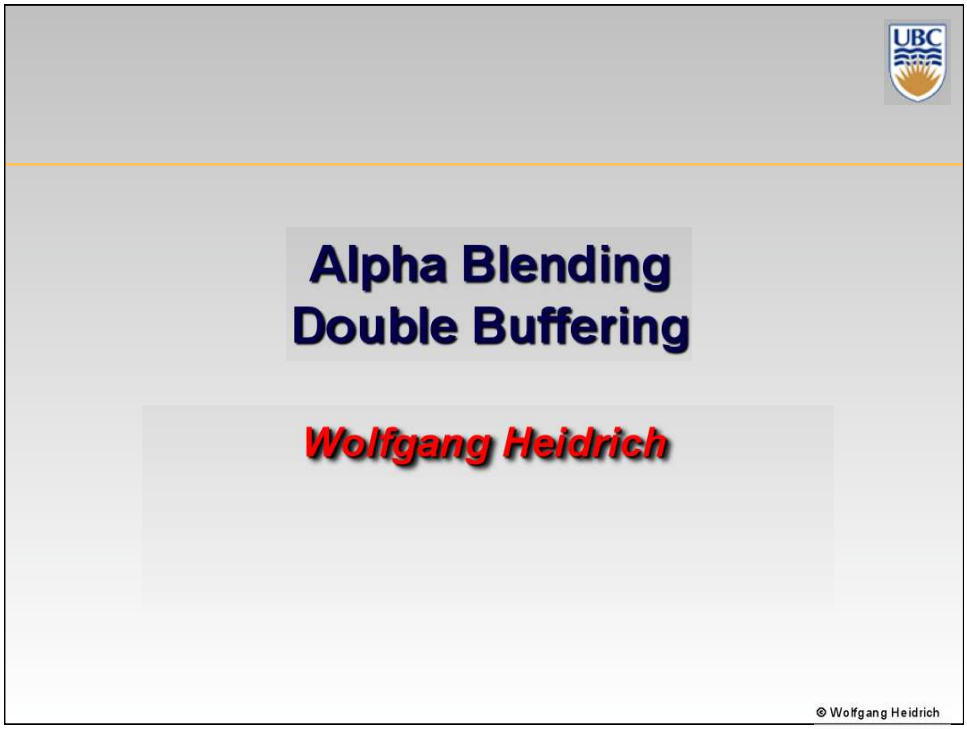


Course News

Assignment 2

- Due Monday!

Quiz 2 MOVED!

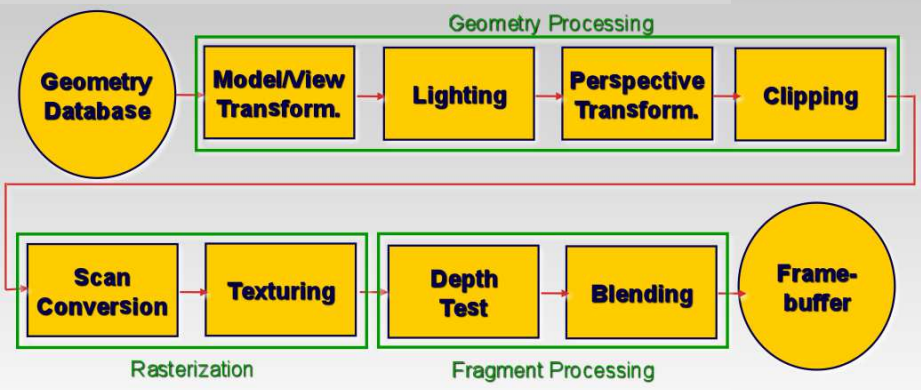
- Friday, March 13 (instead of Wed, March 11)
- Office hours on Wednesday, Thursday (Mar 11/12)
- Out of town Mon, Mar 9
  - *Office hour canceled*
  - *Lecture will take place*

Reading

- No new reading this week

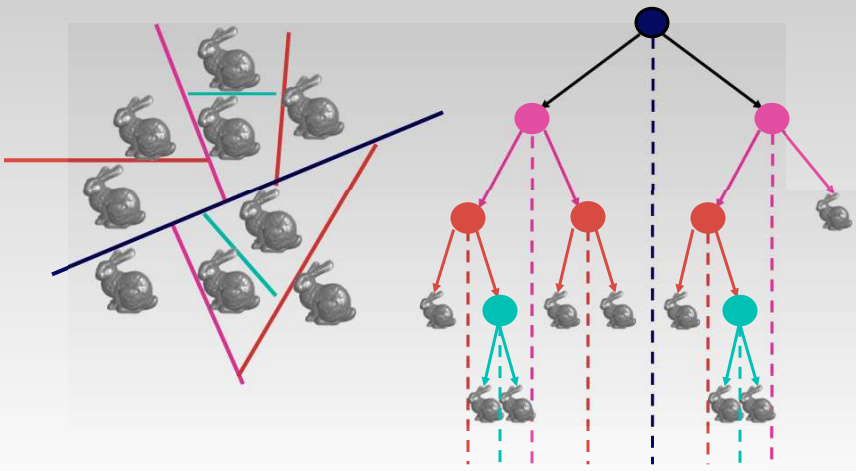
Wolfgang Heidrich

The Rendering Pipeline



Wolfgang Heidrich

Creating BSP Trees: Objects



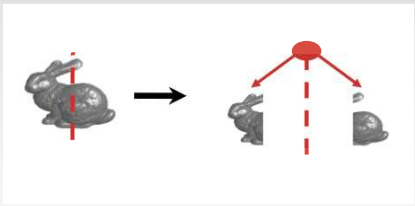
Wolfgang Heidrich

Splitting Objects

No bunnies were harmed in previous example

But what if a splitting plane passes through an object?

- Split the object; give half to each node



Wolfgang Heidrich

Traversing BSP Trees

Tree creation independent of viewpoint

- Preprocessing step

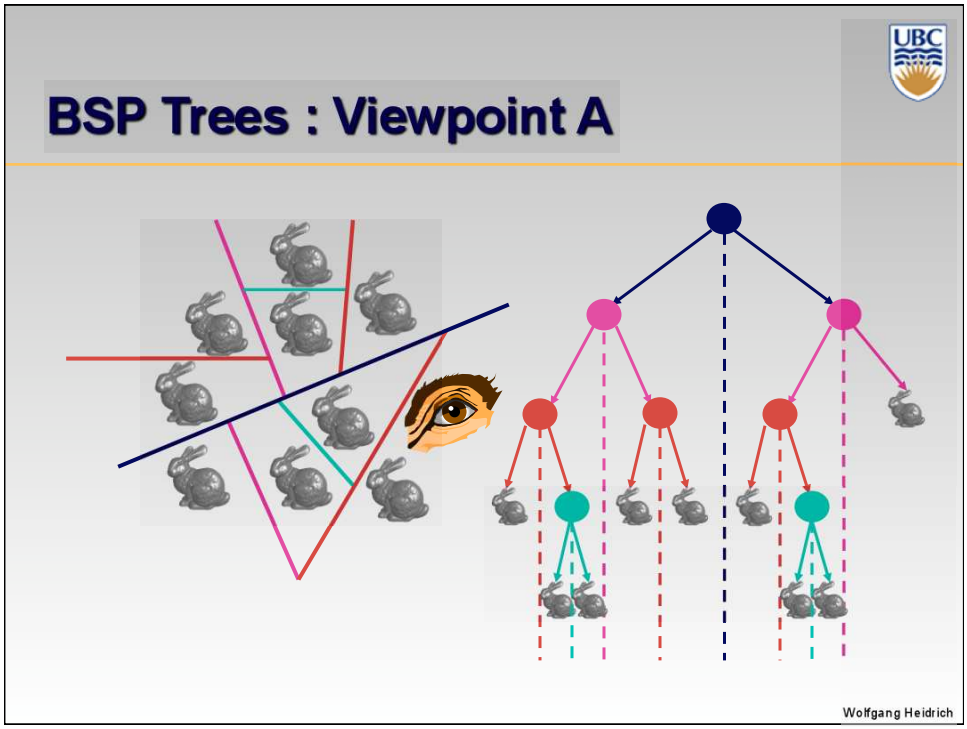
Tree traversal uses viewpoint

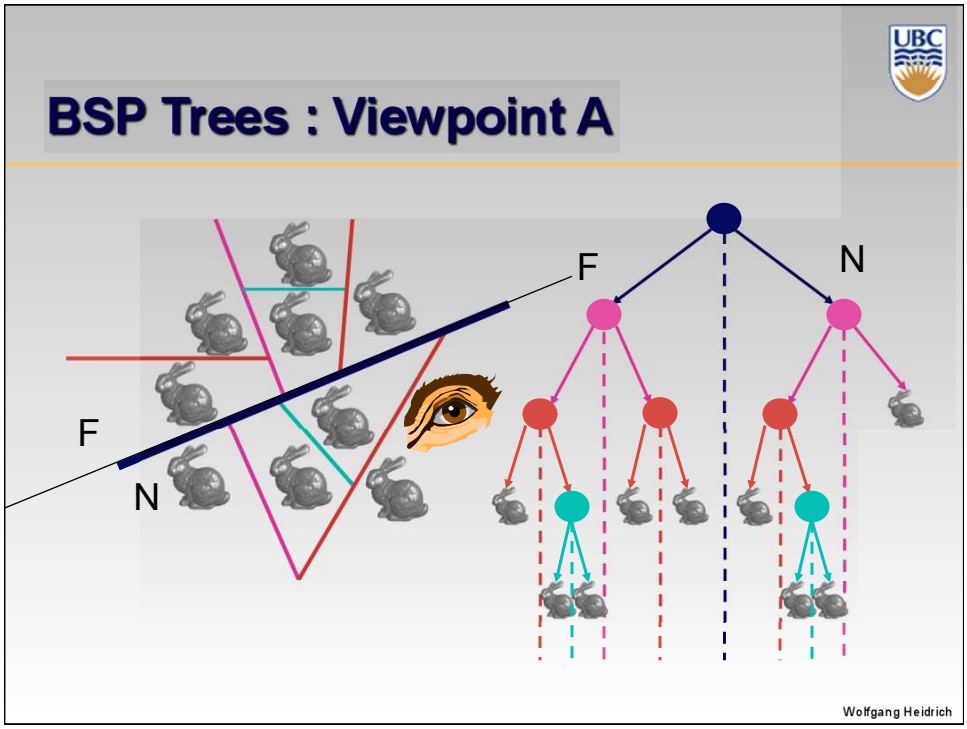
- Runtime, happens for many different viewpoints

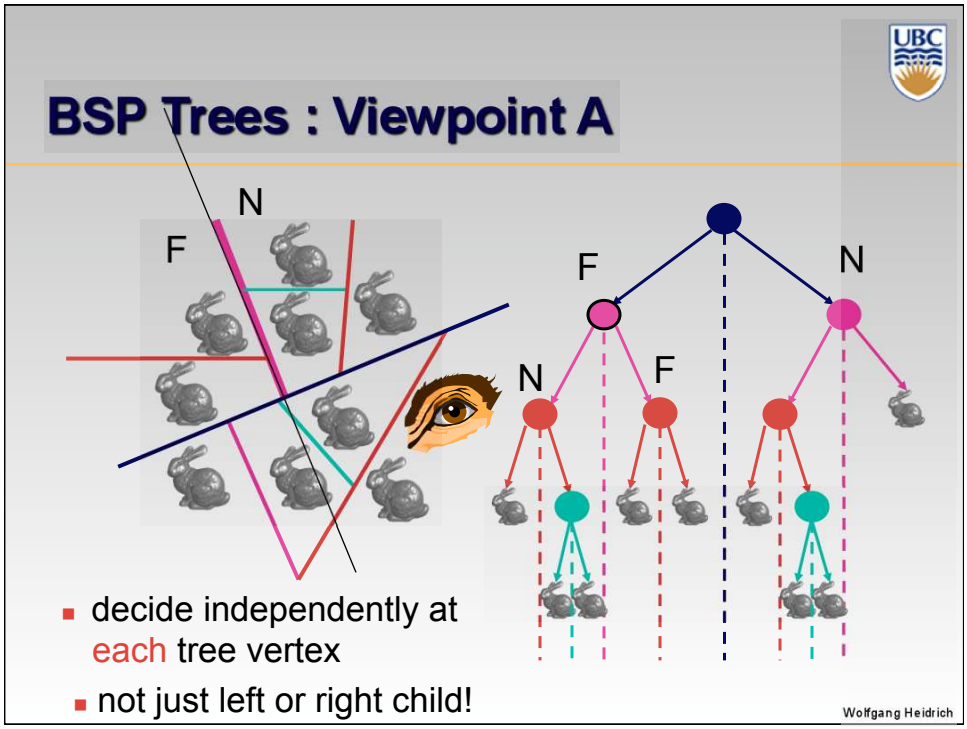
Each plane divides world into near and far

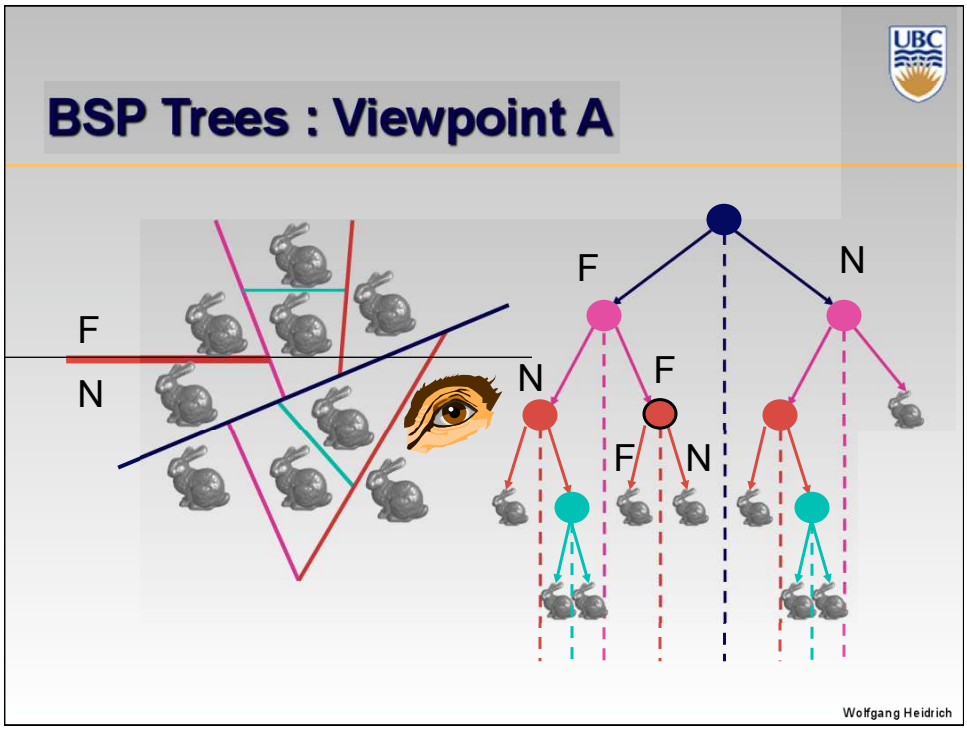
- For given viewpoint, decide which side is near and which is far
  - *Check which side of plane viewpoint is on independently for each tree vertex*
  - *Tree traversal differs depending on viewpoint!*
- Recursive algorithm
  - *Recurse on far side*
  - *Draw object*
  - *Recurse on near side*

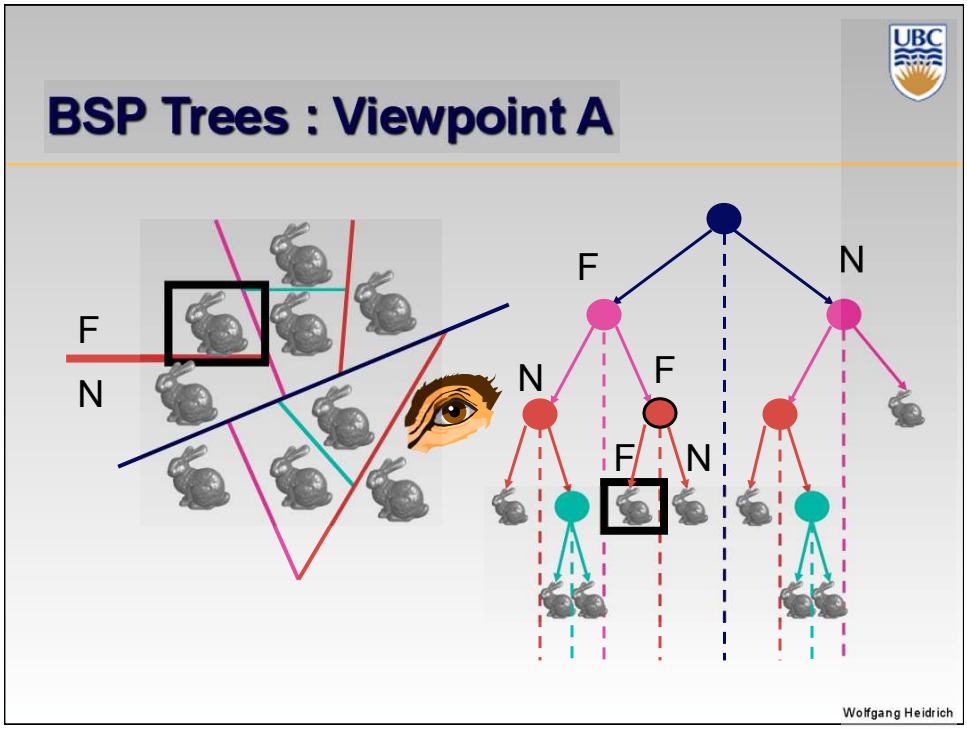
Wolfgang Heidrich

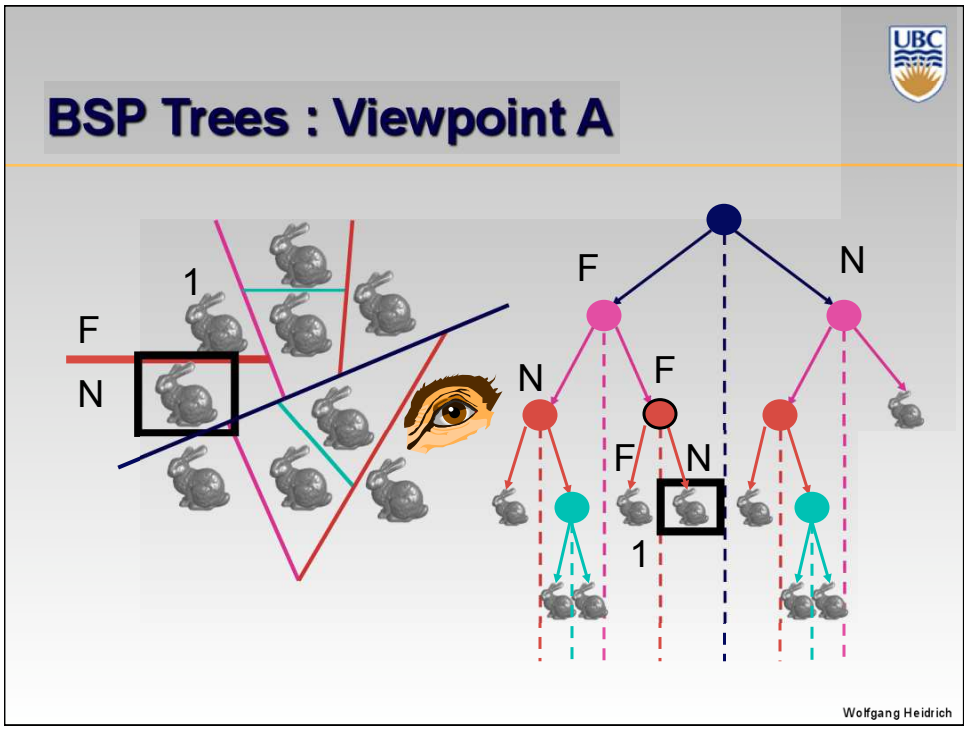

BSP Trees : Viewpoint A
Wolfgang Heidrich

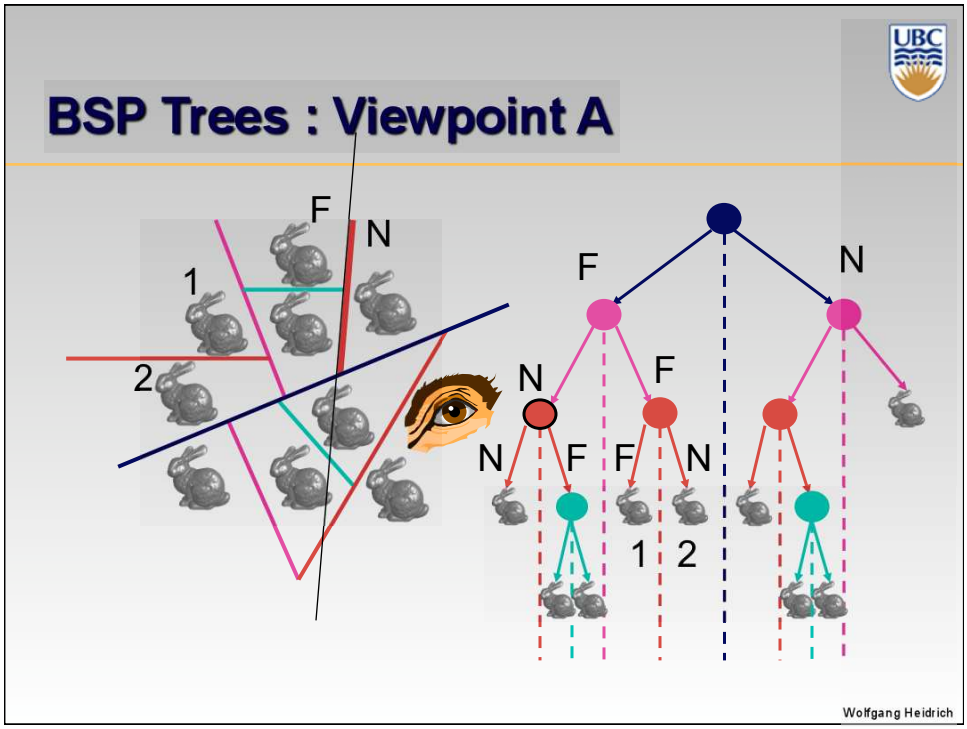

BSP Trees : Viewpoint A
F
N
F
N
Wolfgang Heidrich

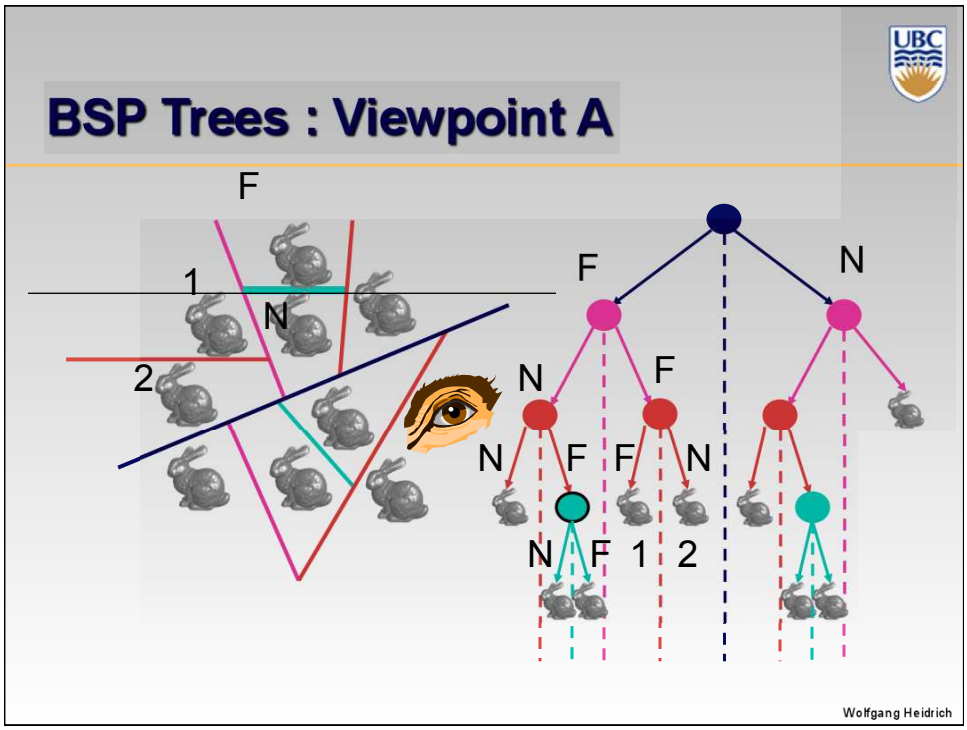

BSP Trees : Viewpoint A
N
F
F
N
N
F
decide independently at each tree vertex
not just left or right child!
Wolfgang Heidrich

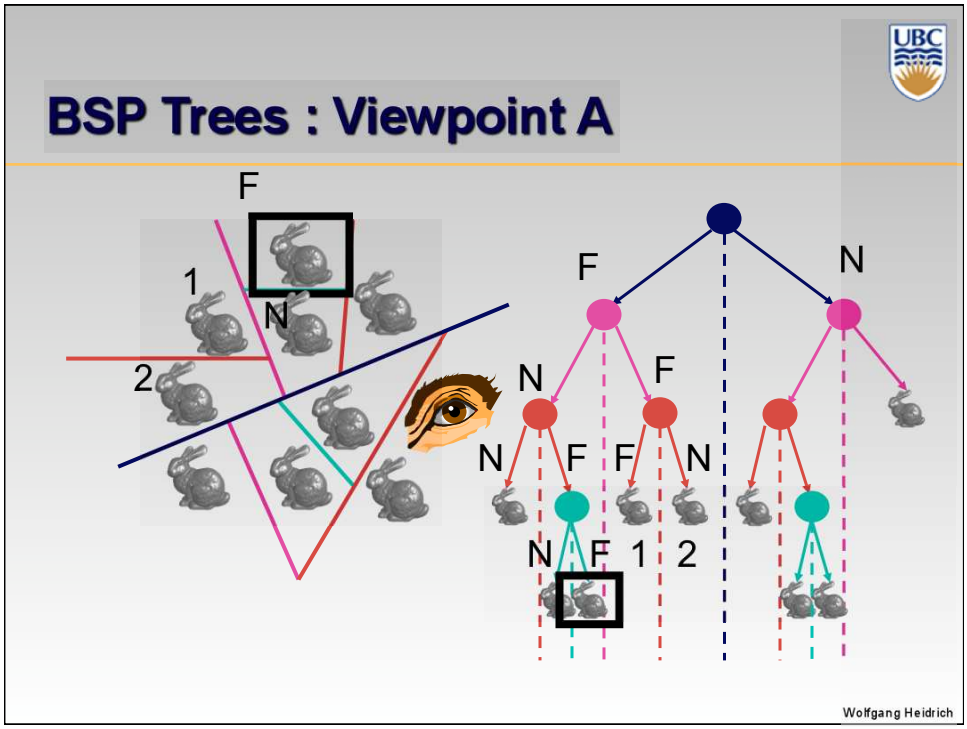

BSP Trees : Viewpoint A
F
N
F
N
N
F
F
N
Wolfgang Heidrich

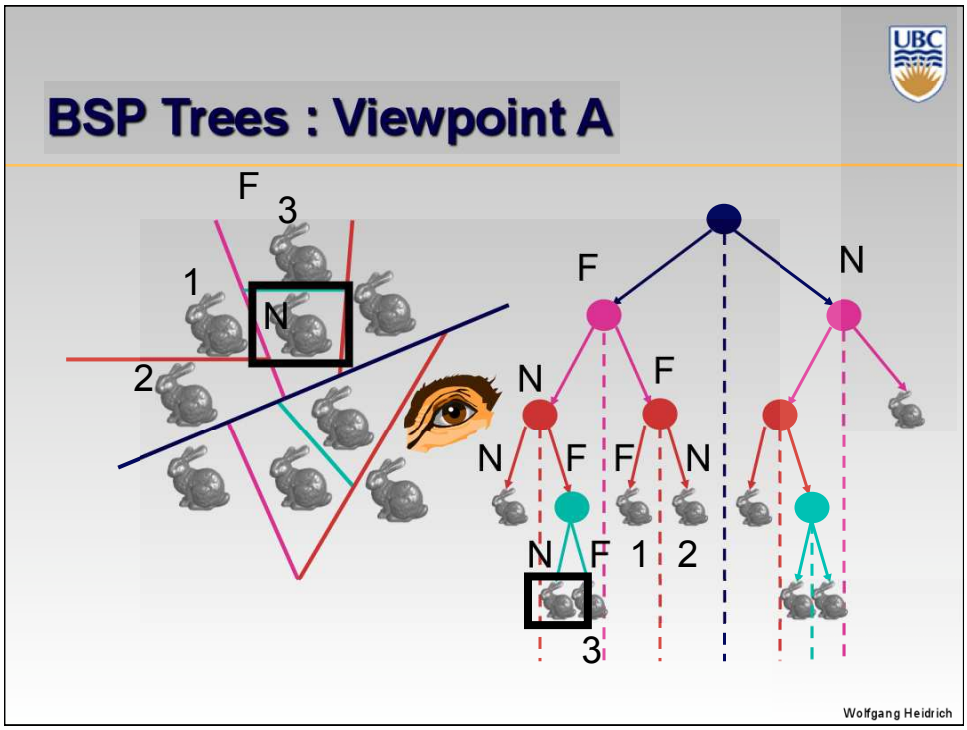

BSP Trees : Viewpoint A
F
N
F
N
F
N
F
N
Wolfgang Heidrich

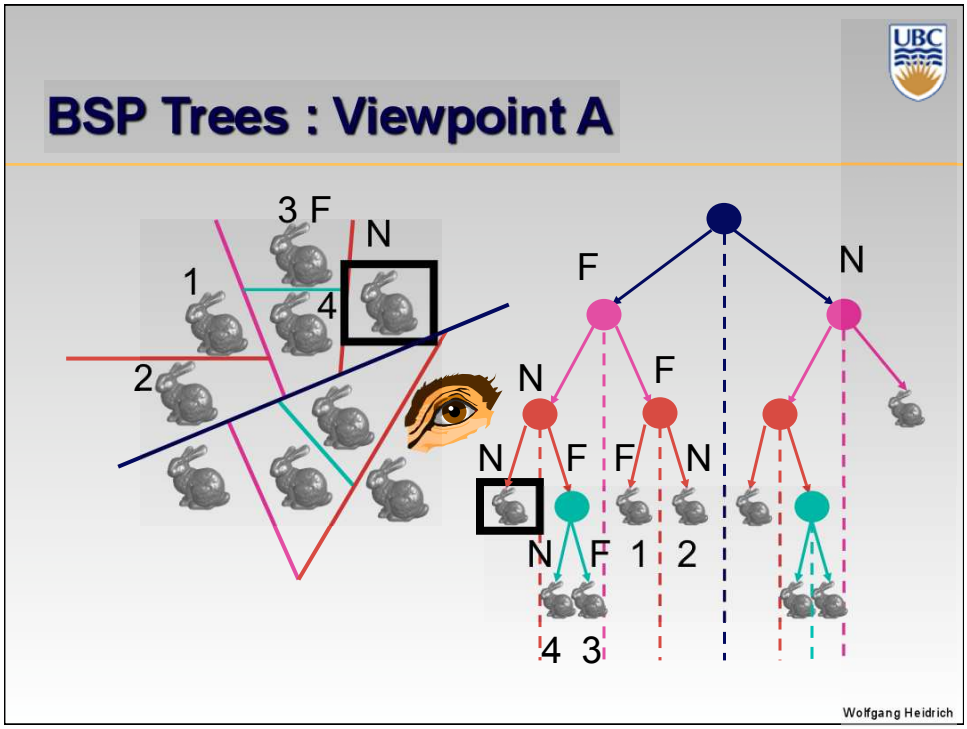

BSP Trees : Viewpoint A
1
F
N
F
N
F
N
F
N
1
Wolfgang Heidrich

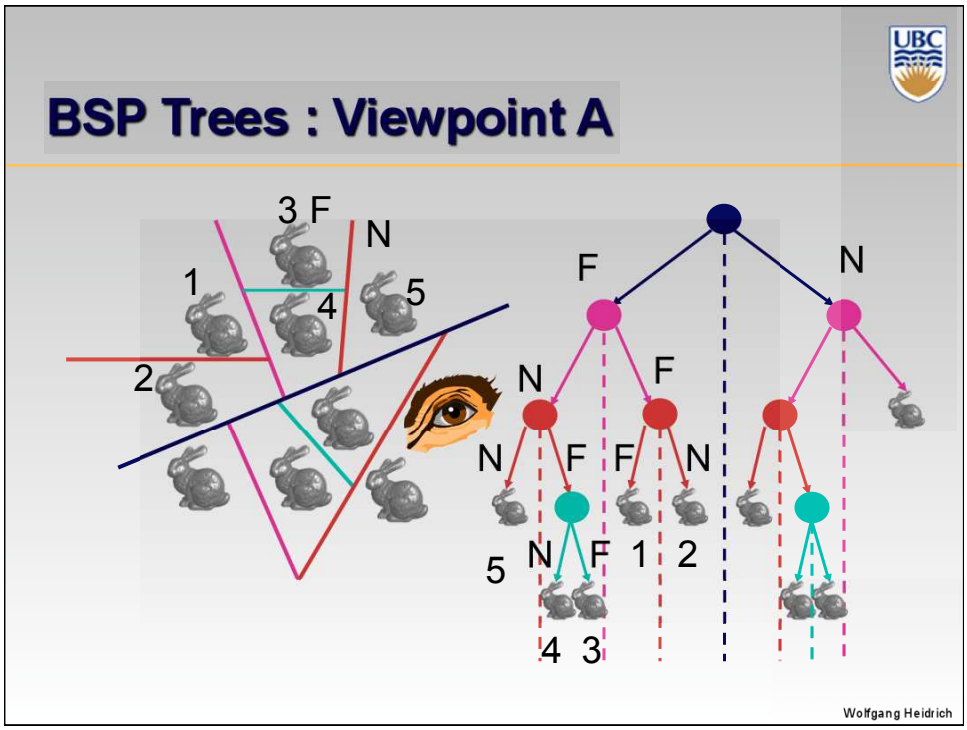

BSP Trees : Viewpoint A
F
N
1
2
F
N
N
F
N
F
F
N
1
2
Wolfgang Heidrich


BSP Trees : Viewpoint A
F
1
N
2
F
N
N
F
N
F
F
N
N
F
1
2
Wolfgang Heidrich

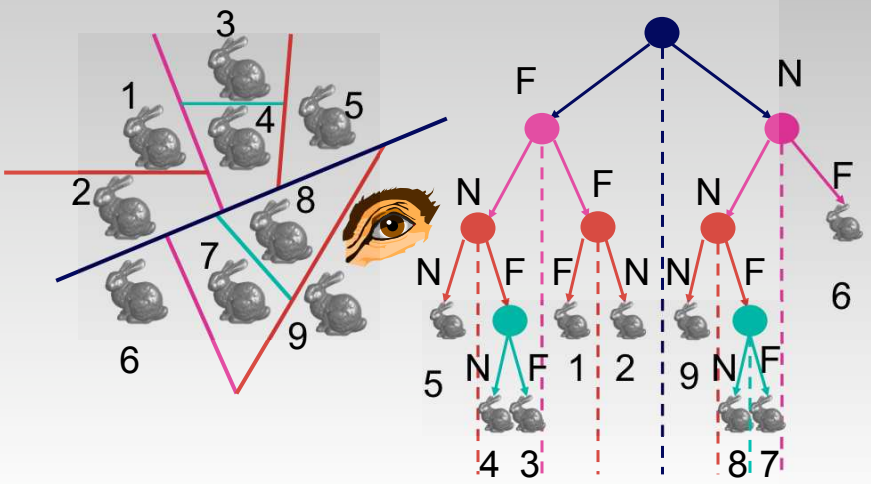

BSP Trees : Viewpoint A
F
1
N
2
F
N
N
F
F
N
N
F
1
2
Wolfgang Heidrich


BSP Trees : Viewpoint A
F
3
1
N
2
F
N
N
F
F
N
N
F
1
2
3
Wolfgang Heidrich


BSP Trees : Viewpoint A
3 F
N
1
4
2
F
N
N
F
N
F
F
N
N
F
1
2
4
3
Wolfgang Heidrich

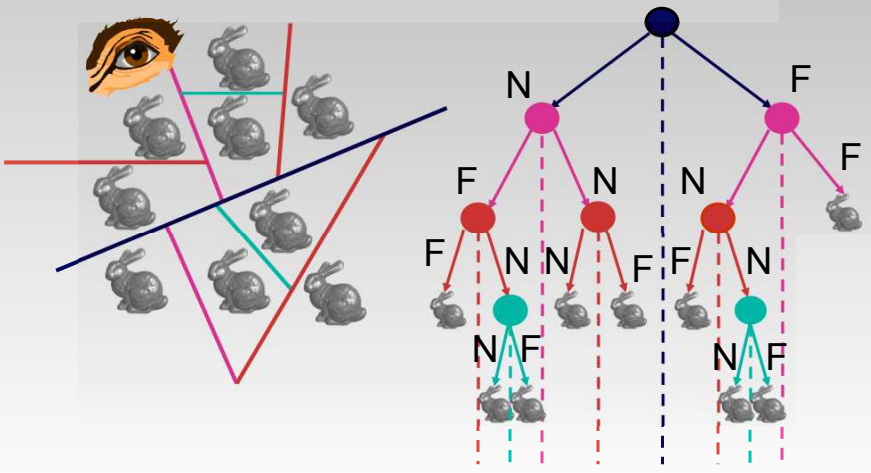

BSP Trees : Viewpoint A
3 F
N
1
4
5
2
F
N
N
F
N
F
F
N
5
N
F
1
2
4
3
Wolfgang Heidrich

BSP Trees : Viewpoint A



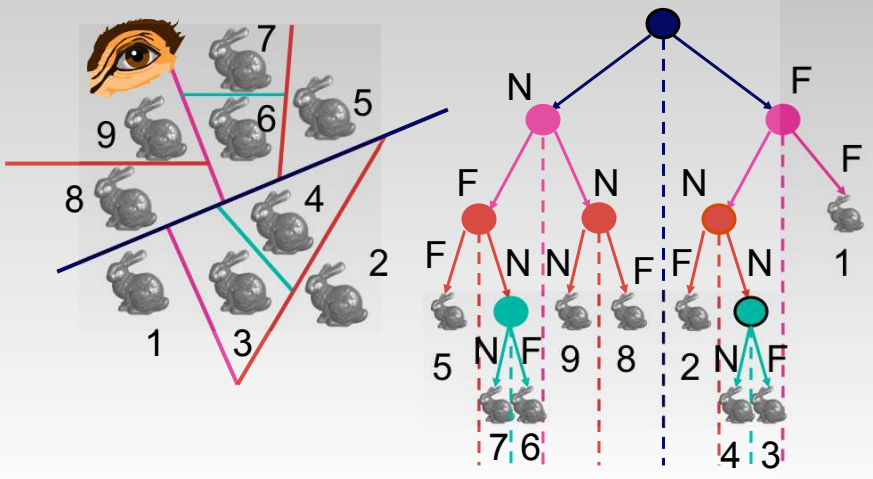
Wolfgang Heidrich

BSP Trees : Viewpoint B



Wolfgang Heidrich

BSP Trees : Viewpoint B



Wolfgang Heidrich

BSP Tree Traversal: Polygons

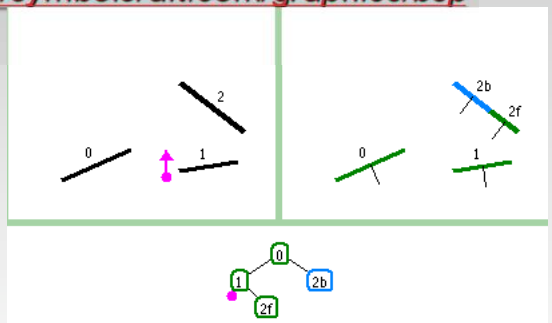
- Split along the plane defined by any polygon from scene
- Classify all polygons into positive or negative half-space of the plane
  - *If a polygon intersects plane, split polygon into two and classify them both*
- Recurse down the negative half-space
- Recurse down the positive half-space

Wolfgang Heidrich

BSP Demo

Useful demo:

http://symbolcraft.com/graphics/bsp



Wolfgang Heidrich

Summary: BSP Trees

Pros:

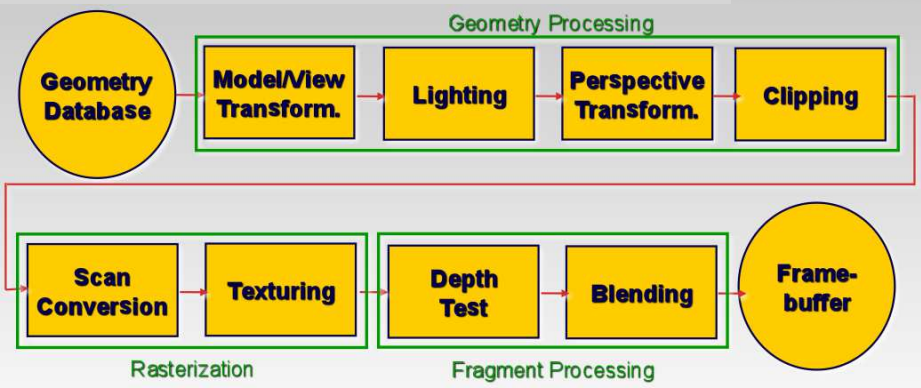
- Simple, elegant scheme
- Correct version of painter's algorithm back-to-front rendering approach
- Still very popular for video games (but getting less so)

Cons:

- Slow(ish) to construct tree: O(n log n) to split, sort
- Splitting increases polygon count: $O(n^2)$ worst-case
- Computationally intense preprocessing stage restricts algorithm to static scenes

Wolfgang Heidrich

The Rendering Pipeline

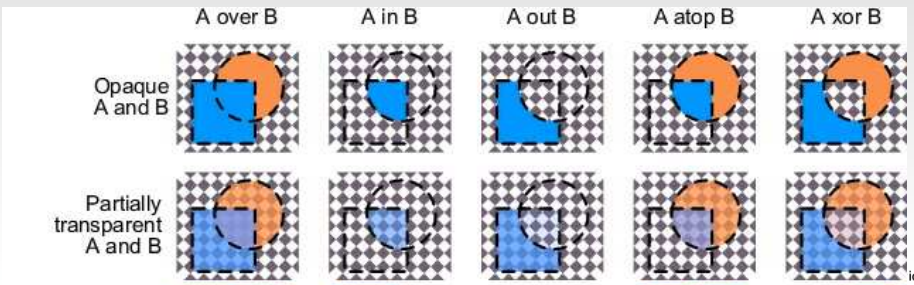


Wolfgang Heidrich

Blending

How might you combine multiple elements?

- New color **A**, old color **B**



Alpha Blending (OpenGL)

Parameters:

- s = source color
- d = destination color
- b = source blend factor
- c = dest blend factor
- d' = bs + cd

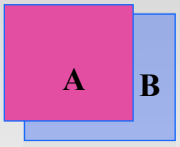
Where

- "Source" means "color/alpha of currently rendered primitive"
- "Destination" means framebuffer value

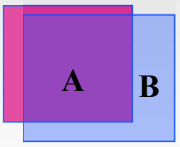
Wolfgang Heidrich

Over operator

- $d' = \alpha_s\, s + (1-\alpha_s)d$
- Examples: $\alpha_A=1$ $\alpha_B=0.4$



A over B: $d'=1*C_A$ $+(1-1)*C_B$

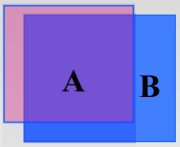


B over A: $d'=0.4*C_B$ $+(0.6)*C_A$

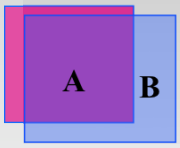
Wolfgang Heidrich

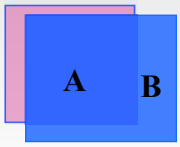
Over operator

- $d' = \alpha_s\, s + (1-\alpha_s)d$
- Examples: $\alpha_A=0.4$ $\alpha_B=1.0$



A over B: $d'=0.4*C_A +(0.6)*C_B$





B over A: $d'=1*C_B +(0)*C_A$

Compariso n from previous

Wolfgang Heidrich

Over operator

- $d' = \alpha_s\, s + (1-\alpha_s)d$
- $\alpha' = \alpha_s\, \alpha_s + (1-\alpha_s)\, \alpha_d$

Wolfgang Heidrich

OpenGL Blending

In OpenGL:

- Enable blending
  - *glEnable(GL_BLEND)*
- Specify alpha channel for colors
  - *glColor4f(r, g, b, alpha)*
- Specify blending function
  - *E.g: glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPH)*
    - C= alpha_new*Cnew + (1-alpha_new)*Cold

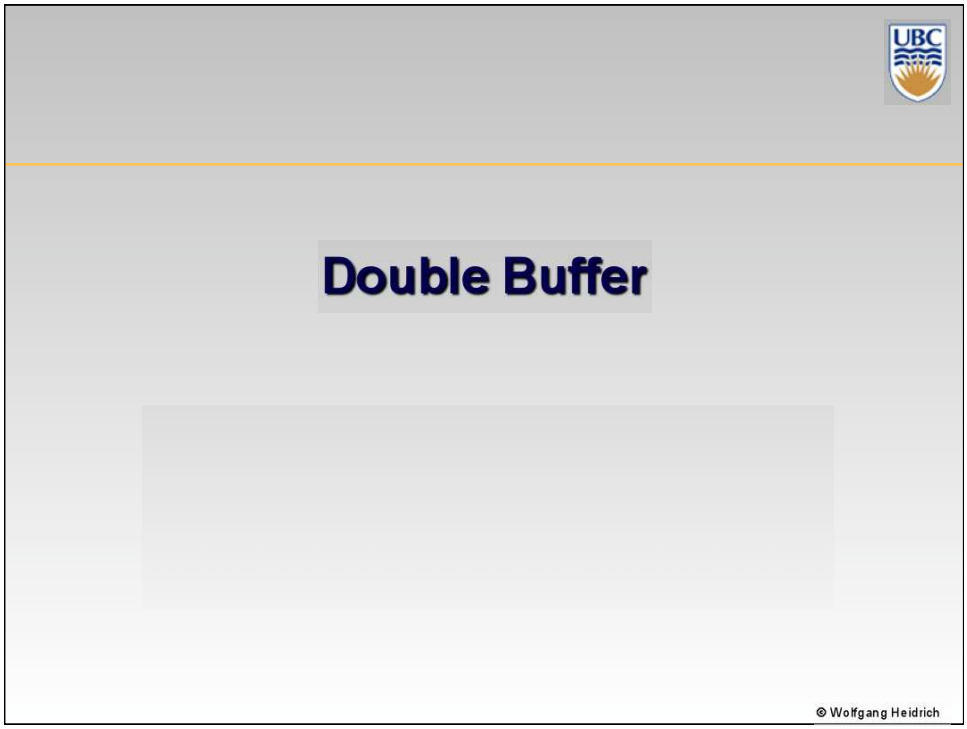
Wolfgang Heidrich

OpenGL Blending

Caveats:

- Note: alpha blending is an order-dependent operation!
  - *It matters which object is drawn first AND*
  - *Which surface is in front*
- For 3D scenes, this makes it necessary to keep track of rendering order explicitly
  - *Possibly also viewpoint-dependent!*
    - E.g. always draw “back” surface first
- Also note: interaction with z-buffer

Wolfgang Heidrich



Double Buffering

Framebuffer:

- Piece of memory where the final image is written
- Problem:
  - *The display needs to read the contents, cyclically, while the GPU is already working on the next frame*
  - *Could result in display of partially rendered images on screen*
- Solution:
  - *Have TWO buffers*
    - Currently displayed (front buffer)
    - Render target for the next frame (back buffer)

Double Buffering

Front/back buffer:

- Each buffer has both color channels and a depth channel
  - *Important for advanced rendering algorithms*
  - *Doubles memory requirements!*

Switching buffers:

- At end of rendering one frame, simply exchange the pointers to the front and back buffer
- GLUT toolkit: glutSwapBuffers() function
  - *Different functions under windows/X11 if not using GLUT*

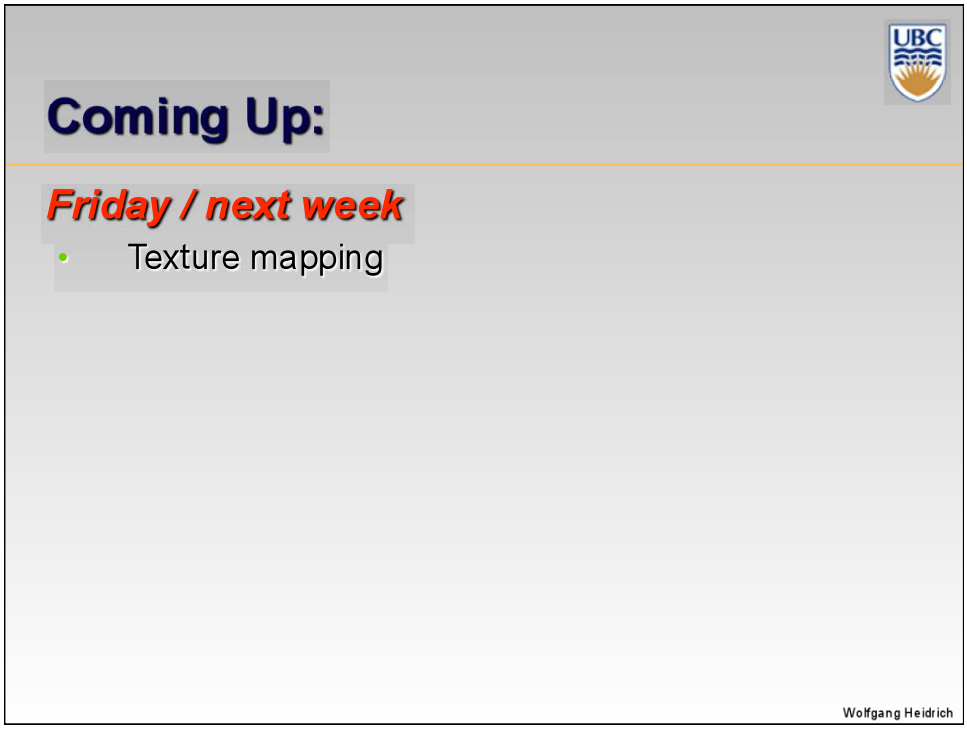
Wolfgang Heidrich

Triple Buffering

Used by some game consoles

- Why?

Wolfgang Heidrich


Coming Up:
Friday / next week
Texture mapping
Wolfgang Heidrich