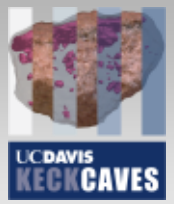


IDAV Institute for Data Analysis and Visualization

Immersive Visual Data Analysis

Oliver Kreylos

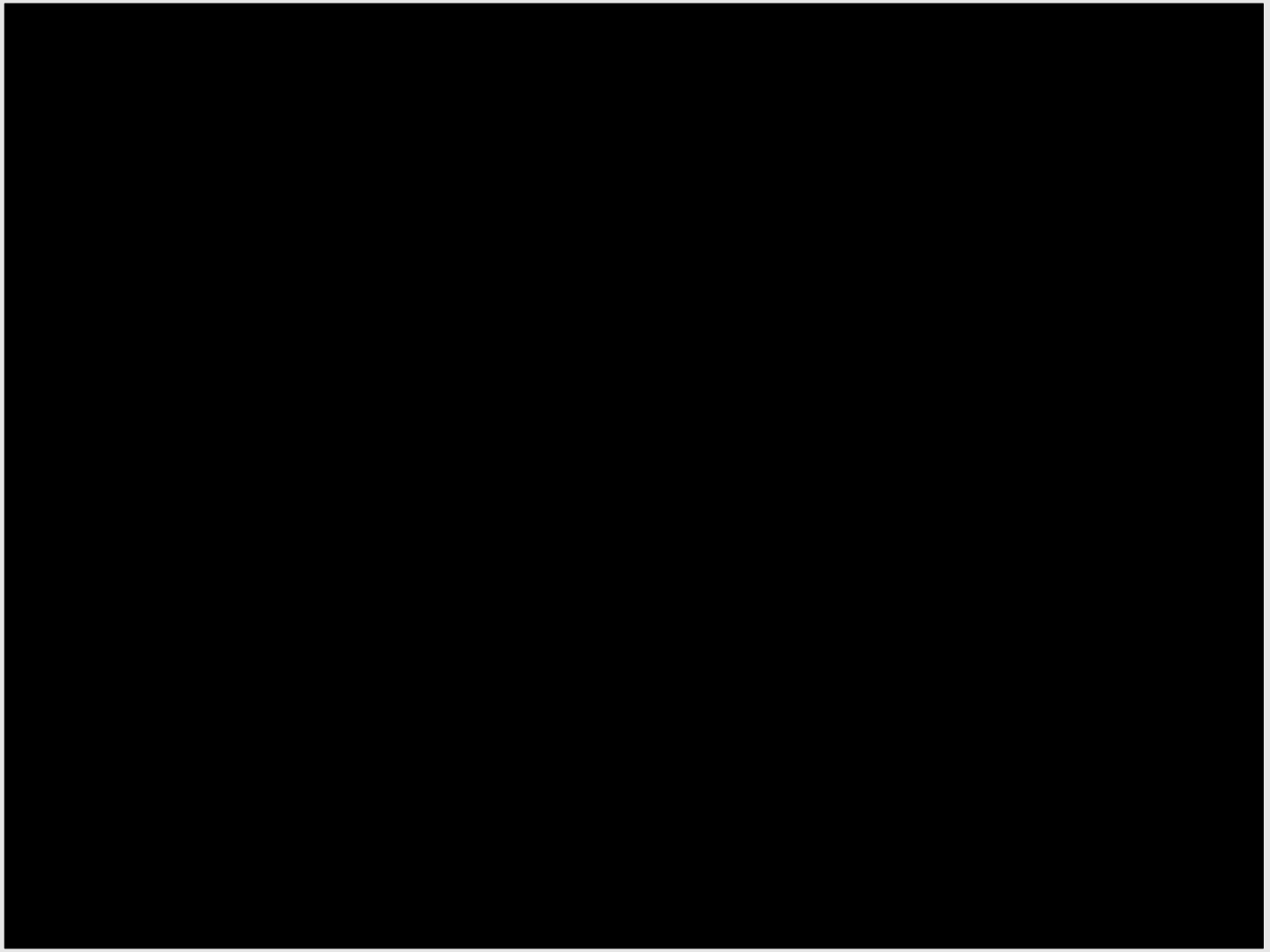
W.M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES)

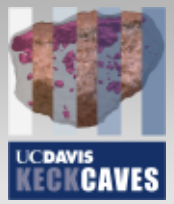
University of California, Davis

KeckCAVES

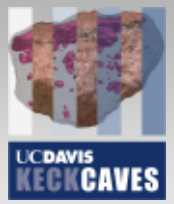
- Interdisciplinary research project
  - Computer science
  - Physical sciences
  - Faculty, post-docs, graduate/undergraduate students
- Develops virtual reality (VR) for scientific data analysis
  - Methods, software, systems
- Visualization facility
  - Shared access to high-end visualization

KeckCAVES





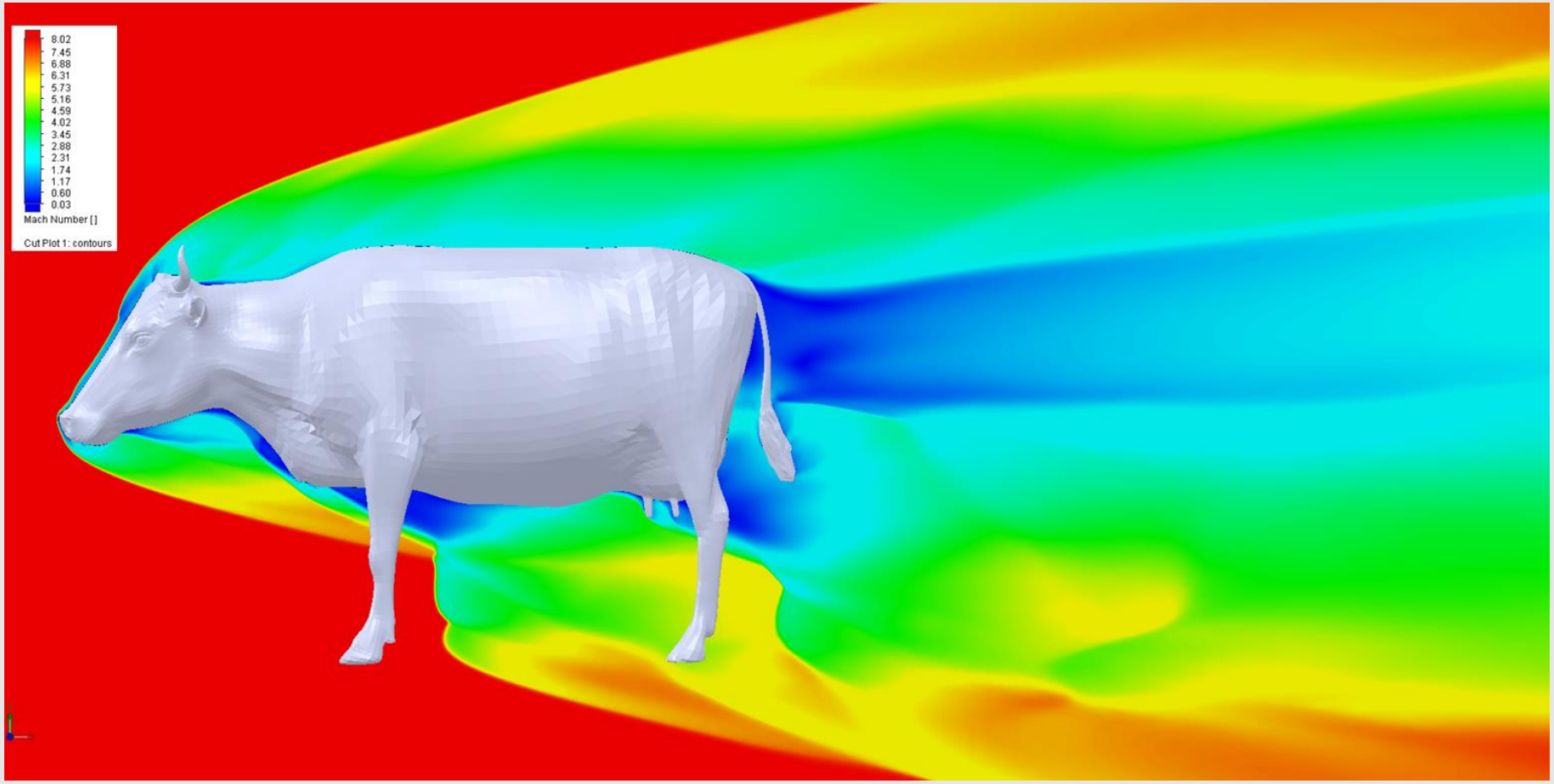
Principles of Scientific Visualization



Data-Driven Science

- Modern science is in the business of creating, processing, and consuming massive amounts of data
- Data sizes are driven by high-resolution sensors and high-performance computing
- Example: Computational Fluid Dynamics (CFD)
- A single wind tunnel simulation can create petabytes of data

CFD: Cow at Mach 8

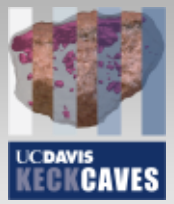


(from http://blogs.mentor.com/robinbornoff/blog/)

Data-Driven Science

- End product of science is **insight**, not **data**
- Scientific process turns data into insight:

- Data analysis usually a multi-step pipeline
- Data analysis is often manual

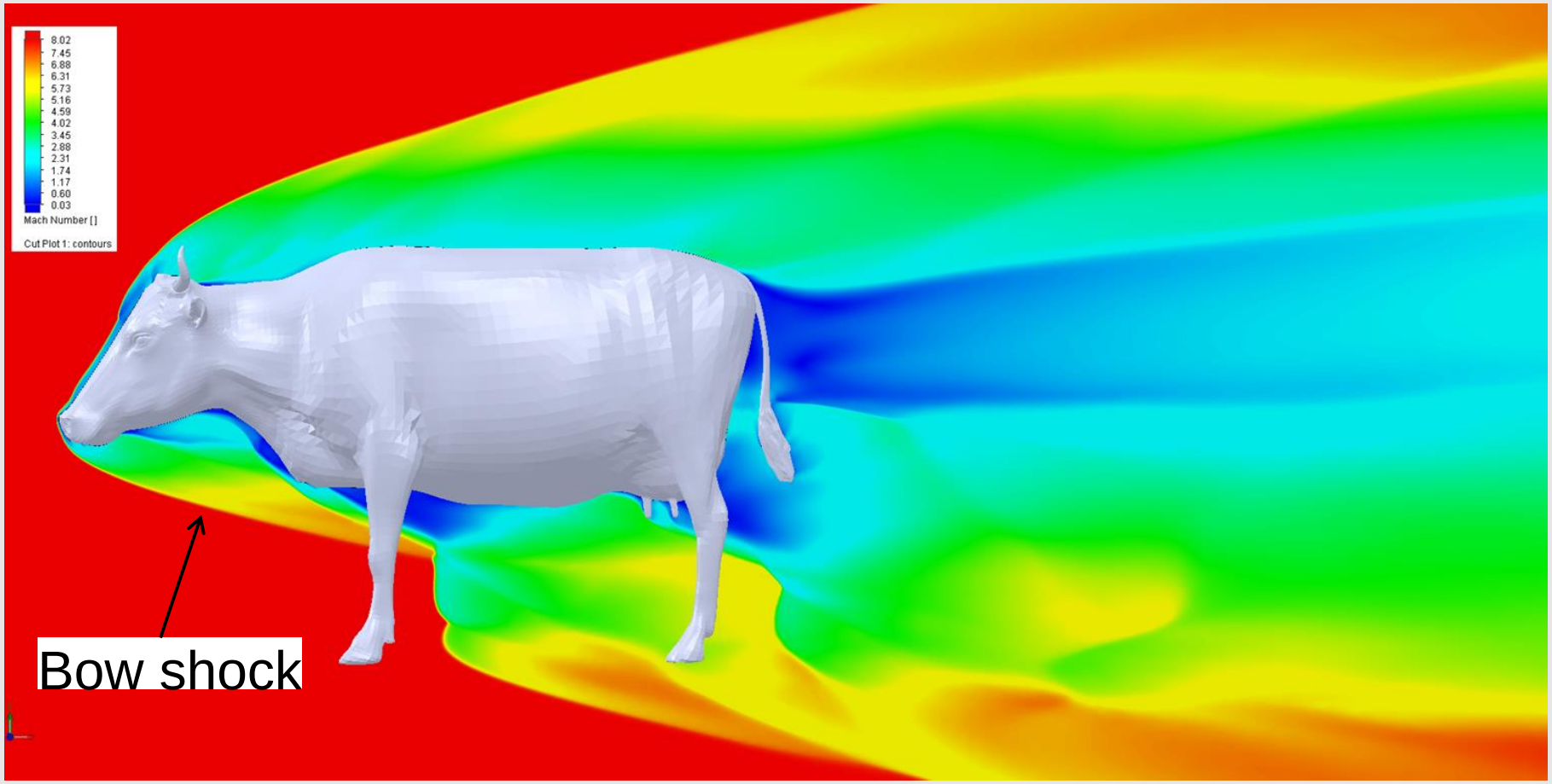


Visualization

“At their best, graphics are instruments for reasoning about quantitative information. Often the most effective way to describe, explore, and summarize a set of numbers – even a very large set – is to look at pictures of those numbers.”

Edward R. Tufte, *The Visual Display of Quantitative Information* (1983)

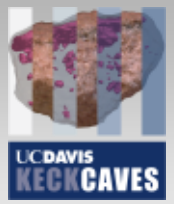
CFD: Cow at Mach 8



(from http://blogs.mentor.com/robinbornoff/blog/)

Classes of Data

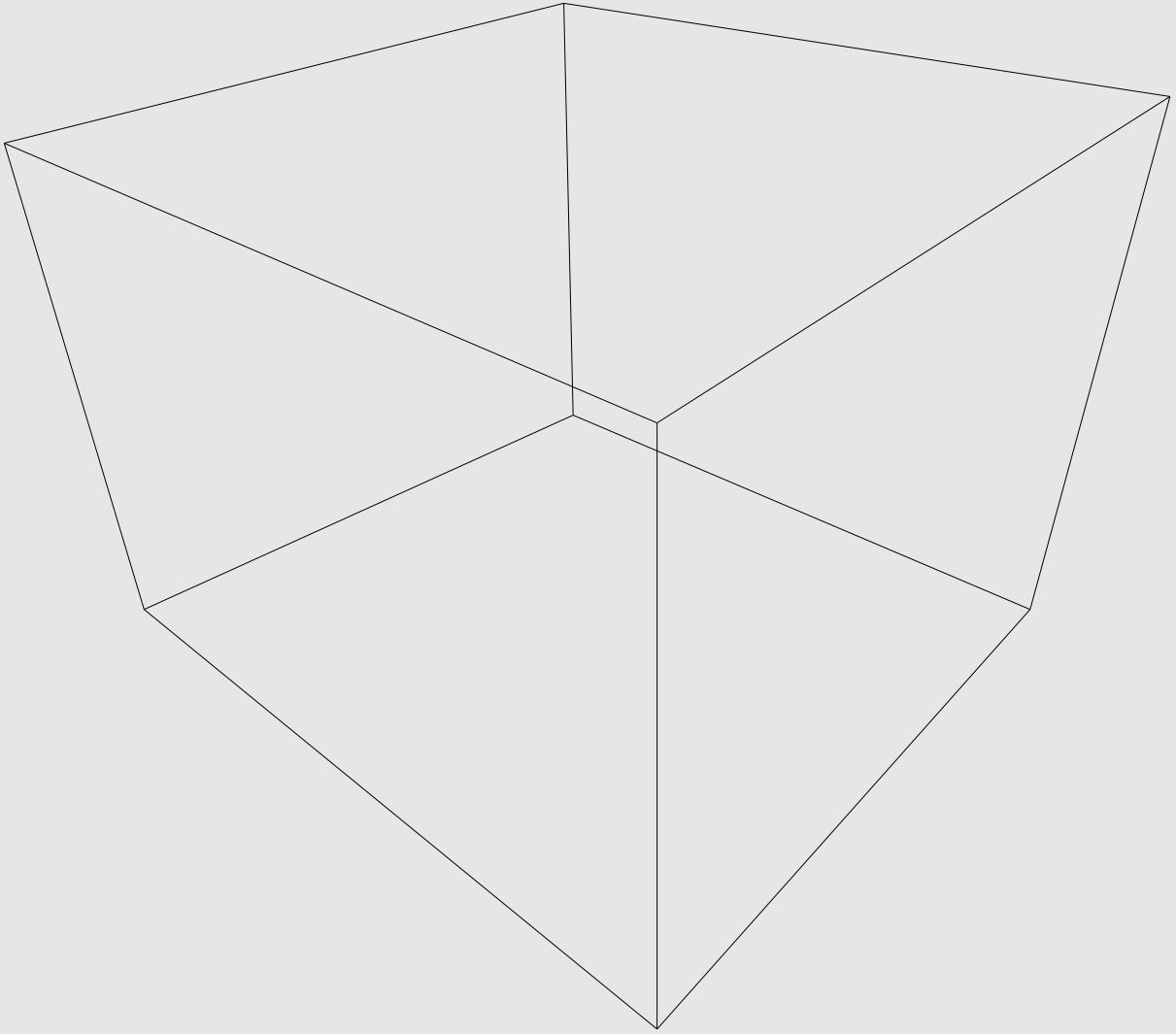
- Two classes of scientific data:
  - Non-spatial
- Gene co-expression networks
  - Spatial
- Air flow around a cow
- Important sub-class:
  - Three-dimensional spatial
- 3D spatial data is problematic for traditional visualization
  - Traditional displays are two-dimensional



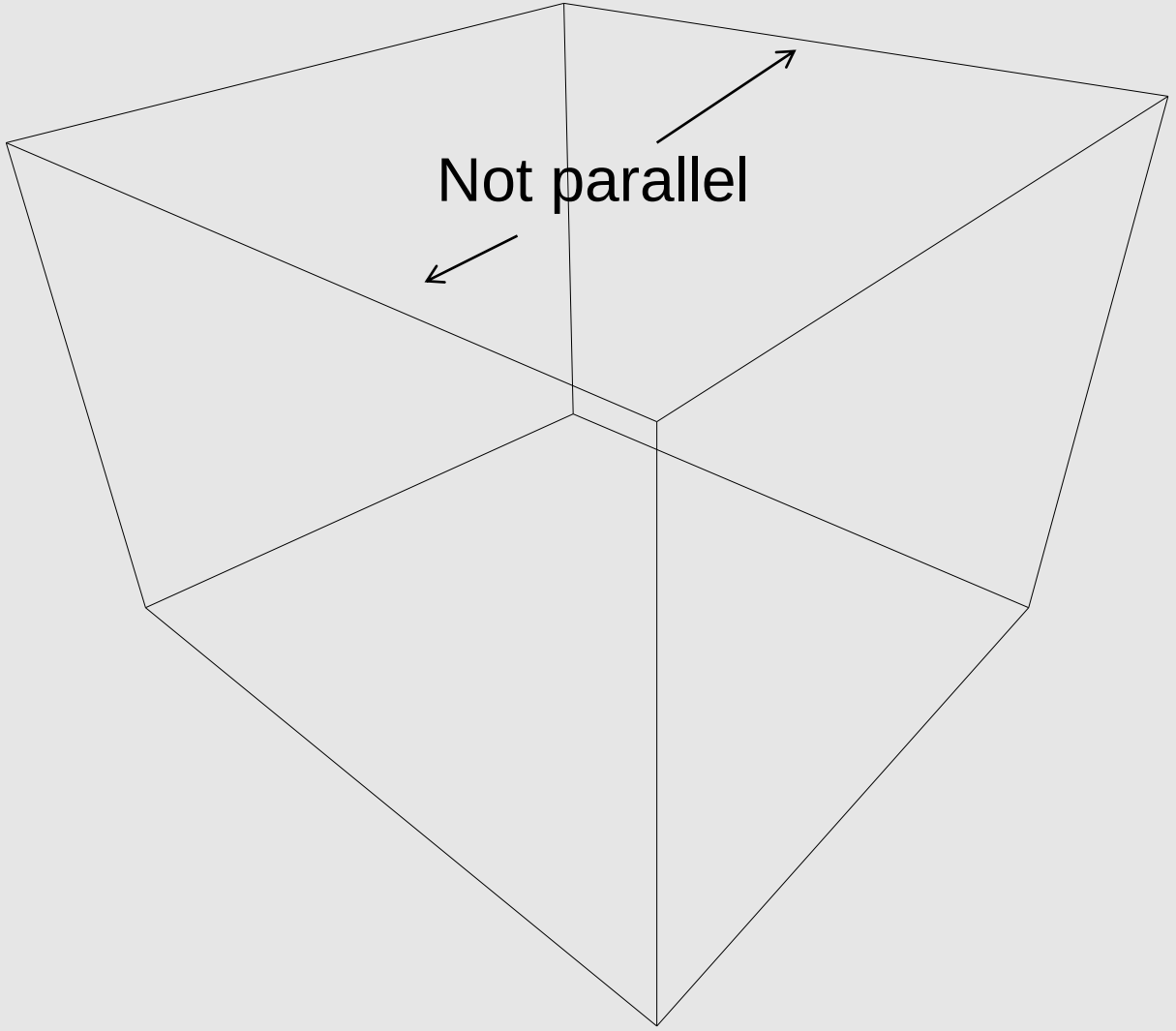
3D Visualization in 2D

- Displaying 3D data in 2D requires projection
- Projection distorts...
  - relative positions
  - distances and sizes
  - angles
  - areas and volumes
- Projection can hide important structure

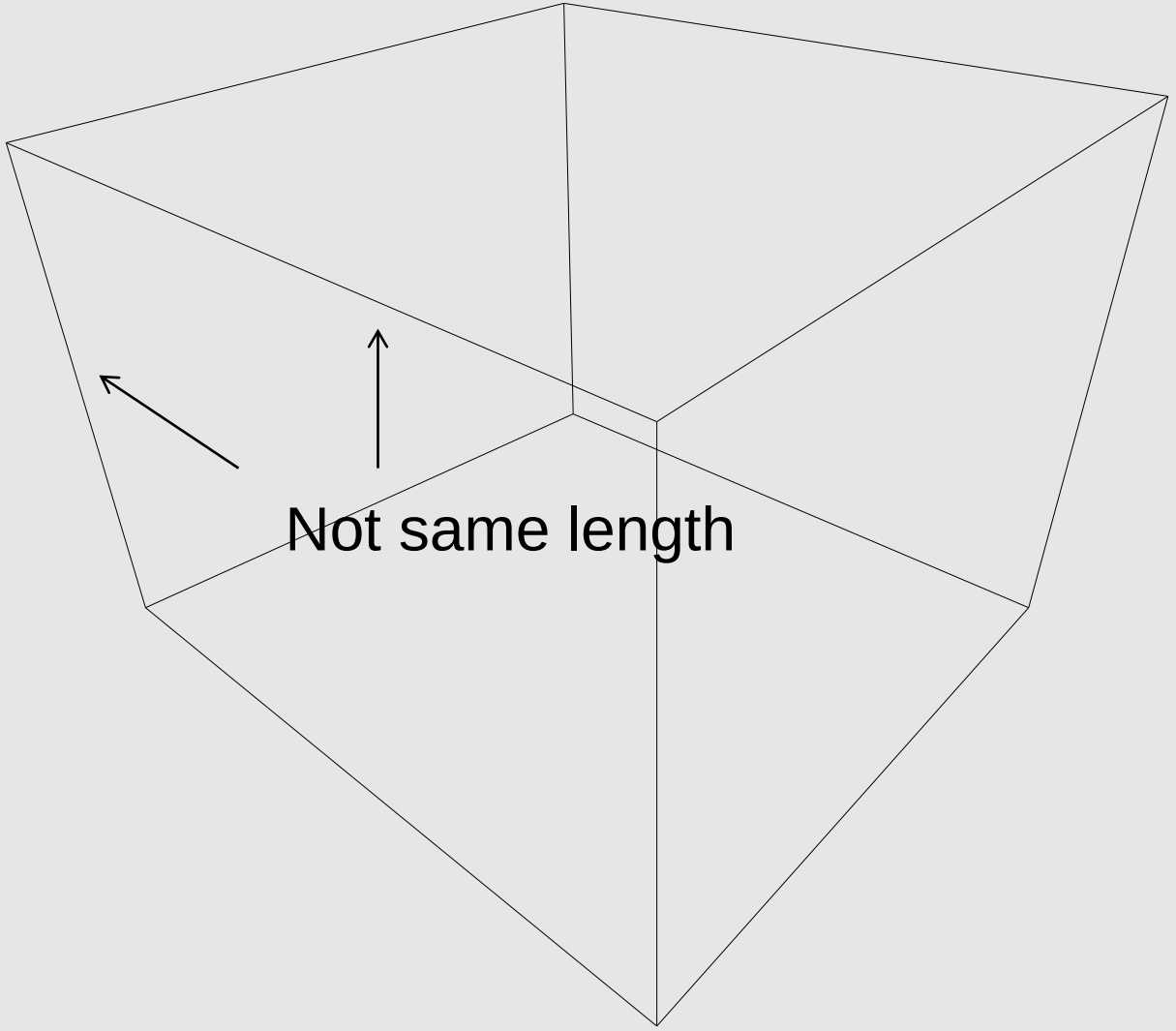
Projection Distortion



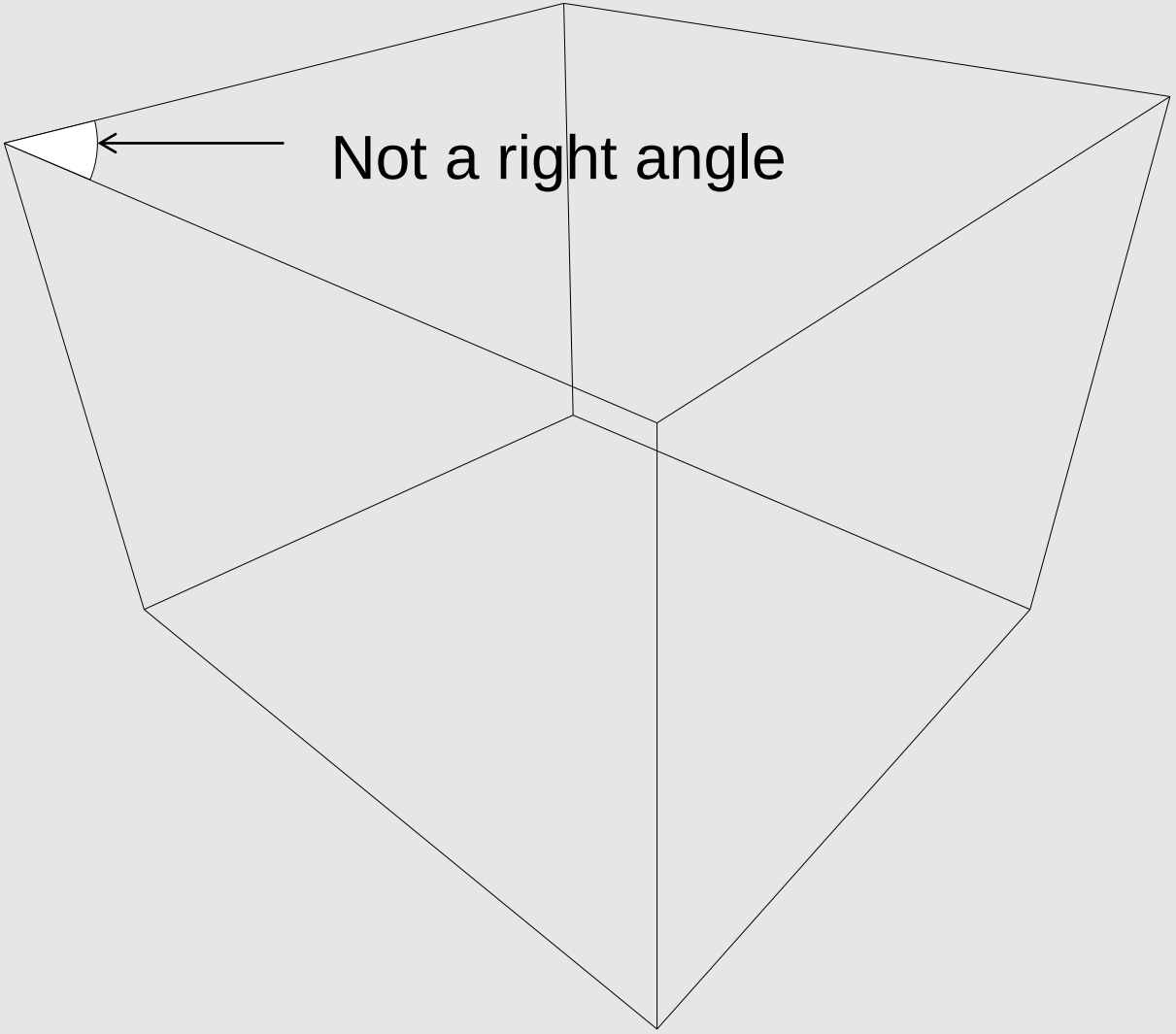
Projection Distortion



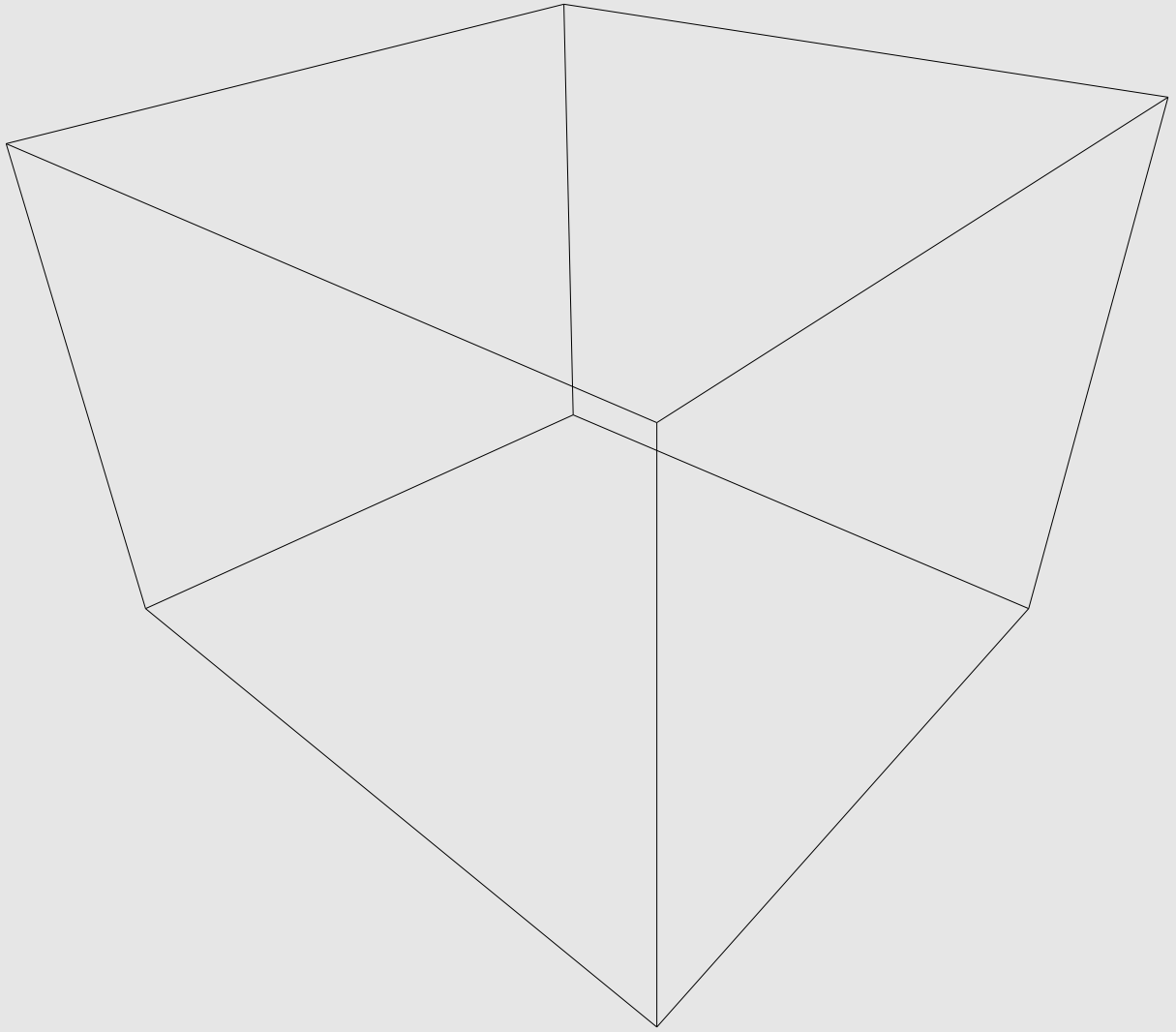
Projection Distortion



Projection Distortion



Projection Distortion

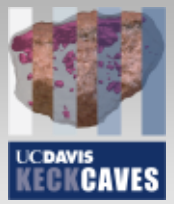


Ceci n'est pas un cube

2D Visualization

- Projection can also create spurious structure

(from http://moillusions.com)



3D Visualization in VR

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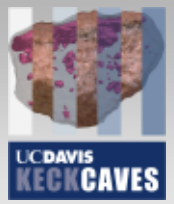
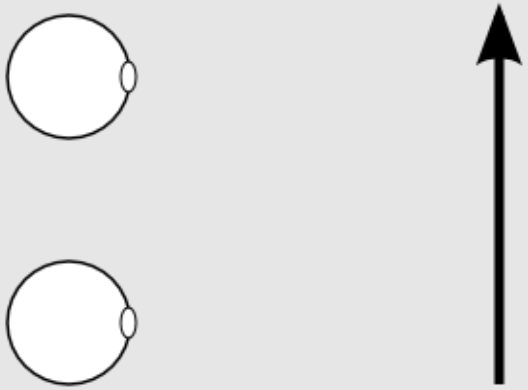
- VR is a display medium for 3D content
- VR presents 3D objects without projection:
  - No distortion of positions, distances, angles, areas, or volumes
  - No hidden or spurious structures
- VR is “holographic”
- VR lets users apply their full power of visual perception to 3D data analysis

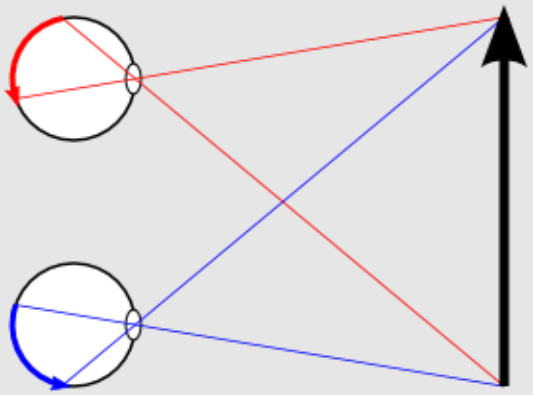


Principles of Virtual Reality

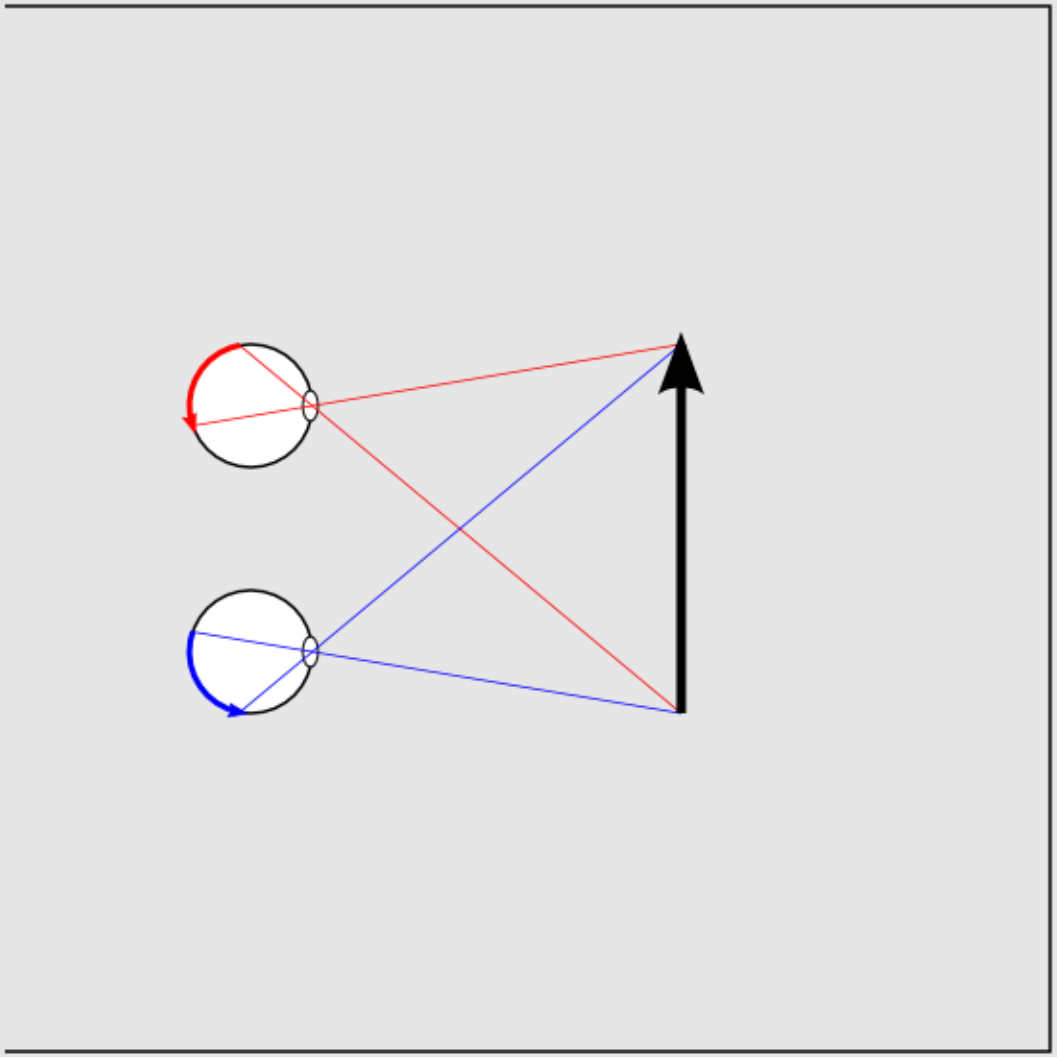
Vision



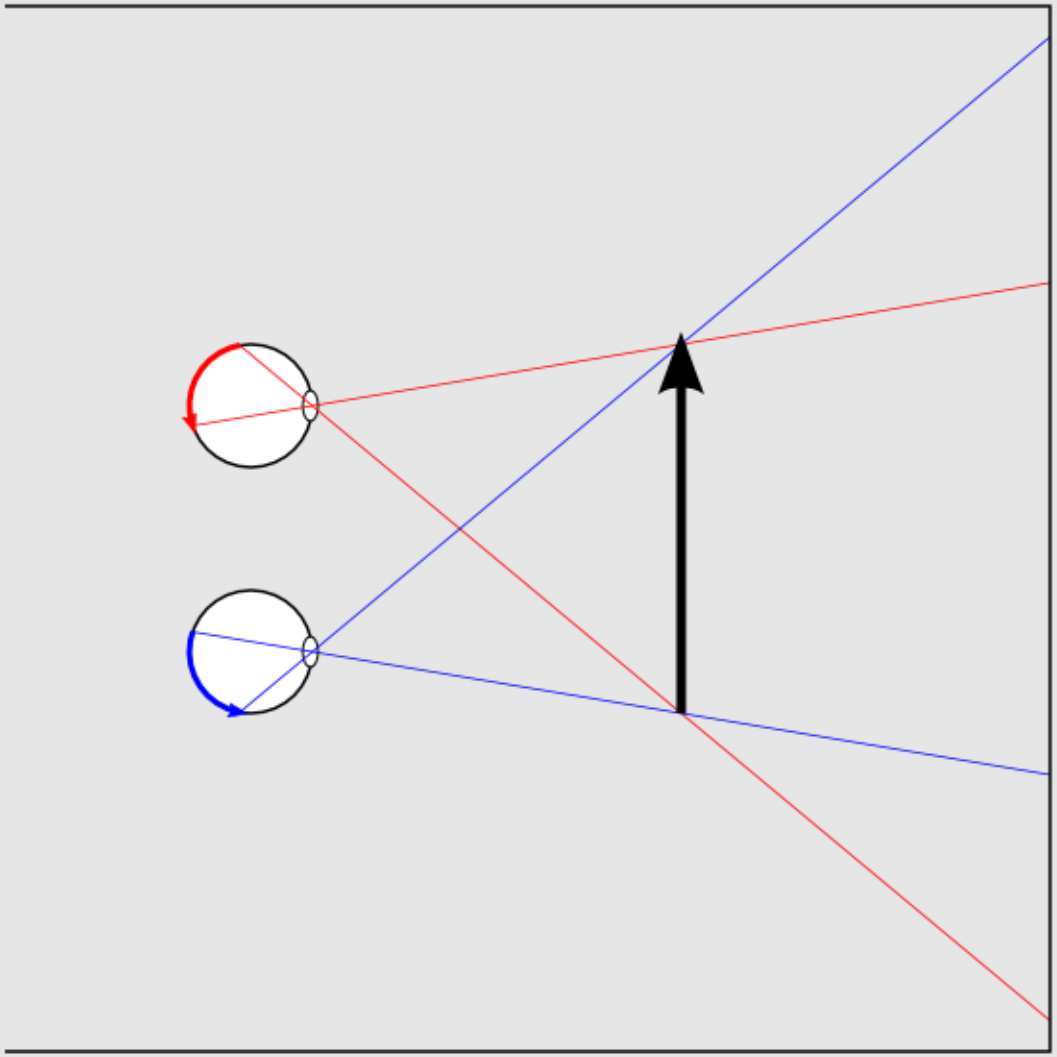
Vision



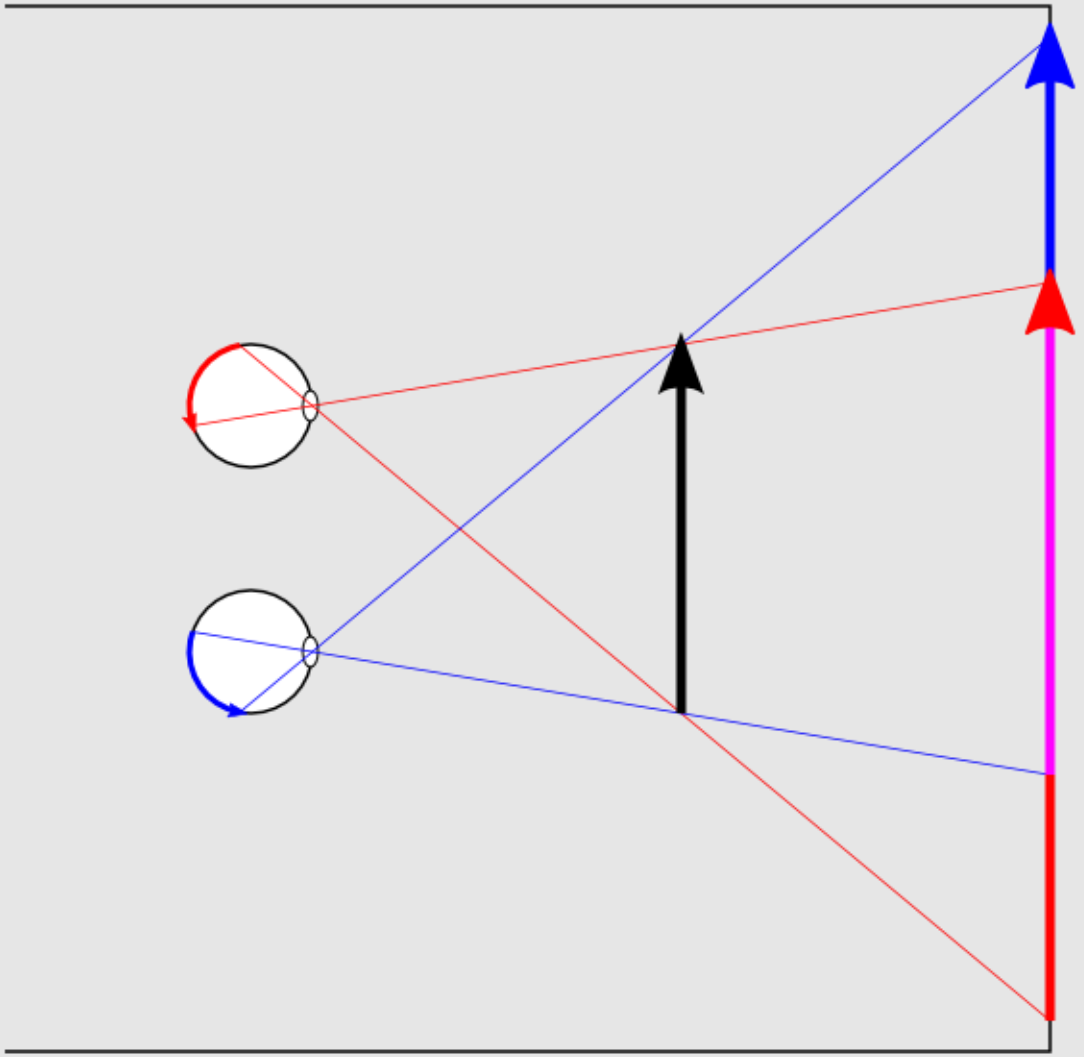
Vision



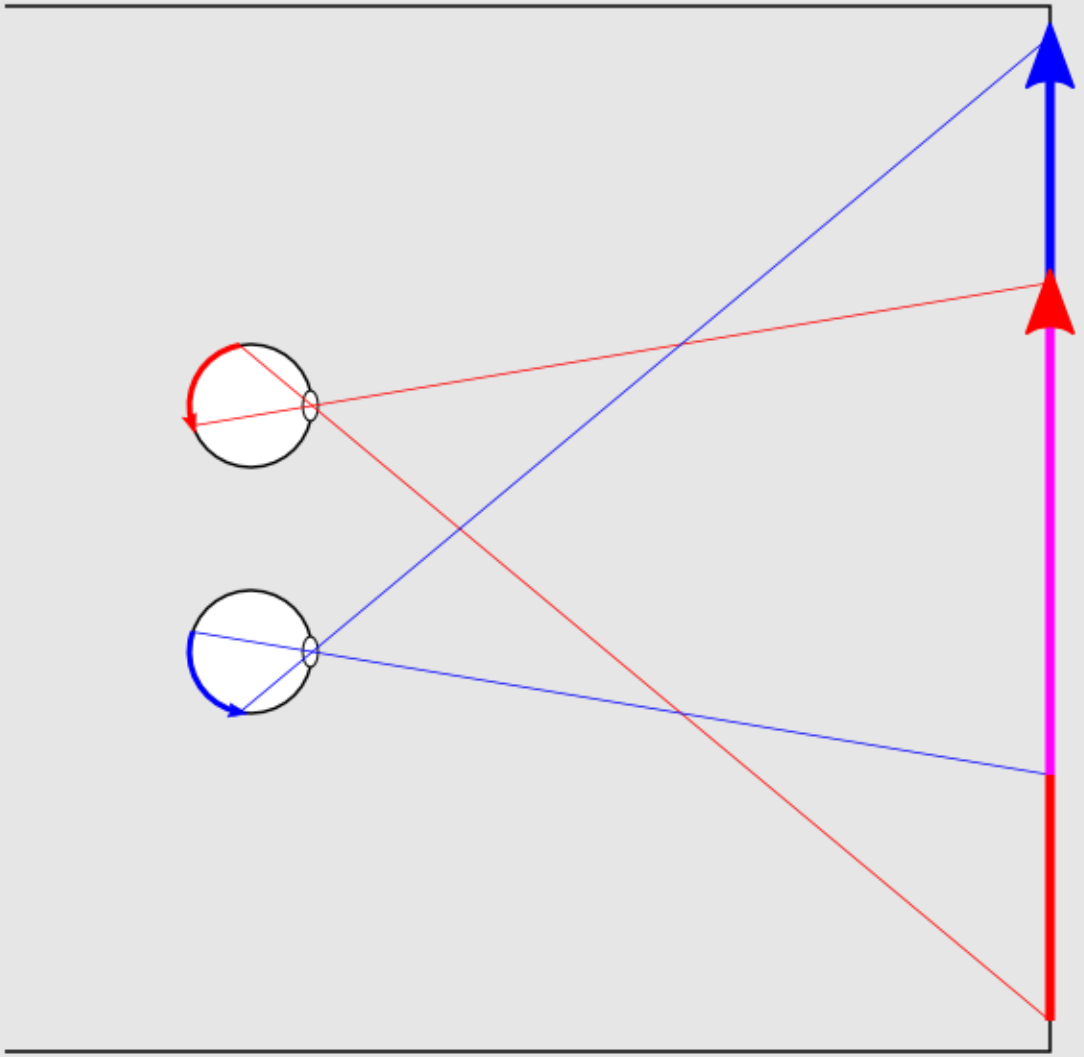
Vision



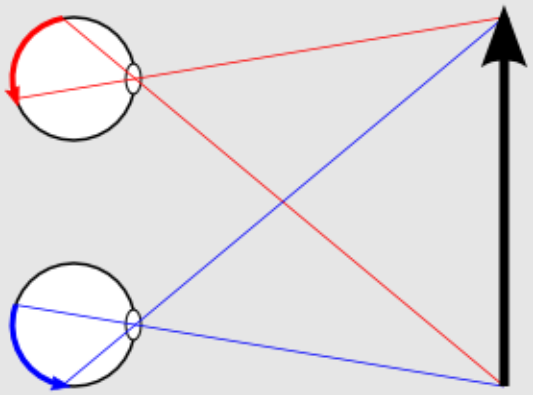
Vision



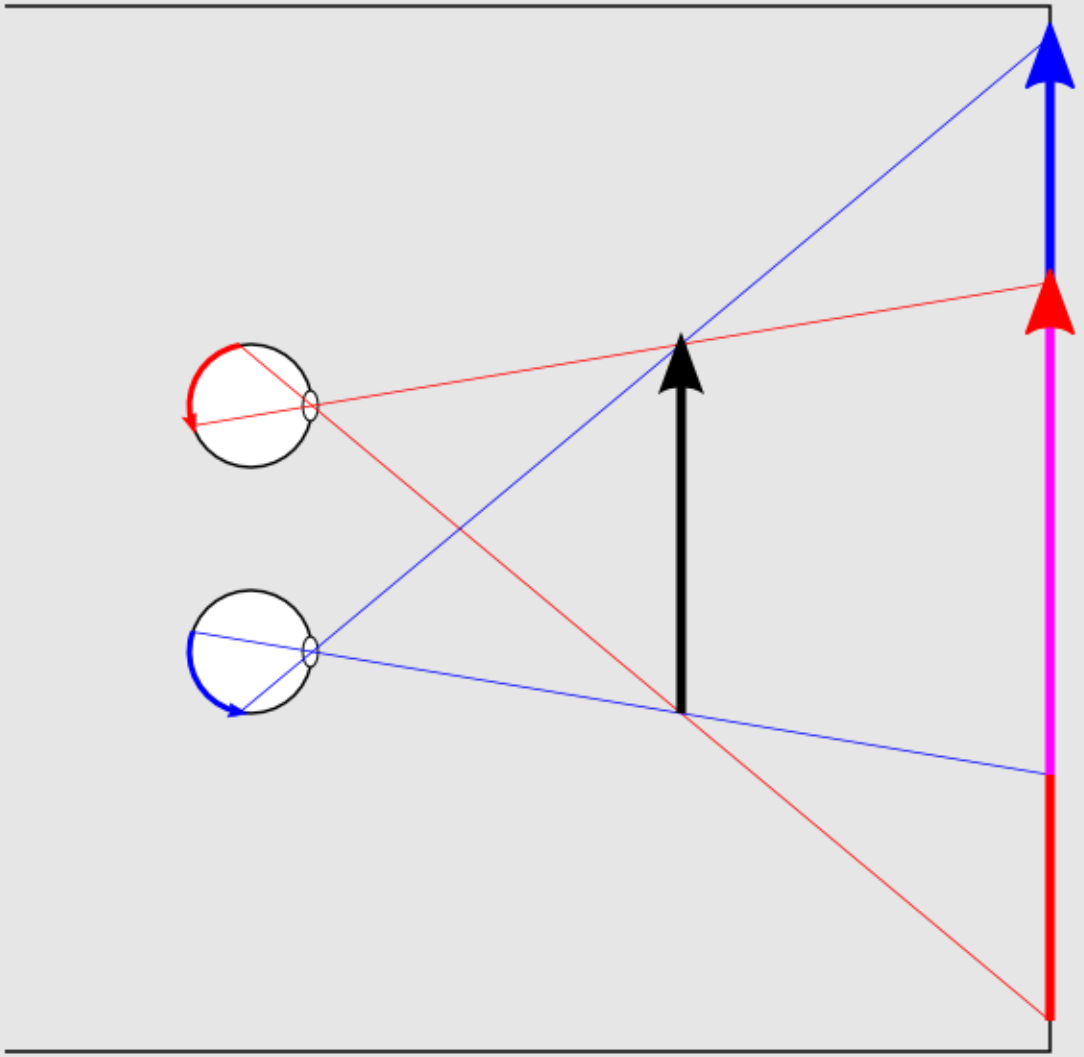
Vision



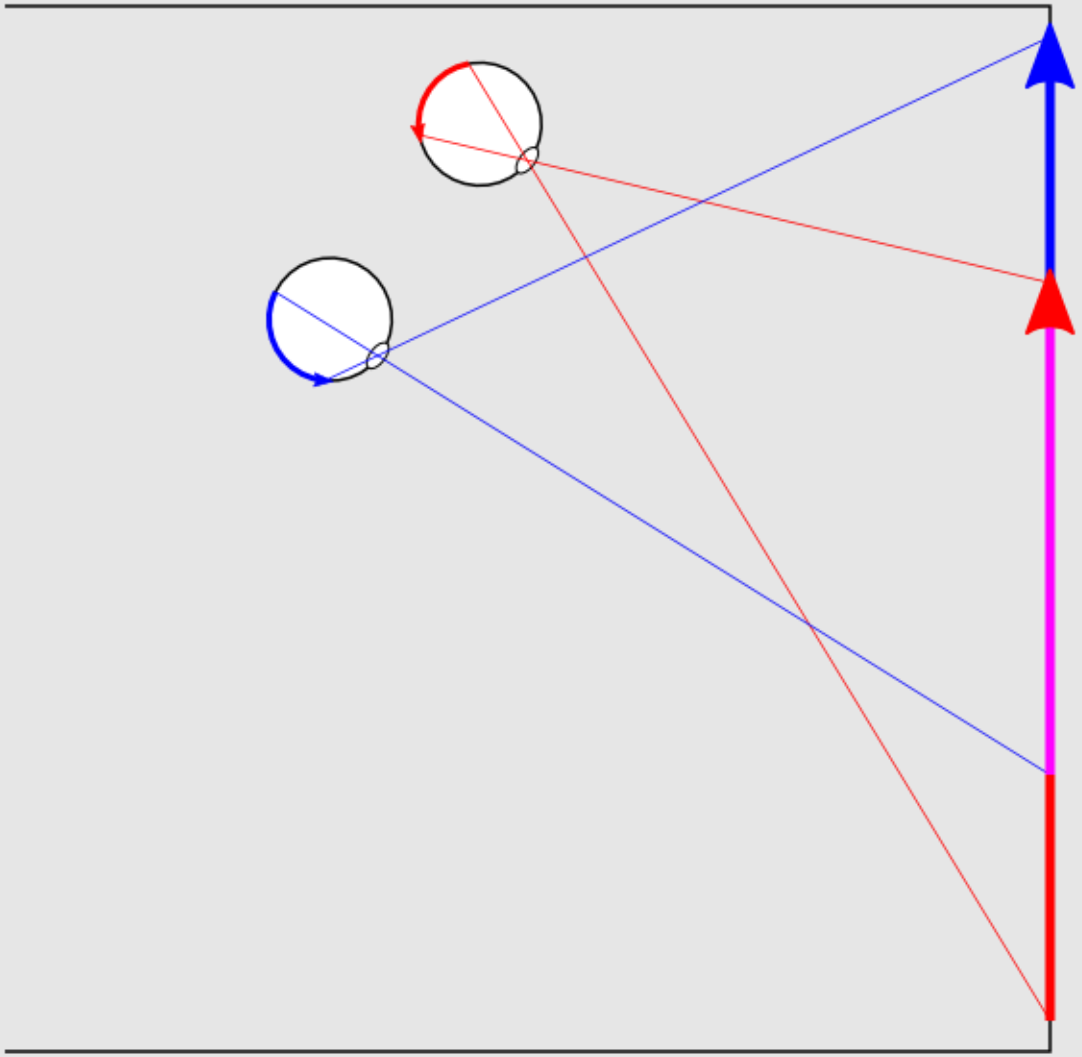
Vision



Movement



Movement



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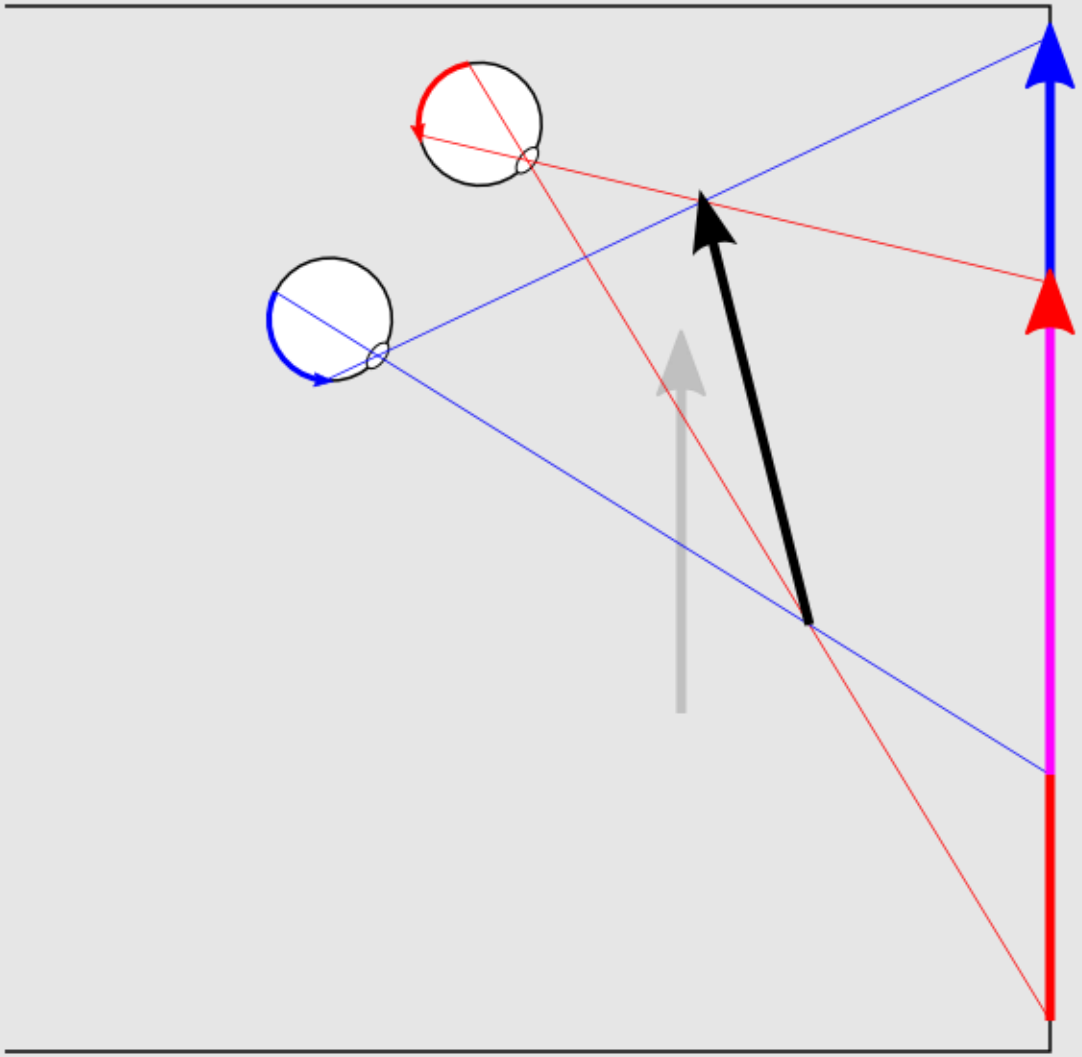
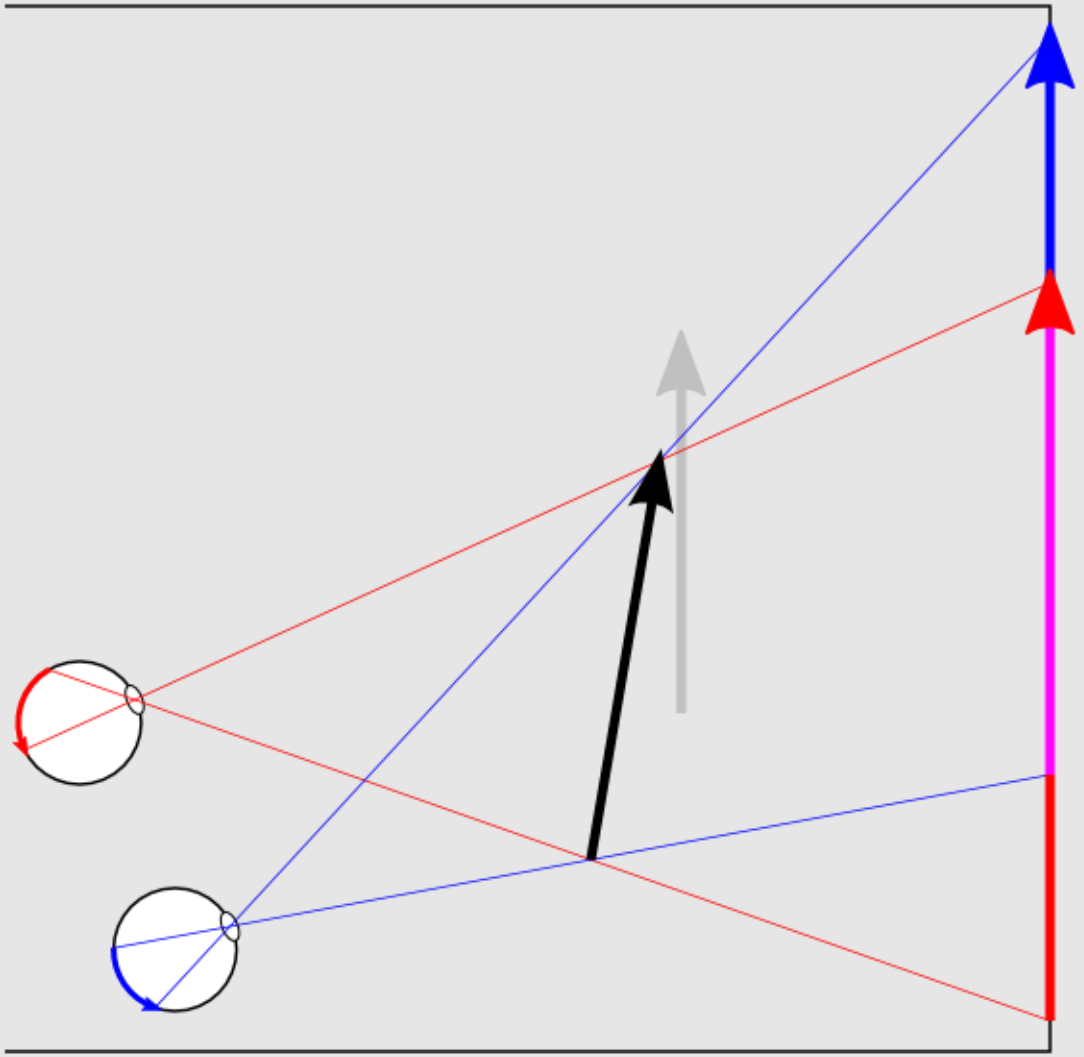
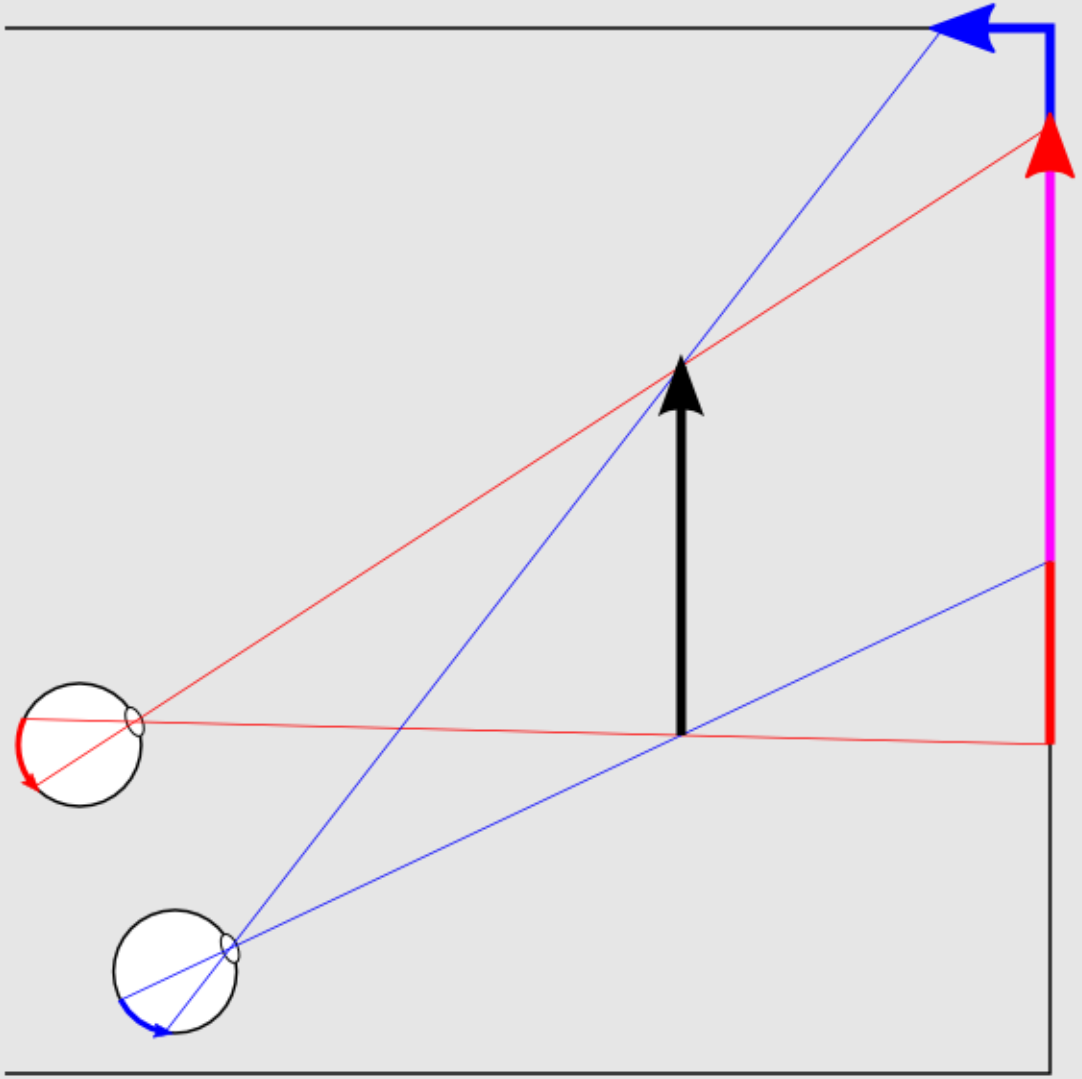


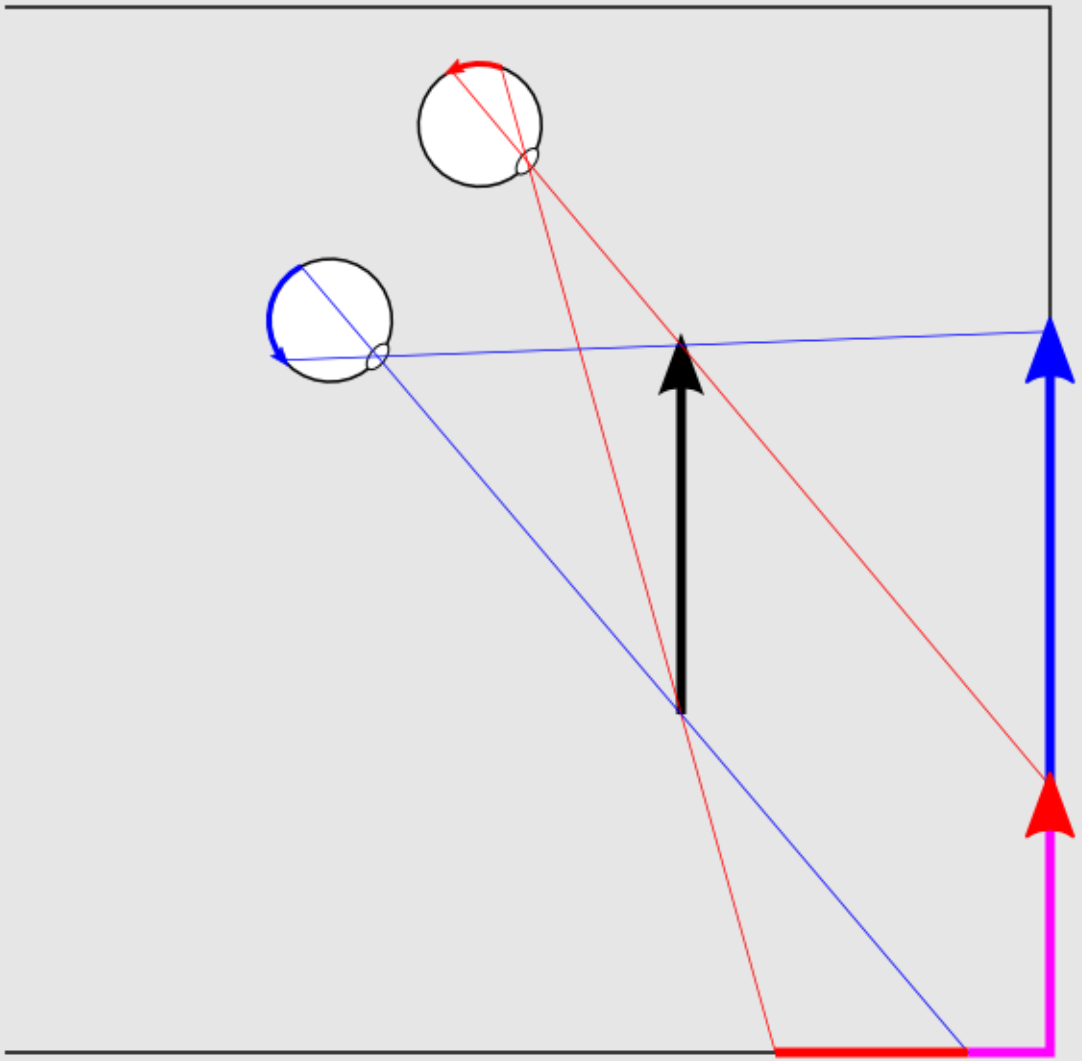
Movement



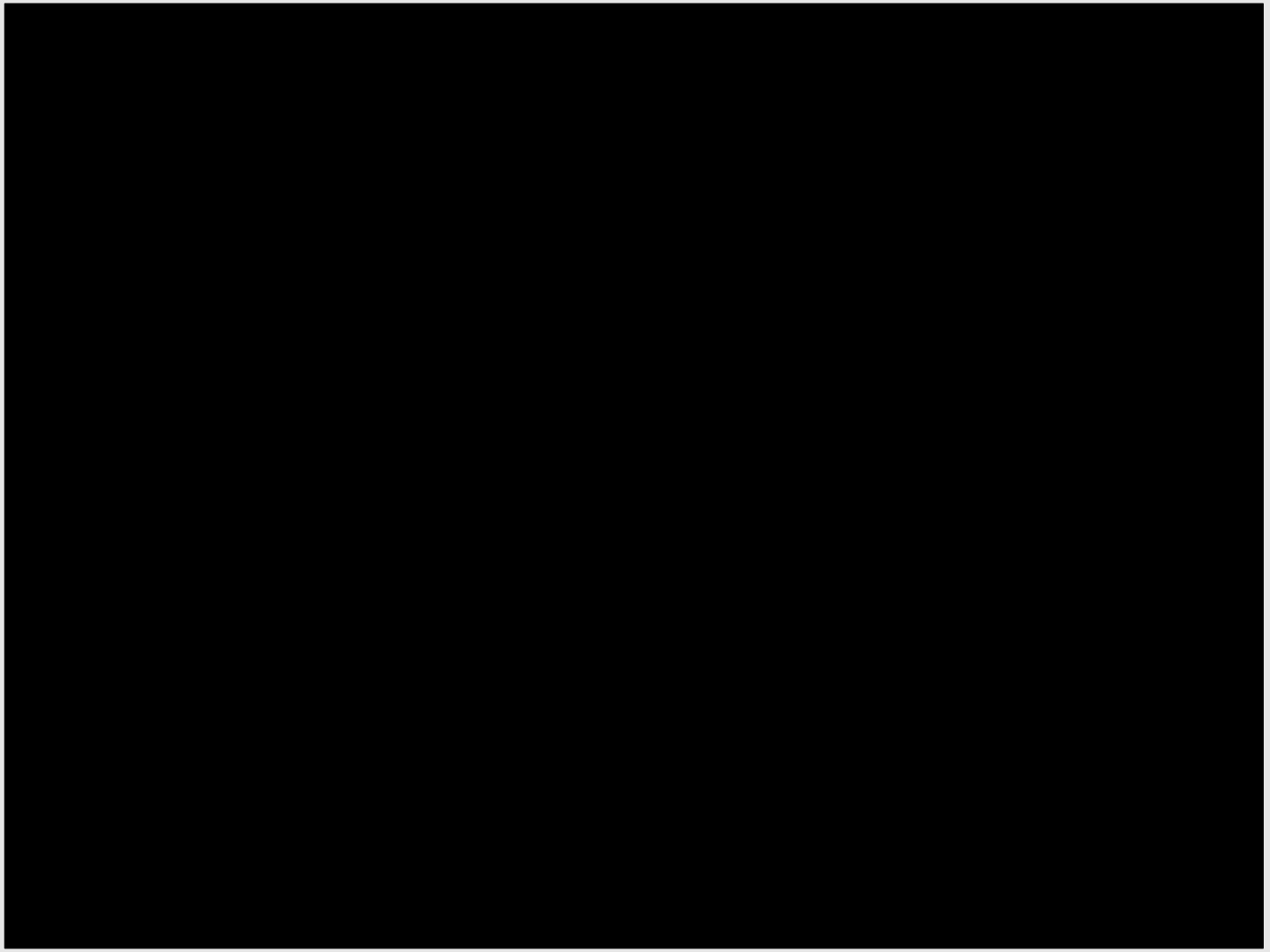
Movement



Movement



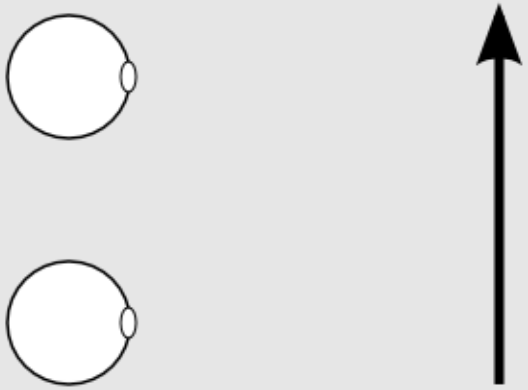
Movement



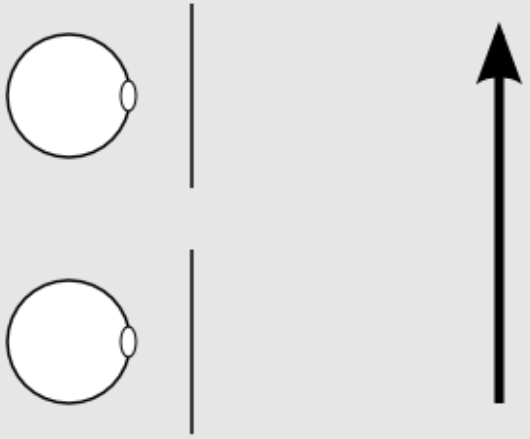
Vintage VR

Modern VR

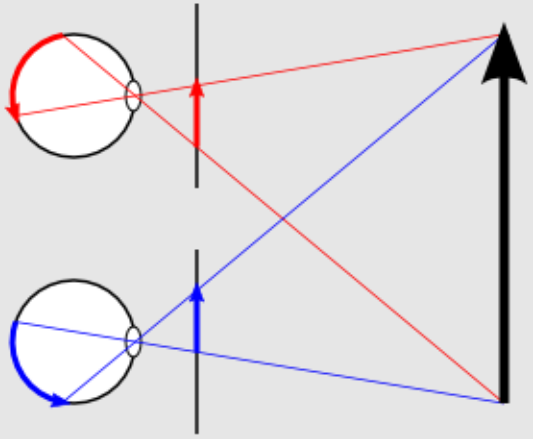
Head-mounted Displays

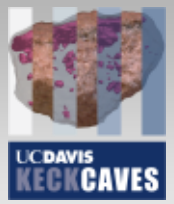


Head-mounted Displays



Head-mounted Displays





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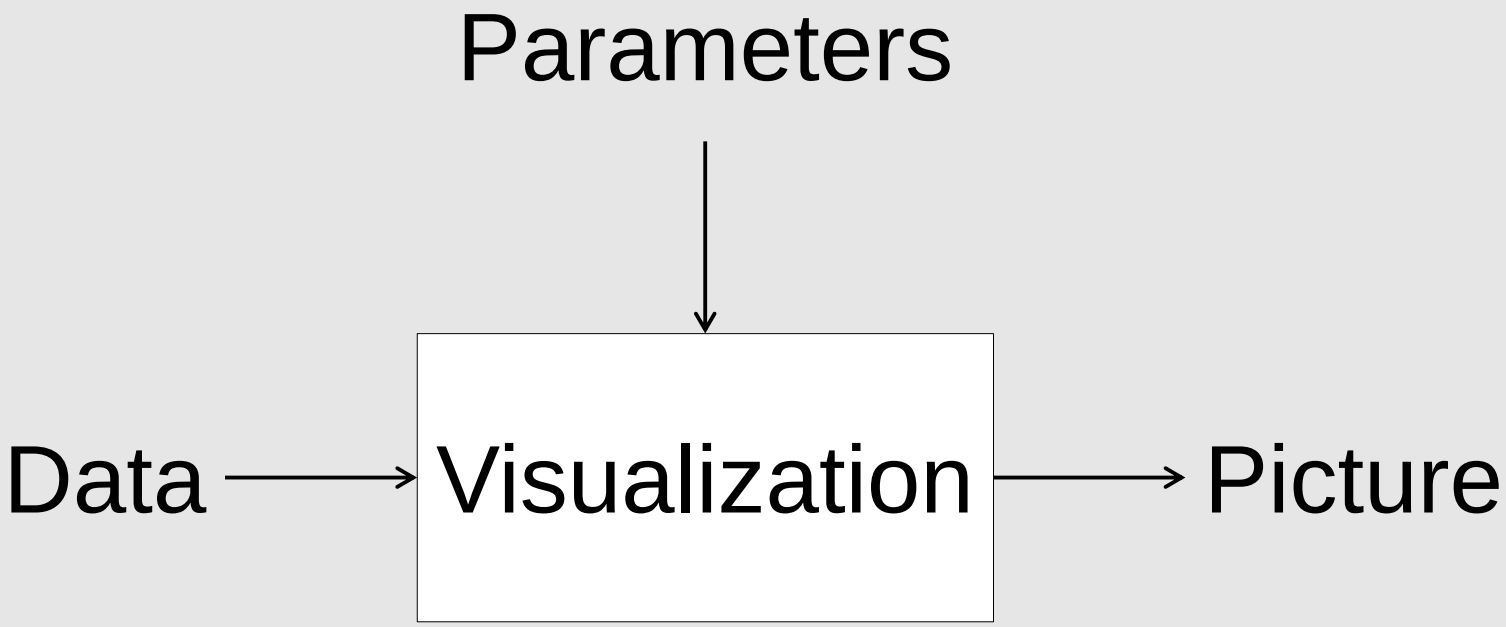
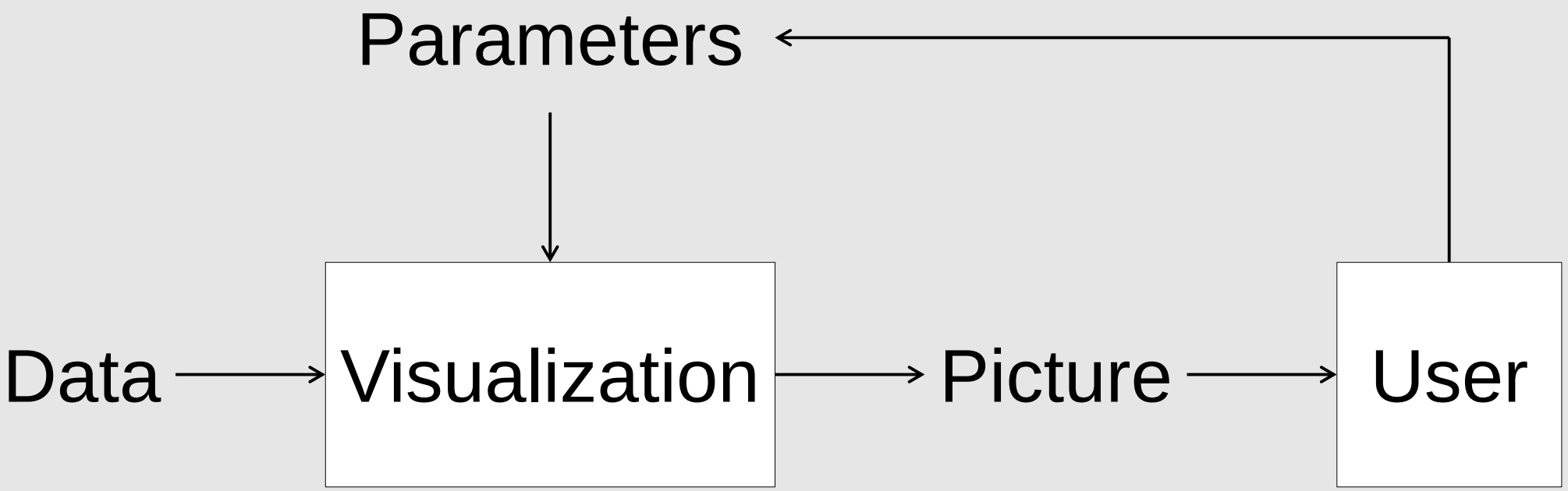
Interactive Visualization

Static Visualization

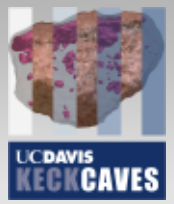


Interactive Visualization



Interaction in VR

- VR is particularly good medium for interaction:
  - "Holographic" 3D display
  - Direct natural 3D interaction
- Hand-held 3D input devices
  - Real-time feedback



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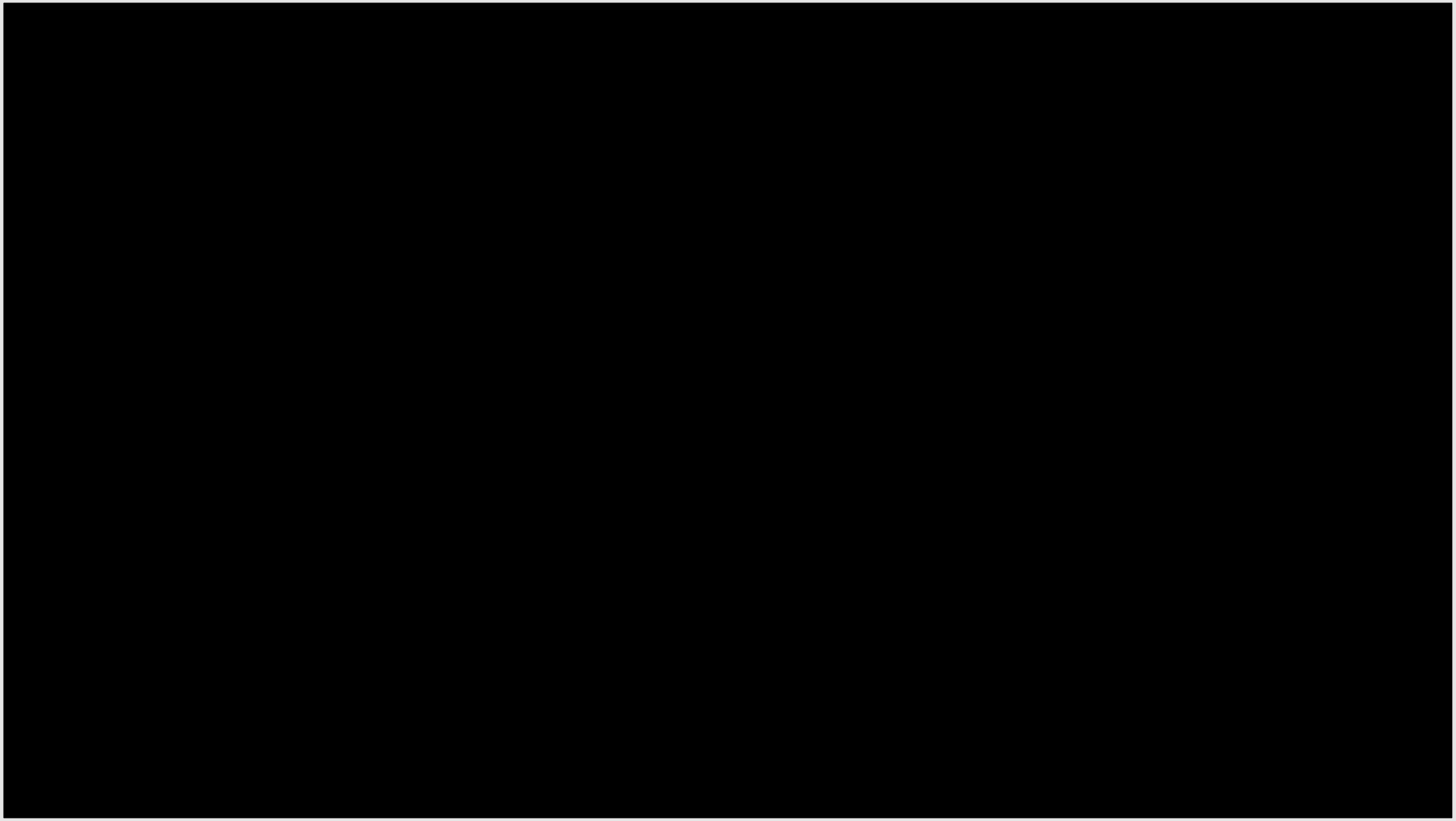
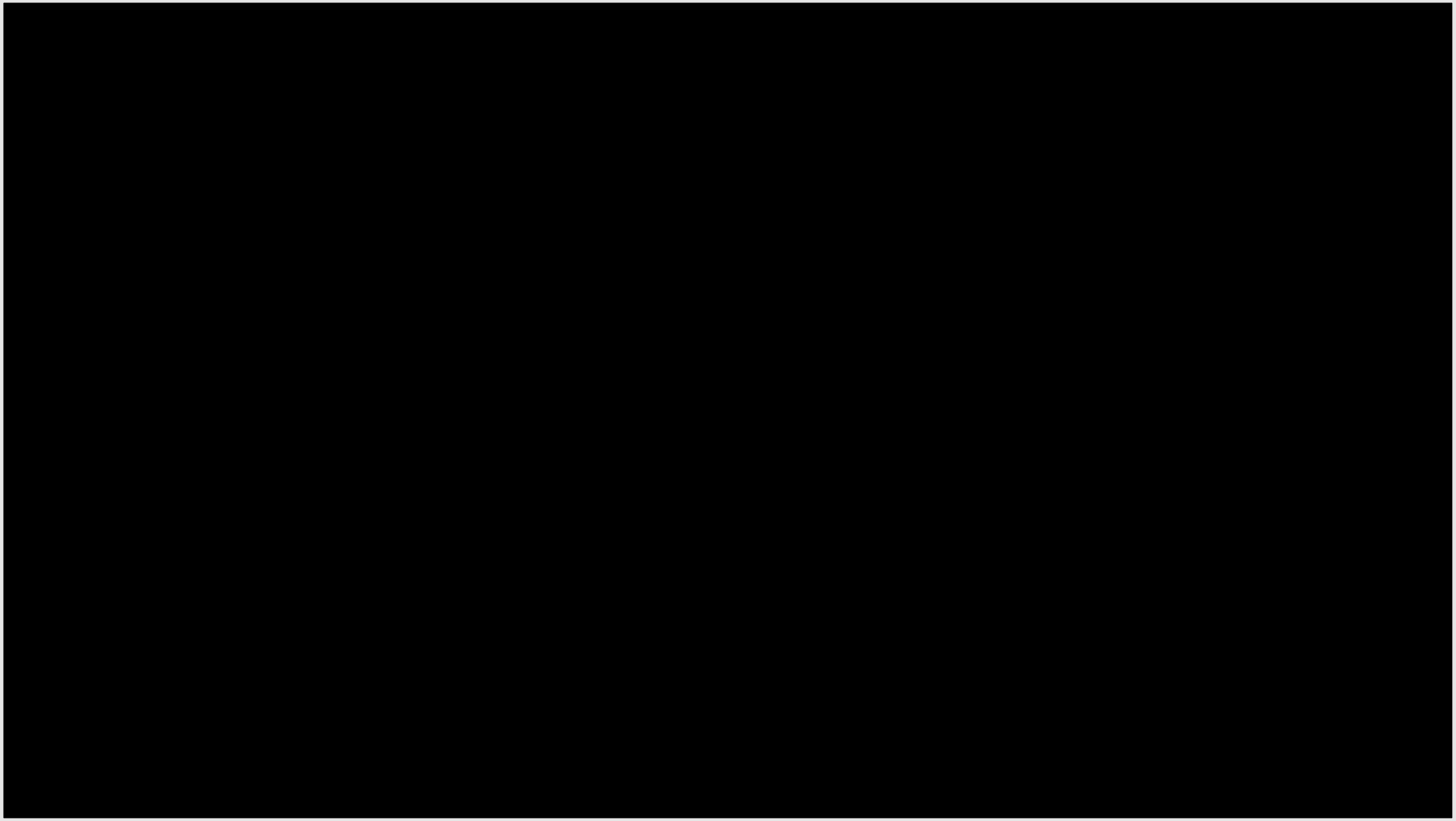
Immersive Visual Data Analysis

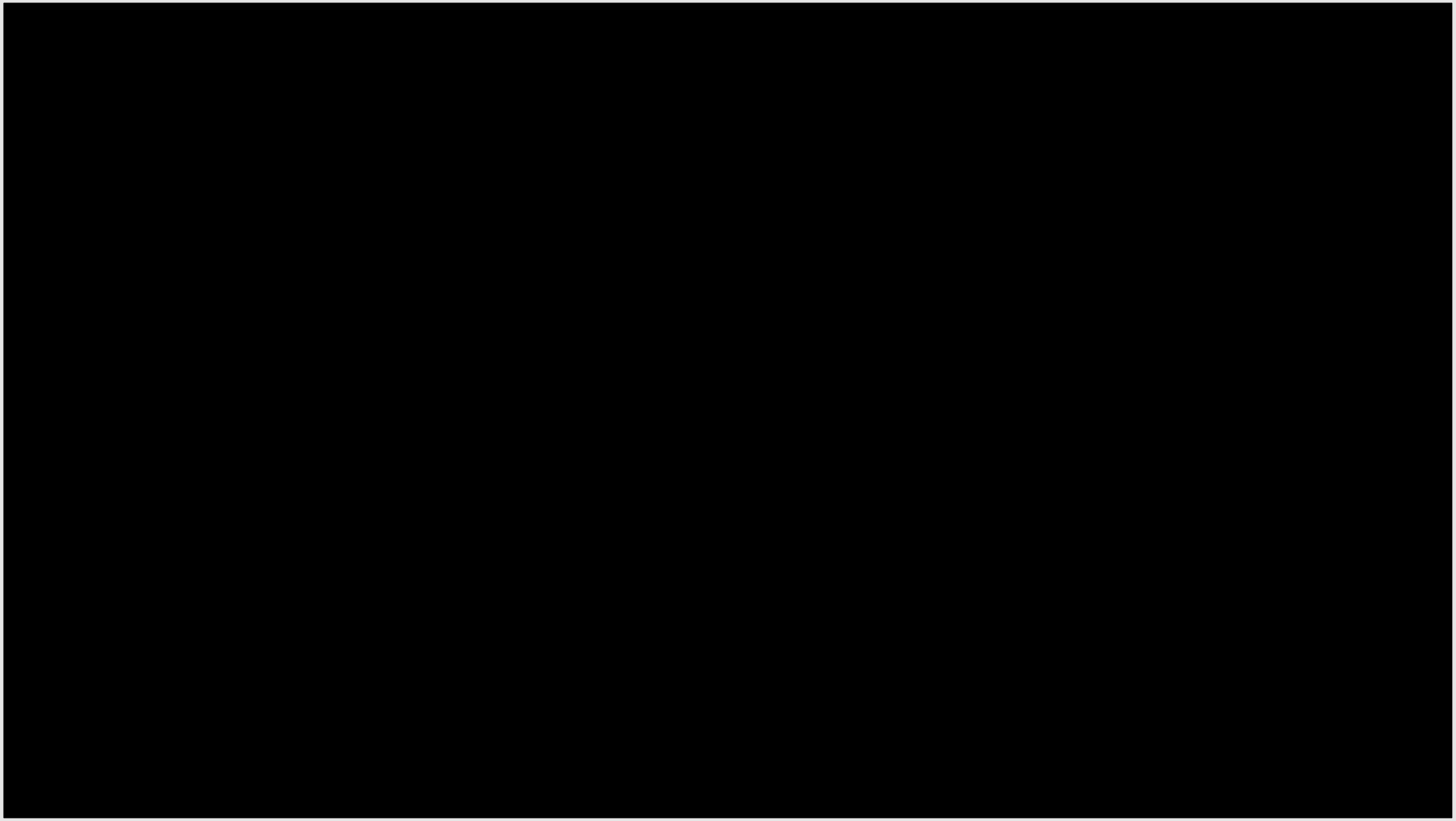
LiDAR Viewer



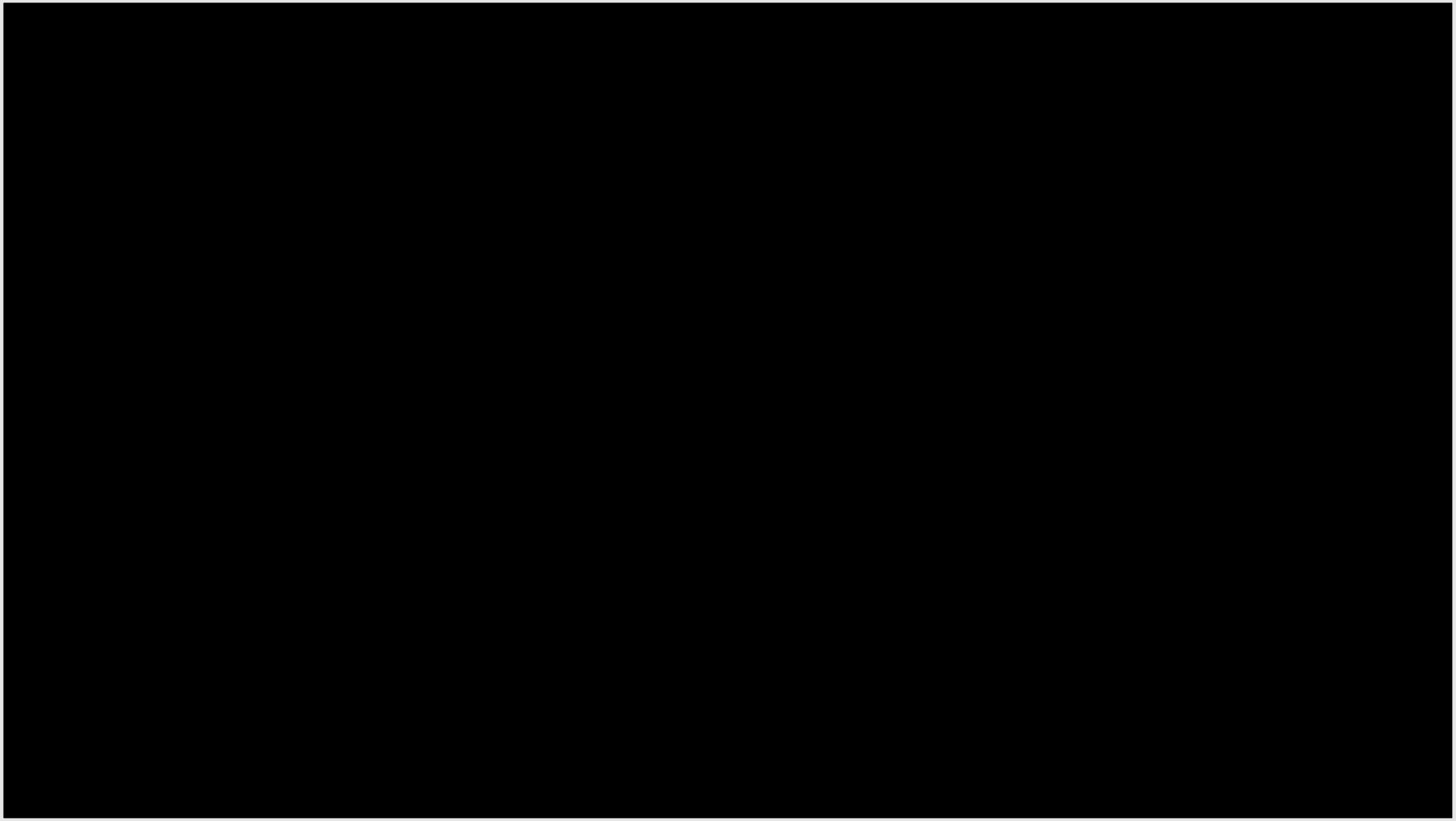
3D Visualizer



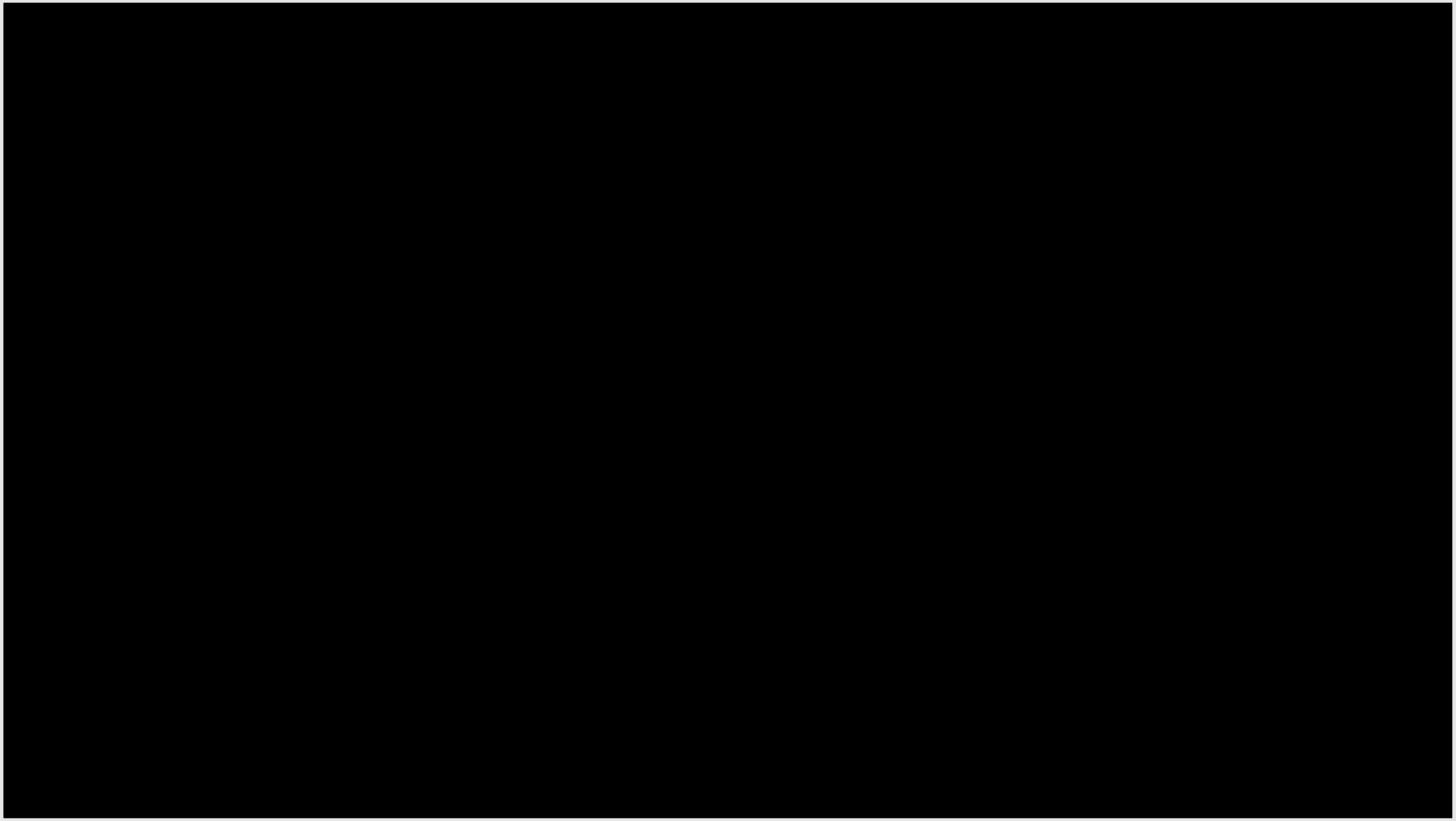
Nanotech Construction Kit

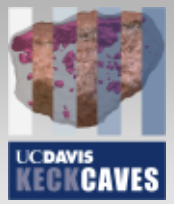


Tele-Collaboration



3D Video Avatars





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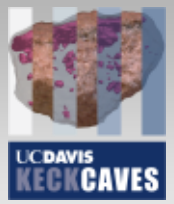
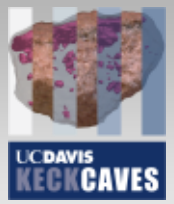
KeckCAVES Software



KeckCAVES Software

- All KeckCAVES software is publicly available
- Free and open-source (GNU GPL)
- Runs primarily on Linux, also on Mac OS X
- http://keckcaves.org



Vrui VR Toolkit

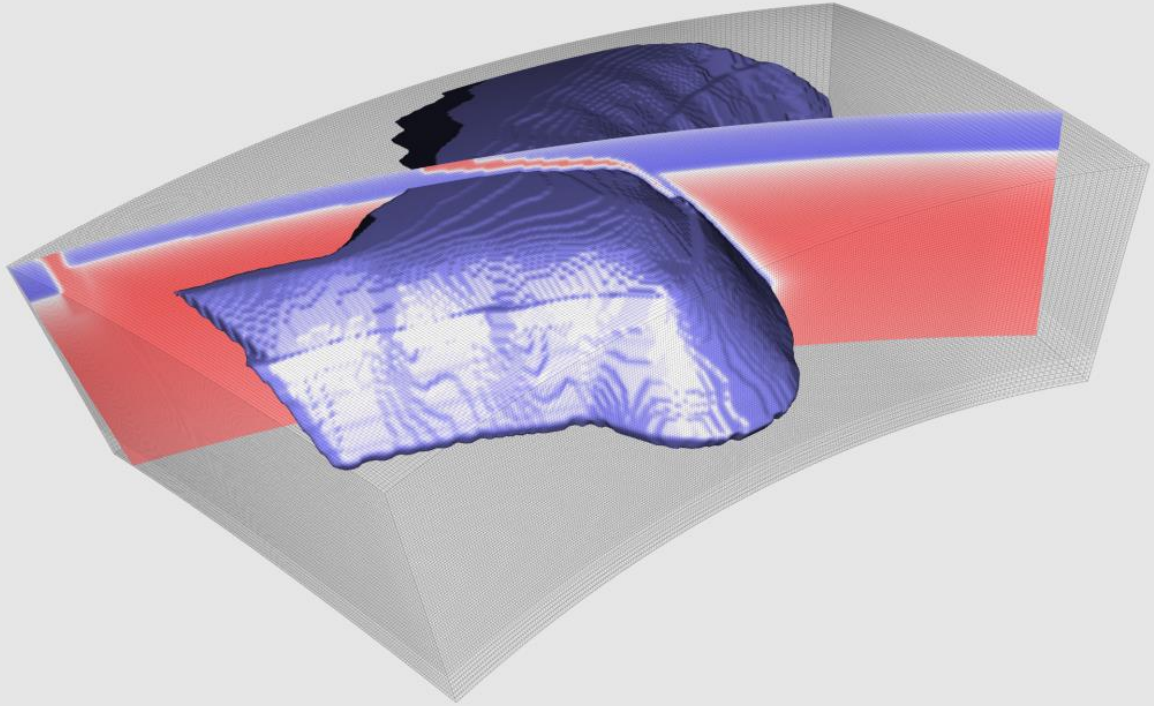
- Foundation for everything else
- Lets VR software run on wide range of hardware
  - Laptop or desktop
  - 3D TVs
  - Projected 3D screens
  - CAVEs et al.
  - Head-mounted displays
- http://idav.ucdavis.edu/~okreylos/ResDev/Vrui

LiDAR Viewer

- Analysis of massive 3D point cloud data
- http://idav.ucdavis.edu/~okreylos/ResDev/LiDAR

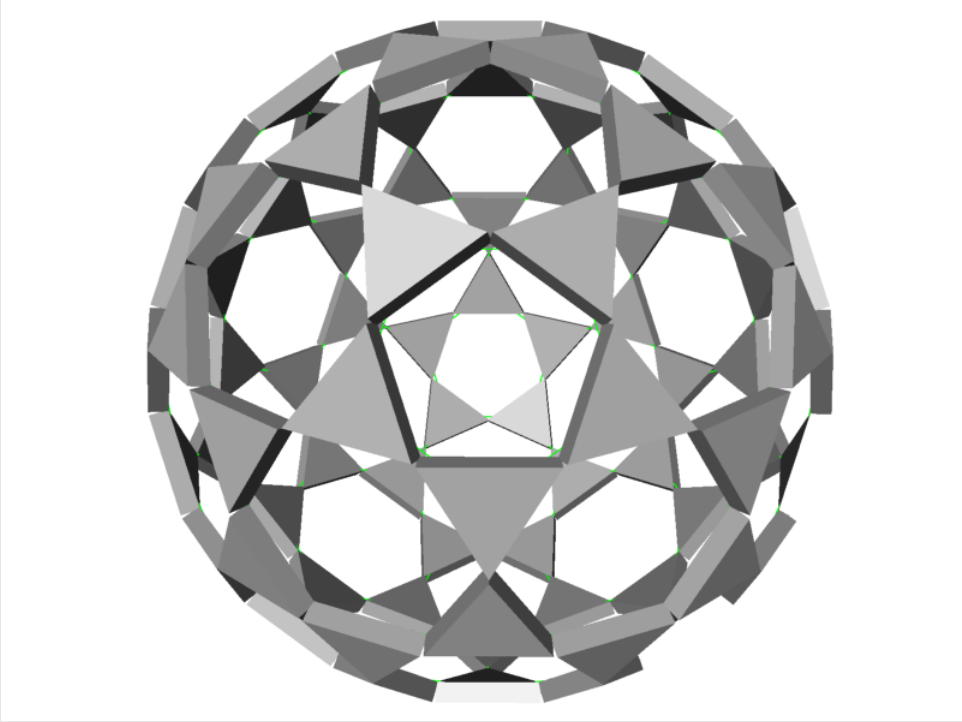
3D Visualizer

- Analysis of 3D gridded volumetric data
- http://idav.ucdavis.edu/~okreylos/ResDev/DataExploration



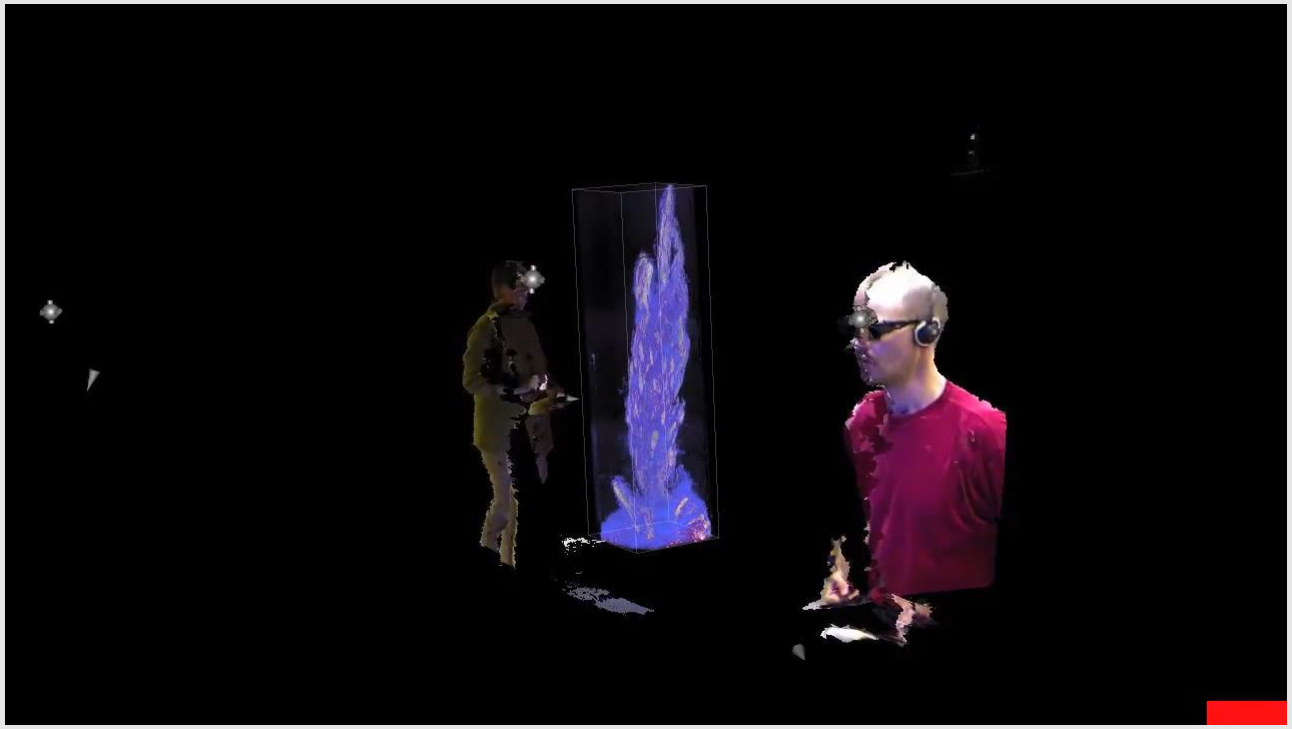
Nanotech Construction Kit

- Interactive creation of molecular structures
- http://idav.ucdavis.edu/~okreylos/ResDev/NanoTech



Tele-Collaboration

- Vrui add-on to connect multiple VR systems
- http://idav.ucdavis.edu/~okreylos/ResDev/Collaboration

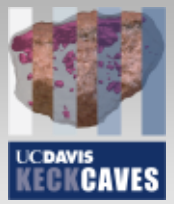


3D Video Avatars

- Capture, transmit, and play 3D video
- http://idav.ucdavis.edu/~okreylos/ResDev/Kinect

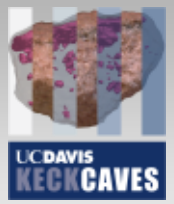
VR Hardware

- Good VR hardware has hit the mass market
- Head-mounted displays:
  - Oculus Rift
  - HTC Vive
- works natively with Vrui
- Easy to buy
  - Best Buy, Amazon, newegg
- Easy to set up
- VR no longer limited to central facilities



Conclusions

- VR is a powerful medium for analysis of 3D spatial scientific data
  - Presents 3D data in “holographic” 3D
  - Supports natural 3D interaction
  - Supports natural collaboration
- KeckCAVES software is publicly available
  - Free and open-source software (GNU GPL)
  - Runs on Linux (and also Mac OS X)
  - http://keckcaves.org
- Anyone can use VR



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Demos!