A Thesis Proposal: *Egocentric Depth Perception in Optical See-Through Augmented Reality*

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December 8, 2006

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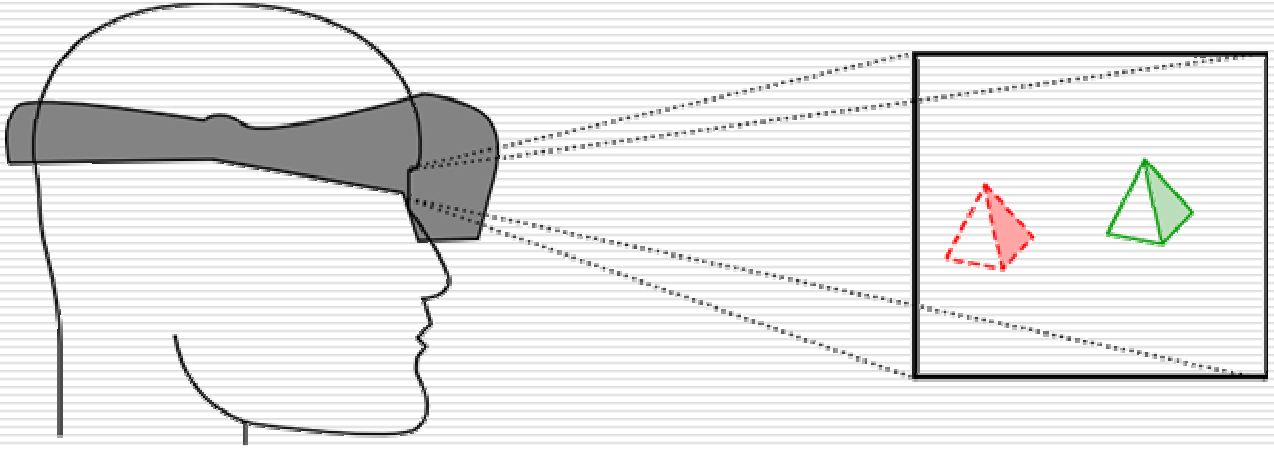
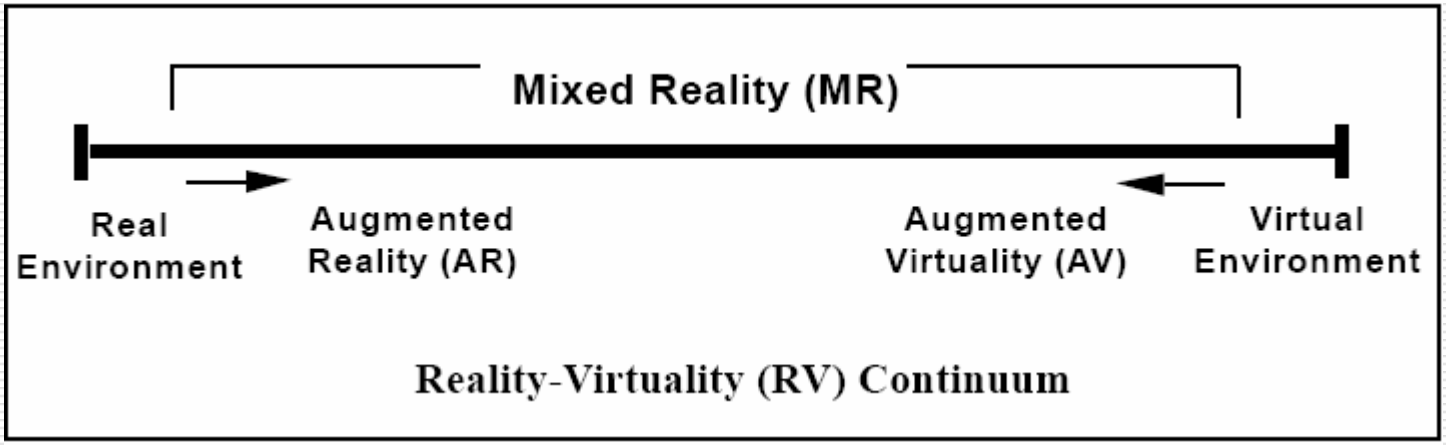
Introduction

- Augmented Reality
  - Enabling users to see what they normally cannot
  - Mixing real and virtual scenes to provide insight
  - Augmenting a user's perception of the environment

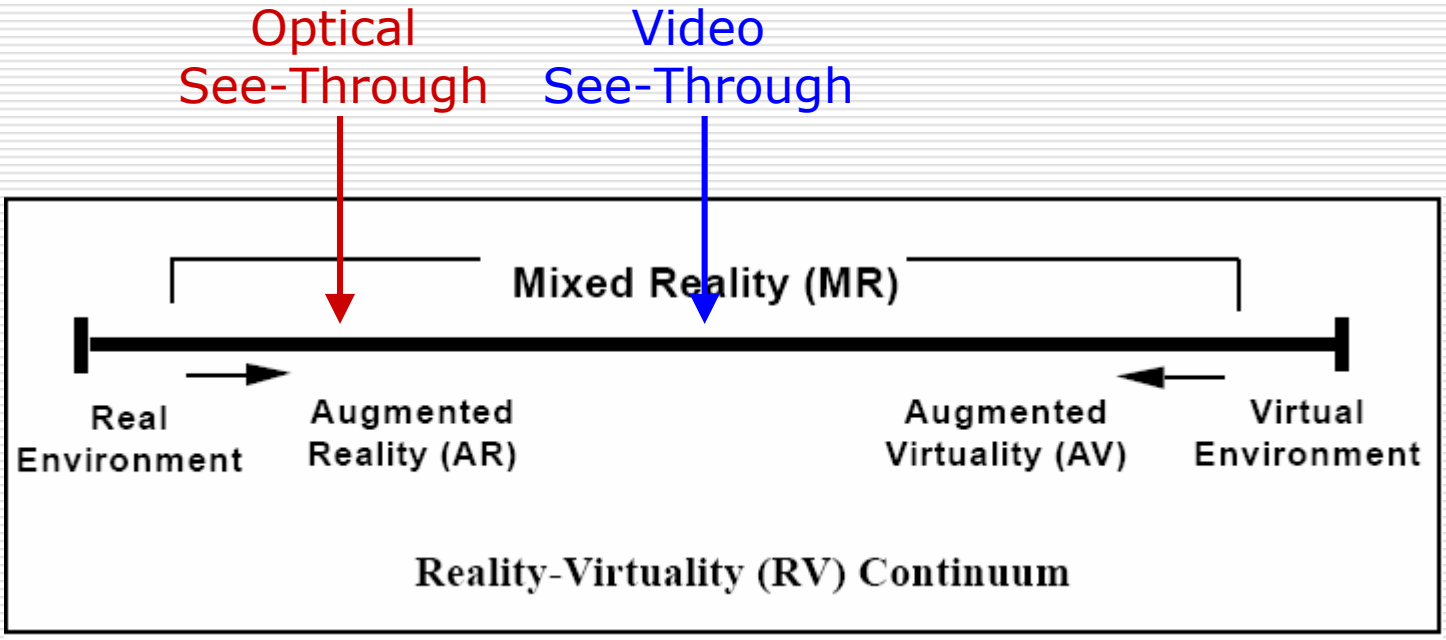


Augmented Reality



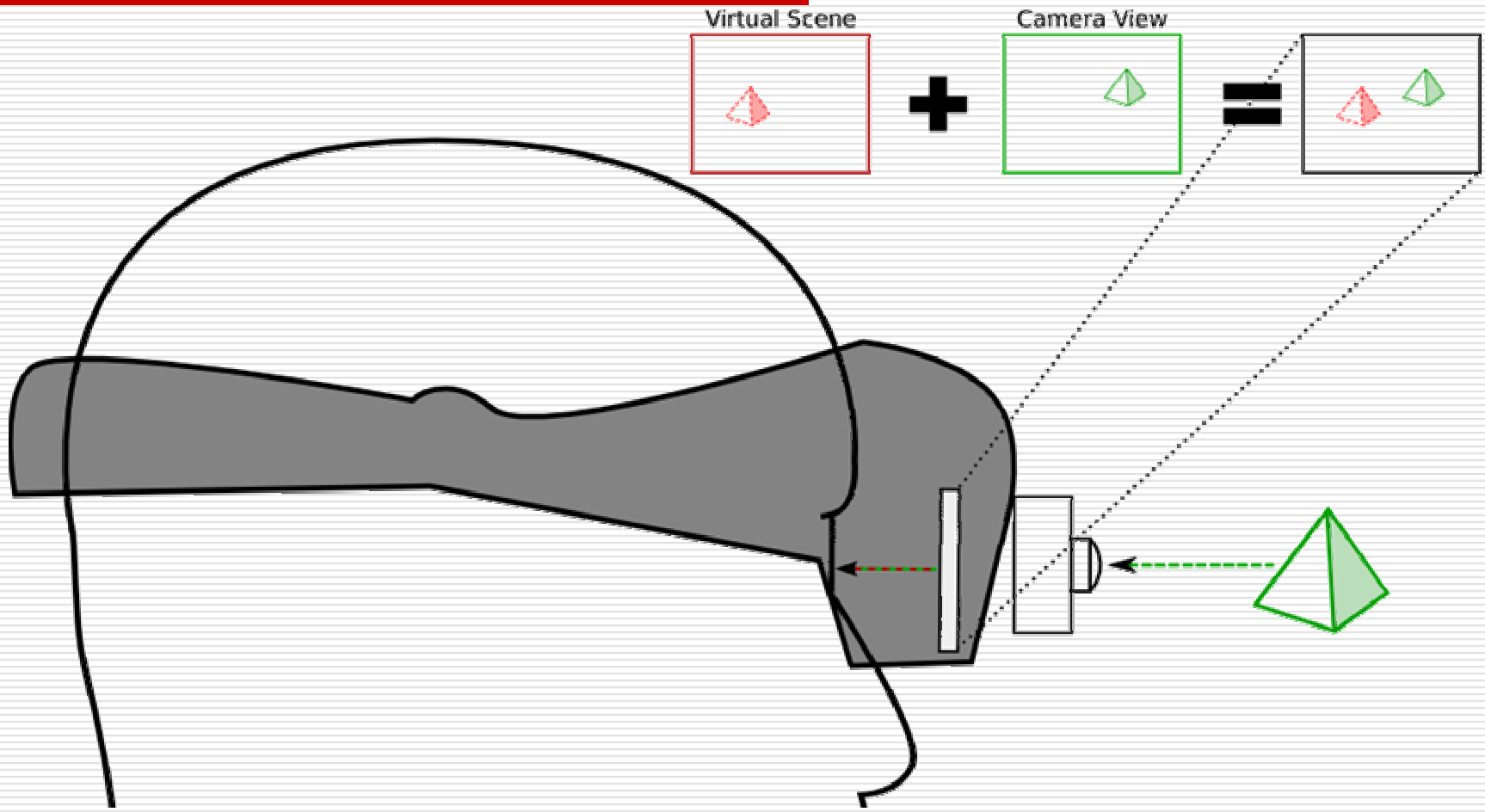
Milgram et al.'s Reality-Virtuality Continuum

Augmented Reality

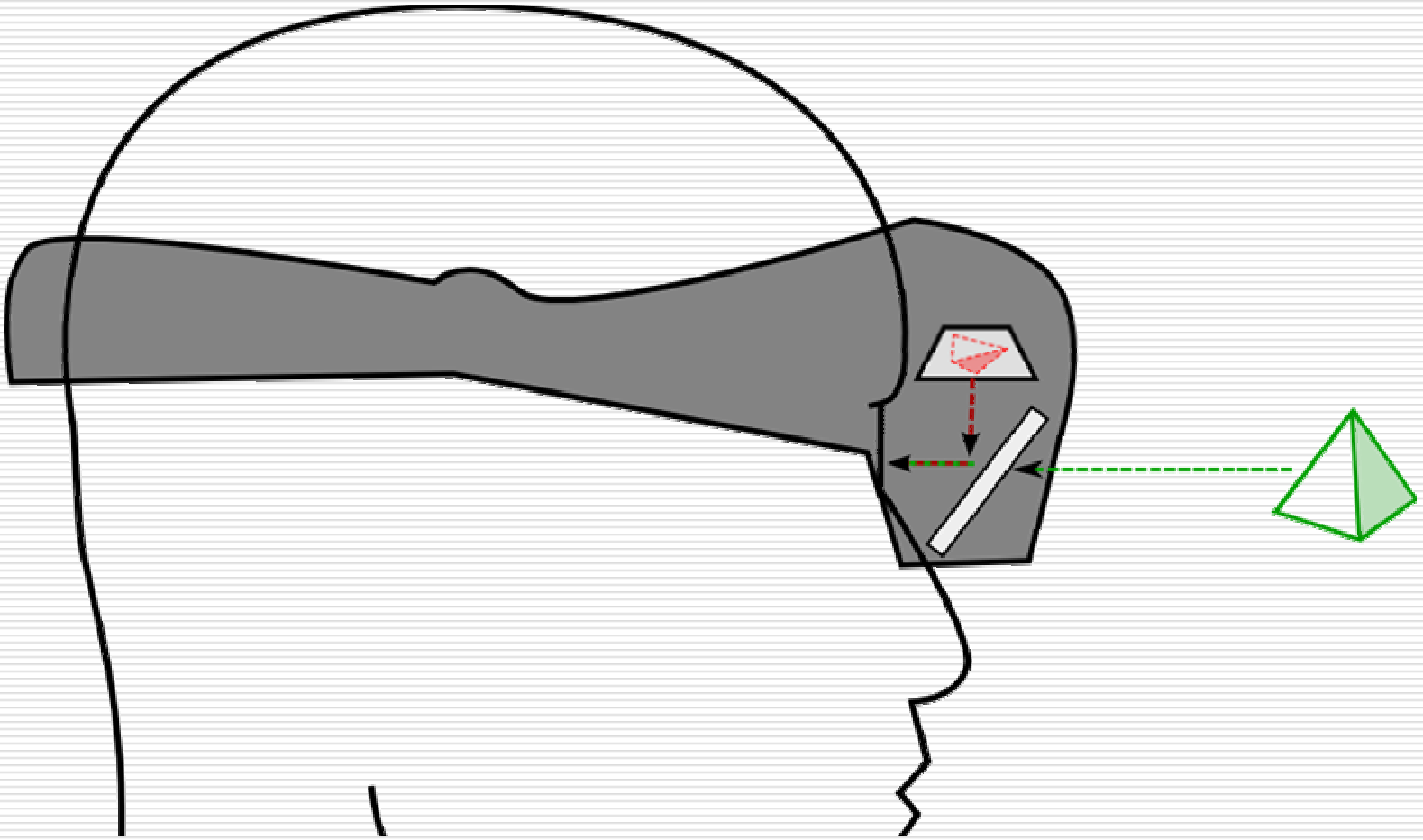


Milgram et al.'s Reality-Virtuality Continuum

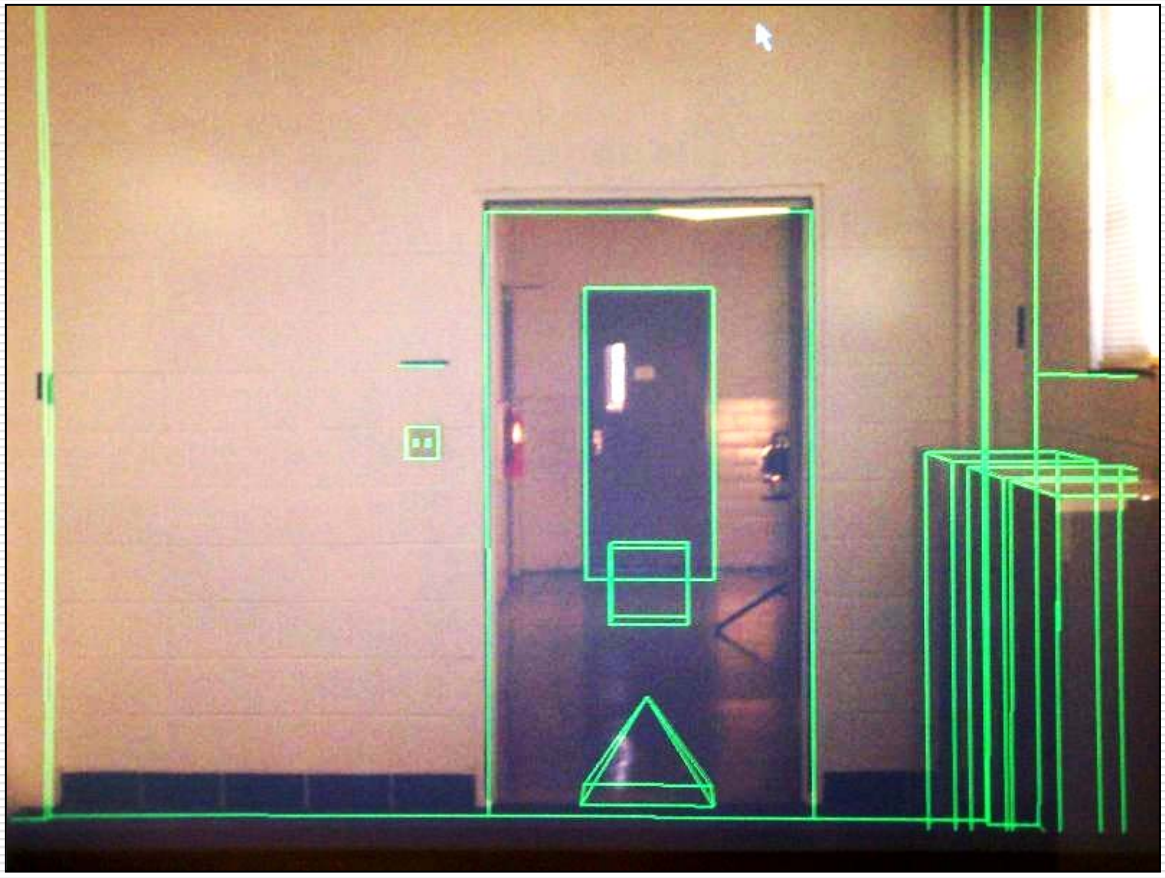
Video See-Through AR



Optical See-Through AR



Optical See-Through AR

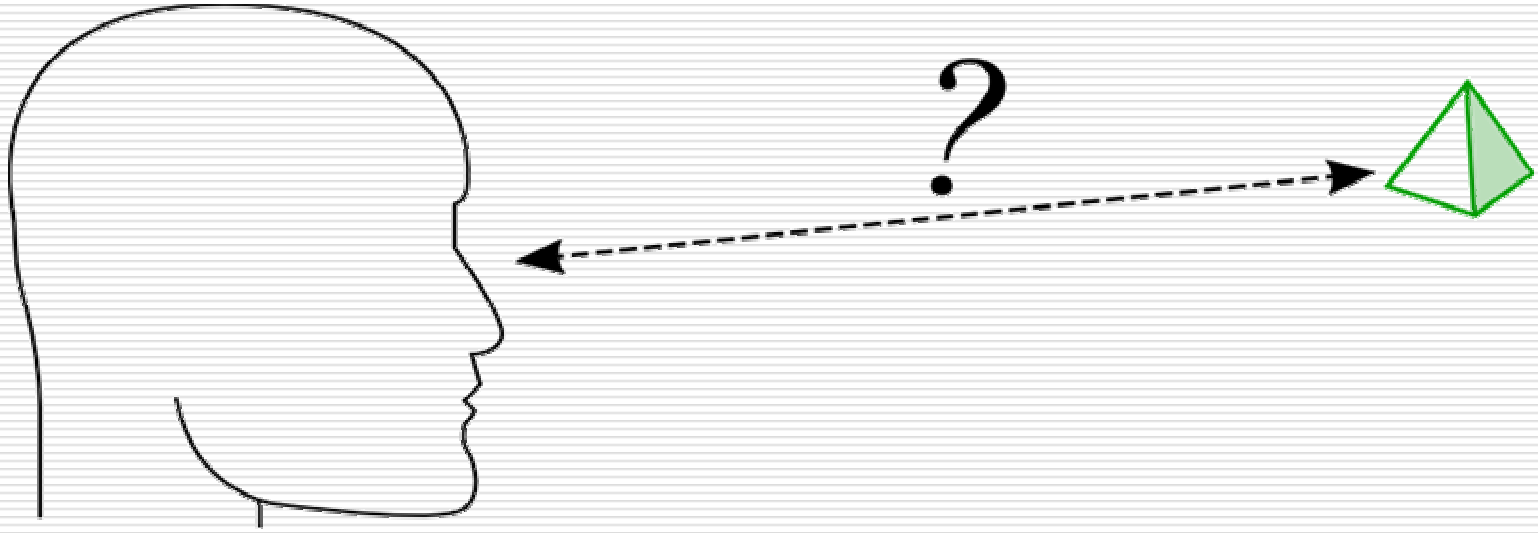


Depth Perception

- Depth Perception is our ability to understand the spatial relationships in the world around us.
- Two Classes:
  - Egocentric
  - Exocentric

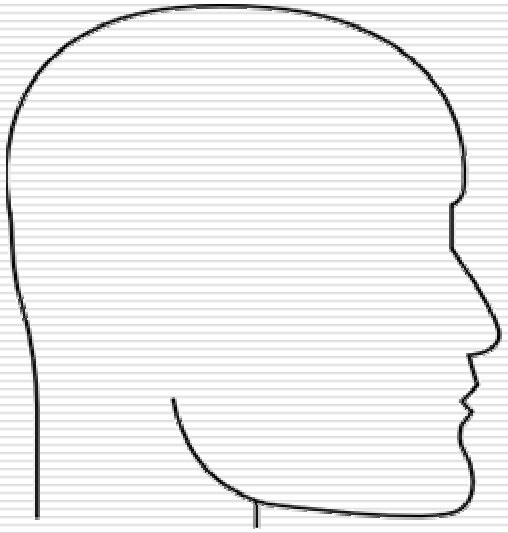
Egocentric Depth Perception

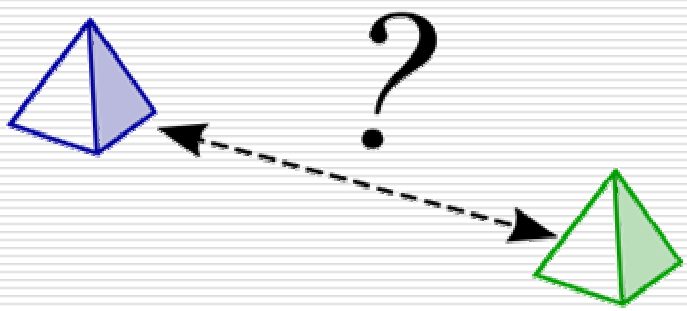
- Our ability to understand the spatial relationships between ourselves and references in the world.



Exocentric Depth Perception

- Our ability to understand the spatial relationships between other references in the world.





Cue Theory

- How do we know where objects are located?
- Cue Theory states that we use hints in our view of the world to develop an understanding of spatial relationships.

Depth Cues

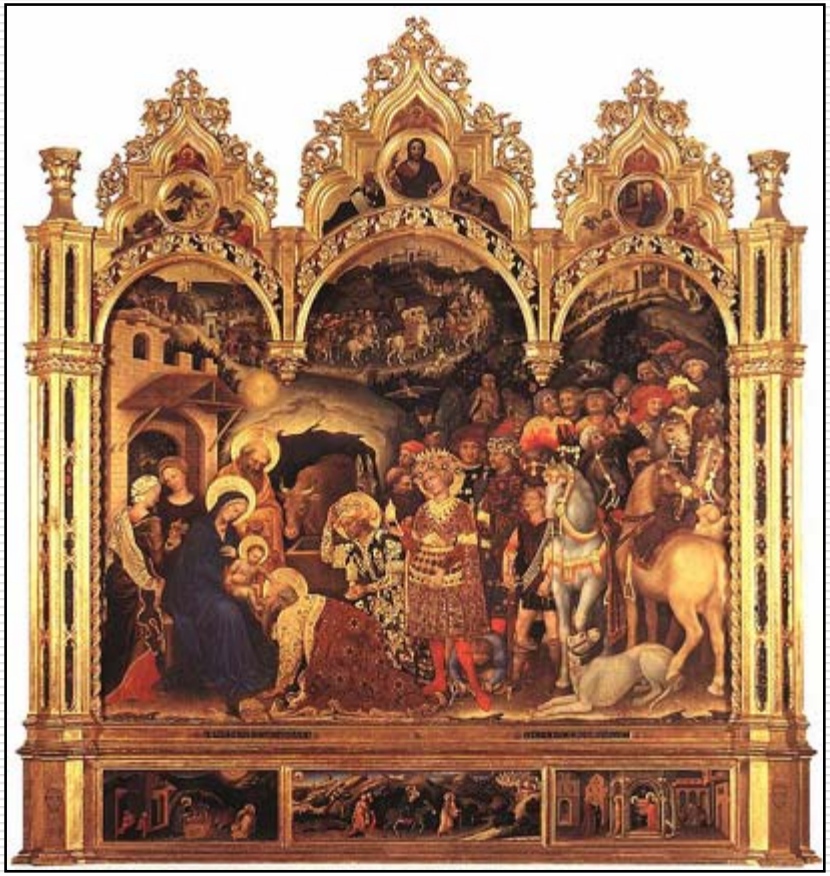
- Depth Cues fall into several categories…
  - Monocular or Binocular
  - Ordinal, Quantitative, or Metrical

Depth Cues

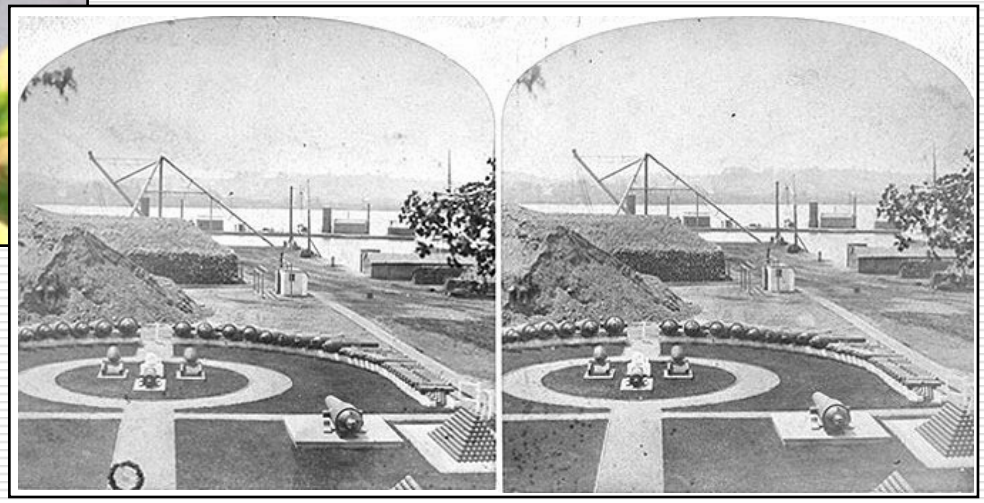
- Humanity – we've always been augmented reality in some way or another…
- Cutting uses this observation to catalogue the development of our understanding of depth cues, as they evolved in art.

Depth Cues

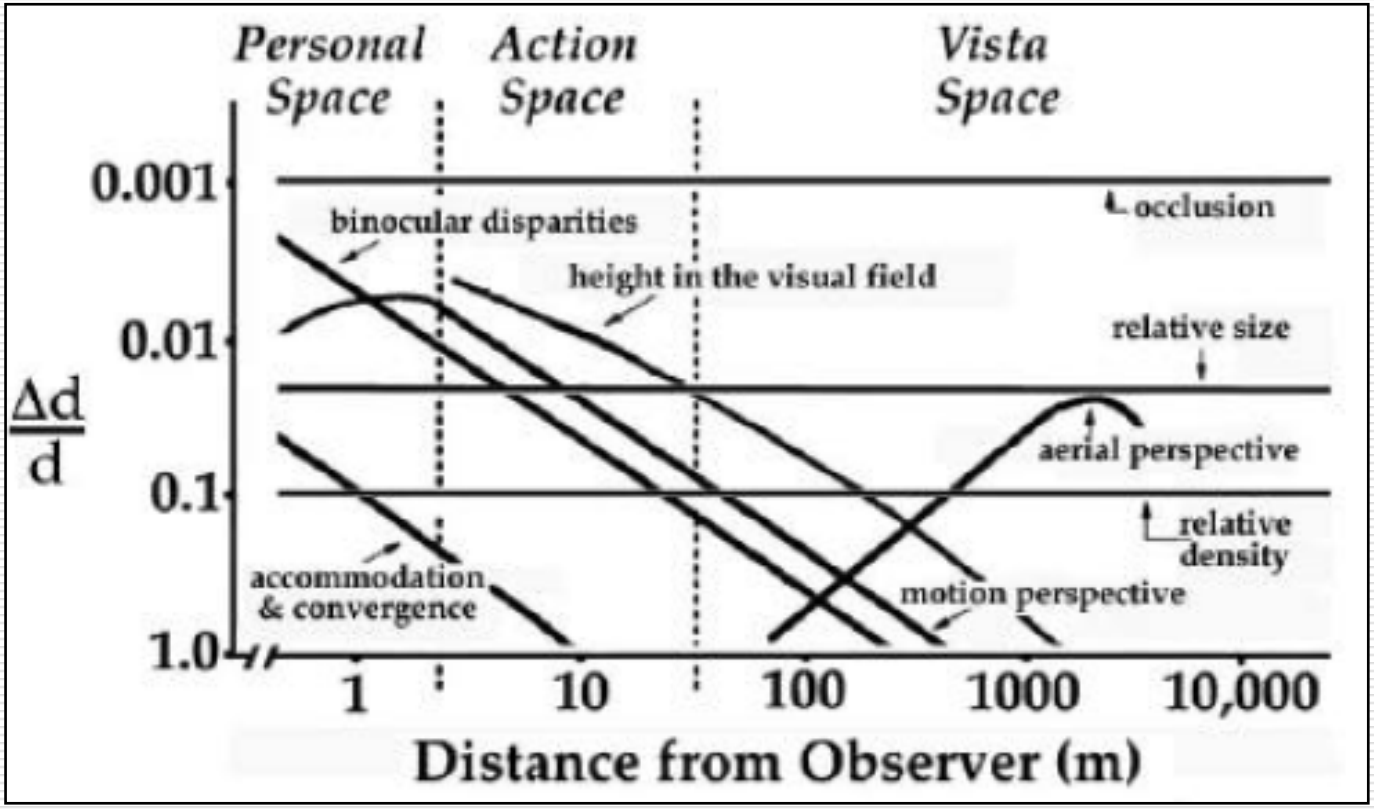
Depth Cues



Depth Cues



Depth Cues


Personal Space
Action Space
Vista Space
0.001
0.01
0.1
1.0
Δd/d
binocular disparities
height in the visual field
occlusion
relative size
aerial perspective
relative density
motion perspective
accommodation & convergence
1
10
100
1000
10,000
Distance from Observer (m)

Depth Perception & AR

- Cuttings discussion of depth perception is very relevant to augmented reality research
  - AR can be viewed as the next evolution in pictorial representation
  - Implies that the cue combinations needed in AR will be some of the most complex and sophisticated yet

Previous Work

- Loomis, Knapp
  - Studied depth perception in VR
  - Open Loop, Motoric Tasks
- Hu, Gooch, et al.
  - Studied effect of cue combinations in VR
  - Used an object placement task
- Swan, Livingston, et al.
  - Studied perceptual matching in OST AR
- Wu, Ooi, He
  - Studied the effect of FOV restrictions on depth perception

Proposed Work

- Hypothesis: The combination of additional and more realistic cues to AR may result in more accurate interpretation of depth relations
- I propose that the hypothesis be tested using a two user studies that gauge perceived depth of real, virtual, and combined objects

Equipment

NVIS nVisor

Sony Glasstron

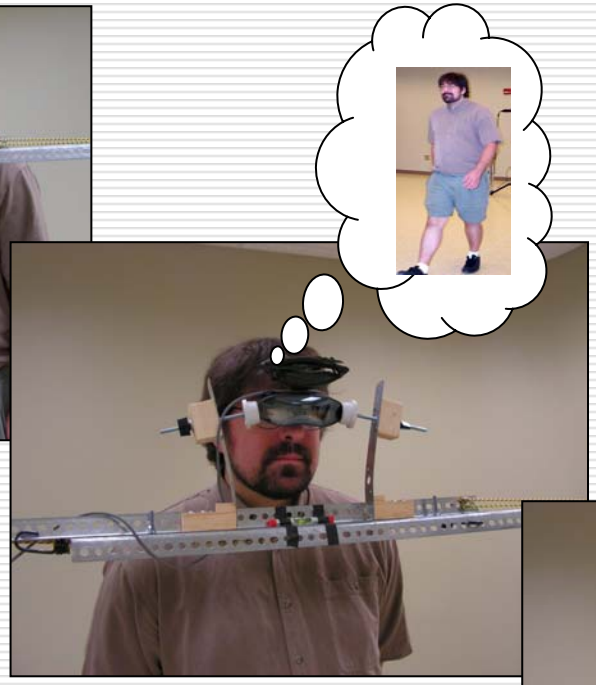
InterSense IS-1200

Graphics Workstations

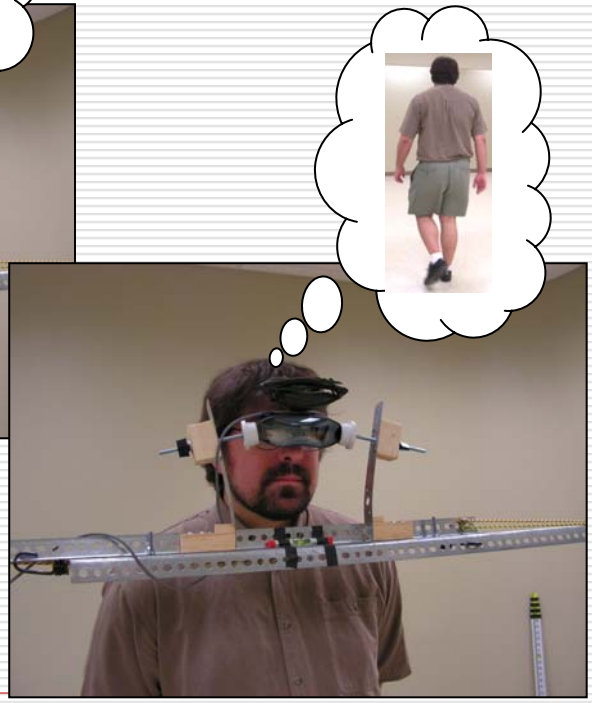
Blind Walking

Imagined Walking

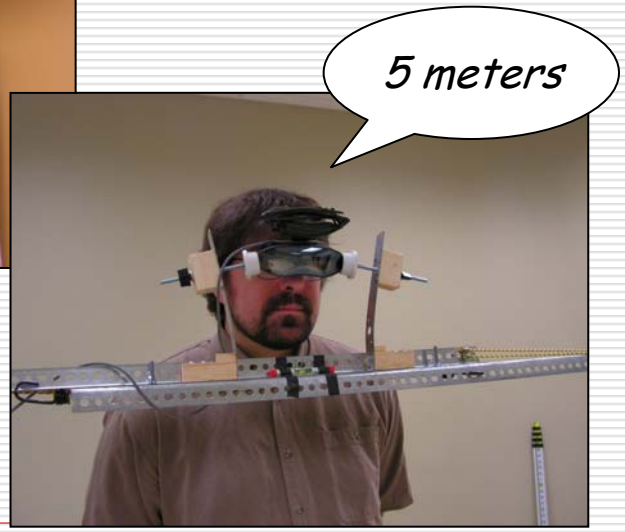
Starts Timer



Stop Timer



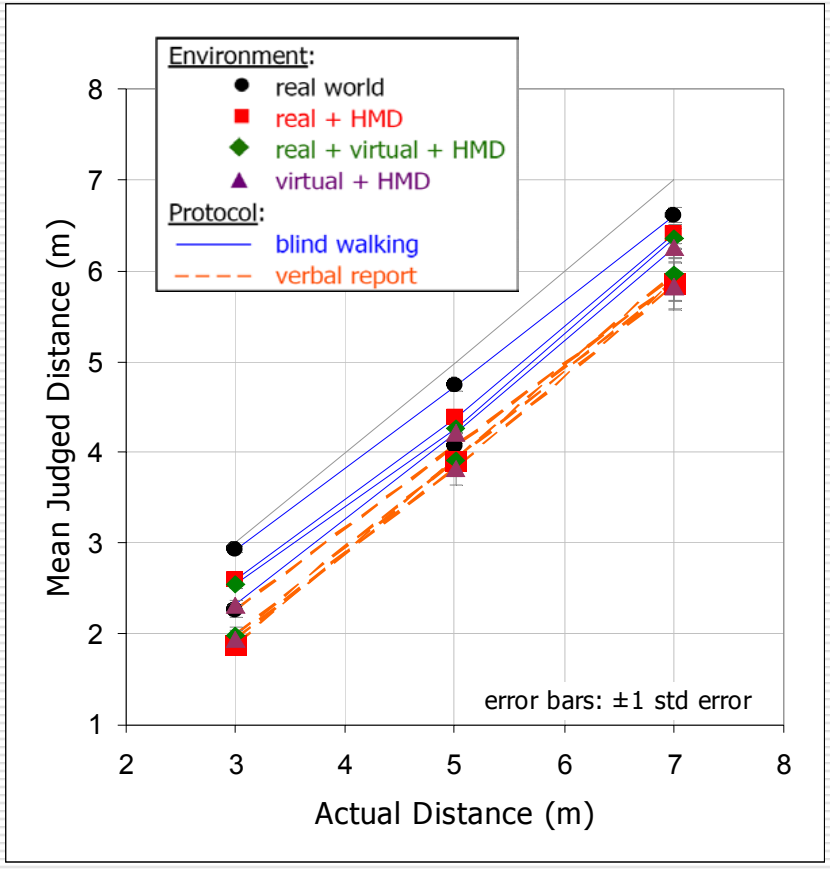
Verbal Report

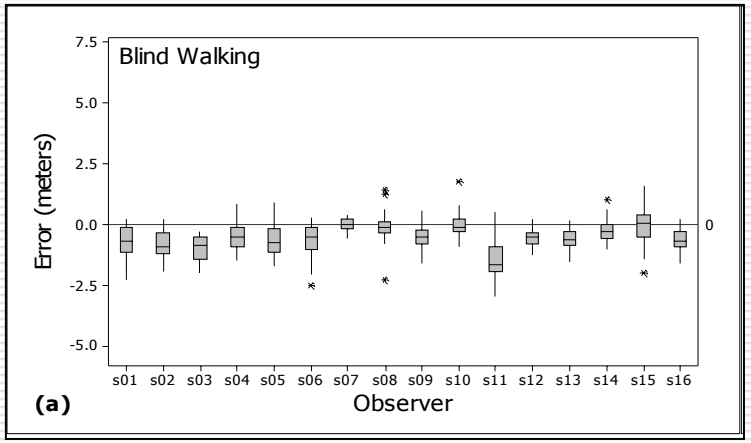


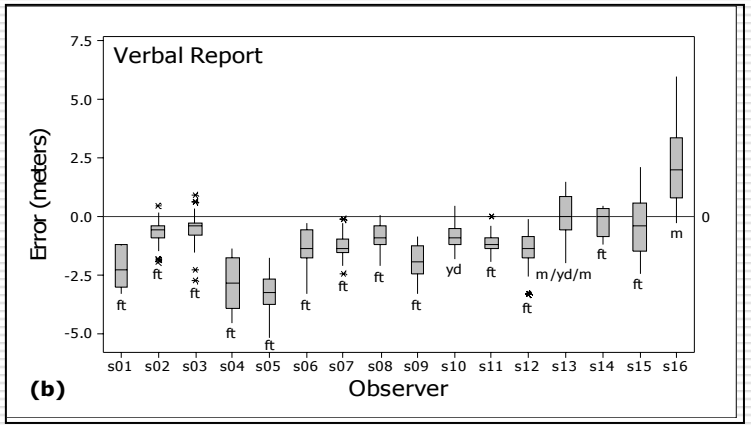
Experiment I

- Completed Summer 2006
- Measured egocentric depth judgments
  - Blind Walking
  - Verbal Report
- Four stimulus types
  - Real
  - Real view through the HMD
  - Combined Real and Virtual
  - Purely Virtual

Experiment I







Experiment II

- To be completed Spring 2007
- Follow up to the Summer 2006 study
- Test the addition of motion parallax
- Same stimulus types
  - Real
  - Real view through the HMD
  - Combined Real and Virtual
  - Purely Virtual

Acknowledgments

- J. Edward Swan, II
- Carrick C. Williams
- T.J. Jankun-Kelly
- Eric W. Kolstad
- Stephanie Doane
- Department of Computer Science & Engineering
- Institute for Neurocognitive Science & Technology
- Office of Naval Research
- National Aeronautics and Space Administration

References

- R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, B. MacIntyre, "Recent Advances in Augmented Reality," *IEEE Computer Graphics & Applications*, vol. 21, no. 7, Nov./Dec. 2001, pp. 34-47.
- P. Milgram and F. Kishino, "A Taxonomy of Mixed Reality Visual Displays," IEICE Trans. Information Systems, vol. E77-D, no. 12, 1994, pp. 1321-1329.
- J.E. Swan, M.A. Livingston, C. Zambaka, H. Smallman, J.L. Gabbard, D. Brown, Y, Baillot, S.J. Julier, G.S. Schmidt, D. Hix, L. Rosenblum, "A Methodology for Quantifying Medium- and Far-Field Depth Perception in Optical, See-Through Augmented Reality," technical report, MSU-050531, Department of Computer Science and Engineering, Mississippi State University, 2005.
- J.E. Swan, M.A. Livingston, H. Smallman, D. Brown, Y, Baillot, J.L. Gabbard, D. Hix, "A Perceptual Matching Technique for Depth Judgments in Optical, See-Through Augmented Reality," *IEEE Virtual Reality 2006*, IEEE Computer Society, pp. 19-26.
- J. Cutting, "How the Eye Measures Reality and Virtual Reality," *Behavior Research Methods, Instrumentation, and Computers*, vol. 29, 1997, pp. 29-36.
- J. Cutting, P. Vishton, "Perceiving Layout and Knowing Distance," *Handbook of Perception and Cognition*, vol. 5, 1995, pp. 69-117.
- M.A. Livingston, C. Zambaka, J.E. Swan, and H. Smallman, "Objective Measures of Effectiveness of Augmented Reality," *IEEE Virtual Reality 2005*, IEEE Computer Society, pp. 287-288.
- J.M. Wolfe, K.R. Kluender, D.M. Levi, *Sensation & Perception*, Sinauer Associates, Sutherland, Massachusetts, 2006.
- B. Wu, T.L. Ooi, and Z.J. He, "Perceiving Distance Accurately by a Directional Process of Integrating Ground Information", *Nature*, 428, March 4th, 2004, pp. 73–77.
- J.M. Loomis, J.M. Knapp, "Visual Perception of Egocentric Distance in Real and Virtual Environments," *Virtual and Adaptive Environments: Applications, Implications, and Human Performance*, Lawrence Erlbaum Associates, Mahwah, New Jersey, 2003, pp. 21-46.
- H.H. Hu, A.A. Gooch, W.B. Thompson, B.E. Smits, J.J. Rieser, and P. Shirley, "Visual Cues For Imminent Object Contact In Realistic Virtual Environments," *Proceedings of the 11th IEEE Visualization 2000 Conference*, Las Vegas, Nevada, 2000, IEEE Computer Society,
- M.R. Bax, "Real-Time Lens Distortion Correction: 3D Video Graphics Cards Are Good for More than Games," *Stanford Electrical Engineering and Computer Science Research Journal*, Spring, 2004, http://ieee.stanford.edu/ecj/spring04.html (current Sep. 14, 2006).
- J J.M. Plumert, J.K. Kearney, J.F. Cremer, K. Recker, "Distance Perception in Real and Virtual Environments," *ACM Transactions on Applied Perceptions*, vol. 2, no. 3, 2005, pp. 216-233.
- P. Willemsen, M.B. Colton, S.H. Creem-Regehr, W.B. Thompson, "The Effects of Head-Mounted Display Mechanics on Distance Judgments in Virtual Environments," *ACM Internation Conference Proceedings Series*, vol. 73, 2004, pp. 35-38.

Questions