CZ2003
Computer Graphics and Visualization

SCSE, NTU

Introduction to Computer Graphics and Foundation Mathematics

Module 1
Lecture 1

Rationale for the Course

- Information visualization and visual analytics as graphics rendering of abstract data becomes more and more important in modern science and technology.
- Creating images by coding mathematics was a necessary skill for content creators in the 80s of the last century. Today, the content is mostly created by using powerful tools and sophisticated modelling and visualization pipelines.
- The skills of making images with raw mathematics and from first principles become very rare.

Learning Objectives

- You will learn how to see geometry and colors beyond simple mathematical formulas and to represent geometric shapes and motions by analytical functions and algorithmic procedures.
- You will develop spatial visualization skills which will permit you to perform 3D rotations and other transformations and motions of geometric objects.
- You will also learn how a common personal computer can be used for solving complex computer graphics problems.

Course

- Mostly online. **100% coursework-based assessment.**
- Lectures (26 hours), tutorials (12 tutorials), labs (5 experiments), final assignment (1 hour).
- **Lectures** (TEL lectures and live online lectures in Zoom) mostly concentrate on making images with math: using mathematics for defining geometric shapes, colors and transformations.
- **Labs** (on your your own computers and with limited access to the SW Lab) start on weeks 3-4 according to the individual lab schedules (see the course site). 5 assignments. Electronic assessments one week after week each lab session. Lab mark contributes **60%** to the final mark (up to 12 marks for each lab).
- **Tutorials** begin on week 2. **Written solutions** must be emailed to the tutors **before each tutorial**. Tutorial solutions will be marked as follows:
  1 mark (~>60% correct), 0.5 mark (~30-60% correct),
  0 mark(~<30% correct, or plagiarism, or no solution is submitted).
  Tutorial marks will contribute **12%** to the final mark (up to 1 mark for each tutorial).
- **Final assignment** will be conducted on revision-exam weeks (TBA). Timed 1-hour online assignment with the same format as the labs. Will contribute **28%** to the final mark.

Lectures

1. **Introduction to computer graphics and foundation mathematics**
   Principles of visualization. Coordinate systems. Time as another dimension. Vectors and matrices. Vector and matrix algebra with application to geometric coordinate space. Geometric meaning of dot and cross products. Surface normal calculation.
2. **Programming computer graphics and visualization**
   Introduction to common computer graphics software used for solving engineering and information visualization problems. Introduction to the software used in the coursework.
3. **Geometric shapes**
   Points, polygons, voxels, and procedural models. Analytical definitions of curves, surfaces, and solid objects. Shape animation and morphing. Principles of graphics rendering.
4. **Transformations and motions**
   Affine transformations. Translation, Scaling, Rotation. Composition of transformations. Motions by parametric functions and time-dependent affine transformations.
5. **Illumination and Texture Mapping**
   RGB color model and light sources. Illumination calculation. Image texture mapping. 3D geometric textures. Appearance assignment to geometry.
6. **Efficient rendering**
   Hierarchical representation. Spatial partitioning. Bounding volumes. Level of detail.

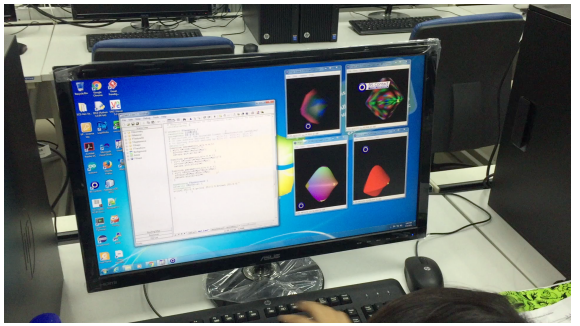
Tutorials (from week 2)

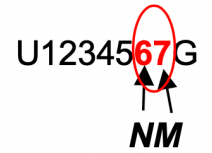
- T1. Coordinate Systems and Vectors
- T2. Mathematical functions in computer graphics
- T3. Geometry: Curves
- T4. Geometry: Planes, Polygons and Bilinear Surfaces
- T5: Geometry: Surfaces by Sweeping
- T6. Geometry: Solid objects
- T7. 2D Transformations
- T8. 3D Transformations
- T9. Motions
- T10. Illumination
- T11. Surface texture mapping
- T12. Efficient rendering

Labs (from week 3): Making Images with Mathematics

Individual personalized marked assignments (up to 12 marks each)

1. Parametric curves
2. Parametric surfaces
3. Parametric solids
4. Implicit Surfaces and Solids
5. Transformations and Motions

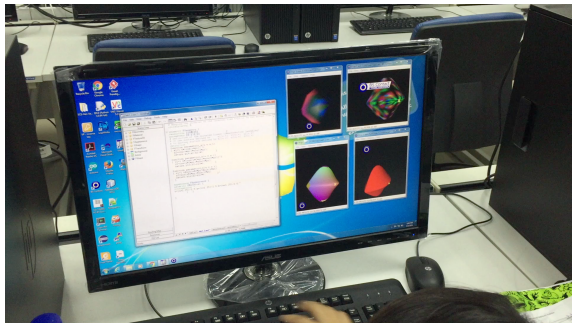




The personalization is based on using two last digits of your matriculation number.

Final Assignment (revision/exam weeks)

1. Individual personalized one-hour lab assignment
2. On your own computers or in the lab
3. Covers multiple topics



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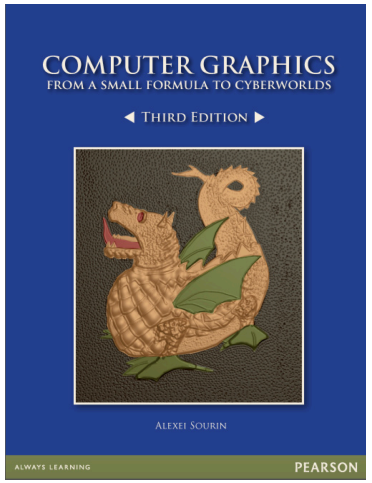
Text Book



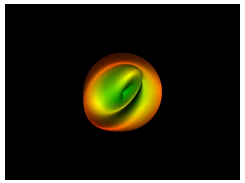
http://www.ntu.edu.sg/home/assourin/Book

Introduction to Computer Graphics and Visualization

- Definitions
- Visualization steps

Definitions

- *Computer Graphics* concerns the pictorial *synthesis* of real or imaginary objects from their computer-based models
- *Visualization*
  To form an image of something; envisage; to make a physical 3D model



- *Image Processing* is the converse process: the *analysis* of scenes, or *reconstruction* of models of 2D or 3D objects from their pictures

Graphics Display

- **Pixel** – picture element
- **Resolution:** number of pixels which can be displayed horizontally and vertically.
- **Number of colors:**
  Maximum actual number of colors depends on the graphics display device and the video card. Device independent colors are programed as real numbers between 0 and 1

LCD Display

- **RGB color model**: addition of *red+green+blue=white*
  used with graphics displays (used in this course)

- **CMYK color model**: subtraction of *cyan+magenta+yellow=black (key)*
  used when printing (not used in the course)

- **Polygonization:** to calculate polygons interpolating surfaces of shapes
- **Shading**: filling in surface of polygons with colored pixels

Visualization Steps

- Define Objects: 3D shapes, defined by polygonal surfaces (triangle sets)
- Define a Viewpoint (viewer position and orientation) and viewing parameters
- Define light source(s): ambient, point, directional, etc.
- Define visible material properties

Summary

- Computer graphics makes images with computers
- Visualization requires: object model (geometry + material), light source(s), observer