CS155 – Computer Graphics

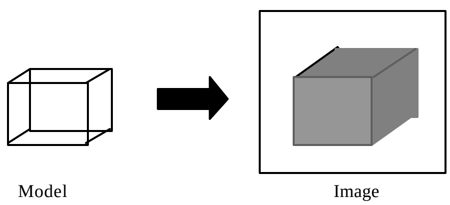
Z Sweedyk
Lecture 6

Class Overview

- Image Processing
- Rendering
- Modeling

YOU ARE HERE

Rendering



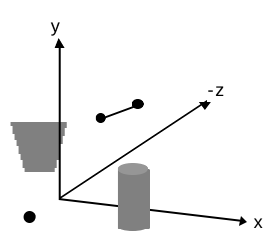
Issues

- Scene description
- Viewer description
- Surface appearance

Scene

- A scene is a collection of geometric primitives located in “world coordinates”

Scene



Primitives in 3D

- Point
- Line segment
- Polygon
- Sphere
- Polyhedron
- Curved surface
- Solid object
- Etc.

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Geometric Models

- Point P: (x,y,z)
- Line Segment L: P_0, P_1
- Polygon R: $P_0, P_1, P_2, \ldots, P_n$
- Sphere S: P, r

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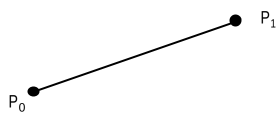
Line Segment in 3D



Line Segment: $P_0 + \alpha (P_1 - P_0)$ for $0 \leq \alpha \leq 1$

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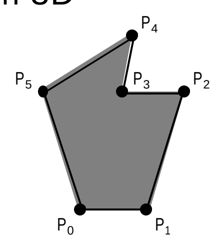
Polygon in 3D

Points on and bounded by the line segments formed by $(P_0, P_1, P_2, P_3, P_4, P_5)$



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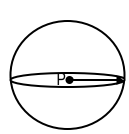
Sphere

All points a distance r from center P



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Save for later …

- Polyhedra
- Curved Surfaces
- Solid Objects
- Etc.

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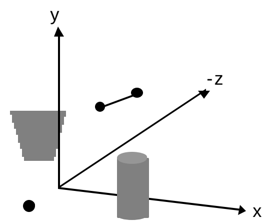
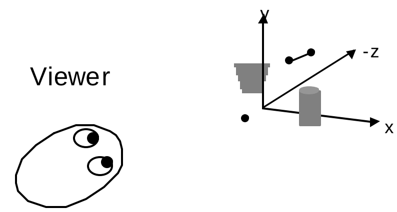
Scene



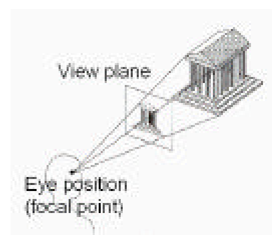
Scene



Issues

- Scene description
- **Viewer description**
- Surface appearance

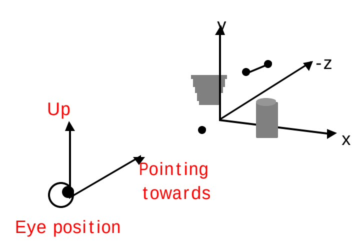
Pinhole Camera Model



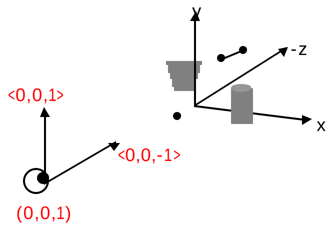
Issues

- How is the eye situated?
- How is the view plane situated?
- How much of the world can be seen?

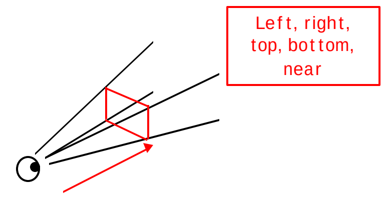
How is eye situated?



Standard Configuration

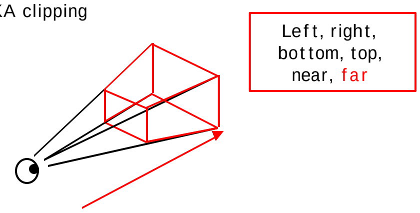


How is the view plane situated ?

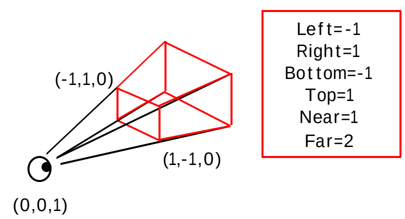


How much of the world can be seen?

AKA clipping



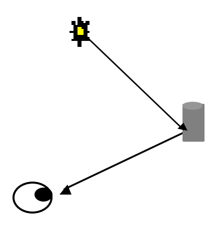
Example



Issues

- Scene description
- Viewer description
- Surface appearance

Surface appearance

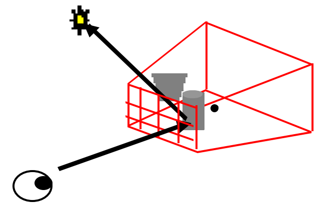


- Light properties
- Material properties
- Geometry
- Etc.

Issues

- Scene description
  - Specify primitives and their orientation in world coordinates
- Viewer description
  - Specify eye orientation and viewing volume
- Surface appearance
  - Specify light and material properties

Rendering by Ray Casting



Rendering by Ray Casting

For each pixel in the view plane

Cast ray from eye through pixel

Determine first surface in frustum intersected by ray

Compute surface appearance at intersection

Rendering by Ray Casting

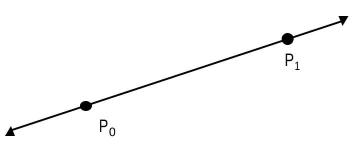
For each pixel in the view plane

Cast ray from eye through pixel

Determine first surface (in frustum) intersected by ray

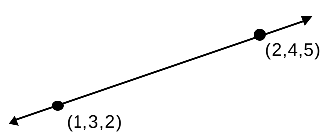
Compute surface appearance at intersection

Line in 3D



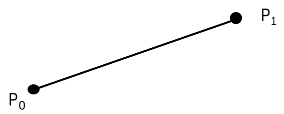
Line: $P_0 + \alpha (P_1 - P_0)$ for $-\infty < \alpha < \infty$

Example Line



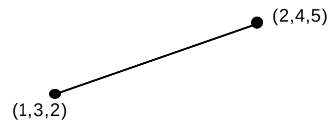
The line consists of the points $(1+\alpha, 3+\alpha, 2+3\alpha)$ for α in $(-\infty, \infty)$

Line Segment in 3D



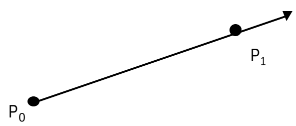
Line Segment: $P_0 + \alpha (P_1 - P_0)$ for $0 \leq \alpha \leq 1$

Example Line Segment



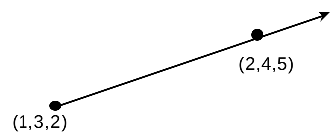
The line segment consists of the points
$(1+\alpha, 3+\alpha, 2+3\alpha)$ for α in [0,1]

Ray in 3D



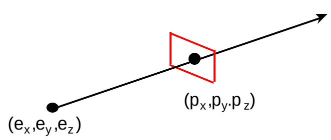
Ray: $P_0 + \alpha (P_1 - P_0)$ for $0 \leq \alpha \leq \infty$

Example Ray



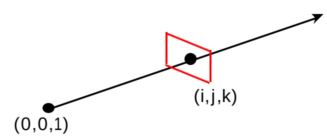
The ray consists of the points
$(1+\alpha, 3+\alpha, 2+3\alpha)$ for α in $[0,\infty)$

Ray Casting Ray



The ray consists of the points
$(e_x+\alpha(p_x-e_x), e_y+\alpha(p_y-e_y), e_z+\alpha(p_z-e_z))$ for
α in $[0,\infty)$

Standard Configuration

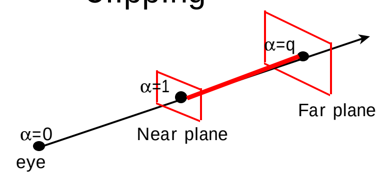


The ray consists of the points
$(\alpha i, \alpha j, 1+\alpha(k-1))$ for α in $[0,\infty)$

Rendering by Ray Casting

For each pixel in the view plane
- Cast ray from eye through pixel
- **Determine first surface (in frustum) intersected by ray**
- Compute surface appearance at intersection

Clipping

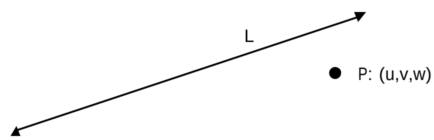


Really want intersection with line segment.

Intersection with ray

- Point
- Line segment
- Polygon
- Sphere

Intersection of a line and a point



L: $(x_0+\alpha(x_1-x_0), y_0+\alpha(y_1-y_0), z_0+\alpha(z_1-z_0))$ for α in $(-\infty,\infty)$

P: (u,v,w)

Intersection of a line and a point

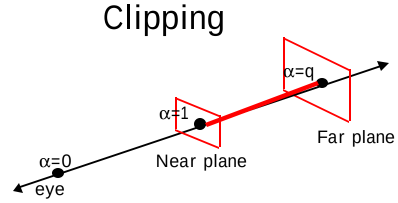
P lies on L if and only if there exists an α that satisfies the following equations:

$x_0+\alpha(x_1-x_0) = u$

$y_0+\alpha(y_1-y_0) = v$

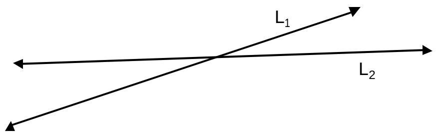
$z_0+\alpha(z_1-z_0) = w$

Clipping



AND α is in [1,q]

Intersection of two lines



L_1: $(x_0+\alpha(x_1-x_0),\ y_0+\alpha(y_1-y_0),\ z_0+\alpha(z_1-z_0))$

L_2: $(u_0+\beta(u_1-u_0),\ v_0+\beta(v_1-v_0),\ w_0+\beta(w_1-w_0))$

for α,β in $(-\infty,\infty)$

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Intersection of two lines

L_1 and L_2 intersect if and only if there exists an α and β that satisfy the following equations:

$$x_0+\alpha(x_1-x_0) = u_0+\beta(u_1-u_0)$$
$$y_0+\alpha(y_1-y_0) = v_0+\beta(v_1-v_0)$$
$$z_0+\alpha(z_1-z_0) = w_0+\beta(w_1-w_0)$$

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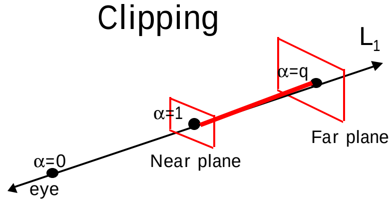
Clipping



AND α is in [1,q]

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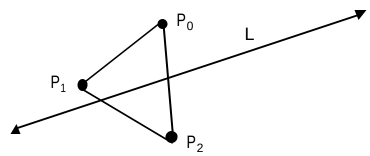
Intersection of a line and a triangle



L: $(x_0+\alpha(x_1-x_0),\ y_0+\alpha(y_1-y_0),\ z_0+\alpha(z_1-z_0))$
for α in $(-\infty,\infty)$

T: $P_0P_1P_2$

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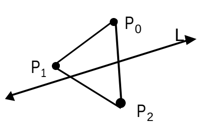
Intersection of a line and a triangle



1. Does L intersect the plane containing T?
2. If so, does the point of intersection lie in T?

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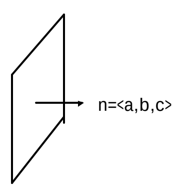
Equation of a Plane



This plane is the set of points (x,y,z) where

$ax + by + cz = d$

$d=ax_0+by_0+cz_0$ where (x_0,y_0,z_0) is any point on the plane.

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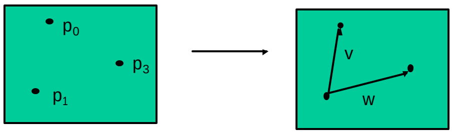
Normal to a Plane



3 points 2 vectors

n=w X v (i.e. cross product)

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The details

- Points: (x_0,y_0,z_0), (x_1,y_1,z_1), (x_2,y_2,z_2)
- Vectors:

  $v=\langle v_x, v_y, v_z\rangle = \langle x_0-x_1, y_0-y_1, z_0-z_1\rangle$

  $w=\langle w_x, w_y, w_z\rangle = \langle x_2-x_1, y_2-y_1, z_2-z_1\rangle$
- Cross Product: n = <A, B, C> =

  $\langle w_y v_z - w_z v_y, \quad -w_x v_z + w_z v_x, \quad w_x v_y - w_x v_y\rangle$

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Intersection of a line and a plane

L and P intersect if and only if there exists an α that satisfy the following equations:

$A(x_0+\alpha(x_1-x_0)) + B(y_0+\alpha(y_1-y_0)) + C(z_0+\alpha(z_1-z_0)) = D$

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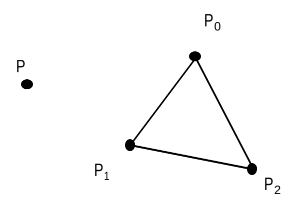
Intersection of a point and a triangle



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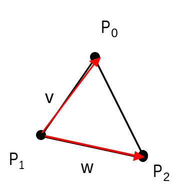
Parametric Representation of T



T is the set of points

$\alpha v + \beta w$ where

α,β are in [0,1]

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The details

- Vertices of triangle:
  $P_0=(x_0,y_0,z_0)$, $P_1=(x_1,y_1,z_1)$, $P_2=(x_2,y_2,z_2)$
- Vectors defined by vertices:

  $v=\langle v_x, v_y, v_z\rangle = \langle x_0-x_1, y_0-y_1, z_0-z_1\rangle$

  $w=\langle w_x, w_y, w_z\rangle = \langle x_2-x_1, y_2-y_1, z_2-z_1\rangle$

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Intersection of a point and a triangle

Point $P=(x,y,z)$ and triangle T: $P_0 P_1 P_2$ intersect if and only if there exist α and β in [0,1] such that

$\alpha v_x + \beta w_x = x$
$\alpha v_y + \beta w_y = y$
$\alpha v_z + \beta w_z = z$

*Vectors v and w are defined as in the last slide.

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The details

- Points: $P_0=(x_0,y_0,z_0)$, $P_1=(x_1,y_1,z_1)$, $P_2=(x_2,y_2,z_2)$
- Vectors:

$v=\langle v_x, v_y, v_z\rangle=\langle x_0-x_1, y_0-y_1, z_0-z_1\rangle$
$w=\langle w_x, w_y, w_z\rangle=\langle x_2-x_1, y_2-y_1, z_2-z_1\rangle$

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Polygons?

- Oh … we love those triangles

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