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DH2323 DGI16

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:

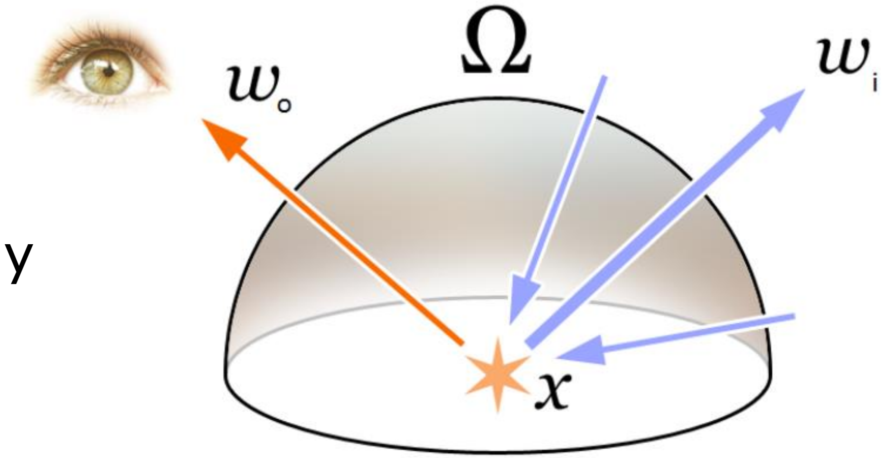
Incoming light function

BRDF

Basis:

Law of conservation of energy

Hemisphere containing all w_i



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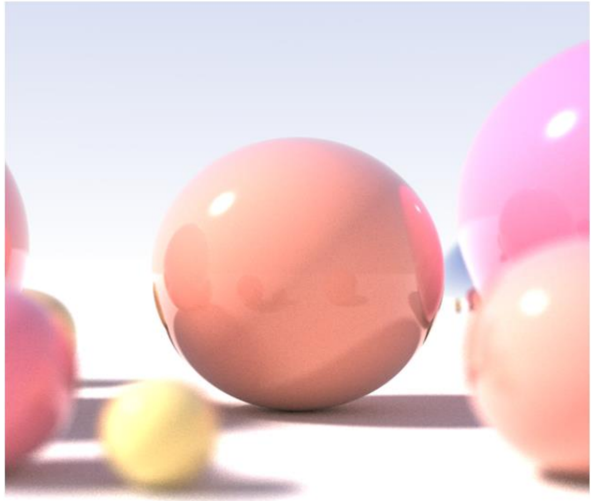
Global Illumination

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

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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

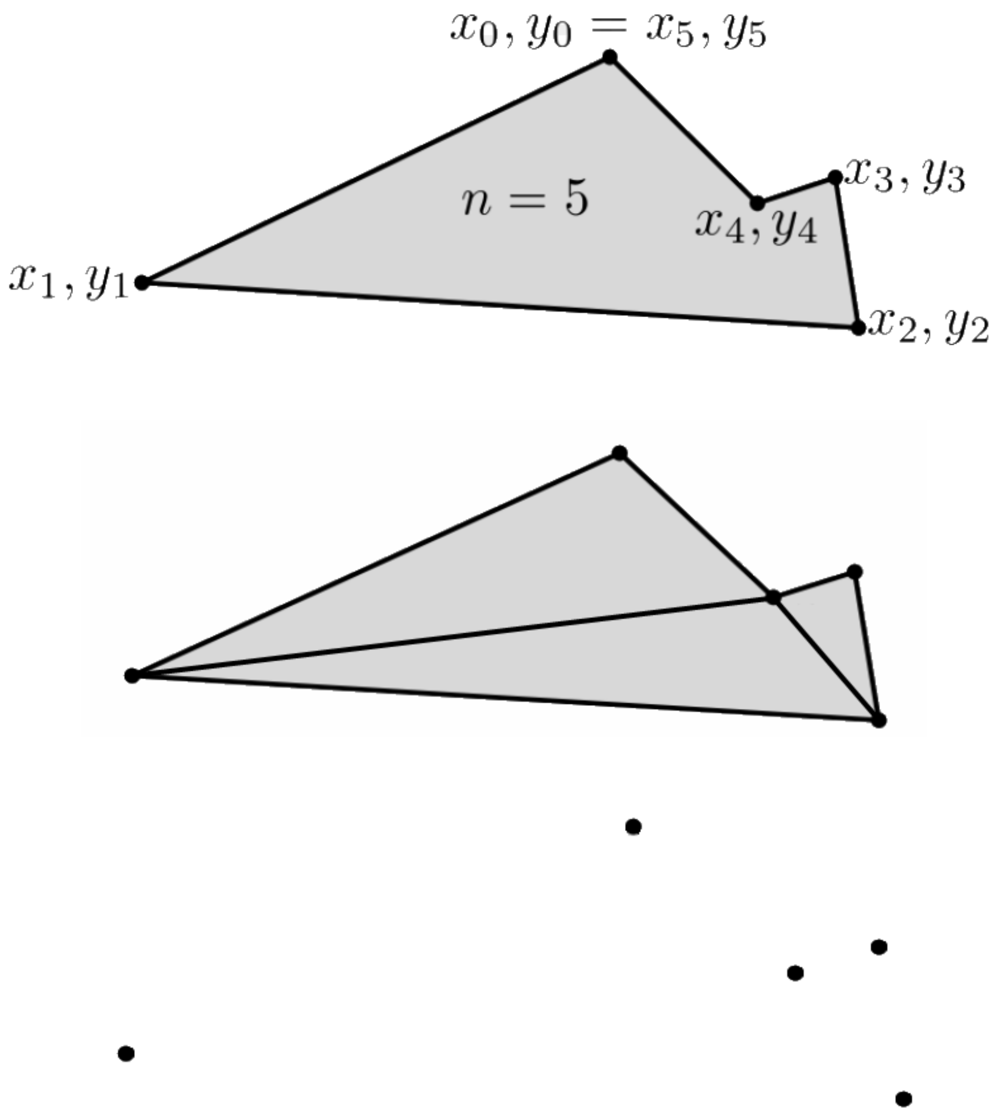
Rasterisation

- 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

Project them onto the 2D surface of the screen

Fill in the interior of the 2D triangles

Core concepts:

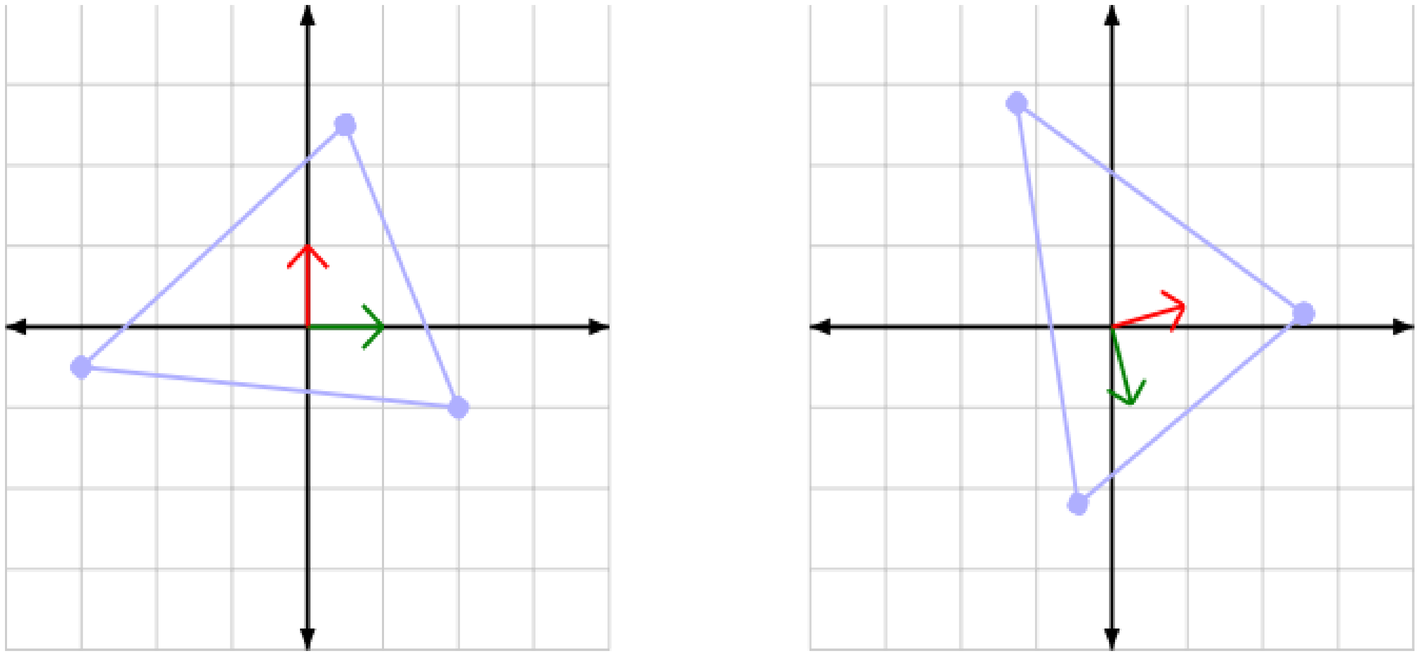
- Geometry and transformations
- Projection
- Clipping
- Scanline Conversion

Geometry Transformations

Matrix multiplication

Translation, scaling, rotation, projection

Familiar?



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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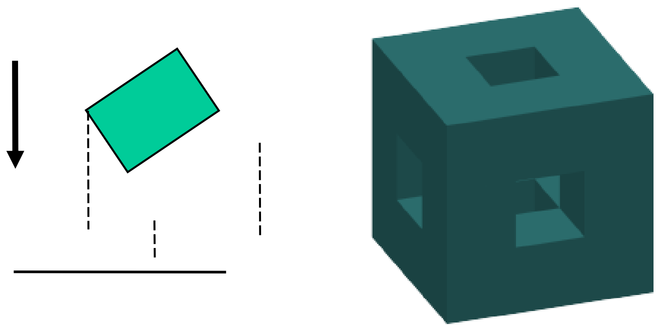
Projection

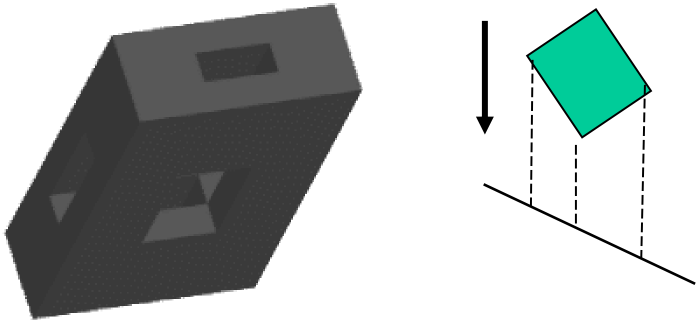
- Remove depth
  - Convert 3D geometry to flat 2D representation
  - Do so for each vertex of each polygon
- Orthographic projection
  - Simply remove z coordinate
  - Viewing volume is a cube
- Perspective projection
  - Single point of projection (focal point)
  - Viewing volume is a pyramid

Parallel Projections



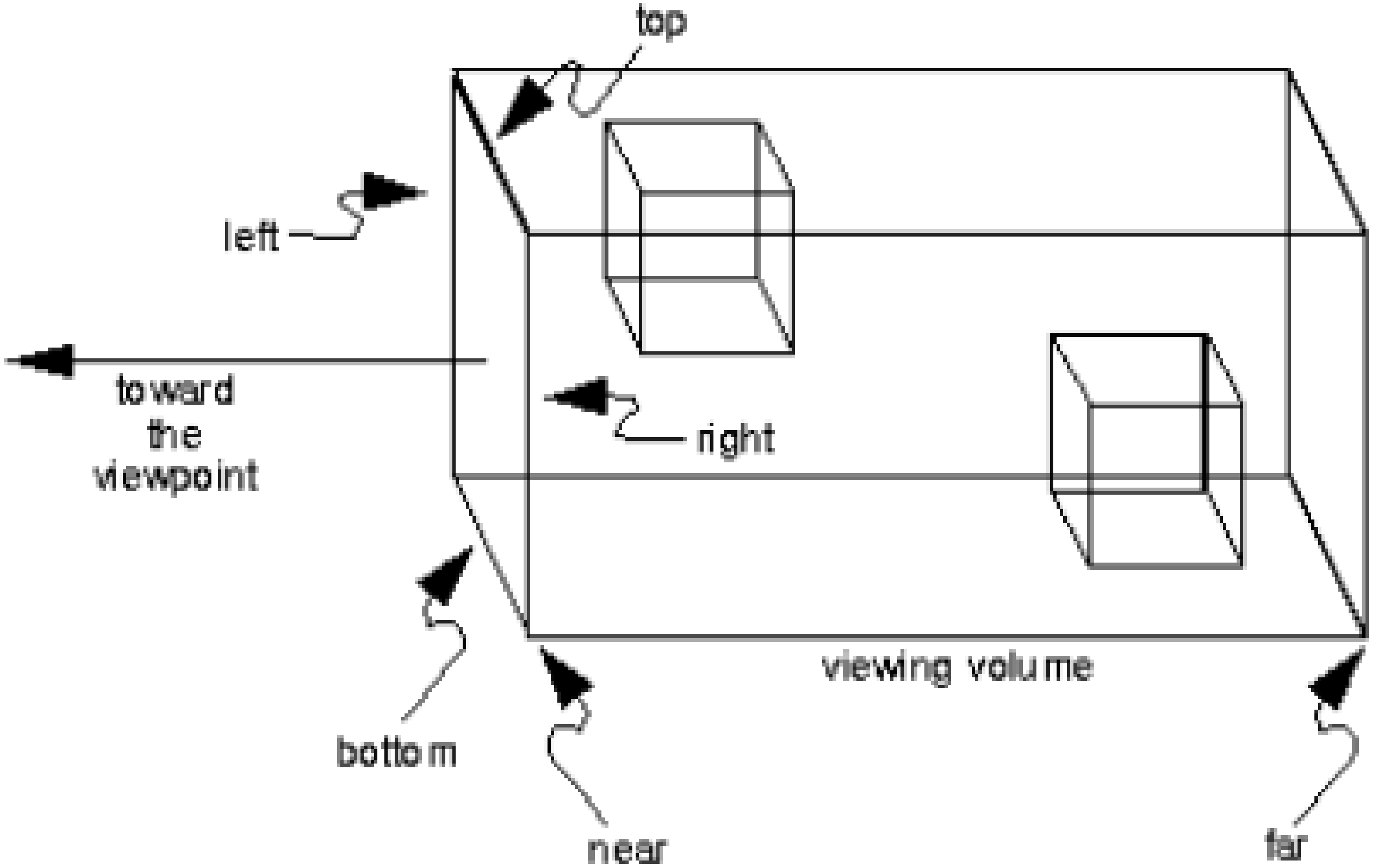
axonometric

orthographic



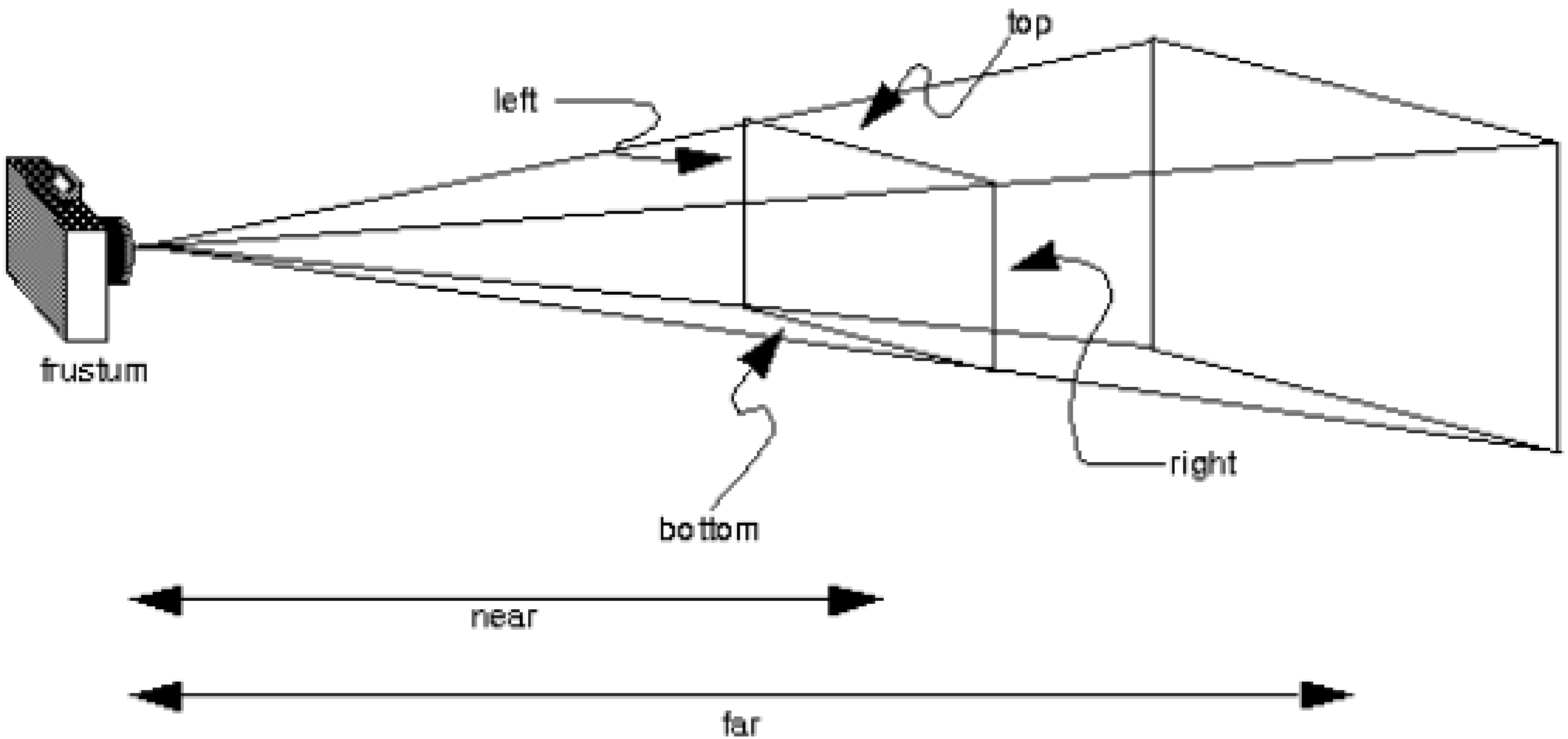
oblique

Orthographic Projection



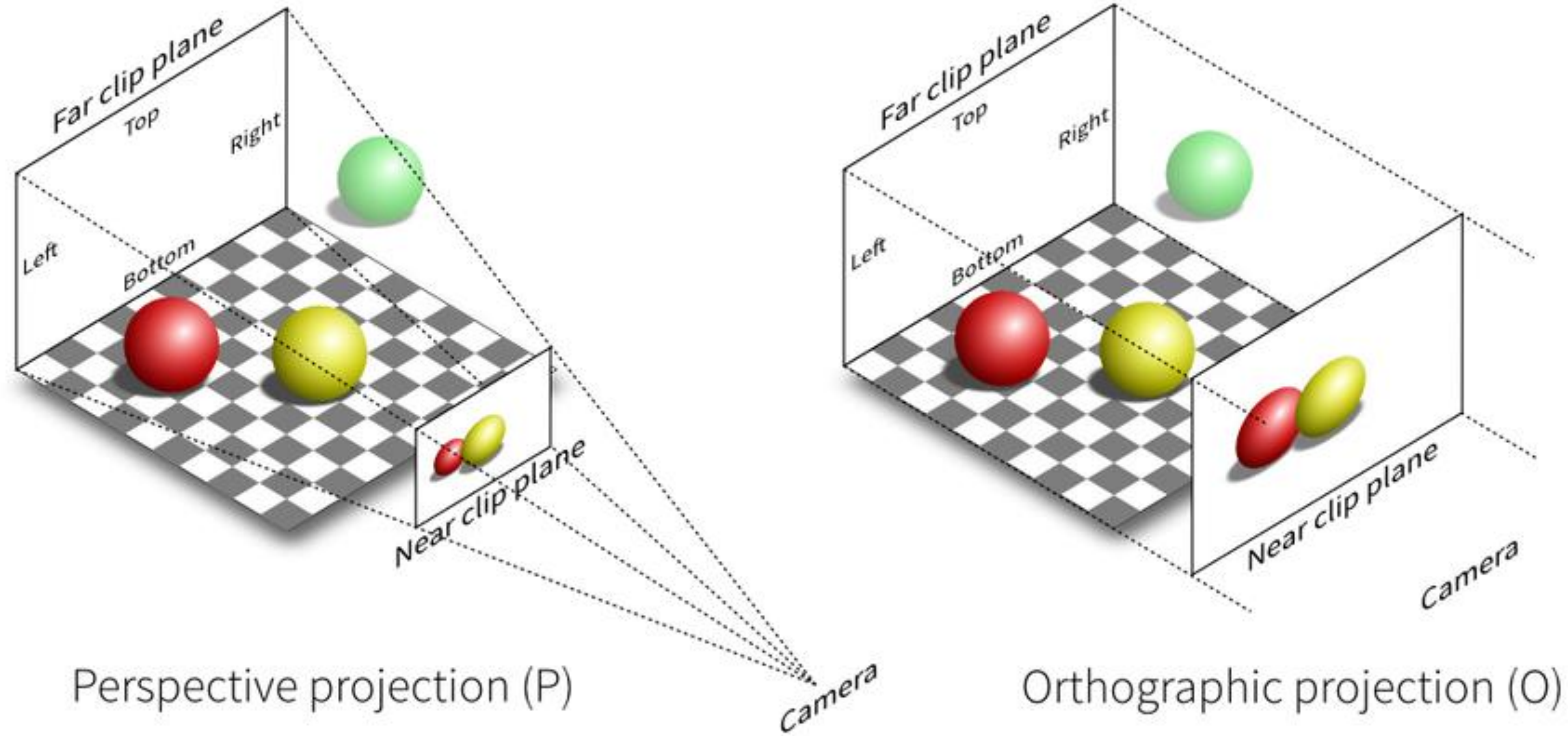
From OpenGL Programming Guide

Perspective Projection



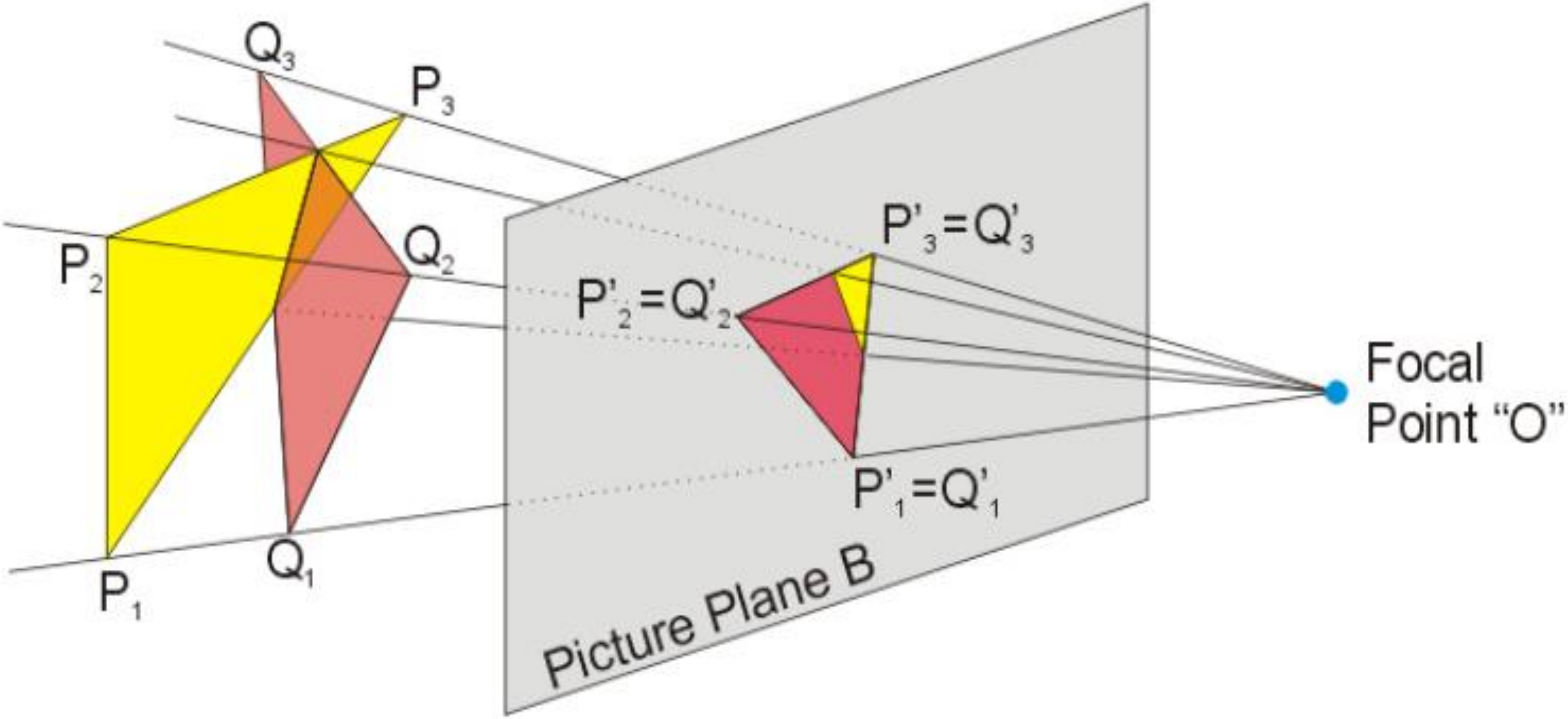
From OpenGL Programming Guide

Example



Nicolas P. Rougier, ERSF Code camp

Projection



Camera Specification

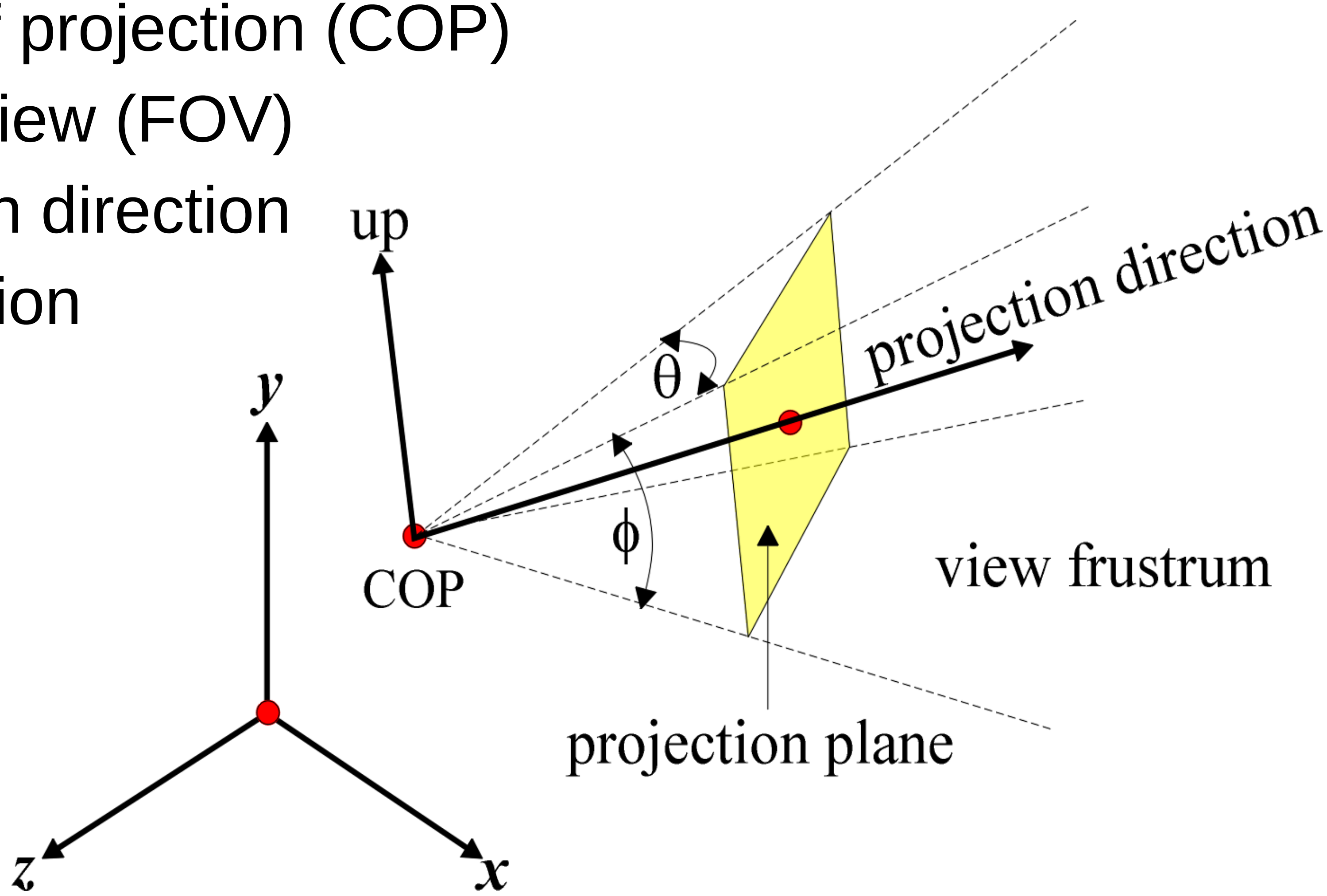
<u>Parameters</u>

Centre of projection (COP)

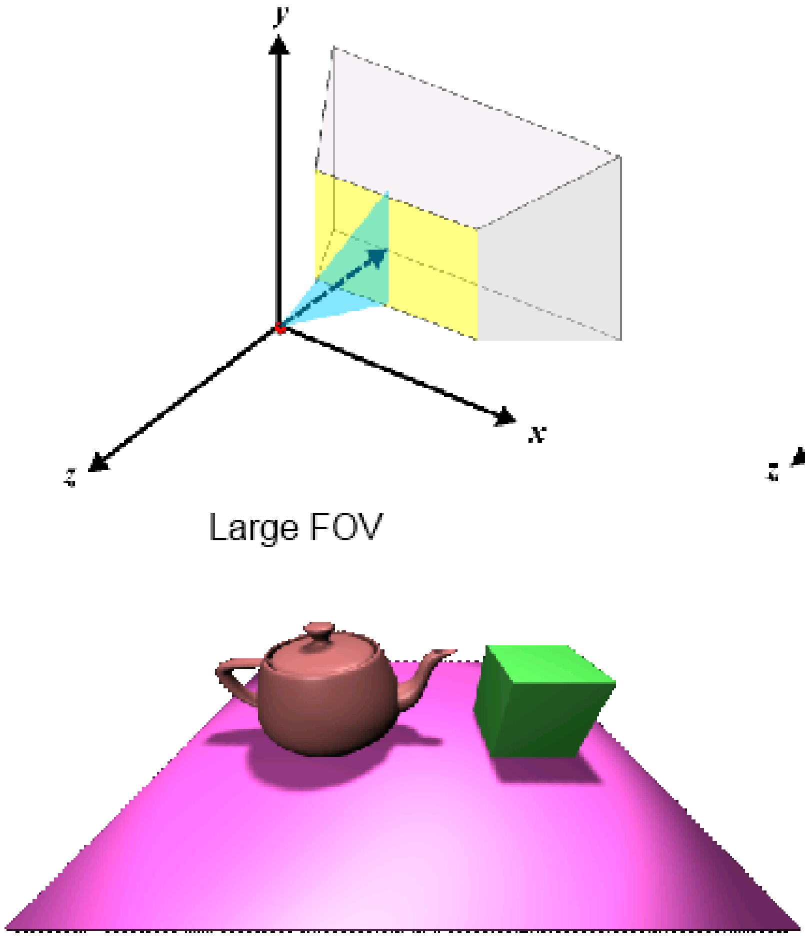
Field of view (FOV)

Projection direction

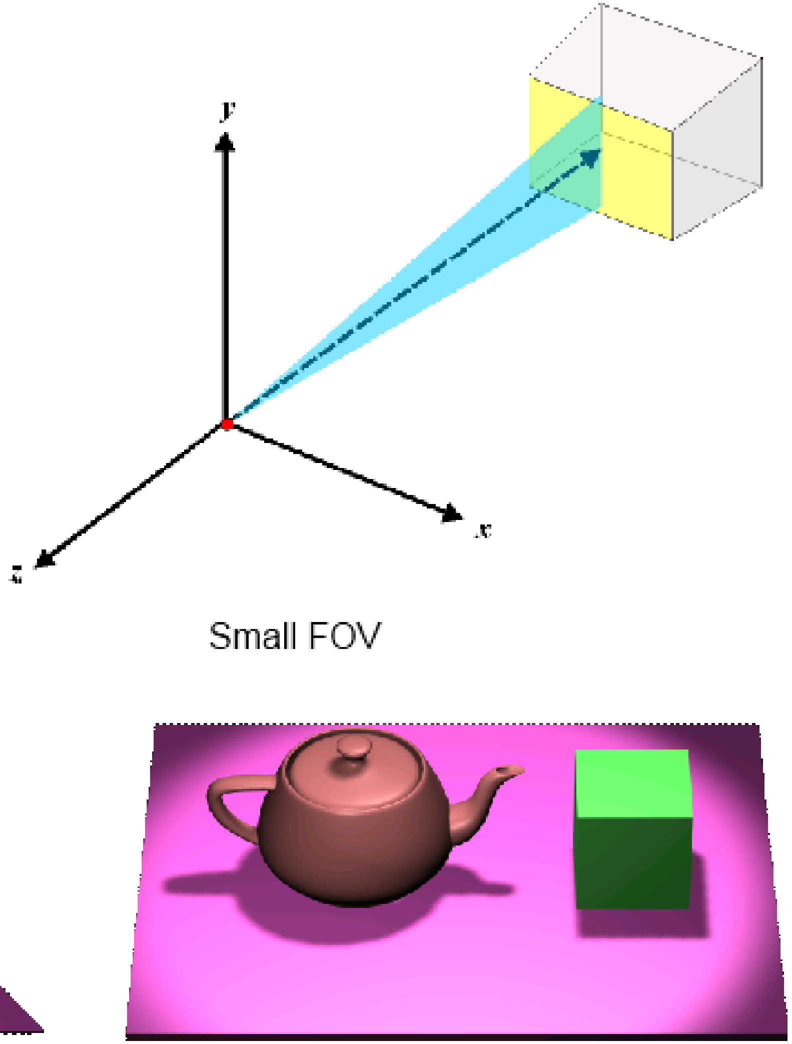
Up direction



Outcomes



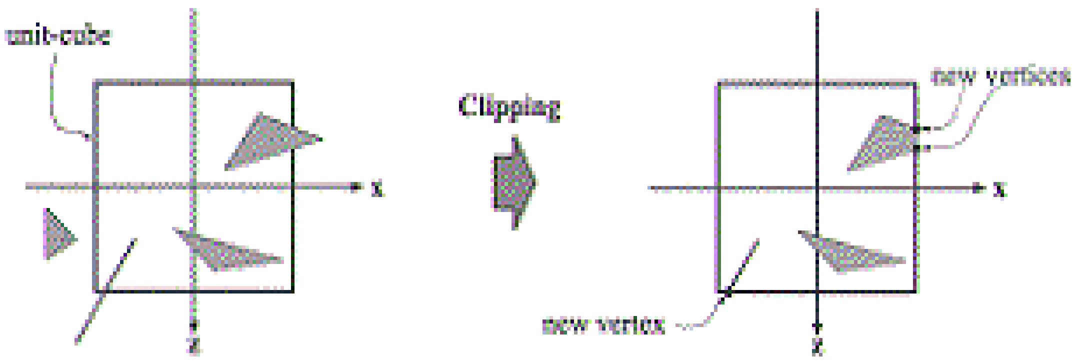
Large FOV



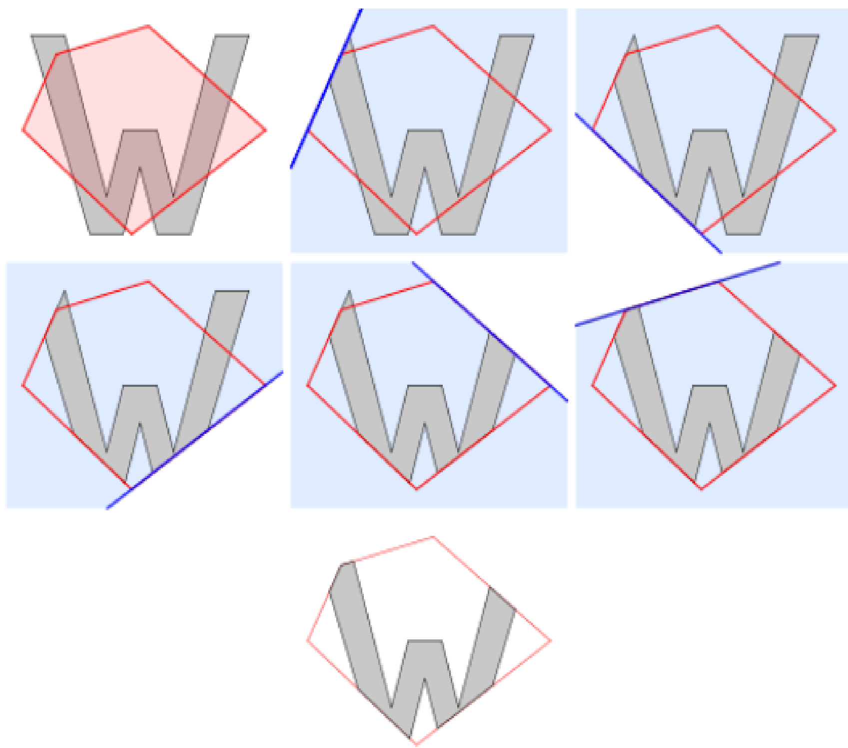
Small FOV

Clipping

- Projected locations may be outside the viewing window
- Truncate triangles to fit them inside the viewing area
  - – e.g. Sutherland-Hodgeman algorithm

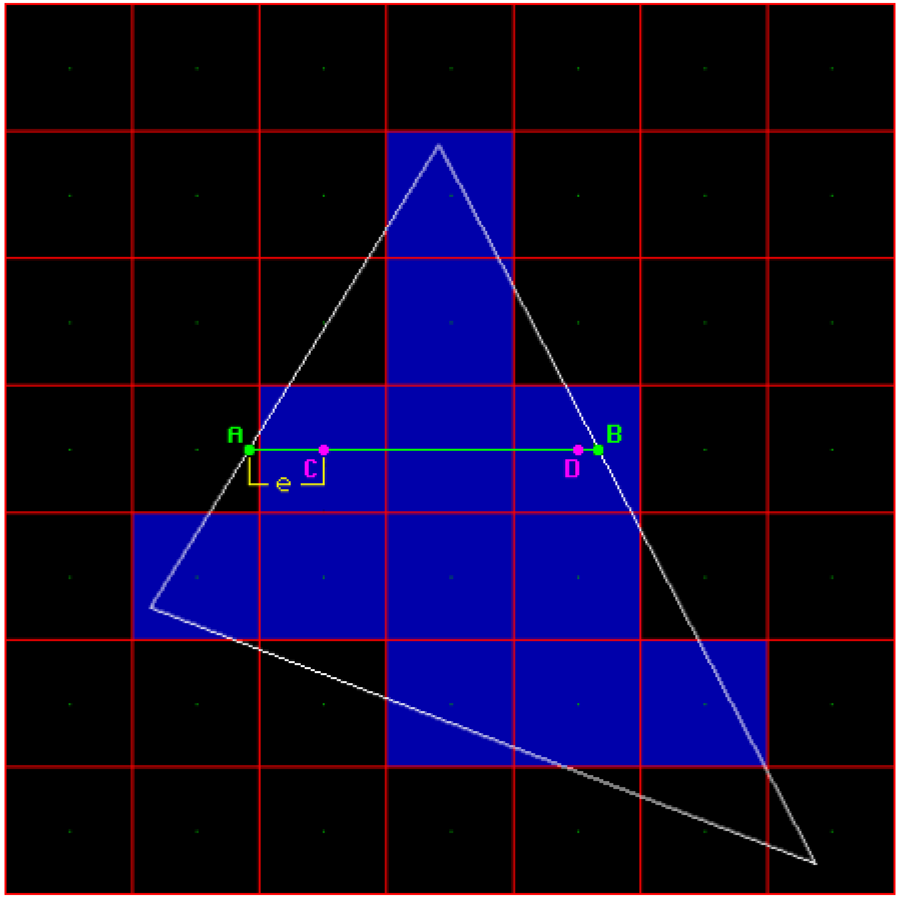


Real-time Rendering, Akenine-Moller, Haines and Hoffman



Scan Conversion

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

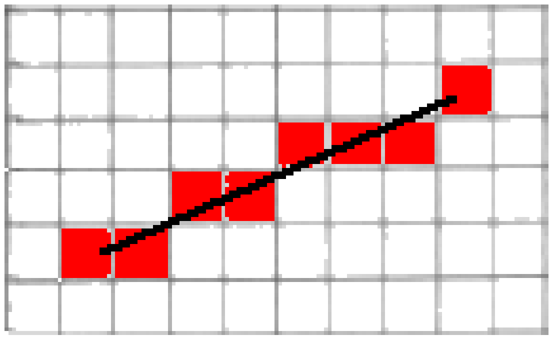


Line Drawing

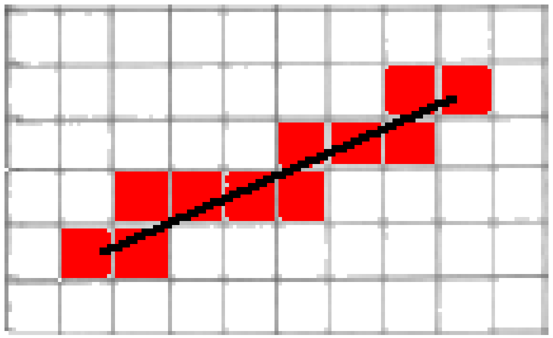
A line usually defined as infinitely thin

How to display using pixels?

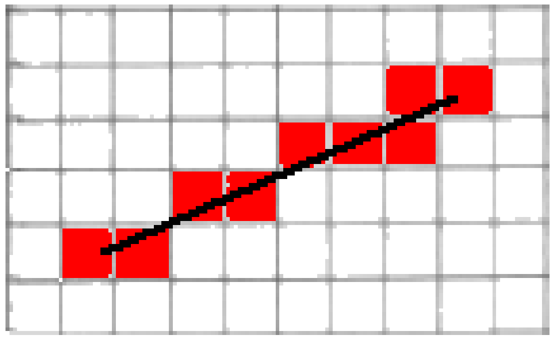
- Fixed and finite area
- Choose pixels that best represent the line
- Different algorithms, providing different results:



mid-point



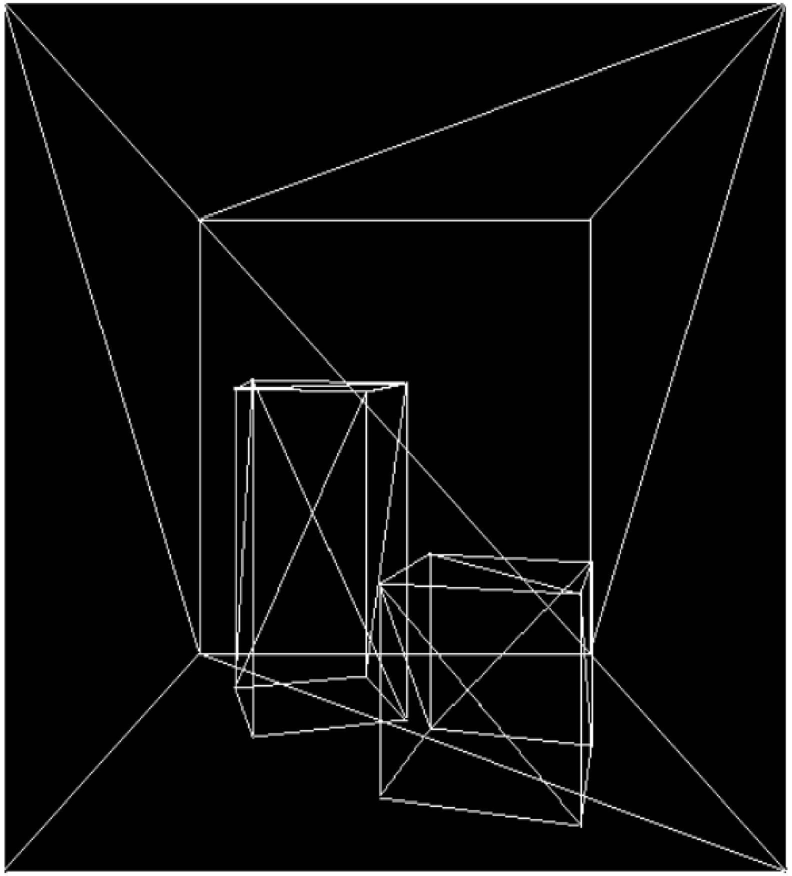
neighbourhood



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
```

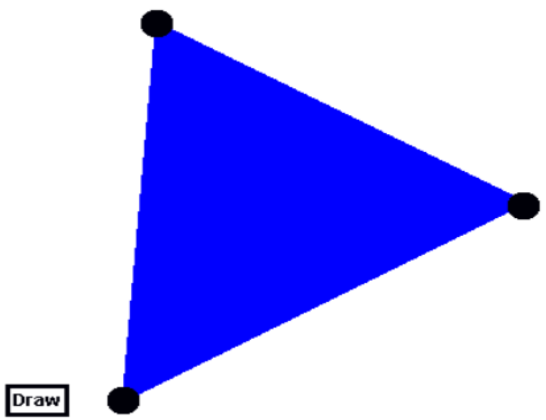
Polygon Filling

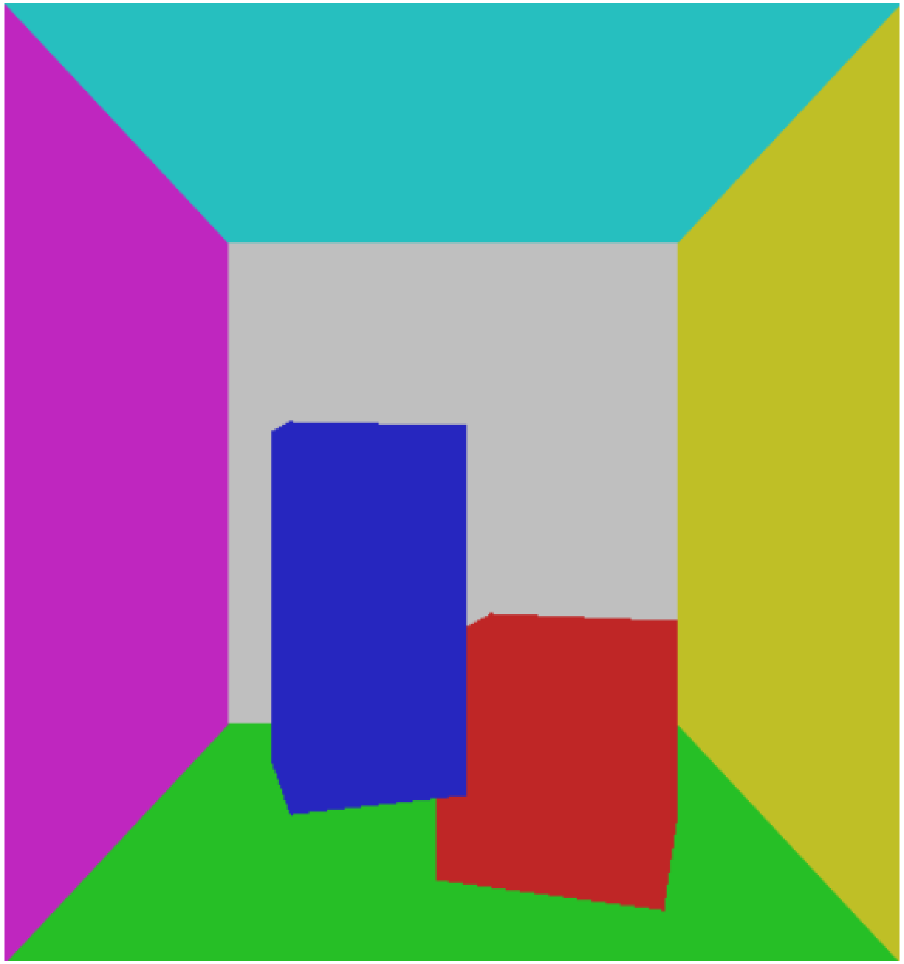
Fill surface

Triangles

Interpolation

Compute edges





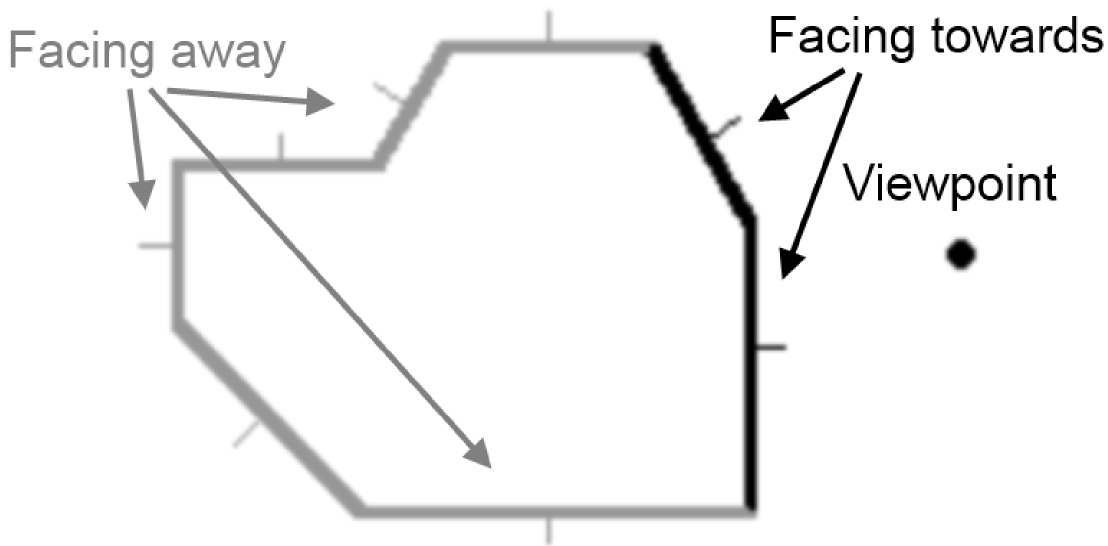
Backface Culling

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*



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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

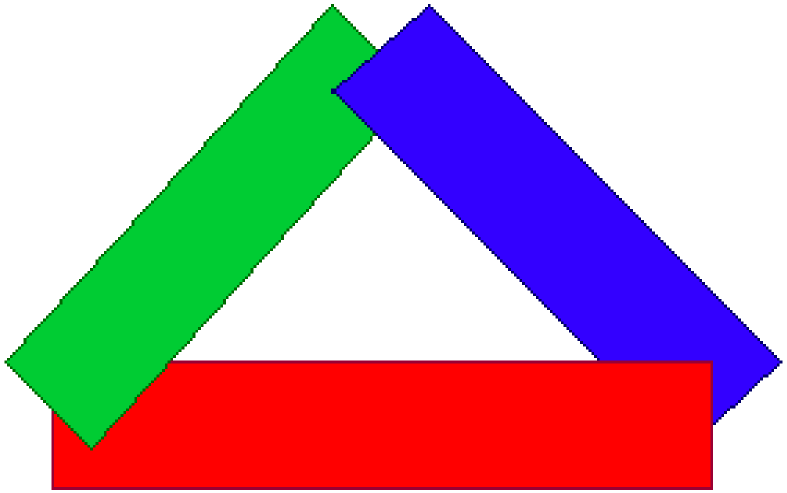
Painter's algorithm
Sort polygons relative to the viewpoint
Render those polygons that are nearer the viewpoint *after* those polygons that are further away from the viewpoint

Problems?

Visible Surface Determination

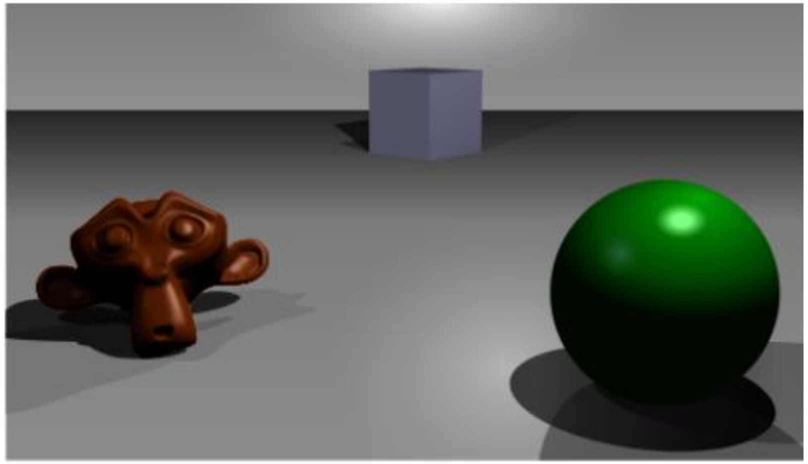
Painter's algorithm
Sort polygons relative to the viewpoint
Render those polygons that are nearer the viewpoint *after* those polygons that are further away from the viewpoint

Problems?

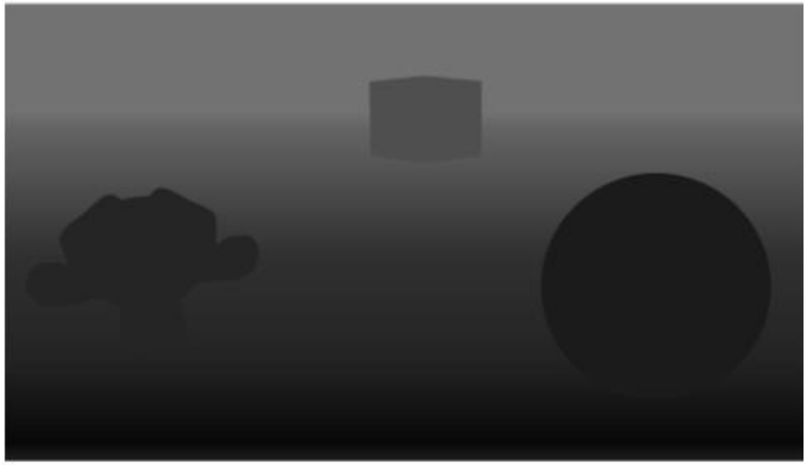


Depth Buffer

- 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

Note: BSP Trees

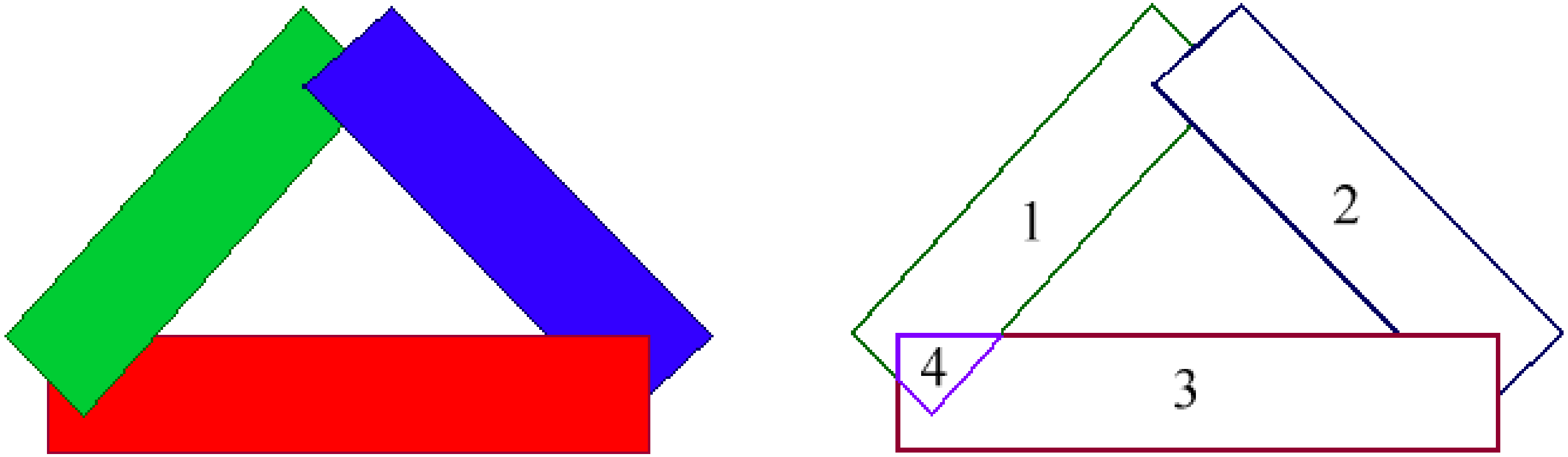
Used by Quake, Quake 2, etc

World-space visibility algorithm

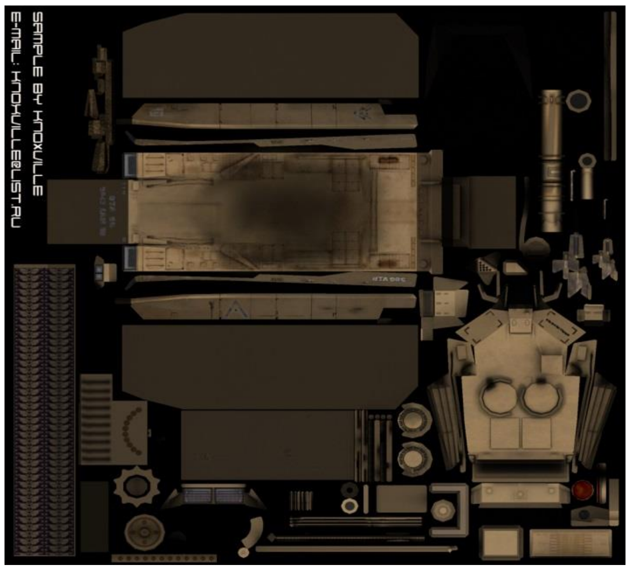
Visibility calculations on a *per polygon* basis

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

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Labs

Animation track, lab 3 posted this Friday

Labs

Animation track, lab 3 posted this Friday

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

- Friday 29th April, 12.30-2p.m, Visualisation (VIC) Studio

  See previous KTH Social posts for directions

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

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Submission dates

Submission date for all labs:

On or before **May 20th**

Through *Bilda* *(will open by end of this week – look out for the notification email)*

Submission date for all projects**:

On or before **May 31st**

Through *Bilda* *(will open by end of this week)*

****Also upload your project specifications to Bilda**