cs155 – z sweedyk

graphics
pipeline
systems

who's who

end user

application program ↔ graphics pipeline

who's who for today

user ↔ graphics pipeline

user defined scene description

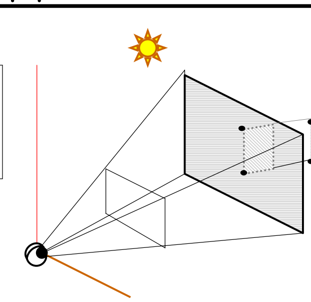
- models
- lights
- view (eye/camera)

graphics pipeline

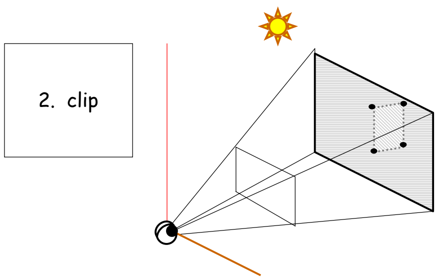
user defined scene description → 1. Build scene → 2. Clip → 3. Project → 4. Scan convert

graphics pipeline 1

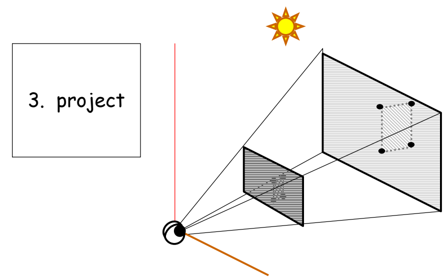
1. build scene



graphics pipeline 2

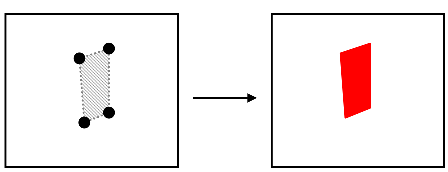


graphics pipeline 3



graphics pipeline 4

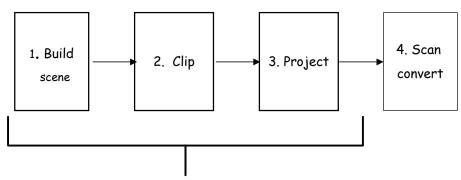
4. scan convert



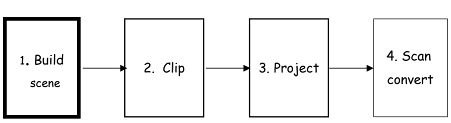
vertices in view plane

frame buffer

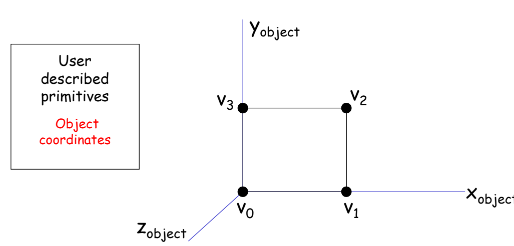
graphics pipeline



graphics pipeline



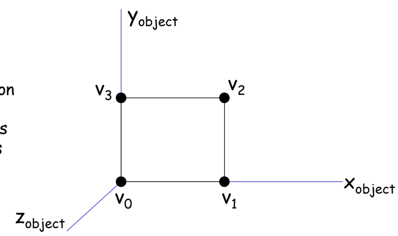
build scene



v_0= (0,0,0), v_1= (1,0,0), v_2= (1,1,0), v_3= (0,1,0)

build scene

pipeline
representation
is in
homogeneous
coordinates



$v_0 = (0,0,0,1)$, $v_1 = (1,0,0,1)$, $v_2 = (1,1,0,1)$, $v_3 = (0,1,0,1)$

primitives

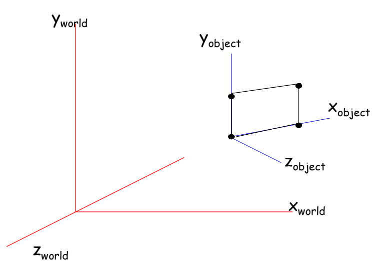
- points
- line segments
- polygons

build scene

User described
modeling
transforms

World
coordinates

Vertex in world
coordinates: $M_{W}v$



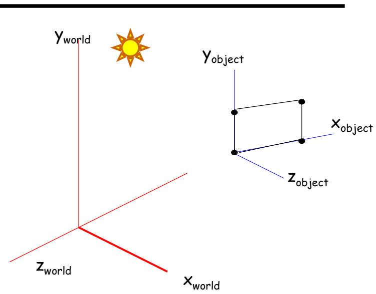
modeling transforms

- scale
- rotate
- translate

build scene

User described
lights

World
coordinates



Lights

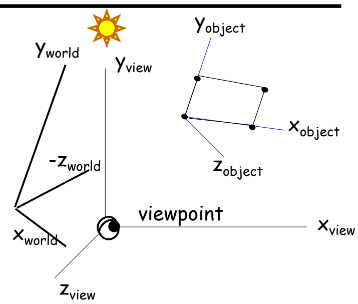
- Ambient
- Directional
- Point
- Spot

build scene

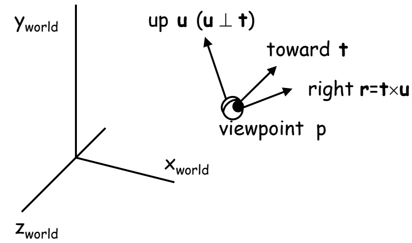
User defined viewpoint
View coordinates

vertex in view coordinates: $M_V M_W v$

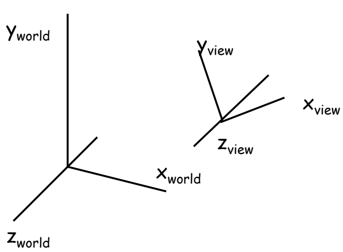
lights in view coordinates: $M_v p$, $M_v \mathbf{d}$



view in world coordinates

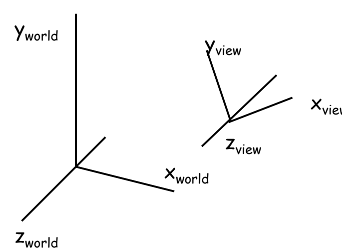


world and view coordinates



world ↔ view coordinates

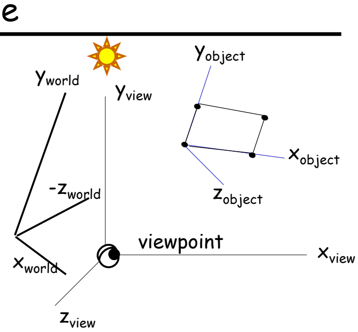
translate & rotate



build scene

vertex in view coordinates: $M_V M_W v$

lights in view coordinates: $M_v p$, $M_v \mathbf{d}$



geometric primitives

object coordinates: v	description of vertex
world coordinates: $M_W v$	description of vertex situated in world
view coordinates: $M_V M_W v$	description of vertex in world as seen from a particular viewpoint

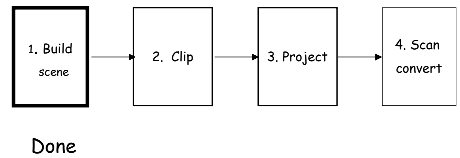
lights

world coordinates: p, **d** — description of light position/direction in world

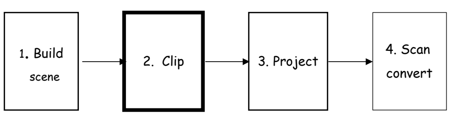
view coordinates: M_Vp, M_v**d** — description of light position/direction in world as seen from a particular viewpoint

note: M_v**d** is shorthand for the "multiply vector" operation we've used before!

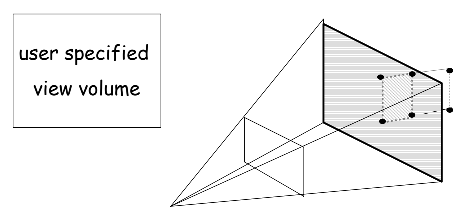
graphics pipeline



graphics pipeline

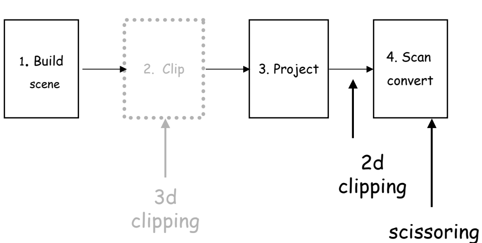


graphics pipeline 2



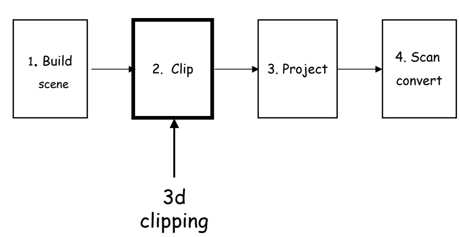
when to clip?

ease vs. pipeline efficiency



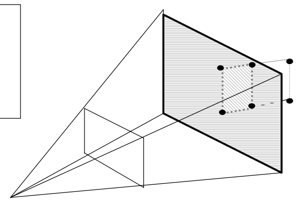
when to clip?

ease vs. **pipeline efficiency**

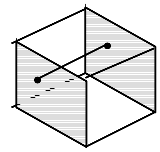


graphics pipeline 2

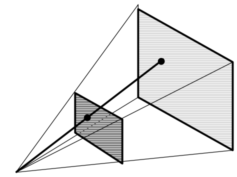
user specified view volume



projection type & view volume

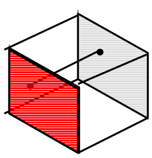


orthographic

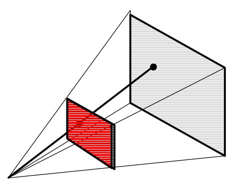


perspective

view window

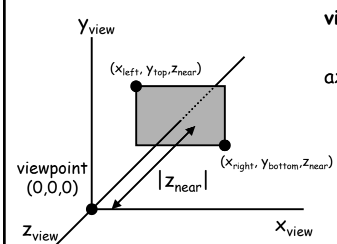


orthographic



perspective

view window specification

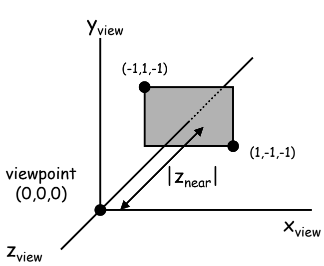


view window (in view coordinates):

axes aligned rectangle

- in view plane $z=z_{near}$
- centered at z axis
- with boundaries $x=x_{left}$, $x=x_{right}$, $y=y_{bottom}$, $y=y_{top}$

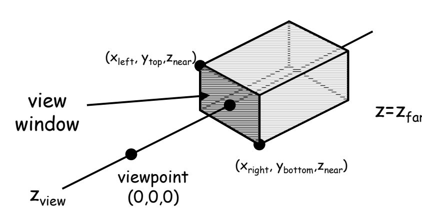
project 3 default



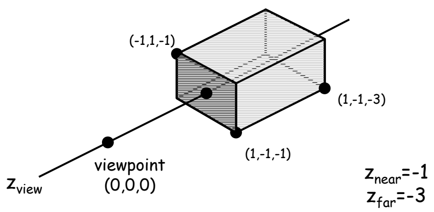
$z_{near} = -1$

orthographic view volume

axes aligned parallelpiped

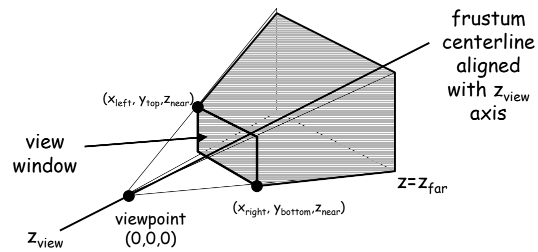


project 3 default

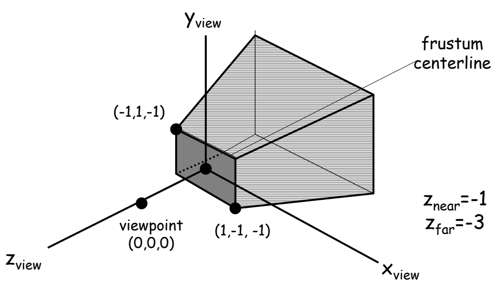


z_{near}=-1
z_{far}=-3

perspective view volume (frustum)



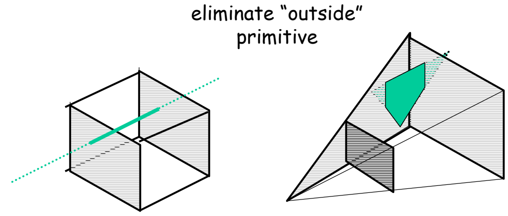
project 3: default frustum



z_{near}=-1
z_{far}=-3

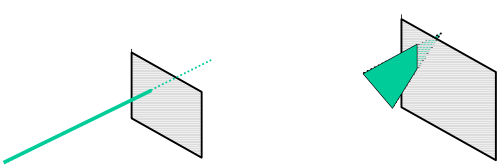
3d clipping

eliminate "outside" primitive



orthographic   perspective

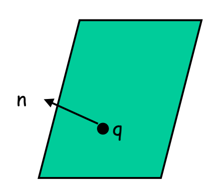
3d clipping



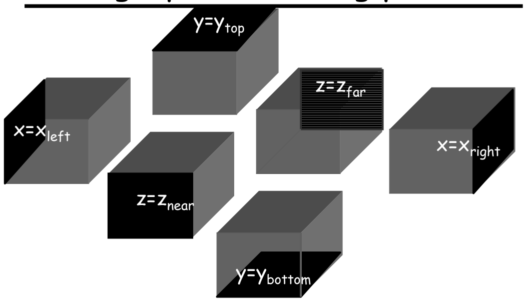
successively clip against each bounding plane of the view volume

bounding plane description

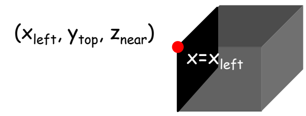
1. point on plane
2. inward-pointing normal



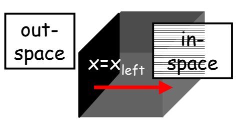
orthographic bounding planes



point on plane

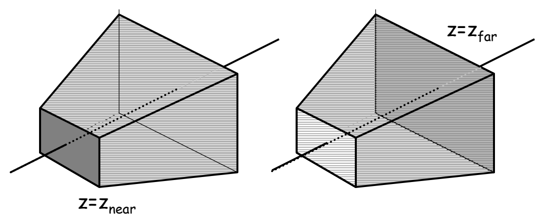


inward-pointing normal

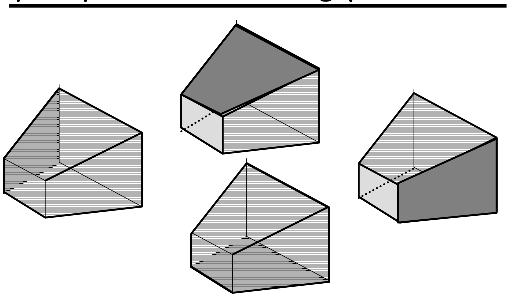


inward pointing normal **n: <1,0,0>**

perspective bounding planes



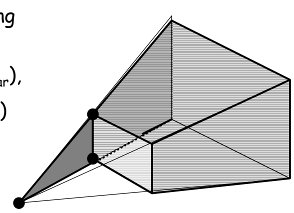
perspective bounding planes



view volume bounding plane

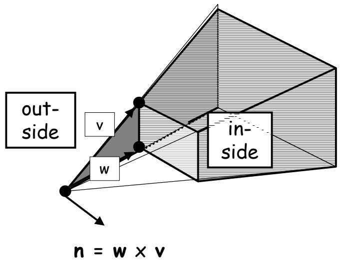
plane containing

(0,0,0),
$(x_{left}, y_{bottom}, z_{near})$,
$(x_{left}, y_{top}, z_{near})$

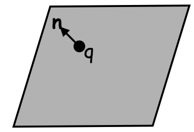


inward-pointing normals

plane containing
(0,0,0),
(x_{left},y_{bottom},z_{near}),
(x_{left},y_{top},z_{near})
with inward pointing normal **n** = **w** × **v**



clipping plane



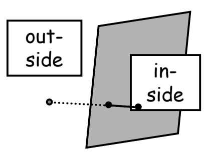
clipping plane specification:

- point q on the plane
- inward pointing normal **n**

3d clipping

given a clipping plane and a graphics primitive

return “in-side primitive”



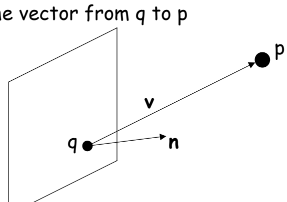
3d clipping

- vertex clipping
- line segment clipping
- polygon clipping

vertex clipping

p is in with respect to the clipping plane iff **n** • **v** ≥ 0 where

- **n** is the inward facing normal
- **v** is the vector from q to p

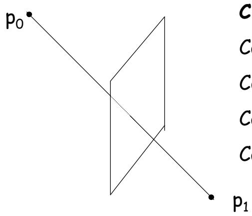


3d clipping

- vertex clipping
- **line segment clipping**
- polygon clipping

line segment clipping

use test for vertex clipping



Classify endpoint p_o & p_1

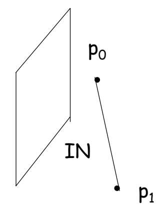
Case: p_o & p_1 in ______

Case: p_o & p_1 out______

Case: p_o in & p_1 out ______

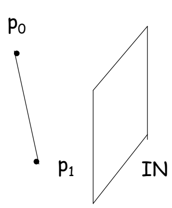
Case: p_o out & p_1 in ______

line segment clipping



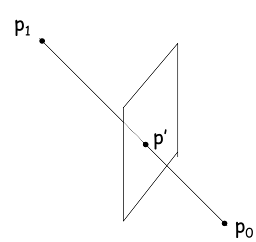
Case p_o & p_1 in:
return (p_0, p_1)

line segment clipping



Case p_o & p_1 out:
return null

line segment clipping

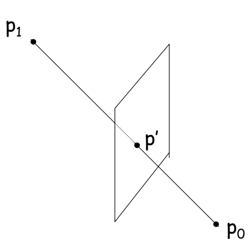


Case p_o in & p_1 out:
return (p_0,p')

Case: p_o out & p_1 in:
return (p',p_1)

do you know how to compute p'?

line segment clipping

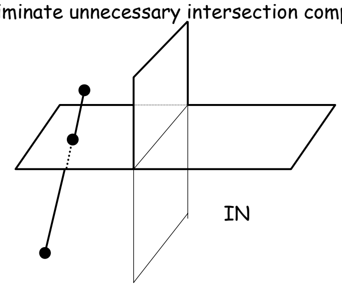


color at p':

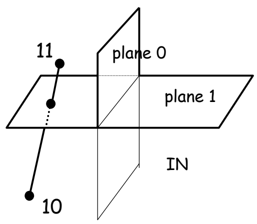
interpolate

out-code optimization

eliminate unnecessary intersection computations



out-code optimization



- assume k clipping planes
- endpoint p has out-code $b_0b_1 \ldots b_{k-1}$:
  - b_i=0 if p is inside plane i
  - b_i=1 else

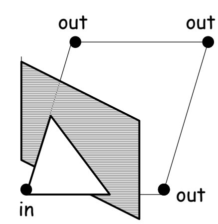
out-code optimization

- compute endpoint out-codes B and B′
- if B AND B′ = __________ return __________
- if B OR B′ = __________ return __________
- clip against plane j where the i^{th} bit of ________ is _______
- restart test

3d clipping

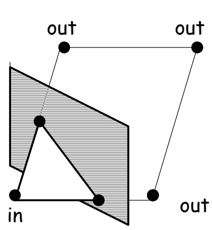
- vertex clipping
- line clipping
- **polygon clipping**

polygon clipping



1. classify vertices

polygon clipping



1. classify vertices
2. compute intersection points of intersecting edges

   &

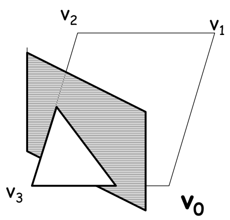
   write out new polygon

polygon clipping

- if v_0 is in then write v_0
- for i=1…n-1
  - case v_i & v_{i+1} in: write v_{i+1}
  - case v_i & v_{i+1} out: do nothing
  - case v_i in and v_{i+1} out: write intersection point
  - case v_i out and v_{i+1} in: write intersection point and v_{i+1}

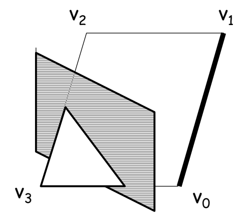
indices taken modulo n

example



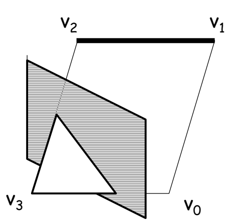
v_0 out: do nothing

example



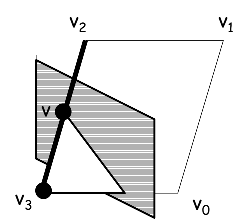
v_0 & v_1 out: do nothing

example



v_1 & v_2 out: do nothing

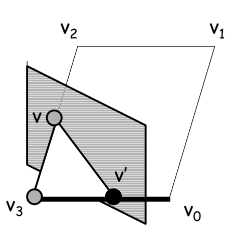
example



v_2 out & v_3 in:

write v, v_3

example



v_3 in & v_0 out:

write v'

polygon clipping

- if v_0 is in then write v_0
- for i=1…n-1
  - case v_i & v_{i+1} in: write v_{i+1}
  - case v_i & v_{i+1} out: do nothing
  - case v_i in and v_{i+1} out: write intersection point
  - case v_i out and v_{i+1} in: write intersection point and v_{i+1}

interpolate along edge to find color at intersection point