Exploring the Laplacian in Computer Graphics
EN 500.111
Fall 2023, 1 credit

Instructor
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Office: Hackerman Hall 136
Office hours: by appointment

Meetings
Th 9:00AM - 10:15AM, Homewood Campus, Bloomberg 178

Prerequisites
All students at Hopkins, including freshmen, are eligible to enroll in this course. It does not have any prerequisites.

Course Information

This course provides a practical, hands-on introduction to computer graphics, serving as an inspiring stepping stone towards the advanced 3 credit course in Computer Graphics. Central to this study is the fundamental concept of "the Laplacian" in computer graphics, an important topic, but not addressed in the 3-credit course. This technology has many practical applications, including computer game modeling, animation, and visual effects in movie production. The concept will be illuminated from both an algebraic and geometric perspective, accompanied by real-life examples and practical exercises. This course is designed to offer an expansive understanding of the role of the Laplacian in computer graphics, further enriched by hands-on opportunities coding with C++.

Course Goals

Specific Outcomes for this course are that
- Knowing what's "the Laplacian" in the context of computer graphics.
- Knowing the applications of "the Laplacian".
- Able to use CMake to compile and run the first C++ code on MacOS/Windows/Ubuntu.
- Knowing how to install/compile/run popular libraries in computer graphics. (Libigl, Polyscope)

Rubric

- Grading is P/F based on attendance and participation.
- There will be an art contest by the end of the course.

- Attendance is mandatory. If you need to miss a class, please email me in advance (before class starts). You may have 1 excused absence, and 1 unexcused absence.

Learning Environment

- Questions are welcomed during the lecture. Raise your hand any time when you have a question. Don't worry about interrupting me.
- Accessibility to a laptop or a PC might affect your learning progress in the hands-on part of this course. If your computer takes half an hour to turn on, that's definitely affecting your progress. Don't hesitate to contact me.
- Don't hesitate to reach out to me for help, if you find the environment not safe, due to discriminative/unfair behaviors/treatments in the classroom.
- Don't hesitate to reach out to me for help, if you find either your friend or yourself started to struggle in my class due to anxiety/stress/depression. (For instance, a 0 signifies you're in your dorm, tearfully cuddling your beloved teddy bear, while a 5 represents you've just earned a Fulbright scholarship. Should your situation rank lower than 3, don't hesitate to contact me.)

Course Topics (10 Weeks, 10 Lectures)

Week	Session's topic	Instructor will	Students will
1	Overview & motivation	Show demos, share stories/anecdotes in the history of math and computers.	Have fun, stay curious.
2	Data	Explain what's image/mesh/point cloud. Will cover how these data are captured by sensors, stored in a computer, and how to access them.	Take notes.
3	Using CMake to compile a C++ codebase, and run it	Before class, pre-record a video about how to install and compile with CMake on MacOS, Windows, and Linux. At class, half-time lecture about CMake, half-time pair-coding with students.	Compile their first C++ code with CMake. The result is coloring a bunny with the code.
4	"The Laplacian" for 2D images	Using the Laplacian for image sharpening.	Take notes.
5	"The Laplacian" for 3D models part1 (meshes)	Using the Laplacian for mesh simplification.	Take notes.
6	"The Laplacian" for 3D models part2 (point clouds)	Using the Laplacian for point cloud simplification.	Take notes.
7	"The Laplacian" as second derivative	Explain why the Laplacian is a second derivative, and how it's derived.	Take notes, do a couple of math exercise questions in class.

8	Workflow of character modeling in game and movie design/ "The Laplacian" and spectral analysis	Explain the industrial workflow/Explore more in depth on the math side why Laplacian helps maintain details of high frequency signals.	Vote for which topic interests you more before class ,and Take notes.
9	Applications of "the Laplacian" in computer graphics and vision (perhaps in the format of guest lecture & pre-contest office hour)	Show examples where the Laplacian benefits applications such as segmentation/reconstruction of geometric data in the real world.	Take notes.
10	Pair coding & Art contest	Leave blanks in a C++ codebase that applies Laplacian to estimate total curvature.	Pair coding in class, and have an art contest.

Resources for Reference

*Note: Our course has no prerequisites, focuses on intuitions, so we are doing lots of handwavings here and there when it comes to math. But it would be beneficial to point you to resources mathematically rigorous in case you are interested in digging. Lectures I mentioned are the most relevant. In general, the whole playlists are good contents. The books are rigorous to another level. Those are super well-written textbooks though. You might find them not that hard to follow.

Optional lectures: Shape Analysis, Justin Solomon, MIT
Lectures 12, Lecture14, Lecture14 Extra Content, Lecture 15 from this playlist:
https://www.youtube.com/watch?v=VjyBp6PrvB4&list=PLQ3UicqQtfNtUcdTMLgKSTTOiEsCw2VBW

Optional lecture: Discrete Differential Geometry, Keenan Crane, CMU
Lecture 18 from this playlist:
https://www.youtube.com/watch?v=mas-PUA3OvA&list=PL9_jI1bdZmz0hIrNCMQW1YmZysAiIYSSS&index=1

Optional lecture: A Quick Introduction to the Laplacian and Bilaplacian Through the Theory of PDEs, Oded Stein, USC:
https://www.youtube.com/watch?v=LUcn9GzhFDA&t=271s

Optional textbook: Botsch M, Kobbelt L, Pauly M, Alliez P, Lévy B., *Polygon Mesh Processing*, CRC Press (2010)

Optional textbook: Mantredo Carmo, *Differential Geometry of Curves and Surfaces* (2016) (Online access: http://www2.ing.unipi.it/griff/files/dC.pdf)