Computer Graphics

An Introduction

Taku Komura

What's this course all about?

We will cover…

Graphics programming and algorithms

Graphics data structures

Applied geometry, modelling and rendering

How to use OpenGL

Not covering : how to use software like Maya, 3D Studio Max, etc.

Other Important things

- You need to know about math
- We will use basic linear algebra
  - Dot product, cross product, matrix calculations
  - Basic calculus, solving linear systems

Please don’t take the course if you don’t like math

Outline for Today

- Classic streams of computer graphics
- Application areas of computer graphics
- About SIGGRAPH
- Overview of the course
  - Topics in Graphics Pipeline, etc

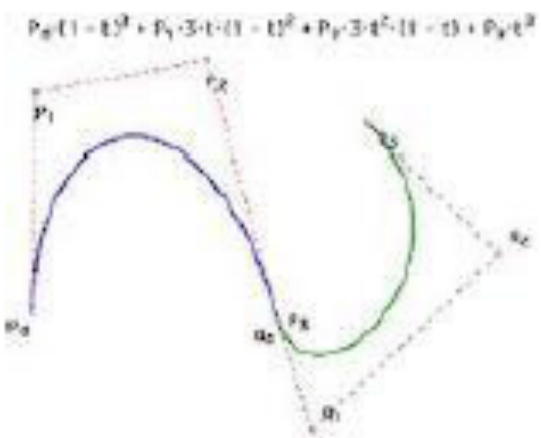
Classic streams of computer graphics

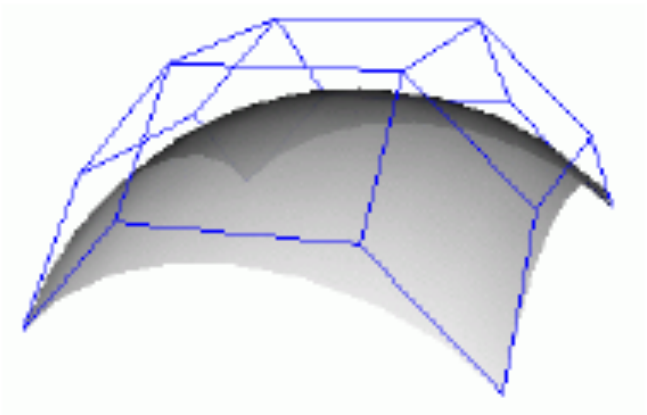
- 2D/3D modeling (aircraft, car manufacturing)
- Interactive applications (computer games, design)
- Realistic rendering (Lots of work at University of Utah)
- Computer art (many people)

2D/3D Modeling

Designing curved surfaces was important for car and aircraft manufacturers in the old days

- Such modeling requires a lot of mathematics
- Lots of mathematicians join the graphics research community nowadays too





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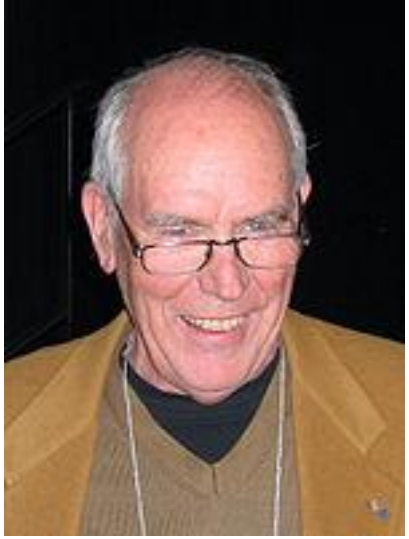
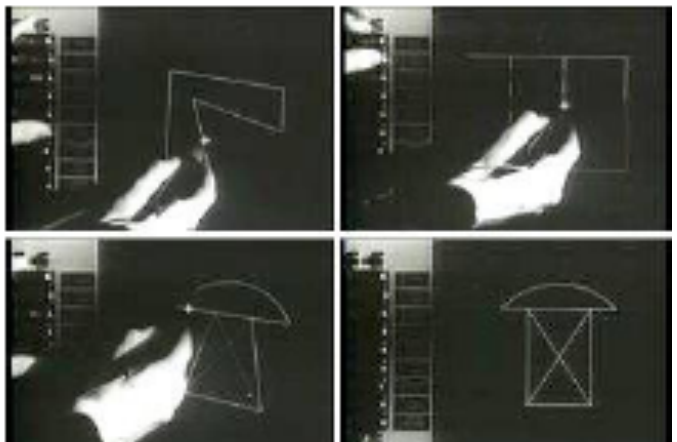
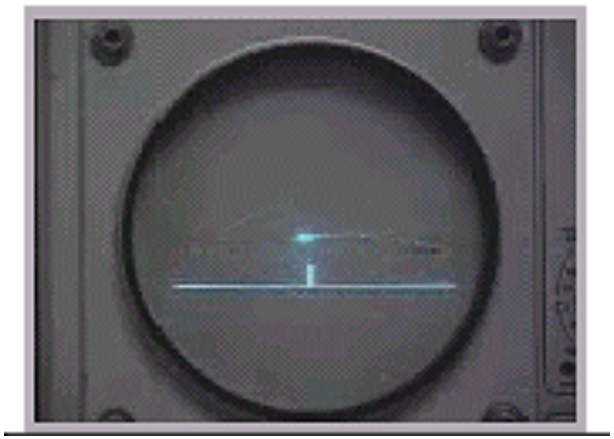
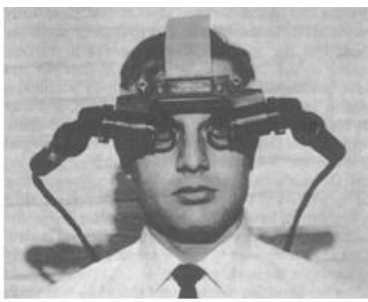
Interactive applications



- Sketchpad (1963, Ivan Sutherland)
- Head mount display (1968, Ivan Sutherland)
- Tennis game (1958), Space war (1962)

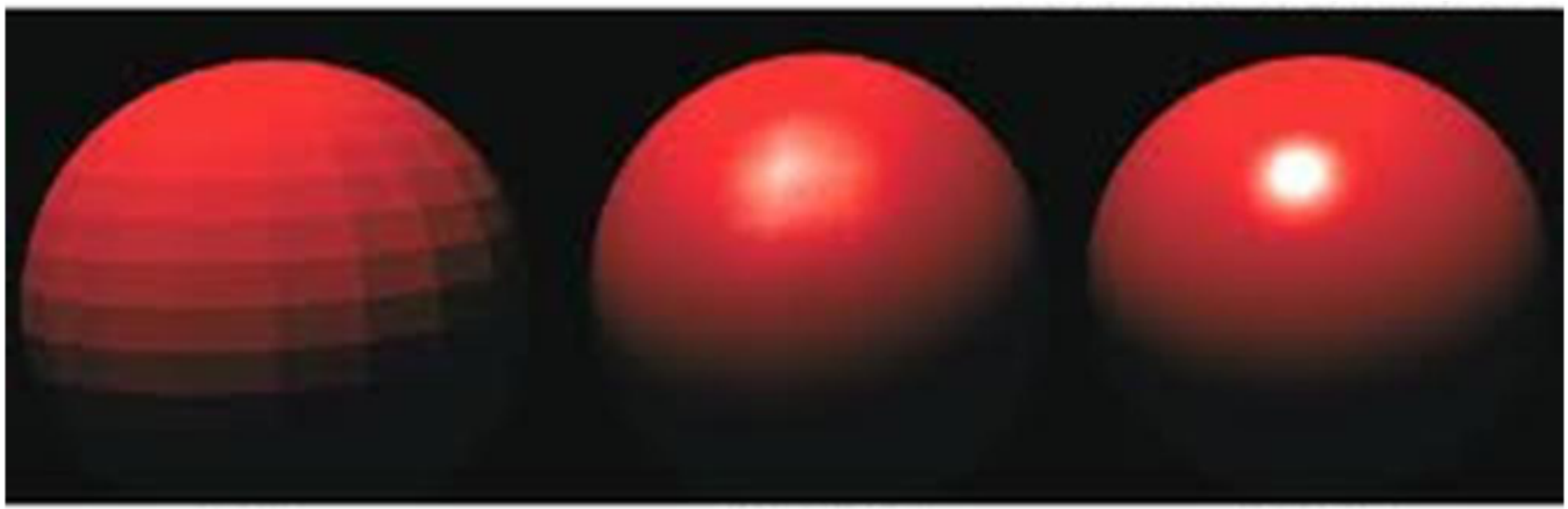






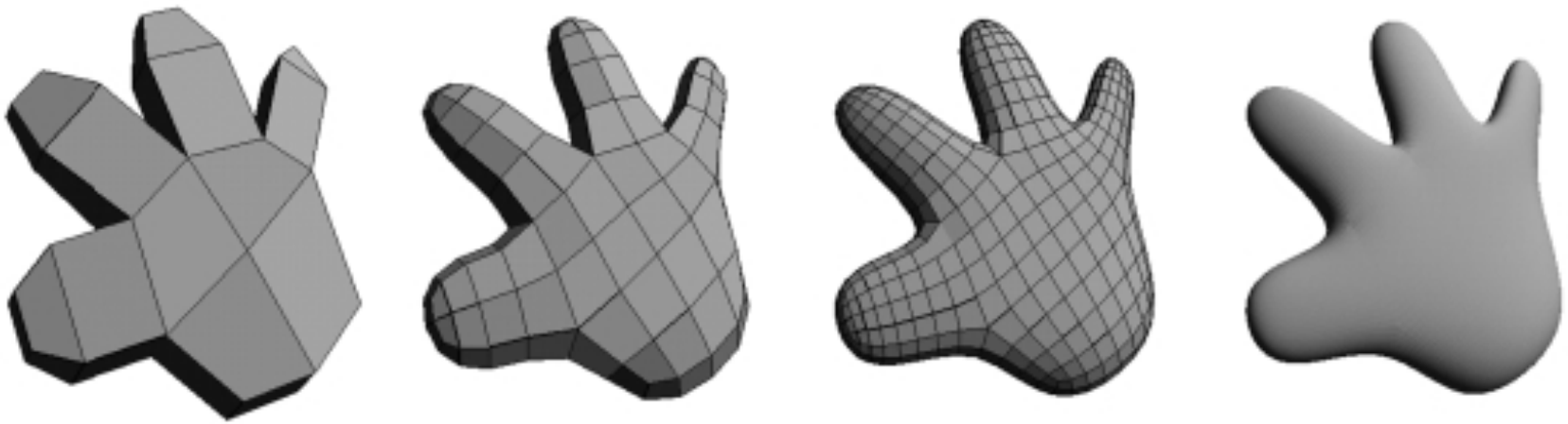
Realistic Rendering (University of Utah)

- Gouraud shading (Gouraud, 1971)
- Phong shading (Phong, 1975)
- Phong illumination model (Phong 1973)

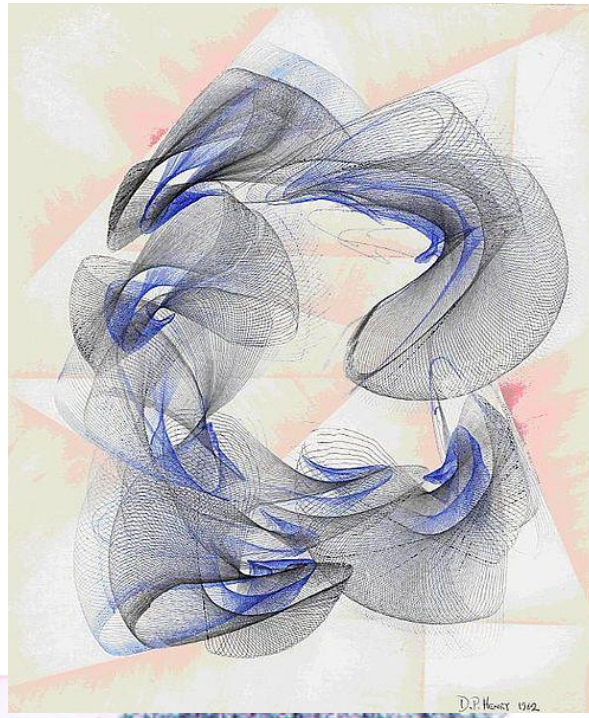


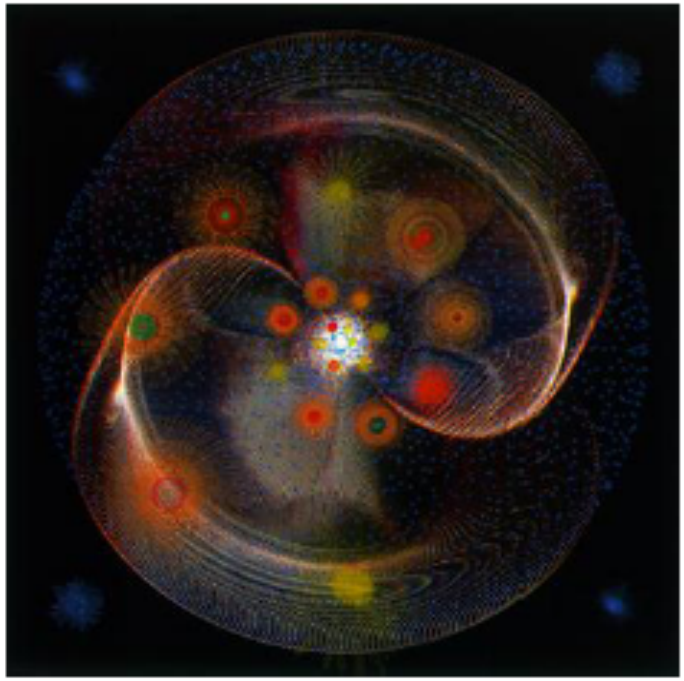
Realistic Rendering (University of Utah)

- Bump mapping (1978)
  – Jim Blinn
- Subdivision surface (Catmull, Clark 1978)



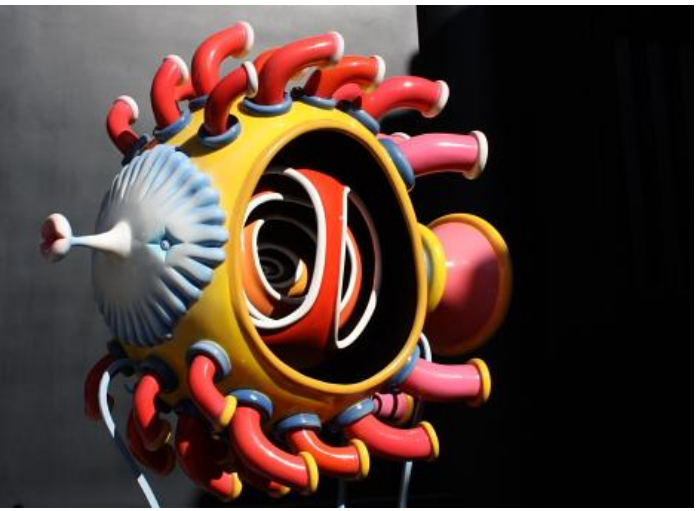
Computer Art (1960-)





Yoichiro Kawaguchi

Motivation : going to Mars



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The Application Areas of Computer Graphics

Computer Animation
Computer Games
Virtual Reality
Scientific Visualization
Human Computer Interactions

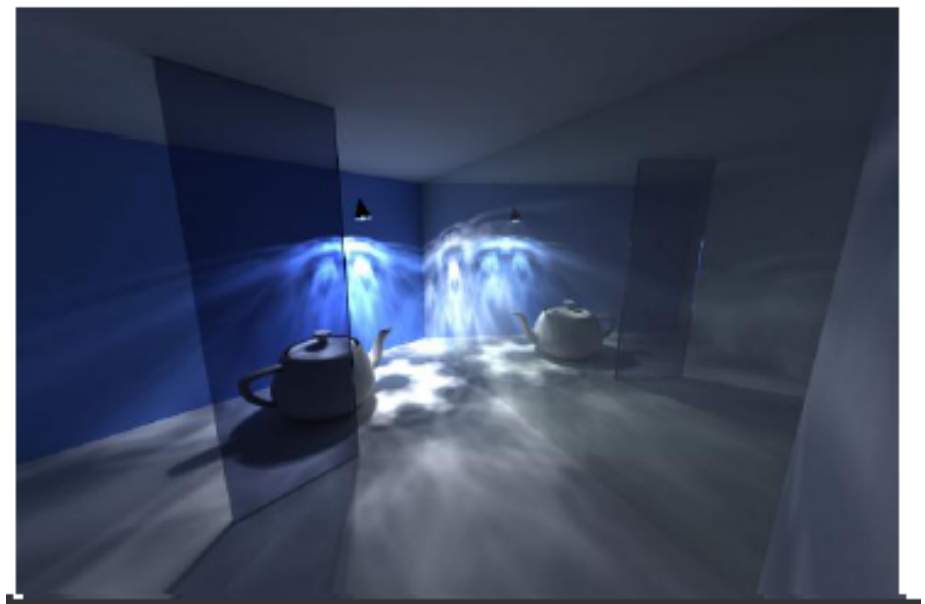
Computer Graphics is about animation (films)

What are the Challenges?

- Realistic Lighting and Reflections:
  - Need to make the lighting condition appear like real
  - Need to make objects reflect the light realistically
- Physical simulations:
  - Fluids (liquid, fire), rigid bodies
- Realistic movements of the faces, bodies, etc.
  - Need to make the imaginary characters appear as if they are really in the environment

Realistic Lighting and Reflections:

- Need to make the lighting condition appear like real
- Need to make objects reflect the light realistically (modeling the reflection model)



Physical Simulation

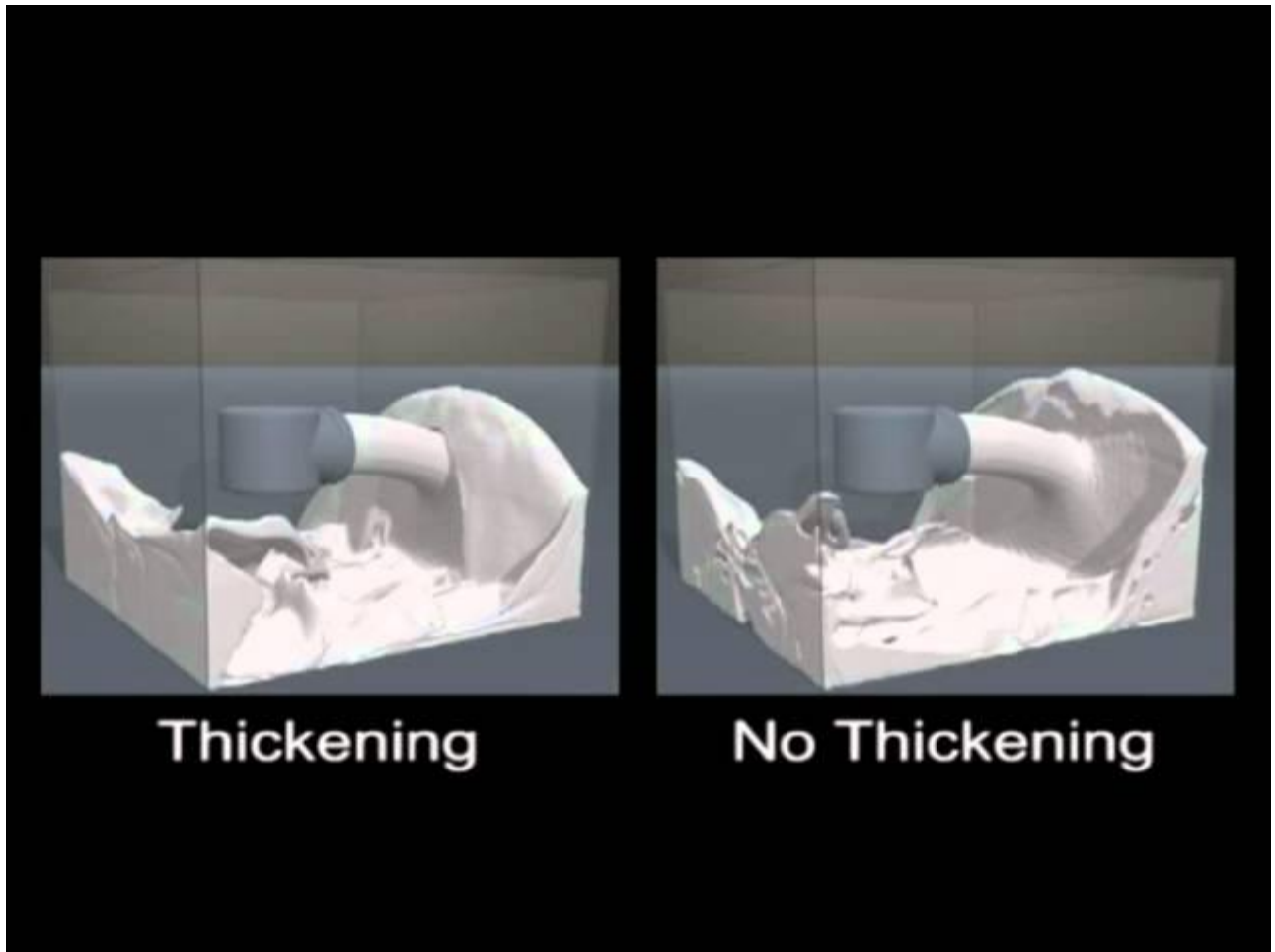
- Cloth

  http://www.youtube.com/watch?v=NoazGEnzsRA

Physical Simulation

- Water

  http://www.youtube.com/watch?v=feBfMf2J8uQ



Physical Simulation

- Rigid objects, destruction, explosions
- http://www.youtube.com/watch?v=bDFnig

Computer Games

What are the Challenges?

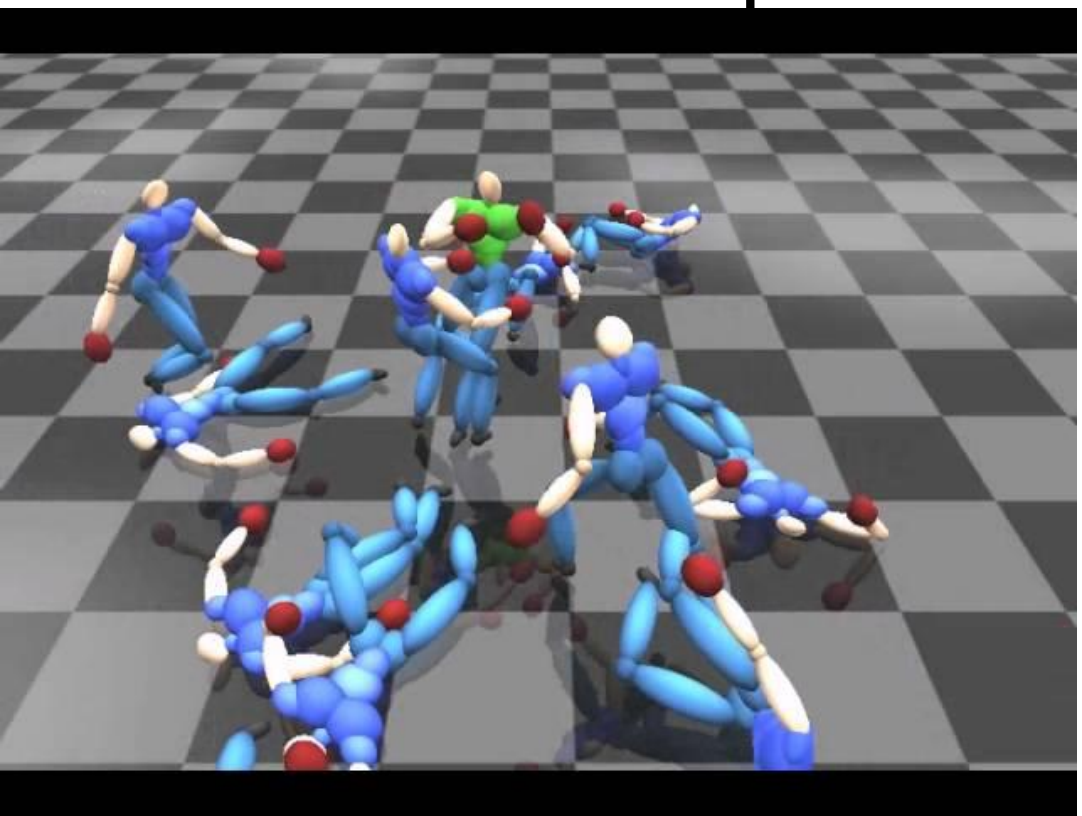
- Everything altogether must run in real-time

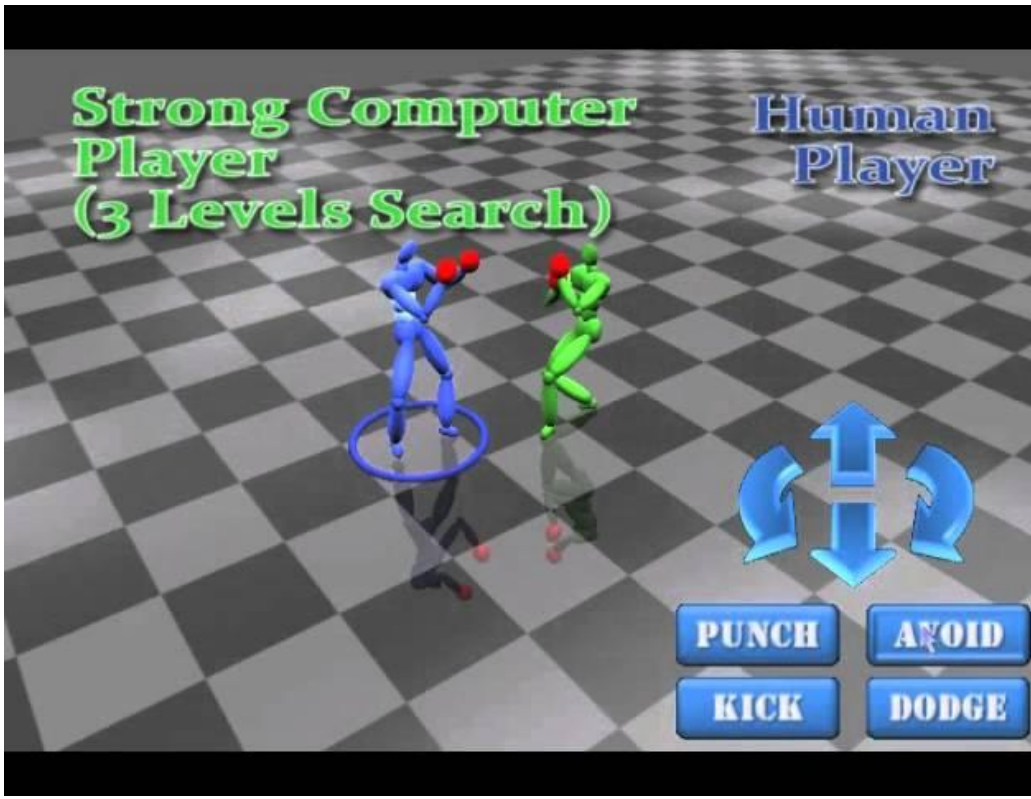
(30 frames per second)

- Rendering (drawing the scene)
- character control (player characters + non player characters)
- Physical simulation (object collision, deformations)
- user input

Character Control

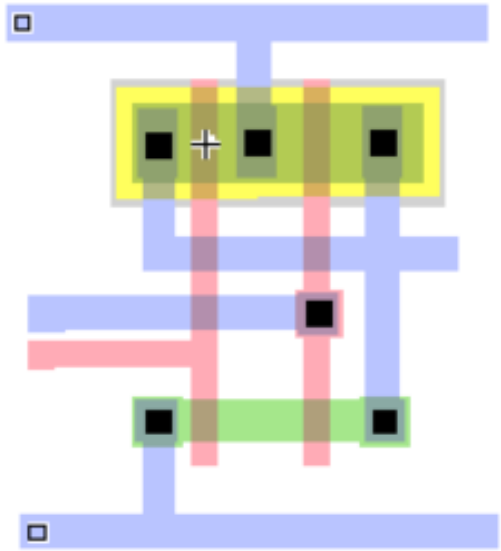
- Controlling the non-player character intelligently
- For player character, selecting an action based on the user input -> smooth transition

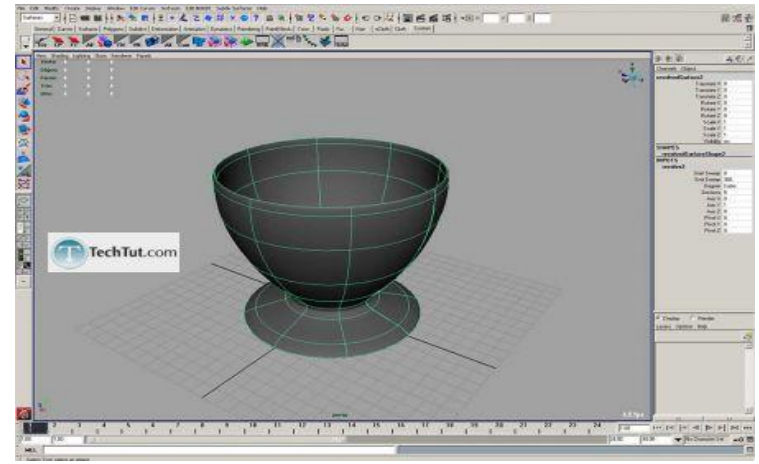


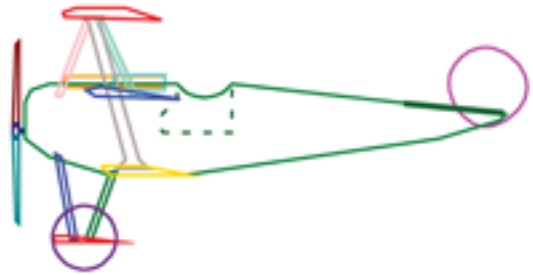


Virtual Reality, Medical Imaging is another driving force

Computer Aided Design, 3D modelling





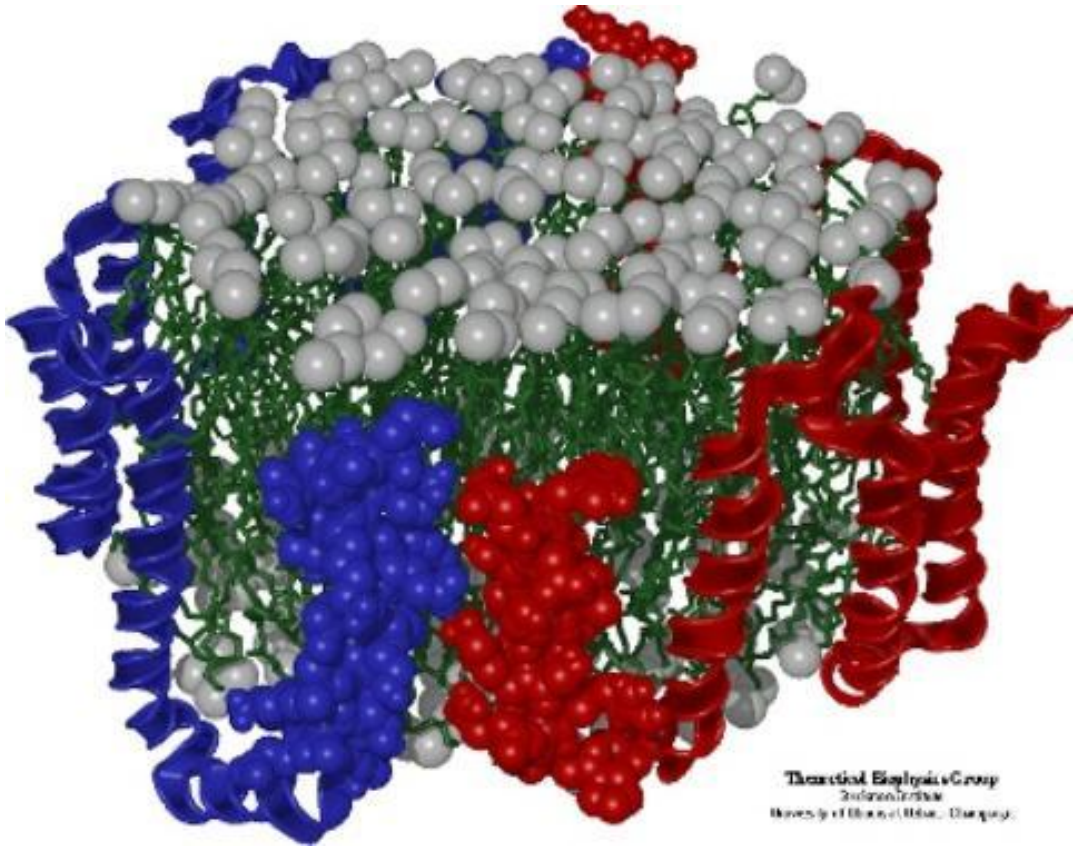


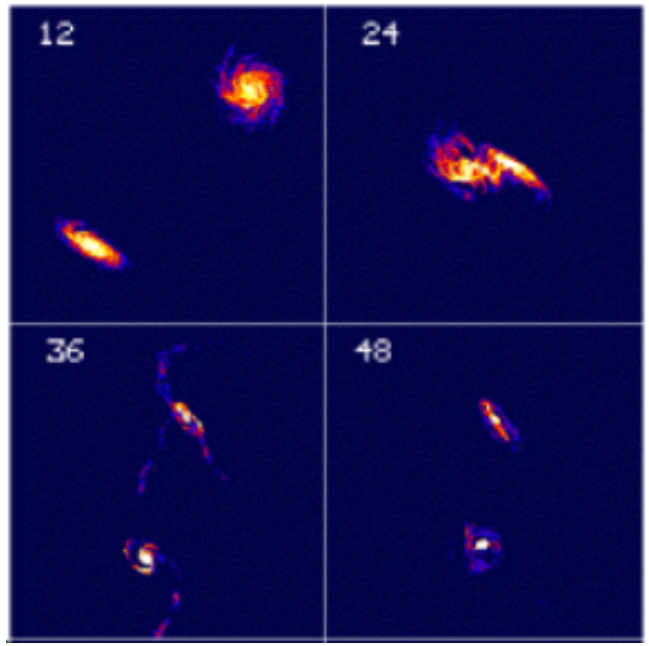
3D modelling

Modelling a cup by Maya

http://vimeo.com/5423236

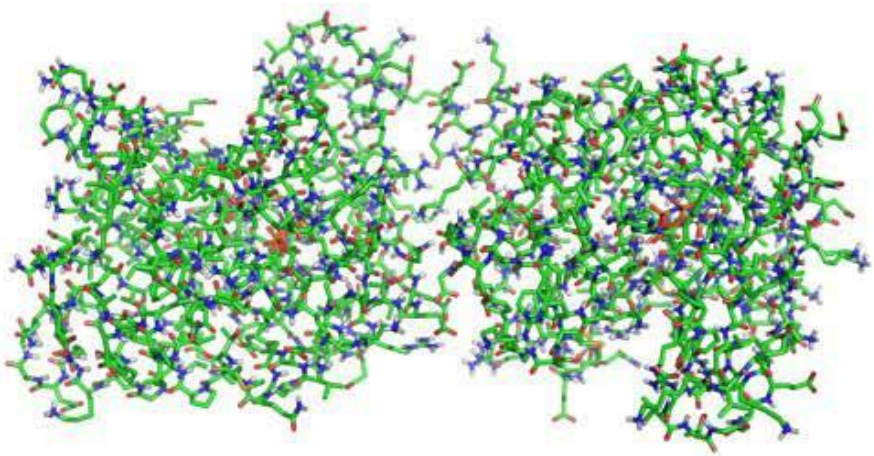
Scientific Visualisation

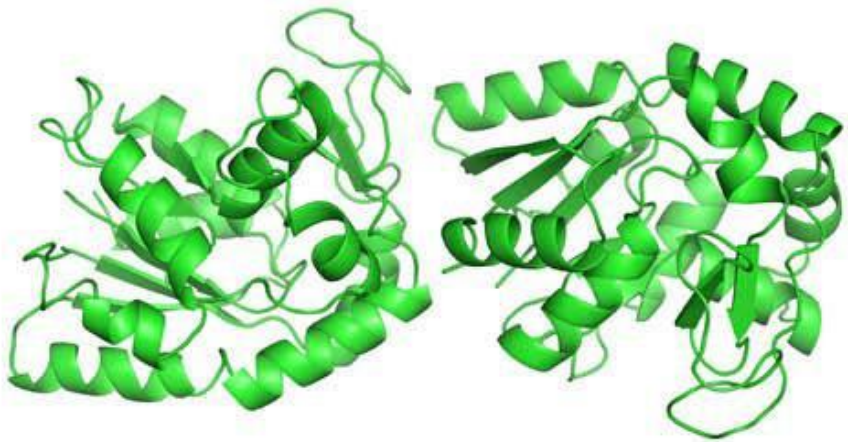




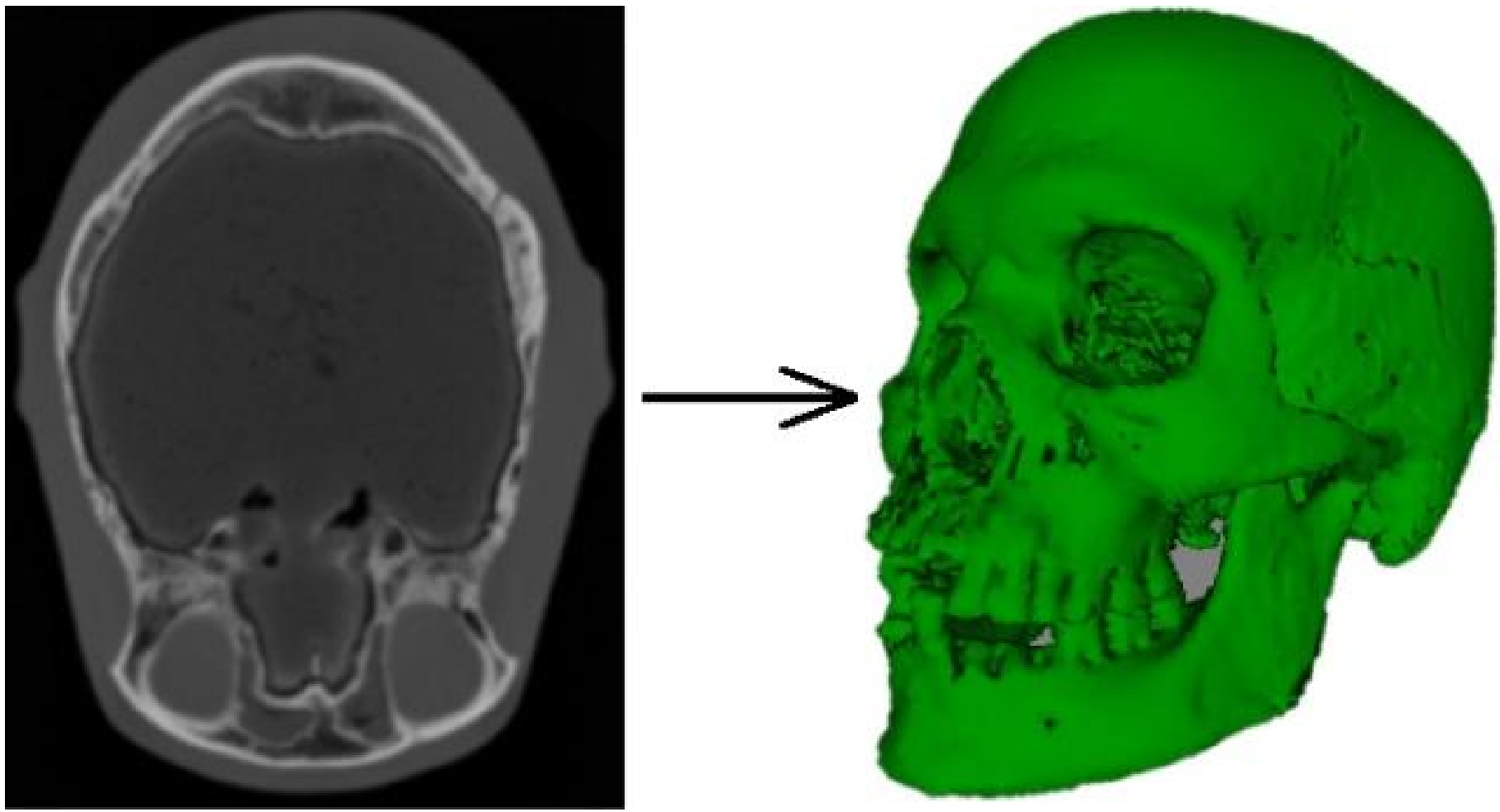
What are the challenges?

- Converting the numbers into something that is easy to understand
- Making use of human's visual perception



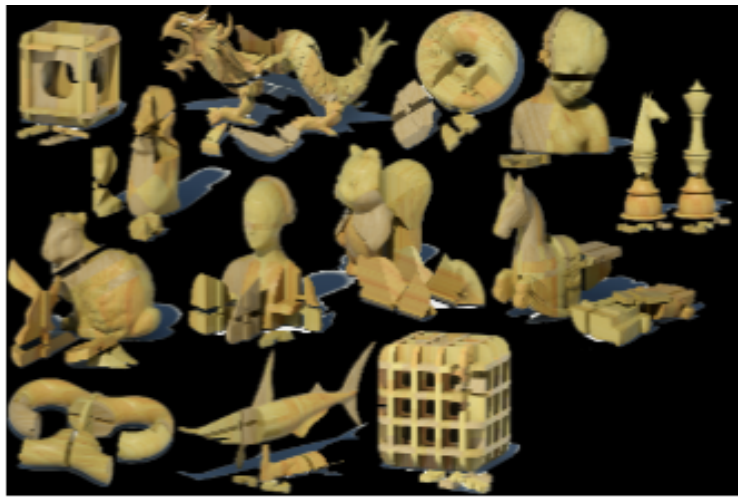


Volume rendering



Human Computer Interactions

- Sketch-based interfaces
- Story telling, puppetry
- puzzles



Teddy http://www.youtube.com/watch?v=e2H35SILmUA

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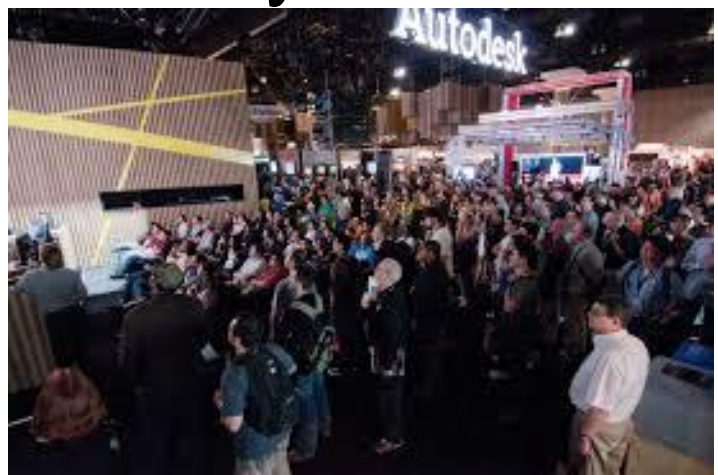
SIGGRAPH

ACMSIGGRAPH

(Special **I**nterest **G**roup on **GRAPH**ics and Interactive Techniques)

- The biggest computer graphics conference in the world that started in 1974
- Now about 20,000 attendees every year
- Most important techniques have been presented at the SIGGRAPH Technical Paper programme
- Getting a paper into SIGGRAPH is very important for CG researchers



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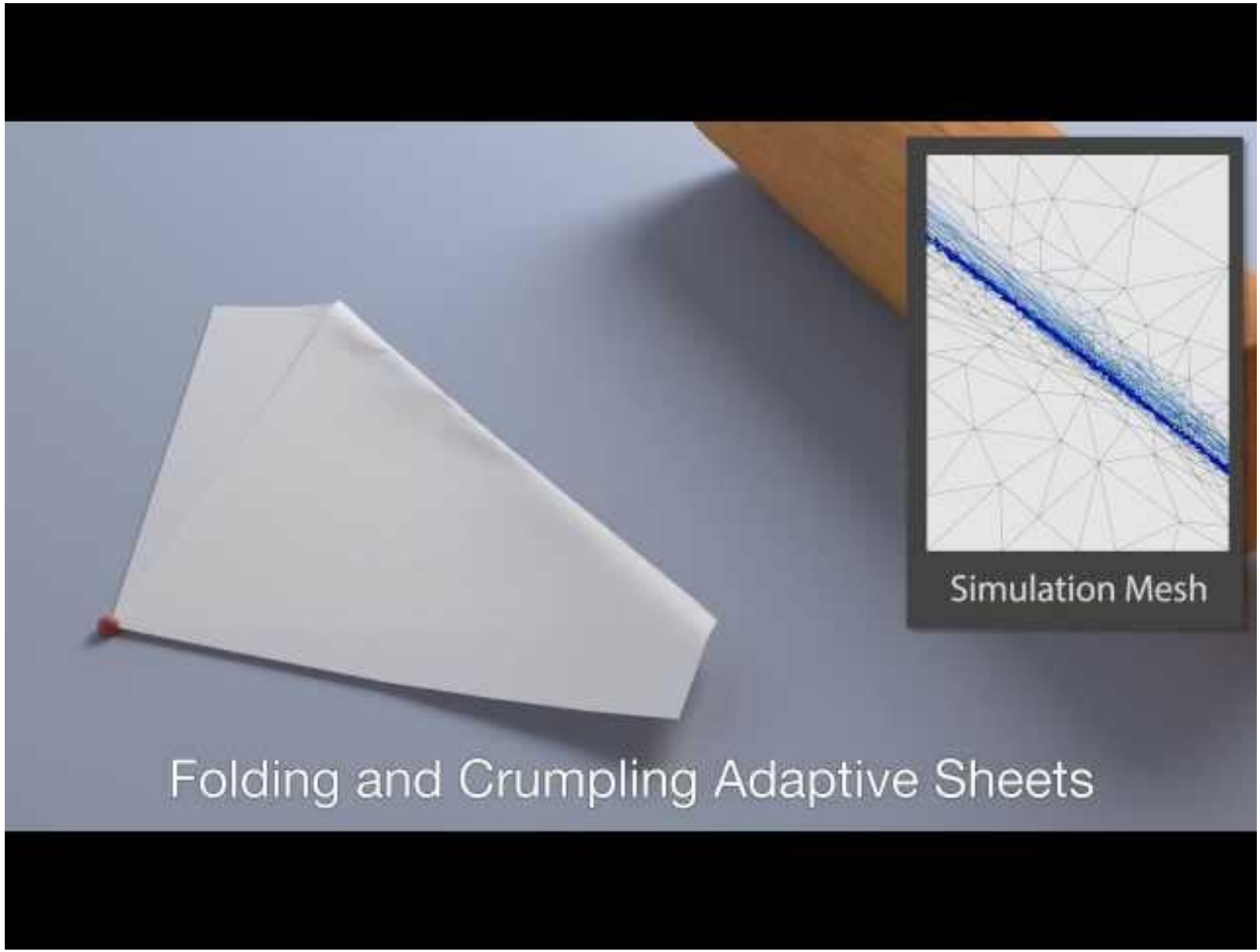



Computer Animation Festival
Electronic Theater, Daytime Selects, and Production Sessions now online!


SIGGRAPH2013
The 40th International Conference and Exhibition on Computer Graphics and Interactive Techniques
Conference 21–25 July 2013
Exhibition 23–25 July 2013
Anaheim Convention Center
Radial Wobble

Overview of the Course

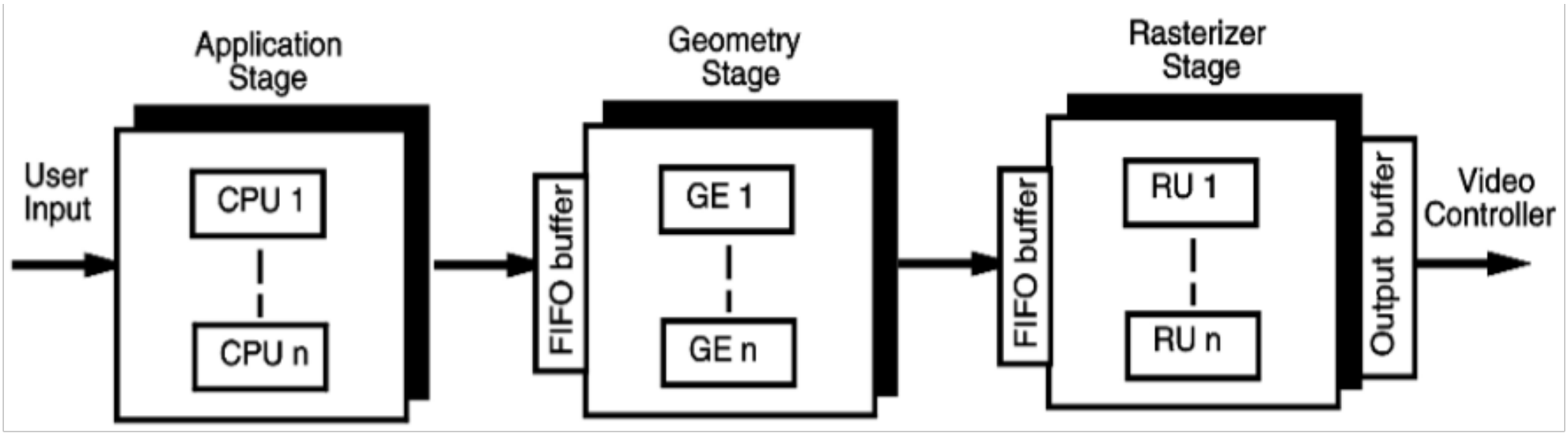
- Graphics Pipeline (Today)
  - 3D transformations
  - (Local lighting effects) Illumination, lighting, shading, mirroring, shadowing
  - Hidden surface removal
  - Rasterization
  - Ray tracing
- Global illumination
- Modelling, Curves and Surfaces

Graphics Pipeline

- Graphics processes generally execute sequentially
- Pipelining the process means dividing it into stages
- Especially when rendering in real-time, different hardware resources are assigned for each stage

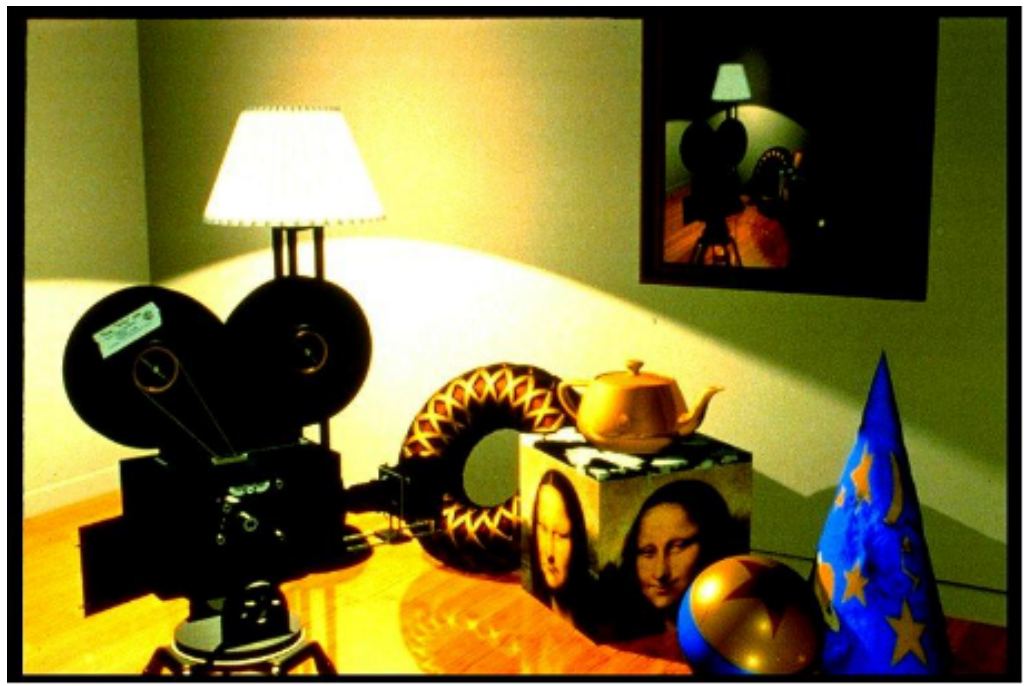
Graphics Pipeline

- There are three stages
  - Application Stage
  - Geometry Stage
  - Rasterization Stage



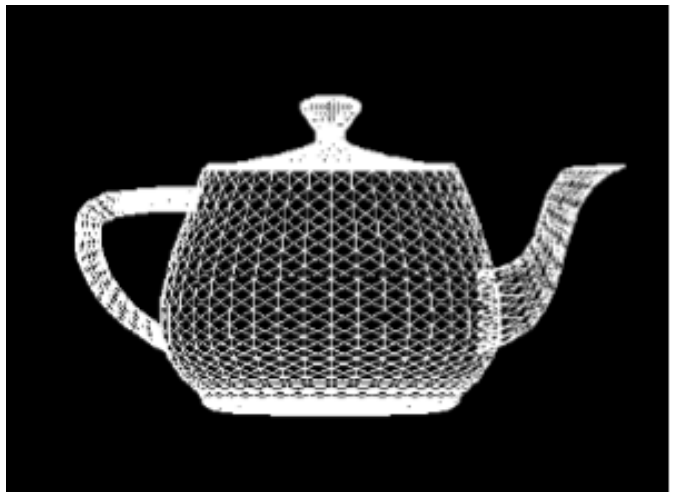
An example thro' the pipeline…

The scene we are trying to represent:



Application stage

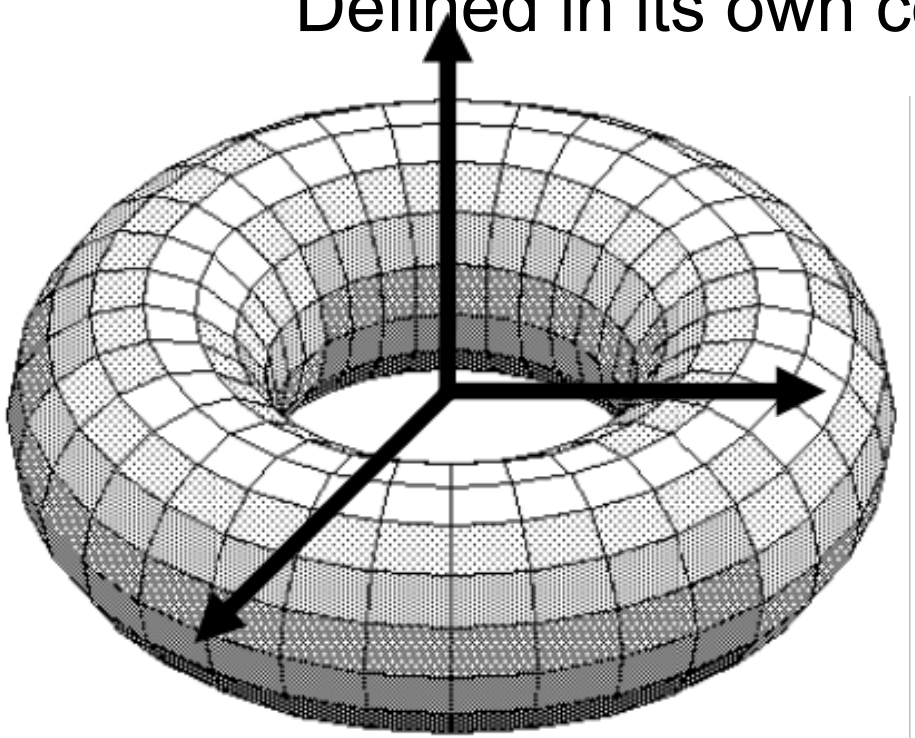
- Entirely done in software by the CPU
- Read Data
  - the world geometry database,
  - User's input by mice, trackballs, trackers, or sensing gloves
- In response to the user's input, the application stage change the view or scene

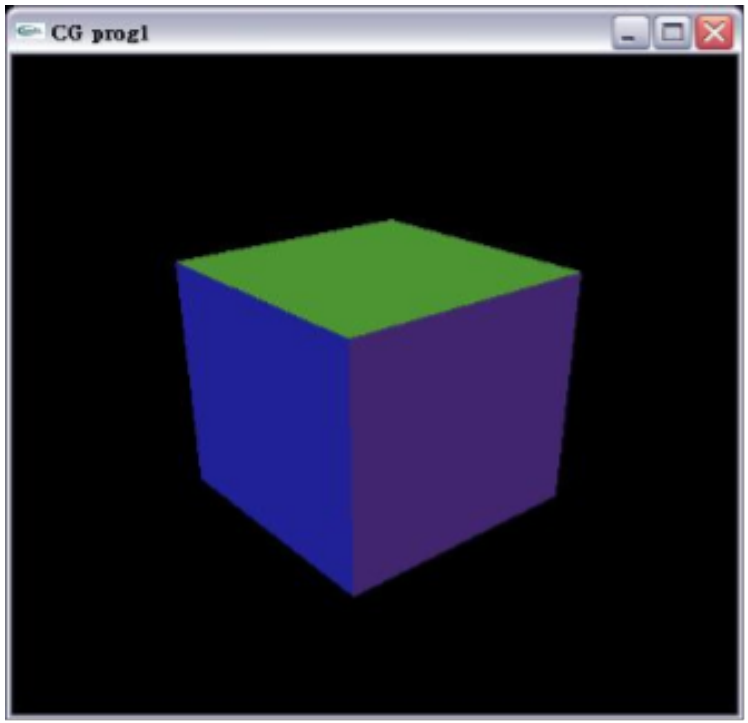


Preparing Shape Models (Lecture 2)

Designed by polygons, parametric curves/surfaces, implicit surfaces and etc.

Defined in its own coordinate system



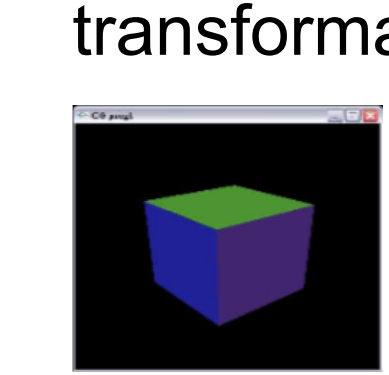


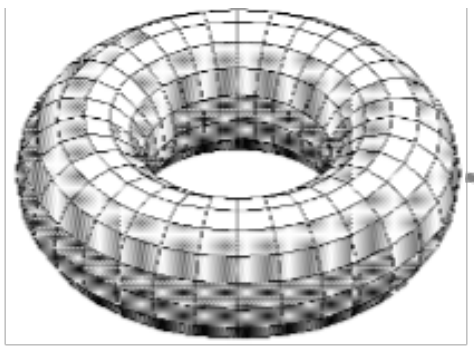
Geometry Stage

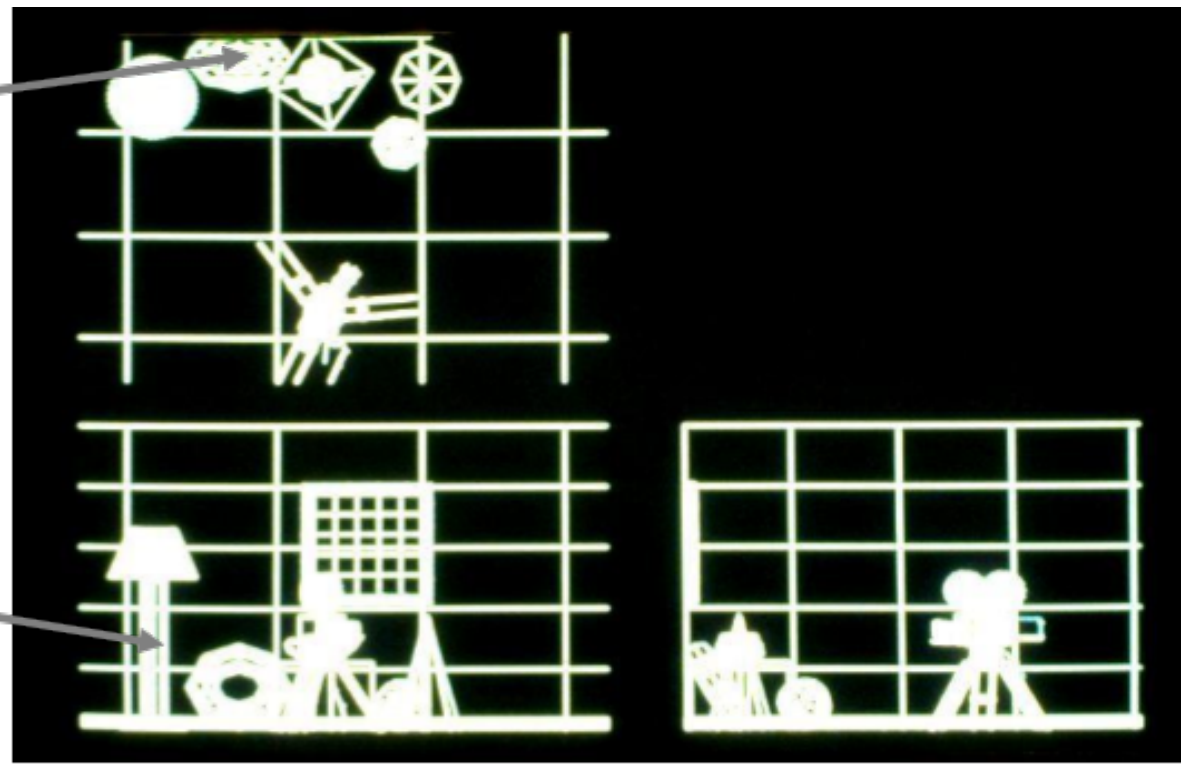
- Applying transformations to the object vertices (scaling, rotating, translating)
- View transformation (viewing from the camera)
- Illumination and shading (for Gouraud shading)

Model Transformation (Lecture 3)

- Objects put into the scene by applying translation, scaling and rotation
- Linear transformation called homogeneous transformation is used
- The location of all the vertices are updated by this transformation

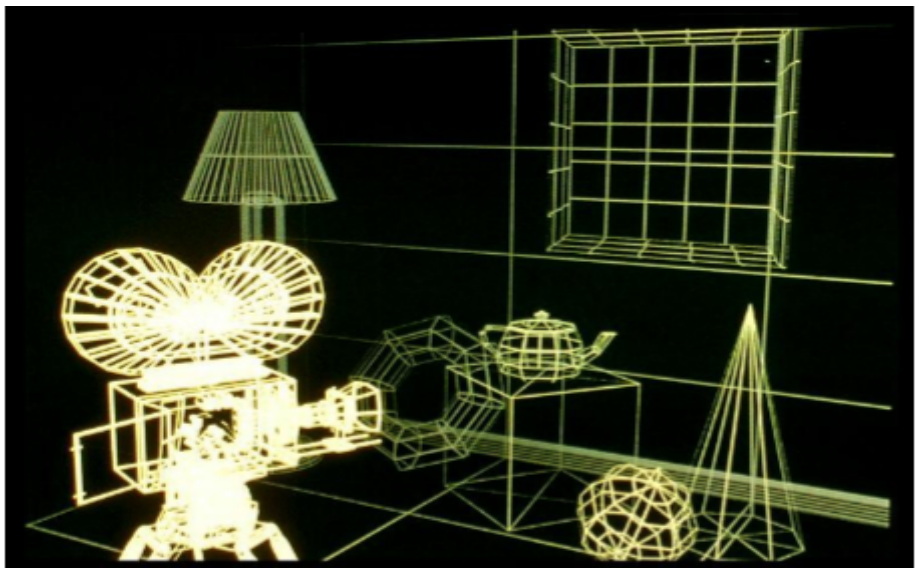


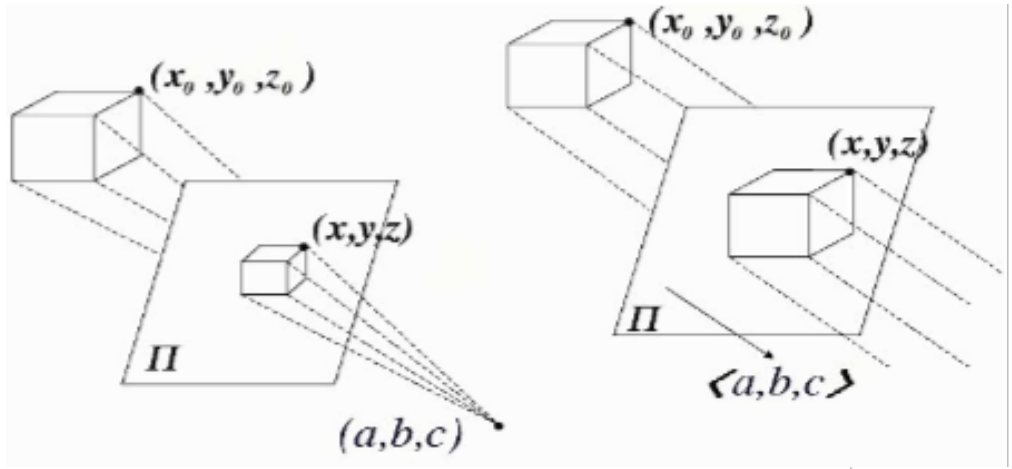


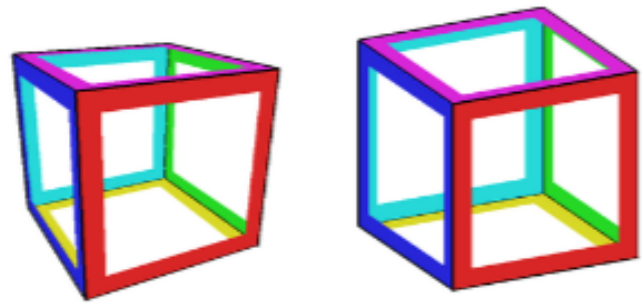


Perspective Projection (Lecture 4)

- We want to create a picture of the scene viewed from the camera
- We apply a perspective transformation to convert the 3D coordinates to 2D coordinates of the screen
- Objects far away appear smaller, closer objects appear bigger

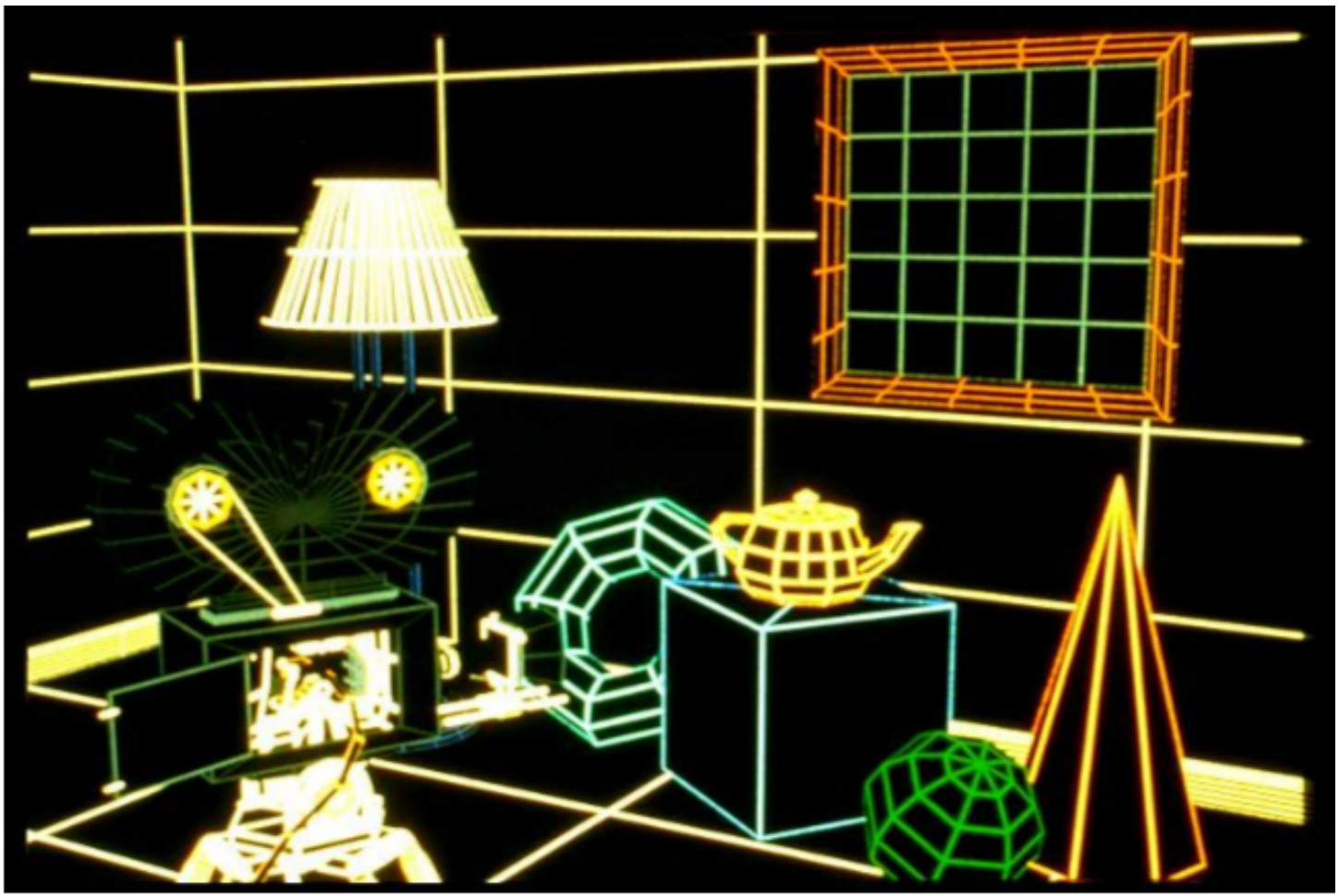






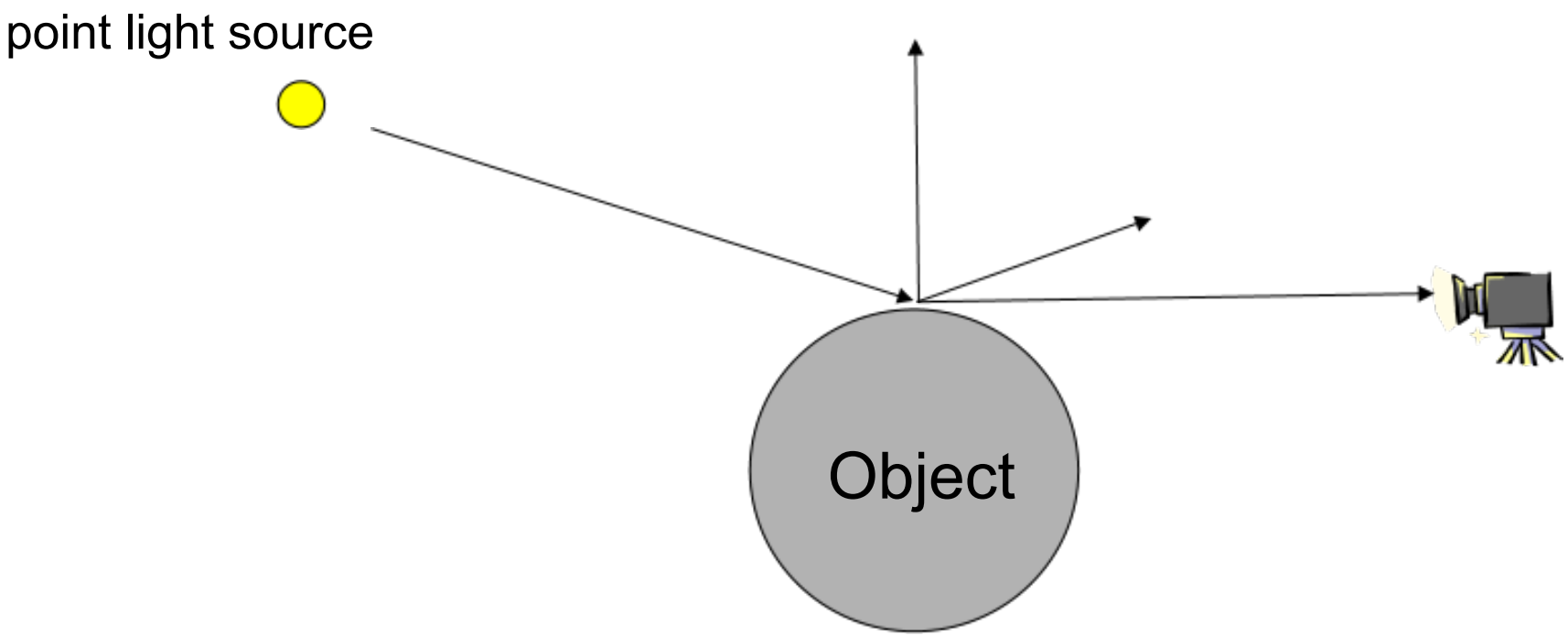
Hidden Surface Removal (Lecture 7)

- Objects occluded by other objects must not be drawn



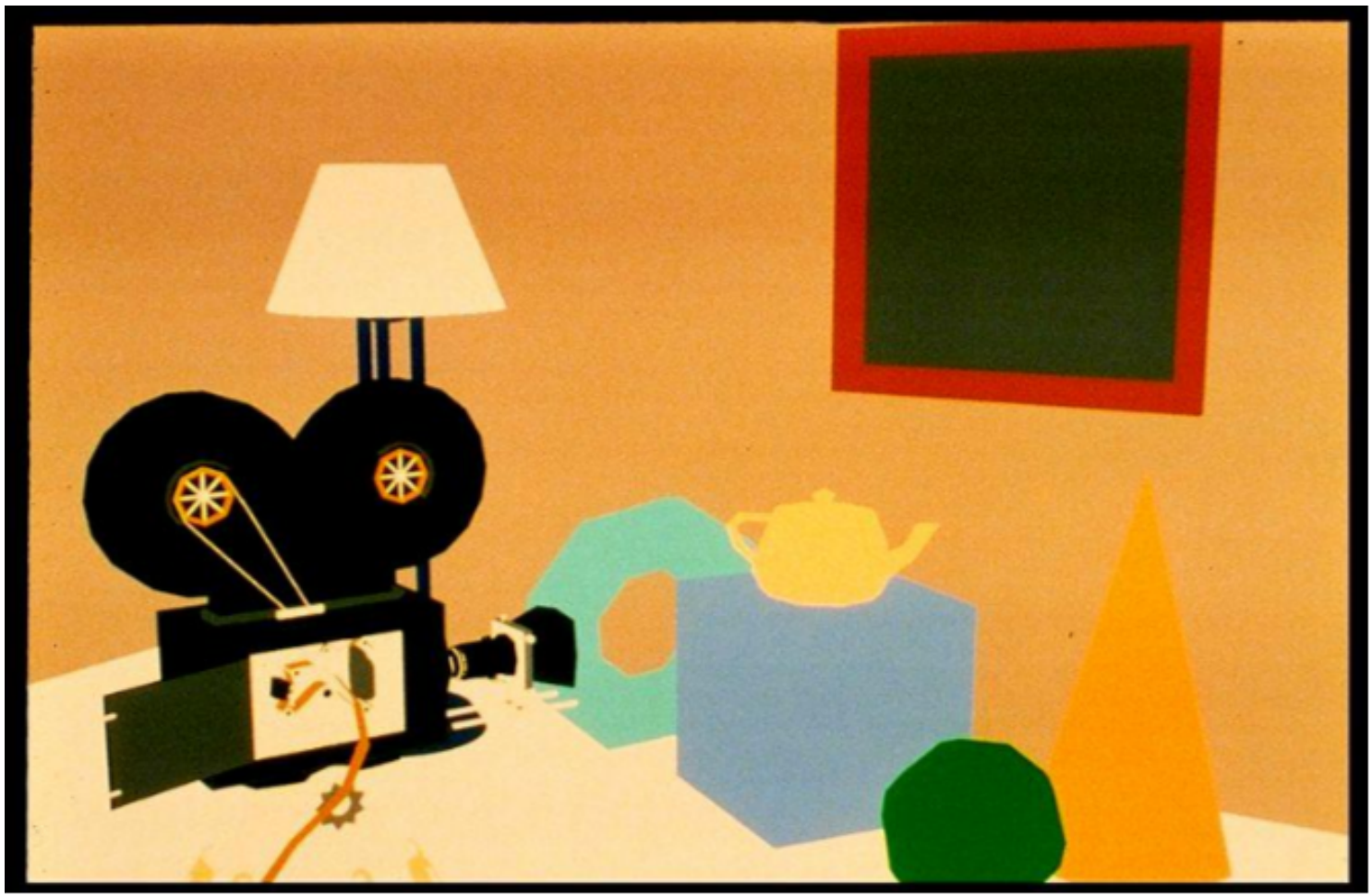
Shading and Lighting (Lecture 6)

- We need to decide the colour of each pixels taking into account the object's colour, lighting condition and the camera position



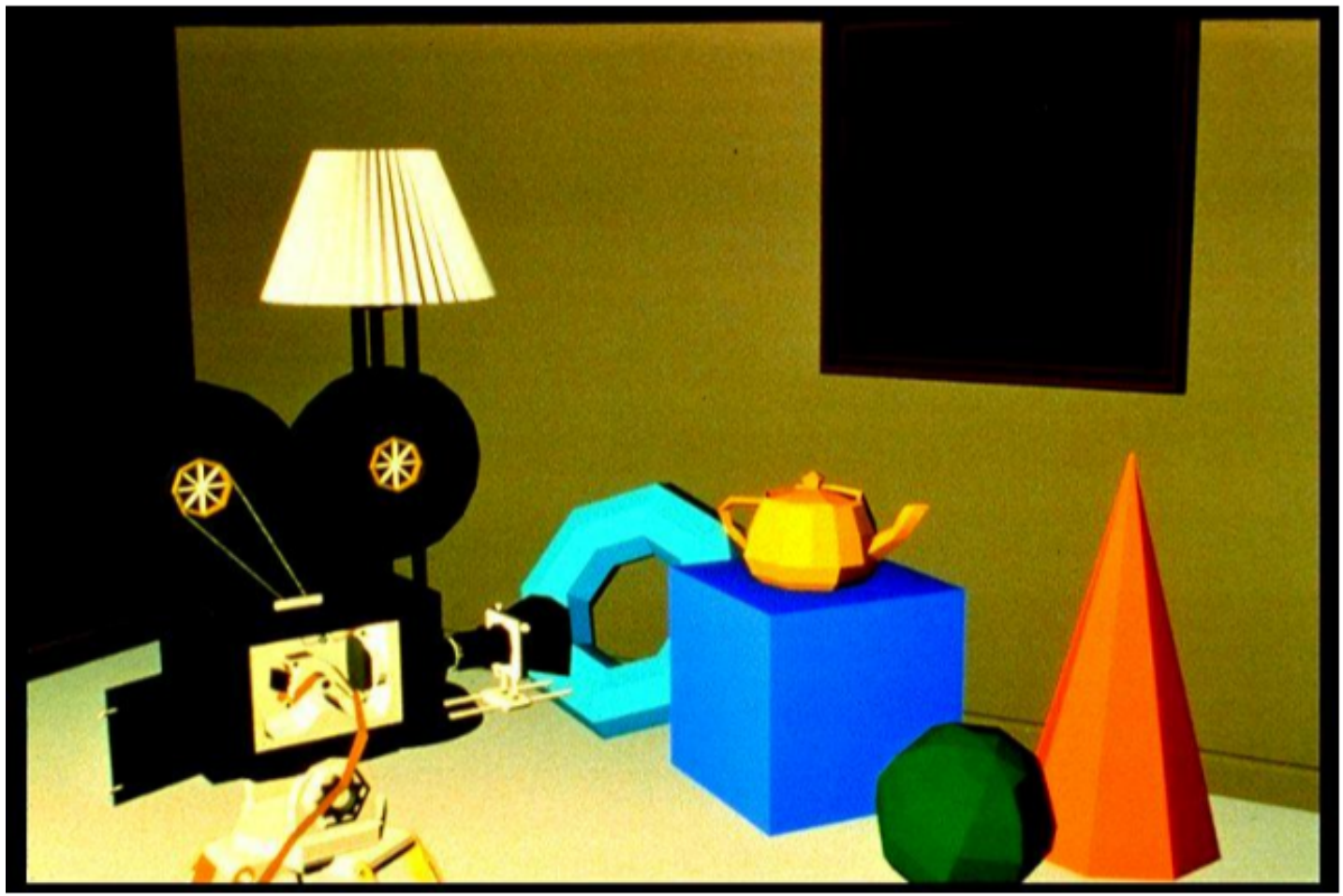
Shading : Constant Shading - Ambient

- Objects colours by its own colour



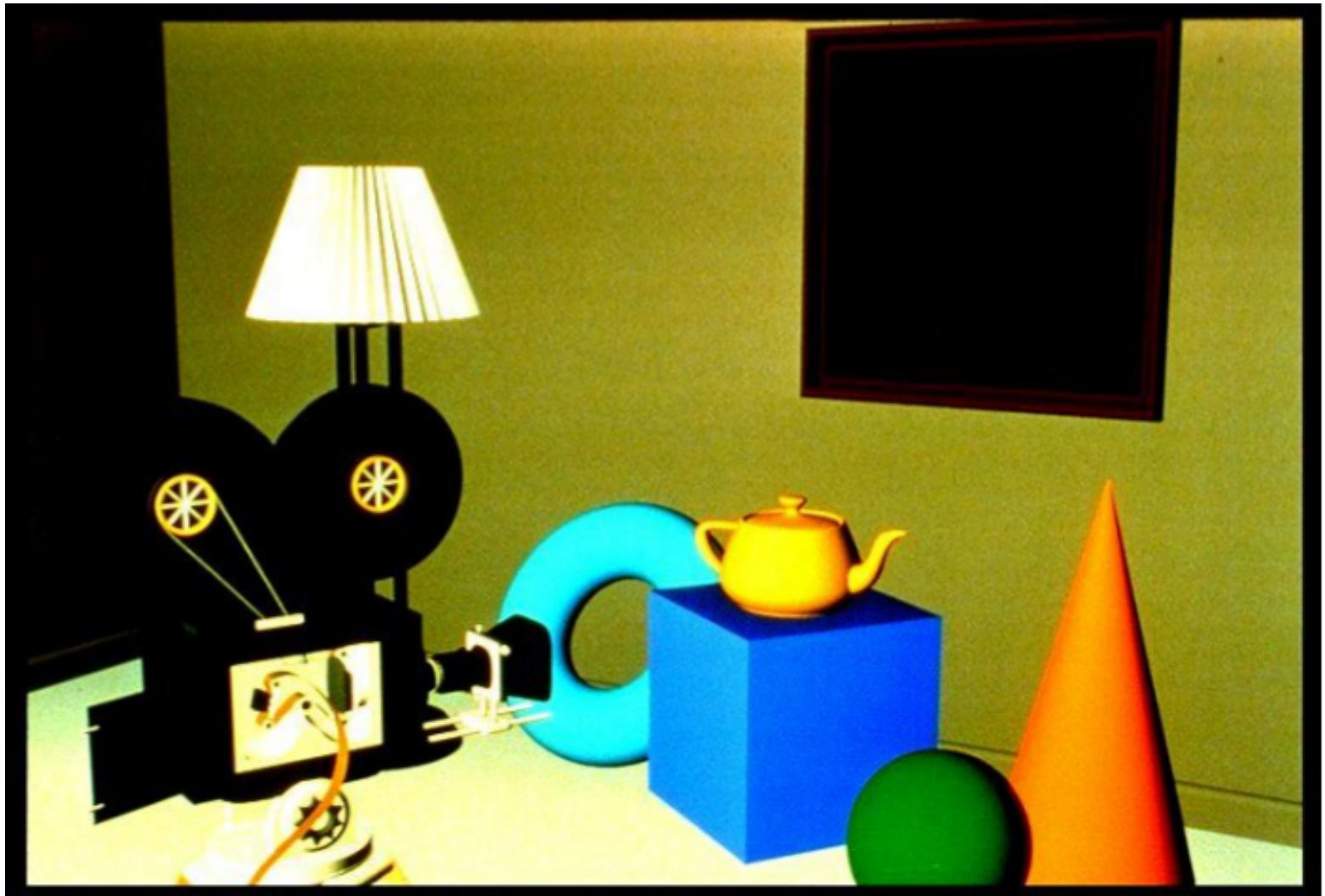
Shading – Flat Shading

- Objects coloured based on its own colour and the lighting condition
- One colour for one face



Gouraud shading, no specular highlights

- Lighting calculation per vertex

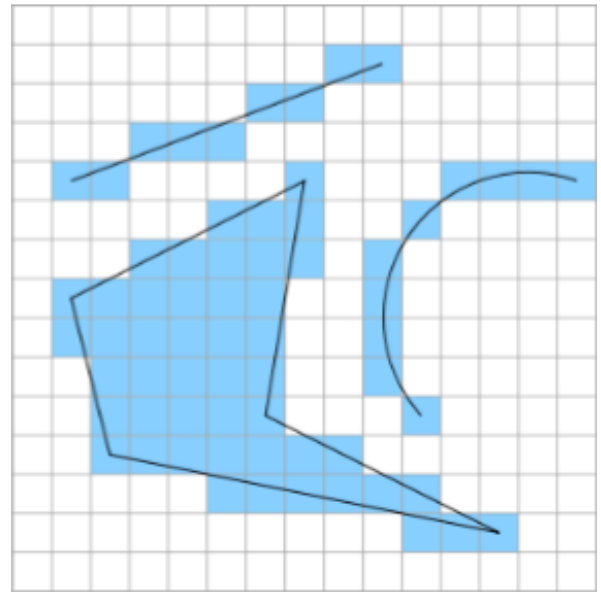


Specular high lights added

Rasterization (Lecture 5)

- Converts the vertex information output by the geometry pipeline into pixel information needed by the video display
- Aliasing: distortion artifacts produced when representing a high-resolution signal at a lower resolution.
- Anti-aliasing : technique to remove aliasing
- Illumination and shading

(for Phong shading)



Anti-aliasing

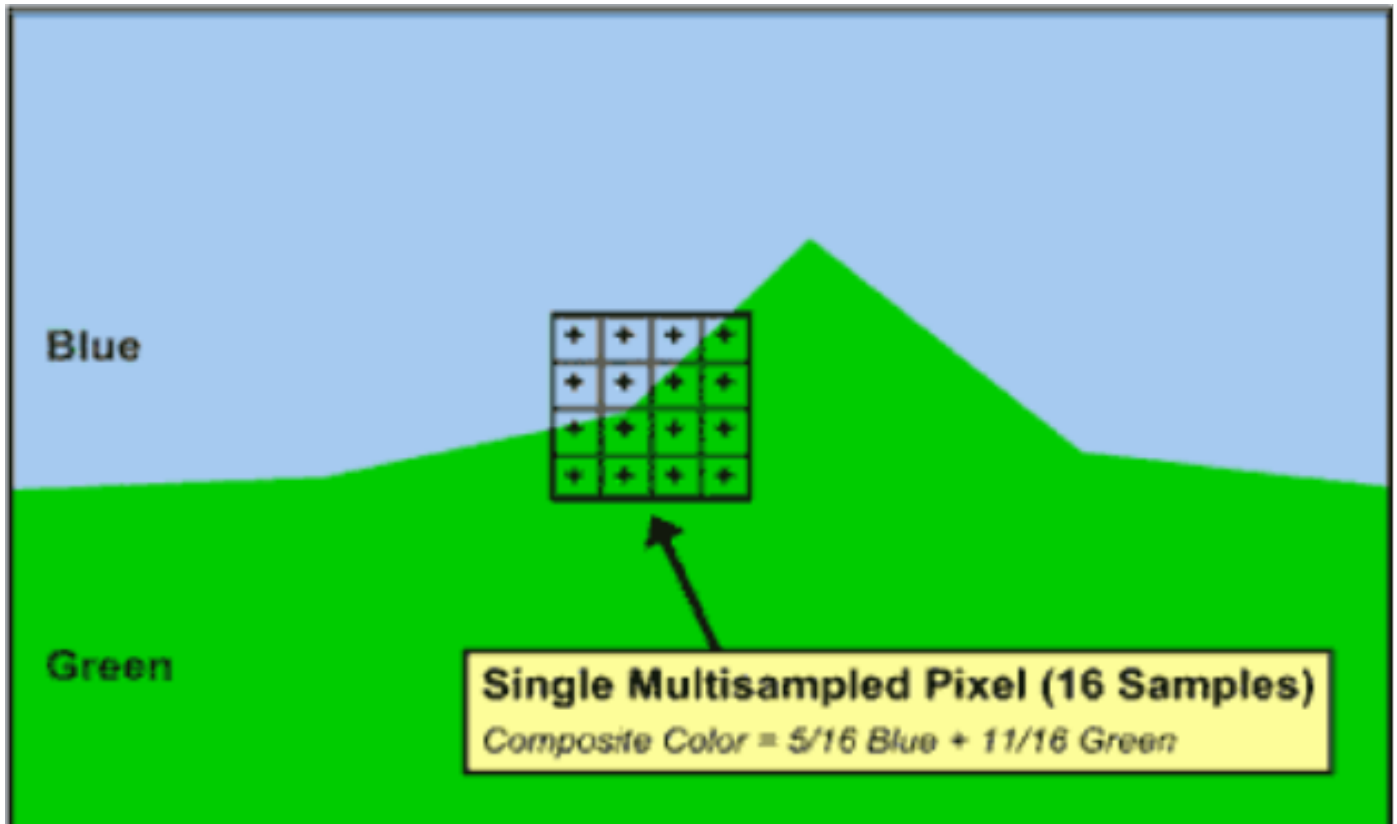
Aliased polygons (jagged edges)

Anti-aliased polygons

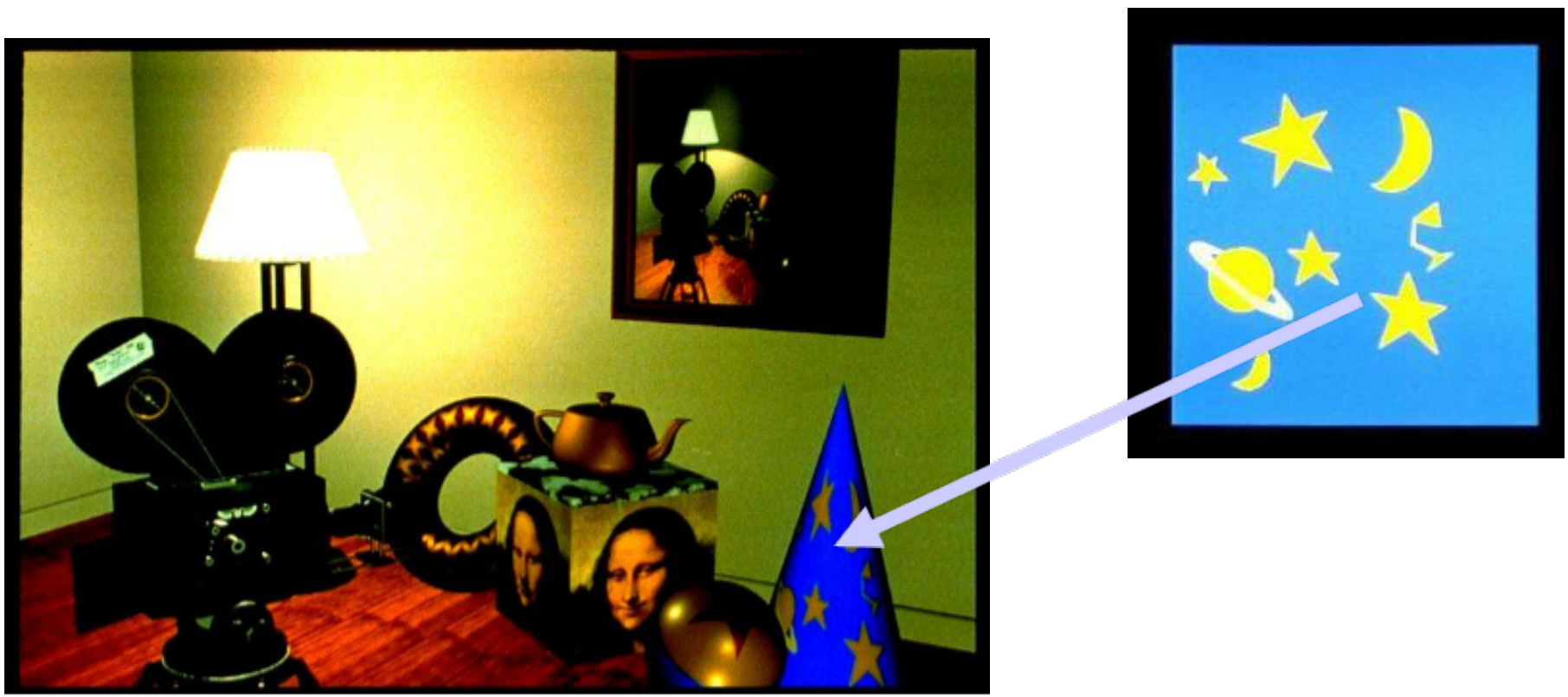
- How is *anti-aliasing* done? Each pixel is subdivided

(sub-sampled) in n regions, and each sub-pixel has a color;

- Compute the average color value



Texture mapping (Lecture 8)

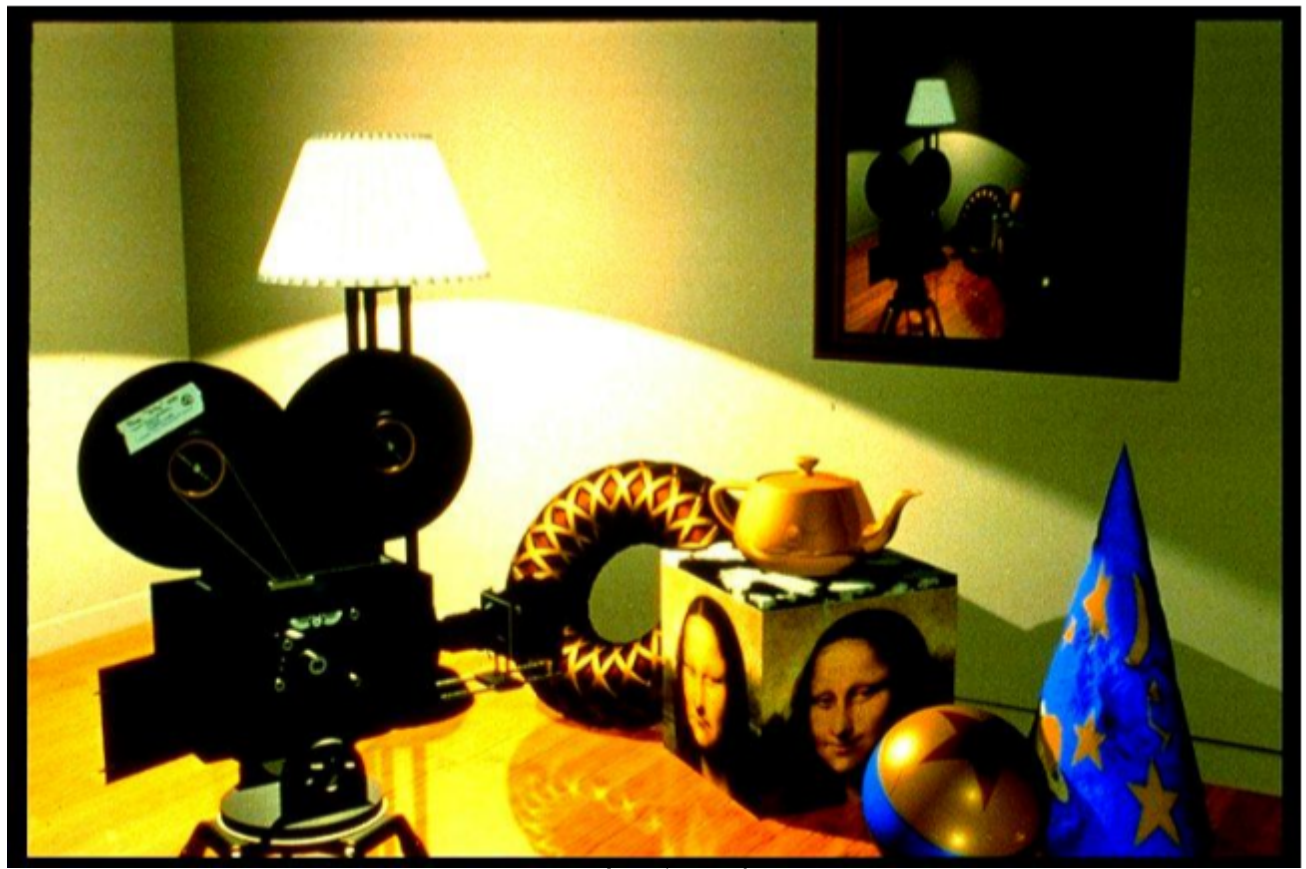


Other effects:

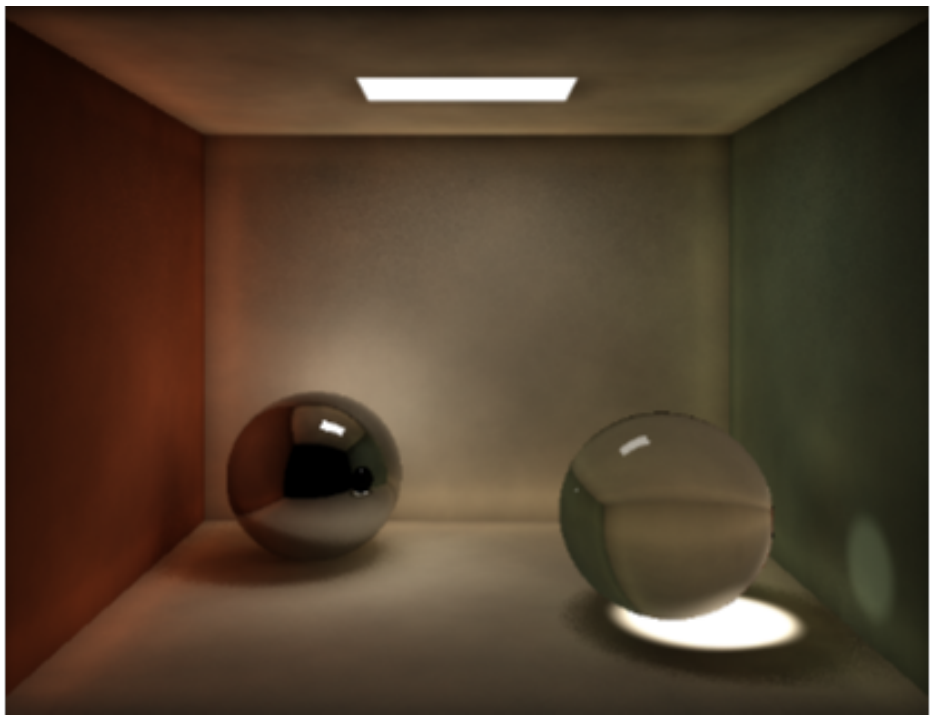
Bump mapping (Lecture 9)

Reflections (Lecture 10),

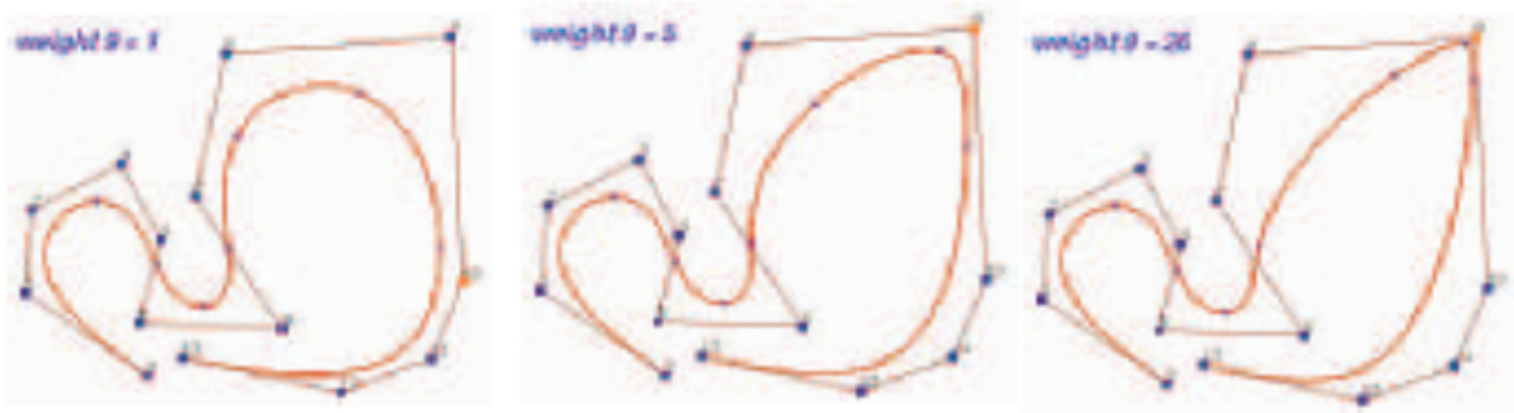
shadows (Lecture 11)

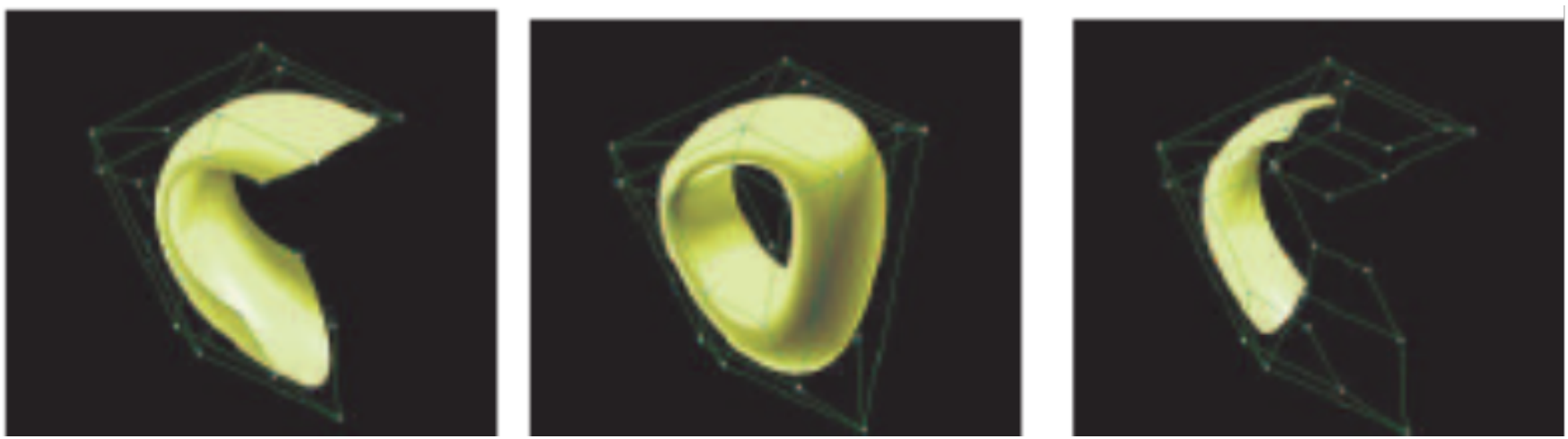


Other covered topics:
Ray Tracing (Lecture 12)
Global Illumination (Lecture 13)



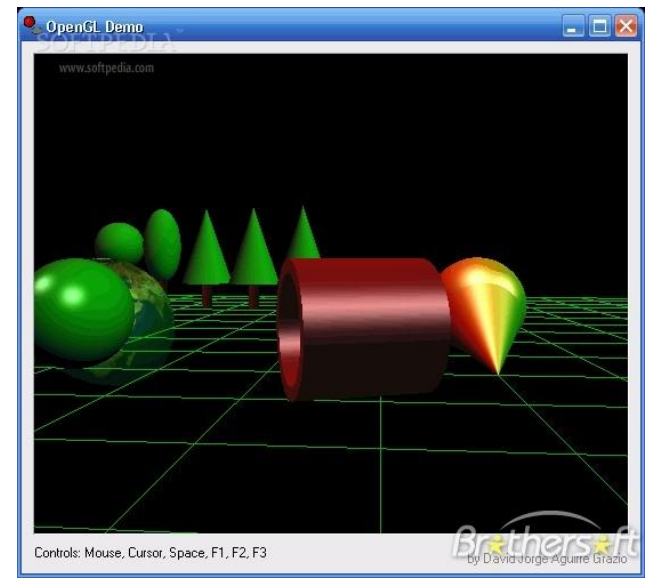
Polynomial Curves, Surfaces (Lecture 14,15)





OpenGL
(Lecture 4 / Lab session)

- OpenGL is a standard computer graphics library for interactive computer graphics
- A TA will give an introductory session for OpenGL



Course support resources

- Graphics course website
- http://www.inf.ed.ac.uk/teaching/courses/cg
  - lecture material,
  - recommended reading,
  - Links to support material for lectures and projects,
  - Practical description and resources

Summary

- The course is about algorithms, not applications
  - Lots of mathematics
- Graphics execution is a pipelined approach
- Basic definitions presented
- Some support resources indicated