Math for Game Designers – Spring 2018 GAMES-GT 321/GAMES-UT321

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Overview

Games have an intrinsic relationship with almost every branch of mathematics. From the randomness described by probability theory to formal logic for puzzles, games of every type are *built* out of math. However, for many designers without a formal education in a quantitative discipline, these areas can be esoteric and difficult to relate to games at first glance. This can handicap a designer's scope, or force them to rely on external help or tools.

This course is designed to remedy that by providing a toolkit of mathematical concepts, with an emphasis on their direct applicability to game design and development. Students will gain a grounding in mathematical concepts useful in game development, with a focus on individual adaptation and implementation, not memorization. This course of study is designed to empower game designers with backgrounds in the arts or humanities with a core framework for understanding math concepts to apply in games of all types.

Course Objectives

- Foster an understanding of a variety of mathematical principles, and learn to recognize when a given concept can be applied.
- Gain experience implementing concepts directly in code, and build a toolbox of functions to draw from in future work.
- Explore core mathematical concepts and discover new applications for them.
- Develop techniques for solving mathematical problems.
- Become familiar with using a spreadsheets program to help solve problems.
- Build experience programming mathematical concepts directly.

Course Format

The course meets once per week. The lecture will be used to introduce the week's topic through a presentation supplemented with in-class exercises and demos. There is no lab, so students will be expected to be proactive with seeking assistance through the class Slack and scheduling meetings with each other for the group projects. Students should expect to put in at least 10 hours per week outside of these two class meetings.

Required Readings

While there will not be a textbook, there will be occasional readings to be completed before a lecture. Students are required to complete the reading, as the lecture will require it as a baseline. Readings will be provided as PDF files or links to online sources.

Projects

There are seven projects in this class. Four small projects, two larger group projects, and final project. When each project is due, you will present your work to the class (briefly for the small projects, a few minutes for the group and final projects). Across all assignments, the focus is on implementation and usage of mathematical concepts, not game design or aesthetic polish.

Small Projects: These are short, circumscribed assignments where you'll implement a given concept. These can be demonstrations or minimally interactive.

Group Projects: These are slightly larger in scope, and collaborative with one or two other students. However, the extra time and effort should be spent on implementing more difficult or ambitious ideas, because as with the small projects the focus is not on polish.

Final Project: This is a more free-form larger project, where you will apply the content of the course in a project of your own design (either individually or with a partner). This should be a more thorough piece, both conceptually and technically, something you could show others or use in your portfolio.

Course Overview

Week 1	Class Introduction, Why Math, Excel Fundamentals & Graph Visualization
Week 2	Functions, Linear & Nonlinear Algebra, Graph Visualization
Week 3	Trigonometry
Week 4	Trigonometry Part 2
Week 5	Vector Math
Week 6	Matrix Math
Week 7	Probability
Week 8	Probability continued (incl. Game Theory & Combinatorics)
Week 9	Calculus
Week 10	Numerical analysis
Week 11	Noise
Week 12	Set Theory Packing / Exact Cover
Week 13	Graph Theory / Graph Isomorphism
Week 14	Fractals & Cellular Automata

Week-by-Week Schedule

PART 1: Reviewing the Classics
This section will focus on areas of math students may have encountered sometime before, and will focus on practical review and applications to games.

Week 1 – Introduction

TOPICS: (1st Lecture) Class overview & expectations, spreadsheet fundamentals & graph visualization, useful set-up for Unity.

ASSIGNED: **Small Project 1**: Writing a graph visualizer in Unity. Over the next two weeks, create a small project capable of visualizing an arbitrary function, expanding on the simple version from class.

Requirement: Write a program capable of charting a linear or nonlinear function.

Options & Ideas:

- 3rd Dimension: Graph on three axes
- Incorporate time: Animate a function over time to show a variable changing
- Can you think of any ways to graph without using a line?
- Low-resolution: What's the best visualization you can make with only 64 by 64 pixels?

Week 2 – Algebraic & Geometric Fundamentals

TOPICS: Review of fundamentals, functions, algebra, linear equations, polynomials & parametric equations, useful geometric axioms.

Week 3 – Trigonometry Part 1

TOPICS: Trigonometric equations, angles & rotation.

DUE: **Small Project 1**:

ASSIGNED: **Group Project 1**: Trigonometry Project. Working in groups of three, create a digital art piece focused on trigonometric relationships.

Requirement: The project must feature direct calculation using trigonometry, not the use of a built-in function (like LookAt or RotateTowards).

Options & Ideas:

- TBD

Week 4 – Trigonometry Part 2

TOPICS: Periodic functions, Fourier series.

Week 5 – Vector Math

TOPICS: Introduction to Vector space and vector algebra.

DUE: **Group Project 1**: Trigonometry Project.

ASSIGNED: **Small Project 2:** Vector Project. Build a simple project utilizing vector math.

Requirement: It must include both Vector addition, and the use of either dot product or cross product.

Options & Ideas:

- TBD

PART 2: Useful Advanced Math
This section will focus on topics students may not have covered previously, but are of particular usefulness in games.

Week 6 – Matrix Math

TOPICS: Introduction to matrices, matrix transformations

Week 7 – Probability

TOPICS: Calculating basic probability & conditional probability, geometric distribution.

DUE: **Small Project 2**: Vector Project.

ASSIGNED: **Small Project 3**: Probability & Randomness Project. For this project, you'll be working in pairs, building a project that capitalizes on the probability concepts from class.

Requirement: TBD

Options & Ideas:

- TBD

Week 8 – Probability Part 2

TOPICS: Game theory & combinatorics, distribution & introductory statistics.

Week 9 –Numerical Analysis

TOPICS: Optimization. Approximation & simulation using integration and iterative algorithms.

DUE: **Small Project 3**: Probability & Randomness Project.

ASSIGNED: **Group Project 2**: Simulation Project.

Requirement: TBD

Options & Ideas:

- TBD

Week 10 – Calculus

TOPICS: Rates of change, review of integrals and differentials.

PART 3: Novel Concepts

These remaining topics could be classes unto themselves, but even an introduction is valuable to enable students to recognize the concept and equip them for further study.

Week 11 – Noise

TOPICS: Pseudo-randomness, noise sampling, waveform math.

DUE: **Group Project 2**: Simulation Project

ASSIGNED: **Small Project 4**: Noise Art. Create something utilizing the noise library from class.

Requirement: You must use at least one noise generator, and at least one noise operator.

Options & Ideas:

- Abstract art creator
- Animate noise over time
- Convert the noise values to musical notes
- A 2D terrain generator

Week 12 – Set Theory

TOPICS: Logic, set algebra, exact cover & subset problems

DUE: **Small Project 4**: Noise Art

ASSIGNED: **Final Project**

Week 13 – Graph Theory

TOPICS: Formal graphs, node navigation, set cover, and pathfinding.

Week 14 – Fractals

TOPICS: Properties of fractals, self-sameness and recursive algorithms.

Grading

Each project will be evaluated with the following criteria:

- **Functionality.** Has the implemented something employing that week's concept? Does the code work successfully?
- **Appropriate for the assignment.** Has the project properly addressed the constraints and parameters of the assignment?
- **Creativity.** Beyond functional implementation, does the work show an imaginative use for a given concept?
- **Presentation.** Each work is presented in material form, were they articulated in a clear and concise way?

Students will be given grades based on a point scale. Each assignment will be graded on a point scale, and these points will be added up to determine the final grade, according to the following:

92-100%	A
90-91%	A-
88-89%	B+
82-87%	B
80-81%	B-
etc.	

The following are the components of the grade:

Participation & Attendance	25
Small Projects *(10 each)*	40
Group Projects *(10 each)*	20
Final Project	20
TOTAL	**100**

Late penalties
All assignments must be turned in on time and will not be accepted late without first speaking to the instructor.

Statement of academic integrity
Plagiarism is presenting someone else's work as though it were your own. More specifically, plagiarism is to present as your own: a sequence of words quoted without quotation marks from another writer or a paraphrased passage from another writer's work or facts, ideas or images composed by someone else.

Accessibility
Your health and safety are a priority at NYU. If you experience any health or mental health issues during this course, we encourage you to utilize the support services of the 24/7 NYU Wellness Exchange 212-443-9999. All students who may require an academic accommodation due to a qualified disability, physical or mental, please register with the Moses Center 212-998-4980. Please let your instructor know if you need help connecting to these resources.

Attendance
Attendance and arriving on time to all class sessions is required and expected, too many unexcused absences will lower your final grade. Three unexcused absences lower your final grade by a letter. Each subsequent unexcused absence will lower another letter grade. Two tardies will count as one absence. Arriving more than 15 minutes late will also count as an absence.

Please submit the following:

1. Cover Page

Please fill the cover sheet as it applies to the proposed course.

Note on estimating course hours:

Typical class hours are 2-3 total hours of work (in-class plus out-of-class) per week per credit hour. For example, a typical 4-credit course will have students working for a total of 8-12 hours per week. Classes may vary from this standard, for example, if the class only meets for 7 weeks of the semester.

Note on course formats:

Select the course format that most closely fits the proposed class. If the class does not fit one of the types, describe the format and list the approximate percentage of in-class time.

- **Lecture / Seminar**: a class where most student work takes place outside of class, such as a humanities course with in-class lectures and discussion, but students complete readings and conduct research, and write papers outside of class time. About 1/3 of student work time takes place in class, and about 2/3 of work time takes place outside of class. For every hour of in-class time, a student works about 2 hours outside of class.

- **Laboratory / Colloquium / Hybrid / Practicum:** a class with some guided work time, such as a production class with a lecture and a lab where the instructor or a teaching assistant instructs as students work. About 1/2 of student work time takes place in class, and about 1/2 of work time takes place outside of class. For every hour of in-class time, the student spends an hour outside of class. Note that this category is for the entire course, not just the lab portion of a class.

- **Workshop / Studio:** a class where almost all of the student work takes place inside the class, such as a dance class where the main activity is training in class. About 9/10 of student work time takes place in class, and about 1/10 of work time takes place outside of class. Students spend a relatively small proportion of time working outside of the formal class meeting.

2. Statement of Purpose

On a separate sheet outside of the syllabus, please provide a brief Statement of Purpose for the course being proposed. The statement should be approximately 200-1000 words in length.

The Statement of Purpose should provide the reviewing committee with information that helps them understand the purpose of the course and how it fits into the existing curriculum at Tisch. For example, is the course part of a larger curriculum shift by a department? Is it filling a hole currently in the curriculum? Is it a revision of an existing course? Remember that most or all of the reviewing committee will not be familiar with the discipline of the course, so feel free to provide background from your field to help us appreciate what about the course is innovative or distinctive and how it will serve the needs of Tisch students.

Also, help the committee understand the intended audience for the course. Is it a highly focused advanced class open to majors only? Or is it an introductory course open to any NYU student? What kind of student will most benefit from the class?

Lastly, if there are existing courses that overlap with the proposed class, particularly in other Tisch departments, help the committee understand the need for the proposed course. Please note that redundancy is not always negative. For example, an introductory course in Open Arts that overlaps with a more focused class open only to majors is perfectly valid. In this case, the Open Arts course gives non-majors at Tisch or from other NYU schools access to the topic. Please discuss any such possible curricular overlaps.

3. Detailed Syllabus

The following are required in every syllabus:

- ☐ **Course Title and Number.**
- ☐ **Course description and student learning objectives.** Clearly explain the class objectives. Outline the content area covered and the skills developed by students through the course.
- ☐ **Course requirements.** Describe the activities of the class, such as labs, recitations, exams, papers, projects.
- ☐ **Schedule of assignments.** List every assignment and its due date (readings, papers, presentations, etc.).
- ☐ **Brief description of assignments.** Each assignment should be clearly described. For example, a written assignment should indicate whether the writing is based on class materials or original research, as well as the word or page count. A presentation should include a target time limit, and what documentation (if any) is required. More detailed descriptions of assignments can be handed out in class during the semester.
- ☐ **Required texts and reading lists.** Page numbers must be given for each reading assignment as well as the week that each reading will be discussed. The syllabus should link the reading to the weekly work and should also indicate the method of assessing that the readings have been completed. In regards to your readings, please comply with NYU's intellectual property policy, which can be found at the following URL:

  http://www.nyu.edu/about/policies-guidelines-compliance/policies-and-guidelines/educational-and-research-uses-of-copyrighted-materials-policy-st.html
- ☐ **Grading criteria.** List the evaluation criteria used to grade each assignment. This may vary per assignment.
- ☐ **Grade breakdown.** Include a percentage breakdown for all work that will impact the final grade.
  Note about attendance: Attendance cannot be part of a percentage of a student's final grade: attendance is mandatory. However, it is common to have a participation component to a grade. Students should be penalized for not attending class, but a student cannot earn a grade merely by attending a class.
- ☐ **Course policies and workload.** Include policies for grading, make-up work, class participation, etc. List the expected hours of work time outside of the class meeting.
- ☐ **Attendance policy.** It is up to each instructor to set the attendance policies for a class, which must be clarified in the syllabus. This includes policies for tardiness as well as excused and unexcused absences. Note that students cannot get credit for a class merely by showing up (there must be other work and assignments). However, coming late to class and missing classes can negatively affect a student's grade, depending on the policy set by the instructor.

While not strictly required, the following are useful elements of a syllabus:

- ☐ **Additional resources.** Listings of organizations, websites, books, or other research materials that will be of use to students enrolled in the class.
- ☐ **Statement of Academic Integrity -** From the TSOA Policy and Procedures Handbook:
  Plagiarism is presenting someone else's work as though it were your own. More specifically, plagiarism is to present as your own:
  - *a sequence of words quoted without quotation marks from another writer*
  - *a paraphrased passage from another writer's work*
  - *facts, ideas, or images composed by someone else*
- ☐ **Accessibility Statement -** The Moses Center recommends including the following:
  Academic accommodations are available for students with documented disabilities. Please contact the Moses Center for Students with Disabilities at 212-998-4980 for more information.

Do not include your statement of purpose as part of the syllabus. Please submit it on a separate page.