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DH2323 DGI15

INTRODUCTION TO COMPUTER GRAPHICS AND INTERACTION

RASTERISED RENDERING

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Based on DGI12 notes by Carl Henrik Ek

The Rendering Equation

Emitted radiance ↓ BRDF ↓ Account for angle w.r.t. light ↓

$$L_o(\mathbf{x}, \omega_o, \lambda, t) = L_e(\mathbf{x}, \omega_o, \lambda, t) + \int_\Omega f_r(\mathbf{x}, \omega_i, \omega_o, \lambda, t)\, L_i(\mathbf{x}, \omega_i, \lambda, t)\, (\omega_i \cdot \mathbf{n})\, d\,\omega_i$$

↑ Incoming radiance

Describes:

- Total amount of light emitted from a point x along a specific viewing direction

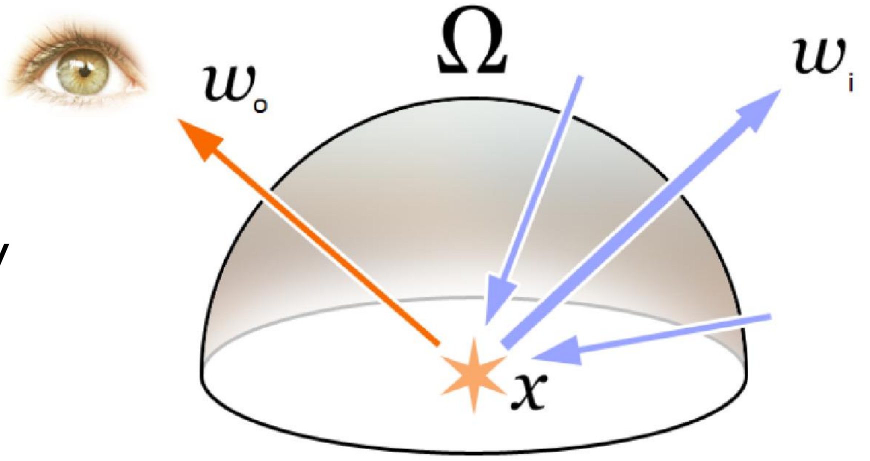
Given:

- Incoming light function
- BRDF

Basis:

- Law of conservation of energy

Hemisphere containing all w_i

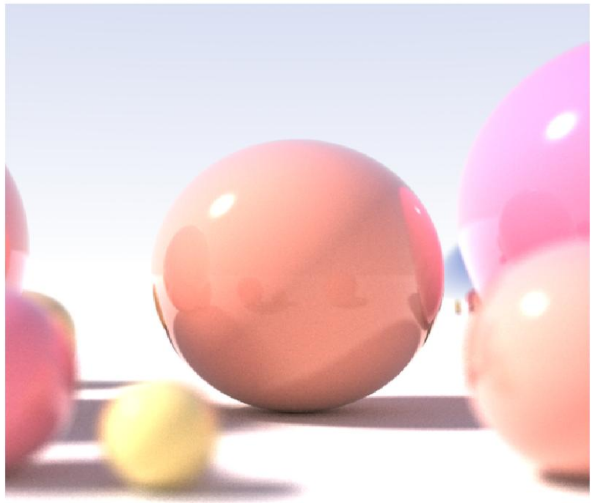


Global Illumination

Ray tracing:
- Good for specular
- Bad for diffuse

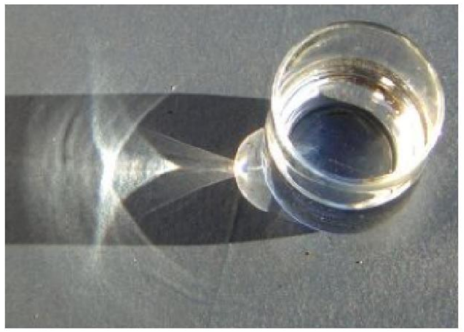
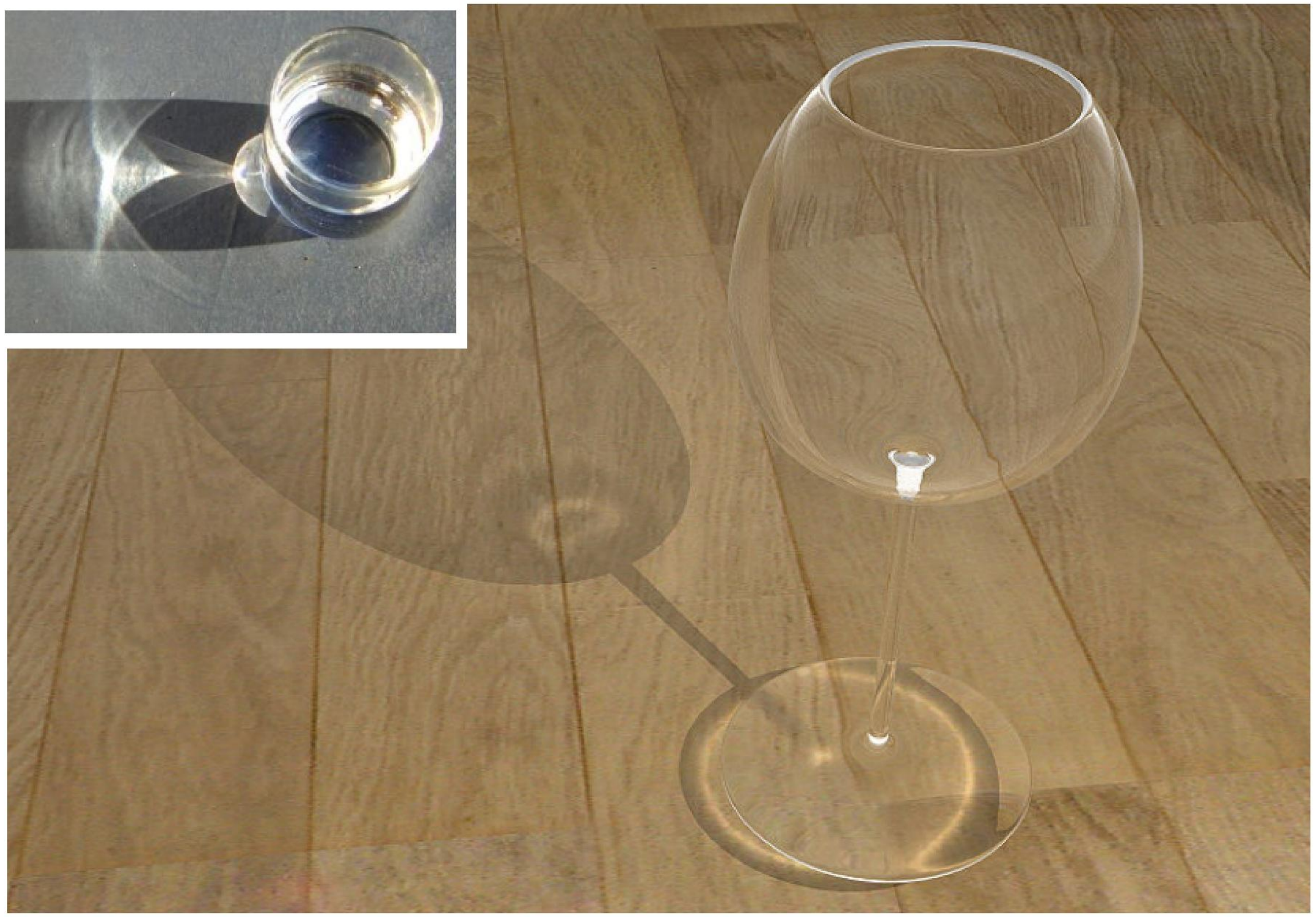
Radiosity:
- Good for diffuse
- Bad for specular

Hybrid techniques



Caustics

- Curved regions of bright reflected or refracted light

Sub-surface scattering

- Light bouncing around inside material before exiting

Ray tracing

Pixel order rendering technique

- Trace at least one ray through each image pixel
- Maintains primitives in geometric scene model
- Queries this for each ray
- Determine which primitive is visible for each pixel

Geometry queries can have high cost

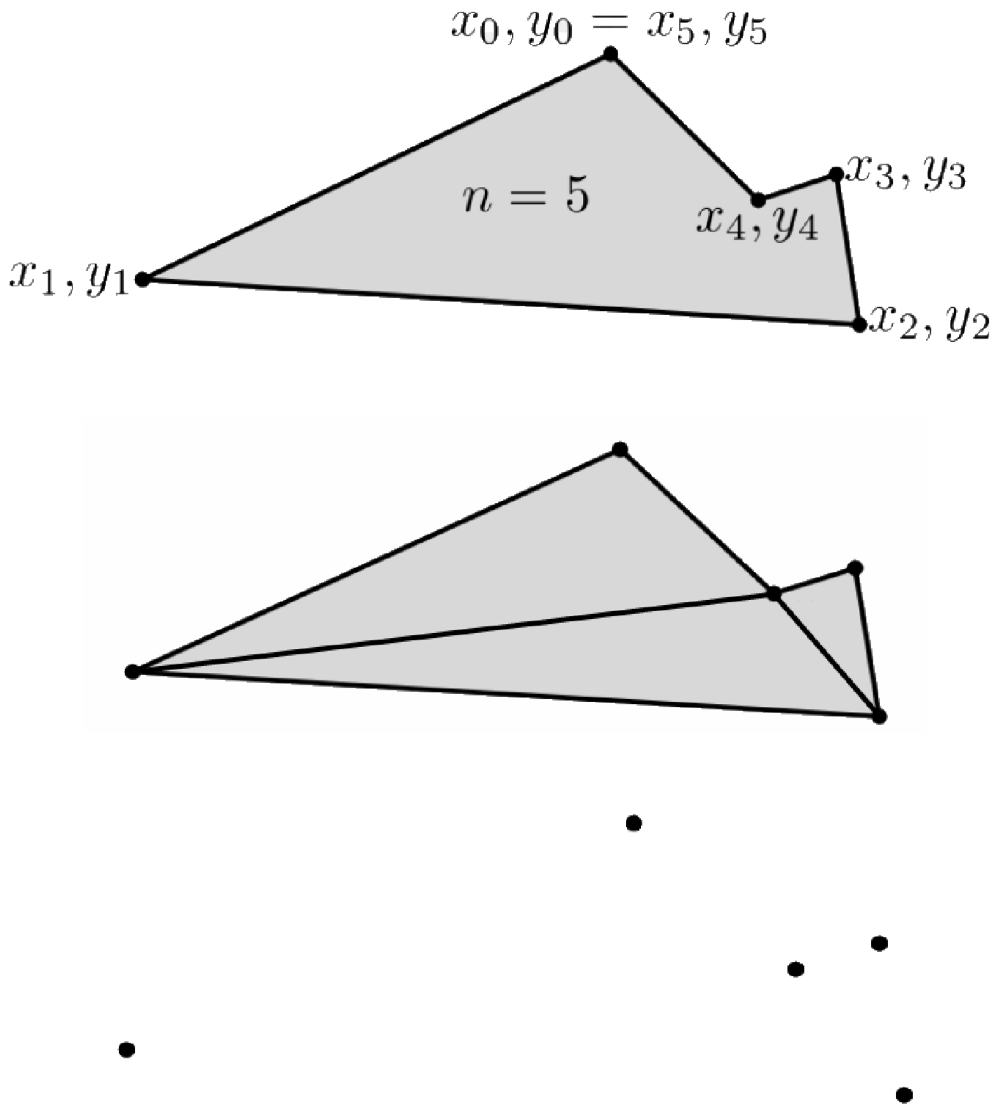
Rasterisation

- Scanline: object order based
- *Fragments*
  - Data for single pixel
  - Frame buffer
- Handle occlusion using depth buffer
  - Later details (more specifically, *fragments*) overwrite earlier ones if closer to camera
- Shade based on vertices and interpolate
  - See lighting and shading lecture

Rasterisation

Process of converting geometry into a raster image (series of pixels)

- 3D scene converted into 2D image
- Polygons
- ...composed of *triangles*
- ...composed of *vertices*



Rasterisation

Rasteriser takes stream of vertices

Moves onto the 2D surface of the screen

Fills interior of 2D triangles

Core concepts:

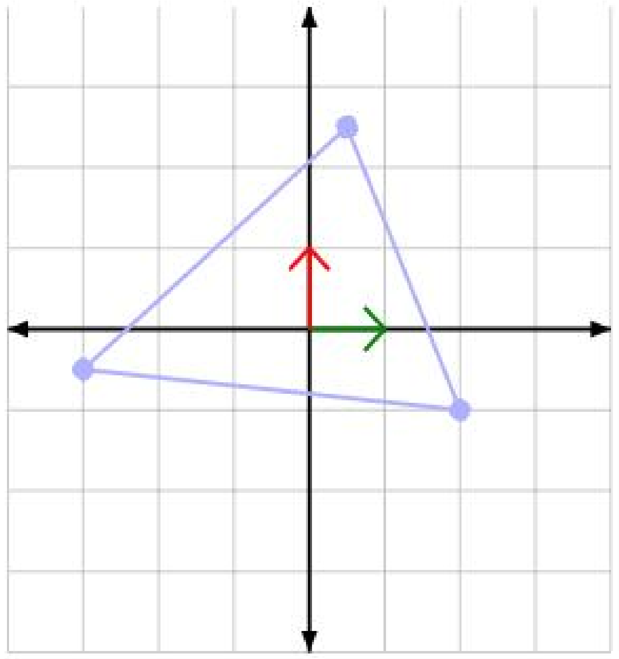
- Geometry and transformations
- Projection
- Clipping
- Scanline Conversion

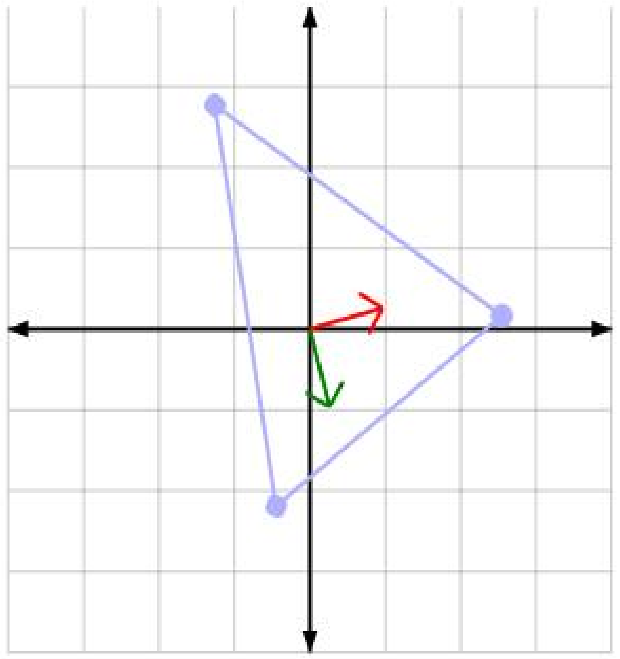
Geometry Transformations

Matrix multiplication

Translation, scaling, rotation, projection

Familiar?





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Transformation Stack

- *Stack* of transforms (i.e. matrices)
  - – Push and pop
- Position stream of input vertices
- Incoming vertices transformed according to the transformation stack
- Remember: local coordinate marker idea

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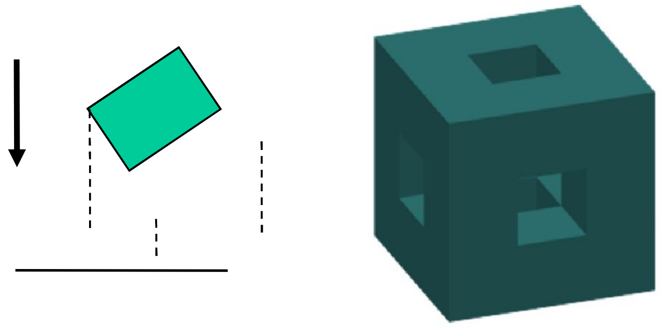
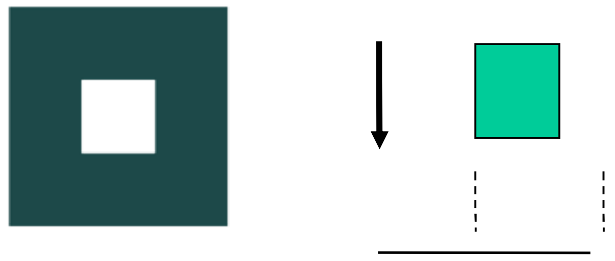
Projection

- Remove depth
  - Convert 3D geometry to flat 2D representation
  - Do so for each vertex of each polygon
- Orthographic projection
  - Simply remove z coordinate
  - Viewing volume is a cube
- Perspective projection
  - Single point of projection (focal point)
  - Viewing volume is a pyramid

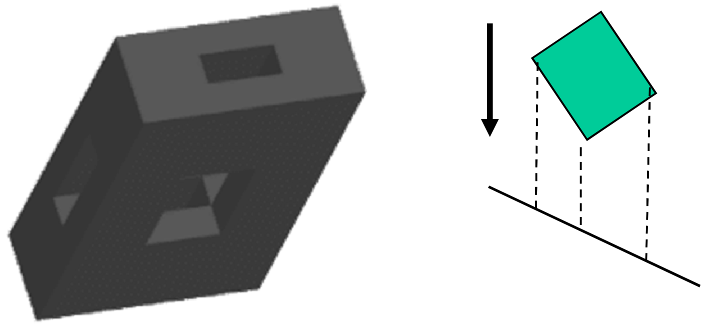
Parallel Projections



axonometric

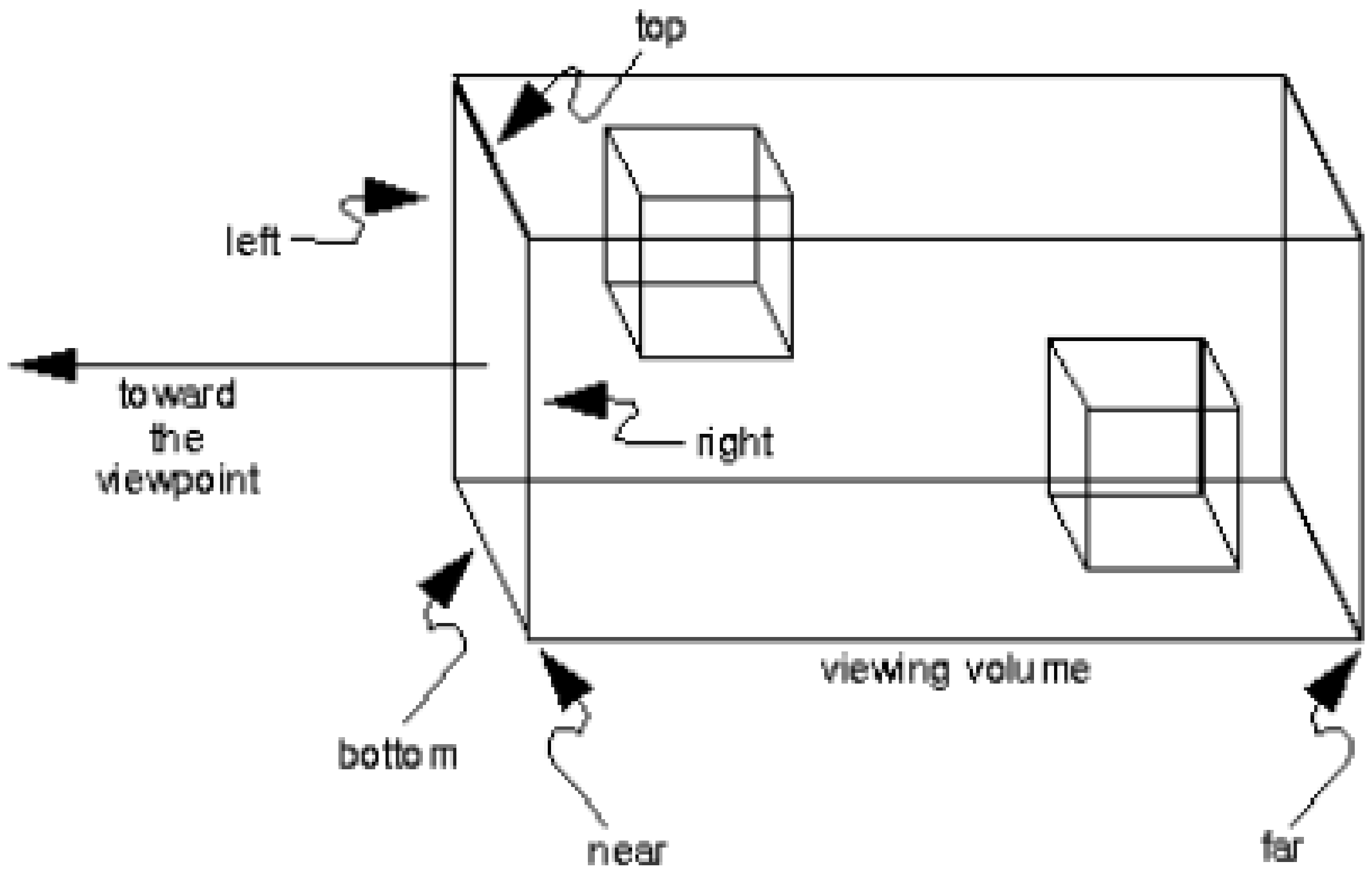


orthographic



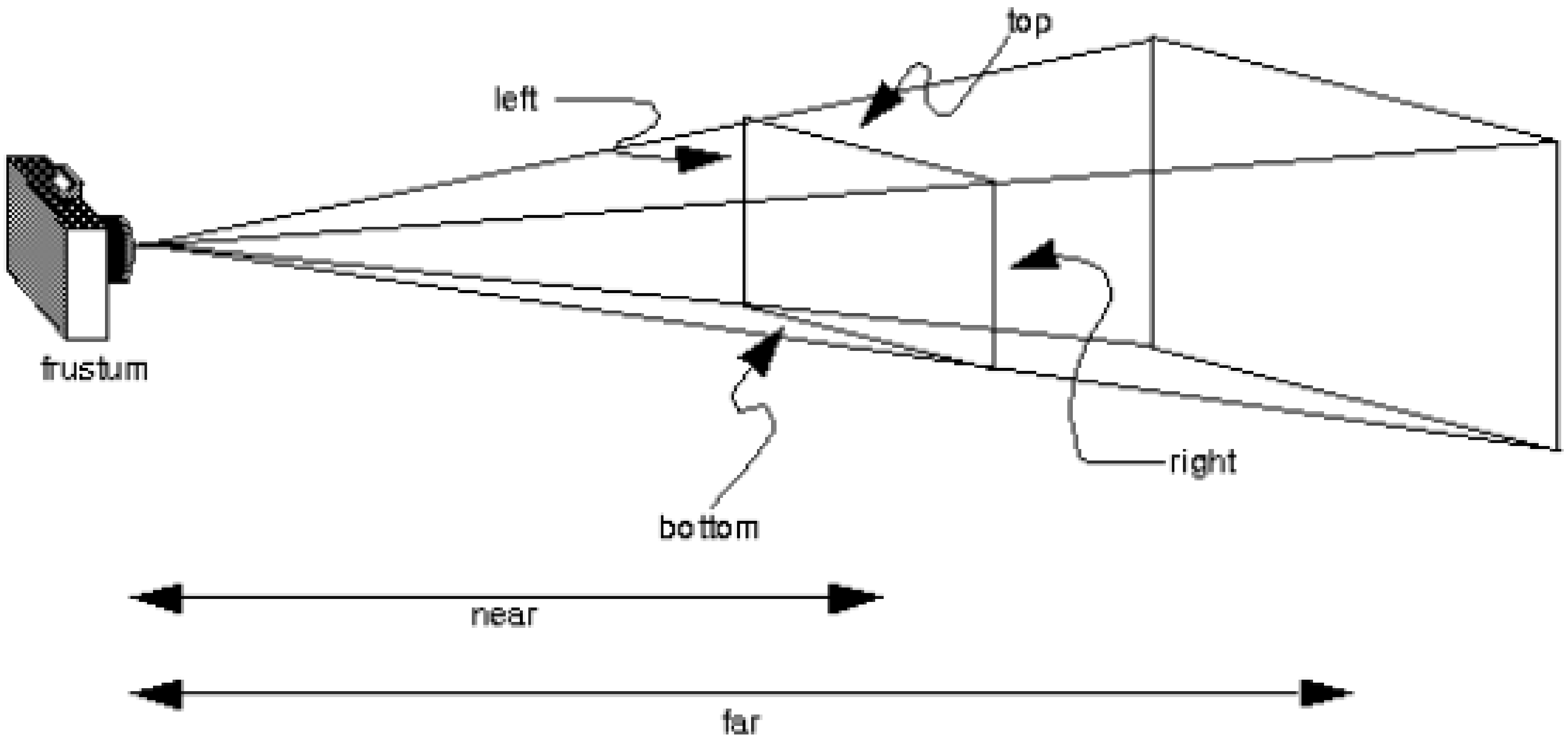
oblique

Orthographic Projection



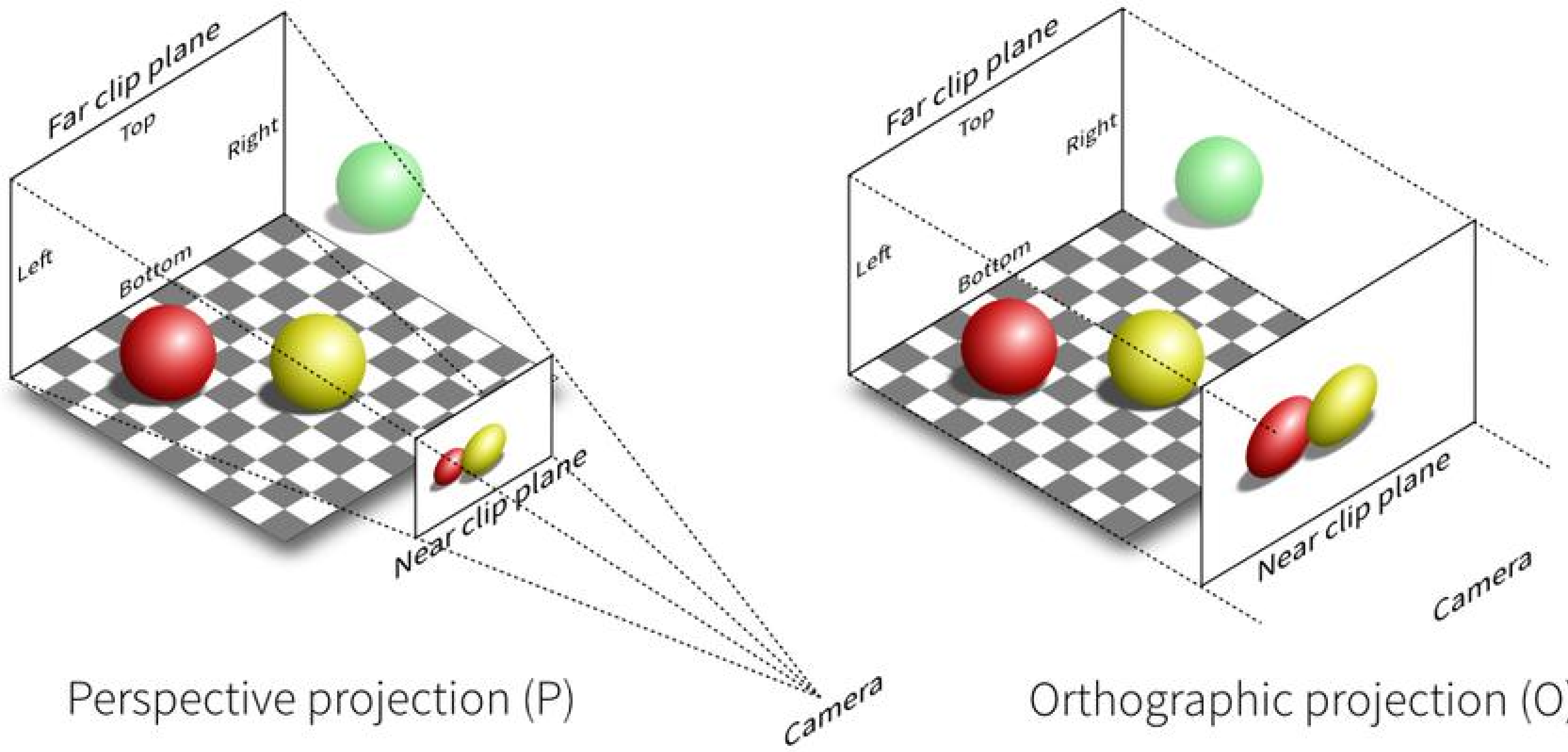
From OpenGL Programming Guide

Perspective Projection



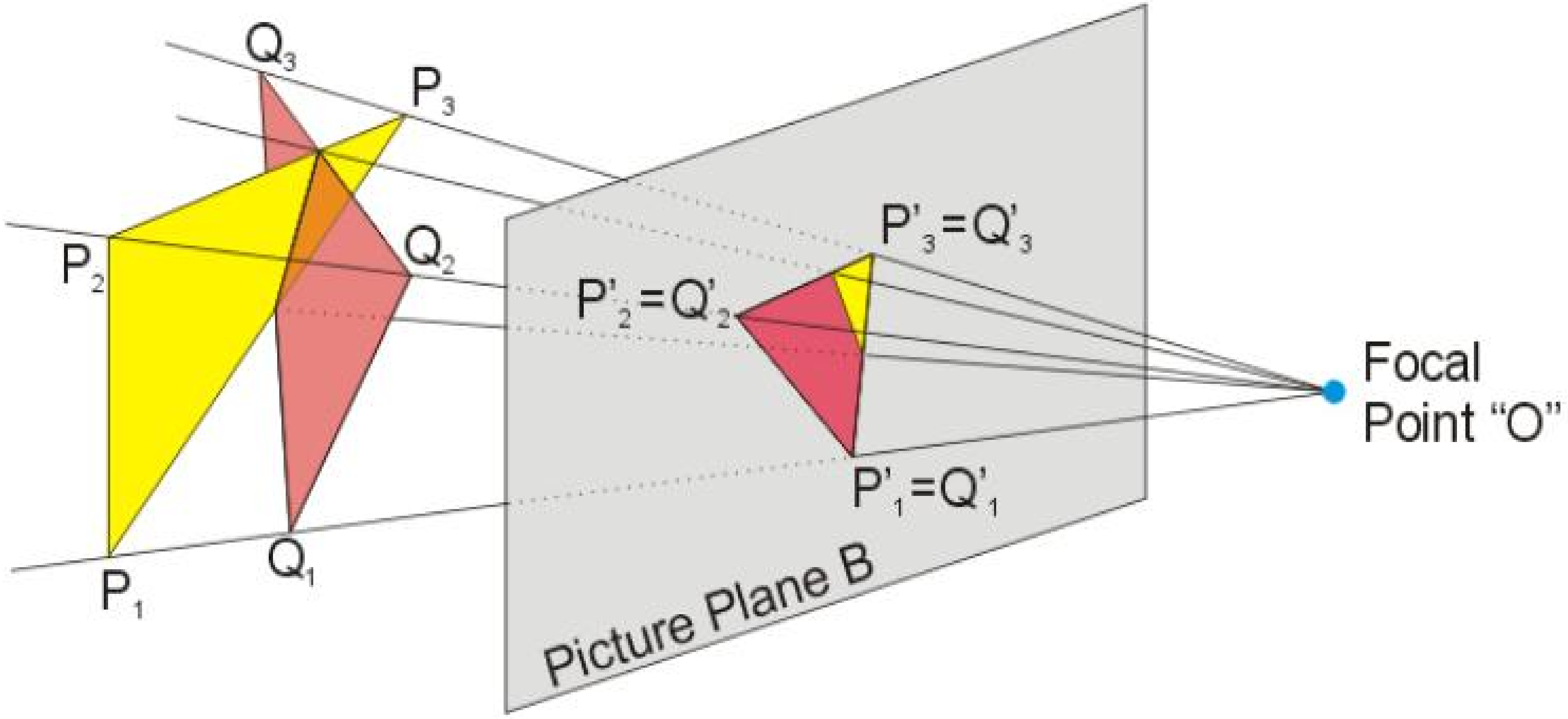
From OpenGL Programming Guide

Example



Nicolas P. Rougier, ERSF Code camp

Projection



Camera Specification

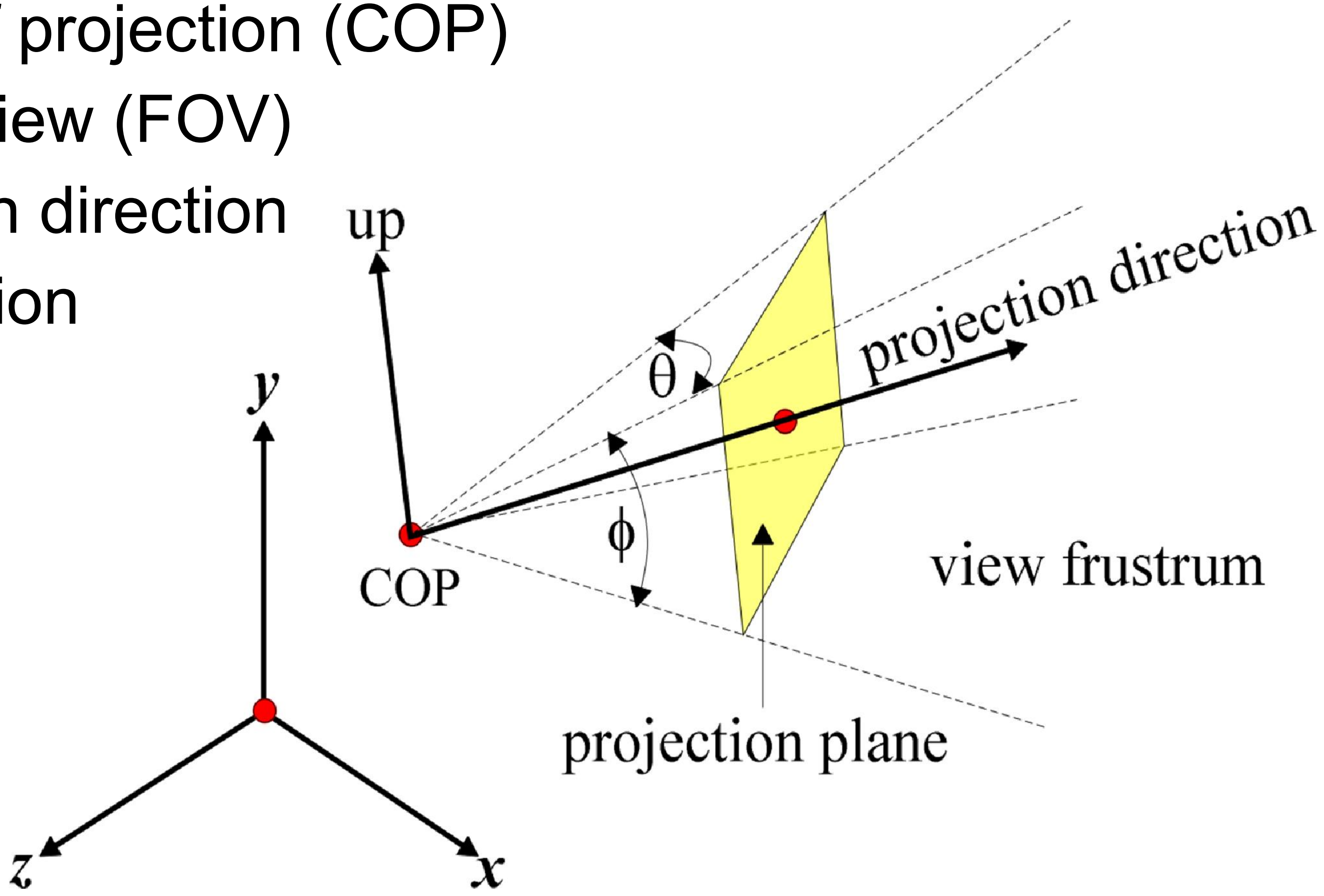
Parameters

Centre of projection (COP)

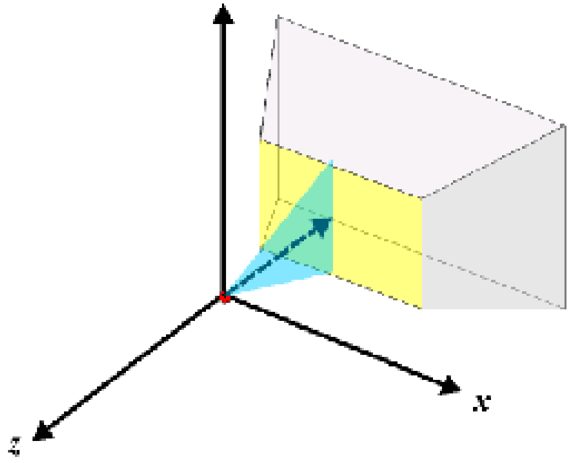
Field of view (FOV)

Projection direction

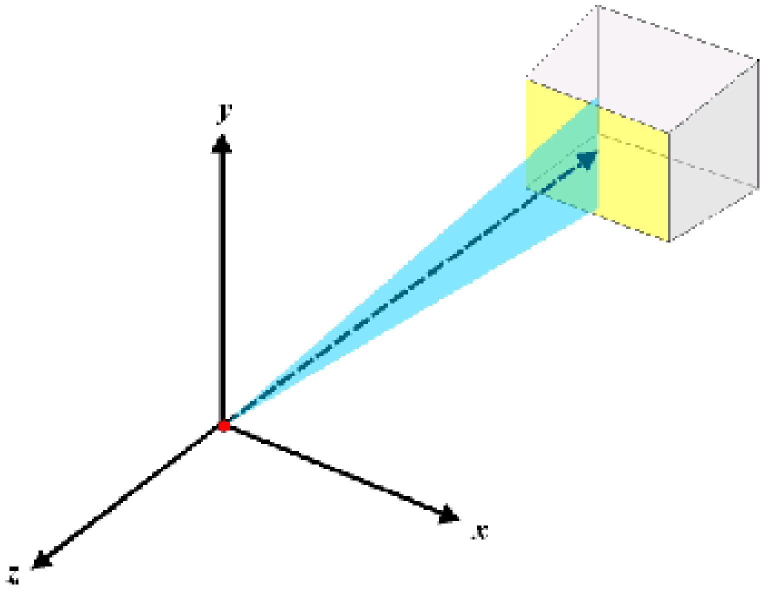
Up direction



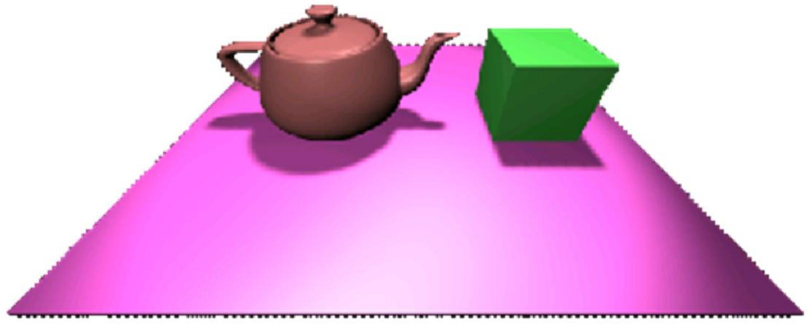
Outcomes

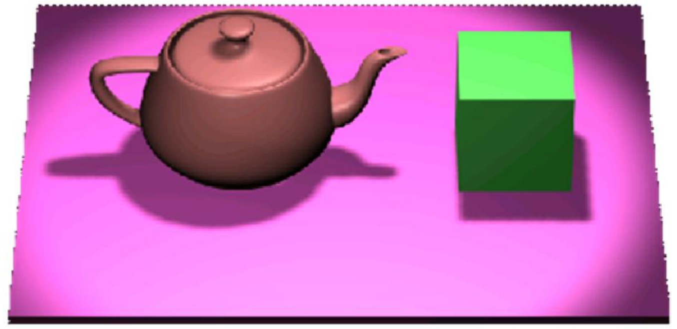


Large FOV



Small FOV



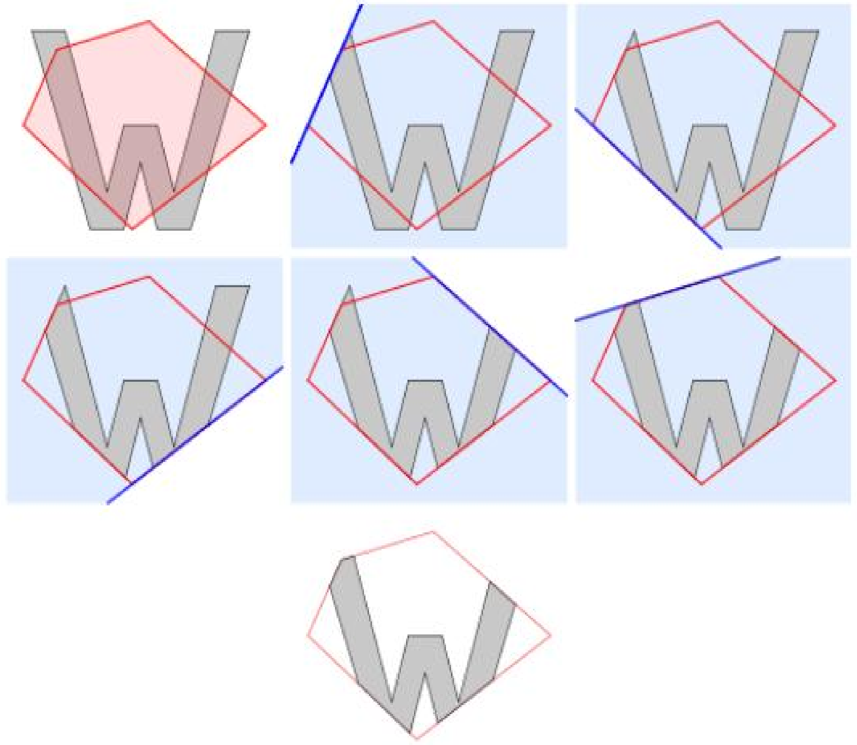


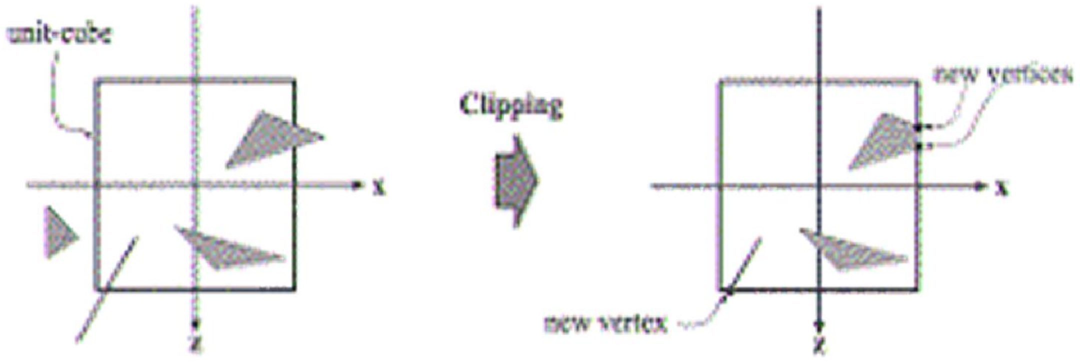
Clipping

Projected locations may be outside the viewing window

Truncate triangles to fit them inside the viewing area

- – e.g. Sutherland-Hodgeman algorithm





Real-time Rendering, Akenine-Moller, Haines and Hoffman

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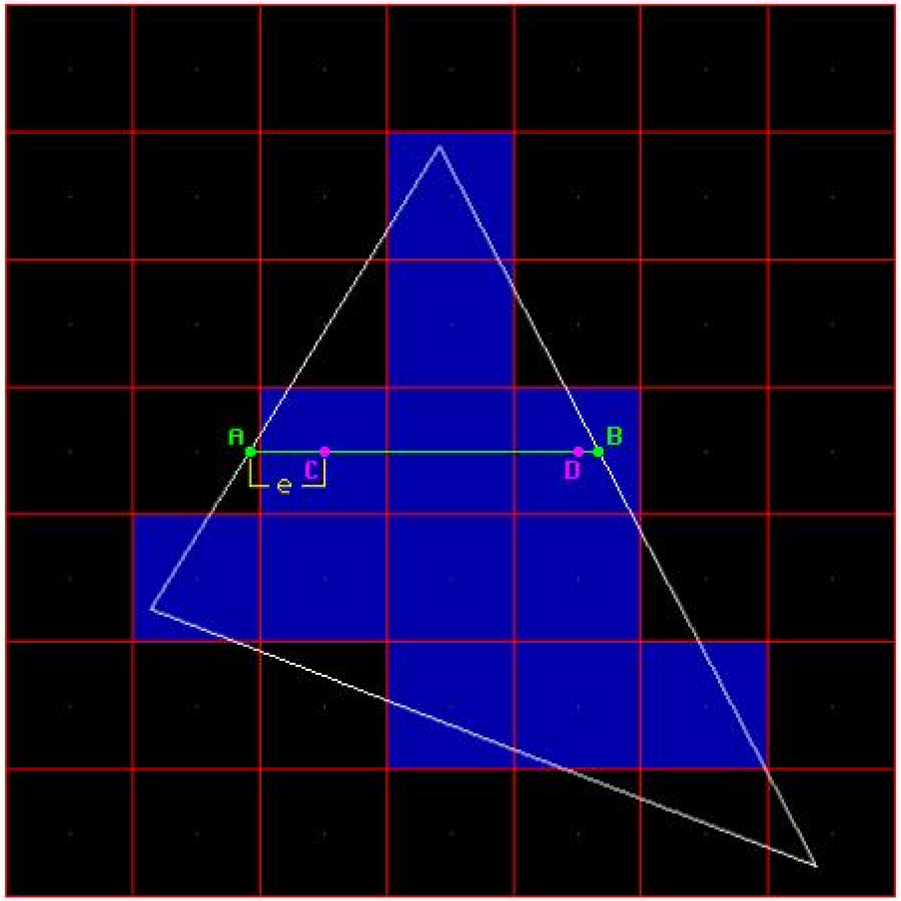
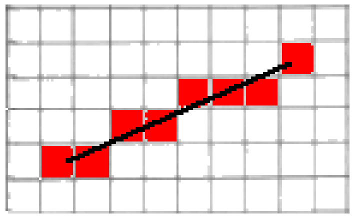
Scan Conversion

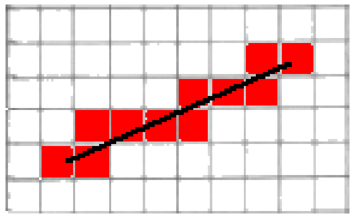
- Fill interior of triangles in image plane
- Use *scanline fill algorithm* to fill polygons
- Framebuffer

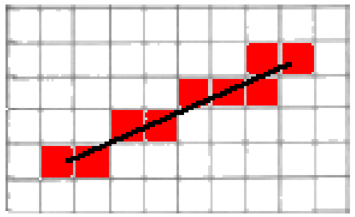


Line Drawing

- A line usually defined as infinitely thin
- How to display using pixels?
  - Fixed and finite area
  - Choose which pixels to fill to best represent the line
  - Different algorithms, providing different results

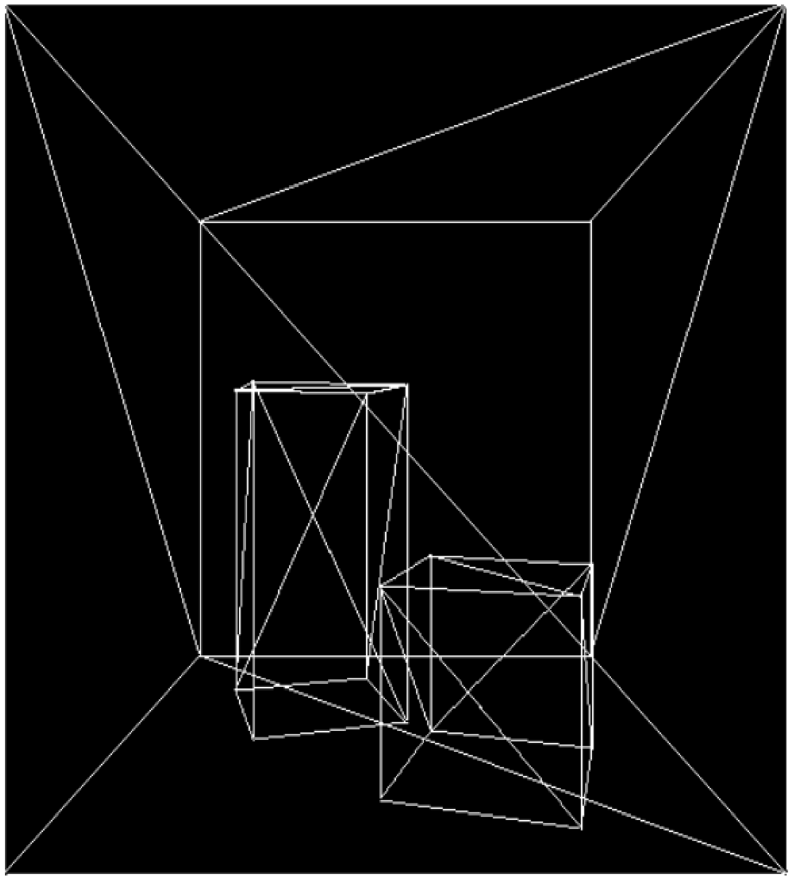

mid-point


neighbourhood


weighted area

Line Drawing

Bresenham's line algorithm



```
dx = x_end - x_start
dy = y_end - y_start
d = 2 * dy - dx
x = x_start
y = y_start
while x < x_end
if d <= 0 then
    d = d + (2 * dy)
    x = x + 1
else
    d = d + 2 * (dy - dx)
    x = x + 1
    y = y + 1
endif
SetPixel(x,y)
endwhile
```

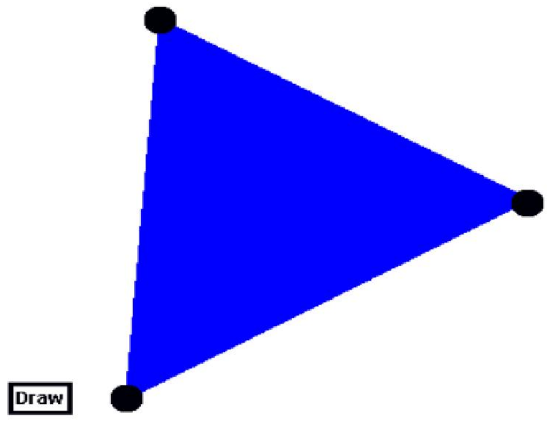
Polygon Filling

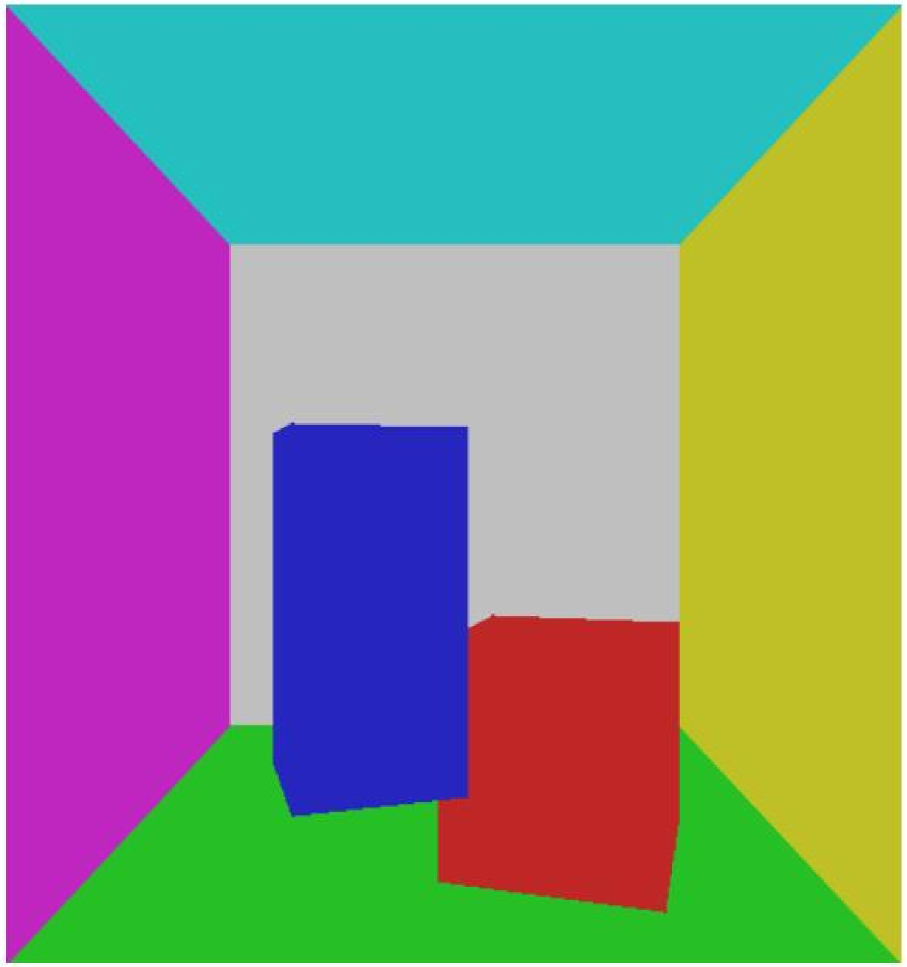
Fill surface

Triangles

Interpolation

Compute edges





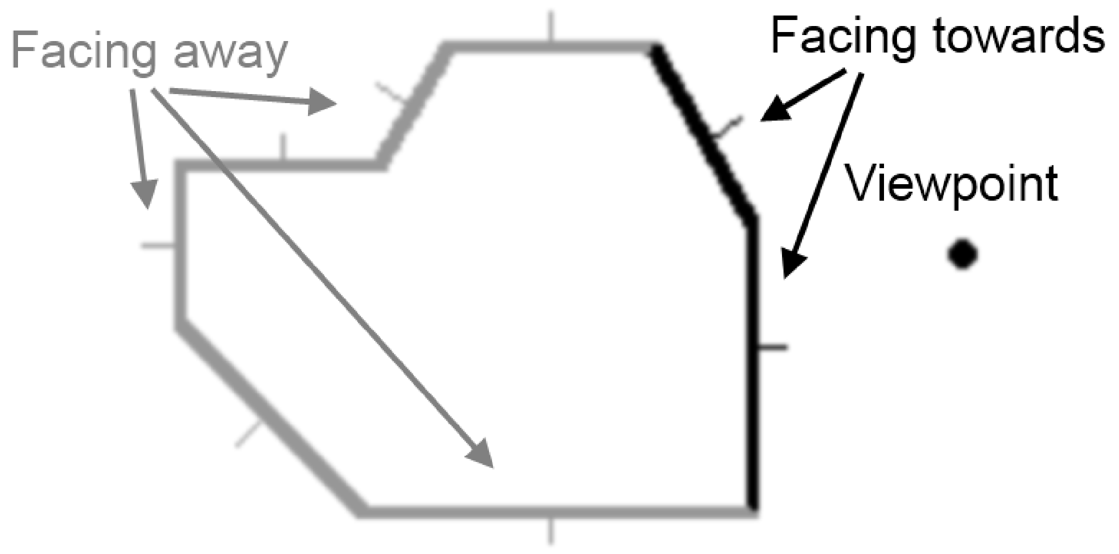
Backface Culling

Objects within the view-frustum may have polygons pointing away from the viewer

Not visible

Back-faces

The process is known as *back-face culling*



Backface Culling

To eliminate back-faces:

```
For each polygon in the scene {
Take its normal vector
Take the view direction vector
Use the dot product the find the angle between normal and view direction
If the angle is LESS than 90 degrees, then the polygon is culled
}
```

Visible Surface Determination

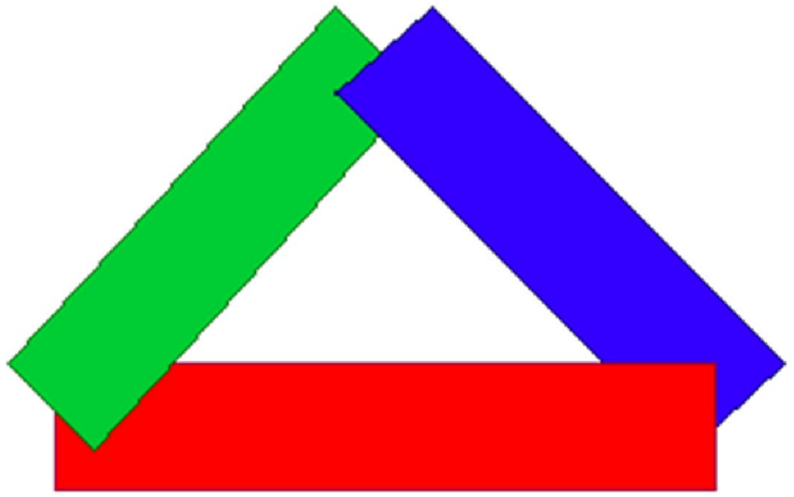
Painter's algorithm
Sort polygons relative to the viewpoint
Render those polygons that are nearer the viewpoint *after* those polygons that are further away from the viewpoint

Problems?

Visible Surface Determination

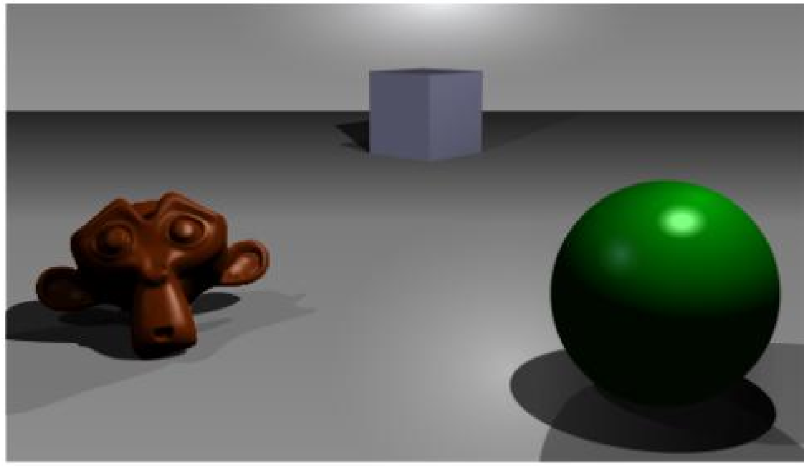
Painter's algorithm
Sort polygons relative to the viewpoint
Render those polygons that are nearer the viewpoint *after* those polygons that are further away from the viewpoint

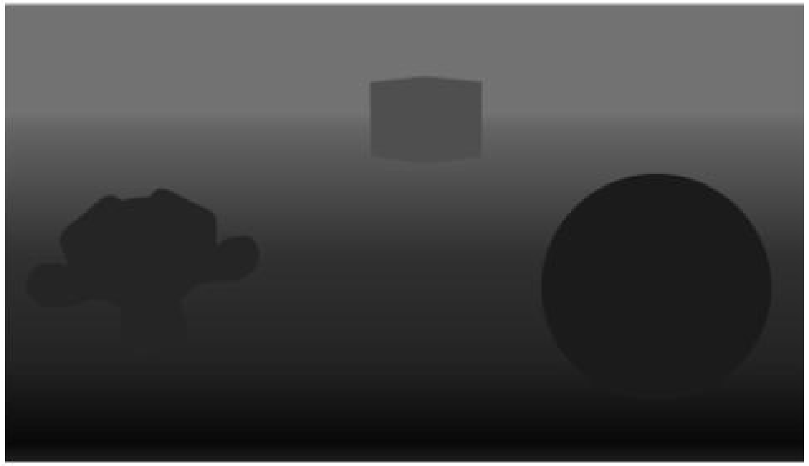
Problems?



Depth Buffer

- Image-space visibility algorithm
- Buffer is 2D array, one element per pixel
- Compute depth of each generated pixel
  - Overwrite depth buffer value if new value is nearer to camera than previous
  - Non-linear, Z-fighting


A simple three-dimensional scene


Z-buffer representation

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Note: BSP Trees

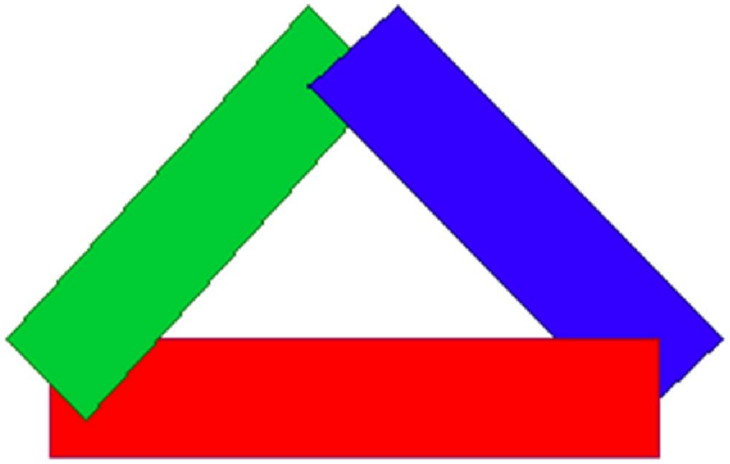
Used by Quake, Quake 2, etc

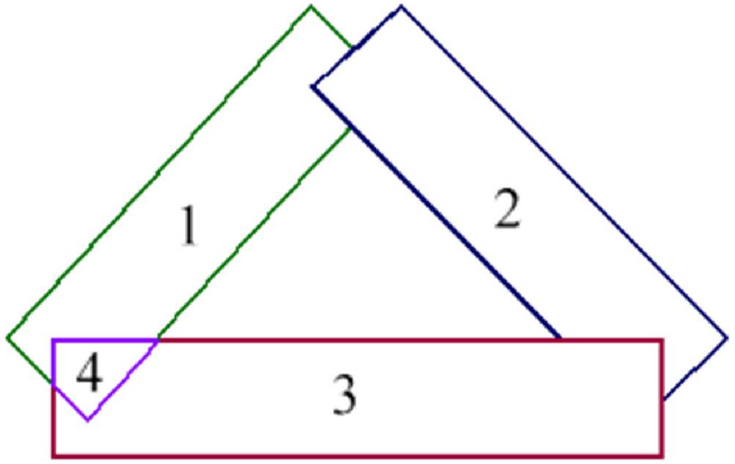
World-space visibility algorithm

Visibility calculations on a *per polygon* basis

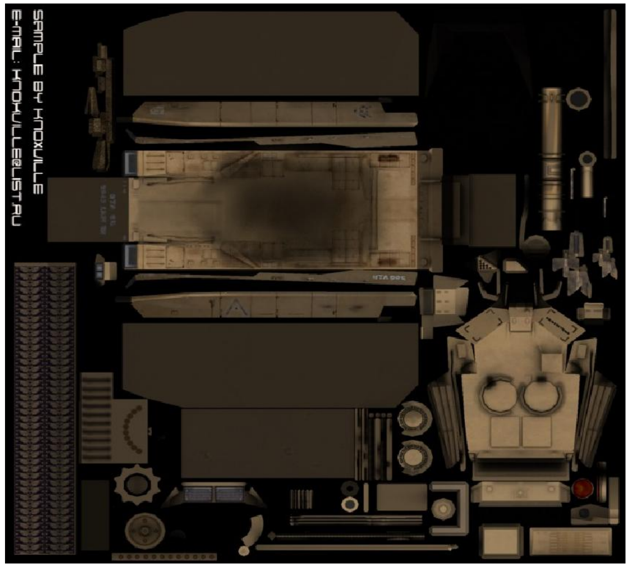
Split polygons

Compare with Z-buffer algorithm



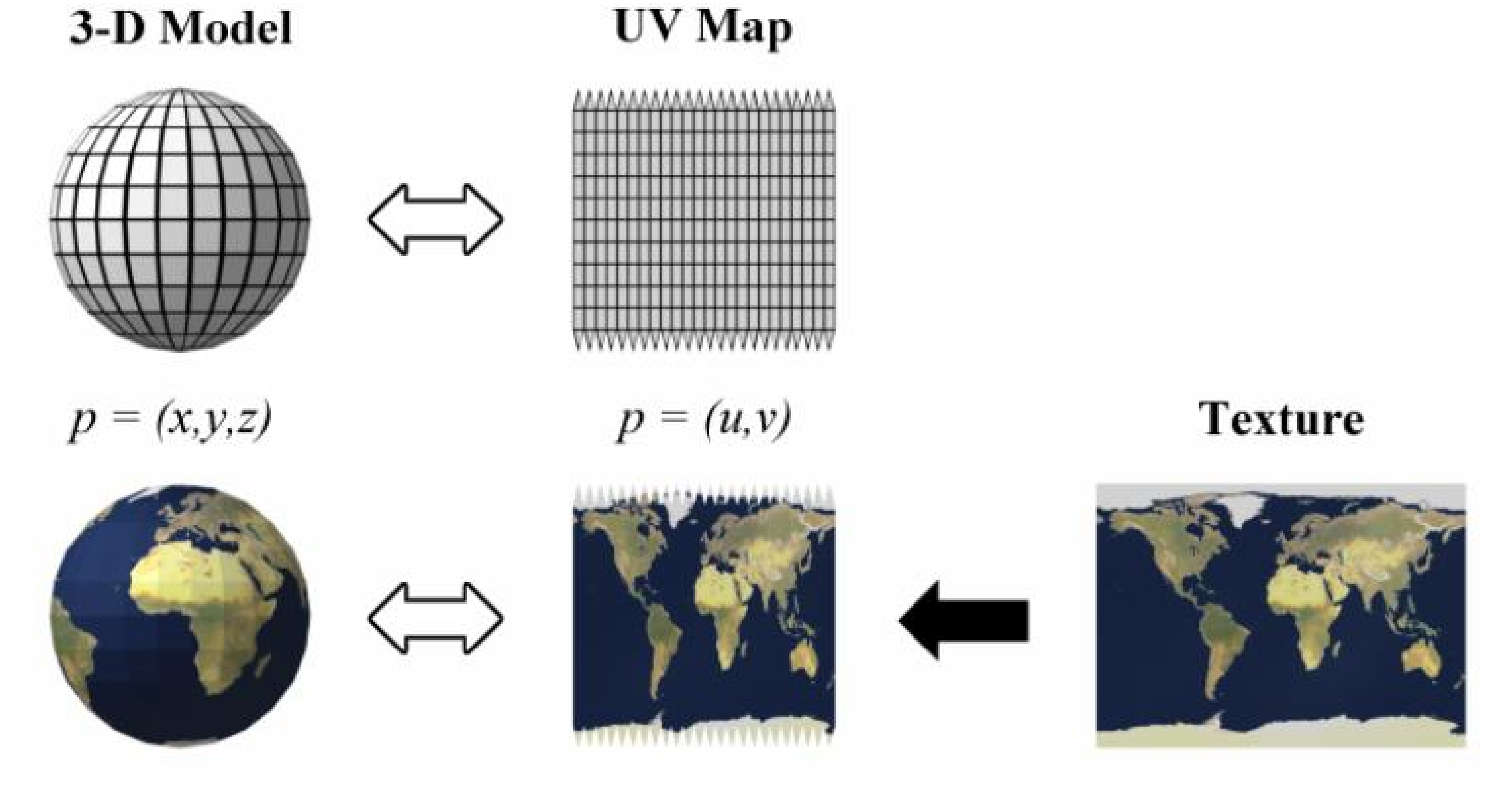


Texturing



- Bitmap (2D image) applied to a triangle
- Each triangle associated with an image
- Each vertex associated with a texture coordinate *(u,v)*
- For each rendered pixel:
  - Lookup corresponding texture element (*texel*)
  - Interpolation

Texturing



Labs

You should be finishing Lab 2 soon

- Any major problems?
- Suggested steps:

```
Fork(continue working on problem)
If (help session happening soon)
 Goto help session and ask(question)
Else
 Post(specific details, KTH Social)
 Wait until (reply or help session)
```

- Try not to crash in meanwhile…

(Physical) Labs Session

- Thursday 23rd April, 1-3p.m, Visualisation (VIC) Studio

  See KTH Social post for directions, etc

- Purposes:
  - Ask questions/get help if in process of completing a lab task
  - Obtain **feedback** if you have work-in-progress
    - Code
    - Documentation

Submission dates

Submission date for all labs:

On or before **May 8th**

Through *Bilda (will open next week for labs)*

Submission date for all projects:

On or before **May 29th**

Through *Bilda (will open nearer the project deadline)*