



دانشگاه یزد  
Yazd Univ.

Computational  
Geometry

# Computational Geometry (Graduate Course)

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Department of Computer Science,  
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Spring 2019-1397-2

Course Outline

Textbook  
Grading  
Prerequisites

Introduction

What is CG?

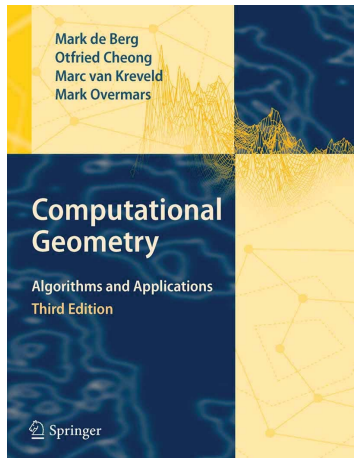
Research on CG

Journals  
Conferences



# Textbook:

Mark de Berg, Otfried Cheong, Marc van Kreveld, Mark Overmars, **Computational Geometry Algorithms and Applications**, 3rd Edition, Springer-Verlag Berlin Heidelberg, 2008.



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# Grading:



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## Grading:

- Midterm exam: 6
- Final exam: 7
- Presentation: 3
- Homework: 4
- **Important:** For passing the course, one should get at least 8 from midterm+final exams.





## CG on Web:

- **Course Webpage:**  
[cs.yazd.ac.ir/farshi/Teaching/CG3973/CG.html](http://cs.yazd.ac.ir/farshi/Teaching/CG3973/CG.html)
- **(Jeff Erickson)**  
[compgeom.cs.uiuc.edu/~jeffe/compgeom/courses.html](http://compgeom.cs.uiuc.edu/~jeffe/compgeom/courses.html)
- **(David Eppstein)** [www.ics.uci.edu/~eppstein/geom.html](http://www.ics.uci.edu/~eppstein/geom.html)
- **(Godfried Toussaint)**  
[www-cgri.cs.mcgill.ca/~godfried/teaching/cg-web.html](http://www-cgri.cs.mcgill.ca/~godfried/teaching/cg-web.html)
- **Computational Geometry Pages**  
[www.computational-geometry.org](http://www.computational-geometry.org)
- and much more ...



## What you need to know:

- **Basic Algorithms and Algorithm Analysis:**  $\mathcal{O}$ ,  $\Theta$  notations, sorting, searching.
- **Basic Data Structures:** Priority Queue (Heap), Binary Search Tree, ... and their analysis.
- **Basic Probability theory:** Expected value, ...
- **Not needed:** Application of CG, programming, knowledge in Geometry.

# Prerequisites:



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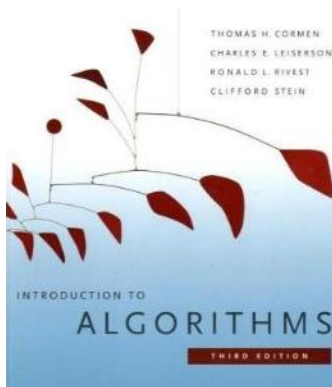
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# Introduction



# What is CG?



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## Computational Geometry

- is a branch of computer science devoted to the study of algorithms which can be stated in terms of geometry.
- is a subfield of the Design and Analysis of Algorithms
- deals with efficient data structures and algorithms for geometric problems
- is about 45 years old
- started out by developing solid theoretical foundations, but became more and more applied over the last years



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## Applications

- Computer graphics,
- Computer-aided design and manufacturing (CAD/CAM),
- Robotics (motion planning and visibility problems),
- Geographic Information Systems (GIS) (geometrical location and search, route planning),
- Integrated Circuit design (IC geometry design and verification),
- and so on.



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The main branches of computational geometry are:

- **Combinatorial computational geometry**, also called **algorithmic geometry**, which deals with geometric objects as discrete entities. A groundlaying book in the subject by Preparata and Shamos dates the first use of the term "computational geometry" in this sense by 1975.
- **Numerical computational geometry**, also called **machine geometry**, computer-aided geometric design (CAGD), or geometric modeling, which deals primarily with representing real-world objects in forms suitable for computer computations in CAD/CAM systems. This branch may be seen as a further development of descriptive geometry and is often considered a branch of computer graphics or CAD.

# What is CG?



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## Combinatorial computational geometry

- The primary goal is to develop *efficient algorithms* and *data structures* for *solving problems* stated in terms of basic geometrical objects: points, line segments, polygons, polyhedra, etc.
- Example: **The closest pair problem**: Given  $n$  points in the plane, find the two with the smallest distance from each other. The brute-force algorithm takes  $\mathcal{O}(n^2)$  time. A classic result: an algorithm that takes  $\mathcal{O}(n \log n)$  time. Also randomized algorithms that take  $\mathcal{O}(n)$  expected time, as well as a deterministic algorithm that takes  $\mathcal{O}(n \log \log n)$  time.
- Computational geometry focuses heavily on *computational complexity* since the algorithms are meant to be used on very large data sets containing tens or hundreds of millions of points.

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## Problem classes

- Static problems
  - 1 **Convex hull:** Given a set of points, find the smallest convex polyhedron/polygon containing all the points.
  - 2 **Line segment intersection:** Find the intersections between a given set of line segments.
  - 3 **Voronoi diagram:** Given a set of points, partition the space according to which point is closest.
  - 4 **Closest pair of points:** Given a set of points, find the two with the smallest distance from each other.
  - 5 **Euclidean shortest path:** Connect two points in a Euclidean space (with polyhedral obstacles) by a shortest path.
  - 6 **Polygon triangulation:** Given a polygon, partition its interior into triangles

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## Problem classes

- Geometric query problems
  - 1 **Range searching:** Preprocess a set of points, in order to efficiently count the number of points inside a query region.
  - 2 **Point location:** Given a partitioning of the space into cells, produce a data structure that efficiently tells in which cell a query point is located.
  - 3 **Nearest neighbor:** Preprocess a set of points, in order to efficiently find which point is closest to a query point.
  - 4 **Ray tracing:** Given a set of objects in space, produce a data structure that efficiently tells which object a query ray intersects first.

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## Problem classes

- Dynamic problems
- Variations
  - Point in polygon: Decide whether a point is inside or outside a given polygon.



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## Problem classes

- Dynamic problems
- Variations
  - Point in polygon: Decide whether a point is inside or outside a given polygon.





## Journals

- 1 Computational Geometry: Theory and Applications (CGTA)
- 2 Discrete & Computational Geometry (DCG)
- 3 International Journal of Computational Geometry and Applications (IJCGA)
- 4 Journal of Computational Geometry
- 5 Other algorithmic journals



## Conferences

- 1 ACM Symposium on Computational Geometry (SOCG)
- 2 Canadian Conference on Computational Geometry (CCCG)
- 3 European Workshop on Computational Geometry (EWCG)
- 4 Iranian Conference on Computational Geometry (ICCG) (2nd one in a month at Sharif University of Technology)
- 5 International Conference on Computational Geometry and Computer Vision
- 6 Others, like SODA, STOC, ESA.



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