoeyink

Subhash Suri
Washington University
Computer Science Dept.
1 Brookings Drive
Campus Box 1045
MO 63130-4899 St. Louis
USA
e-mail: suri@cs.wustl.edu
url: www.cs.wustl.edu/~suri

Marc Van Kreveld
Utrecht University
Dept. of Computer Science
Padualaan 14
Postbus 80.089
NL-3508 TB Utrecht
THE NETHERLANDS
phone: +31-30-2534119
fax: +31-30-2513791
e-mail: marc@cs.uu.nl
url: www.cs.uu.nl/~marc

Jeffrey S. Vitter
Duke University
Computer Science Dept.
D315 Levine Science Research Center
Box 90129
NC 27708-0129 Durham
USA
phone: +1-919-660-6548
fax: +1-919-660-6502
e-mail: jsv@cs.duke.edu
url: www.cs.duke.edu/~jsv

Emo Welzl
ETH Zurich
Institut fur Theoretische Informatik
ETH-Zentrum
CH-8092 Zurich
SWITZERLAND
phone: +44-1-632-7370
fax: +44-1-632-1172
e-mail: emo@inf.ethz.ch
url: www.inf.ethz.ch/department/TI/ew

Rephael Wenger
Ohio State University
Dept. of Compurter & Information Science
2015 Neil Avenue
OH 43210 Columbus
USA

phone: +1-614-292-6253
fax: +1-614-292-2911
e-mail: wenger@cis.ohio-state.edu

Peter Widmayer
ETH Zurich
Institut fur Theoretische Informatik
ETH-Zentrum
CH-8092 Zurich
SWITZERLAND
phone: +41-1-632-74 00
fax: +41-1-632-1399
e-mail: widmayer@inf.ethz.ch