Birla Institute of Technology and Science, Pilani
Second Semester 2022-2023
Course Handout Part II

Date: 16/01/2023

In addition to the Part-I (General Handout) for all courses appended to the timetable, this portion gives further specific details regarding the course.

Course No. : CS F402
Course Title : Computational Geometry
Instructor-in-Charge: Dr. Manjanna B

1. Scope and Objective:

The objective of this the course is to introduce each individual student to computational geometry – a branch of the theory of algorithms that aims at solving problems involving geometric objects, and their application areas. In particular, one will

- learn various algorithmic approaches, and assess their strong and weak points in a particular context, thus gaining an ability to choose an appropriate approach for a given concrete problem.
- engage in design, analysis, and implementation of algorithms and data structures for geometric problems;
- these geometric problems arise in a wide variety of application areas such as computer graphics, computer-aided design, geographical information systems, robotics, spatial databases, sensor networks, and to a lesser extent, computer vision and machine learning.

The scope of this course includes a number of computational geometry topics such as testing point inclusion in a polygon, computing convex hulls, intersection detection, geometric searching, proximity problems, arrangements, triangulations, geometric sampling, and geometric optimization.

2. Text Book:

T1: M. de Berg, M. van Kreveld, M. Overmars, and O. Schwarzkopf. Computational Geometry: Algorithms and Applications. Springer-Verlag, 3nd edition, 2008

3. Reference Books:

R1. Geometric Approximation Algorithms, Sariel Har-Peled, AMS Series in Mathematical Surveys and Monographs
R2: David Mount's lecture notes, Fall 2021
R3. Computational Geometry: An introduction, Franco P. Preparata and Michael Ian Shamos, Springer-Verlag, 1985
R4. Computational Geometry in C, Cambridge University Press, 1988
R5. Introduction to Algorithms, Cormen et al.
R6. Geometry: Combinatorics and Algorithms Lecture notes, 2018 (https://geometry.inf.ethz.ch/)
AR. Additional reading assigned by the Instructor

4. Course Plan

No. of Lectures	Objectives	Topic	Reference
1-3	To understand Preliminaries	Mathematical and geometric review. mathematical models of computation, representation of basic geometric objects, convexity, polytopes, testing point inclusion in a polygon	T1: Ch 1 R1: Ch 1
4– 8	To learn algorithms for Convex hulls based on various techniques	Planar convex hulls, higher dimensional convex hulls, randomized, output-sensitive, and dynamic algorithms, applications of convex hull	T1: Ch 1
9– 12	To understand Intersection detection in 2D and 3D	Segment intersection, line sweep, map overlay, halfspace intersection , polyhedral intersection	T1: Ch 2
13-16	To learn algorithms and data structures for Geometric Searching	segment, interval, and priority-search trees, point location, persistent data structure, BSPs, Quad trees, fractional cascading, range searching, nearest-neighbor searching	T1-Ch 5, Ch 6, Ch 10, 12, 14 Ch 16 R1: Ch 2
17-19	To solve various Proximity Problems using a variety of techniques	Closest pair, Voronoi diagram, Delaunay triangulation and their subgraphs, spanners, well separated pair decomposition	T1-Ch 7 R1: Ch 3
20-22	To study algorithms for building Arrangements of simple geometric objects	Arrangements of lines and hyperplanes, sweep-line and incremental algorithms, lower envelopes, levels, and zones, applications of arrangements	T1 – Ch 8
23-25	To study algorithms for Triangulations of points and polygons	Monotone and simple polygon triangulations, point-set triangulations, optimization criteria, Steiner triangulation, Delaunay refinement	T1 – Ch 3, Ch 9
26-29	To learn Geometric sampling and study various concepts and algorithms based on that	Computing Cuttings by random sampling, epsilon-nets and approximations, VC dimensions and applications to geometric optimization,	R1-Ch 4, 5, 6, 7
30-33	To study Geometric Optimization	LP-type problems, parametric searching, approximation techniques	T1: Ch 4 R1: Ch 15, 16
34-38	To understand Visibility and motion planning	Visibility graphs, Art gallery problem, shortest paths, ray shooting.	T1 - Ch 13, Ch 15
39-42	To prove some Worst-case lower bounds	Algebraic computation-tree, reductions for various problems, a few 3SUM-hard geometric problems	

5. Evaluation Scheme:

S. No.	Component	Duration	Weightage (%)	Date & Time	Remarks
1.	Quiz 1	40 min.	10%	As announced by the Instructor	Pre-MIDSEM, Open Book
2.	Research Paper Presentation	---	10 %	As announced by the Instructor	---
3.	Programming Assignment	---	10 %	As announced by the Instructor	Spread across the semester
4.	Mid-sem Exam	1.5 hrs	30%	18/03 4.00 - 5.30PM	Open Book
5.	Comprehensive Exam	3 hrs.	40%	20/05 AN	Open Book

Research Paper Presentation Details:

Papers in computational geometry appear in a variety of computer science journals, including Algorithmica, the Journal of Algorithms, the Journal of the ACM, the ACM Transactions on Algorithms, the SIAM Journal on Computing, and others.

There are three specialized journals primarily devoted to this field, **Discrete and Computational Geometry (DCG)**, the **International Journal of Computational Geometry & Applications (IJFCS),** and **Computational Geometry, Theory and Applications (CGTA)**.

There is an annual International **Symposium on Computational Geometry, (SOCG)** whose proceedings are of the high quality work in the area. There is also a Canadian conference in the field, the **Canadian Conference on Computational Geometry (CCCG)**, as well as annual workshops in Europe and the Far East. Other well-established theory conferences, such as **STOC**, **FOCS**, **SODA**, or **WADS/SWAT**, also get a good share of high-quality geometry papers.

Every student either individually or in a group of up to three people must choose a paper published in any of the above conferences/journals or similar high-quality ones, and present it to the class and the instructor. The aim of this component is that students must thoroughly understand how the geometric problem(s) are solved in the paper, and the techniques used to develop the solutions, and see if other techniques could be used in their place to improve the result, or not, also, see if the techniques in the paper can be applied to solve other similar problems. In this way, one is expected to get something substantive out of the experience. Each student is encouraged to find their own topic and a recent paper on the topic, but a number of topics will be discussed in the class or one can discuss with the instructor during Chamber Consultation hours. You should start thinking about the topic for this component as soon as possible, and get it approved by the instructor. The evaluation of this component will be based on the following two things:

(i) A well-written report that expresses your analysis of the work in your selected paper, other findings by you, as explained above.

(ii) A presentation to the class highlighting the major contributions of the paper (the primary measure of assessment will be the clarity with which you present the ideas in the paper and your ability to effectively communicate the results in the paper to your peers, and to the instructor.

Programming Assignment Details:
As a prerequisite, here one must have experience with C, C++, or Python. The problems/algorithms for the programming assignment will be discussed during the classes or will be posted in CMS. The evaluation of this component will be based on the following two things:

(i) A well-written report that contains your solution (at least pseudocode) and the time required for each individual test dataset, and conclusions of the experimental work.

(ii) Demonstration of your code to the instructor, during which one must run his/her code, answer the queries, and do modifications in the code, as asked by the instructor, and rerun it.

Note that there is an open-source C++ library, the Computational Geometry Algorithms Library (CGAL), the use of which for the programming assignment will be decided by the instructor.

6. **Chamber Consultation hours**: To be announced in the class.

7. **Make-up Policy:**
Prior Permission of the Instructor-in-Charge is usually required to take a make-up for a test. A make-up test shall be granted only in genuine cases on justifiable grounds.

8. **Notices:** Notice regarding the course will be displayed on the CMS.

9. **Academic Honesty and Integrity Policy:** Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

Dr. Manjanna B.,
Instructor-in-charge
CS F402