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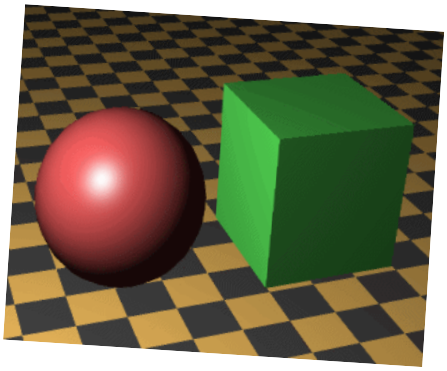
COMP27112

Computer Graphics and Image Processing



2: Introducing image synthesis

Toby.Howard@manchester.ac.uk

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Introduction

In these notes we'll cover:

- Some orientation – how did we get here?
- Graphics system architecture
- Overview of OpenGL / GLU / GLUT

- These notes are intended to be read in conjunction with the OpenGL programming manual – that's where all the detailed programming information is

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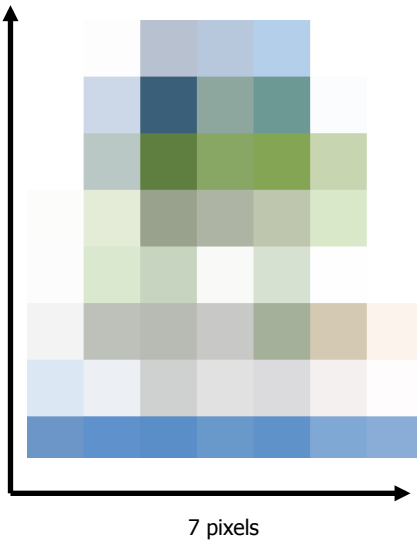
Raster graphics displays

- Raster graphics uses a 2D array of pixels (screens) or dots (printers)
- So images must be sampled
- The more samples, the better the fidelity
- But always an approximation



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Raster graphics displays

- Raster graphics uses a 2D array of pixels (screens) or dots (printers)
- So images must be sampled
- The more samples, the better the fidelity
- But always an approximation

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Alternative: Vector Displays

- The first type of graphical display
- Cathode Ray Tube and controller
- Draws vectors… essentially lines from point A to point B
- Usually monochrome (apparent colour here is done with transparent plastic overlays!)

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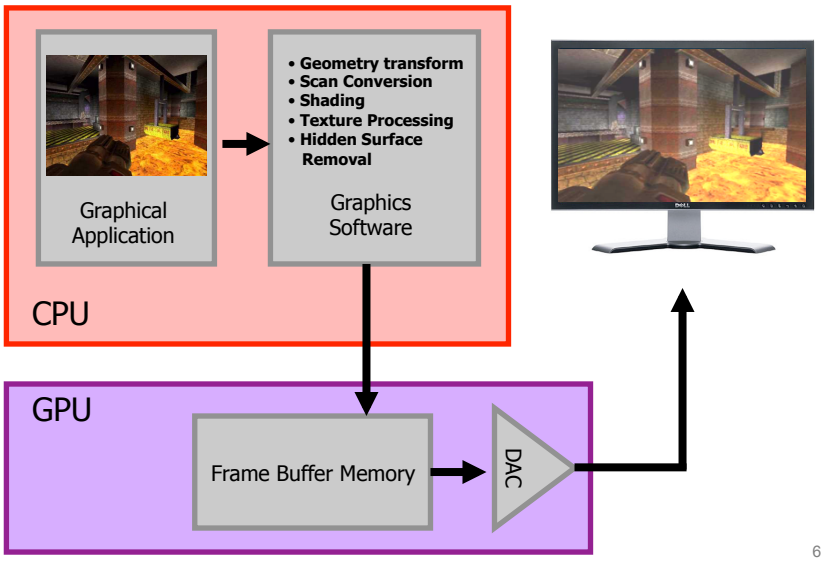
Basic graphics system architecture



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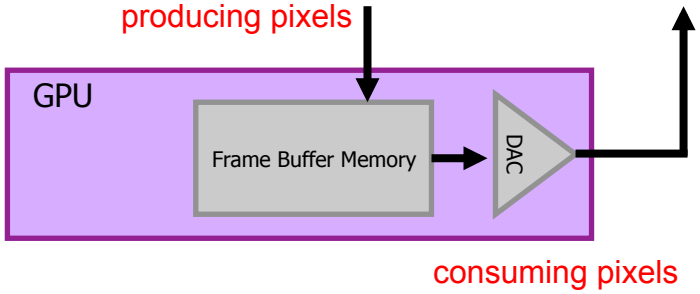
Basic graphics system architecture

This is the classic producer/consumer situation



How do we **synchronise** the two activities?

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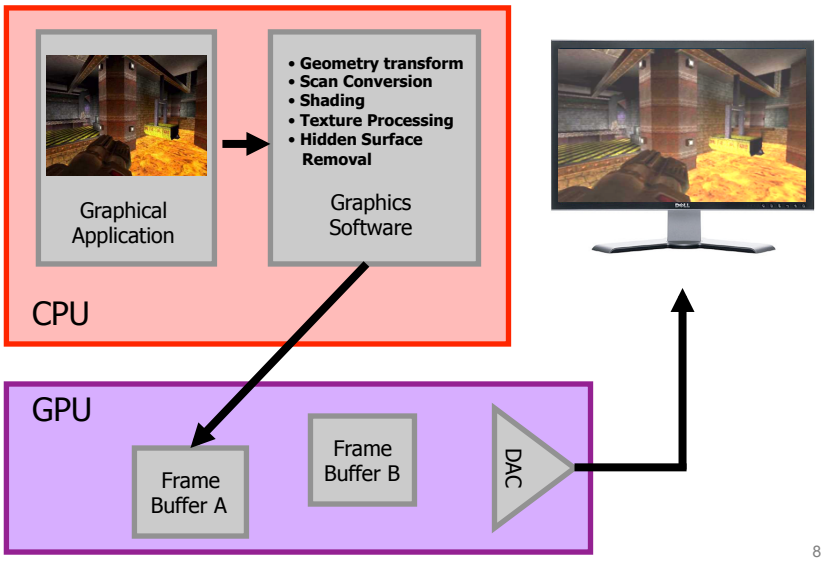
Double buffering



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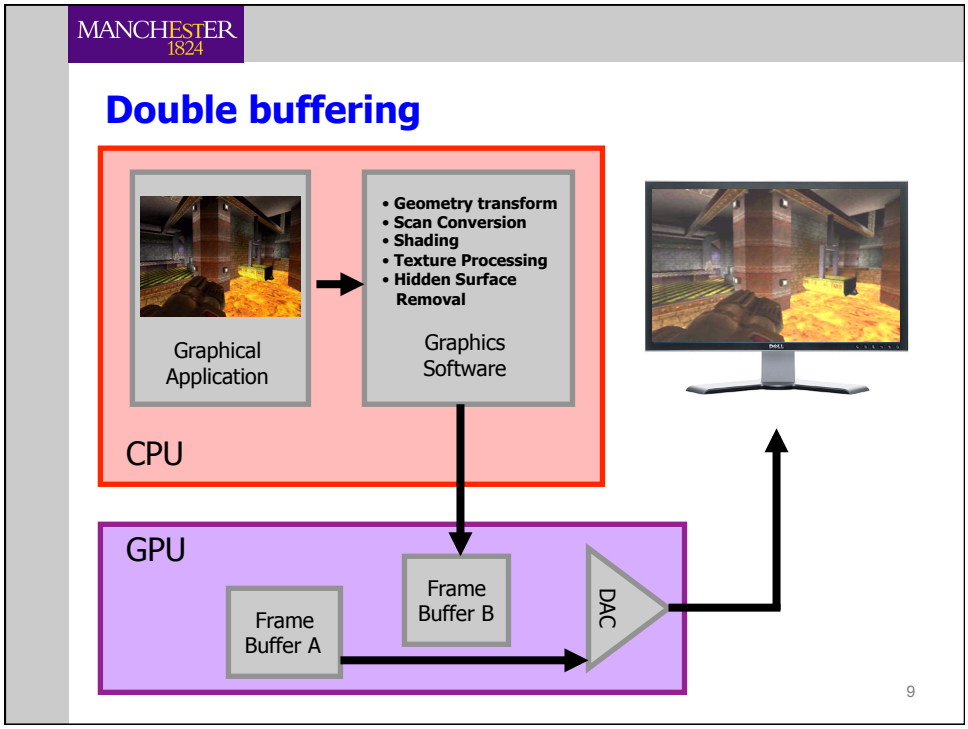
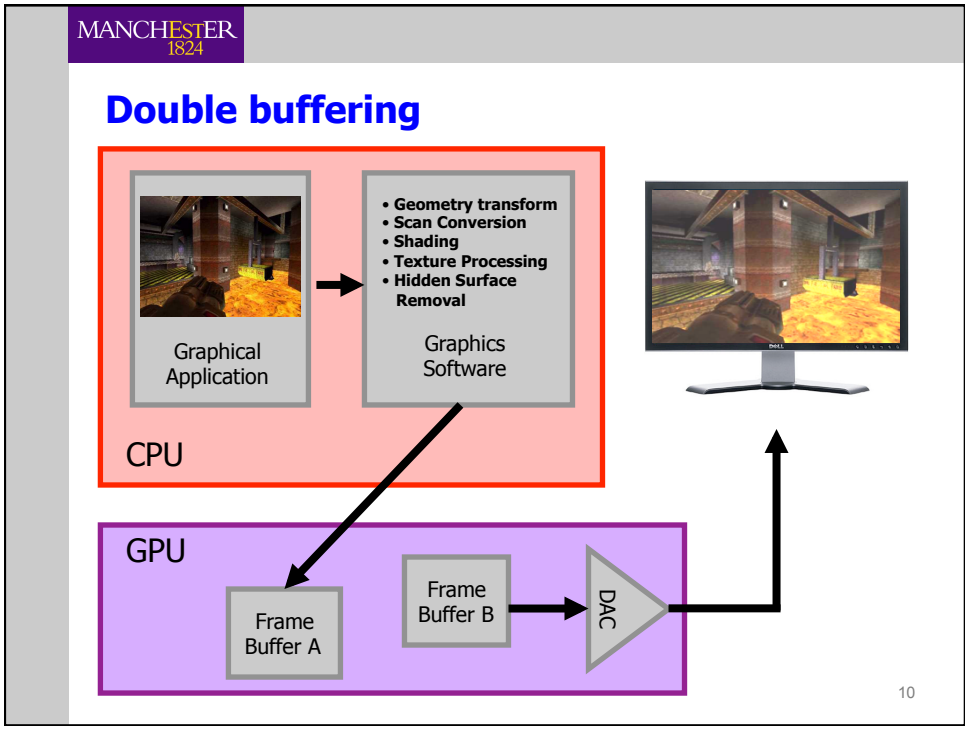

MANCHESTER 1824
Double buffering
• Geometry transform
• Scan Conversion
• Shading
• Texture Processing
• Hidden Surface Removal
Graphical Application
Graphics Software
CPU
GPU
Frame Buffer A
Frame Buffer B
DAC
9


MANCHESTER 1824
Double buffering
• Geometry transform
• Scan Conversion
• Shading
• Texture Processing
• Hidden Surface Removal
Graphical Application
Graphics Software
CPU
GPU
Frame Buffer A
Frame Buffer B
DAC
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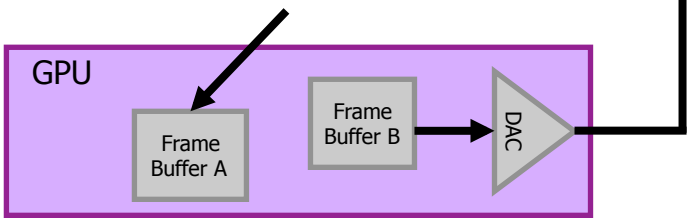
Double buffering

The swap between the buffers takes place during the vertical retrace time of the monitor (aka VBLANK) – the time between the end of drawing one frame, and beginning to draw the next.

This time is a function of the refresh rate of the monitor (typically 75Hz).

In OpenGL, the `glutSwapBuffers()` command requests that a swap be scheduled for the next retrace.



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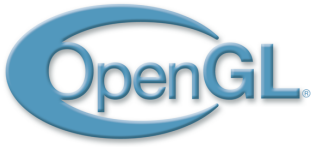
OpenGL

- Open Graphics Library



- platform/language-independent
- origins in Silicon Graphics' proprietary GL
- OpenGL first released 1992
- Today: open standard for portable graphics programming (www.opengl.org)

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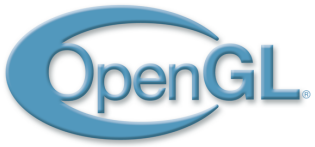
OpenGL vs. DirectX



- OpenGL
  - Open standard, run by the **Khronos Group**
  - Cross-architecture (Win/Mac/Linux…)
- DirectX
  - Owned by Microsoft

- Functionally, the two systems are broadly similar
- For an in-depth comparison, see http://en.wikipedia.org/wiki/Comparison_of_OpenGL_and_Direct3D

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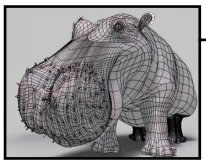
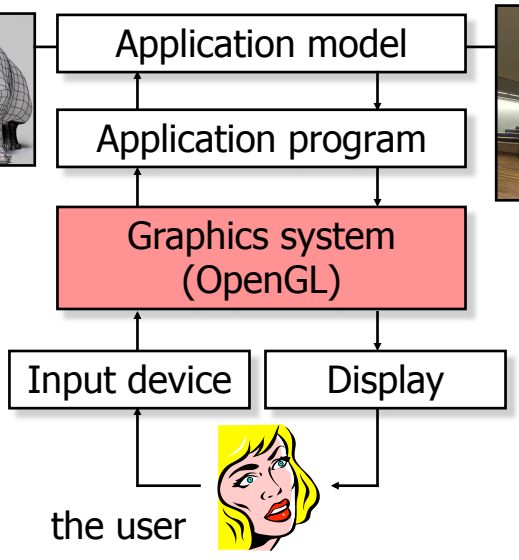
Where OpenGL fits in





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The OpenGL API

- OpenGL is a **specification** of an Application Programmer's Interface (API)
- A set of functions for doing 3D computer graphics
- used in industry, engineering, CAD, CGI/ SFX, research, games, education – everywhere

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OpenGL evolution

- OpenGL functionality has evolved over time:
  - OpenGL v1, v2: "fixed pipeline" – fixed functionality
  - OpenGL v3+: "programmable pipeline" – extensible functionality: programmers write "shader" micro-programs
  - OpenGL 4.5 (Aug 2014)
- In this introductory course we use the fixed pipeline
  - **pro**: programming is simpler, more built-in support
  - **con**: lack of flexibility, cannot fully exploit GPU

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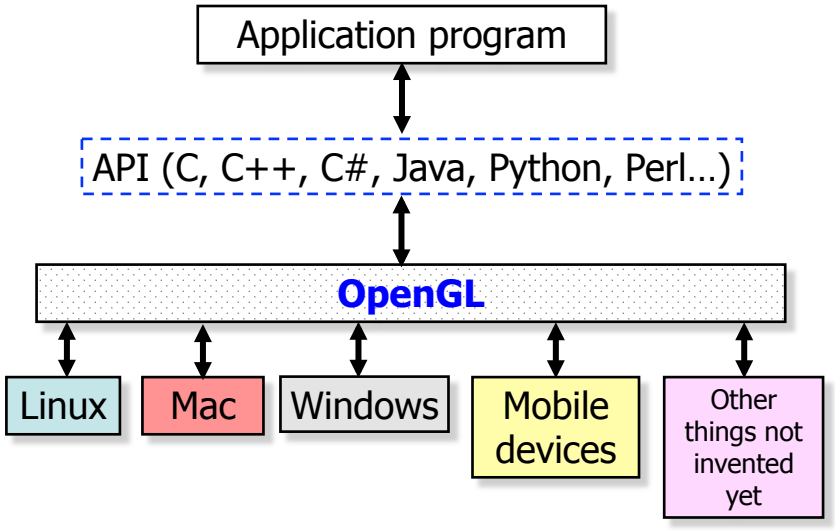
Portability



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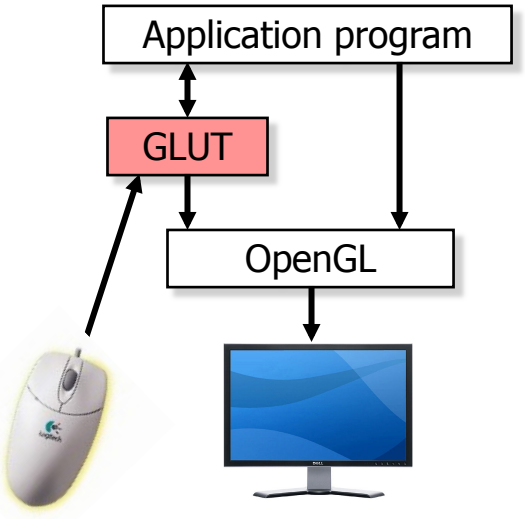
OpenGL and interaction

- OpenGL only generates pixels
- it **doesn't** handle interaction devices
- for interaction, we use an additional library (called GLUT, see later)



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OpenGL graphics

- The main features of OpenGL
  - 3D graphics (points, lines, polygons…)
  - coordinate transformations
  - a camera for viewing
  - hidden surface removal
  - lighting and shading
  - texturing
  - pixel (image) operations
- We'll take a whirlwind tour

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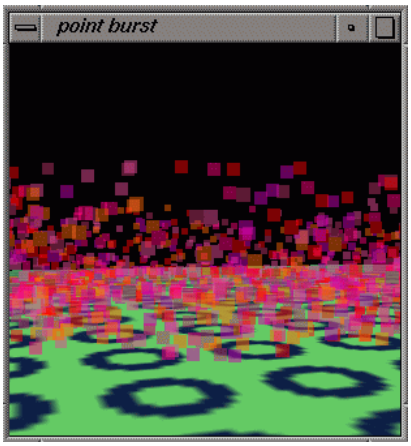
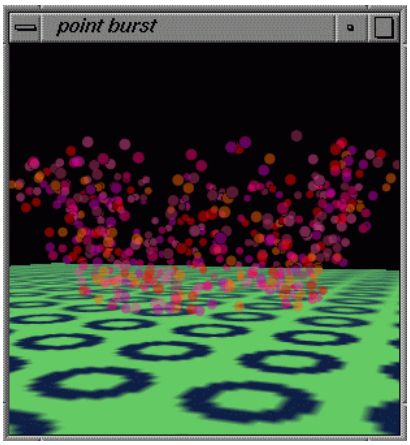
Points



Regular points



Anti-aliased points

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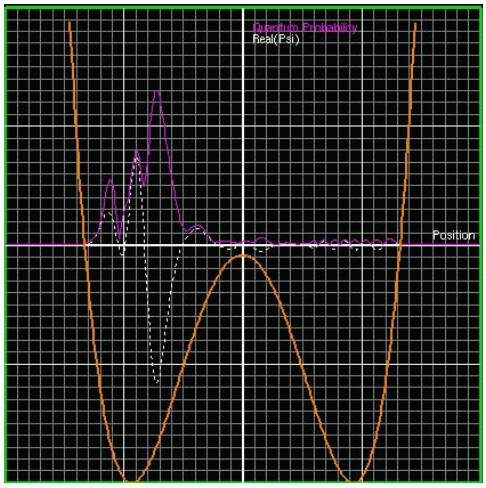
Lines

- Lines, like all graphical primitives, have two kinds of property:
  - **geometry** (shape)
  - **attributes** (appearance)



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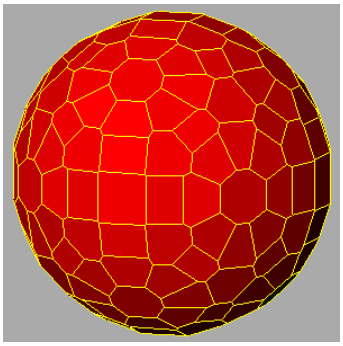
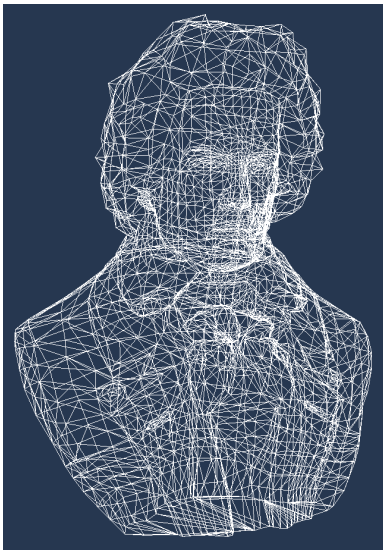
Polygons

- Triangles
- Quadrilaterals
- Convex polygons





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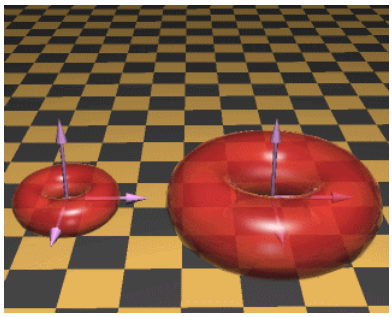
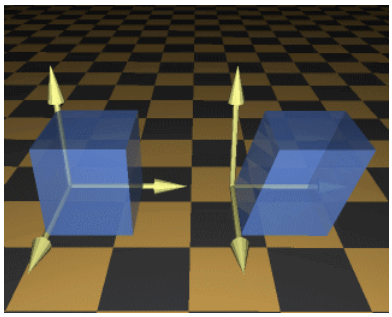
Transformations

- OpenGL expresses coordinate transformations as 4x4 homogeneous matrices



scaling



shearing

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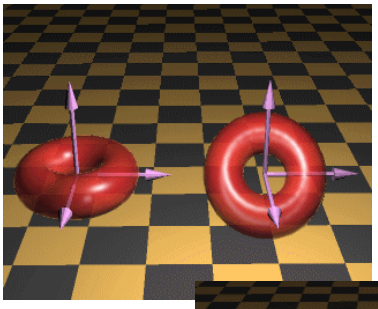
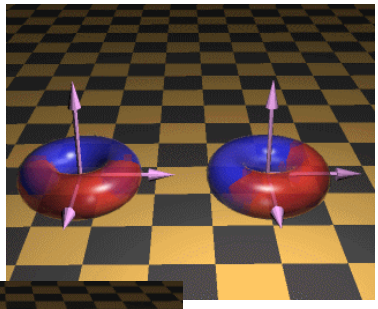
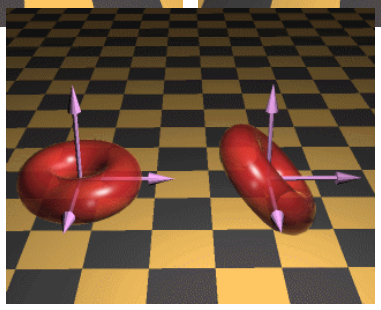
Transformations



rotation about x



rotation about y



rotation about z

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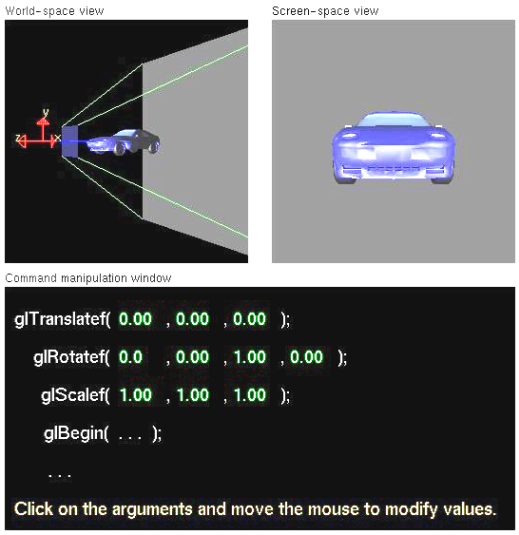
Transformations

- Transformations can be combined and nested
  - Allowing complex objects to be assembled from simpler parts



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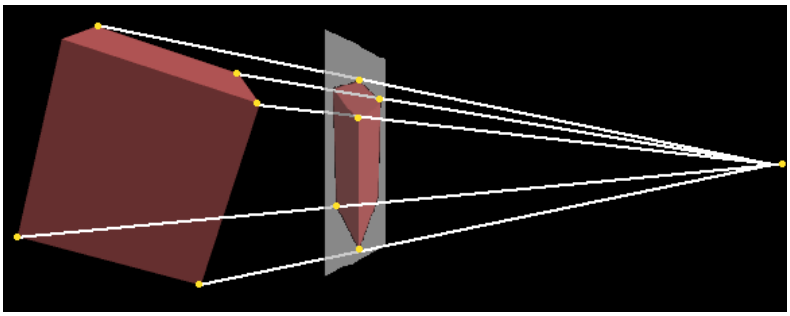
The camera model

- Creating 2D views of 3D scenes
  - perspective projection
  - parallel projection



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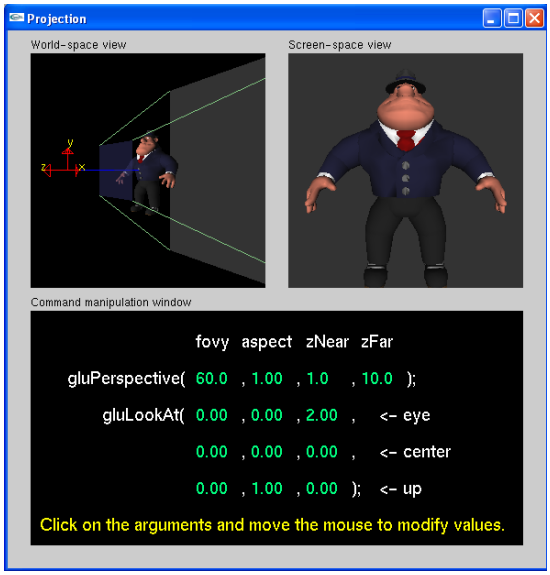
The camera model



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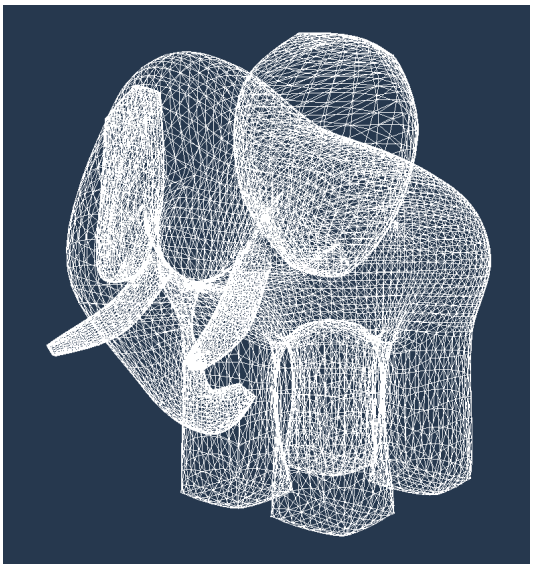
Hidden-surface removal



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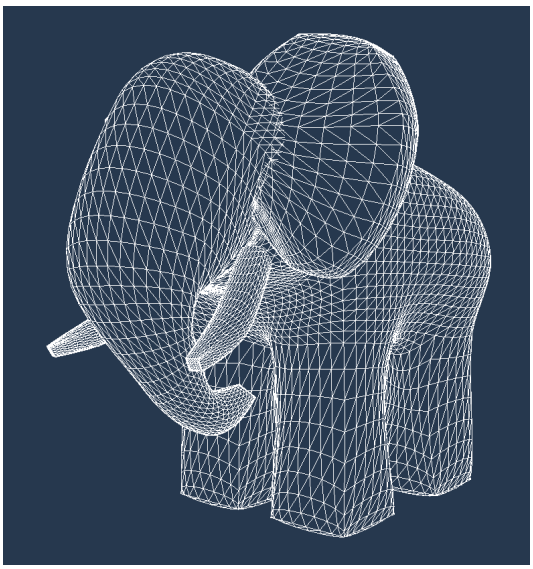
Hidden-surface removal



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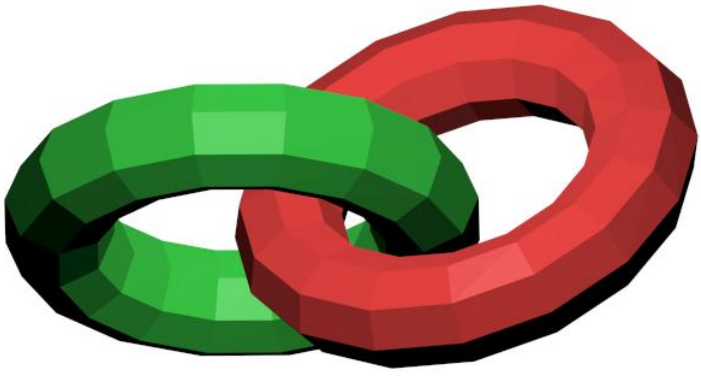
Lighting and shading



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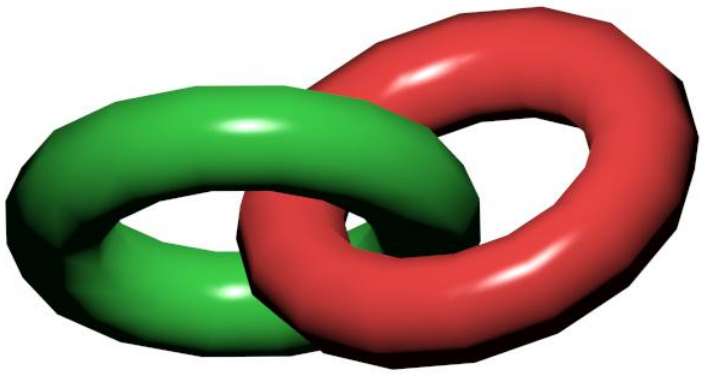
Lighting and shading



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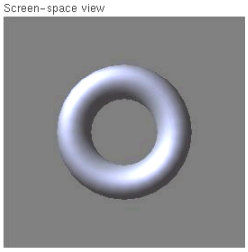
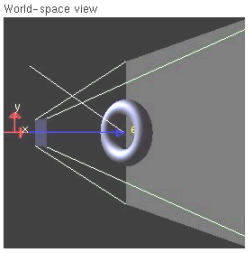
Lighting and shading

Screen-space view



World-space view



Command manipulation window

```
GLfloat light_pos[ ] = {  -2.00 , 2.00  , 2.00  , 1.00  };
GLfloat light_Ka[ ] = {  0.00  , 0.00  , 0.00  , 1.00  };
GLfloat light_Kd[ ] = {  1.00  , 1.00  , 1.00  , 1.00  };
GLfloat light_Ks[ ] = {  1.00  , 1.00  , 1.00  , 1.00  };

glLightfv(GL_LIGHT0, GL_POSITION, light_pos);
glLightfv(GL_LIGHT0, GL_AMBIENT, light_Ka);
glLightfv(GL_LIGHT0, GL_DIFFUSE, light_Kd);
glLightfv(GL_LIGHT0, GL_SPECULAR, light_Ks);

GLfloat material_Ka[ ] = { 0.11  , 0.06  , 0.11  , 1.00  };
GLfloat material_Kd[ ] = { 0.43  , 0.47  , 0.54  , 1.00  };
GLfloat material_Ks[ ] = { 0.33  , 0.33  , 0.52  , 1.00  };
GLfloat material_Ke[ ] = { 0.00  , 0.00  , 0.00  , 0.00  };
GLfloat material_Se =  10  ;

glMaterialfv(GL_FRONT, GL_AMBIENT, material_Ka);
glMaterialfv(GL_FRONT, GL_DIFFUSE, material_Kd);
glMaterialfv(GL_FRONT, GL_SPECULAR, material_Ks);
glMaterialfv(GL_FRONT, GL_EMISSION, material_Ke);
glMaterialfv(GL_FRONT, GL_SHININESS, material_Se);
```

Click on the arguments and move the mouse to modify values.

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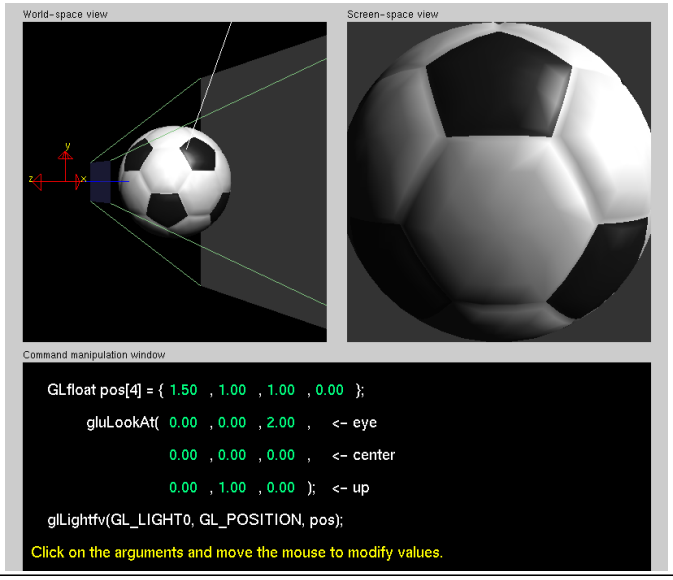
Light position



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Textures

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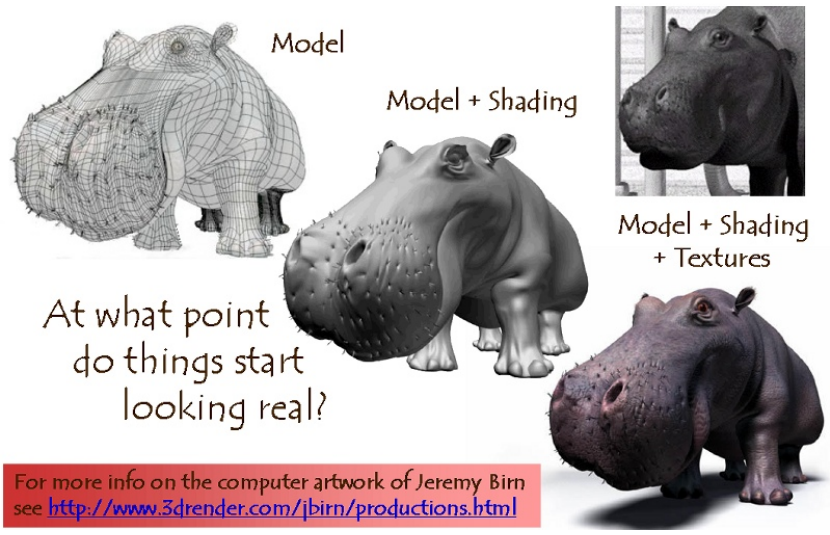
Modelling and rendering



For more info on the computer artwork of Jeremy Birn see http://www.3drender.com/jbirn/productions.html

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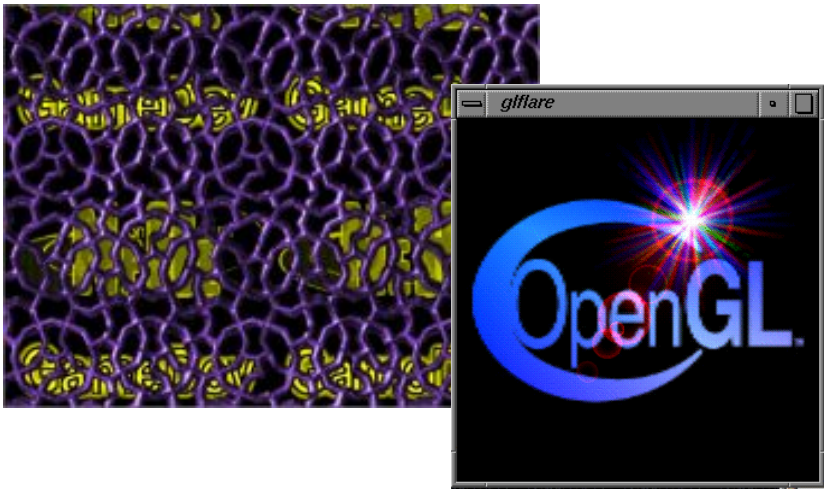
Image compositing



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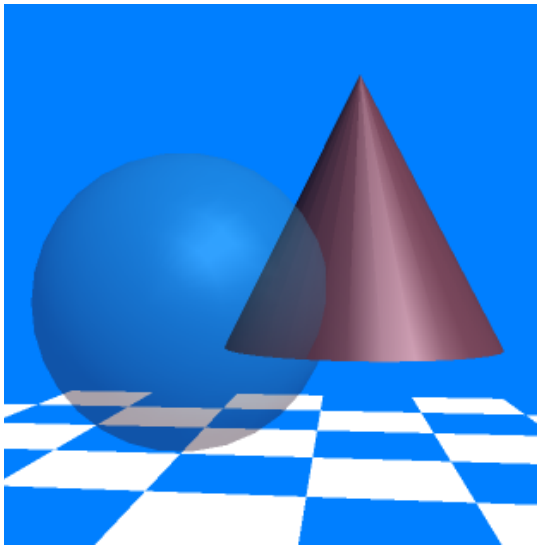
Alpha-blending for transparency



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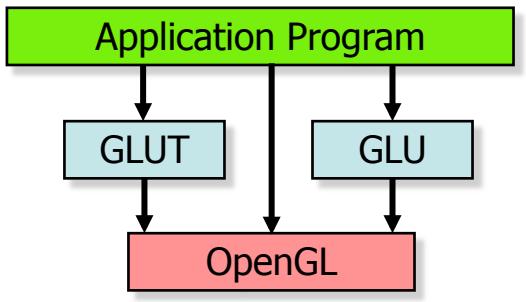
Support libraries

- OpenGL supports low-level rendering only
- for convenience, two support libraries were developed: GLU and GLUT
- they sit "on top of" OpenGL



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GLU

- GL Utility Library (GLU)
- provides functions which "wrap up" lower-level OpenGL graphics
  - Curves, surfaces, cylinder, disc, quadrics...
- Utility functions
  - Viewing
  - Textures
  - Tessellation
- Command reference:
  - http://www.opengl.org/sdk/docs/man/

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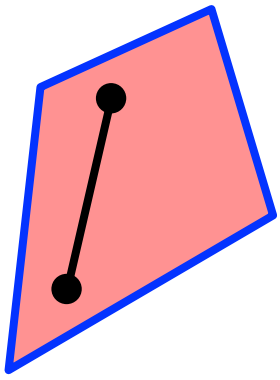
OpenGL needs convex polygons

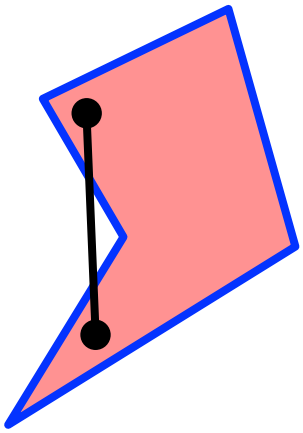


Convex polygon

How to decide if a polygon is convex or not?

Q: Is it possible to find 2 points inside the polygon such that the line between them goes outside the polygon?

A: If it IS NOT possible, the polygon is convex.



Non-Convex polygon
("concave" polygon)

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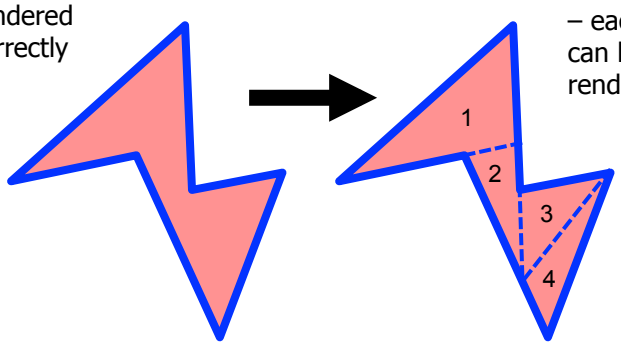
Tessellation

- GLU provides functions to tessellate polygons

BEFORE: This **concave** polygon can't be rendered correctly

AFTER: A set of **convex** polygons – each of which can be correctly rendered



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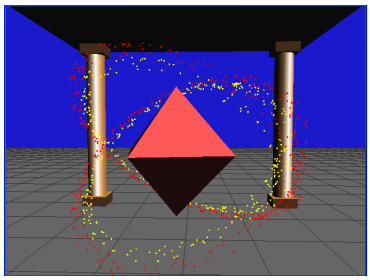
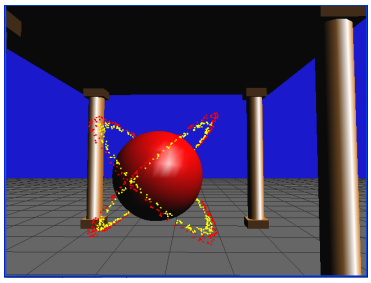
GLUT

- GL Utility Toolkit (GLUT)
- Interaction
  - interaction (mouse and keyboard)
  - simple menu system
- Primitives
  - Sphere, torus, cone, cube
  - [Tetra | Octo | Dodeca | Icosa] hedron
  - Teapot
- Command reference:
  - Link to PDF on course webpage





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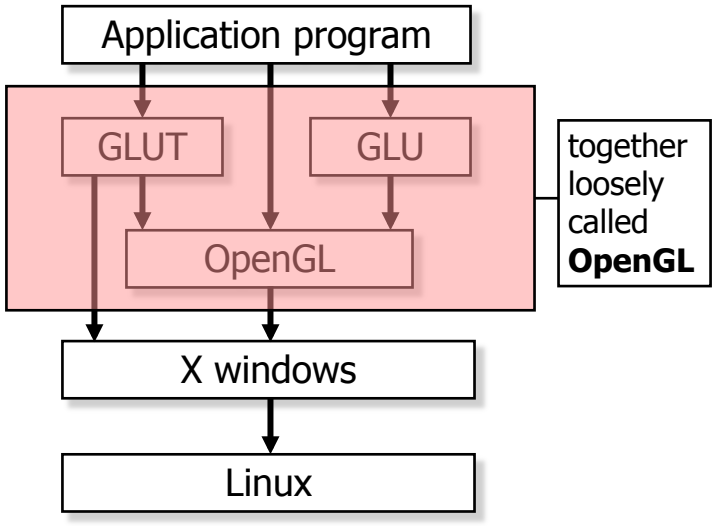
OpenGL on Linux



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What do do next

1. OpenGL manual – go through Tutorial in Chapters 1-6.
2. Do Coursework 1

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