

Geodetic Science 837
Lect MWF 9:30 - 10:18
Lab R 12:30 - 2:18

Computational Cartography
G4
Mendenhall Lab 255

Prerequisites: Geod Sci 786 or CSE 680 or permission of instructor

Website: <http://carmen.osu.edu/>

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Call No. 22356-3

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OBJECTIVES

Course will explore topics in computational cartography: computational techniques needed to manipulate cartographic and spatial data structures efficiently. Students will examine the inherent complexity of computational problems in cartography and the complexity of currently available algorithmic solutions.

COURSE CONTENT

The course will review several computational methods for managing, transforming, and viewing digital cartographic data sets. Emerging techniques from computational topology, computational geometry, computer graphics, discrete mathematics, and algorithm analysis will be examined for potential use on cartographic and related spatial data sets. The following topics will be surveyed:

- Review of spatial data structures and algorithms for digital cartography.
- Computational topology and computational geometry methods for geographic data.
- Inventory of computational cartography problems and their complexity.
- NP-hard problems in computational cartography: the label placement problem.
- Computational issues in map generalization.
- Robustness issues and approximation methods in cartography.
- Improved algorithms for computing map transformations.
- Possible additional topics: conflation, error handling, map overlay, graphs on surfaces.

TEXTBOOK

Computational Geometry, deBerg, van Kreveld, Overmars, and Schwarzkopf, 2000, Springer-Verlag.

ADDITIONAL REFERENCES

AUTOCARTO Symposium Proceedings, 1983 - 2008.

Spatial Data Handling Symposium Proceedings, 1985 - 2008.

Algorithmic Foundations of GIS, van Kreveld, Nievergelt, Roos, and Widmayer, 1997, Springer-Verlag.

Label Placement Bibliography: <http://www.inf.fu-berlin.de/~awolff/map-labeling/bibliography.html>

REQUIRED STUDENT PARTICIPATION and ASSESSMENT

Each student will be expected to prepare and deliver one 20-minute presentation by gathering and organizing material related to one of the weekly topics. Students will also provide feedback on the relevance and success of each topic presentation. Open problems will be discussed extensively during the lectures. Each student will receive a letter grade based on the following: Presentation (20%), classroom participation (15%), homework (25%), midterm exam (15%), final exam (25%).

TOPICS AND SUBTOPICS FOR GS 837

REVIEW OF SPATIAL DATA STRUCTURES AND ALGORITHMS FOR DIGITAL CARTOGRAPHY

1. Geometric Primitives: Point, Line, Region (Triangle, Rectangle, Polygon, Surface), Volume (Solid).
2. Digital Representations of Primitives: Coordinate pairs, sets of coordinate pairs; other real number and real vector invariants (radius, coefficients of surface equations, normal to surface, etc.); computational solid geometry versus boundary representations: tradeoffs.
3. Organizational Issues for Primitives: Topology: completeness and consistency; Combinatorial complexity; Data structures for efficient access; Physical storage concerns.
4. Finite-precision issues for digital spatial data: Representability; robustness; stability.

COMPUTATIONAL GEOMETRY METHODS AND ANALYSIS

1. Tree structures for searching and preprocessing.
2. Computer Graphics applications.
3. Finite precision geometry and robustness.
4. Spatial subdivision methods: Triangulations, Voronoi Diagrams, Quadtrees, and other structures.
5. Sweep Algorithms, Incremental Algorithms, Divide-and-Conquer Algorithms.
6. Convex hulls, Visibility Relations, Geometric interactions.

INVENTORY OF COMPUTATIONAL CARTOGRAPHY PROBLEMS AND THEIR COMPLEXITY

1. Line Intersection: Robustness Concerns; Topology Building in most general setting.
2. Topological Editing: Topology Checking versus Topology Construction.
3. Map Overlay: Topology building under strong assumptions about component layers.
4. Spatial Partitions and Coverings: Efficient local decomposition; R-trees versus Quadtrees.
5. Label Placement: Optimization of partially understood constraints.
6. Generalization: Simultaneous solution of even less understood constraints.

NP-HARD PROBLEMS IN COMPUTATIONAL CARTOGRAPHY: THE LABEL PLACEMENT PROBLEM

1. Early work on the Label Placement Problem.
2. Freeman-Ahn approach: Graph Theory methods.
3. Freeman-Doerschler approach.
4. Computational Geometry Analysis of problem: what makes some versions NP-hard.

COMPUTATIONAL ISSUES IN MAP GENERALIZATION

1. Selection/omission of features and its complexity.
2. NP-hard global line simplification.
3. Representations of features at different scales.
4. Changing topology at different scales.
5. Feature displacement: limitations.
6. Feature displacement: consistency.

RANDOMIZED ALGORITHMS FOR CARTOGRAPHY

1. Randomization and its advantages.
2. Avoiding worst-case situations: Delaunay triangulations.
3. Advantages of well-distributed points.

IMPROVED ALGORITHMS FOR COMPUTING MAP TRANSFORMATIONS

1. Piecewise Affine Transformations.
2. Conformal Transformations and Approximations.
3. Ellipsoid computations using truncated series.
4. Projections.

ROBUSTNESS ISSUES AND APPROXIMATION METHODS IN COMPUTATIONAL CARTOGRAPHY

1. Finite-precision geometry.
2. Exact-precision arithmetic and BIGINTs.
3. Algebraic and geometric number fields.
4. Chee Yap's and Victor Milenkovic's results.

PARTITIONING AND PREPROCESSING STRATEGIES FOR VERY LARGE SPATIAL DATA SETS

1. Triangulations.
2. Grid Structures, Bucketing.
3. Trees: Quadtrees, R-Trees, k-d trees.
4. Voronoi Diagrams and their utility.
5. Local and parallel processing opportunities.

COMPUTATIONAL TOPOLOGY FOR MAPS

1. Topological surfaces/cell complexes.
2. Topological sweep algorithms.
3. The Jordan Curve Theorem and corollaries.

SELECTED TOPICS: CONFLATION, ERROR HANDLING, GRAPHS ON SURFACES

1. Conflation: homeomorphism of mapping spaces.
2. Conflation: feature matching in mapping spaces.
3. Error modeling: Goodchild's approaches.
4. Error representation: error taxonomies and maps.
5. Error propagation: process modeling.
6. Graphs on surfaces: Schnyder, Robinson, Seymour
7. Graphs on surfaces: Map overlay problems