Understanding the benefits of immersive virtual reality: from interaction to visualization

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Duke immersive Virtual Environment (DiVE)

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About Me

- Research scientist at Duke University
- Serve as Director of the Duke immersive Virtual Environment – DiVE
- Background on Human-Computer Interaction
- Experimental VR research
- Benefits of VR
- 3D User Interfaces

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VIRTUAL REALITY

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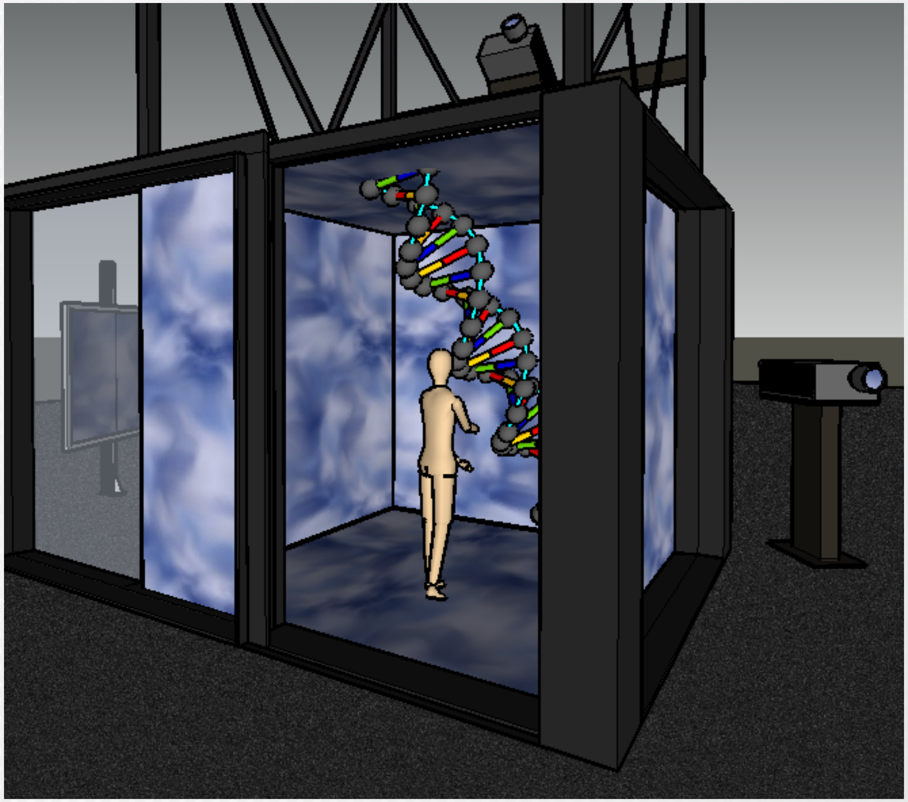

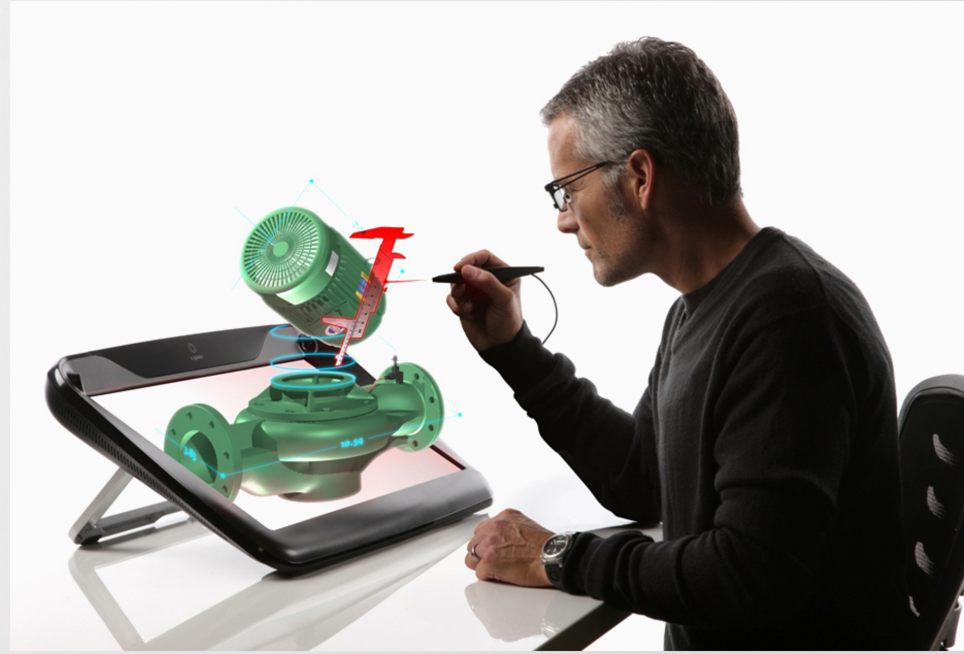

Displays!

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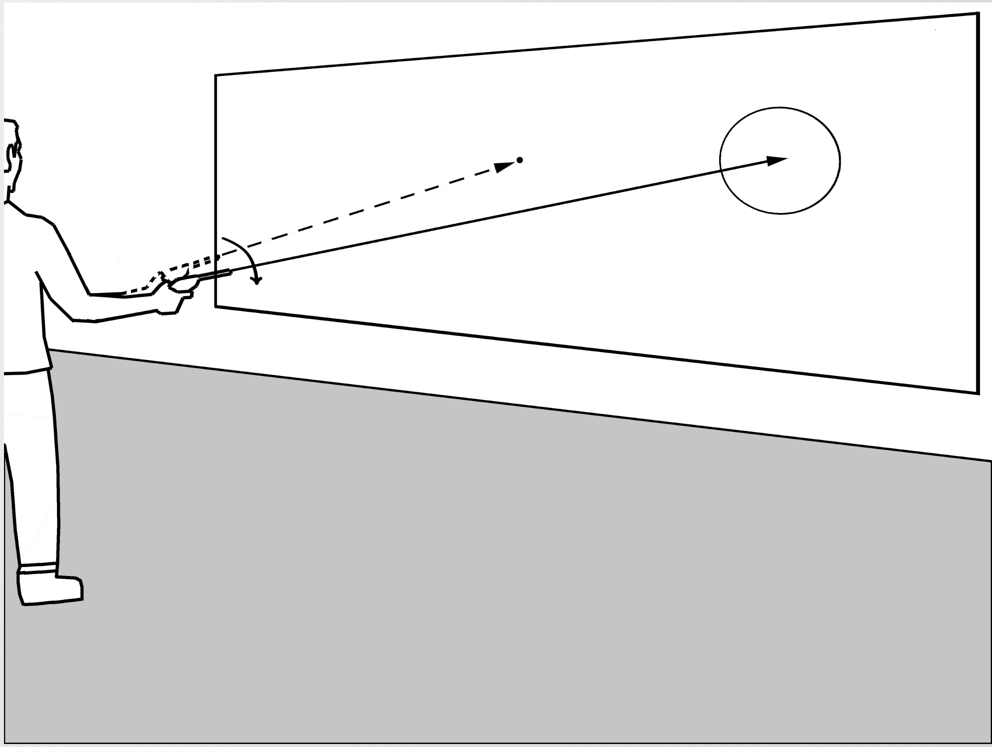

Interaction?

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Virtual Reality

- Definition

A synthetic, spatial (usually 3D) world seen from a first-person point of view. The view in a VE is under the real-time control of the user.

Bowman et al., 2004

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Virtual Reality Research

- How usable is immersive VR?
  - Understanding human performance limits with 3D interaction
  - Building effective 3D interaction techniques
- How useful is immersive VR?
  - Tasks that benefit from immersive displays
  - Concrete applications

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Interaction in Immersive VR

- Virtual hand intuitive, but limiting
- Distal Pointing (laser pointing) widely used for interaction in immersive VR

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Distal pointing

- Inherent precision issues
  - Exponentially difficult to point at small or remote objects
- **Enhancements** should be provided to increase pointing precision
- Developed two high-precision distal pointing techniques

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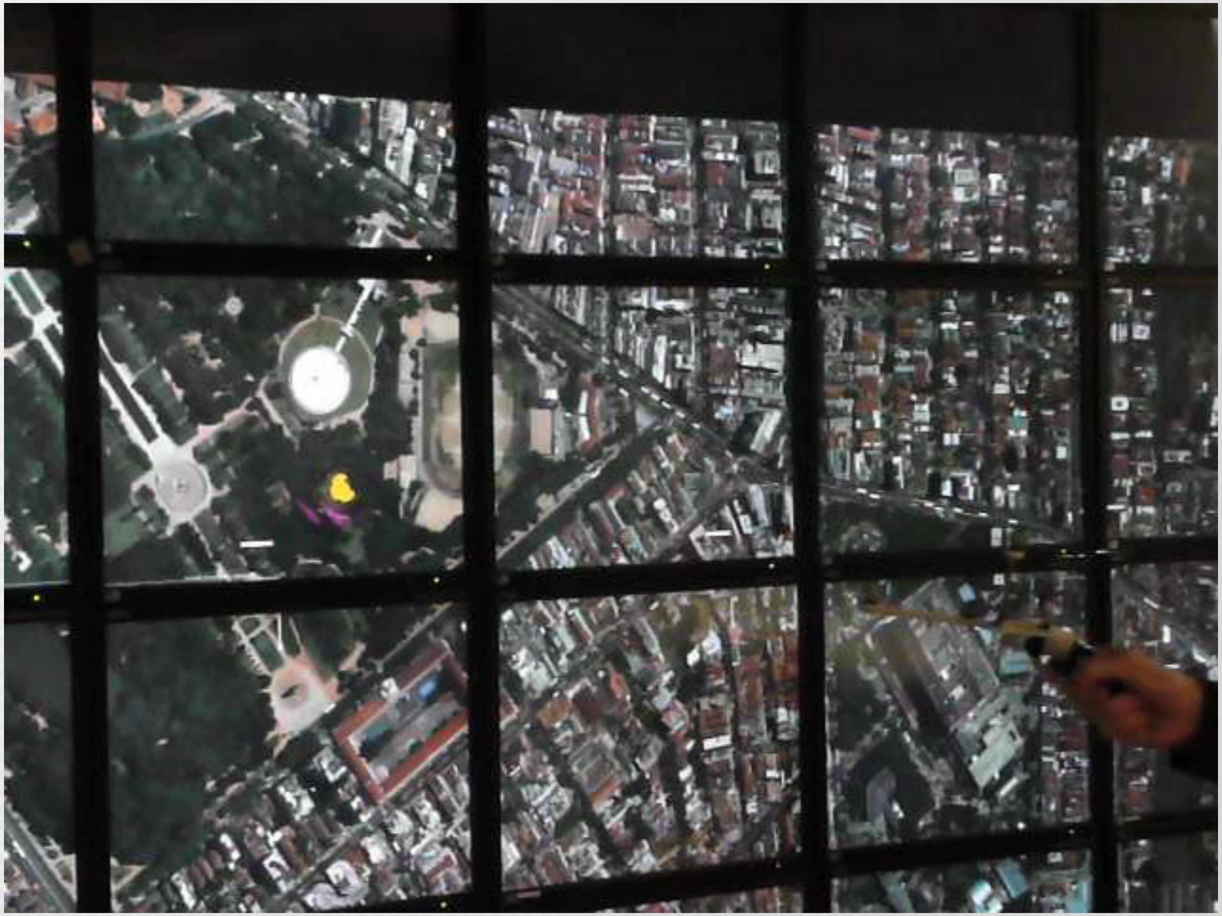
ARM

- Simple technique that toggles between absolute and relative (high-precision) pointing



DyCoDiR

- Dynamic Control/Display Ratio
- Required precision inferred by the application

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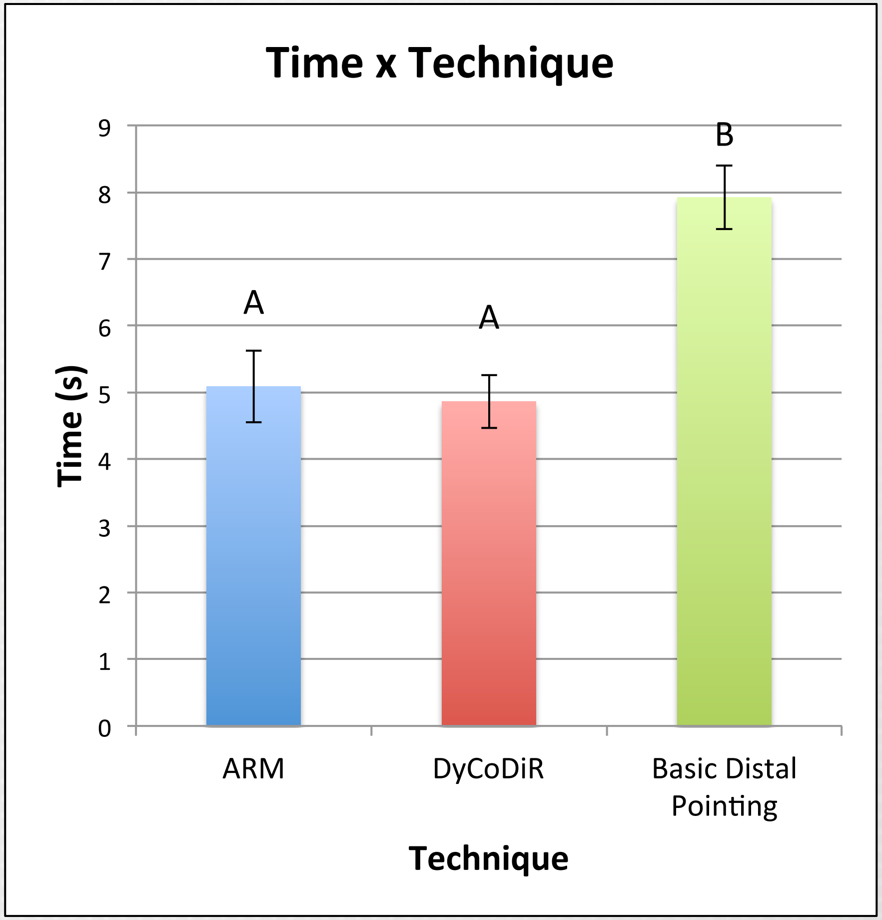
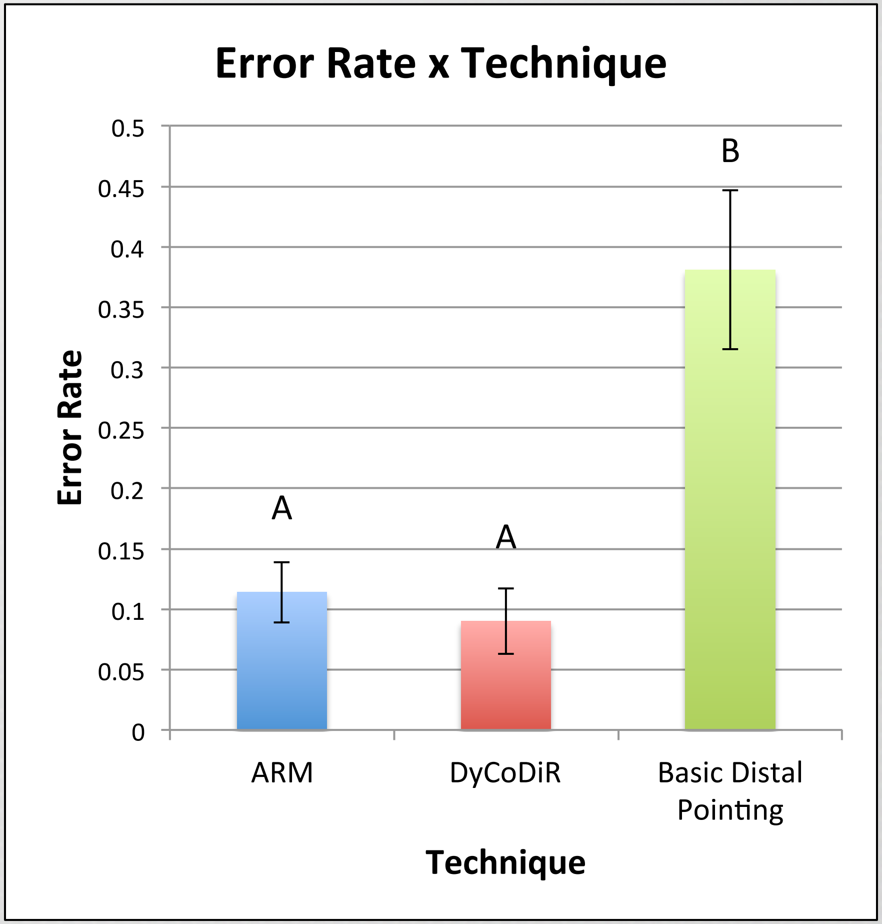
Comparative analysis





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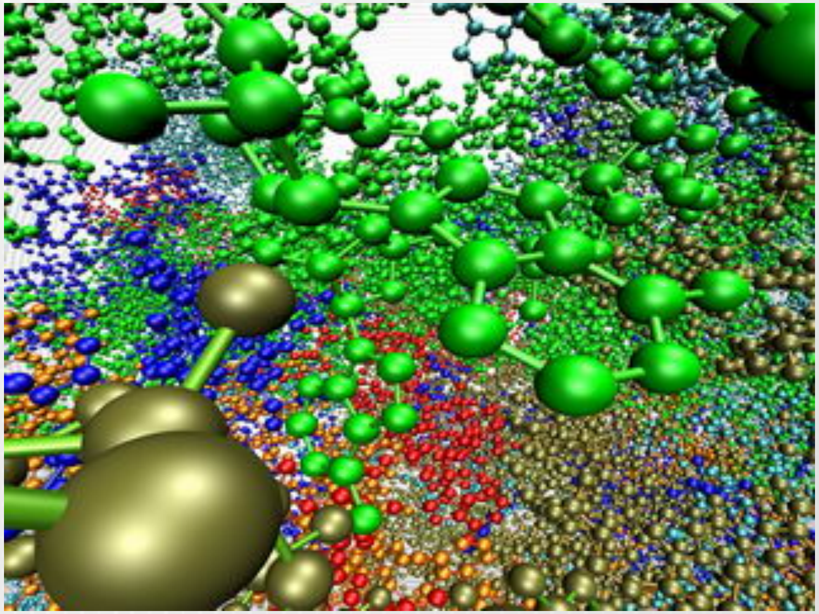
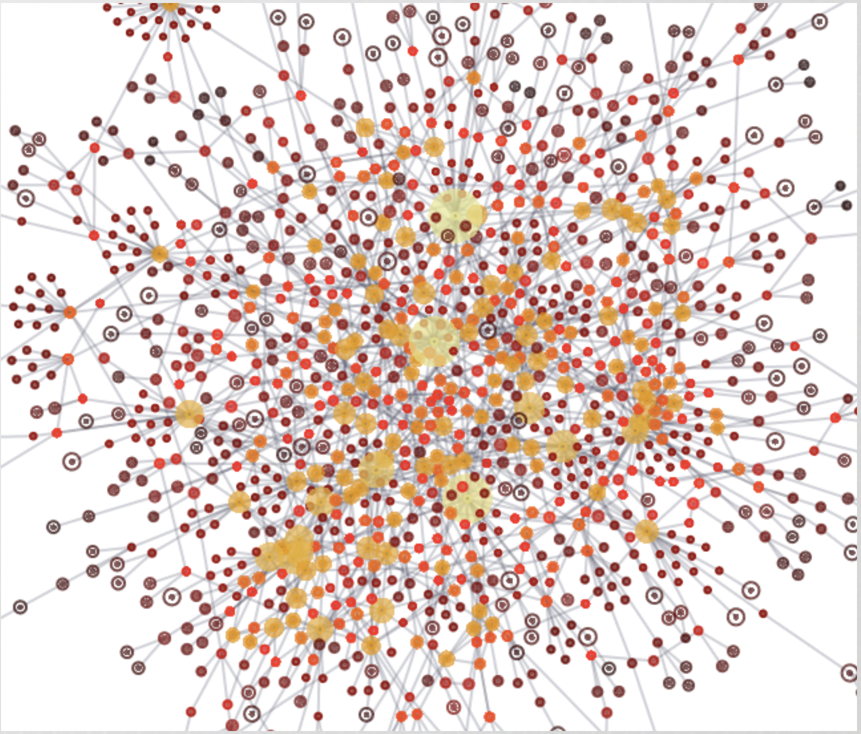
Edge cases for interaction

- Highly-cluttered interfaces





A different approach

- Usually selections are immediate
  - Require high precision
- Gradual refinement of target space
  - Low accuracy stages over time
- Selection by Progressive refinement

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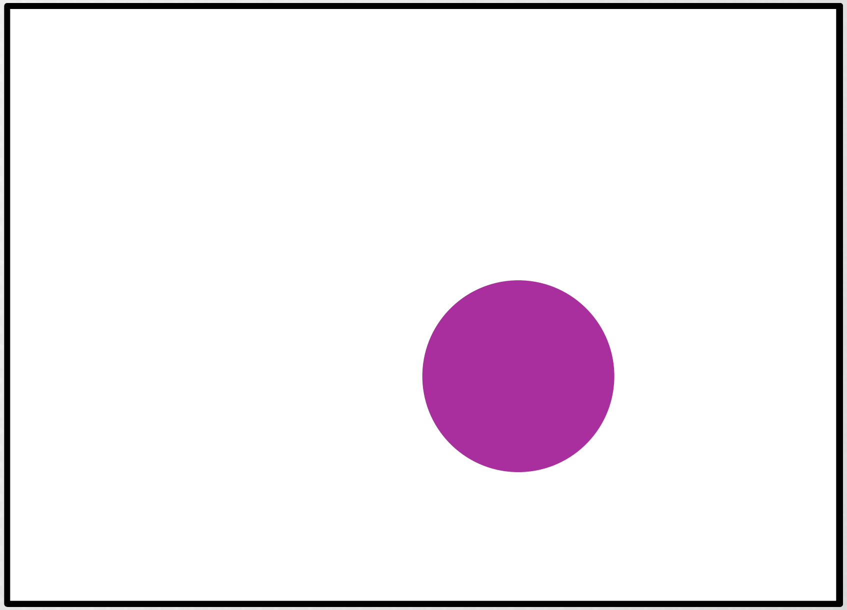
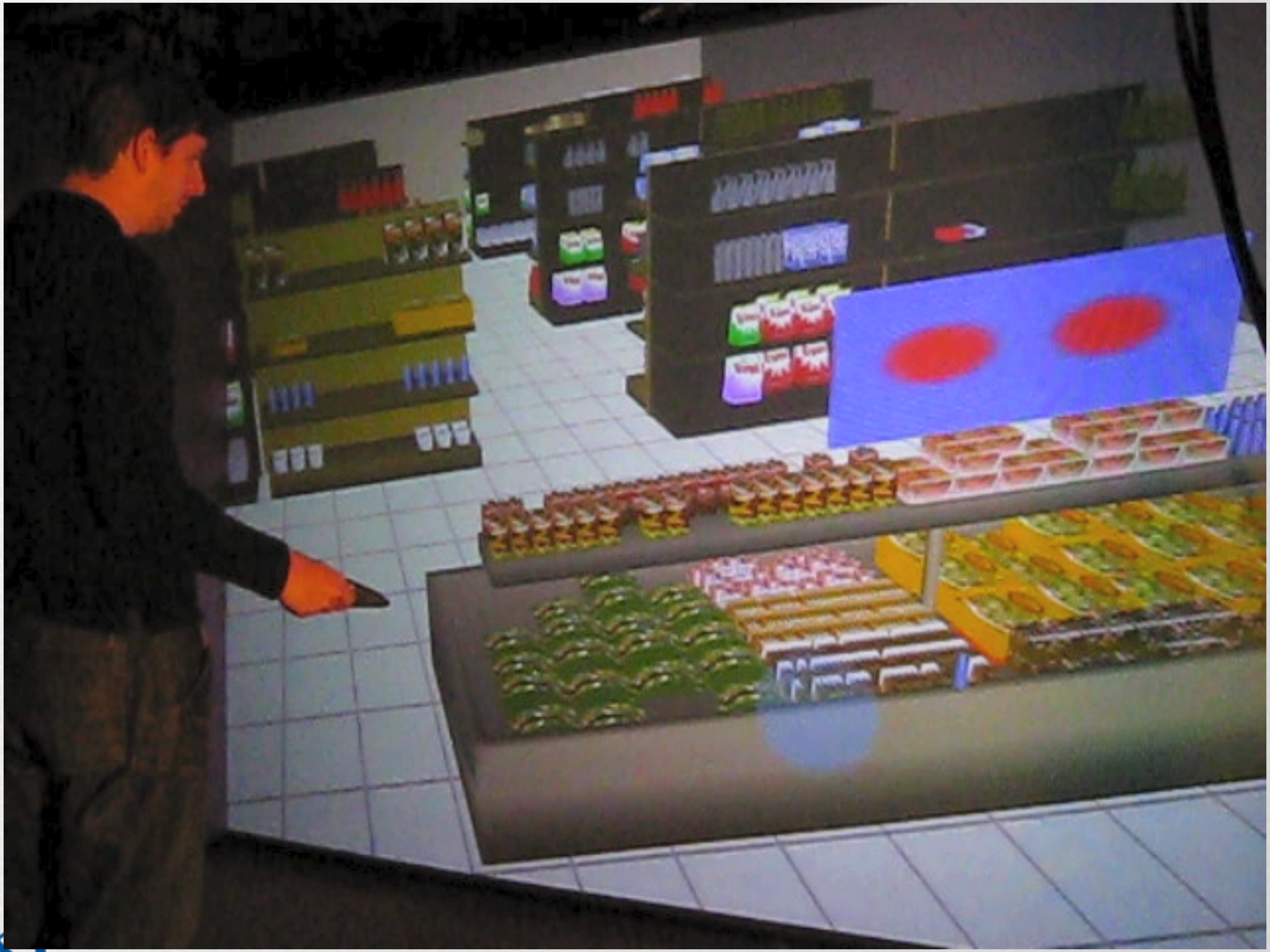
Selection by progressive refinement

- Concept: Gradually reduce the set of selectable objects until only one target remains



SQUAD - Sphere-casting followed by QUAD-menu selection



Comparative Evaluation – SQUAD vs. Basic Distal Pointing

- SQUAD was faster than distal pointing for small targets and sparse environments
- However, SQUAD led to virtually no errors, showing the high accuracy supported by the technique
- Guideline: progressive refinement techniques should be used when there is a high penalty for errors

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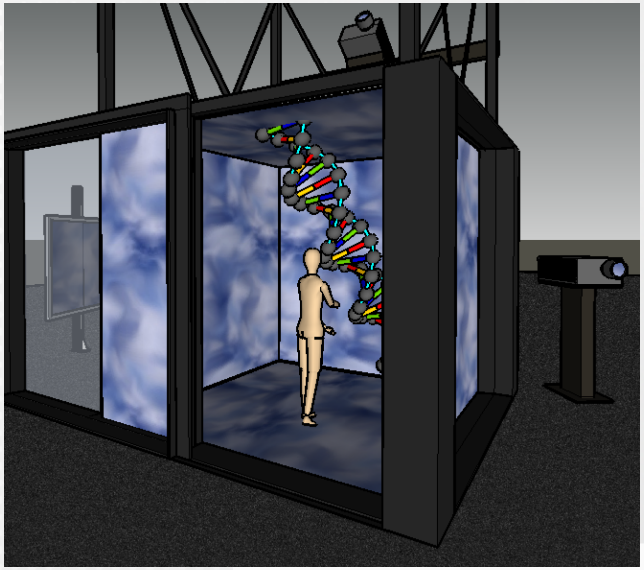
Virtual reality display types



Projection-based

Head-mounted displays

Table-top displays

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Components of display fidelity

- Display fidelity: realism of the display in relation to our capacity to perceive the world
- Higher fidelity leads to more immersive displays
- Multiple dimensions
  - Field of View
  - Field of Regard
  - Stereoscopy
  - Resolution
  - Graphics Realism
  - ...
- Rather than “immersive” vs. “non-immersive” VR, level of immersion is defined as a multidimensional continuum

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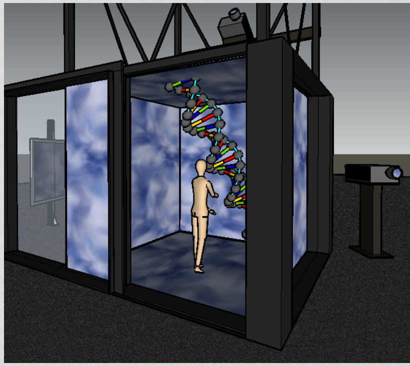
Displays in immersion continuum



Less immersive

More immersive

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Advantages of Immersive VR

- More and better depth cues
- Proprioceptive cues
- Greater spatial understanding
- More accurate and efficient visual analysis
- Better training transfer

How can we prove these?

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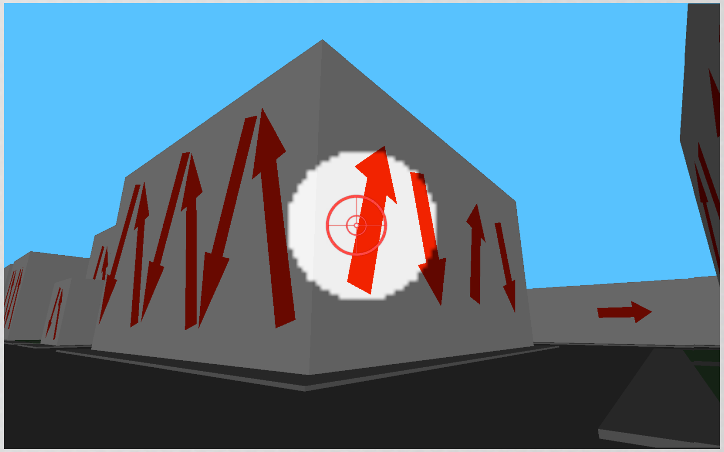
Effects of field of view and visual realism on VR training effectiveness


- Visual scanning task
  - Identify threats (people holding weapons)
  - Avoid non threats
- Strategy
  - Sweeping pattern
- HMD
  - 102^{o} x 64^{o} FOV
- Three phases
  - Learning (scanning strategy)
  - Training (threat identification)
  - Assessment



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Paper under review. Collaboration with Eric Ragan, Doug Bowman, Cheryl Stynson, Siroberto Scerbo and Ryan McMahan

Study Design

- Independent variables
  - Field of view and scene complexity

- Metrics
  - Number of identified threats and visual scanning strategy
- Assessment done in High FOV / High Scene Complexity
  - Simulating "real world"

Results

- Effects of FOV
  - Training performance better with higher FOVs
  - No effect of FOV on training transfer either on performance or strategy
- Effects of visual realism
  - No effect of visual realism on assessed task performance
  - Low realism led to low adherence to scanning strategy
- Conclusions
  - Important to train in realistic environment
  - Learning is a more important metric than performance to assess training transfer

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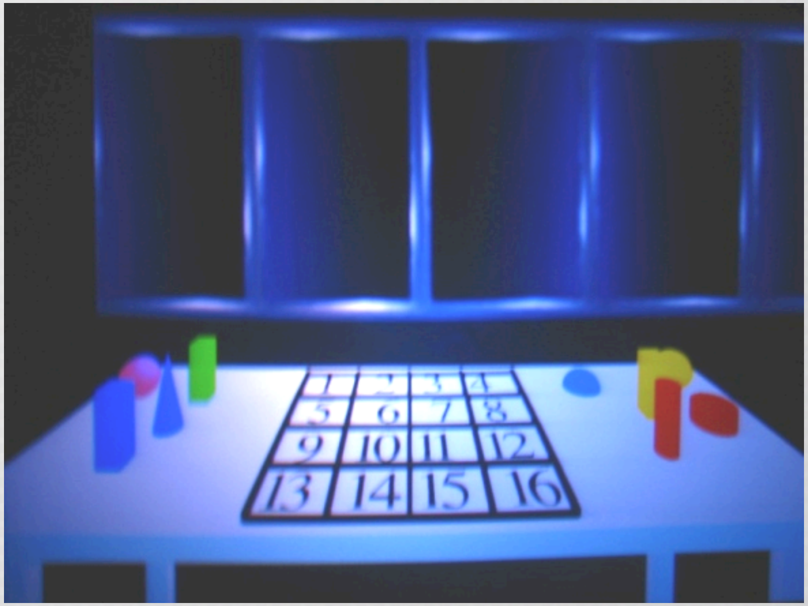
Levels of immersion for procedure memorization tasks

- What components of display fidelity afford procedure memorization?
- Study conducted at VT CAVE
- Abstract Procedure
  - 8 steps
  - "Move the blue cone to position #12" (1 step)



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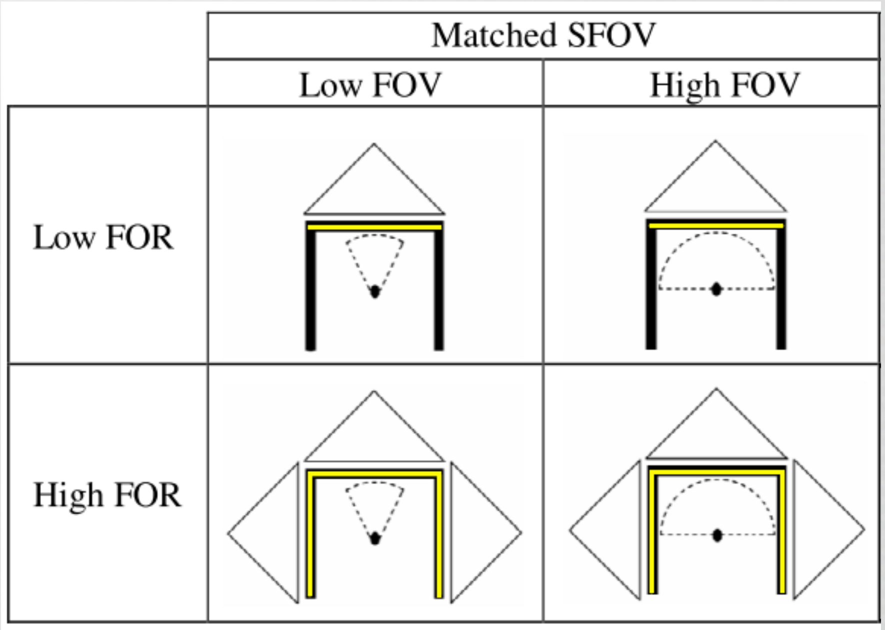
E. Ragan, A. Sowndararajan, R. Kopper, and D. A. Bowman. "The Effects of Higher Levels of Immersion on Procedure Memorization Performance and Implications for Educational Virtual Environments." Presence: Teleoperators and Virtual Environments (2010).

Design

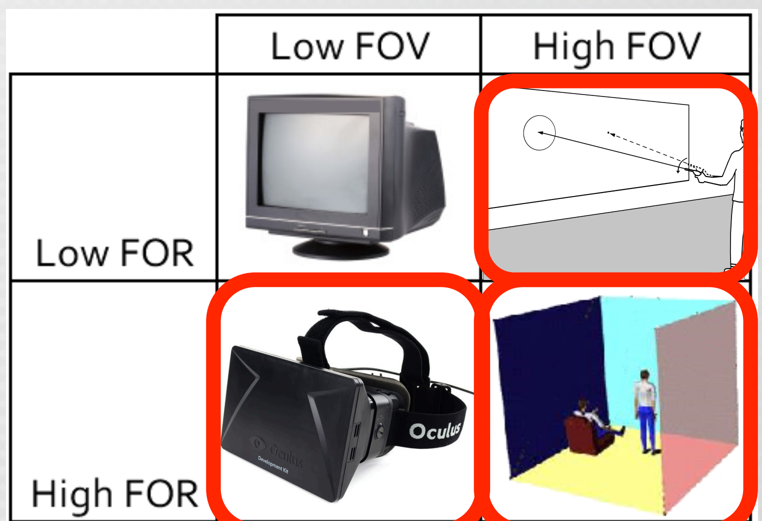
- Independent variables
  - Field of view
  - Field of regard



Results

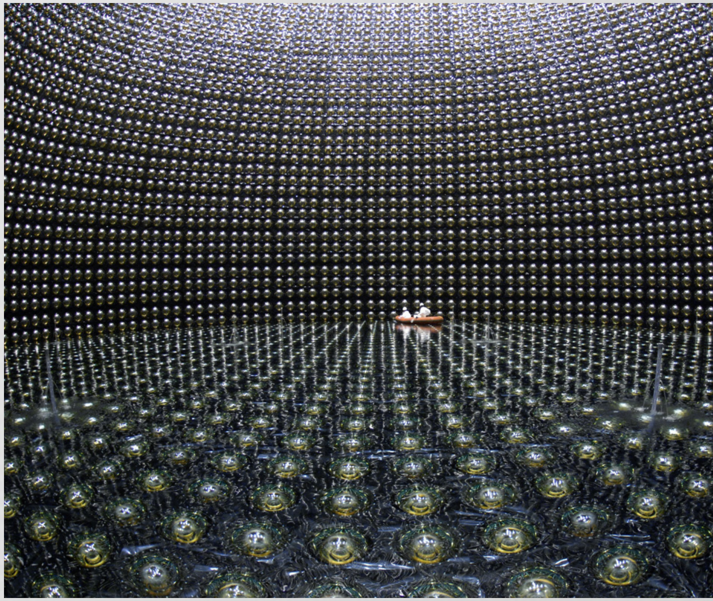
Time	Matched SFOV	
	Low FOV	High FOV
Low FOR	78.76	52.73
High FOR	49.54	45.53

Errors	Matched SFOV	
	Low FOV	High FOV
Low FOR	3.46	1.00
High FOR	0.58	0.21



Neutrino Physics Immersive Interactive Visualization

- Super-Kamiokande (Super-K)
  - Water-based Cherenkov radiation detectors
  - Neutrino data calculated from Cherenkov energy signature
  - Large and multilayered datasets



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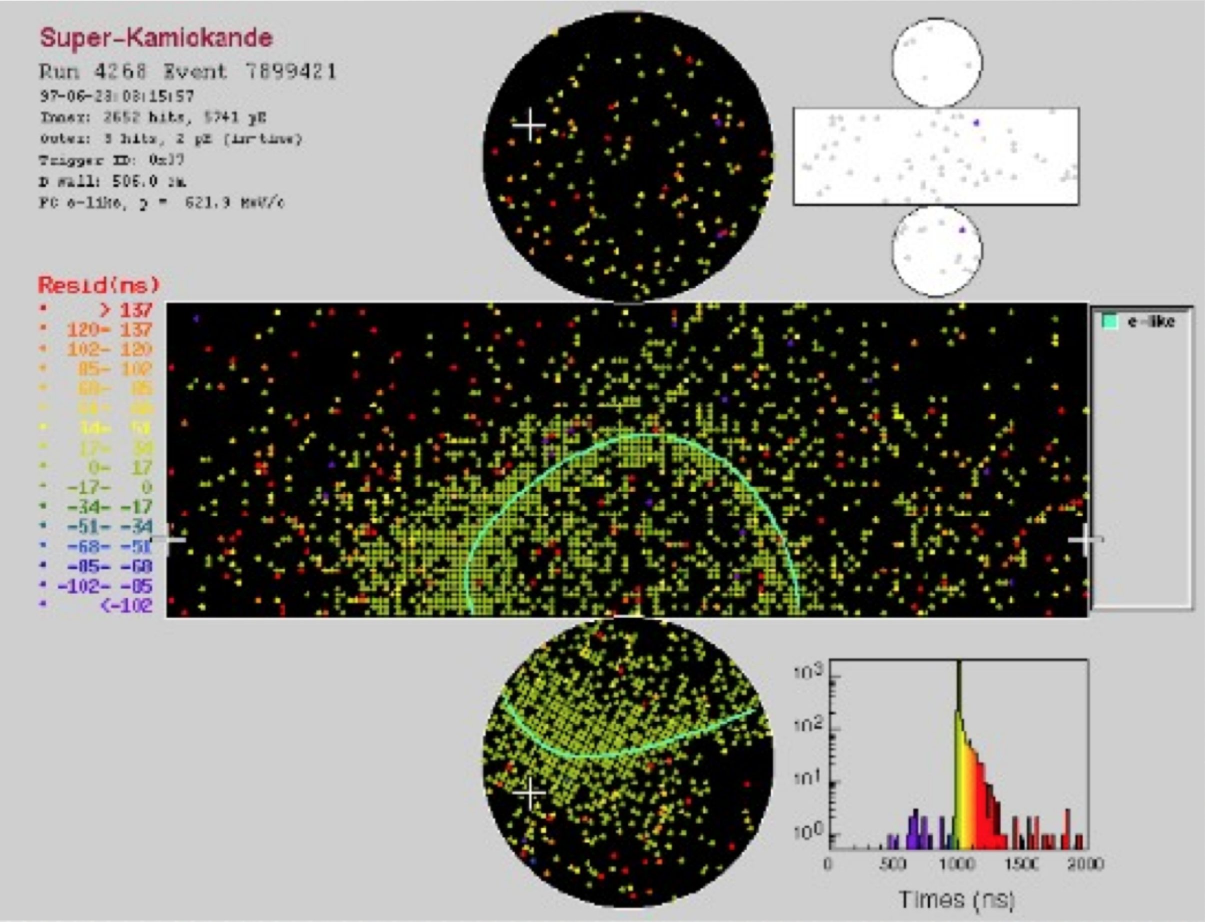
Elizabeth Izatt, Kate Scholberg, and Regis Kopper. "Neutrino-KAVE: An Immersive Visualization and Fitting Tool for Neutrino Physics Education." In IEEE Virtual Reality Conference Posters (2014).

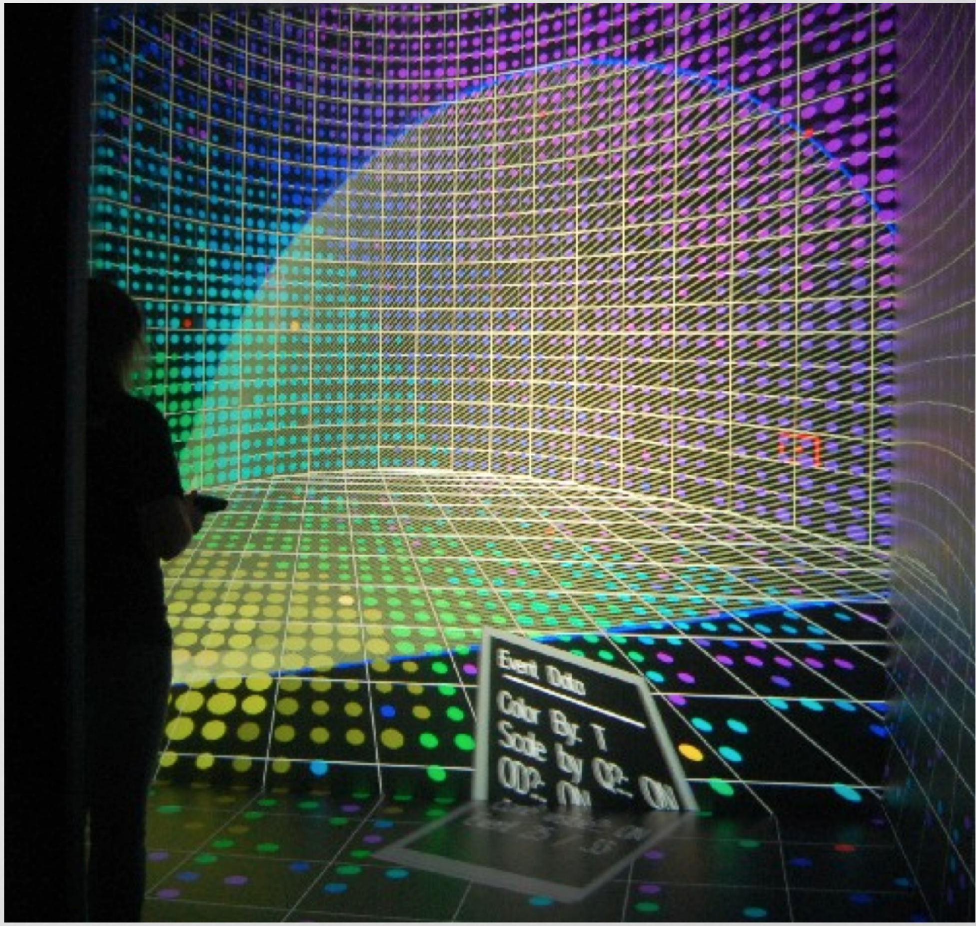
Existing Tools

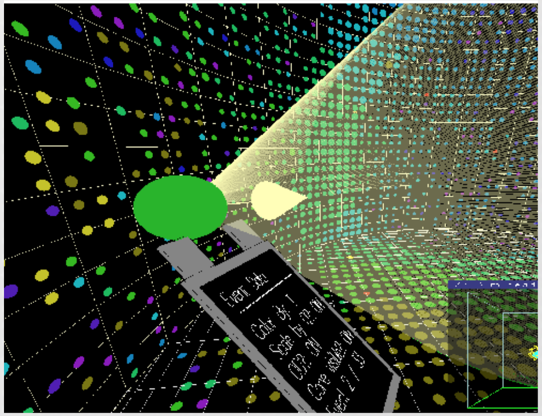
- Superscan



The Super-KAVE Application

- 1:1 model of Super-K
- Event visualizations
- Wrist-bound time playback
- Manual fitting mode





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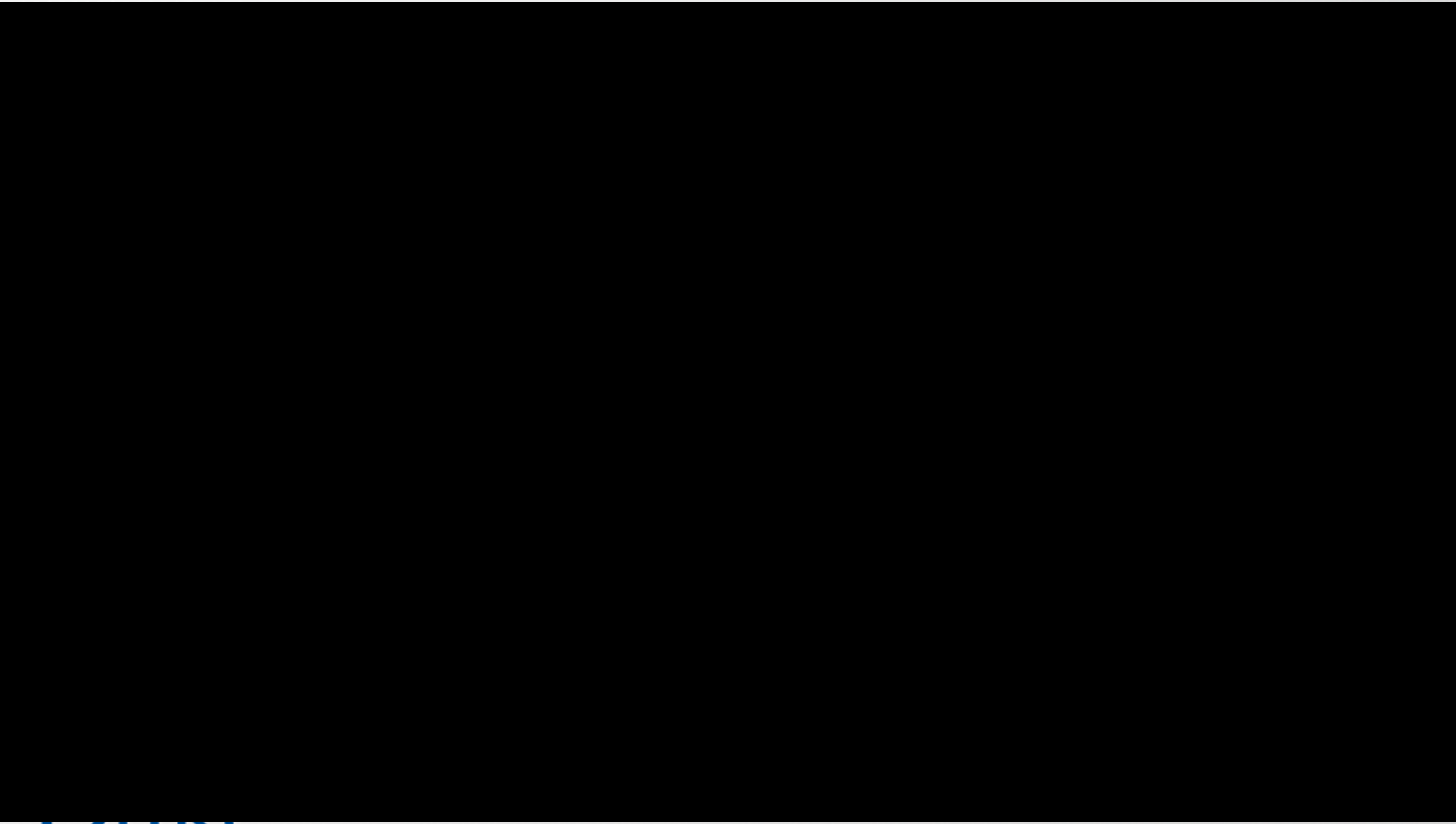
Video: Super-KAVE

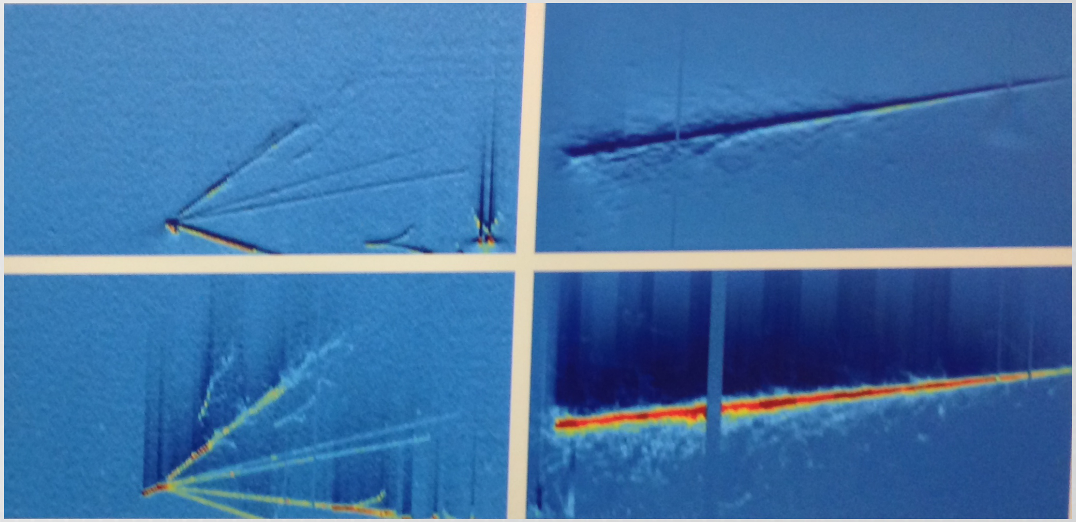


Super-KAVE

- Currently, app runs in the DiVE
- Oculus application coming soon!

Neutrino Physics

- Currently, project serves as an education and outreach tool
  - Automatic fitting, existing desktop tool
- Future detectors (e.g., liquid argon time projection chamber), may produce unique insight in an immersive system
  - Complex data structure
  - Currently, no perfect automatic fitting



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Neutrino Physics and Virtual Reality

- As with other applications, we can't assume that VR will be effective
- We need to find use cases that may benefit from VR and validate it through user studies
- For example: use an HMD, a CAVE and a desktop to analyze complex neutrino event displays.

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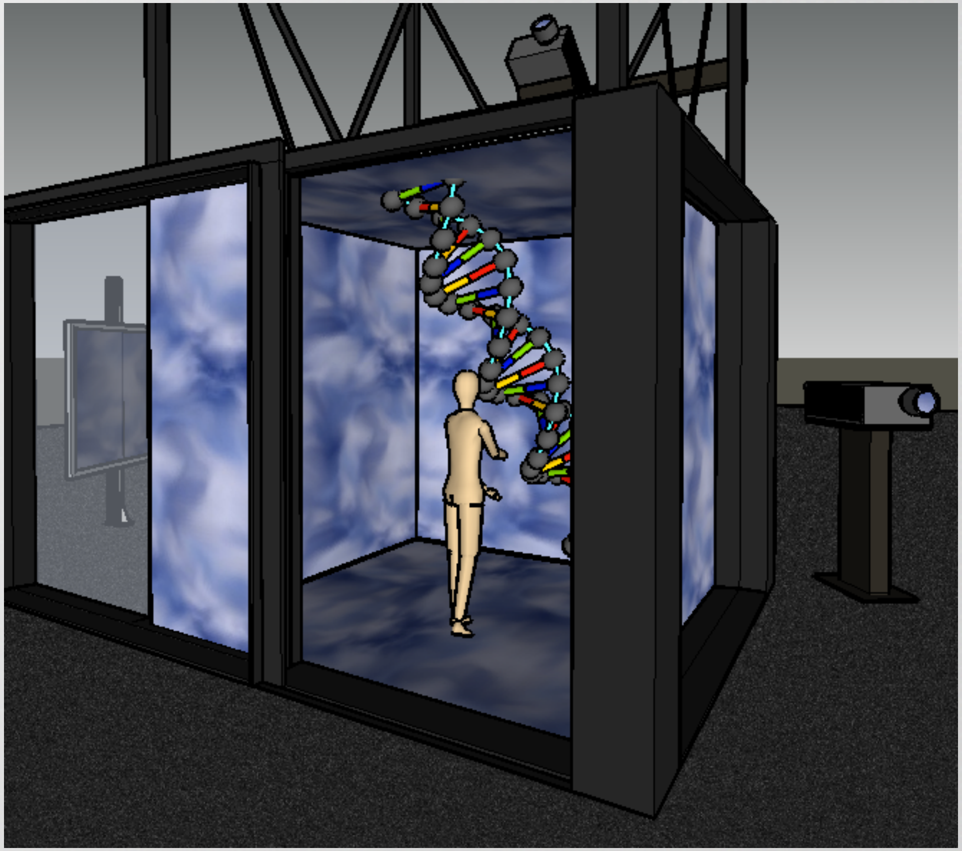
Duke Virtual Reality Infrastructure

- The Duke immersive Virtual Environment (DiVE)
  - 6-sided immersive visualization chamber
  - Six projectors
  - Motion tracking of head and hands
  - Stereoscopic graphics
  - Multiple users
  - Unique infrastructure
  - Highest (?) level of immersion



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Other VR Infrastructure

- Oculus Rift
  - High-fidelity, consumer-level head mounted display
- zSpace
  - Immersive Desktop Workbench
- Cross-platform development with Unity3D

CAVE or HMD?

CAVE	HMD
High FOR	High FOR
High FOV	Lower FOV
Input device occlusion	No occlusion
User body is visible	User is disembodied ☆
Multiple users (although single controller)	Single user (potentially networked) ☆
High cost	(Very) Low cost

- CAVE is more immersive overall, but very few studies compare the different types of displays in realistic tasks.
- More studies should be done in order to quantify the benefits not only of VR displays, but between different types of VR displays.

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Thank you!

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For more information:

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