Lecture 7:

Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE 1993

The LAIR: Lightweight Affordable Immersion Room 2009

COMP 30025J

Dr. Abraham Campbell

Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE

- Cruiz-Neira, Sandin , DeFanti
- PAPER that named the CAVE immersive display

Abstract

- CAVE(CAVE Automatic Virtual Environment)
- Creates an immersive space using projection technology
- Makes tracking easier due to the configuration
- Advantages and disadvantages of this new [paradigm discussed.

Conclusions

- CAVE showed a new effective and convincing immersive form of VR
- Large field of view with less distortions than a typical HMD

Introduction

- Virtual Reality term still debated in 1993 but this paper final agreed that Howard Rheingold's book "Virtual Reality" definition would win out , (credited to Jaron Lanier)
- Attempting to create the Ultimate Display
- We can separate out the VR requirements from traditional computer graphics.
- Differs from the BOOM (display on a swinging arm) and a HMD

Introductions continued

- VR and depth cues
  1. Occlusion (hidden surface)
  2. Perspective projection
  3. Binocular disparity (stereo glasses)
  4. Motion Parallax (head motion)
  5. Convergence (amount eyes rotate toward centre of interest, basically your optical range finder)
  6. Accommodation (eye focus, like a single-lens reflex as range finder)
  7. Atmospheric (fog)
  8. Lighting and Shadows

1.2 CAVE Motivations

- HMD are heavy and uncomfortable , they still are ☺
- CAVE design was the first attempt at an alternative solution
- VR like all uses of computer science goes in cycles depending on what abilities of a given technology generation .
- At this moment , the VIVE and Oculus are in the lead but new projective rendering techniques could end their predominance but not for some time.

1.3 CAVE design

- Goals
  1. The desire for higher-resolution colour images and good surround vision without geometric distortion.
  2. Less sensitivity to head-rotation induced errors
  3. The ability to mix VR imagery with real devices (like one's hand, for instance)
  4. The need to guide and teach others in a reasonable way in artificial worlds
  5. The desire to couple to networked supercomputers and data sources for successive refinement

2 Projection Details : CUBE shape and Projection paradigm

- CAVE is based on a CUBE shape.
- It uses a Silicon Graphic library (precursor to OpenGL)

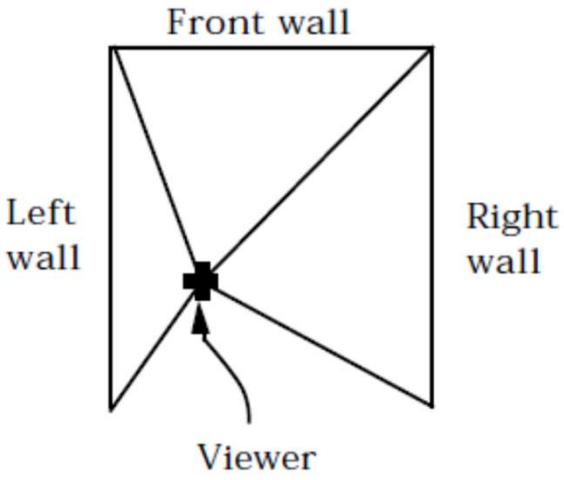


Figure 2: Off-axis projection

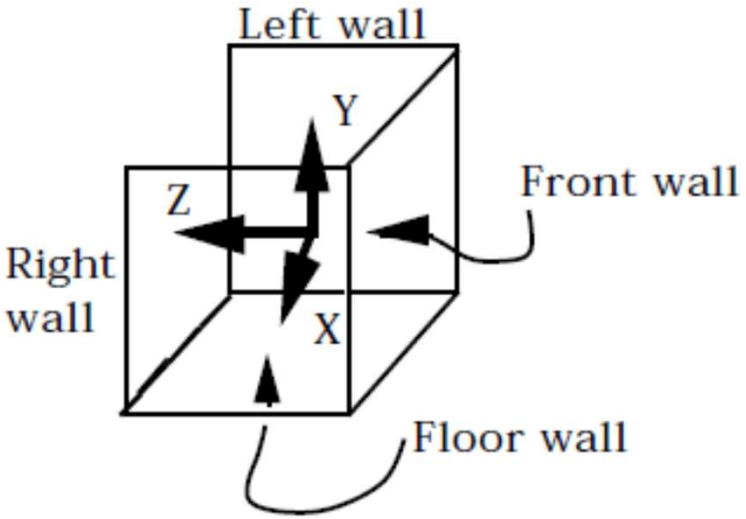


Figure 3: CAVE reference system.

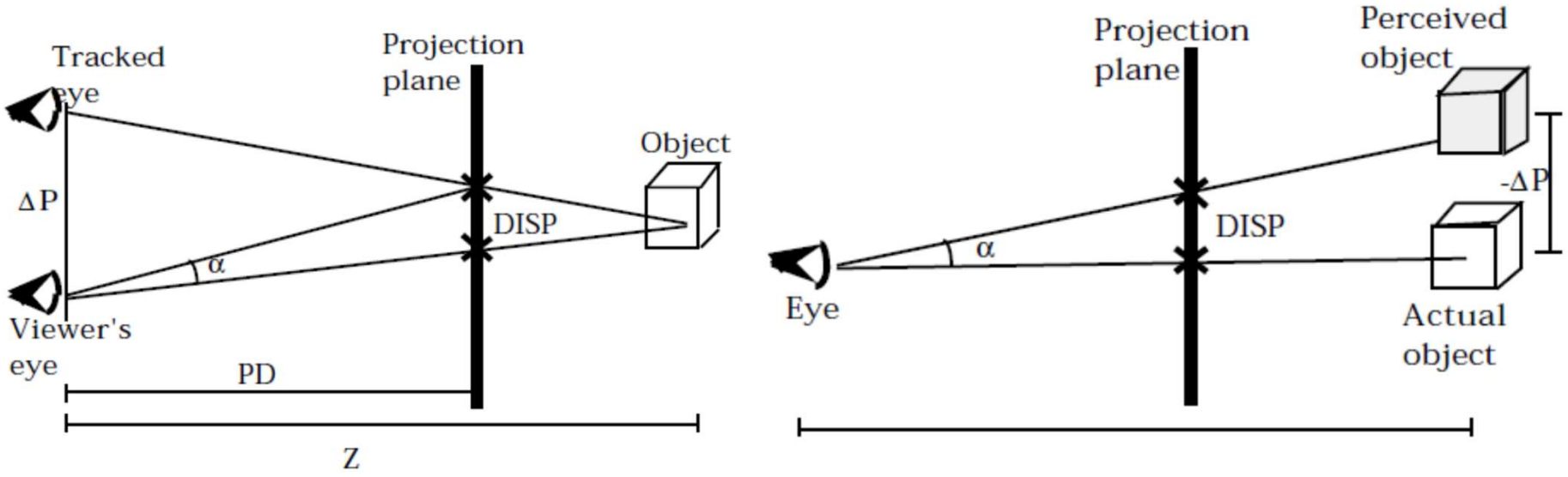
3 Stereo vision Details

- Convergence
  - Dual projectors for each wall thus each eye sees a different image
- Frame sequential Stereo
  - Minimum of 60 hz per eye so 120 frames per second
- Distortion Correction
  - Modified Device coordinates , last step in your set of projection matrices
- Minimizing user shadows
  - No shadow on back project, any shadow from the top will normally be behind the user

3 Stereo vision Details Cont.

- Frame Accuracy synchronization
  - Must be under 8 ms
- Edge Matching
  - Projecting onto the floor avoids breaking any edges
- Minimizing Occlusion by participants
  - Need for a guide to avoid users occluded each other
- Motion sickness
  - Projective Rendering does require the fast horizon tilting that a HMD requires

4. Quantitative Analysis of the Effect of tracking Noise and latency



Both HMD and CAVE suffer tracking errors , but due to the fact that horizontal plane does not need to tilt in a CAVE, one element of tracking error is reduced
The new FOVE HMD will address this issue, and thus will be potentially more accurate than both a CAVE and traditional HMD

6 CAVE shortcomings

- Cost
  - 100,000 dollars or more to create
- Ability to project on all six sides of the CAVE
  - Can’t not project to all sides
- Light Spillage
  - Lighting floor can be difficult, also projector must be calibrated which increases cost dramatically
- Utilizing the CAVE medium to its full potential
  - Design difficulties as a different paradigm to VR HMD

6 CAVE shortcomings

- Fragility
  - Tracking setup and projectors are not kid proof or museum ready
- New control Paradigm
  - No keyboard or mouse , so new controller needed
- Directional Sound
  - Possible with more speakers OpenAL solves much of this problem.
- Ability to Document
  - Video recordings can not capture the experience.

8 Future Work & 9 References

- Future work points that the capacity of the CAVE is depended on improved Network speed
- This is a very accurate statement but internal PC interfaces have developed faster.
- References
  - One self reference
  - 10/11/12 reference provides one of the best Triptych I’ve read
  - Plato -> Sutherland Ultimate display -> Virtual Reality (Rheingold)
  - Also reference OpenGL early precursor

LAIR –Lightweight Affordable Immersion Room

- Paper that addresses the shortcomings of the CAVE design,
- (I’m on author on this paper so I will do my best to be objective)
- Short paper so we read it in order

Abstract

- 360 Immersive VR room,
- Trying to develop a system between a power wall and CAVE
- Reducing Space and cost requirements

1 Introduction & 2 Previous Work

- Defines approach to explore an improved version of a CAVE
- Describes the idea in a figure
- References the Powerwall as another solution

3 LAIR

- 360 view
- Has an area C where I user does not occlude any projector and thus can walk around freely
- 3.5 m^2 room

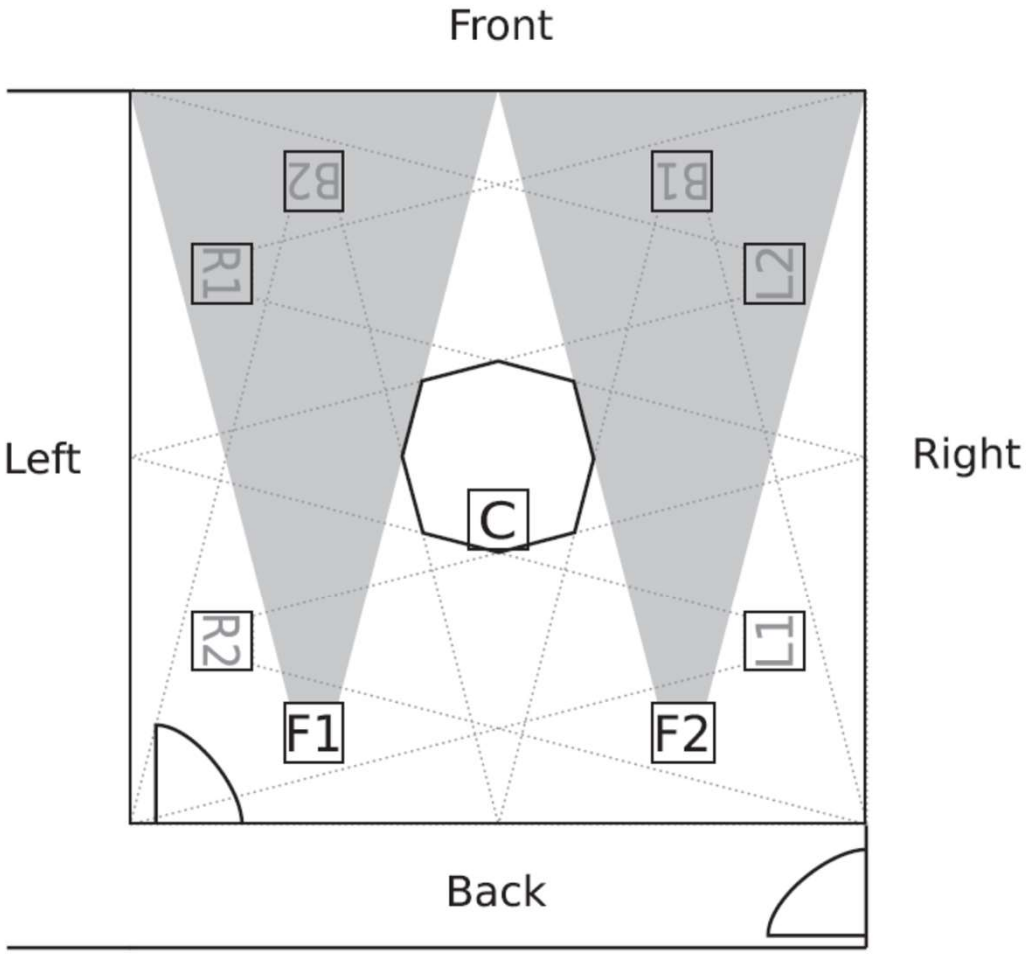


Figure 1. *Projector layout: A user standing in the central octagonal region will not cast shadows on the walls. F1 and F2 are the projectors for the front wall. C is the central projector to be used as an information display.*

3 LAIR Cont.

- Heat and power issues
- Large Fans were need to support air conditioning in the room
- Splitter boxes used to get 8 separate displays

4 Conclusions

- Offers a 360 view
- Inexpensive setup relative to a full CAVE
- Small footprint compared to CAVE's

References

- No self references (short paper we had to remove them)
- References original CAVE so authors had done their homework

Next weeks paper

- Next week we are going to discuss Mobile AR apps

Location-based Mobile Augmented Reality Applications Challenges, Examples, Lessons Learned

By Philip Geiger, Marc Schickler, Rudiger Pryss, Johannes Schobel, Manfred Reichert