Indian Institute of Technology Kharagpur

Spring Semester 2022

COMPUTER SCIENCE AND ENGINEERING

CS60064: Computational Geometry

Instructors: Bhargab B. Bhattacharya and Partha Bhowmick
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Course hours: L-T-P: 3-0-0; Credit = 3
Pre-requisites: Basic Algorithms, Data structures, and Programming Experience

Teaching Assistants: Faraaz Rahaman Mallick (faraazrm@gmail.com)
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Semester Commencement: Tuesday, 04 January 2022; **Closing:** Wednesday, 13 April 2022

Class Timing: WED (10:00-10:55); THURS (09:00-09:55); FRI (11:00-11:55).
Course Page: https://moodlecse.iitkgp.ac.in/moodle/login/index.php
Moodle **Student Registration Key** for the Course: STUBBPB22

Textbook and Notes:

- M. de Berg, O. Cheong, M. van Kreveld, and M. Overmars: C*omputational Geometry: Algorithms and Applications* (3rd edition), Springer Verlag, 2008.
- David M. Mount: CMSC 754 *Computational Geometry Lecture Notes*, Department of Computer Science University of Maryland 2002 (http://www.cs.umd.edu/~mount/754/Lects/754lects.pdf).

Other References

- S. L. Devadoss and J. O'Rourke: *Discrete and Computational Geometry*, Princeton University Press, 2011.
- F. Preparata and M. Shamos: *Computational Geometry: An Introduction (3rd edition),* Springer Verlag,1993.
- J. O'Rourke: *Computational Geometry in C (2nd edition),* Cambridge University Press, 1998.
- J. O'Rourke, *Art Gallery Theorems and Algorithms*, Oxford Univ. Press, 1987.
- K. Mulmuley: *Computational Geometry: An Introduction Through Randomized Algorithms,* Prentice Hall, 1994.
- S. Ghosh: *Visibility Algorithms in the Plane,* Cambridge University Press, 2007.
- Jacob E. Goodman, Joseph O'Rourke, and Csaba D. Tóth (Ed.): *Handbook of Discrete and Computational Geometry*, Third Edition, CRC Press, 2017.
- Jiri Matousek: *Lectures on Discrete Geometry*, Springer, 2002.
- Erik D. Demaine and Joseph O'Rourke: *Geometric Folding Algorithms*: *Linkages, Origami, Polyhedra,* Cambridge University Press, 2007.
- Micha Sharir and Pankaj Agarwal: *Davenport Schinzel Sequences and Their Geometric Applications*, Cambridge University Press, 2010.
- Godfried T. Toussaint, *The Geometry of Musical Rhythm*, CRC Press, 2013.
- Marvin Minsky and Seymour Papert: *Perceptrons – An Introduction to Computational Geometry*, MIT Press, 1969.

Web Resources

- NPTEL Video Course on Computational Geometry by Sandeep Sen, Department of Computer Science & Engineering, IIT Delhi, and Pankaj Agarwal, Dept. of CS, Duke University, USA (http://www.nptelvideos.in/2012/11/computational-geometry.html)
- Lecture Slides on Computational Geometry by Martin Held, University of Salzburg, Austria (https://www.cosy.sbg.ac.at/~held)
- Godfried T. Toussaint's page: http://cgm.cs.mcgill.ca/~godfried/teaching.html
- CGAL Computational Geometry Library (https://www.cgal.org/)
- K. Mehlhorn and St. Näher: *The LEDA Platform of Combinatorial and Geometric Computing*, Cambridge University Press, 1999 (https://people.mpi-inf.mpg.de/~mehlhorn/LEDAbook.html).
- Computational Geometry (Wolfram Research) (http://mathworld.wolfram.com/topics/ComputationalGeometry.html)
- David Eppstein's Geometry in Action (https://www.ics.uci.edu/~eppstein/geom.html)
- David Eppstein's Geometry Junkyard (https://www.ics.uci.edu/~eppstein/junkyard/)

Journals and Conferences

- CGTA: Computational Geometry: Theory and Applications
- DCG: Discrete and Computational Geometry
- IJCGA: International Journal of Computational Geometry
- SoCG: Symposium on Computational Geometry
- CCCG: Canadian Conference on Computational Geometry

Online Platforms: Microsoft Teams, Google Meet, Narration-embedded PPT, Moodle will be used as convenient. Appropriate links and schedules will be sent to the students in advance by email.

Evaluation:

- Homework/Term Papers/Quiz: 50%
- Two Tests (90 min each): 50% (= 25% $\times$ 2)

  For doing Homework/Assignments/Presentations, the students are requested to form disjoint teams, each team comprising *two students.* A student may work individually as well, if so desired. In order to form teams, please coordinate with TA's who will share a google doc file soon.

Outline of Syllabus

- Introduction: historical perspective, geometric preliminaries, scope of discrete, computational, and digital geometry, motivating examples
- Polygons, diagonals, and triangulations; point inclusion, polygonization of point-sets, orthogonal polygonization; orientation test; lattice polygons, Pick's theorem
- Line-segment intersections, plane-sweep techniques, polygon union and intersections
- Algorithms for polygon triangulation, monotone polygons, planar subdivision, DCEL representation
- Visibility, art-gallery problems
- Convex-hull algorithms
- Proximity problems; max, min rectangular queries
- Geometry of casting
- Geometric data structures, orthogonal range searching, fractional cascading, point location
- Arrangements and duality; discrepancy, visibility graphs
- Combinatorial geometry: Pancake theorem, Ham-Sandwich cuts, Borsuk-Ulam Theorem
- Helly's theorem, rectilinear geometry: intersection and union of rectangles
- Voronoi diagram and Delaunay triangulation
- 3Sum-Hard problems in computational geometry
- Applications of computational geometry to VLSI Design, robot motion planning, and other areas
- Empty-space recognition, maximum empty rectangle (MER) among point sets, matrix searching*
- Facility location*
- Epsilon-nets and VC-dimension*

* if time permits

Tentative Calendar for CS60064: Computational Geometry, Spring 2022

Semester Commencement: Tuesday, 04 January 2022; **Closing:** Wednesday, 13 April 2022

Class Timing: WED (10:00-10:55); THURS (09:00-09:55); FRI (11:00-11:55).

Homework and Test Schedule

Friday, 07 January 2022: Issue of Homework Set 1 (Due: 21 January 2022)

Friday, 21 January 2022: Issue of Homework Set 2 (Due: 28 January 2022)

Wednesday, 26 January 2022: Institute Holiday (Republic Day)

Friday, 11 February 2022: Issue of Homework Set 3 (Due: 24 February 2022)

Friday, 25 February 2022: Online Test-1; 11:00 AM – 12: 30 PM

Saturday to Monday, 26 February 2022 – 28 February 2022: Techno-Management Festival (Kshitij)

Thursday, 03 March 2022: Issue of Homework Set 4 (Due: 11 March 2022)

Friday to Sunday, 04 March 2022 – 06 March 2022: Spring Fest

Friday, 18 March 2022: Institute Holiday (Holi)

Friday, 25 March 2022: Issue of Homework Set 5 (Due: 06 April 2022)

Friday, 08 April 2022: Online Test-2; 11:00 AM – 12: 30 PM; End of Class

Thursday, 21 April 2022, Submission of grades; **End of Semester**

In addition, there may be some Quizzes or Term Papers (to be decided later)