# AMS345/CSE355: Computational Geometry, Fall 2024

**Instructor:** Joe Mitchell, Math Tower P-139A, 631-632-8366, joseph.mitchell@stonybrook.edu

**Lectures/Class Time Period:** Mondays and Wednesdays, 2:00pm-3:20pm, in Javits 103, starting Monday, August 26, 2024. Class meetings are captured (and streamed live) via Zoom.

**Credit:** 3 credits

**Brightspace:** We are using Brightspace, a digital learning environment, for this course. To learn more and for SUNY Online helpdesk information, visit: https://brightspace.stonybrook.edu

**Structure of Class in Fall 2024:** The class will be delivered in person (Section 01) and online (Section 02). Section 02 (online) students are welcome to attend classes in person (especially on the dates of the midterm and final), subject to the availability of seats in the classroom.

NOTE: While the class time lectures will be captured/recorded (assuming no technical glitches), the course is **synchronous** (not asynchronous): students are expected to attend and hopefully participate in the classes, and there will be "Questions of the Day" associated with the class meetings, which count towards the class grade. This is meant to encourage students to attend and stay current with the class.

Exams (Midterm and Final) will be conducted in a dual mode, with details to follow later. Most likely the exams will be administered in person in the classroom, with online students encouraged to attend in person; there will be a remote option for those in Section 02, conducted electronically, and each student taking an exam remotely will be expected to have the necessary equipment and software, including Respondus Lockdown Browser (and Respondus Monitor).

Students in Section 01 will be expected to take the exams in person in the classroom, using a laptop/computer they bring to class (there will be a paper option in case of emergencies); these students will not be required to run Respondus Monitor (the remote video camera proctoring), as they will be proctored in person and will be able to ask questions in person and have access to a hard copy of the exam.

Students in Section 02 will not be required to take the exams in person, but will be given the option to do so, and encouraged to do so (up to the capacity of the classroom). If taking an exam remotely, video remote proctoring (Respondus Monitor) will be required for exam security.

The course content will be available in the Brightspace learning management system (LMS), combining both synchronous and asynchronous types of delivery. Students must be mindful of all course expectations, deliverables and due dates. All assignments and many course interactions will utilize internet technologies. See "Technical Requirements" section for more information. Regular communication and details of course content will be provided on Blackboard throughout the course. In Brightspace, you will access video recordings, course materials, assignments, and other resources.

The lecture content on the main topics of the course will be provided asynchronously via "Modules" posted on Brightspace; these are recorded sessions in which I go through the lecture material topic by topic, in a structured and organized manner. Each Module has a label and a number, as well as an indication of how many minutes it is. You are expected to view the Modules and are responsible for the lecture content in them. In order to stay current with the topics being discussed in the Class Time Period meetings, try to follow the schedule in the Calendar on Brightspace (which you can import into your Google Calendar, if you like): there, each date of a class meeting has associated with it the modules that are relevant to the discussion that day.

The Class Time Period will be utilized for in person discussion, which will include a summary of the lecture material that I will present and discuss in person; they will be available remotely through streaming and recordings (on Zoom). These meetings are optional in the sense that all of the lecture material is available in the Modules. Students will find the Class Time Period discussions helpful, hopefully, as they will include working examples, reviewing concepts from the lecture Modules, discussing homework problems,

taking questions from students, going over practice exams in preparation for the midterm and final, etc. These live sessions will be streamed and recorded (on Zoom) and available for access later, asynchronously. My goal is to engage as many students as possible personally, and get interaction going in class so that we can help you study in the most productive manner possible.

**Office Hours:** The instructor and TAs have explicitly reserved time slots each week to be available for you to obtain extra assistance, ask questions, and discuss course materials.

Office hours for Joe and the TAs are (tentatively) given below. Some office hours are available in person, some on Zoom (to accommodate remote students in Section 02), some potentially in both modes.

Explicit instructions for accessing office hours, along with any updates/changes to office hours, for the instructor and TAs will be maintained on Brightspace. The instructor and TAs will also be reachable through email at other times (see the section on "Communication" below).

**Question of the Day:** To foster engagement, we will have discussions that will include questions that arise on the topics being discussed, and at least one of these questions (the "Question of the Day" (QOTD)) will become available to students during the class time, in the midst of our discussions, and will be answerable on Brightspace in a brief window of time given to answer the QOTD. Participation in class, via answering the QOTD, will be part of the assessment used in assigning grades.

Note that you need to have access to Brightspace on some device in order to answer (and get credit for) the QOTD during each class meeting. Be sure you come to class with such a device.

**Attendance:** In order to stay current with the course content, it is important that you attend class meetings live (in person or on Zoom), and a portion of your course grade will be based on your attending class and responding to brief questions (the QOTD) given at a random time during each class meeting: Those responses will be entered via Brightspace, so it is important that you have ready access to Brightspace during class time, whether you are in the classroom in person or participating remotely.

On Brightspace the topics (and module numbers) for each class meeting are indicated with each date the class meets. Each date of a class meeting has associated with it the modules that are relevant to the discussion that day.

**Joe's Office Hours:** Joe's office hours (tentative): Tuesdays (2:30-4:00) and Wednesdays (3:30-4:00), or by appointment/email. Office hours will be conducted via Zoom; links are provided via Brightspace. If there is ever a need to shift the office hours, I will communicate this to you via Brightspace.

**Teaching Assistants:** Some office hours will be in person in the AMS Help Room (Harriman 202); some/all will be available on zoom. Details and links to be posted on Brightspace. (No office hours in the first week of classes, August 26-30.)

Youngin Kim (youngin.kim.1@stonybrook.edu); office hours Tuesdays and Thursdays, 5:00-6:00pm

Tejas Ravi (tejas.ravi@stonybrook.edu); office Mondays and Wednesdays, 4:30-6:00pm

Sam Wronoski (Samuel.wronoski@stonybrook.edu); office hours Mondays and Wednesdays, 12:15-1:45pm

**Piazza discussion board:** We will be using Piazza for class discussion. The system is designed to get you help fast and efficiently from classmates, the TAs, and myself. You are encouraged to post questions (and answers!) on Piazza.

Find our class page at: `https://piazza.com/stonybrook/fall2024/ams345cse355` (If you are not already signed up automatically, you can sign up there.)

**Communication:** Brightspace will be used for posting announcements, information, assignments, and exams. Course-related questions should be posted to Piazza. (It is possible that we will also use course discussion boards on Brightspace; if so, this will be announced on Brightspace.)

For personal/private issues, please use email, as listed at the top of this syllabus. If you use Brightspace's Email Tool, it will automatically include your full name, course name, and section when you send emails. The instructor and TAs strive to respond to your emails as soon as possible, but please allow 24–48 hours for a reply. Your Stony Brook University email must be used for all University related communications. All correspondence will be sent to your SBU email account. Please plan on checking your SBU email account regularly for course related messages. To log in to Stony Brook Google Mail, go to `http://www.stonybrook.edu/mycloud` and sign in with your NetID and password.

**Text:** There are two textbooks, and reading assignments and problems will come from both:
*Discrete and Computational Geometry*, by Devadoss and O'Rourke, and
*Computational Geometry in C (2nd ed)*, by O'Rourke.
These books and several other related books are available in the Math/Physics Library. One of the additional books in the library that may be useful is *Computational Geometry: Algorithms and Applications*, by de Berg, Cheong, van Kreveld, and Overmars. (This text is used in the graduate version of this course, AMS 545/CSE 555.)

**Course Description:** [from Undergraduate Bulletin] The design and analysis of efficient algorithms to solve geometric problems that arise in computer graphics, robotics, geographical information systems, manufacturing, and optimization. Topics include convex hulls, triangulation, Voronoi diagrams, visibility, intersection, robot motion planning, and arrangements. This course is offered as both AMS 345 and CSE 355.

**Prerequisites:** Officially, the prerequisite is listed as: "AMS 301; programming knowledge of C or C++ or Java." I will try to minimize dependence on prerequisites and will review material as needed. You will find basic concepts of combinatorics (counting, graphs, recursion) to be very useful; AMS 301 is good background, and this course is designed to build on what you have learned in AMS 301. Knowledge of basic design and analysis of algorithms is also very useful. Finally, it is helpful to have some experience with *some* programming language (e.g., Java, C, C++, Python, Matlab, etc). We will occasionally look at simple code fragments (usually in C), as examples of algorithm implementations; however, you do not need to be an experienced "programmer" (in C or any other language) to take this course.

**Course Topics:** A detailed schedule/calendar will be on Brightspace. Topics will include:

- Polygons, triangulation, visibility, art gallery problems
- Convex hulls
- Voronoi diagrams, Delaunay diagrams, proximity problems
- Point location search
- Arrangements of lines, hyperplanes; geometric duality
- Intersection problems
- Polygonal subdivisions, polyhedra
- Visibility, shortest paths, motion planning
- Clustering, classification, topics in CG relevant to machine learning

See the detailed Learning Outcomes at the end of this syllabus.

**Lecture Modules:** Relevant Lecture Modules (recorded presentations, posted to Brightspace) for each Homework/Exam:

HW1: Modules 1-8
HW2: Modules 9-14
HW3: Modules 15-18
HW4: Modules 19-21
Midterm: HW1-HW4
HW5: Modules 22-24
HW6: Modules 25-28
HW7: Modules 29-30
HW8: Modules 31-34
Final: HW5-HW8

**Homeworks:** There will be 8 (equally-weighted) homework assignments, tentatively due on the following evenings (upload to Brightspace): Sept 10, Sept 19, Oct 1, Oct 10, Oct 31, Nov 12, Nov 21, Dec 5 Due dates/times are subject to change; any changes will be announced and posted on Brightspace.

Homework will be posted on Brightspace as assignments; you upload your solutions there. Many/most students write their solutions on paper, then scan/upload to Brightspace. (There are many applications that readily allow you to scan pages to a pdf file from your smartphone; examples include Office Lens and CamScanner.) You are also welcome, of course, to submit solutions prepared electronically, with word processing, figure-drawing packages, etc. I can highly recommend the free software Ipe (`https://ipe.otfried.org/`) for drawing figures; it is particularly helpful in computational geometry, with tools to draw certain structures (Voronoi diagrams, etc).

Homework sets will include "practice problems"; these are meant for your practice – please attempt them, and better yet, solve them and write them up. You are **not** to submit the practice problems; you will be able to check your answers yourself, against the solutions, which will be distributed on Brightspace. You will be responsible for material on all of the practice problems – this material can appear on the midterm/final!

**Homework Policy: Homework due dates are strictly enforced**; with instructor approval for an *extenuating circumstance*, you can submit at most **one** late homework, provided it is submitted before solutions are posted. You may discuss homework problems with other students taking the course and with the instructor and teaching assistants. **The work that you turn in should always be *your own* write-up, and you should show that you personally understand everything that you write.** You are **not** to view other student writeups or use them (**or use internet resources**) while writing your own solution. **Please make certain that your writing is neat and clear, and that you have expressed your reasoning.** You will be assessed on both the correctness and the clarity of your answers.

Submitted homework must be legibly written. Problems that ask you to "prove" or "explain" something—*i.e.*, those that require words—must be written logically and in complete sentences. Parts of a solution should not be crossed out or located discontinuously on the page; you should instead rewrite your solution to make it easy to read. **Homework that does not meet these expectations will not be graded and will not receive credit.**

**Class Participation:** You are encouraged to ask questions in class during the Class Time Period, either by speaking out in class or on Zoom (unmute and speak, possibly after "raising your hand" in Zoom), or by typing in a question to the chat on Zoom. You are particularly encouraged to ask questions if you do not understand something or if you spot errors that I make in class – yes, I will make mistakes, and I hope we will all learn from them! I will always do my best to answer thoughtfully, politely and clearly; if you do not understand my response, ask again for clarification. In class, there will potentially also be Polls conducted via Zoom and in person.

Participation is important for following the class material and for being able to answer the Question of the Day when it is available.

You are also encouraged to participate (asynchronously) via the Piazza discussions, where students pose questions and help answer each other's questions. Students can also contribute questions or ideas via email. In some cases, students contribute to the class by implementing an algorithm that they can demo, possibly by sharing a link with the class. Another form of participation might be to record a short video in which you demo a program, explain a concept, or dive deeper into a problem related to material from class. (Some prior students in this class have done original work that has led to publication.)

Participation (either synchronously or asynchronously) will be considered in borderline letter grade assignment.

**Exams:** There will be two equally-weighted exams: a midterm (tentatively given on Mon, Oct 21, to be confirmed) and a (noncummulative) final given during the first half of the (confirmed) assigned final exam period (Wed, Dec 18, 2:15-5:00pm). For each of the exams, practice exams will be made available, along with solutions, and we will have dedicated review in class, to help students prepare.

During the second half of the final exam period, you will have the option to take a "Second-Chance Midterm". If you take the second-chance midterm, the new midterm score will be $0.8x_{high} + 0.2x_{low}$, where $x_{high}$ is the higher of the two scores (original and second-chance) and $x_{low}$ is the lower of the two scores.

**Respondus:** Our course is using Respondus LockDown Browser and Monitor (Section 02) for exams. You must install Respondus Lockdown Browser for Stony Brook, available at `https://download.respondus.com/lockdown/download.php?id=772113517`, prior to the start of the first exam. Should you need help during the exam, click the chat button on the bottom of the screen.

**Grades:** Your total average score will be based on 35% for each exam (midterm and final), 20% questions of the day (QOTD), and 10% homework (after dropping 2 lowest scored problems from the 16 submitted problems (2 per homework set)).
I will use your total average score to assign a letter grade; there is no pre-established scale or curve. (Typical letter grade distribution: About 1/3 A's, 1/3 B's, and 1/3 lower grades. Median letter grade is typically "B" or "B-".)

**How to Succeed in this Course:**

- Read and follow instructions in all course announcements.
- Keep current with the course calendar.
- View all posted lecture modules and review notes/slides associated with each module. Do this in a *timely* manner, in advance of the synchronous Class Time Period discussions about the modules. Use the calendar to stay on schedule!
- Attend synchronous Class Time Periods to see additional problems solved and to get help with homework assignments; participate by asking questions. If you miss a synchronous meeting, be sure to watch the recorded session of it.
- Complete all Questions of the Day associated with class meetings
- Take advantage of office hours to get additional help, as needed.
- Post questions and respond with answers on the course discussion pages on Piazza. Students often lead discussions there on course material and specifics of homework assignments, etc.
- Complete all assigned readings in the course; examine as many recommended readings and references as time permits
- Review all practice exam questions; take practice exams and compare to provided solutions to make sure you understand what you may not have done correctly.

**Information Dissemination:** Announcements and email communications will be done via Brightspace, with emails to your Stony Brook University email address. You are responsible for checking Brightspace and your email regularly. Exceptions will not be granted if you forward your Stony Brook emails to another account and a message is missed.

Course materials will be posted on Brightspace, including:

- This syllabus.
- Homework assignments and solution notes (posted within a few days after the hw is due).
- Class participation "Question(s) of the Day".
- Practice exams, and solutions.
- Other handouts and examples.

Discussions about questions, homework problems, etc will also appear on Piazza, where students are highly encouraged to post and respond to questions.

**Disability Policy:** If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC (Educational Communications Center) Building, room 128, (631) 632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and Disability Support Services. For procedures and information go to the following website: `http://www.stonybrook.edu/ehs/fire/disabilities`

**Academic Integrity Policy:** Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at `http://www.stonybrook.edu/uaa/academicjudiciary/`

**Critical Incident Management:** Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn.

**Electronic Communication Statement:** Email and especially email sent via Brightspace is one of the ways the faculty officially communicates with you for this course. It is your responsibility to make sure that you read your email in your official University email account. For most students that is Google Apps for Education (`http://www.stonybrook.edu/mycloud`), but you may verify your official Electronic Post Office (EPO) address at

`http://it.stonybrook.edu/help/kb/checking-or-changing-your-mail-forwarding-address-in-the-epo`.

If you choose to forward your official University email to another off-campus account, faculty are not responsible for any undeliverable messages to your alternative personal accounts. You can set up Google Mail forwarding using these DoIT-provided instructions found at

`http://it.stonybrook.edu/help/kb/setting-up-mail-forwarding-in-google-mail`.

If you need technical assistance, please contact Client Support by calling (631) 632-9800 or send an email to supportteam@stonybrook.edu.

**Student Technology Services:** TLT provides academic technology support to all students. If you require assistance with Brightspace or other academic technologies, please contact TLT at: helpme@stonybrook.edu; Phone: 631.632.9602; Chat; `http://www.stonybrook.edu/helpme` or visit a SINC Site.

Students who need assistance with their personal devices can contact DoIT's service desk at: 631.632.9800, submit an online request, or visit the Walk In Center on the 5th floor of the Melville Library (West Campus), Room S-5410. For more information, visit: `https://it.stonybrook.edu/students`

**Learning Outcomes** Learning outcomes for the course are as follows:

- Demonstrate an understanding of the geometry, combinatorics, and computation of discrete geometric structures including:
  - convex hulls of finite point sets in two and three dimensions;
  - simple polygons, polygonal domains, planar straight-line graphs, special classes of polygons (monotone, star-shaped, etc);
  - visibility and visibility coverage of polygons, including the Art Gallery Theorem;
  - triangulations and convex decompositions of point sets and planar polygonal domains;
  - planar graph properties that apply to the combinatorial analysis of geometric decompositions;
  - Delaunay diagrams and related proximity graphs on finite point sets in the Euclidean plane (Euclidean minimum spanning trees, nearest neighbor graphs, relative nearest neighbor graphs, Gabriel graphs);
  - Voronoi diagrams;
  - arrangements of lines in the plane;
  - geometric duality, including point-line duality in the plane and its application to problem solving.
- Demonstrate an understanding of the design and analysis of algorithms to solve algorithmic problems with geometric data:
  - learn to think algorithmically and to formulate precise algorithmic problems;
  - perform worst-case analysis of an algorithm in the language of big-Oh notation;
  - learn to develop precise algorithmic models of problems that arise in data analysis, interactions with the physical world, engineering, and operations research;
  - understand and utilize algorithmic paradigms in the design and analysis of discrete algorithms, including divide-and-conquer, plane sweep, incremental insertion, and hierarchical methods;
  - understand how primitive computations are done on geometric data using principles of vector analysis and analytic geometry;
  - understand the use of geometric data structures for segment intersection, triangulation, convex hull computation, and point location search.