

CS3451: Computer Graphics

The Beautiful Computer Graphics

Bo Zhu

School of Interactive Computing
Georgia Institute of Technology





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About

Awards

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SIGGRAPH 365



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The ACM SIGGRAPH community is a global nonprofit organization serving the evolution of computer graphics and interactive techniques. With thousands of members across the world, the researchers, artists, developers, filmmakers, scientists, and business professionals of ACM SIGGRAPH are building the future of digital art and interactive design.

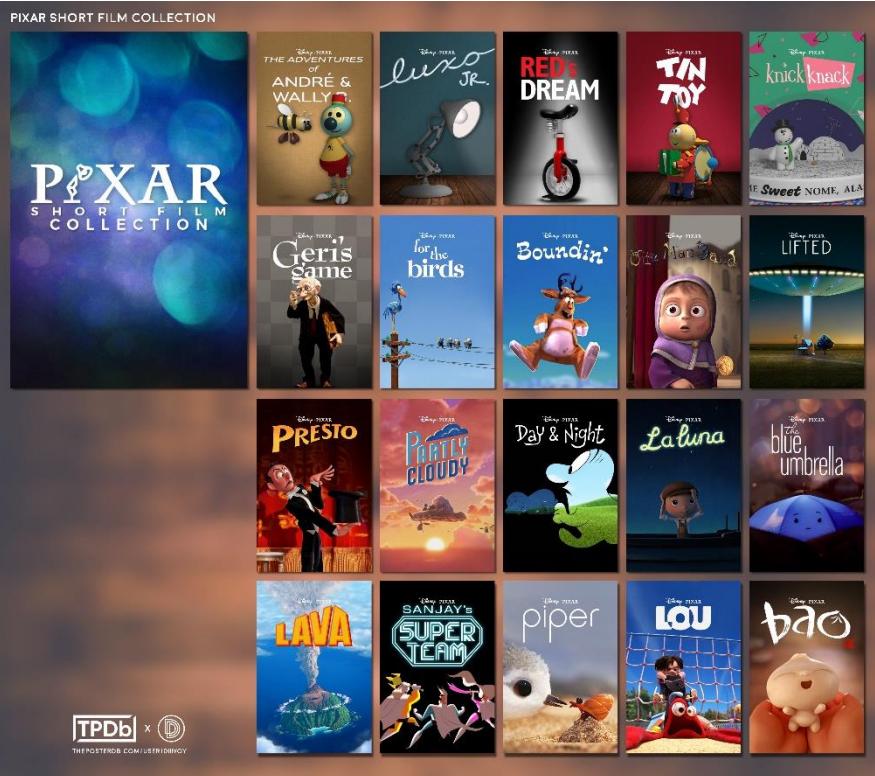
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Electronic Theater in SIGGRAPH

PIXAR SHORT FILM COLLECTION



SIGGRAPH Short Films



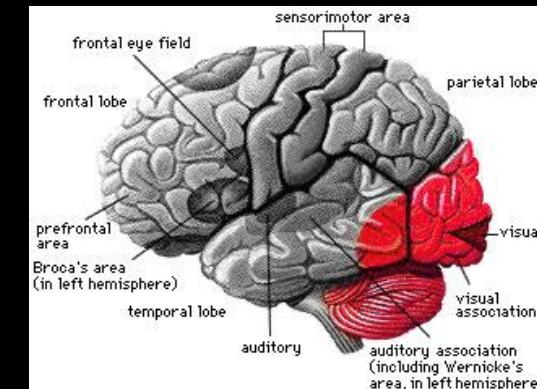
Motivational short
film for this Year ☺



GT

What is computer graphics?

- The use of computers to synthesize and manipulate visual information on a computer screen.



Eyes are the highest bandwidth port into the head

Humans are visual creatures!



Computer graphics is *everywhere* !

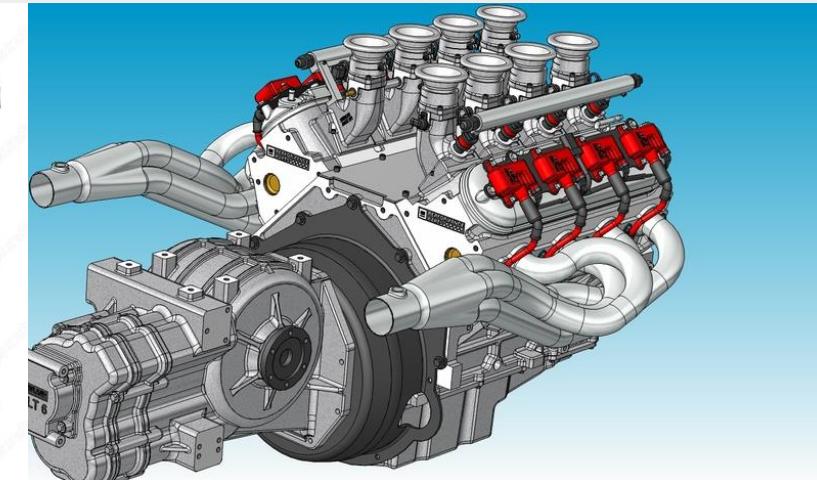
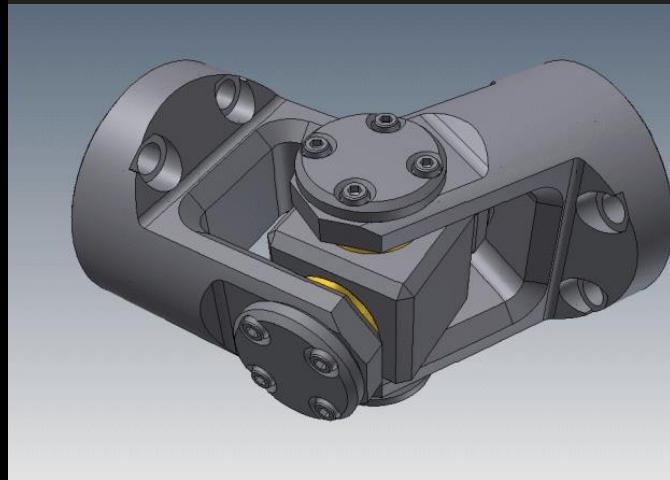
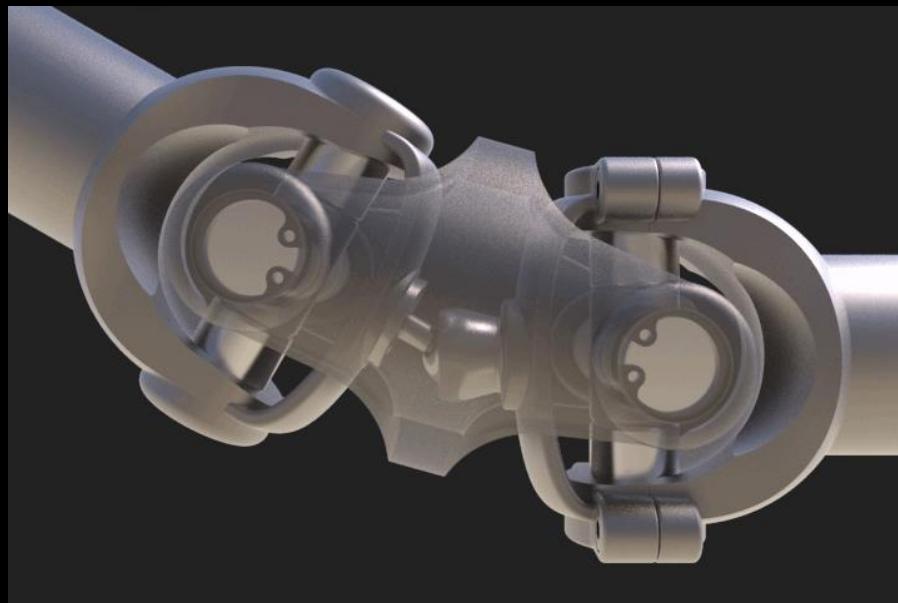
Animated Films



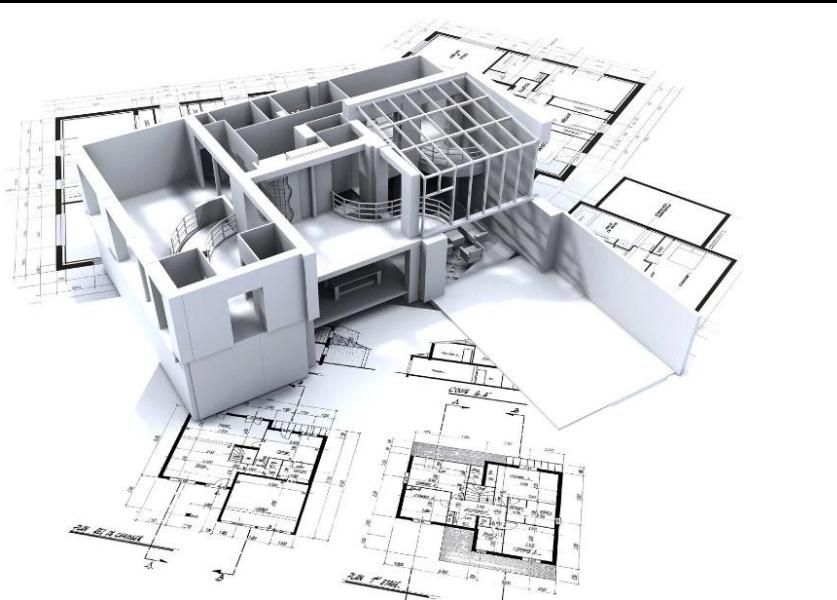
Video Games

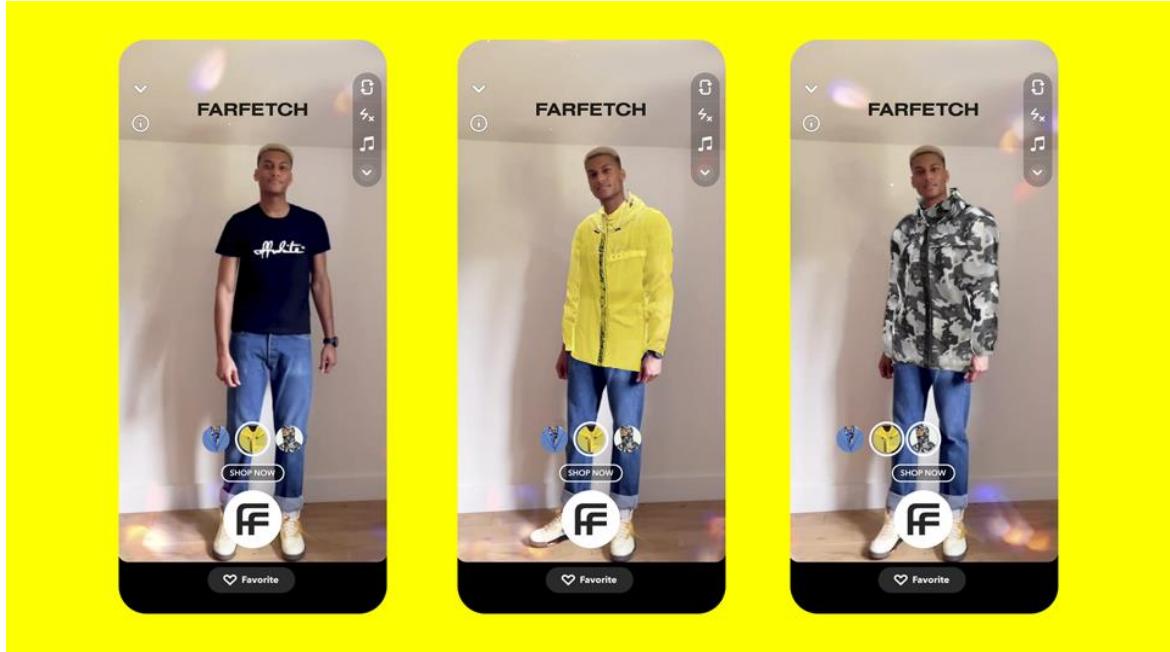


Computer Aided Design/Visualization



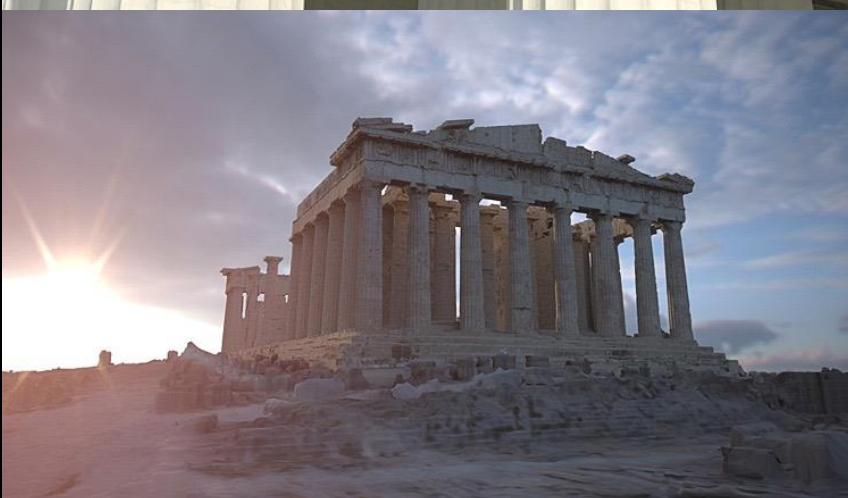
Architectural Design



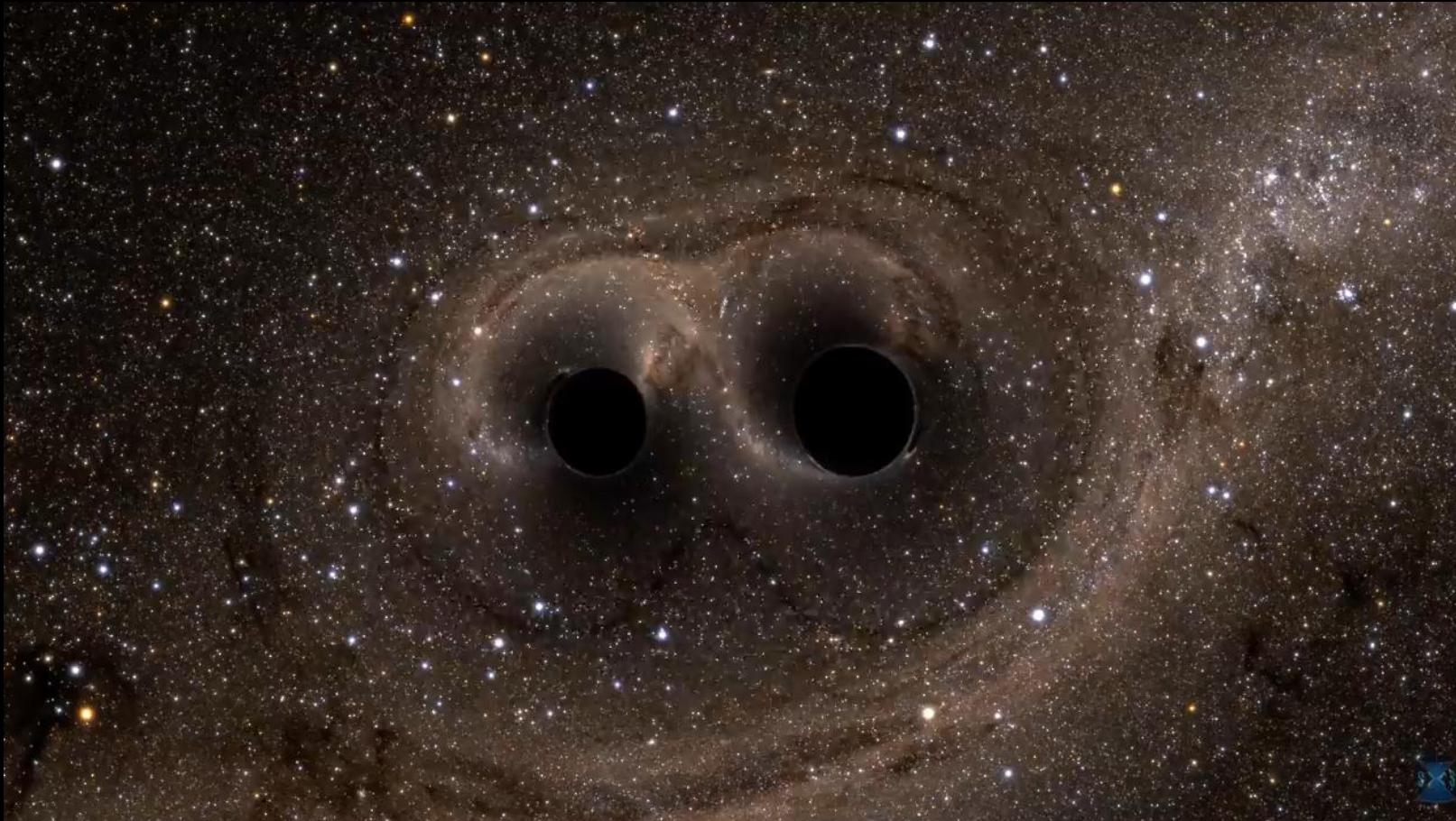


Advertising & E-commerce

Cultural Heritage



Scientific Visualization



LIGO Caltech : MIT

GT

Graphic Arts



Interactive Graphical Design



Virtual Surgery



3D Reconstruction

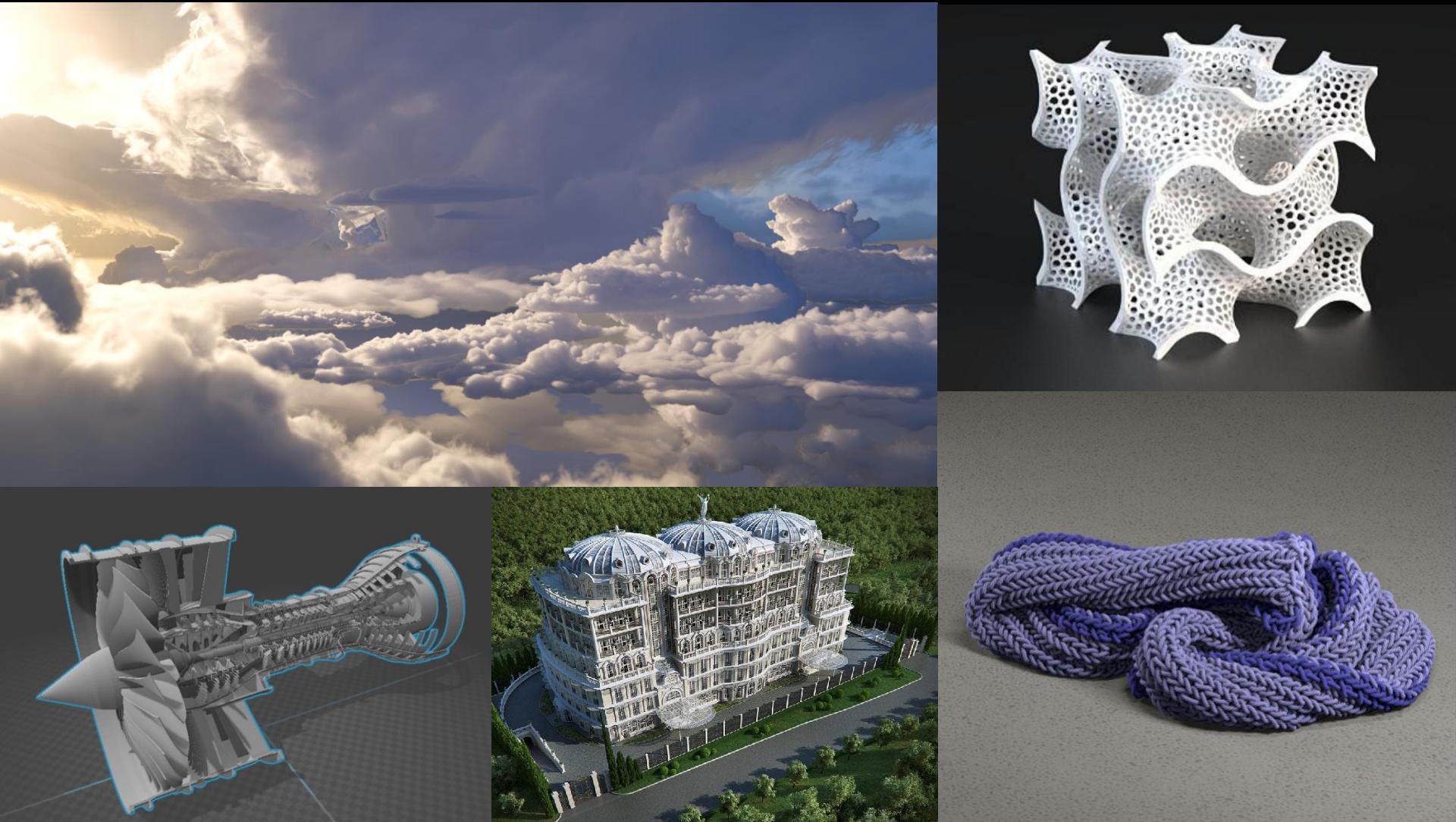
NVIDIA #InstantNeRFSweepstakes
Some entries . . . and the two winners



Generative Graphics

Computer Graphics Challenges

Complex 3D Surfaces & Volumes



Various Material Styles



Realistic Motion and Physics

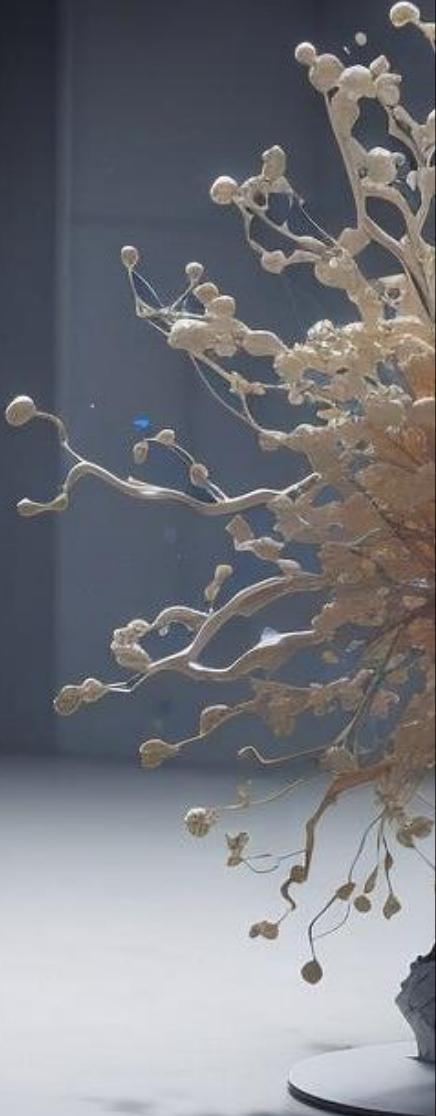


WALL-E (Pixar, 2008)

Real-Time Performance

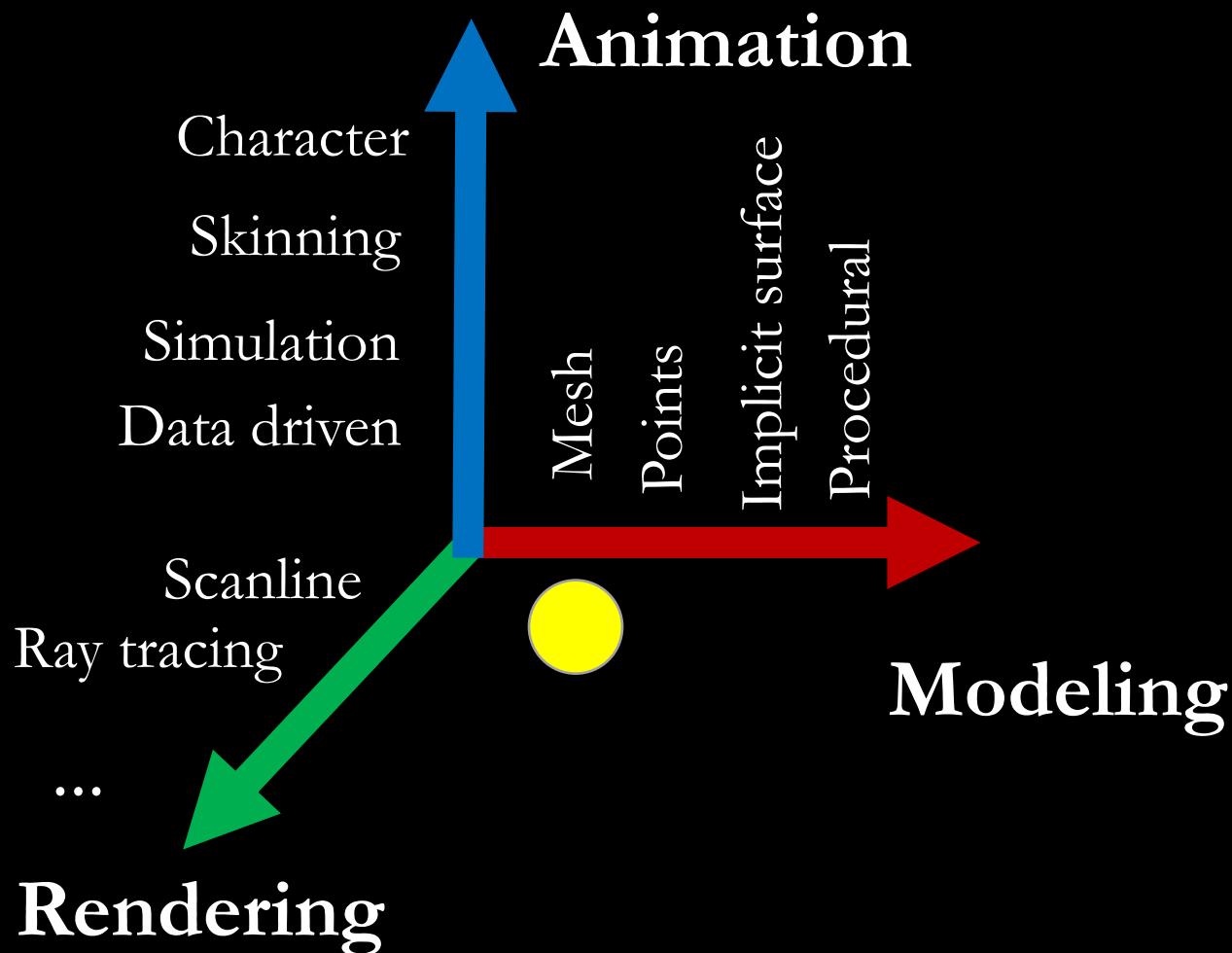


Connect to the Real World



Course Overview

Course Structure



Content Overview

Modeling

- Mesh processing
- Parametric shape
- Implicit surface

Animation

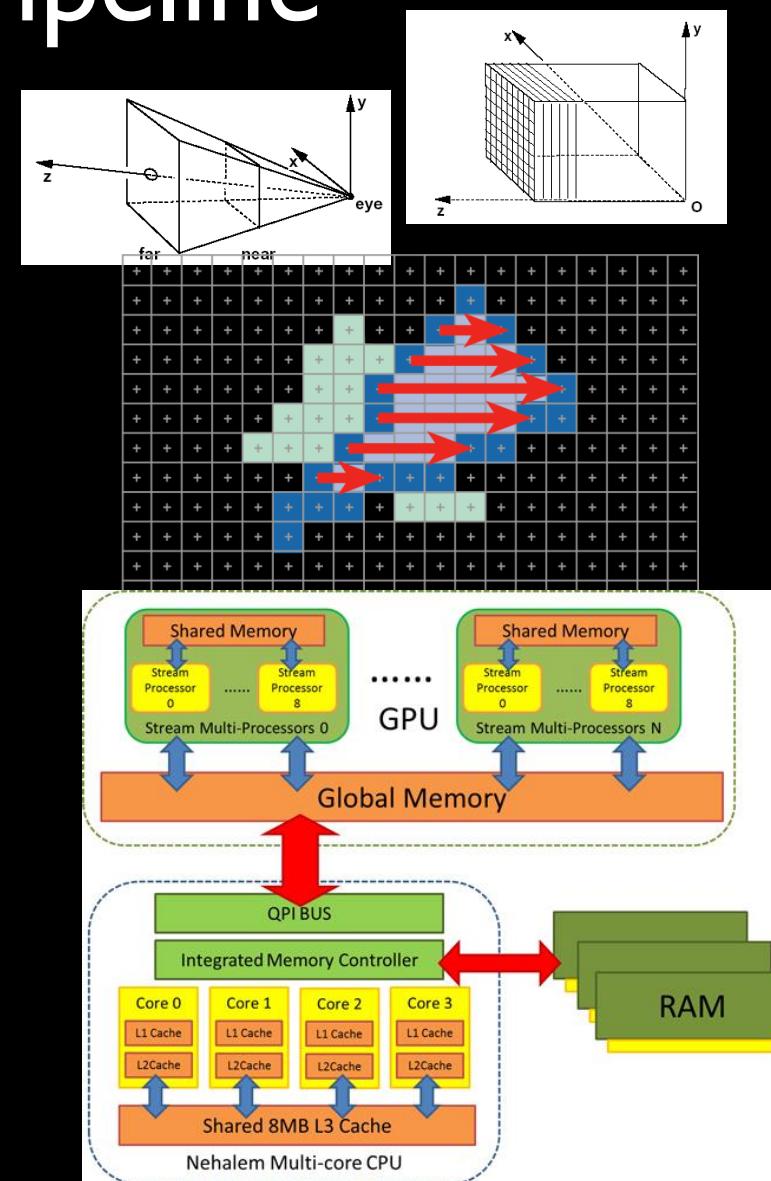
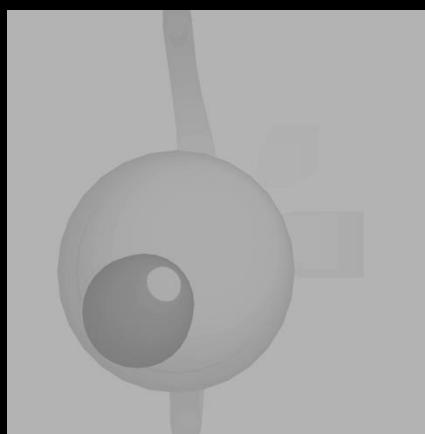
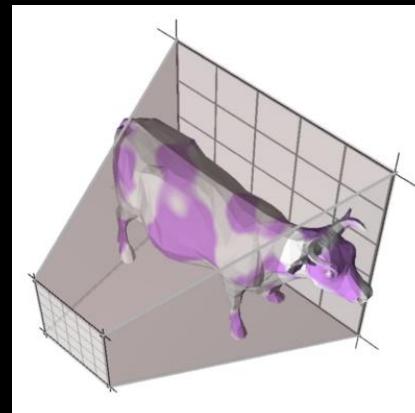
- Particle system
- Procedural modeling
- Articulation and skinning
- Physically-based animation

Rendering

- Scanline Rendering, OpenGL
 - Lighting, sampling, texturing,
- Ray Tracing
- Global Illumination

Foundation: The Graphics Pipeline

- Transformations
- Clipping
- Rasterization
- Visibility



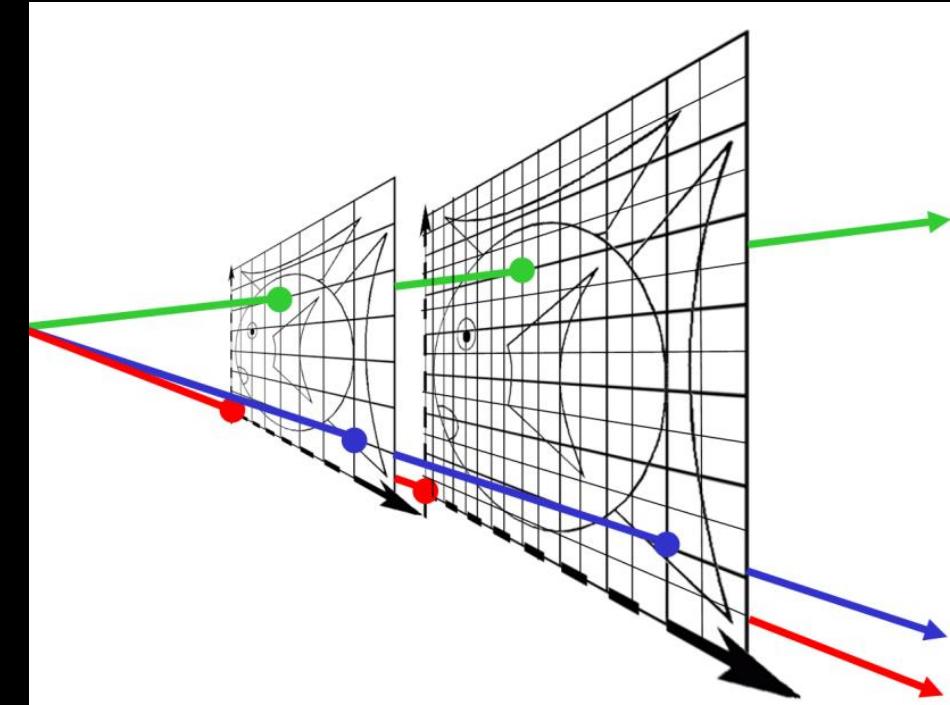
Foundation: Linear Algebra

- Transformation
- Homogeneous coordinates
 - Add a fourth dimension
- Perspective

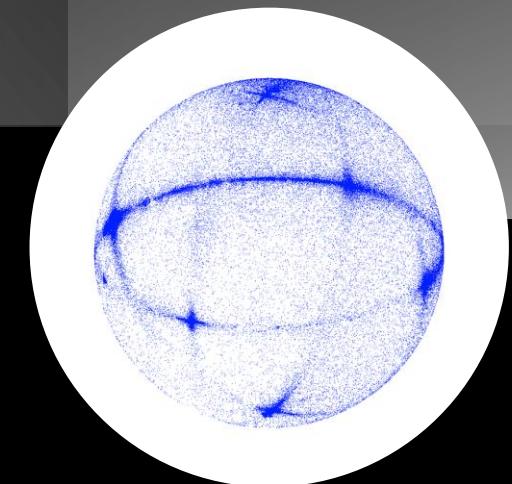
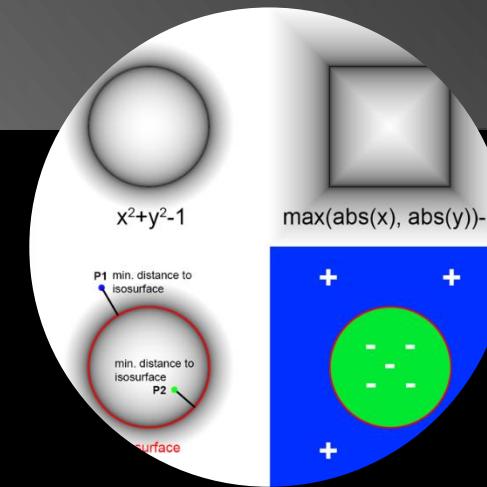
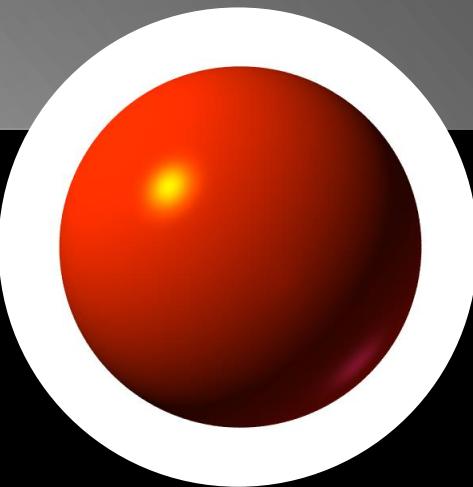
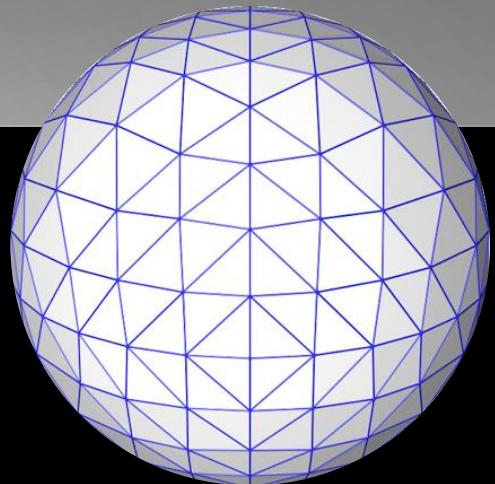
$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} ax+by+cz+d \\ ex+fy+gz+h \\ ix+jy+kz+l \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ z' \\ 0 \end{bmatrix} = \begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 0 \end{bmatrix} = \begin{bmatrix} ax+by+cz \\ ex+fy+gz \\ ix+jy+kz \\ 0 \end{bmatrix}$$

MIT EECS 6.837, Durand and Cutler

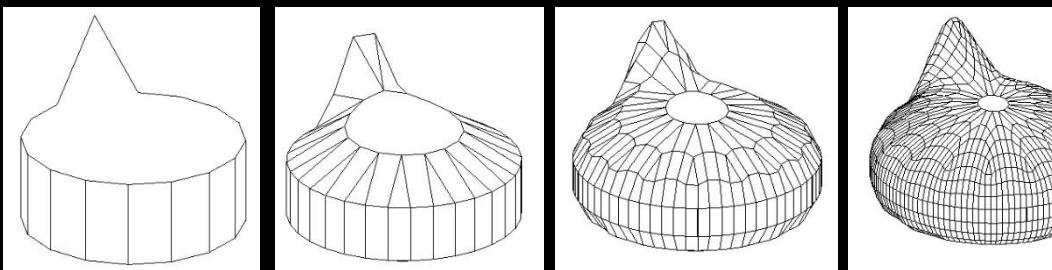
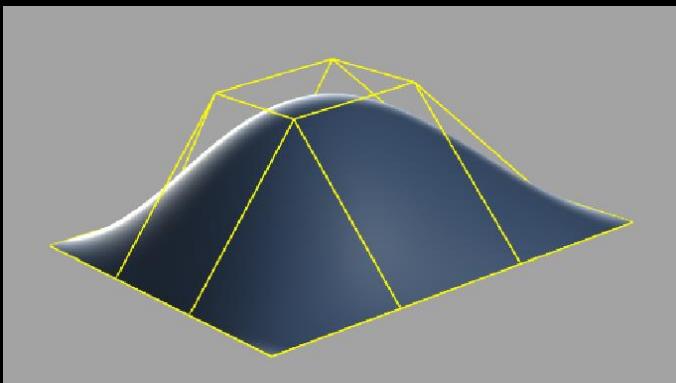


How to represent a sphere?

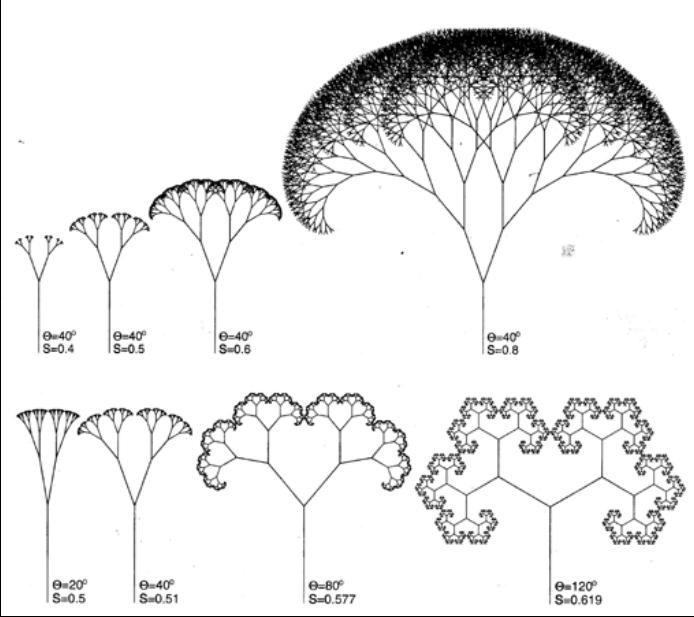


Modeling: Mesh

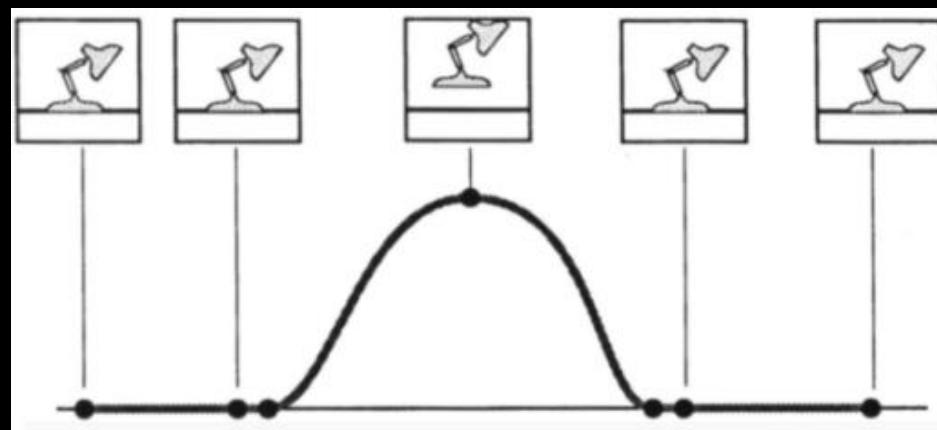
- Curves and surfaces
- Subdivision surfaces



Procedural Modeling



Animation: Keyframing



ACM © 1987 "Principles of traditional animation
applied to 3D computer animation"

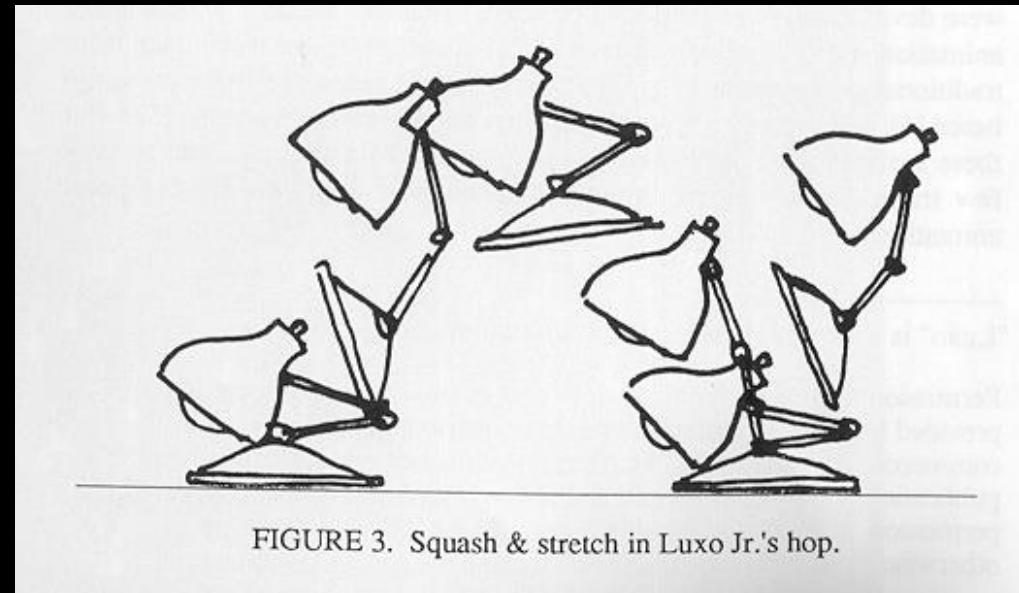
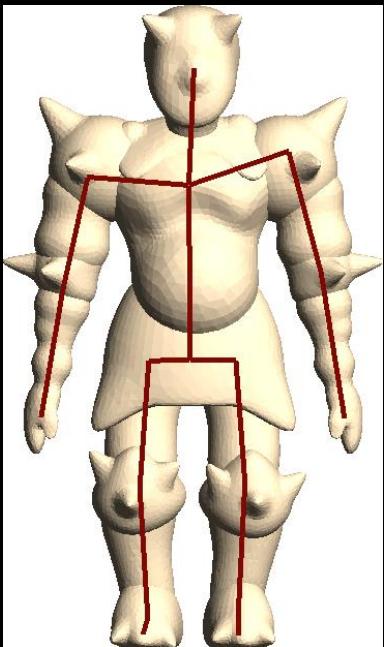


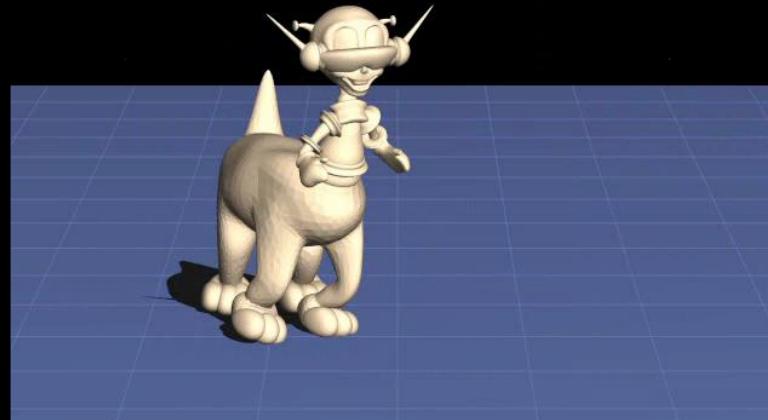
FIGURE 3. Squash & stretch in Luxo Jr.'s hop.

Animation: Skeleton and Skinning

- Animate simple “skeleton”
- Attach “skin” to skeleton
 - Skin deforms smoothly with skeleton
- Used everywhere (games, movies)

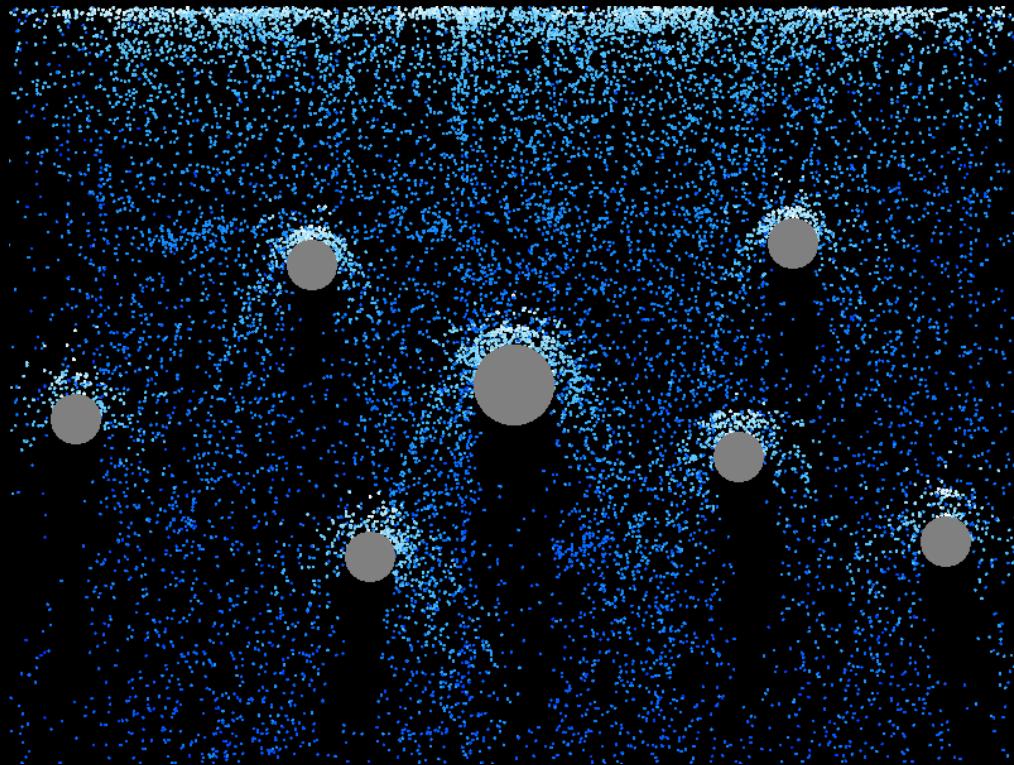


Ilya Baran



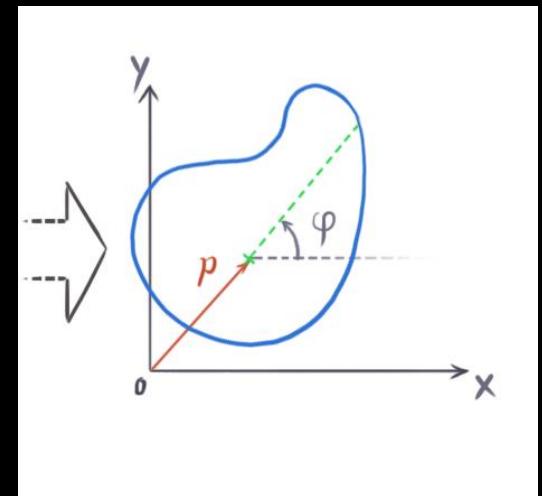
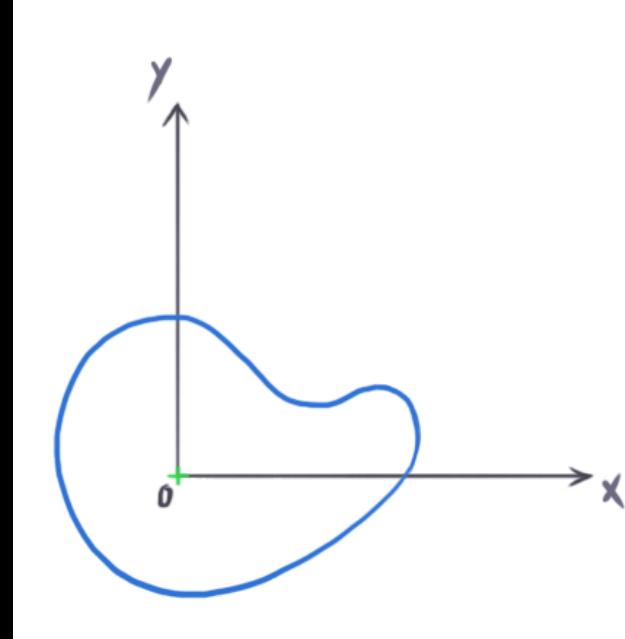
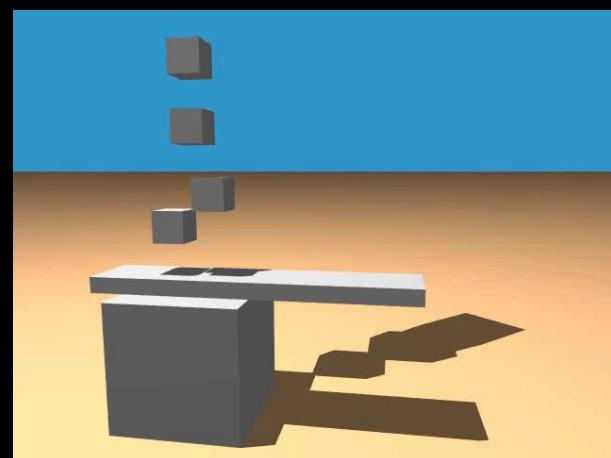
Epic Games

Animation: Particle Systems



dissolving particle shapes
VEX Particle Count 10 - 32 Million

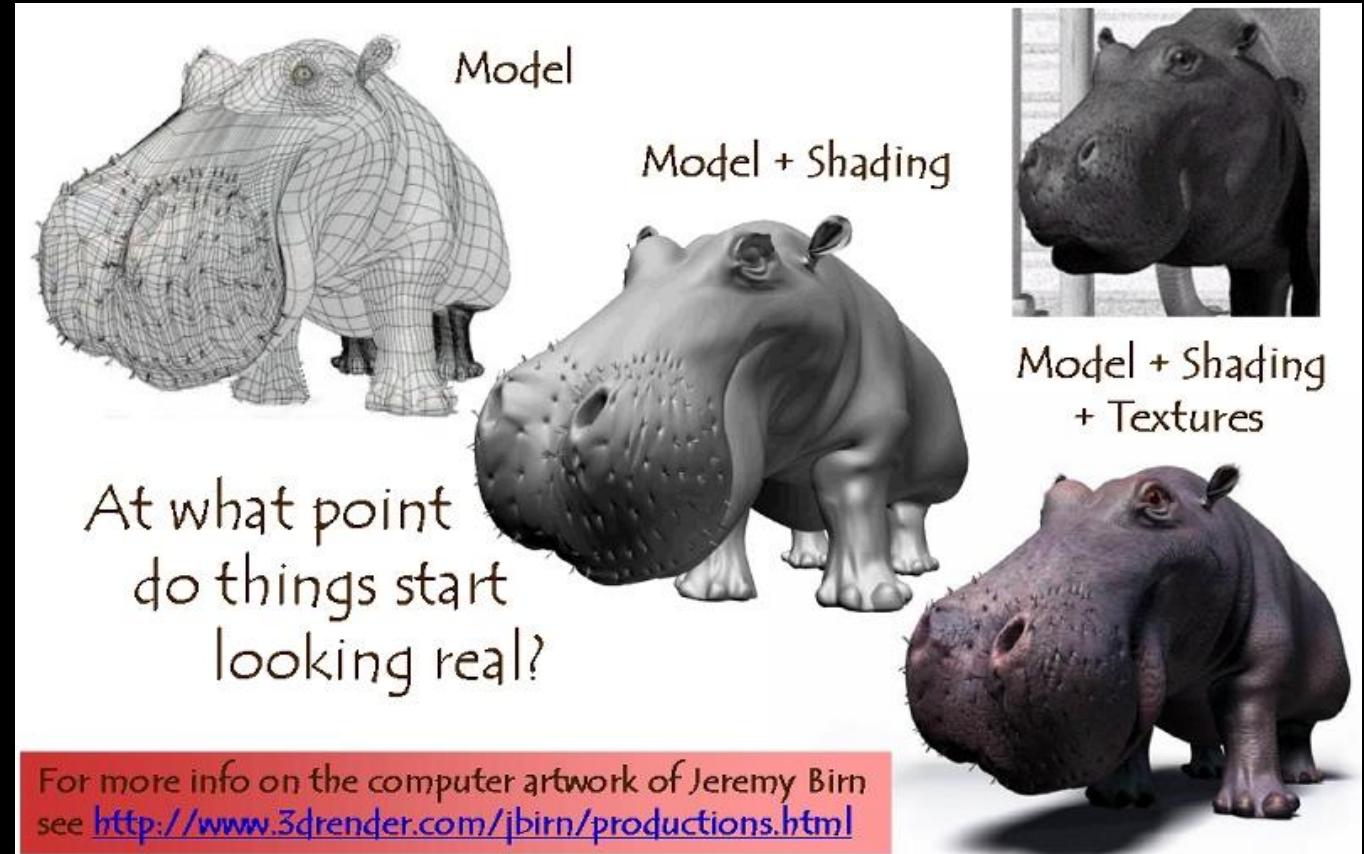
Animation: Physically-Based Animation



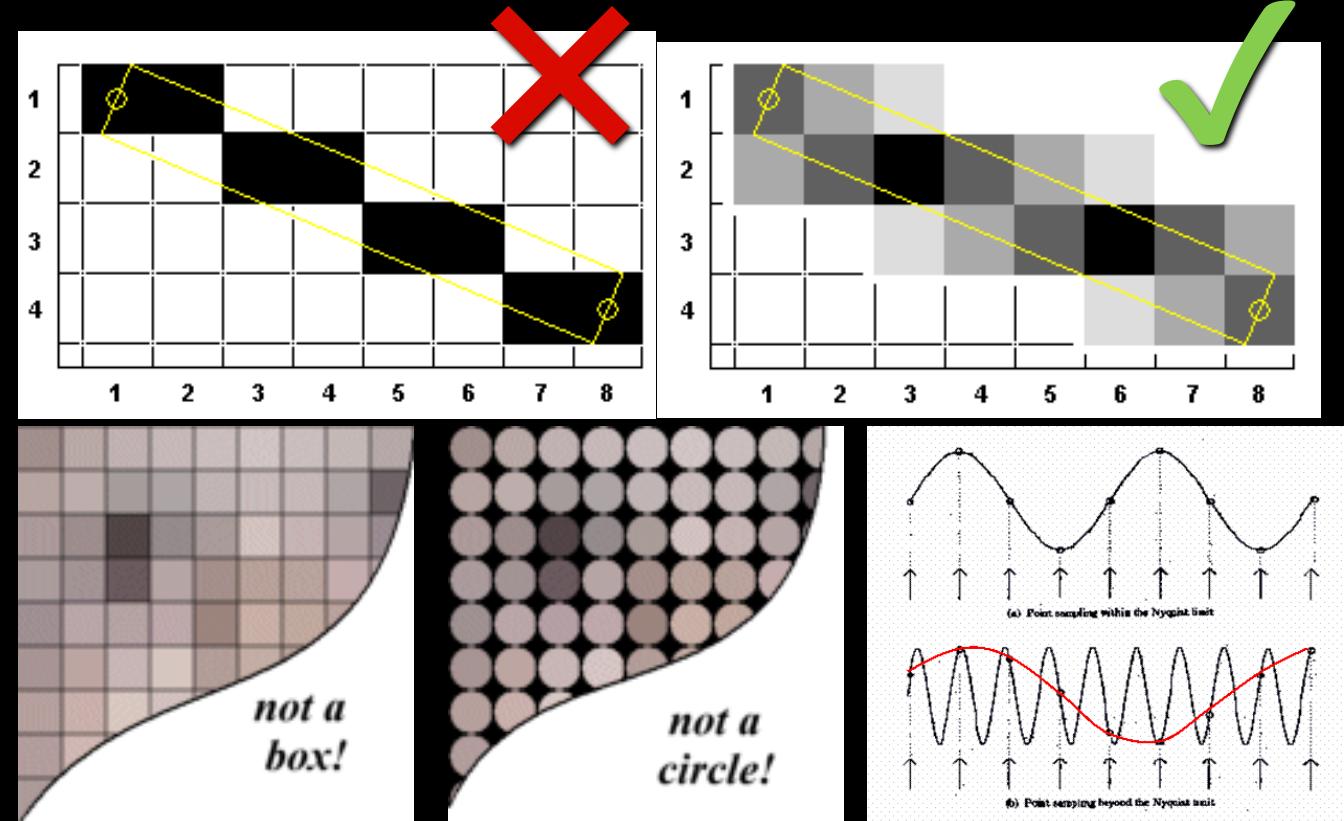
Rendering: Lighting and Shading



Rendering: Texturing and Mapping

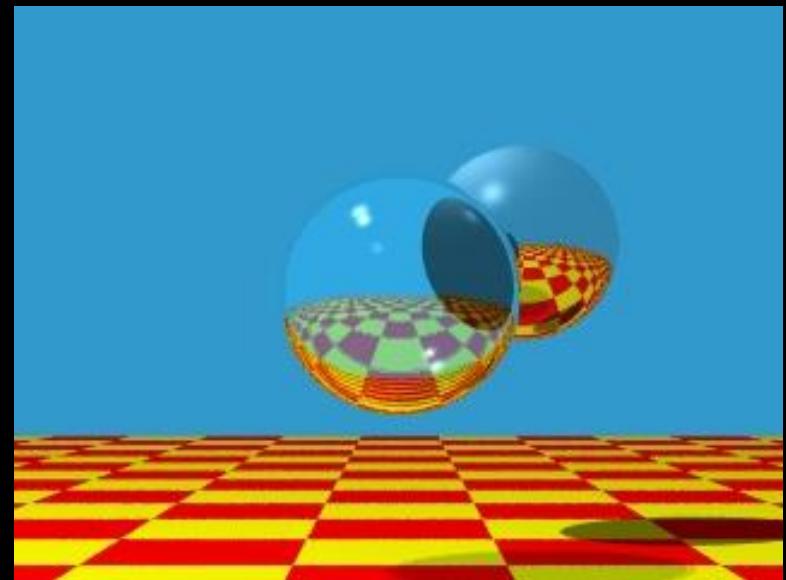


Rendering: Sampling & Antialiasing



Rendering: Ray Tracing

- Shade (interaction of light and material)
- Secondary rays (shadows, reflection, refraction)



Rendering: Shadows

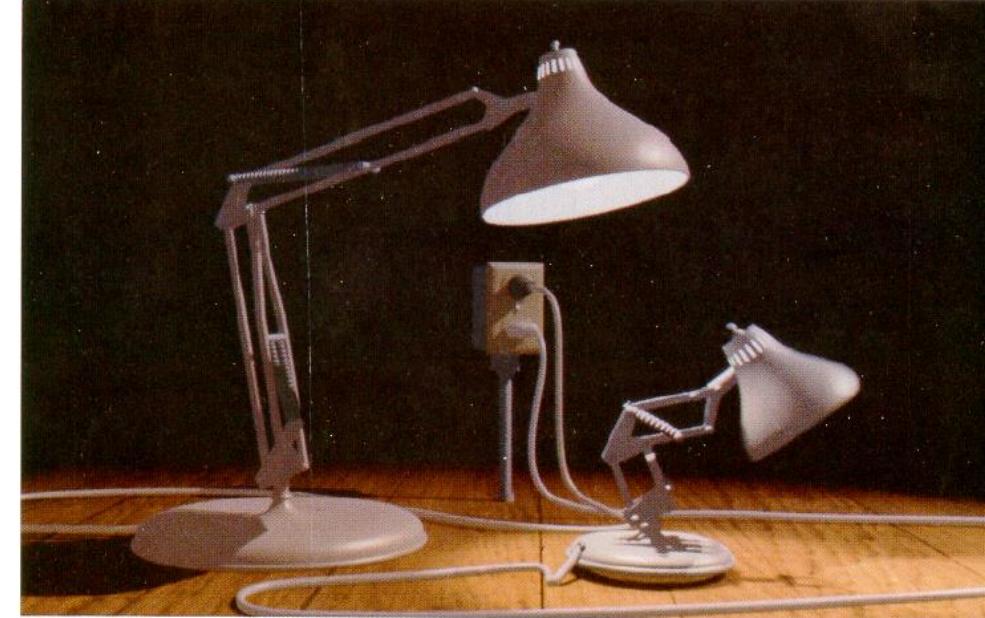


Figure 12. Frame from *Luxo Jr.*

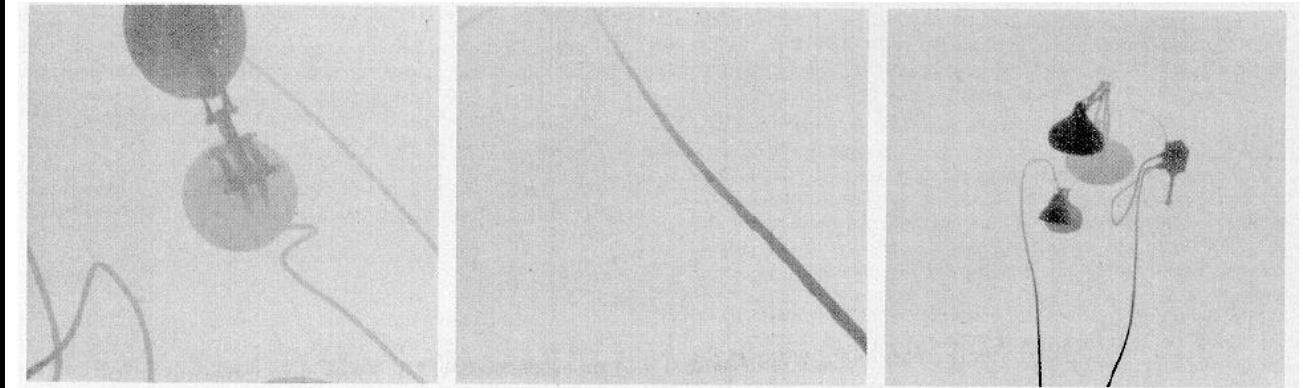
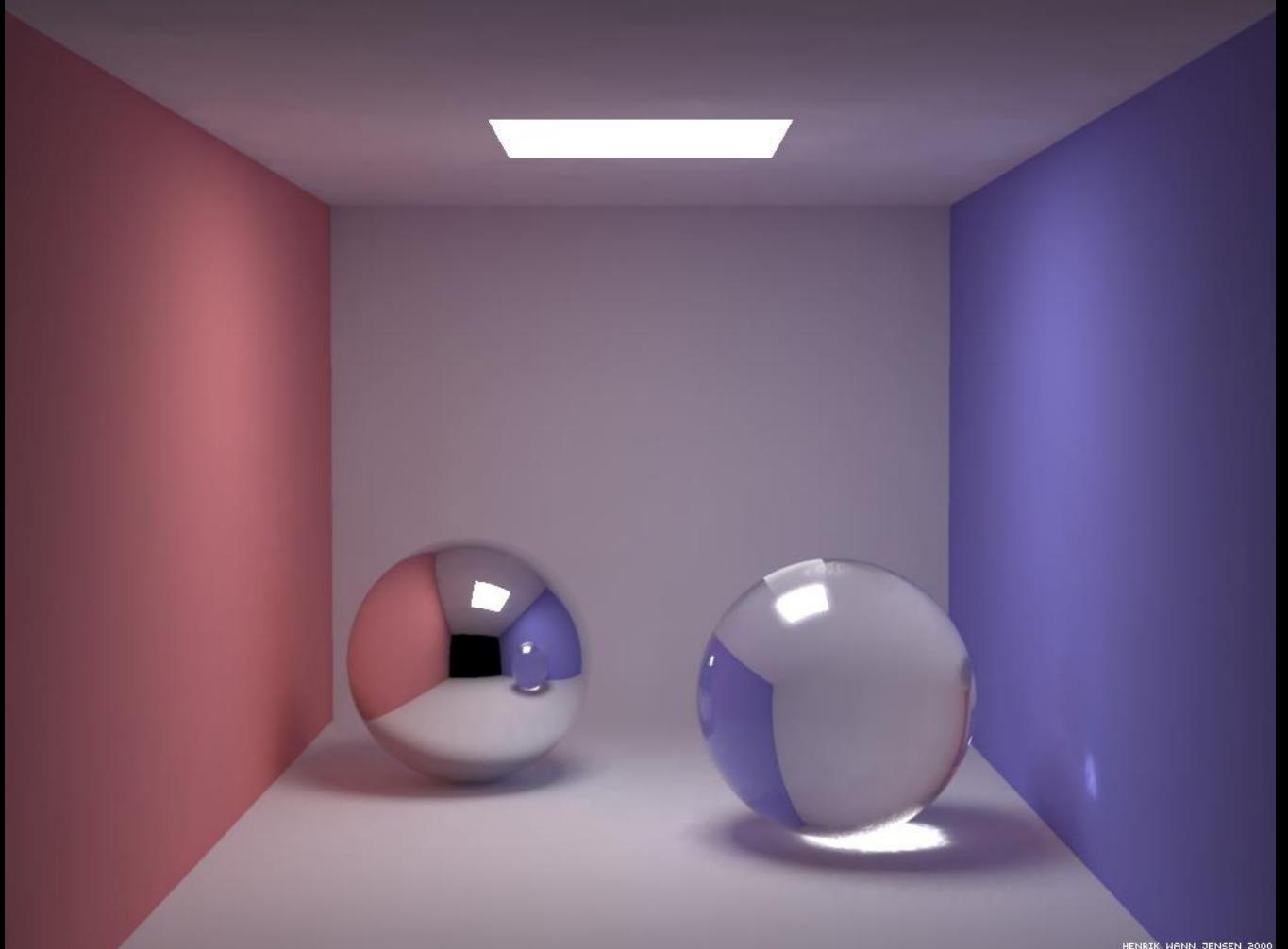


Figure 13. Shadow maps from *Luxo Jr.*

Rendering: Global Illumination

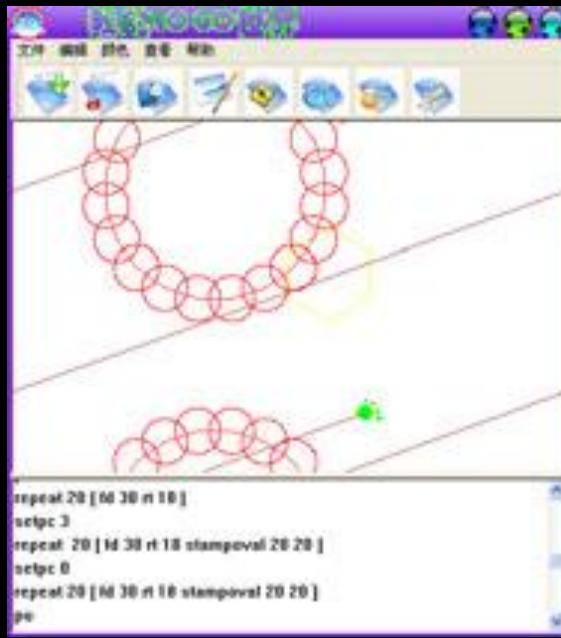


Computer Graphics and Me



About me

- Bo Zhu
- Studied at Shanghai Jiao Tong University for B.Eng and M.S.
- Ph.D. at Stanford CS
 - Studying computer graphics, physics-based animation, and fluid simulation
- Postdoc at MIT CSAIL
 - Studying computational fabrication, computational design, and 3D printing
- Assistant Professor of CS at Dartmouth College
 - Studying computing techniques for complex physical systems
- Starting at GT IC as an assistant professor from 2023 fall



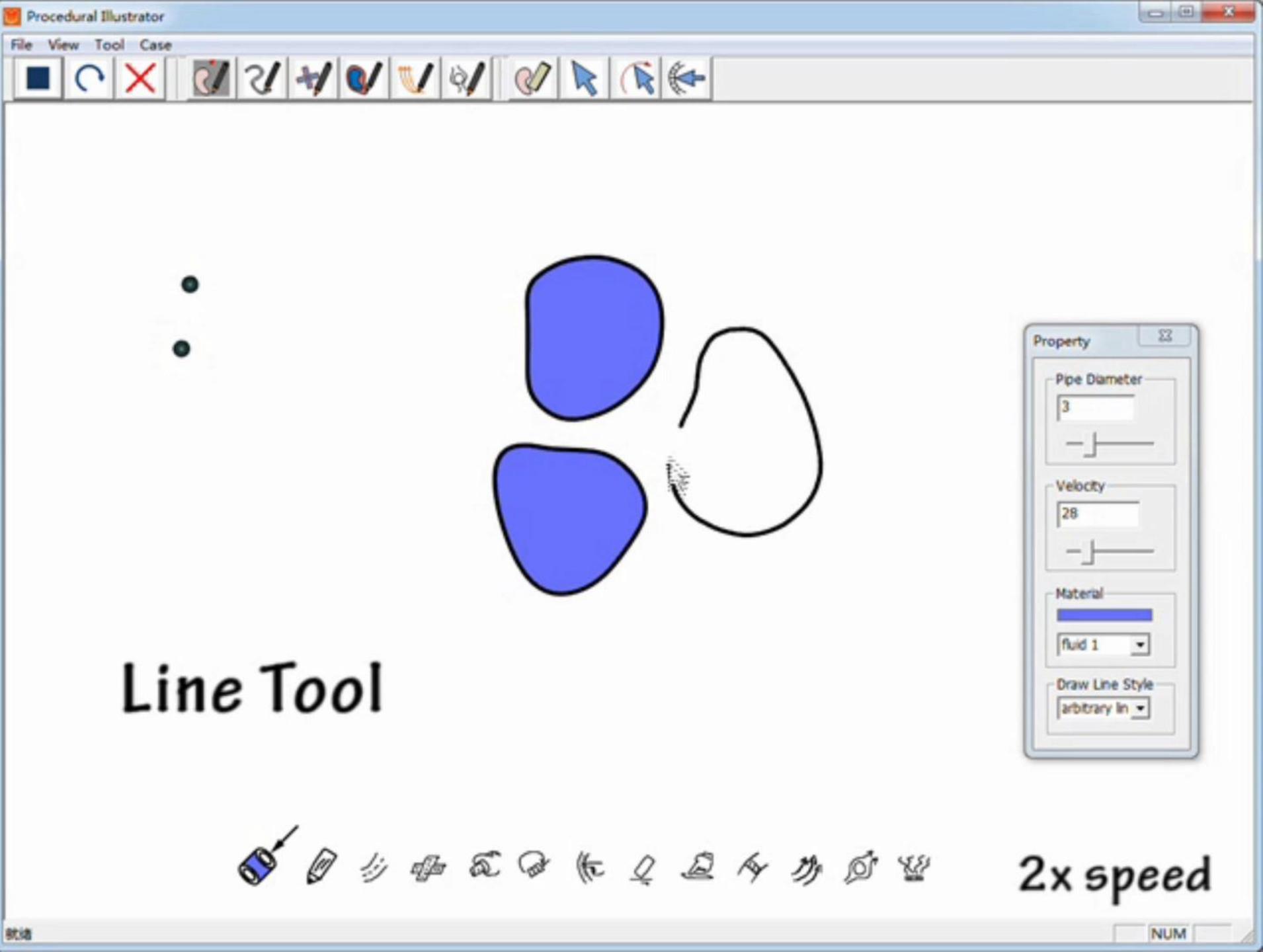
My Motivation to Study Graphics

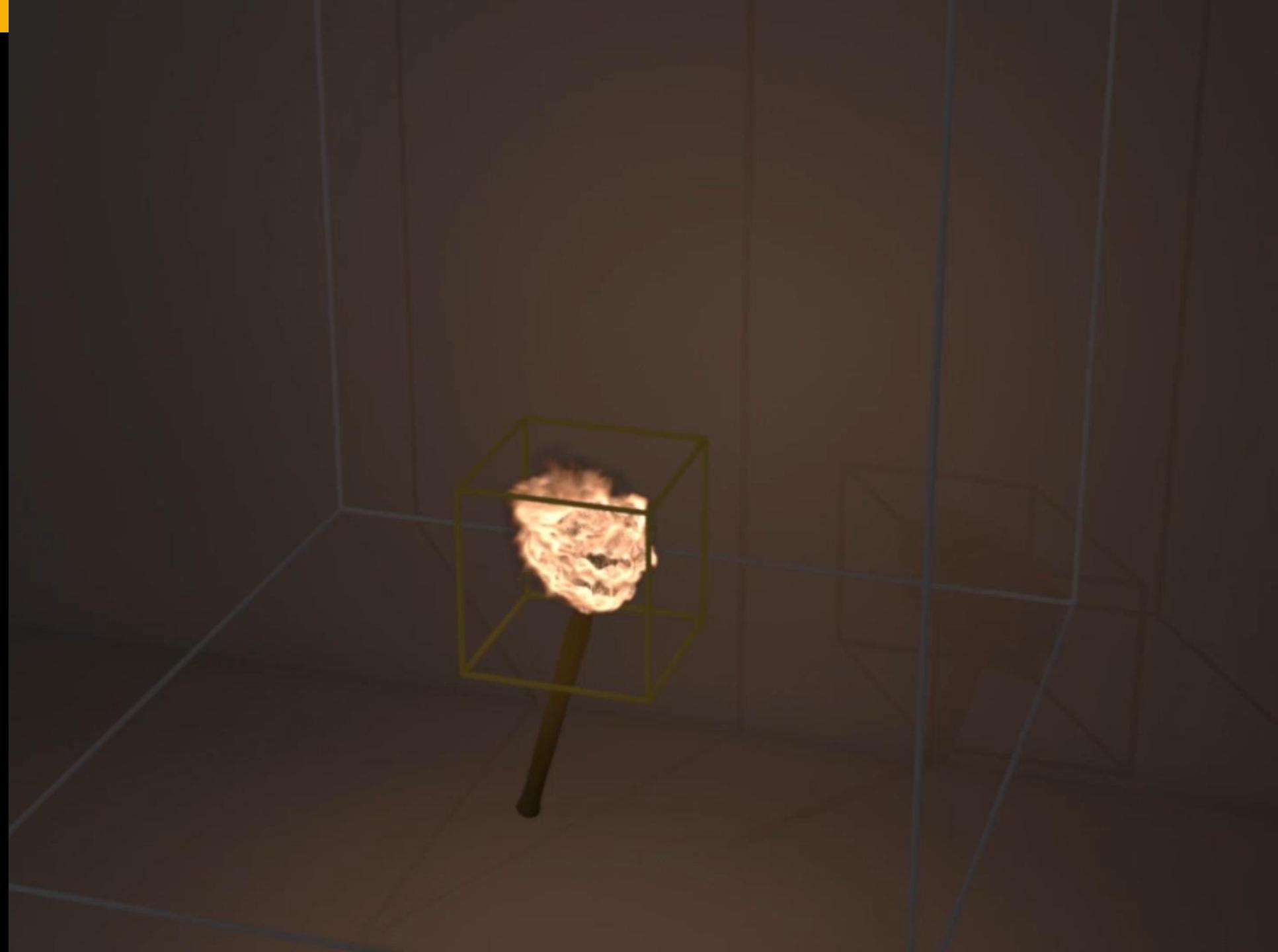


My Motivation to Study Graphics

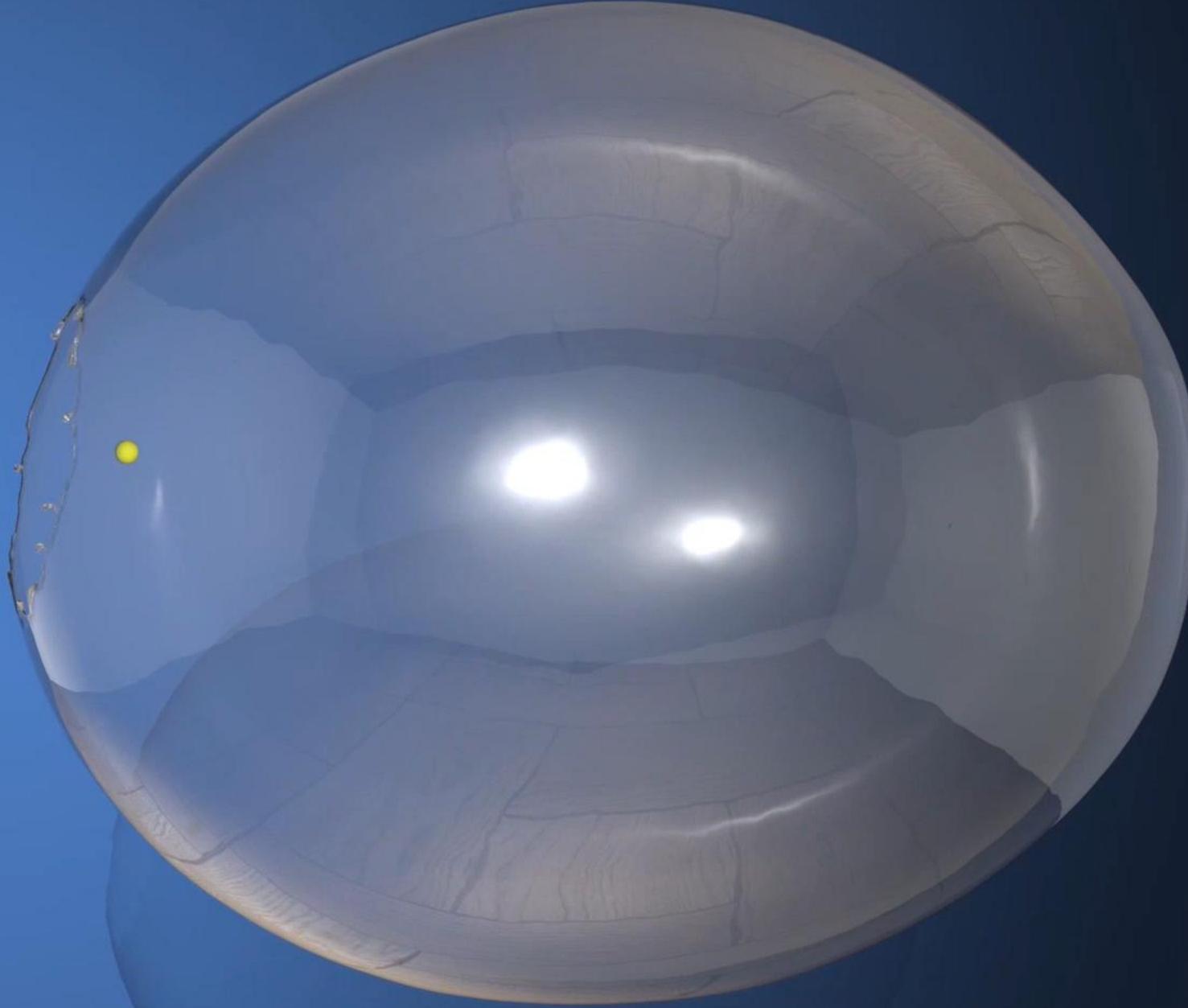


Int





GT



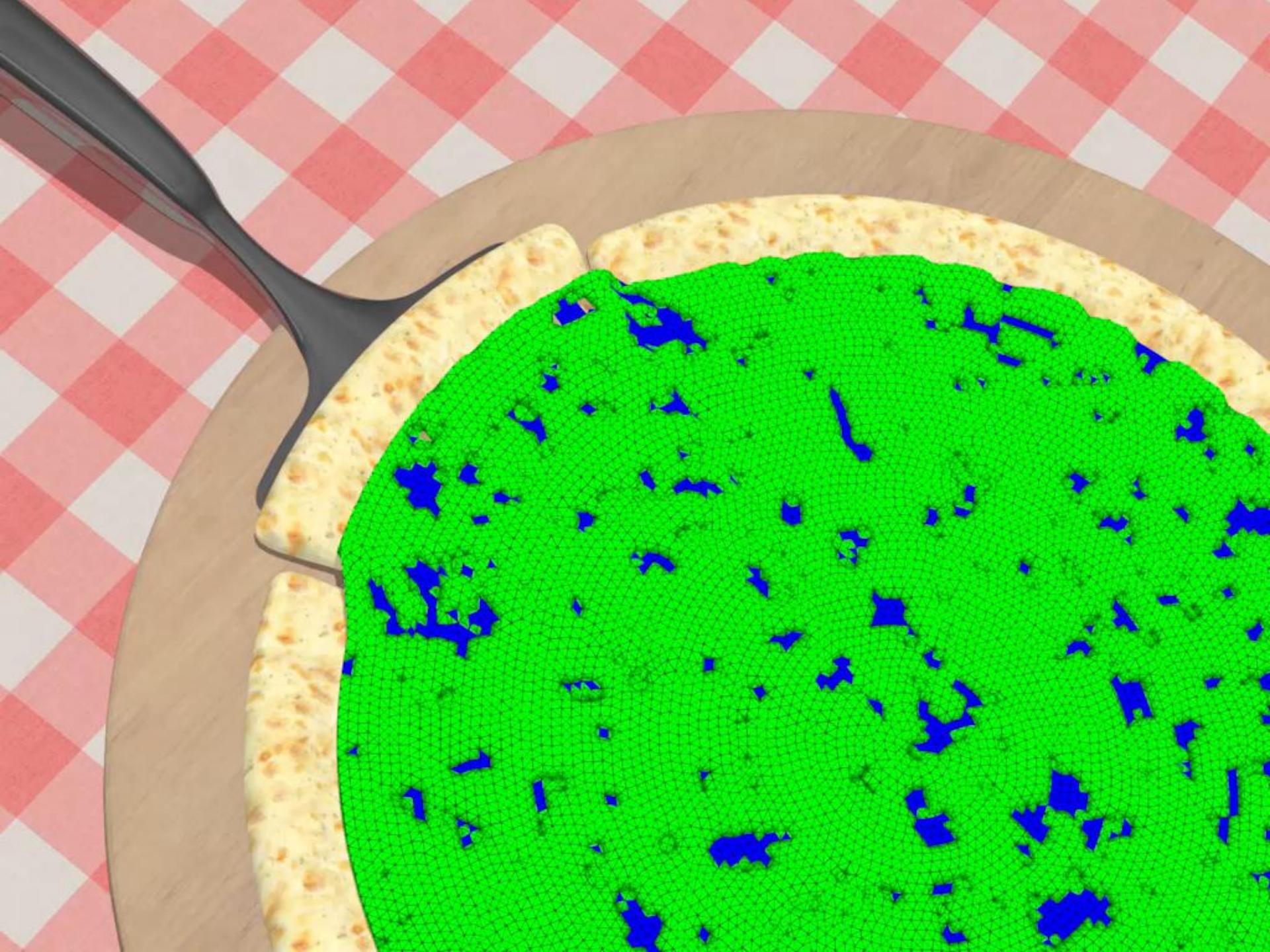
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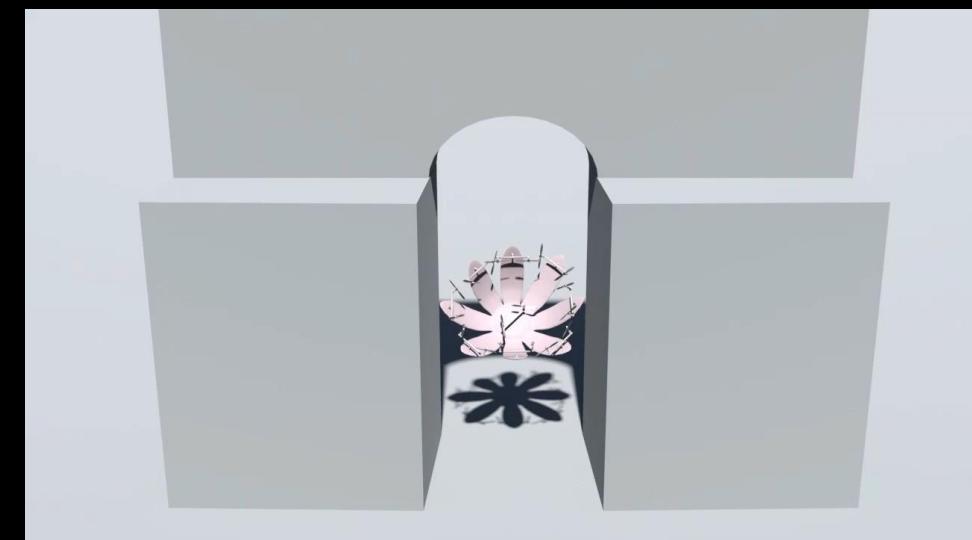
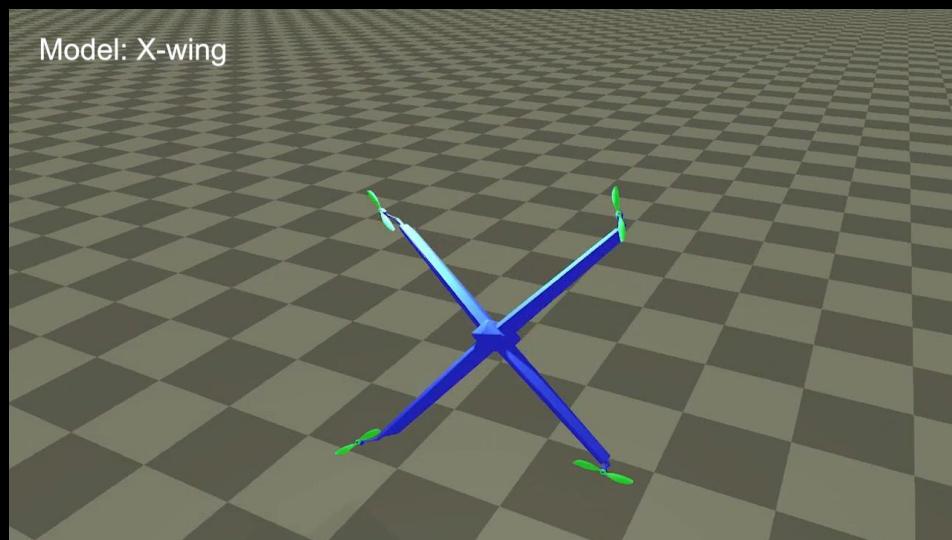
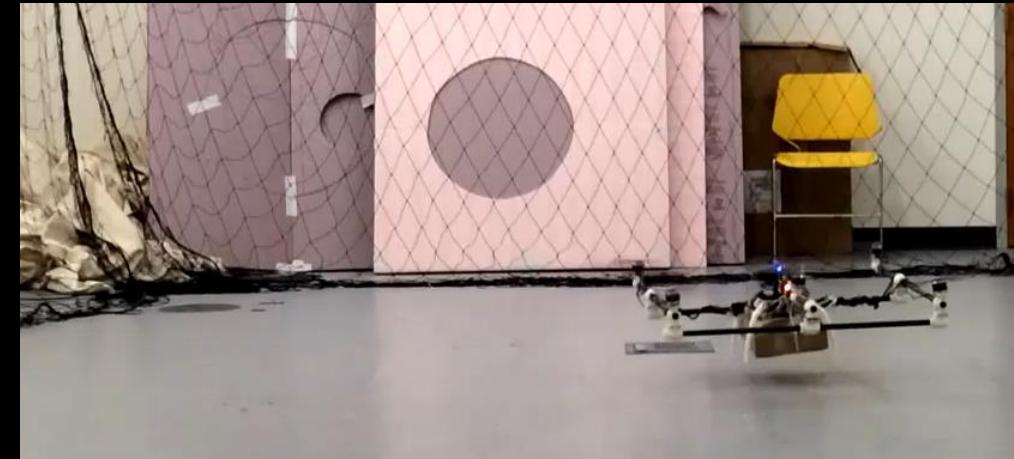
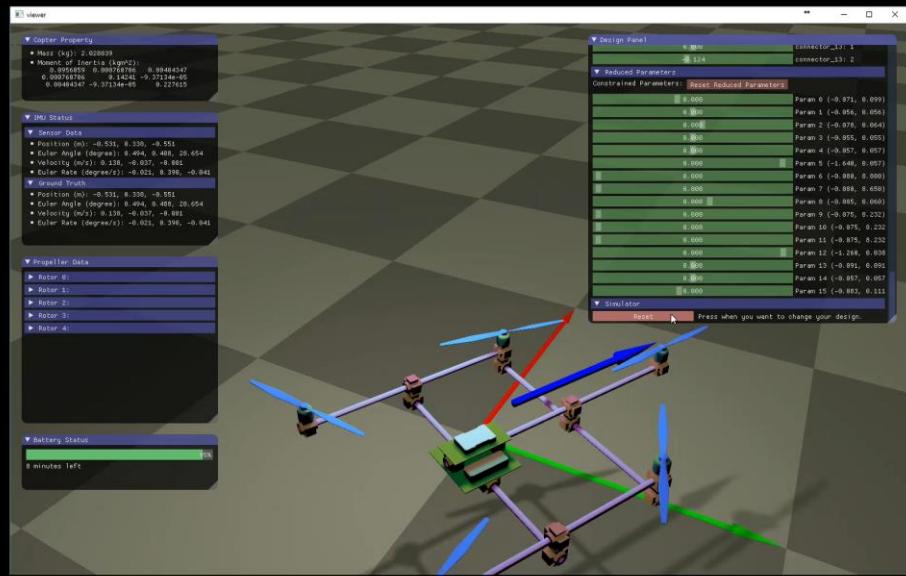
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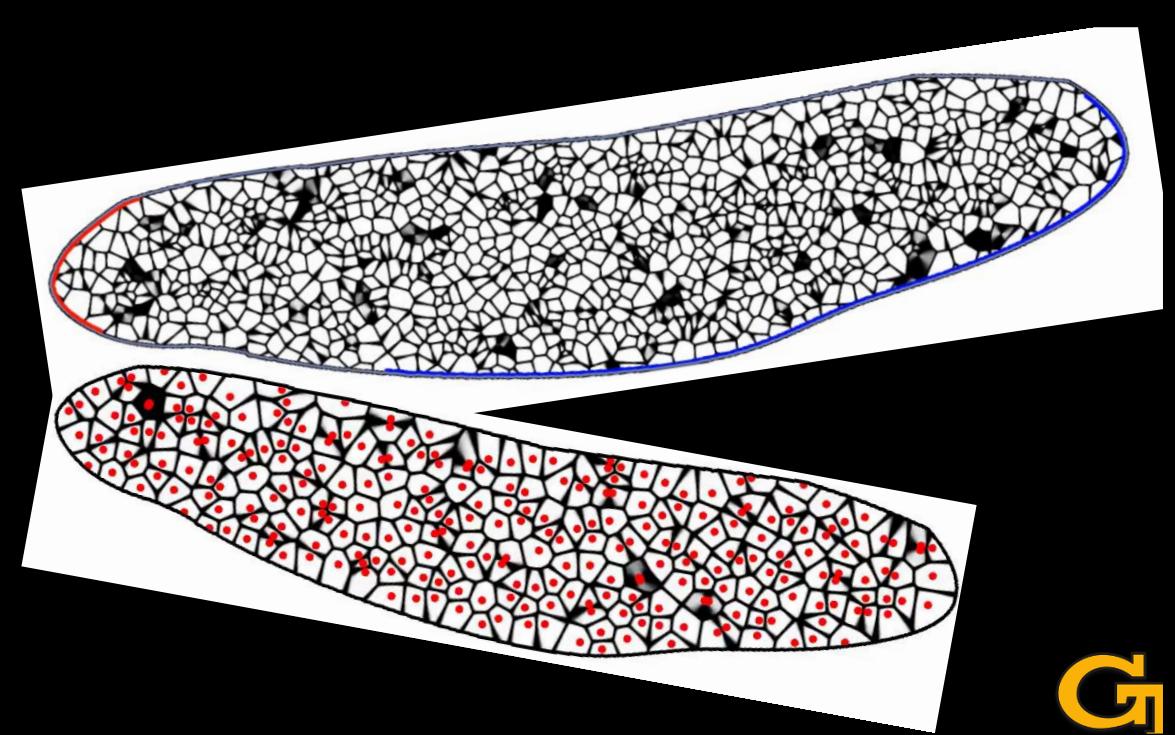
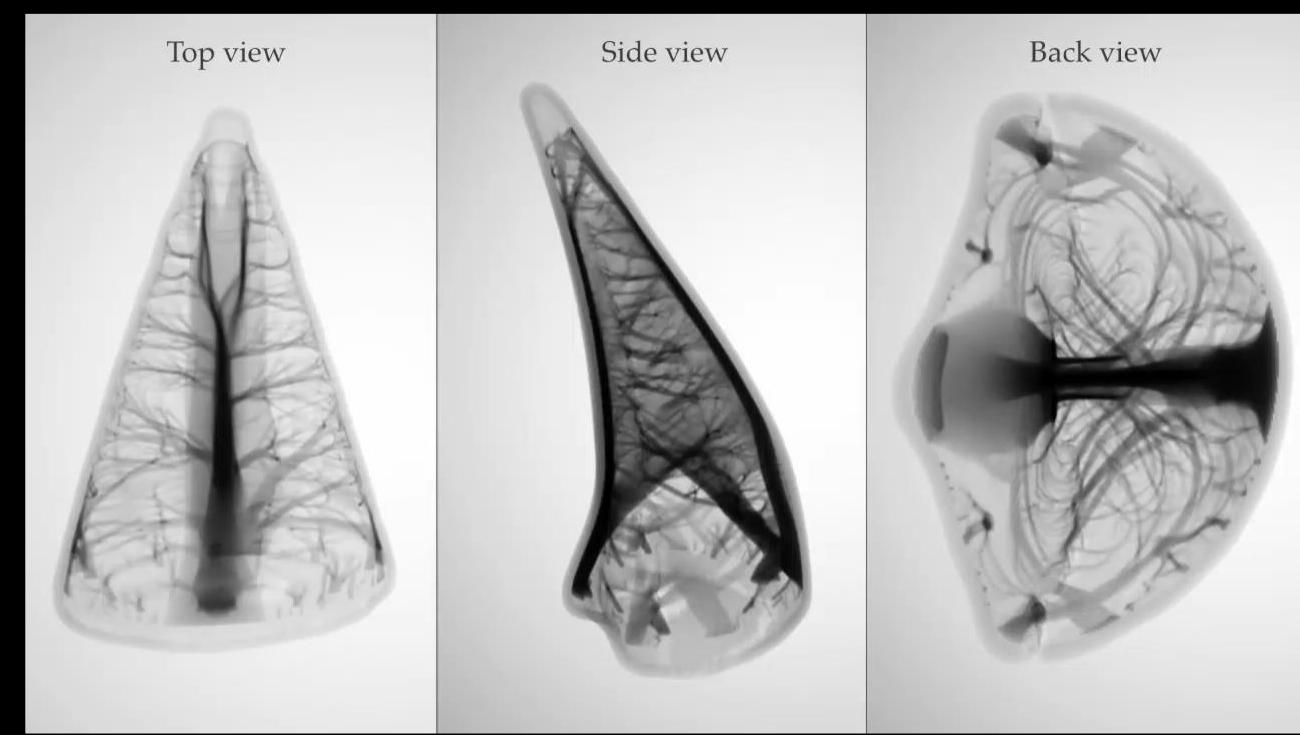
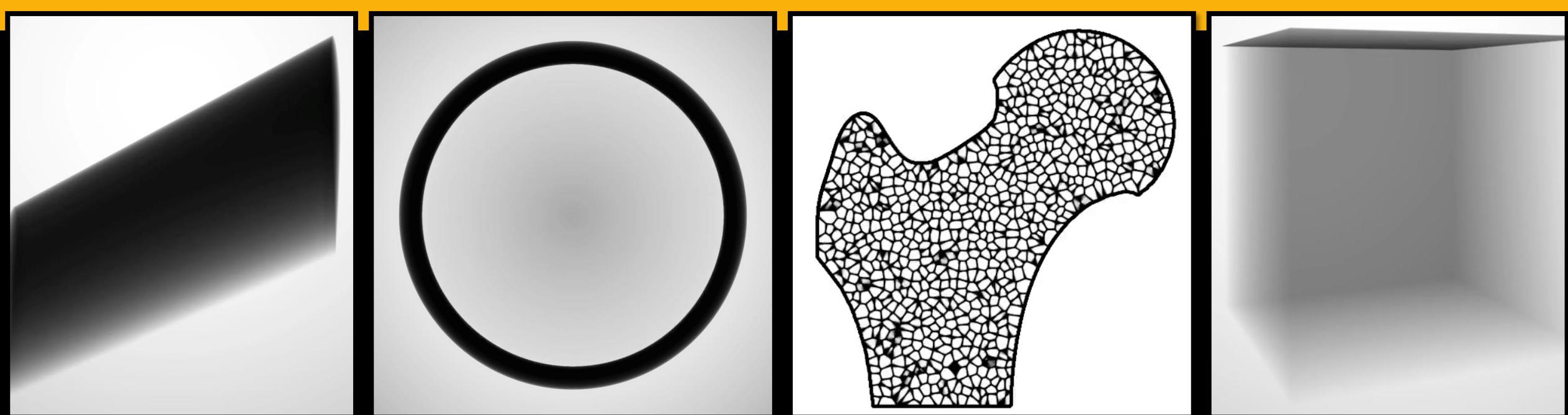


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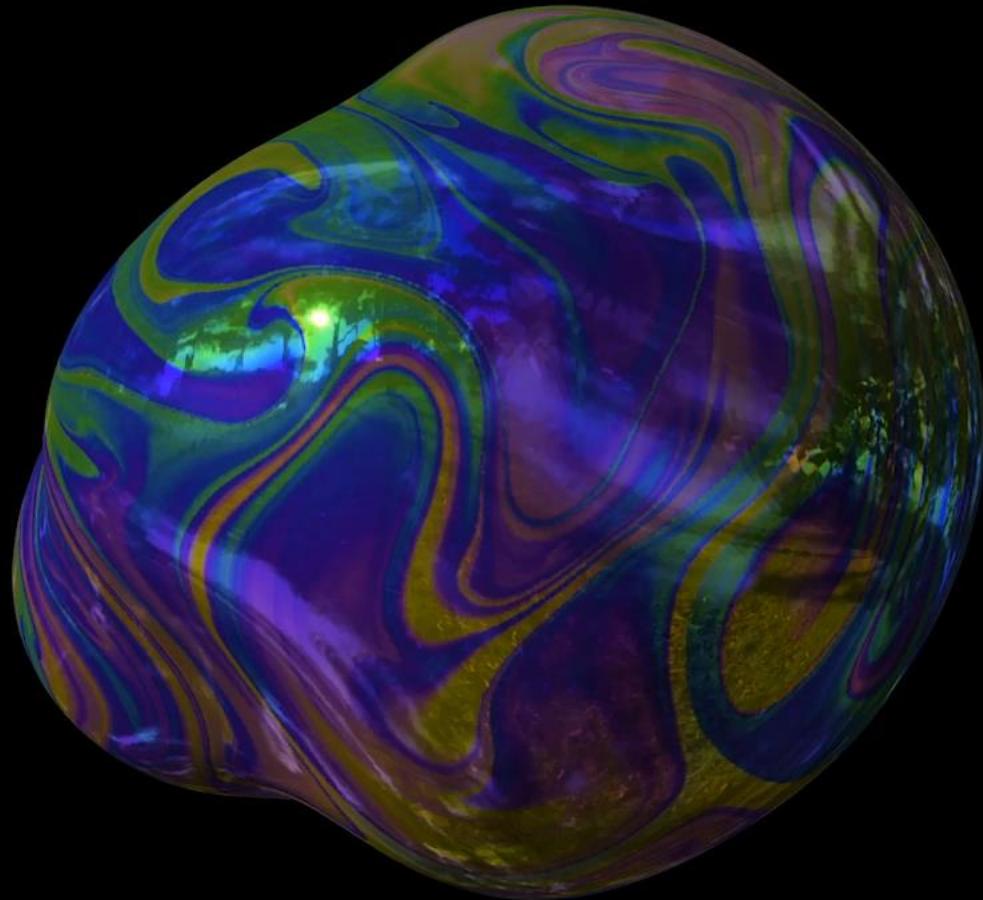
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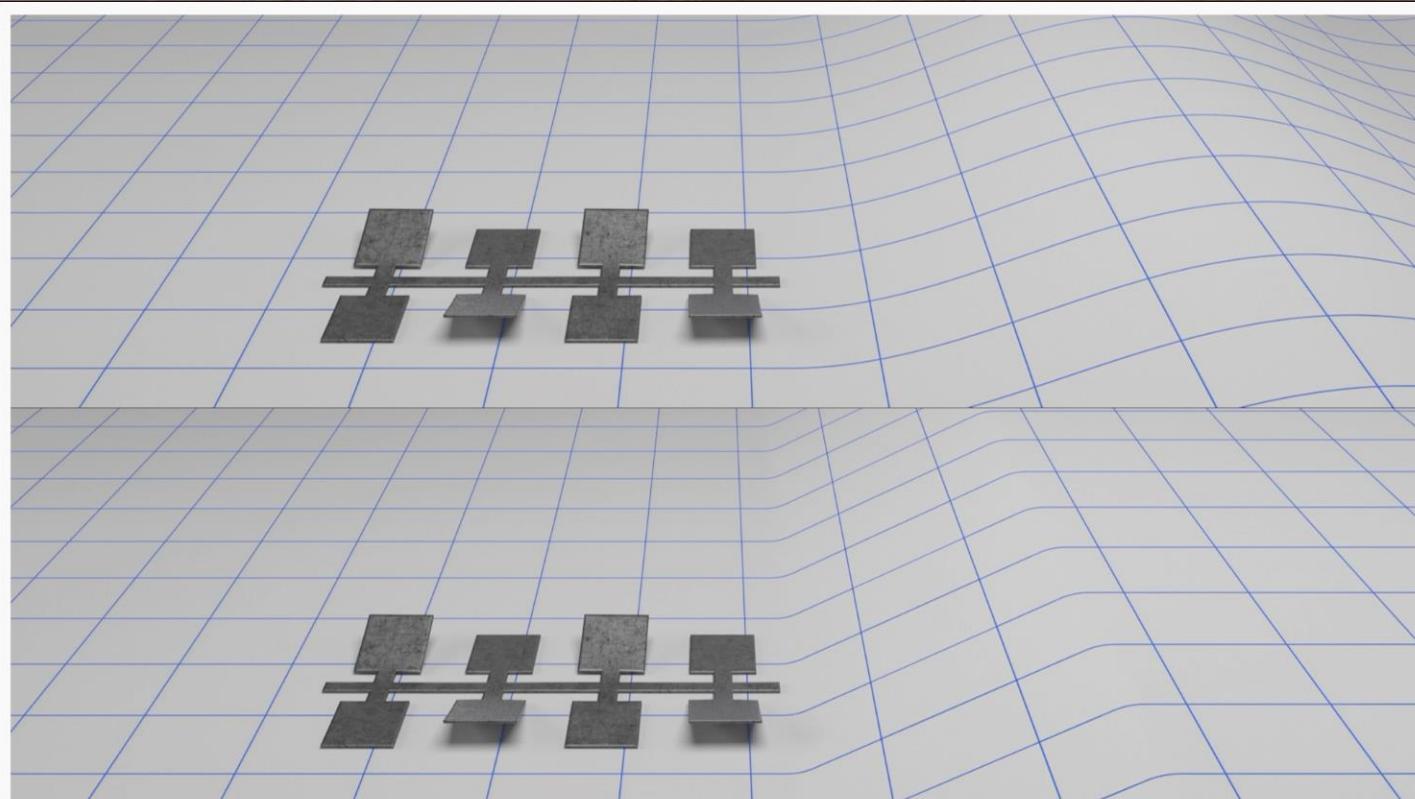


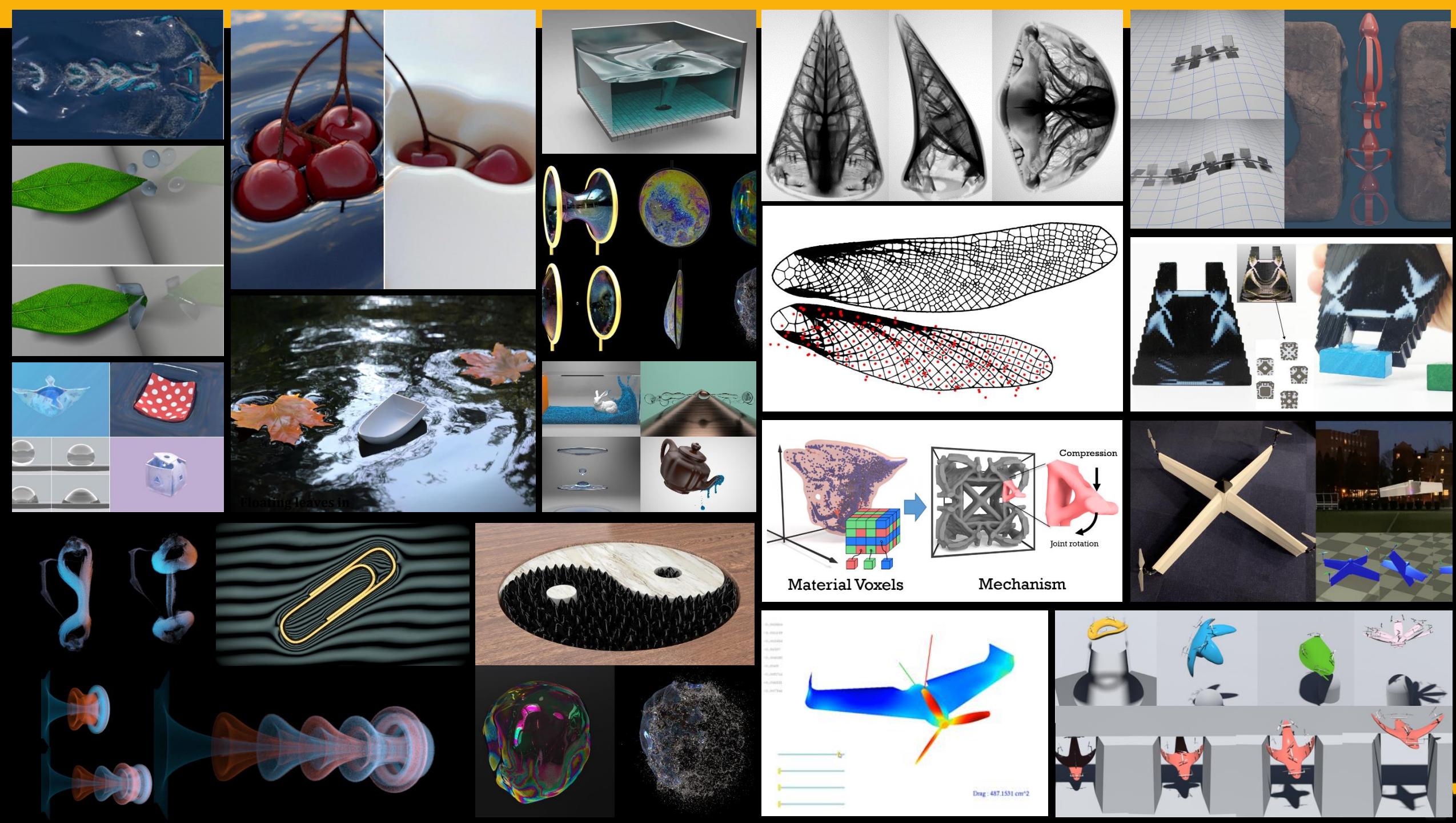




GT







Course Logistics

Meetings

- Lectures: MW 11am-12:15pm
 - May have a 3-minute break in-between ☺
- Office hours:
 - MW 12:30-1:30pm, Klaus 3146
 - TAs' OH will be posted on Canvas

Course Instructor

- **Instructor:** Bo Zhu
- **Email:** bo.zhu@gatech.edu
- **Office Hours:** MW 12:30-1:30pm, Klaus 3146
- **TA Team:** Zhiqi Li, Kevin Sadi, Vibha Raghu, Duowen Chen, Yuchen Sun, Jackson Crandell, Mengdi Wang, and Ibrahim Abotaleb



Course Website

Canvas

(posting homework and course slides)

+

Piazza

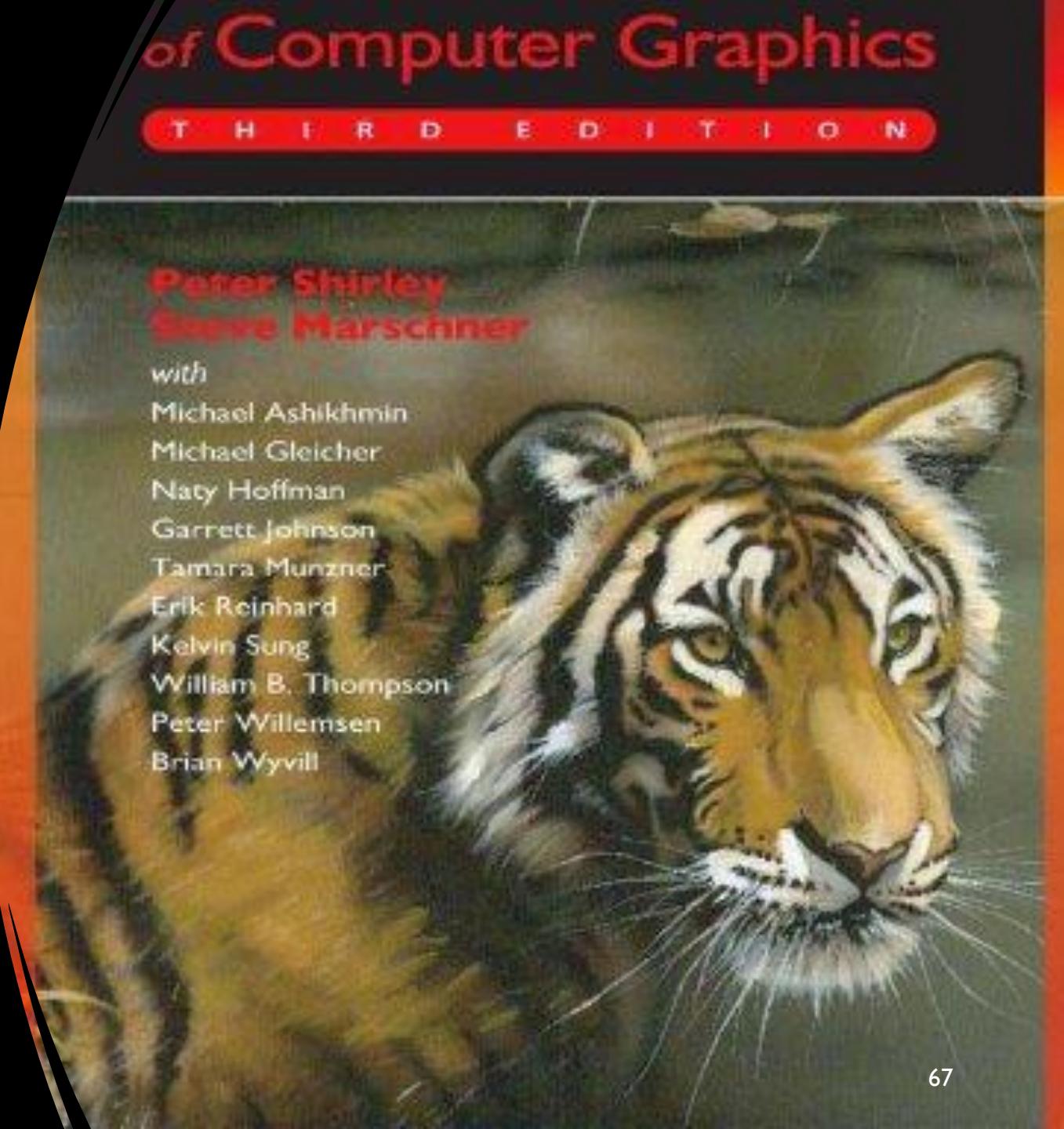
(questions, suggestions, discussions)

Join Piazza via the Canvas link



Textbook and Reading

- *Fundamentals of Computer Graphics*
Shirley/Marschner, edition ≥ 3 .
- **Reading Assignments**
- We will post a reading assignment on Canvas every week to guide your reading tasks



Starter code

- Modeling+Animation+Rendering
 - Vectormath library + window system
 - C++ + Eigen + OpenGL
 - Maintained in GitLab

- <https://gitlab.com/boolzhu/cs3451-computer-graphics-starter-code/>

Skills

- Coding
 - C++ 11
 - Eigen for the vector math library
 - OpenGL for CPU-GPU communication
 - **GLSL for shading effects**
- Linear Algebra
 - Matrix, vector, linear (sparse) systems

Deliverables (Tentative)

- Weekly programming assignments (60%)
 - About 8 weekly programming assignments in total, each ~8%
- Mid-terms (20%)
 - Two one-hour midterm exams, each 10%
- Final Projects (15%)
- Presentation and participation (5%)



Midterms

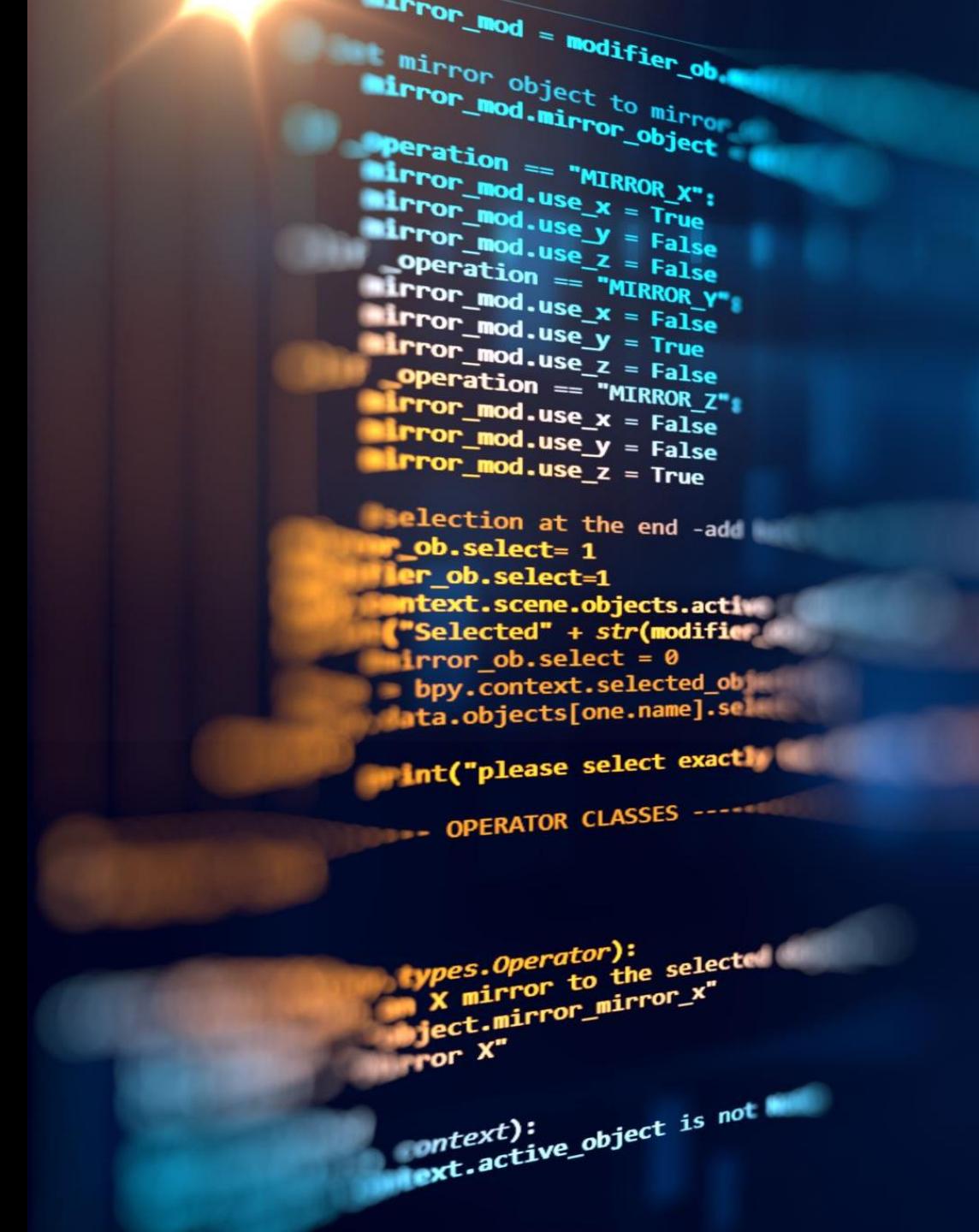
- Two midterm exams
- Solve two theoretical problems within 60 minutes
- Week 6 and Week 12 (tentative schedule).
- Review session will be held and practice problem sets will be posted.

A chalkboard with several mathematical concepts and derivations:

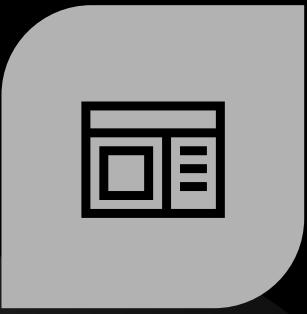
- A graph of a function $y = g(x)$ is shown with a secant line drawn through it, labeled "Secant Lines".
- A tangent line is shown at a point on the curve, labeled "Tangent Line".
- The derivative is defined as $f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$.
- The derivative is also derived using the difference of squares: $f'(x) = \lim_{h \rightarrow 0} \frac{(x+h)^2 - x^2}{h} = \lim_{h \rightarrow 0} \frac{x^2 + 2xh + h^2 - x^2}{h} = \lim_{h \rightarrow 0} \frac{2xh + h^2}{h} = \lim_{h \rightarrow 0} h(2x + h)$.
- The limit $\lim_{h \rightarrow 0} h$ is shown as equal to zero.

Programming Assignments

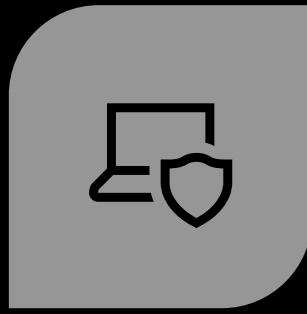
- Implement a classic graphics algorithm
- Starter code will be provided
- Submit both the code and the result image/video
- Group discussions are encouraged
- Most of the assignments will be **open-ended**
- Coding need to be finished **independently**



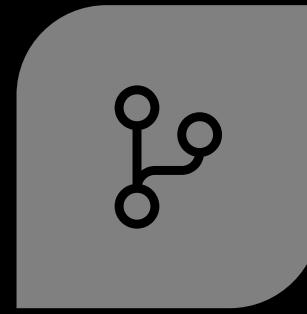
Creative Expression



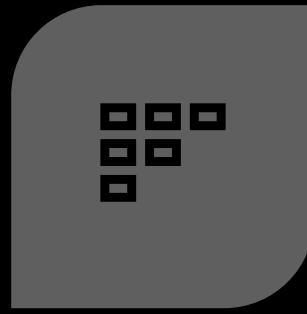
CREATE A VISUAL APPEALING
MODEL/ANIMATION/IMAGE
USING THE TECHNIQUES YOU
HAVE LEARNT FROM CLASS



THE PROJECT WILL BE
EVALUATED BASED ON BOTH
TECHNICAL AND AESTHETICAL
ASPECTS



OPEN-ENDED



EACH TEAM MAY HAVE UP TO
THREE TEAM MEMBERS

Final Project



Implement a graphics algorithm to demonstrate your in-depth understanding of one of the graphics techniques



Open-ended: you may customize your study path in modeling, animation, or rendering



Each team may have up to three team members

Projects in Previous Years

Students' Demo Reel (2021)

Students' Demo Reel (2023)





CS345 I

Computer Graphics

- Modeling
- Rendering
- Animation

Enjoy your journey, and good luck!