

## Visual Rendering for VR

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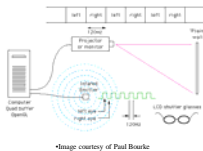
## Stereo Graphics

- Our left and right eyes see two views, which are processed by our visual cortex to create a sense of depth
  - Computer renders slightly-different views for the two eyes
  - Different approaches



## Active stereoscopic projection

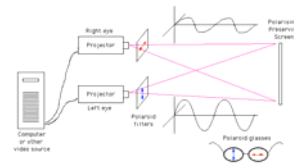
- Shutter glasses
  - Project at 120Hz and switch between left and right eye (so each eye gets 60Hz frame rate)



\*Image courtesy of Paul Bourke

## Passive stereoscopic projection

- Polaroid glasses

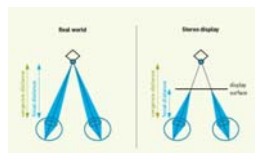


\*Image courtesy of Paul Bourke

## Vergence-Accommodation Conflict

Scientific Literature has identified vergence-accommodation conflict causes a variety of psychophysical problems including:

- induced binocular stress
- difficulty in fusing the two images into a stereo pair
- the perception of scene geometry
- discomfort



(Image is from [Kroeker 2010]).

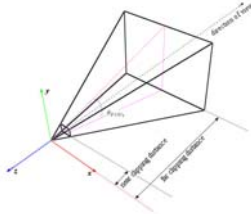
## The Challenge

- Popular press has reported a number of viewers complaining about 3D movies giving them headaches, nausea, blurred vision, and other symptoms of visually-induced motion sickness
- A principal suspect is widely believed to be the vergence-accommodation conflict



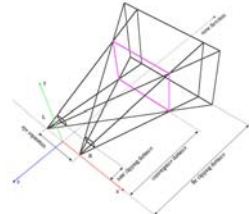
From: <http://gemmahodgson.wordpress.com/tag/salt-shaker/>

## Frustum projection



<http://www.animesh.no/2011/05/rendering-3d-anaglyph-in-opengl.html>

## Stereo frustum



<http://www.animesh.no/2011/05/rendering-3d-anaglyph-in-opengl.html>

## Stereo frustum

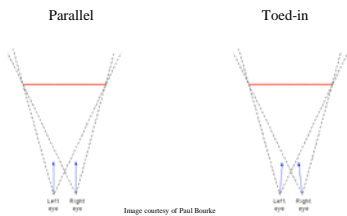
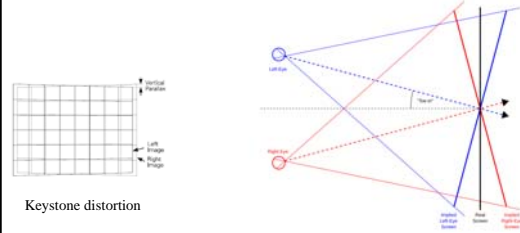


Image courtesy of Paul Bourke

## Problems with toed-in approach



Keystone distortion

Woods et al. (1993)

[http://dx.doi.org/10.1002/1098-2795\(200308\)24:8%3C1098::AID-SPM1098%3E3.0.CO;2-8](http://dx.doi.org/10.1002/1098-2795(200308)24:8%3C1098::AID-SPM1098%3E3.0.CO;2-8)

## Creating stereo pairs with skewed-frustum

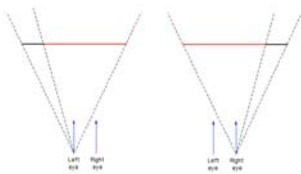


Image courtesy of Paul Bourke

## Creating stereo pairs with skewed-frustum

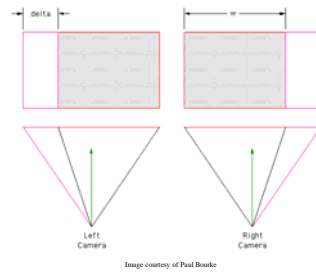


Image courtesy of Paul Bourke

## Depth perception

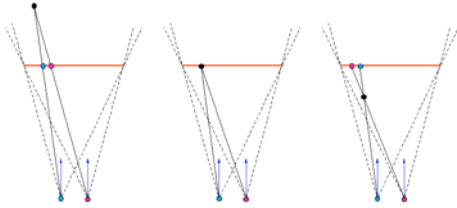


Image courtesy of Paul Bourke

## Visual fatigue (Ukai and Howarth, 2008)

- Separation of color causes binocular rivalry
  - Constant switching between red and blue
  - Little is known about long-term health effects
- Inevitable cross-talk in polarized filters
- Time-sharing shutters reduce frame rate
  - Flickering is the most significant cause of visual fatigue
- Vergence-accommodation problem

## Stereo Rendering

- Extra work for the second rendering
  - How can we minimize it
- Problems with stereo textures
  - Stereo makes textures/microgeometry look flat/painted-on

## Easing Re-Rendering

- Image Morphing: 1997 Darsa, Silva, Varshney
- Post-rendering 3D Warping: 1997 Mark, Bishop, McMillan
- Time Warping: 2013 John Carmack

## Goal: Reduce Latency

- Sensor Read
- Rendering
- Display

## Goal: Reduce Latency

- Sensor Read 1
- Rendering
- Sensor Read 2
- Warping
- Display

## On the Magic Leap discussion...

- A very fast configurable zone plate to provide nearly correct depth cues
  - Re-focus light at 12 levels of focus (0.25 to 3m)

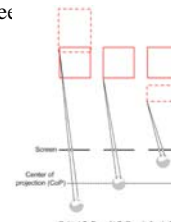


## Multi-viewer

(Pollock et al. 2012)

Viewers perceive depth differently, depending on where they are standing

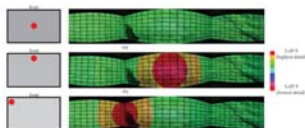
- Less distortion with backward displacement
- Render correct stereo image based on the location of the viewer that is nearest to the screen



## Acuity-driven rendering

(Papadopoulos and Kaufman 2013)

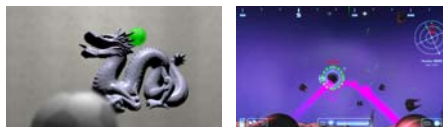
- Stony Brook Gigapixel Display
- Humans can only discriminate two points that are  $1/60$  angle apart
  - Therefore display lower resolution images when the viewer is far away from the display
  - Kind of like mipmapping



## Gaze-driven rendering

(Mantiuk et al. 2013)

- Depth-of-field visualization controlled by gaze direction
- Display information by looking at objects



## LOD for 3D Graphics

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David Luebke

NVIDIA Research

Martin Reddy

Pixar

Amitabh Varshney

University of Maryland

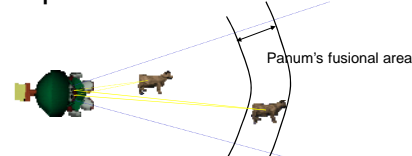
Ben Watson

North Carolina State University

Rob Huebner

Nihilistic Software

## Depth of Field LOD



- Resolution of element dependent upon the depth of field focus of the user's eyes, i.e. objects out with the fusional area appear in lower detail
- Under binocular vision, both eyes converge on object at certain distance in order to focus retinal image
- Objects in front or behind this fusional area are unfocused, suffering from double images
- Must track both eyes accurately to evaluate convergence distance

Slide 24

Lecture 7

## Visual Perception Software



*Vermeer*  
"Officer and Laughing Girl", 1658-60

120 x 135 degrees FOV  
No eccentricity blurring  
No velocity blurring

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"Officer and Laughing Girl", 1658-60

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Eccentricity blurring  
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## Visual Perception Software



*Vermeer*  
"Officer and Laughing Girl", 1658-60

120 x 135 degrees FOV  
Eccentricity blurring  
Velocity = 60 deg/s