CSCI 4229/5229 Computer Graphics Fall 2024

Course Objectives

- Class: Theory and principles
  - Attendance is highly encouraged
- Assignments: Practical OpenGL
  - Applications
- No tests or exams
- By the end of the course you will:
  - Be conversant in computer graphics principles
  - Be well versed in the use of OpenGL
  - Understand what OpenGL does internally

Class Attendance

- If you are in the distance session, it is highly recommended that you join live by Zoom
  - Permits real time interaction
- If you feel ill, attend via Zoom
- Class Attendance in person or via Zoom is expected
  - Amplifies expectations and issues related to assignments
  - Covers additional examples not on Canvas

Course Outline

- Basics (1/3)
  - Projections, transformations, clipping, rendering, text, color, hidden edge and surface removal, and interaction
- Advanced (1/3)
  - Illumination, shading, transparency, texture mapping, parametric surfaces, shaders
- Project (1/3)
  - Whatever you're interested in: games, modeling, visualization, 'Google Earth', ...

Why OpenGL?

- Modern, widely used and actively supported
  - Games
  - 3D visualization
- Cross platform
  - Windows
  - Mac
  - *NIX
  - iPhone, Android and WebGL
- Open source and vendor implementations
  - MESA 3D (source code available)
- Many language bindings

Instructor

- Willem A (Vlakkies) Schreüder
- Email: vlakkies@colorado.edu
  - Begin subject with 4229 or 5229
    - I have a draconian mail filter
  - Resend email not answered promptly
- Office Hours:
  - Monday 3-4pm via Zoom
  - Thursday 12:30-1:30pm in person or by Zoom
  - Email me to set up Zoom at other times
- Weekday Contact Hours: 6:30am - 9:00pm

Assumptions

- You need to be fluent in C
  - Examples are in C
    - You need to know how to program and compile
  - You can do assignments in any language
    - I may need help getting it to work on my system
    - Use C or C++ unless you have a good reason
- You need to be comfortable with linear algebra
  - Vectors, surfaces, normals
  - Matrix and Vector multiplication
  - Dot and cross products
  - Rotation matrices

Grading

- Satisfactory complete all assignments => A
  - The goal is to impress your friends
- Assignments ***must*** be submitted on time unless prior arrangements are made
  - Most due Wednesday evening 11:59 pm
    - Extensions must be requested before due date
    - Grace period until Thursday morning at 08:00am
    - **Emailed assignments or attached as comments on Canvas will not be accepted**
- Assignments must be completed individually
  - Stealing ideas are permitted
  - OpenGL code from the web may be used
  - Make it your own and improve on it

Grading Expectations

- Code reuse is acceptable
  - Give credit where it is due
  - You take responsibility for errors in reused code
  - You need to make a substantial improvement
    - I'm looking to see that you have insight in the material and put in a significant effort
    - Simply turning in downloaded code with minor changes is unacceptable and an Honor Code violation
- No grade => respond to my comments and resubmit
- **Grade <100 means NOT SATISFACTORY (not an A)**

Example Programs

- Illustrates specific aspects
  - mode variable heavily overloaded
  - one concept at a time
- Designed to be a starting point
  - you are expected to improve on it
  - cut and paste will not get you an A
- **The course is no intended to teach OpenGL, but rather the principles underlying graphics**

Text

- OpenGL Programming Guide (9ed)
  - Shreiner et al.
  - “OpenGL Vermillion Book”
  - Older edition was the “OpenGL Red Book”
  - Download previous editions as PDF
  - Recommended but not required

Other Texts

- OpenGL: A Primer, 3/E
  - Edward Angel
  - Excellent and very accessible
  - Inexpensive
  - Third edition adds new material (shaders)
- OpenGL SuperBible: Comprehensive Tutorial and Reference (7ed)
  - Sellers, Wright & Haemel
  - Good all-round theory and applications
  - 6e & 7e is all OpenGL 4 which is a challenge

Theoretical text

- Computer Graphics: Principles & Practice (3ed)
  - Hughes, van Dam, McGuire, Sklar, Foley, Feiner & Akeley
  - Avoid 1ed (Pascal), 2ed (very dated)
  - Get it if you want to know more of the theory

Embedded OpenGL texts

- OpenGL ES 3.0 Programming Guide
  - Ginsburg & Purnomo
  - OpenGL Embeded Systems (iPhone & Android)
  - Subset of OpenGL, 1.3 and 2.0 very different
  - ***Not recommended for beginners***
- iPhone 3D Programming
  - Philip Rideout (O'Reilly series)
  - iPhone specific, but C/C++ oriented so translates well to Android (using the NDK)
  - My personal favorite for portable OpenGL ES

OpenGL Resources

- Safari
- www.google.com
  - Need I say more?
- www.opengl.org
  - Code and tutorials
- nehe.gamedev.net
  - Excellent tutorials
- www.mesa3d.org
  - Code of “internals”
- Class forum

Assignment 0

- Due: Wednesday September 4 at 11:59pm
- Find the course on Canvas
- Submit
  - Your name and study area
  - Platform (Hardware, Graphics, OS, ...)
  - Background and interests in computer graphics
  - Project ideas (if you have one already)
  - Distance students let me know about special circumstances and schedules
  - Do office hours work for you

My information

- Mathematical modeling and data analysis
  - PhD Computational Fluid Dynamics [1986]
  - PhD Parallel Systems (*CU Boulder*) [2005]
- Use graphics for scientific visualization
- Open source bigot
- Program in C, C++, Fortran and Perl

Assignments

Week 1: Who Am I
Week 2: Compile and run Gears
Week 3: Visualizing the Lorenz Attractor
Week 4: Drawing Scene in 3D
Week 5: Orthogonal/Perspective Projection
Week 6: Lighting
Week 7: Lighting and Textures
Week 8: Project Proposal
Week 10: Project progress report
Week 12: Project Review
Week 14: Project Final

Complete assignments early if you want

How to get started

- Get OpenGL to work on your platform
  - *Installing OpenGL* on Canvas
  - Compile and run *Hello World* examples
- If you are using Windows
  - Install MSYS2 and use pacman
  - Compile with -DUSEGLEW (see my examples)
- If you are on an X based (*NIX) platform:
  - yum install freeglut-devel
  - apt-get install freeglut3-dev
  - Run glxinfo and check if *direct rendering: yes*
- OS/X based on OpenGL
  - Xcode command line
  - Use homebrew to install glfw, SDL, etc

Assignment 1

- Due: Wednesday September 11 at 23:59
- Compile and run *gears* and answer a few questions
- This ensures that you have a working OpenGL environment on your machine
- Practice creating a *makefile*
  - After this I expect correct makefiles

Assignment 2

- Due: Wednesday September 18 at 23:59
- Write an OpenGL based visualization of the Lorenz Attractor
  - At a minimum show a static line path in 3D
  - User control of attractor parameters
  - Add rotation using cursor keys
  - Use your imagination
- The purpose is scientific visualization
  - Do some science

  http://mathworld.wolfram.com/LorenzAttractor.html
- Example 6 is your friend

Assignment 3

- Due: Wednesday September 25 at 23:59
- Write an program to visualize a 3D scene
- Scene must consist of solid 3D objects
  - You must create objects yourself
    - no GLU/GLUT or imported objects
  - You must replicate some generic objects
- Scene must be viewable from different vantage points under user control
- *Add 3D objects to Assignment 2*

Assignment 4

- Due: Wednesday October 2 at 23:59
- Write an program to visualize a 3D scene using both orthogonal and perspective projections as well as first person navigation
- *Add perspective projection to Assignment 3*
- *I don't provide a first person example*

Assignment 5

- Due: Wednesday October 9 at 23:59
- Write an program to visualize a 3D scene with lighting
  - Make the light move to show lighting effects
  - Select solid objects that show lighting effects
  - Still no glu/glut or imported objects
- *Add lighting to Assignment 4*
- ***WARNING: THIS IS A VERY DIFFICULT ASSIGNMENT***

Assignment 6

- Due: Wednesday October 16 at 23:59
- Write an program to visualize a 3D scene with lighting and textures
- End of progression of homework assignments
- *Add textures to Assignment 5*

Project

- Should be a program with a significant graphics component
  - Something useful in your research/work?
  - Graphical front end to simulation
  - Graphical portion of a game
  - Expect more from graduate students
- Deadlines
  - Proposal: Wednesday Oct 23
  - Progress: Wednesday Nov 13 (progress report)
  - Review: **Monday** Dec 2 (must run)
  - Final: **Tuesday** Dec 10 (no resubmit)

Project Grading

- Half the total grade for the class
- The grade assigned for the ***final*** submission is what is counted
- Grades assigned for the progress report and the review are my assessment of what that final grade will be, and is not counted towards the class grade
  - Canvas is not smart enough to do this, so don't go by the totals it gives you

Topics for CSCI 4239/5239 Advanced Computer Graphics

- Shaders
  - Explicitly programing the GPU
- Embedded Systems
  - iPhone, Android, WebGL
- GPU work threads (CUDA & OpenCL)
- Ray Tracing

Nuts and Bolts

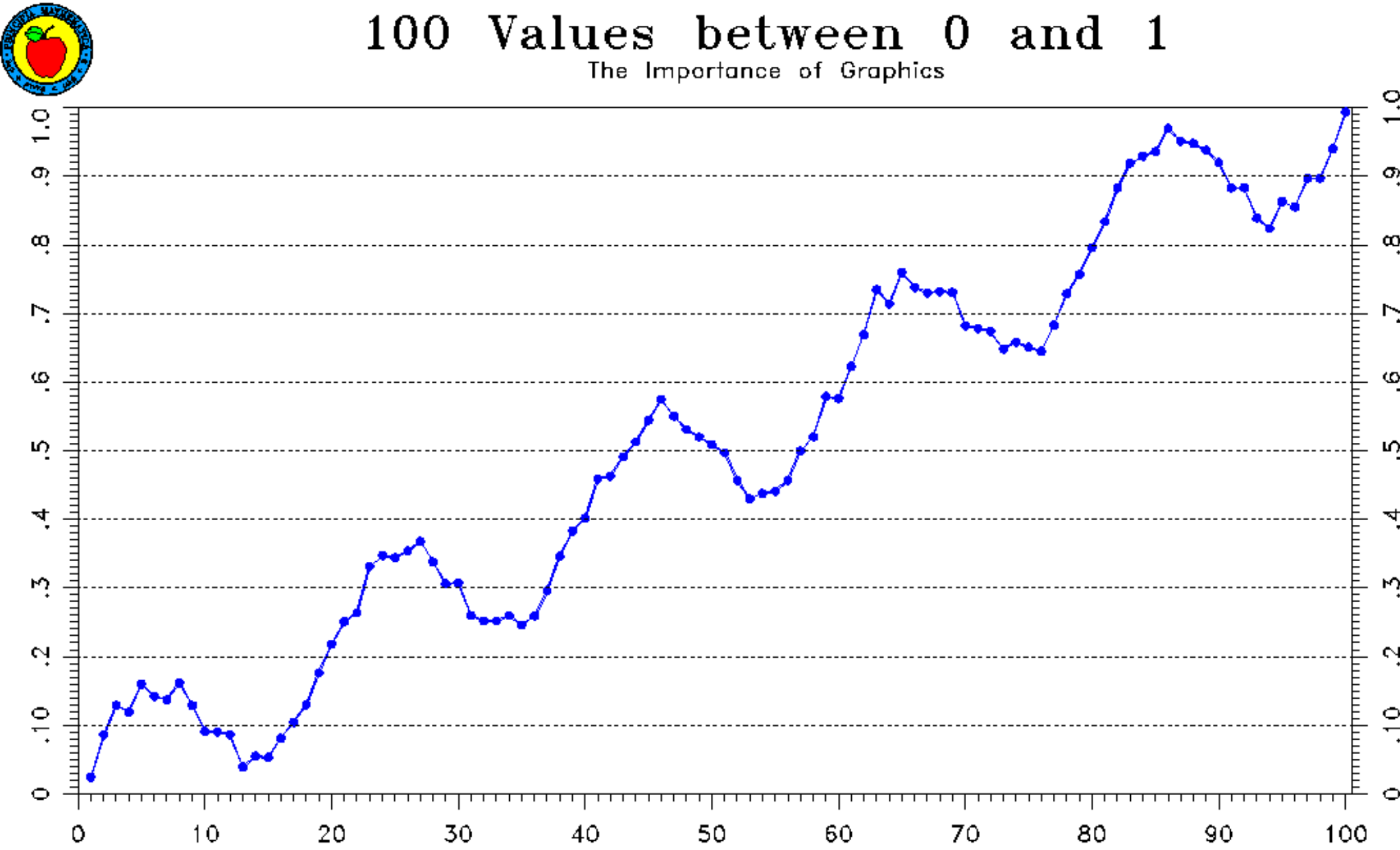
- Complete assignments on any platform
  - Assignments reviewed under Ubuntu 22.04 LTS
  - Set #ifdef so I can compile and run it
- Submit using Canvas
  - Single ZIP file
  - Name executables hw1, hw2, ...
  - Create a makefile so I can do *make clean;make*
  - Set window title to *Assignment X: Your Name*
- Include number of hours spent on assignment
- *Check my feedback and resubmit if requested*
- This is a BIG class, ***PLEASE*** submit cleanly

A few hints

- My machine runs Linux x86_64
  - gcc/g++ with nVidia & GLX
    - -Wall is a **really** good idea
  - case sensitive file names
  - int=32 bit, long=64 bit
  - little-endian
  - fairly good performance
- How to make my life easier
  - Try it on a Linux box
  - Stick to C/C++ unless you have a good reason to use something else
- ***Maintain thy backups…***

The Importance of Graphics: 100 Values between 0 and 1

0.024	0.086	0.129	0.119	0.160	0.142	0.137	0.162	0.129	0.091
0.090	0.086	0.039	0.055	0.053	0.081	0.104	0.130	0.176	0.218
0.251	0.264	0.331	0.347	0.344	0.354	0.368	0.338	0.306	0.307
0.260	0.252	0.252	0.260	0.246	0.259	0.296	0.346	0.383	0.402
0.459	0.463	0.491	0.513	0.544	0.575	0.550	0.531	0.520	0.509
0.497	0.457	0.430	0.438	0.441	0.457	0.500	0.520	0.579	0.576
0.623	0.669	0.735	0.714	0.760	0.738	0.730	0.732	0.731	0.682
0.678	0.674	0.648	0.658	0.651	0.645	0.683	0.729	0.757	0.796
0.834	0.883	0.919	0.929	0.936	0.970	0.951	0.948	0.938	0.920
0.883	0.883	0.839	0.824	0.863	0.855	0.897	0.897	0.940	0.994


100 Values between 0 and 1
The Importance of Graphics
0
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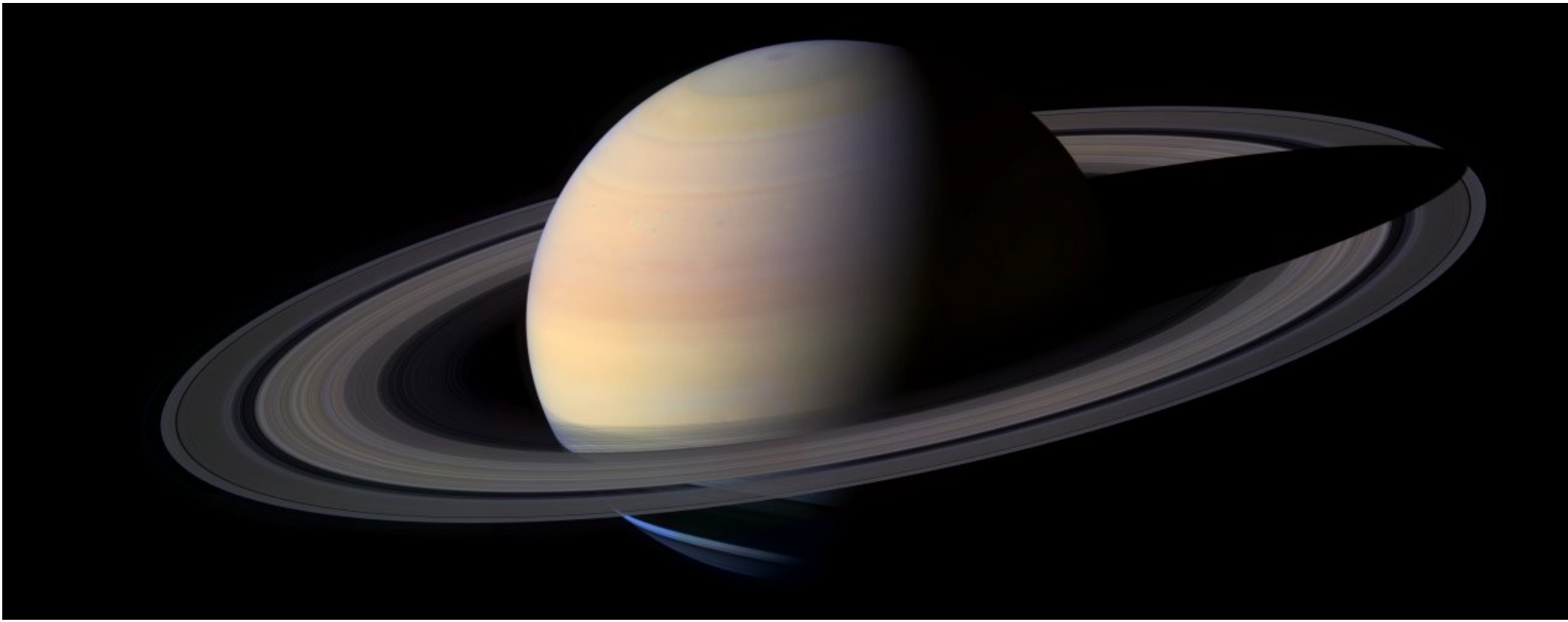
1.0
0
10
20
30
40
50
60
70
80
90
100

Graphic Design

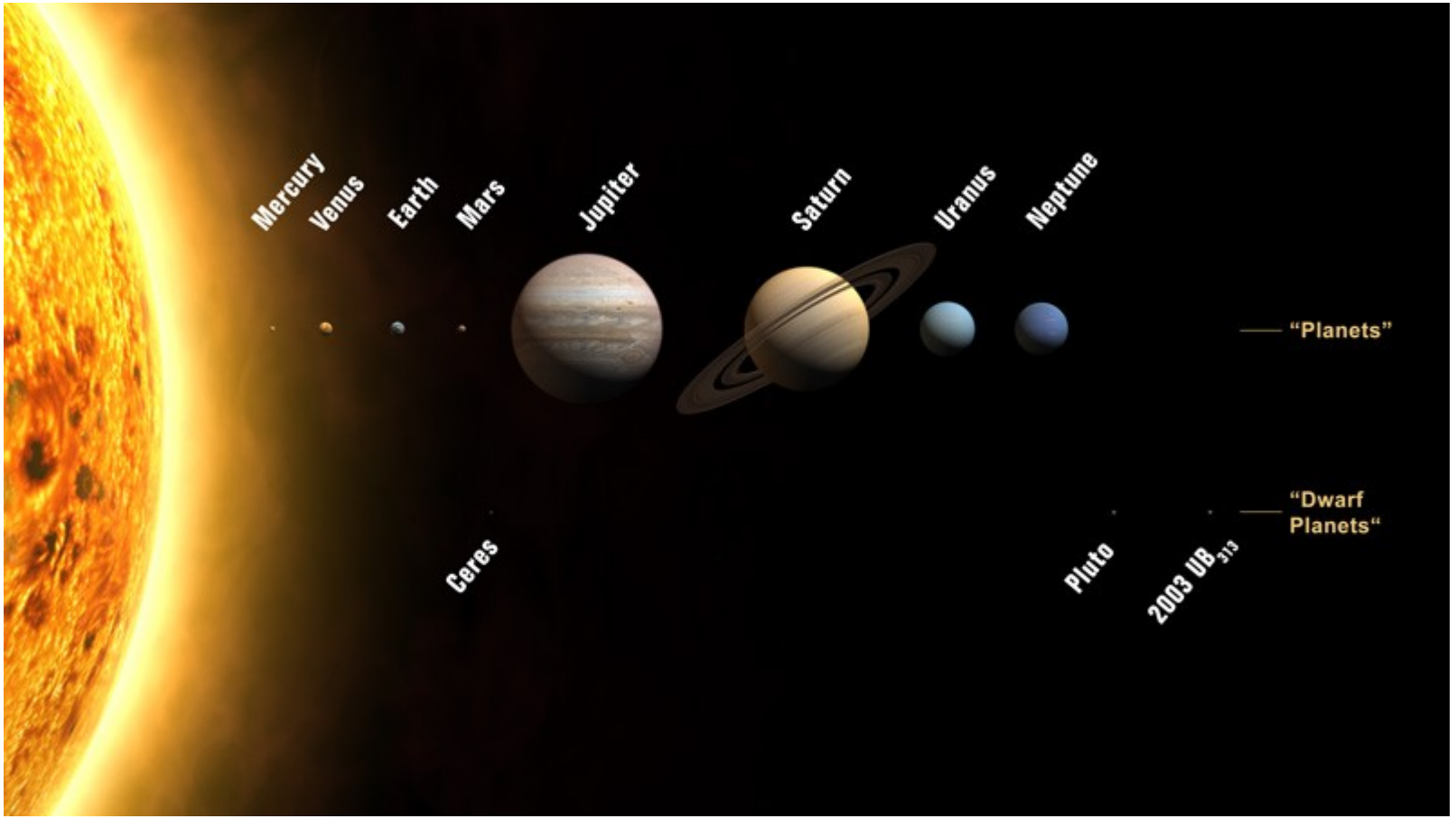
- 2D vs. 3D
  - Cool vs. informative
- Edward R. Tufte
  - Visual Explanations
  - Envisioning Information
  - The Visual Display of Quantitative Information
  - Beautiful Evidence

Saturn from Cassini Probe



Colorado Fall Colors

What is wrong with this picture?



In the beginning....

Storage Tube Terminals

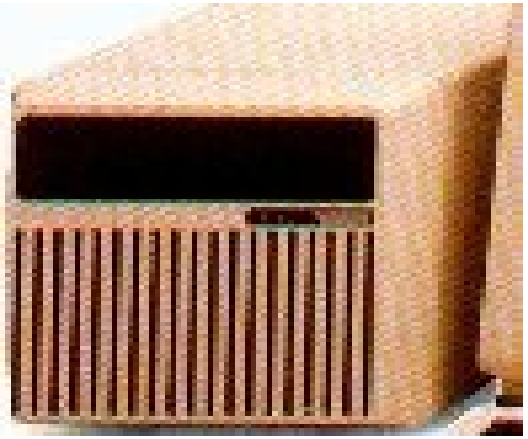
Storage Display Images

Color: Multiple Pen Plotters

Raster Graphic Terminals

Color Inkjets

Workstations: Apollo DN 330
12 MHz 68020, 3MB RAM, 70MB disk



Workstation, Desktop, Laptop, Phone, Communicator..