CSCI 4229/5229 Computer Graphics Summer 2021

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

- It is highly recommended that you join the live Zoom class
  - Permits real time interaction
  - Amplifies expectations and issues related to assignments
  - Additional examples
- Zoom etiquette
  - Mute yourself when joining
  - It is OK to interrupt if I don’t notice your raised hand or question in the chat window
  - Turn on your camera when participating in an ongoing discussion

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 and Android
- 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 (Zoom):
  - Before and after Class
  - By appointment
- 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 Sunday evening 11:59 pm
  - Grace period until Monday morning at 08:00am
  - **Assignments emailed or attached as comments on Canvas will not be accepted**
  - BBA students: Let me know about exceptions
- Assignments must be completed individually
  - Stealing ideas are permitted
  - OpenGL code fragments from 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 an assignment from a previous semester with minimal changes is ***not*** acceptable
- 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 Vermilion Book”
  - Older edition was the “OpenGL Red Book”
  - Download early editions as PDF
  - Recommended but not required

Other Texts

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

Theoretical text

- Computer Graphics: Principles & Practice (3ed)
  - Foley, van Dam, et. al.
  - 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
  - Munshi, Ginsburg, Schreiner
  - 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** June 2 at **noon**
- 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)
  - BBA students let me know about special circumstances and schedules
  - Office hours

My information

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

Zoom Considerations

- *Who Am I* Zoom:
  - **Wednesday** June 2 at 3pm-5pm
  - Turn on your camera so I see you at least once
  - This will have a waiting room – be patient.
- Mute your audio when joining.
- If you have a question:
  - Ask a question in chat
  - If I don’t notice the chat question, unmute yourself and interrupt me.
- For other office hours email me and I will send you a Zoom invite

Homework Assignments

Hw 0: Who Am I

Hw 1: Visualizing the Lorenz Attractor

Hw 2: Drawing Scene in 3D

Hw 3: Lighting and Textures

Hw 4: Project Proposal

Hw 5: Project Review

Hw 6: Project Final

How to get started

- Get OpenGL to work on your platform
  - *Installing OpenGL with GLUT*
  - 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
  - homebrew for glfw, SDL, etc.

Assignment 1

- Due: Sunday June 6 at 23:59
- Write an OpenGL based visualization of the Lorenz Attractor
  - At a minimum show a line path in 3D
  - User control of attractor parameters
  - Change view angle 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 2

- Due: Sunday June 13 at 23:59
- Write an program to visualize a 3D scene
- Scene must consist of solid 3D objects
  - You must create all 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
- Generate scene in orthogonal, add perspective and first person navigation

Assignment 3

- Due: Sunday June 20 at 23:59
- Write an program to visualize a 3D scene with lighting and textures
  - Make the light move to show lighting effects
  - Select solid objects that show lighting effects
- *Add lighting to Assignment 2*
- *Then add textures*
- **WARNING: This homework is a LOT harder than the first two**

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: **Mon June 21 23:59pm**
  - Review: **Sun June 27 23:59pm**
  - Final: **Wed June 30 23:59pm**
- ***Homeworks should lay the groundwork***

Project Grading

- Half the total grade for the class
- The grade assigned for the ***final*** submission is what is counted
- Grades assigned for 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

CSCI 4239/5239
Advanced Computer Graphics

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

Nuts and Bolts

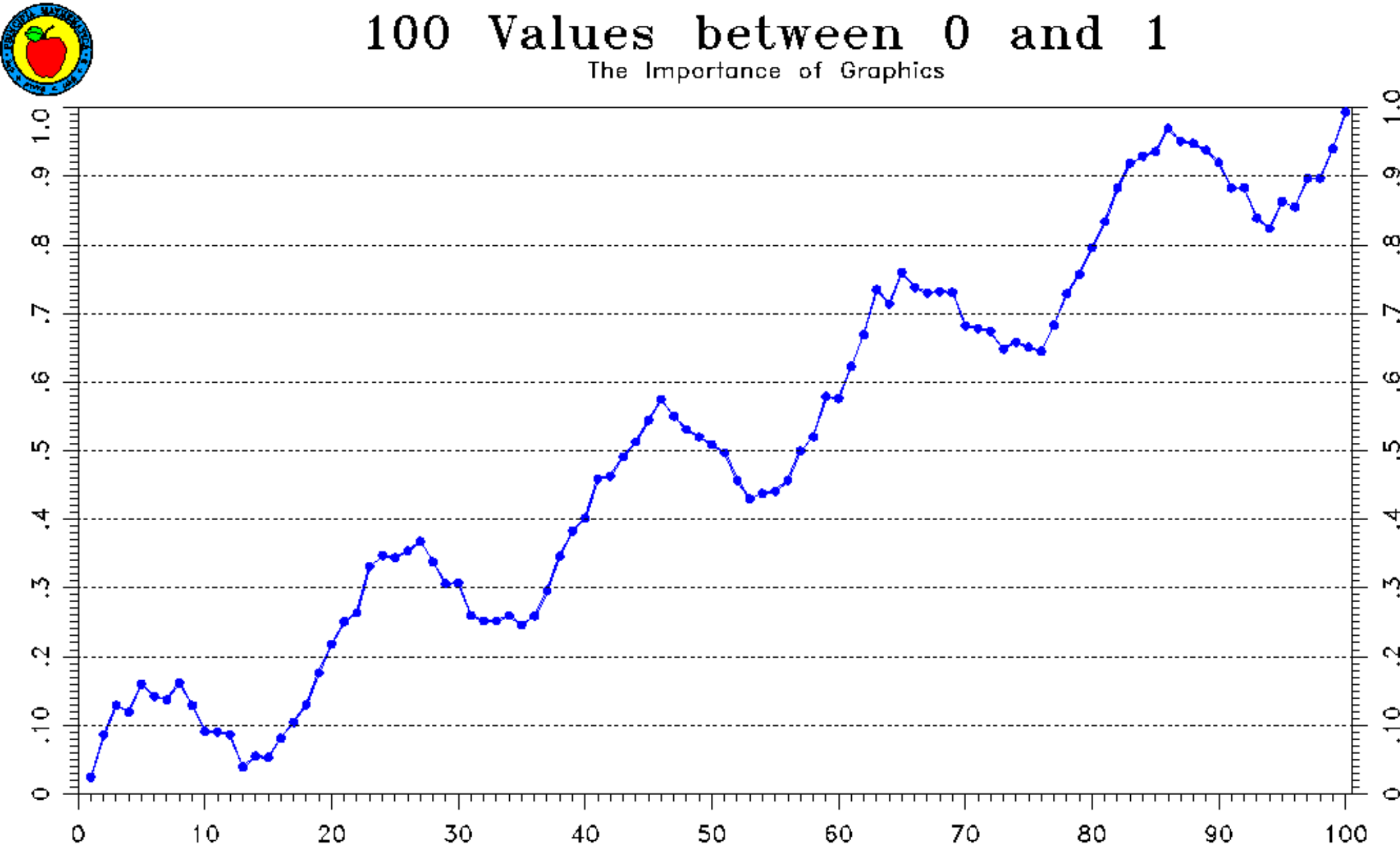
- Complete assignments on any platform
  - Assignments reviewed under Ubuntu 20.04
- Submit using Canvas
  - ZIP
  - Name executables hw1, hw2, ...
  - Create a makefile so I can do *make clean;make*
  - Set window title to *Assignment X: Your Name*
- Include number of hours spent on task
- *Check my 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=32bit, long=64bit
  - 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
.10
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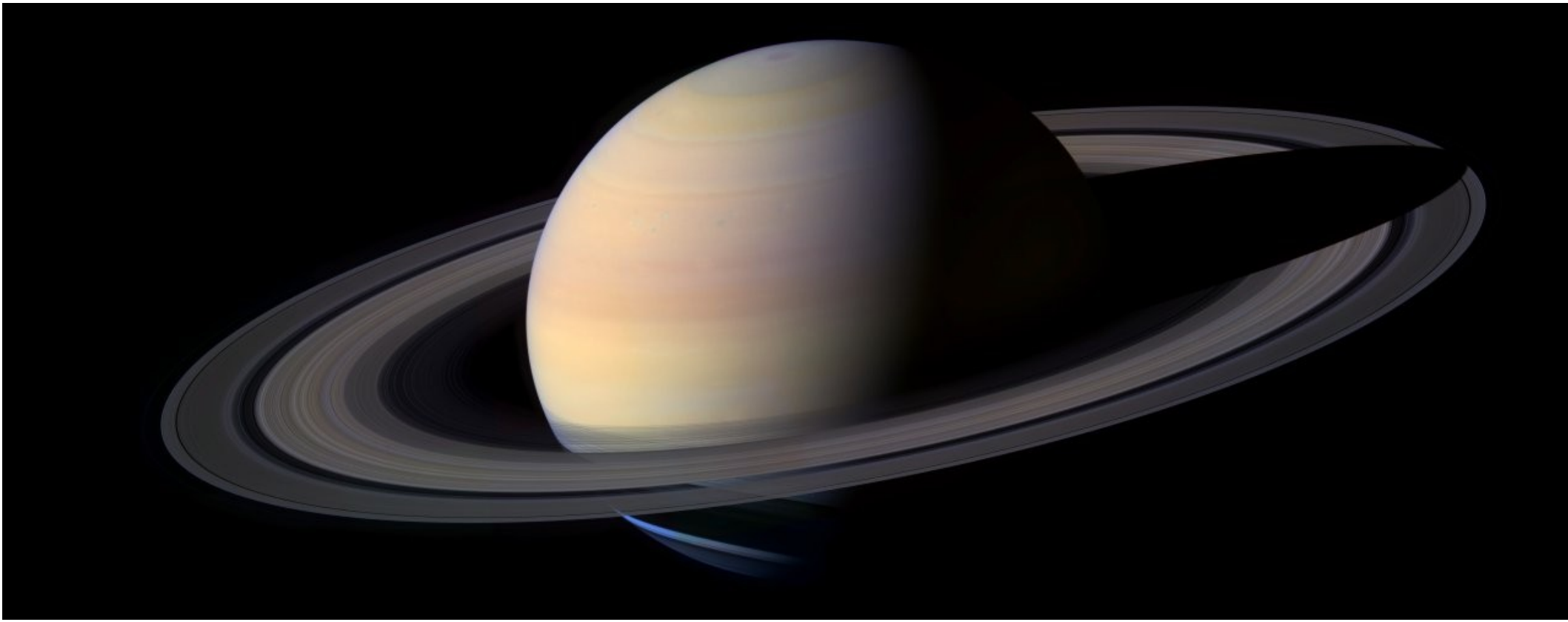
1.0
0
10
20
30
40
50
60
70
80
90
100

Graphic Design

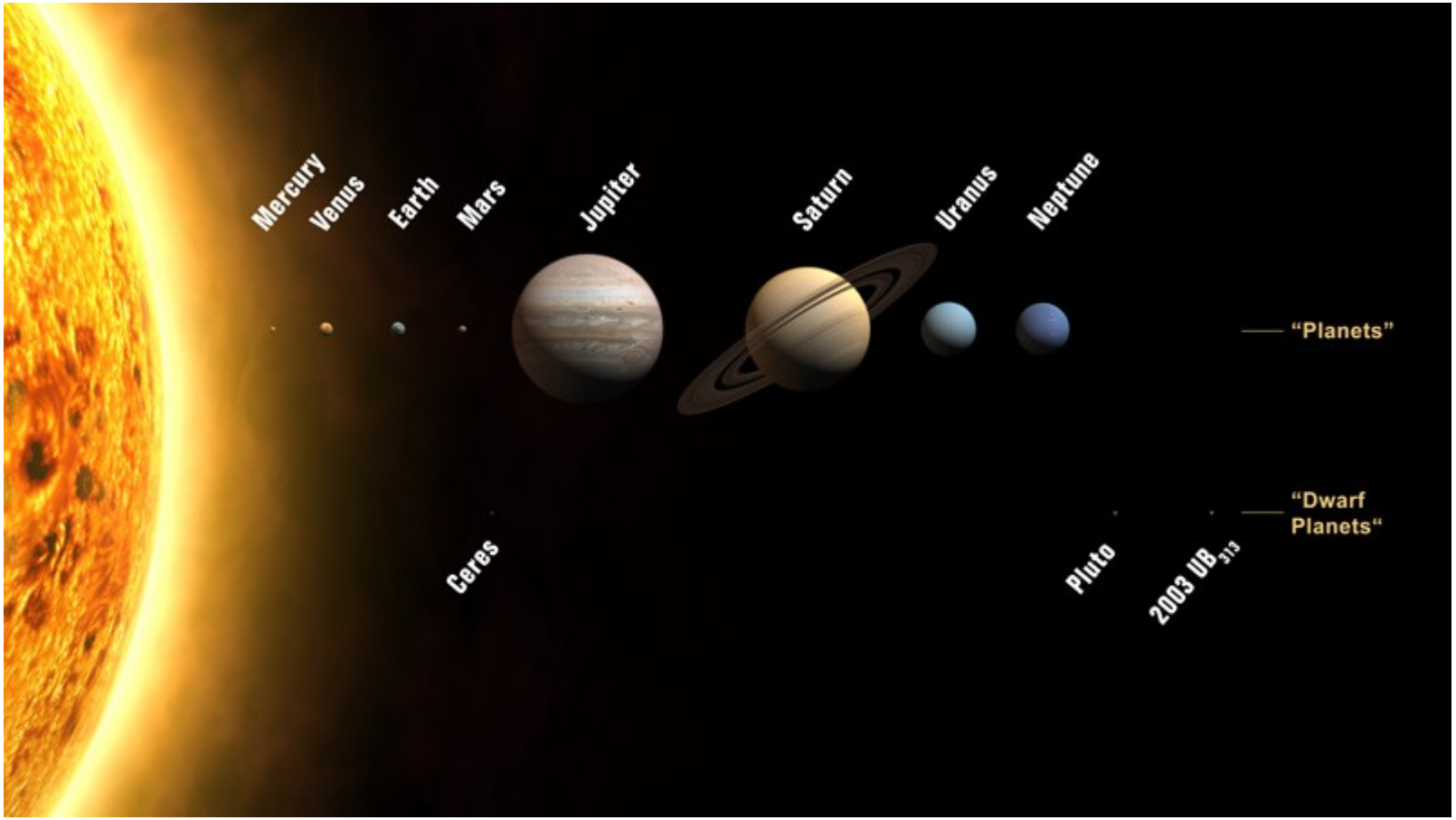
- 2D vs. 3D
  - Cool vs. informative
- Edward R. Tufte
  - Visual Explanations
  - Envisioning Information
  - The Visual Display of Quantitative Information
  - Beautiful Evidence

Saturn from Cassini Probe



Colorado Fall Colors

What is wrong with this picture?



In the beginning....

Storage Tube Terminals

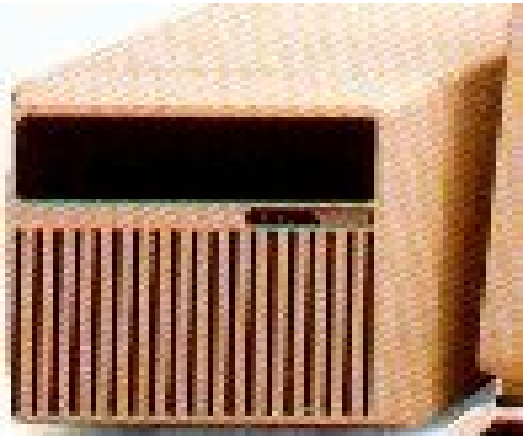
Storage Display Images

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..

Plotting Packages

- PLOT-10: Tektronix 4010 graphics
- PLOT88: PC graphics
- DISSPLA: NCAR graphics
- GINO: Portable graphics
- DIGLIB: LLNL device-independent, open source
- GKS: Graphics Kernel System (2D vector)
- PHIGS: 3D Interactive Graphics
- OpenGL and DirectX

The rise of OpenGL

- Originated as SGI IrisGL
- Vendor-neutral OpenGL controlled by ARB
- Hides the details of hardware
  - Software emulation when necessary
  - Hardware acceleration when possible
- Supports 2D to advanced 3D graphics
- Portable to most hardware and OS with WGL, AGL and GLX
- Hardware range from phones to Big Iron

Focus of OpenGL

- OpenGL 1 (1992)
  - Hardware abstraction
- OpenGL 2 (2004)
  - Add Shaders (Programming the GPU)
- OpenGL 3 (2008)
  - Focus on shaders and new hardware
  - Deprecates many features
- OpenGL 4 (2010)
  - Core & Compatibility Profiles
  - Merge desktop and embedded versions

Gaming and Graphics

- Text based/ASCII graphics (Pong, PacMan)
- 2D monochrome line graphics (Astroids)
- 2D images & sprites (Mario)
- 3D graphics
  - Flight Simulators (2D -> 3D)
  - First Person Shooters
  - Multi-player games
- Games push the envelope
  - Realism
  - Speed