Depth and Space Perception

Regan Mandryk

Disclaimer

Many of these slides include animated gifs or movies that may not be viewed on your computer system. They should run on the latest downloads of Quick Time and Windows Media Player

Outline

- Depth cues
- Using depth cues on 2D displays
- Creating 3D displays
  - Stereoscopic displays
- The future of 3D displays
- Examples of interfaces utilizing depth

Occlusion

- **The closest opaque object blocks farther objects from view**
- **Probably the strongest depth cue**
- **Provides only binary information**

Linear Perspective

- **Parallel lines converge to a single point**
- **Robustness of linear perspective (Kubovy, 1986)**

http://www.mhhe.com/socscience/intro/ibank/set2.htm

Size Gradient

- **Objects which are farther away are smaller than objects which are closer**
- **Note how the size of the boat and rider vary with distance**

Sculls by Gustave Caillebotte
http://psych.hanover.edu/Krantz/art/scolls.jpg

Texture Gradient

- **Texture becomes denser with distance from viewer**
- **Note how cobblestone pattern varies with distance**

Paris Street: A Rainy Day by Gustave Caillebotte
http://psych.hanover.edu/Krantz/art/texture.html

Texture Example

http://www.mhhe.com/socscience/intro/ibank/set2.htm

Depth of Focus

- **Principle of *Accommodation***
- **We bring objects of interest into sharp focus, rest of image becomes blurred**
- **Computationally expensive**
- **Know where someone is looking**

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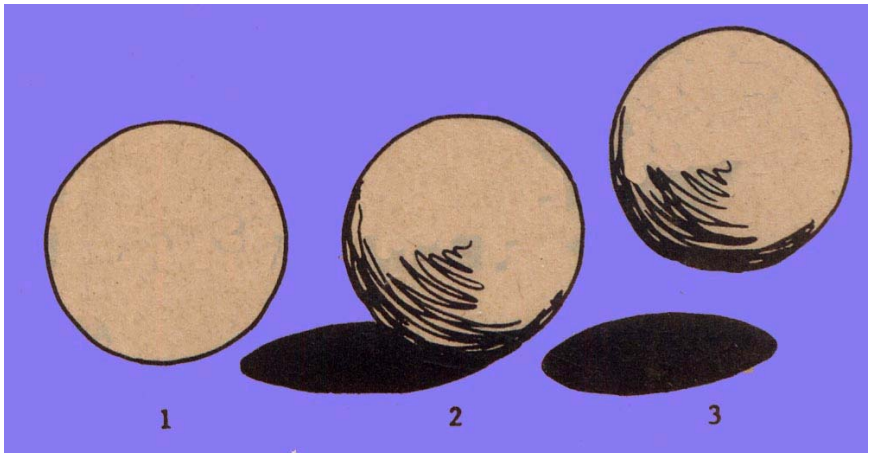
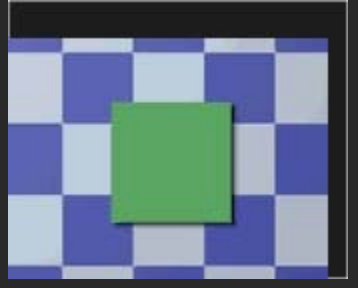
Cast Shadows

- **Provides information about the height of an object above the plane**

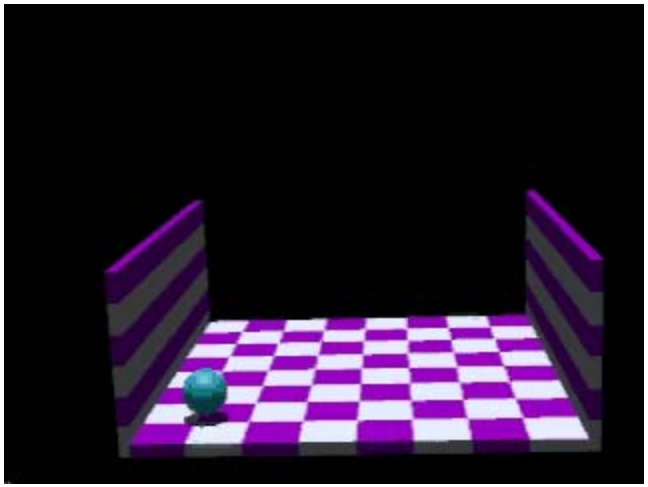


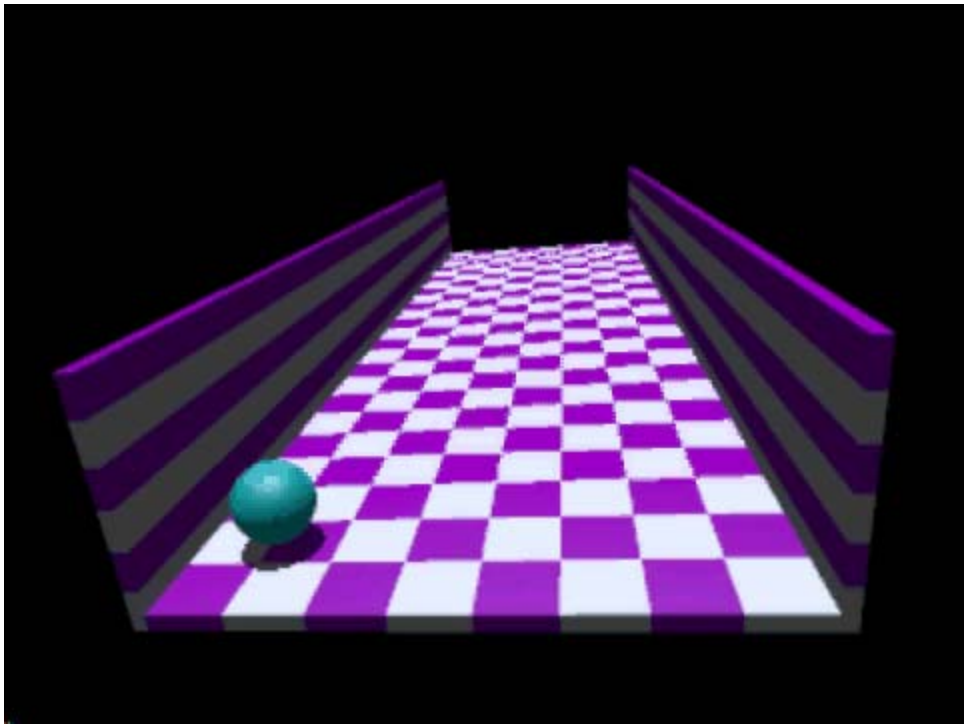
http://www.azwestern.edu/psy/dgershaw/lol/VisualDepth1.html

Cast Shadows (2)



Cast Shadows are very powerful when objects are in motion or for inducing apparent motion





Videos from Kersten et al. 1997.
http://gandalf.psych.umn.edu/~kersten/kersten-lab/shadows.html

Motion Parallax

- Dynamically changing pattern of light on retina
- Things nearby seem to move quickly and things far away move slower
- Relative horizontal position of objects change
- Owls use motion parallax

Movie: http://psych.hanover.edu/Krantz/MotionParallax/MotionParallax.html

Kinetic Depth Effect

- **Depth is perceived when observing a rotating two dimensional figure**
- **Object is perceived as rigid rather than a series of lines**

  Kinetic Depth Movie: http://web.mit.edu/~jcshieh/www/935Project/ske_main.html

- **Depth is also perceived due to the Stereokinetic effect**

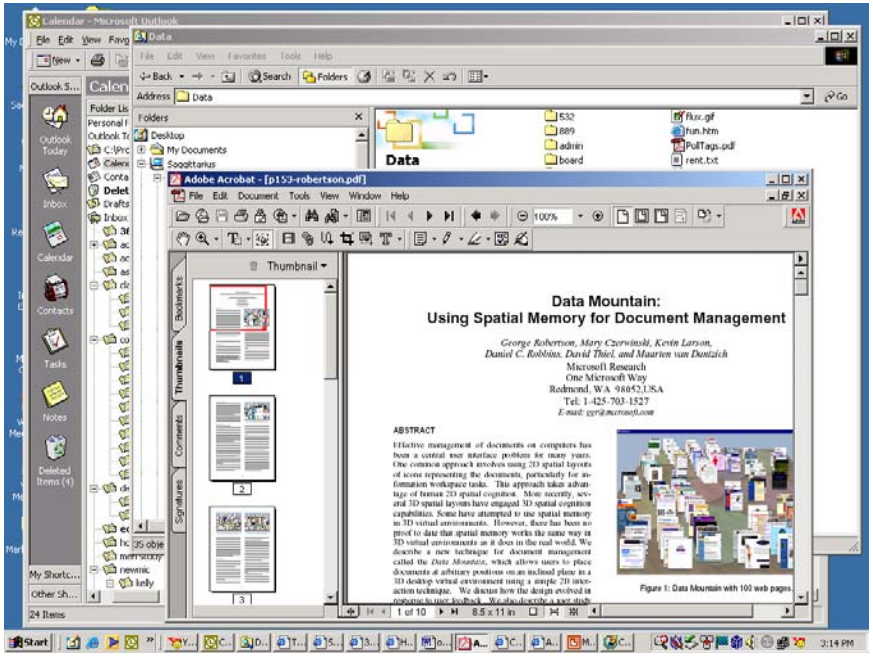
  Stereokinetic effect movie: http://web.mit.edu/~jcshieh/www/935Project/ske_main.html

Monocular Depth Cues

- Occlusion
- Linear Perspective
- Size Gradient
- Texture Gradient
- Depth of Focus
- Cast Shadows
- Motion Parallax
- Kinetic Depth Effect

2D Interfaces: Occlusion

- **Standard in most GUIs**
- **Occluding windows are in front of occluded windows**



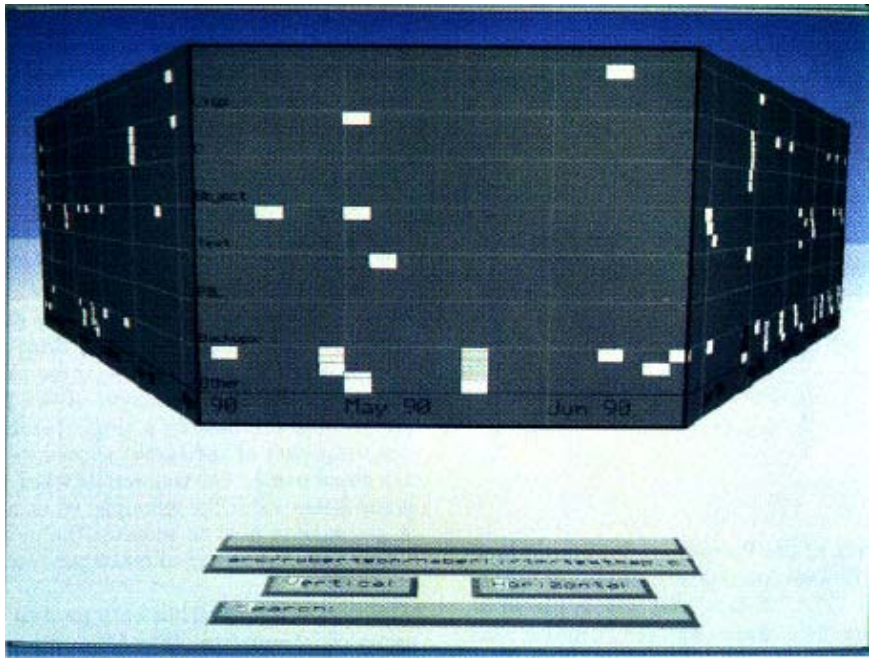
2D Interfaces with Depth Cues

- **Screen real estate problem**
  - **Focus plus context displays**
  - **Continuous Zoom**
  - **Lens Techniques (Detail in Context)**
- **Organization of numerous elements**
- **Complex Visualizations**

Perspective Wall

- **Focus plus Context Display**

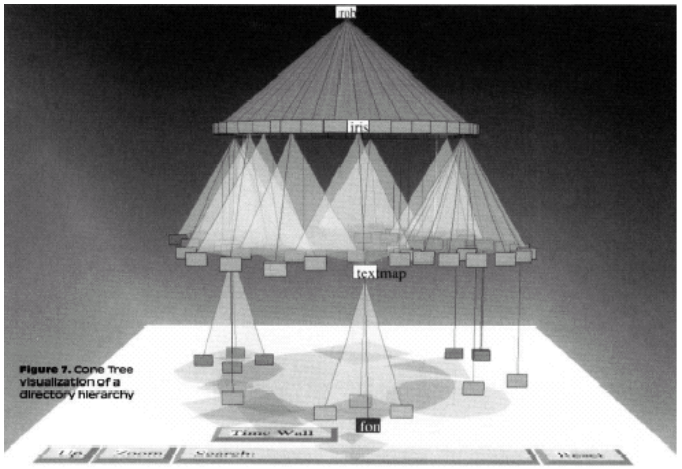
- **Linear perspective**
- **Size Gradient**
- **Texture Gradient**
- **Shading**

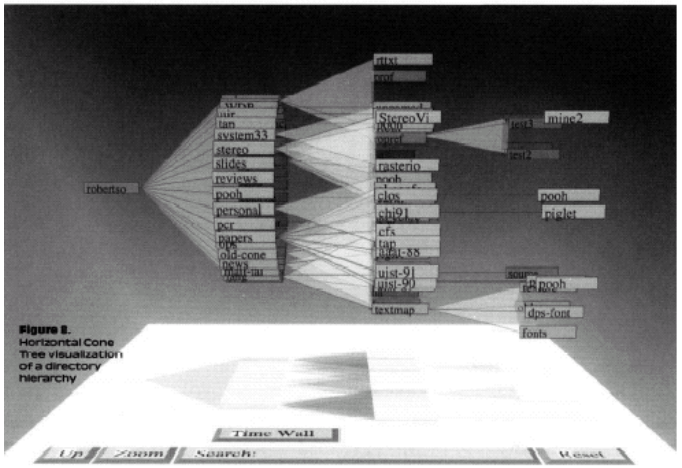


- **Mackinlay et al. 1991**

Cone Trees

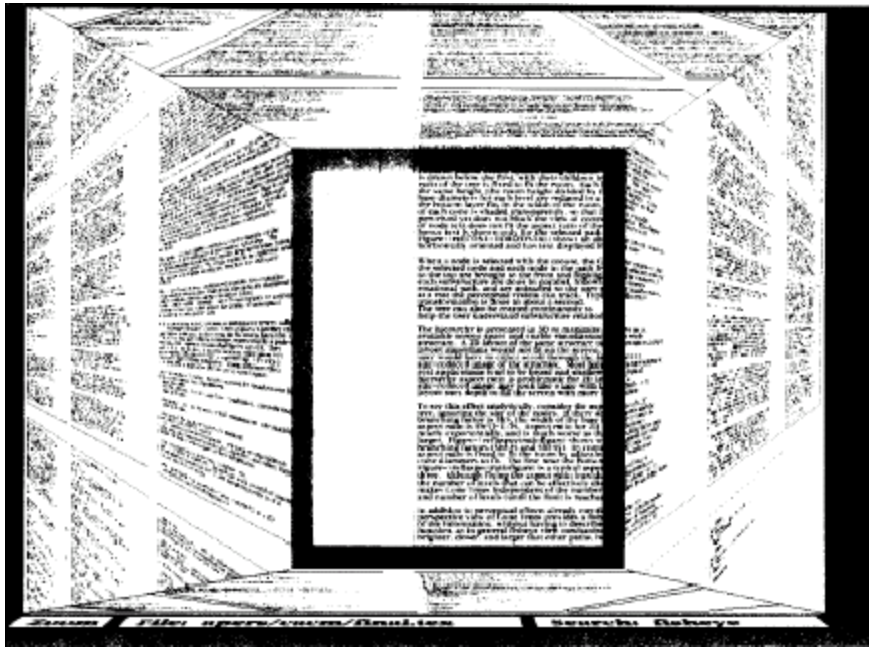
- **Organization of File and Directory Hierarchies**
- **Occlusion**
- **Structure from Motion**
- **Robertson et al. 1993**

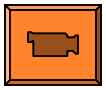




Document Lens

- **Detail plus Context Display**
- **Numerous other lenses for many other applications since this lens**
- **Robertson et al. 1993**





Idelix

Data Mountain

- Organization of Web Pages
- Linear Perspective
- Occlusion
- Size, Texture Gradient
- Cast Shadows
- Robertson et al. 1998

3D Desktop

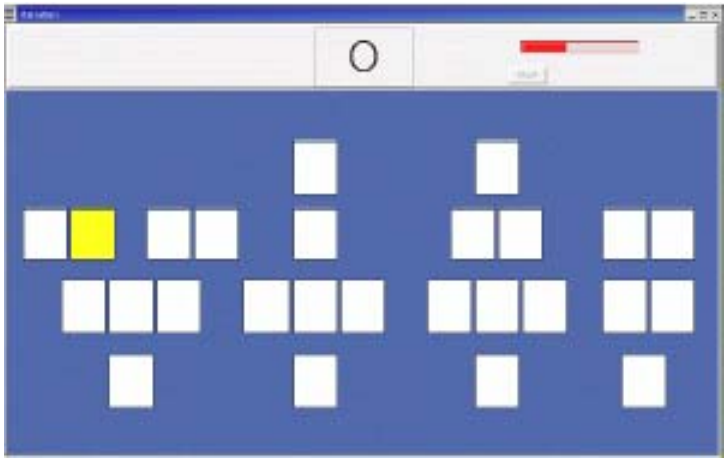
- **Demo Movie:**
  http://www.clockwise3d.com/products/products.html

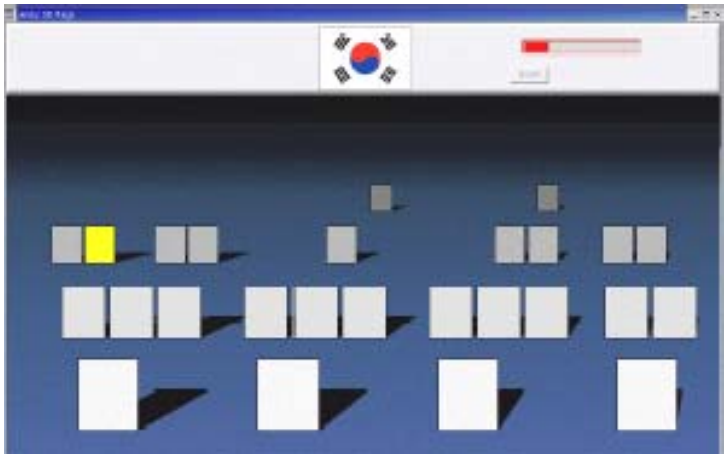
Artificial Depth Cues

- **3D position from line segments dropped to the ground plane leveled differences between stereo and mono displays (Kim et al., 1991)**

Artificial Depth Cues (2)

- **Proximity luminance covariance**
  - **E.g. Items that are farther are darker**
  - **Cockburn (submitted)**
- **Principle of Atmospheric Depth**
  - **Aerial perspective**





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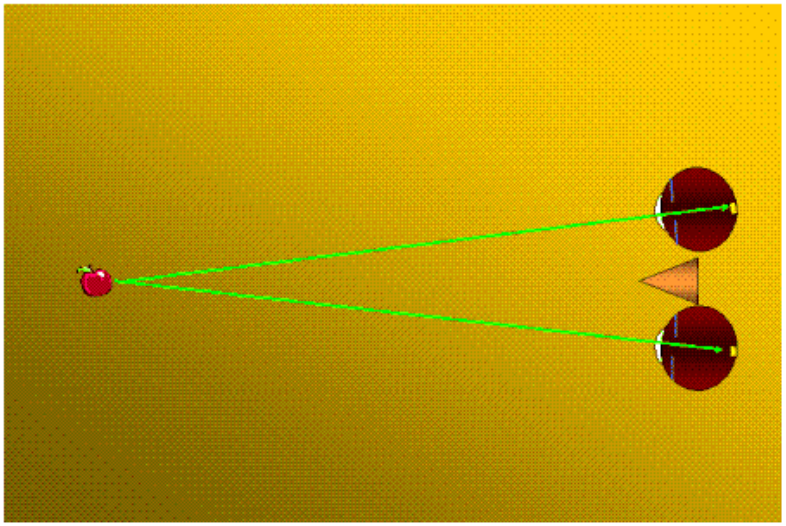
http://krantzj.hanover.edu/Krantz/art/aerial.html

Eye Convergence

- **Binocular Cue**
- **Vergence angle of eyes created by distance from eyes to object**
- **Better for relative information than absolute information**

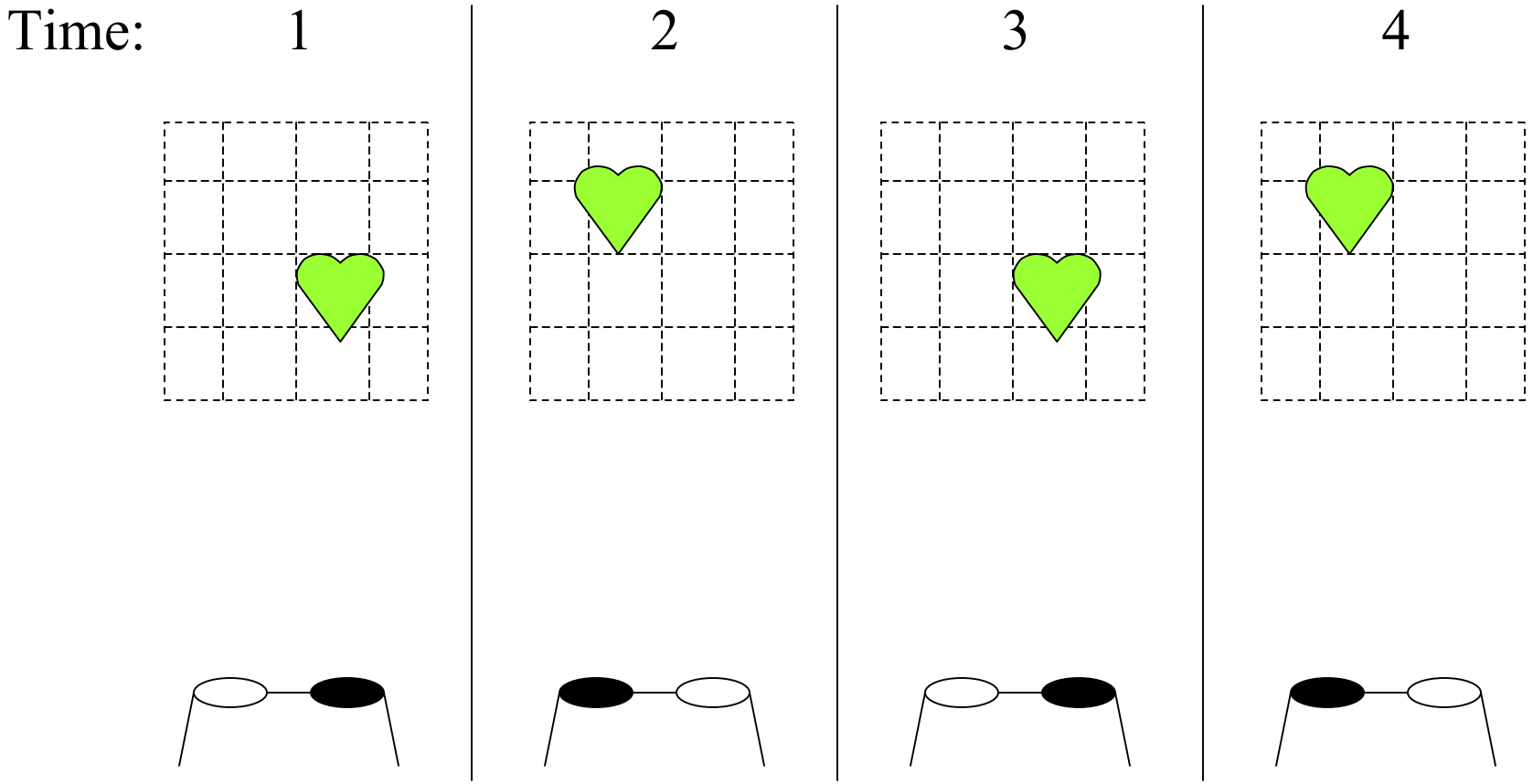


http://psychlab1.hanover.edu/Classes/Sensation/Vergence/index.html

Stereoscopic Displays

- Two images are presented in alternating sequence; one to the left eye, one to the right eye
- Alternating glasses used to view appropriate image
  - LCD shutter glasses
  - Polarized glasses

Stereoscopic Displays



Stereoscopic Displays (2)

- **Stereo Cameras**
  - **Endoscopic Surgery**
- **Gaze Tracking**
  - **Position information from head tracking sensors or eye gaze sensors alters rendered images**
  - **Adds motion parallax cue to stereo display**

Example

Two User Responsive Workbench

Agrawala et al., 1997

Problems with Stereo Displays

- **Diplopia**
  - **Failure of visual system to fuse left and right eye images**
  - **Panum's fusional area**
  - **Accommodation helps avoid diplopia**
- **Frame Cancellation**
  - **Screen edge occludes image appearing in front of screen**

Problems with Stereo Displays (2)

- **Distant Objects**
  - **Stereoscopic depth cue only relevant to 30m from the viewer**
- **Vergence-Focus Problem**
  - **Eye Convergence and Accommodation are coupled in visual system**
  - **Screen-based and Head-mounted VR systems represent vergence but not focus**
  - **Results in eye strain**

Future "True" 3D displays

- **Vergence-Focus Problem Revisited**
  - **Gaze (eye + head) tracking**
  - **Can include depth of focus in stereo displays**
  - **Reduce eye strain**
- **Virtual Retina Display**
  - **Scans a pattern of light directly onto the retina**
  - **Low-vision aid**

Space Perception Theory

- **Varying theories on how depth cues combine to form perception of space**
- **Task dependent**
  - **Object docking, object rotation, object translation, target acquisition, path tracing**

A note about HCI and Psychology

- **Principles of psychology can be used to create effective digital displays**
- **The ability of digital displays to reproduce images not possible in the physical world can contribute to psych theory**
  - **E.g. Hierarchy of depth cues for space perception**
- **Mutually Beneficial**

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- **Ware, C. (2000). *Information Visualization: Perception for Design*. Morgan Kaufmann, San Francisco.**