A SURVEY OF LARGE HIGH-RESOLUTION DISPLAY TECHNOLOGIES: SYSTEMS, APPLICATIONS, FRAMEWORKS, INTERACTION TECHNIQUES AND USER EVALUATIONS

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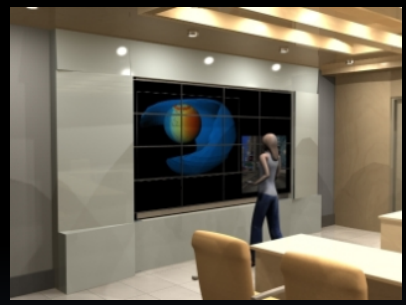
Large Public Display

- Digital Information Display (DID)
  - Digital information display (a.k.a. Digital Signage) in public spaces, e.g. airport, bank, shopping centers
  - Typically display only; No interactivity
- In Near Future
  - Interactive digital information displays everywhere, e.g. digital tables, digital façade, etc
  - High-resolution tiled display
  - Support user interaction



Tiled Display

- High-resolution, scalable, seamless tiled displays can be built using multiple projectors or LCD panels
- Advantages
  - High-resolution, Scalability, Cost efficiency
- Disadvantage
  - Difficult to manage multiple PC clusters
  - Difficult to develop applications for a cluster-based tiled display system
  - Difficult to support user interaction on a tiled display

Systems

- LambdaVision
  - 55 LCD panel, 100 megapixel tiled display wall by 10 gigabits network, by Electronic Visualization Laboratory, UIC

http://www.youtube.com/watch?v=BuIXoKoDeBk

Systems

- NASA Hyperwall-2
  - 23 x 10 feet wide, 128 panels, 256 million pixels tiled display

Systems

- Highly Interactive Parallelized Display Space (HIPerSpace)
  - Nearly 287 million pixels (35640 x 8000 pixels) tiled display wall by UCSD, Calit2

Systems

- Stallion Visualization Cluster
  - 75 high-resolution Dell 30-inch displays, 307 million pixels tiled display by TACC (Texas Advanced Computing Center), U Texas

Applications

- Public Information Displays
- Scientific Visualization
- High-resolution Image Viewing
- High-Definition Video Streaming
- Interactive 3D Map
- Presentation & Collaboration
- Command & Control
- Art & Entertainment

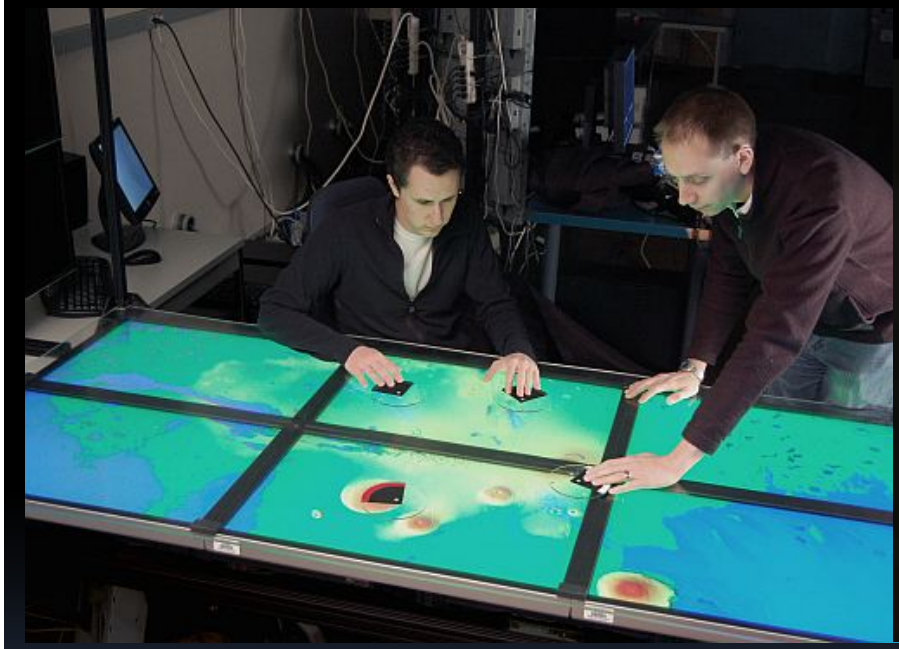
Applications

- Public Information Displays

CityWall(a large multi-touch display in a city center) in Helsinki, Finland

Applications

- Scientific Visualization - Geographical Data Simulation

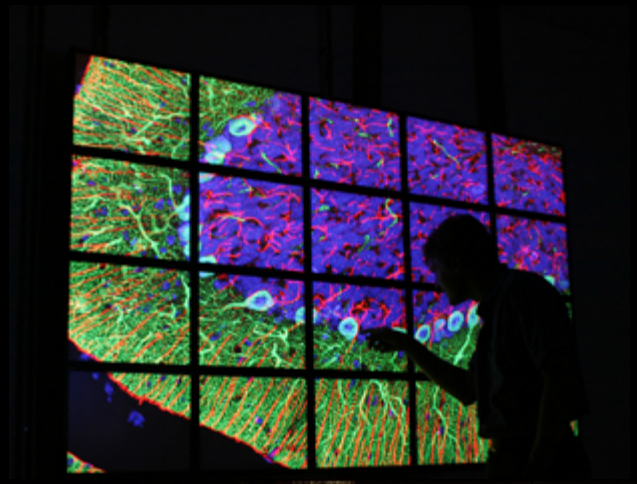


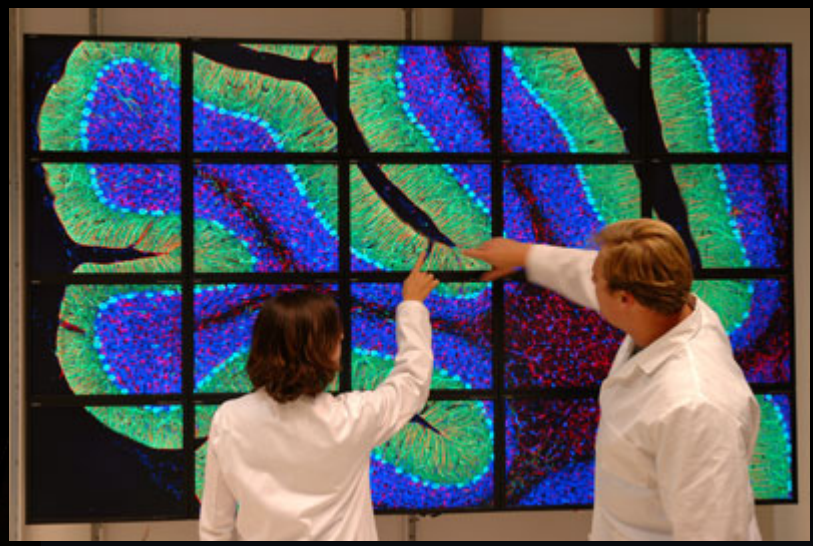
RainTable (using LambdaTable) by Electronic Visualization Laboratory at the University of Illinois at Chicago in collaboration with the Department of Geology at the University of Minnesota

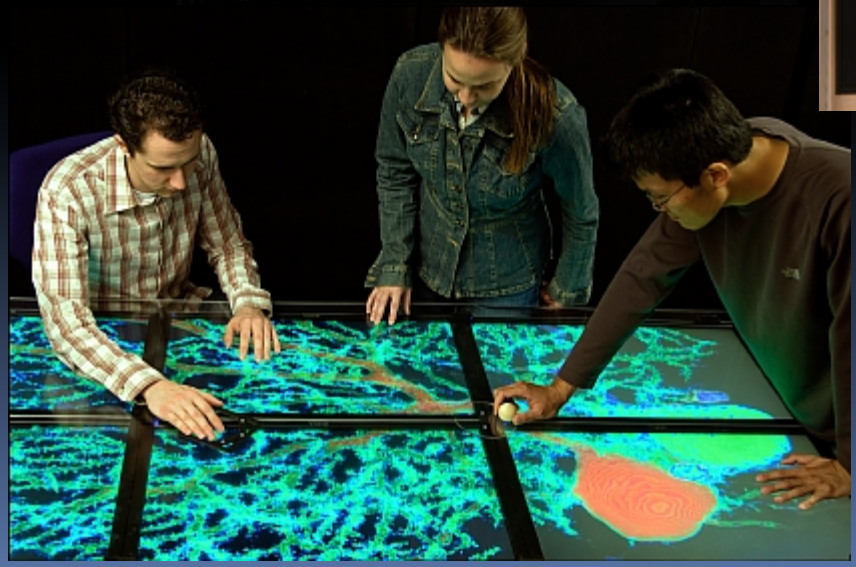
http://www.youtube.com/watch?v=yaTovvEp7Ig

Applications

- High-Resolution Image Viewing



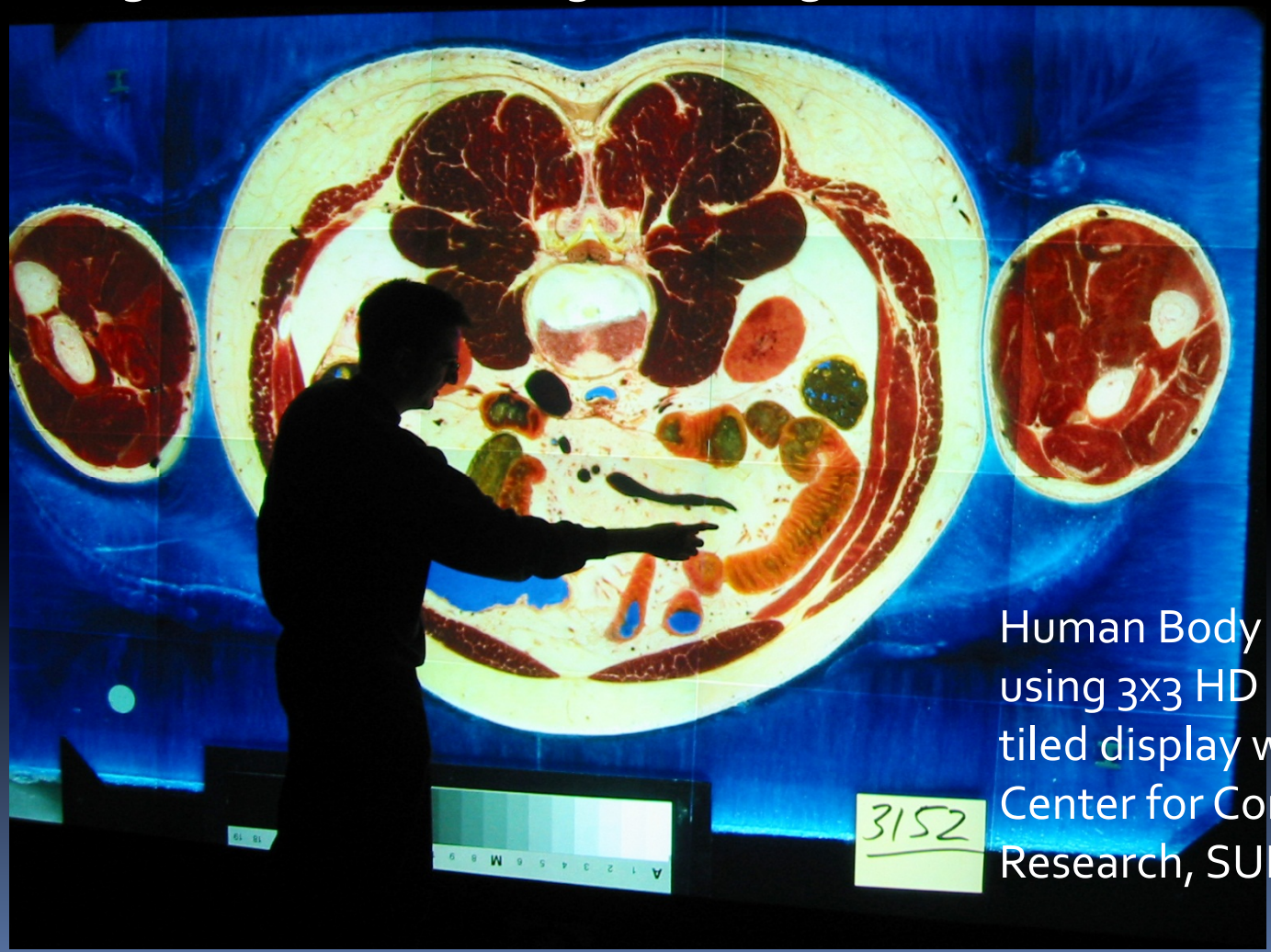




Rat Cerbellum Imaging, using BioWall by NCMIR (National Center for Microscopy and Imaging Research), UC San Diego & using LambdaTable by EVL/UIC

Applications

- High-Resolution Image Viewing



Human Body Imaging, using 3x3 HD projector tiled display wall, by Center for Computational Research, SUNY Buffalo

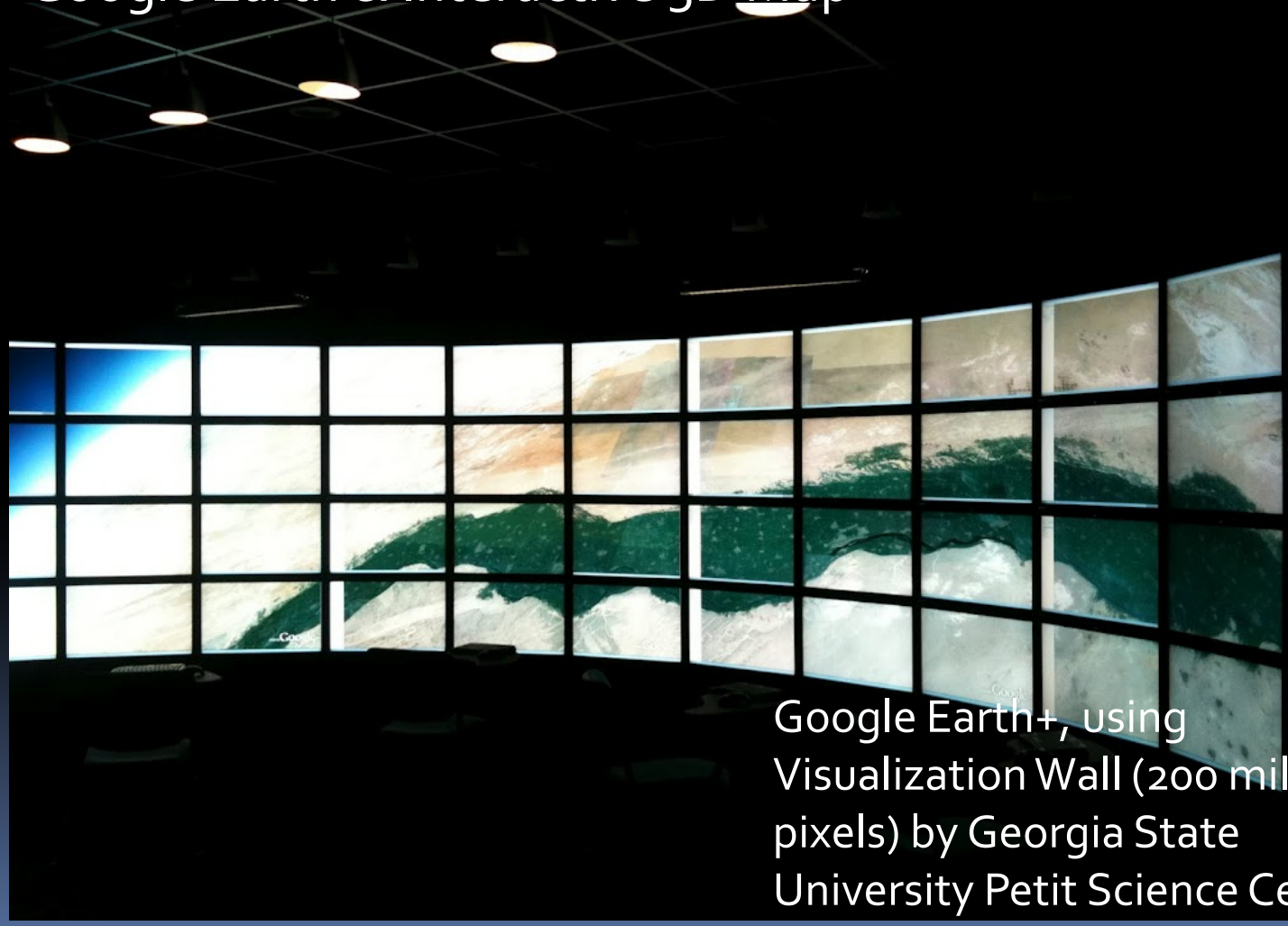
Applications

- High-Definition Video Streaming

HD video streaming on a tiled display (3072 x 2304 pixel) between Osaka Univ., Kyoto Univ, & Iwate Pref Univ.

Applications

- Google Earth & Interactive 3D Map



Google Earth+, using Visualization Wall (200 million pixels) by Georgia State University Petit Science Center

Applications

- Virtual Prototyping – View models in great detail while maintaining spatial reference

Virtual Prototyping using MegaWall, by Interactive Graphics Institute, ETRI, Fraunhofer IGD

Applications

- Presentation & Demonstration

VNC Viewer (Virtual Network Computing) graphical desktop sharing system, by EVL/UIC

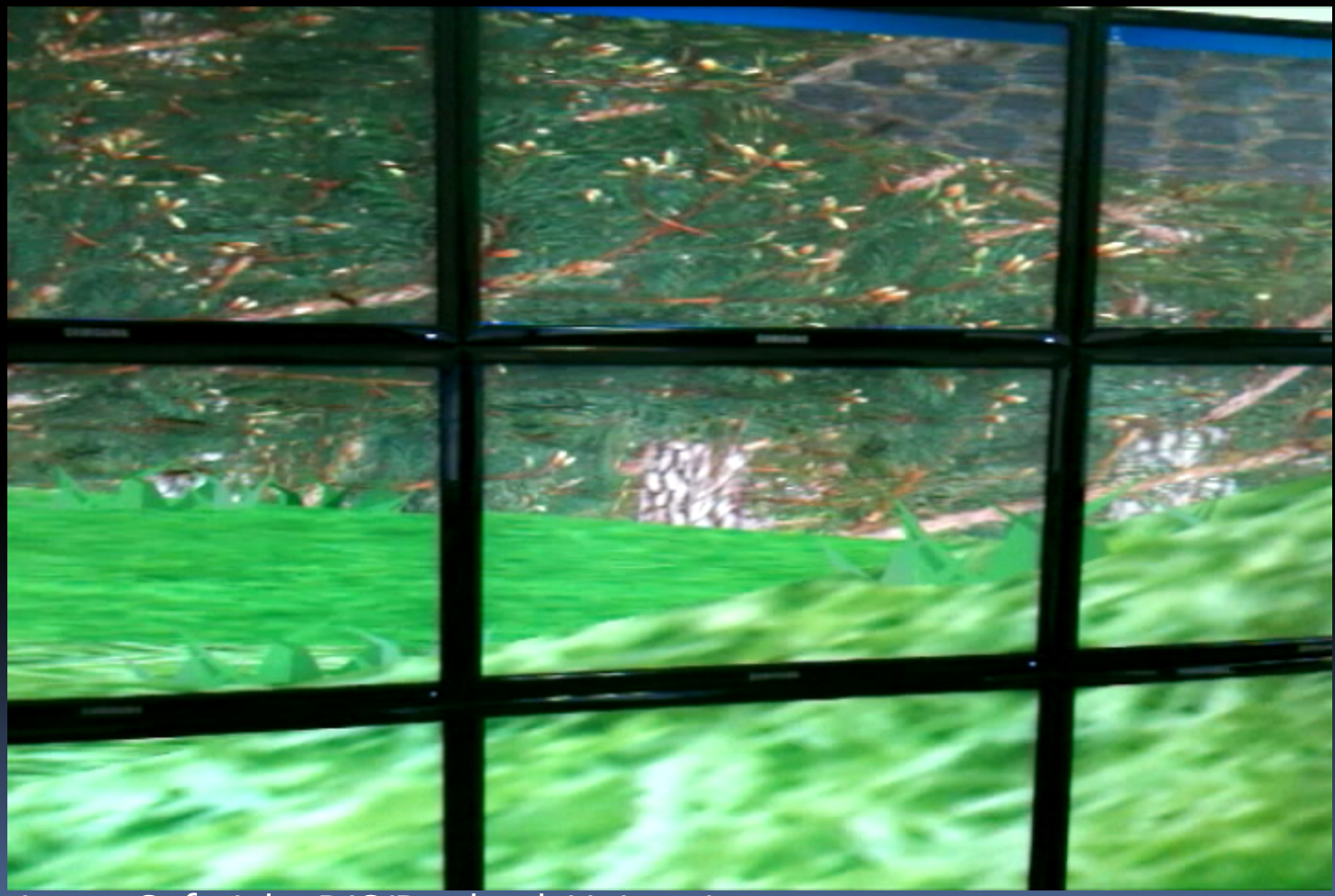
Applications

- Art & Entertainment

Interactive exploration of an image collection on HiPerSpace, by UC San Diego, Calit2, CRCA (Center for Research in Computing and the Arts)
http://www.youtube.com/watch?feature=player_embedded&v=-YlT1qFhJhk

Applications

- Art & Entertainment



Insect Safari, by DIS/Dankook University

Applications

- US Army's next generation artillery command and control environment – 3x3 UltraSlim 9xHD Video Wall

- US Air Force, Global Strike Command – 24x8 inch (9562x3072 resolution)

Applications

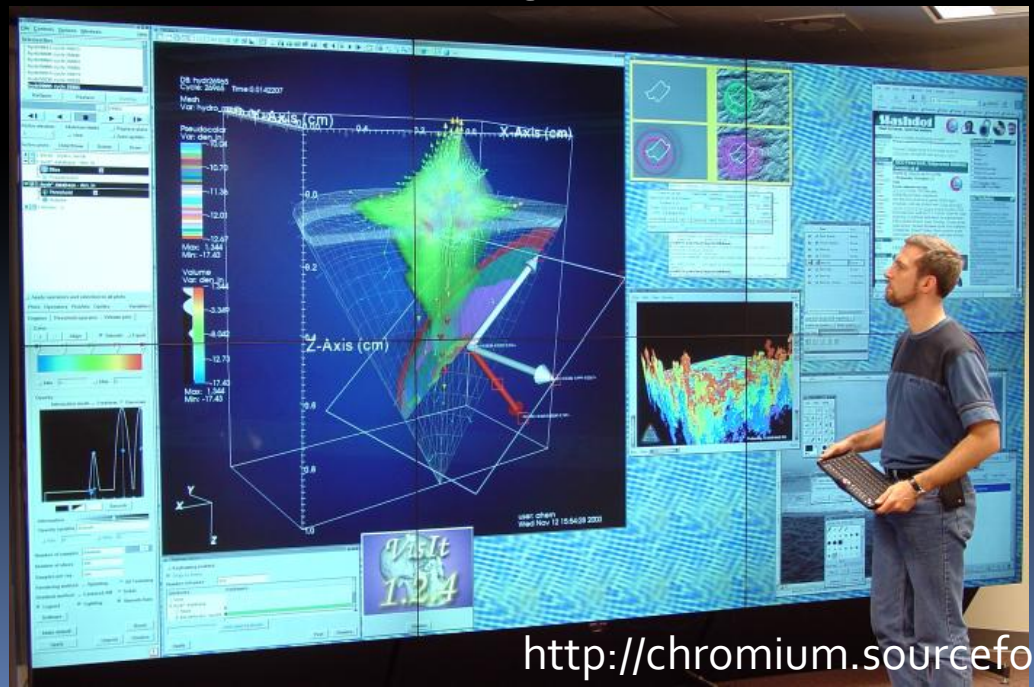
- Video Security System

Frameworks

- There are some framework for tiled display application development.
  - Mostly focused on distributed rendering or scalability
  - Need to support multiple users to interactively view and use the multiple applications on the tiled display simultaneously at the same time
  - Need to support distributed rendering/system programming
  - Need to support various input devices
  - Need to support easy development of the interactive tiled display applications

Frameworks

- WireGL / Chromium, by Stanford University
  - 3D graphics parallel rendering toolkit on a cluster system
  - Distributed rendering mechanism by dividing a large image onto small sized image
  - But, performance degradation by increased image size



http://chromium.sourceforge.net/doc/LLNLcopy.html

Frameworks

- Equalizer, by University of Zurich
  - OpenGL-based parallel rendering middleware by sharing a virtual camera information
  - Support the interface class for event handling
  - But, interface driver needed for a new input device

http://www.equalizergraphics.com/

Frameworks

- GARUDA, by Deemed University
  - Open Scene Graph (OSG)-based tiled display framework targeted for low-end PC clusters
  - But, tightly-coupled with OSG, and only keyboard/mouse interaction

http://cvit.iiit.ac.in/projects/computationalDisplays/

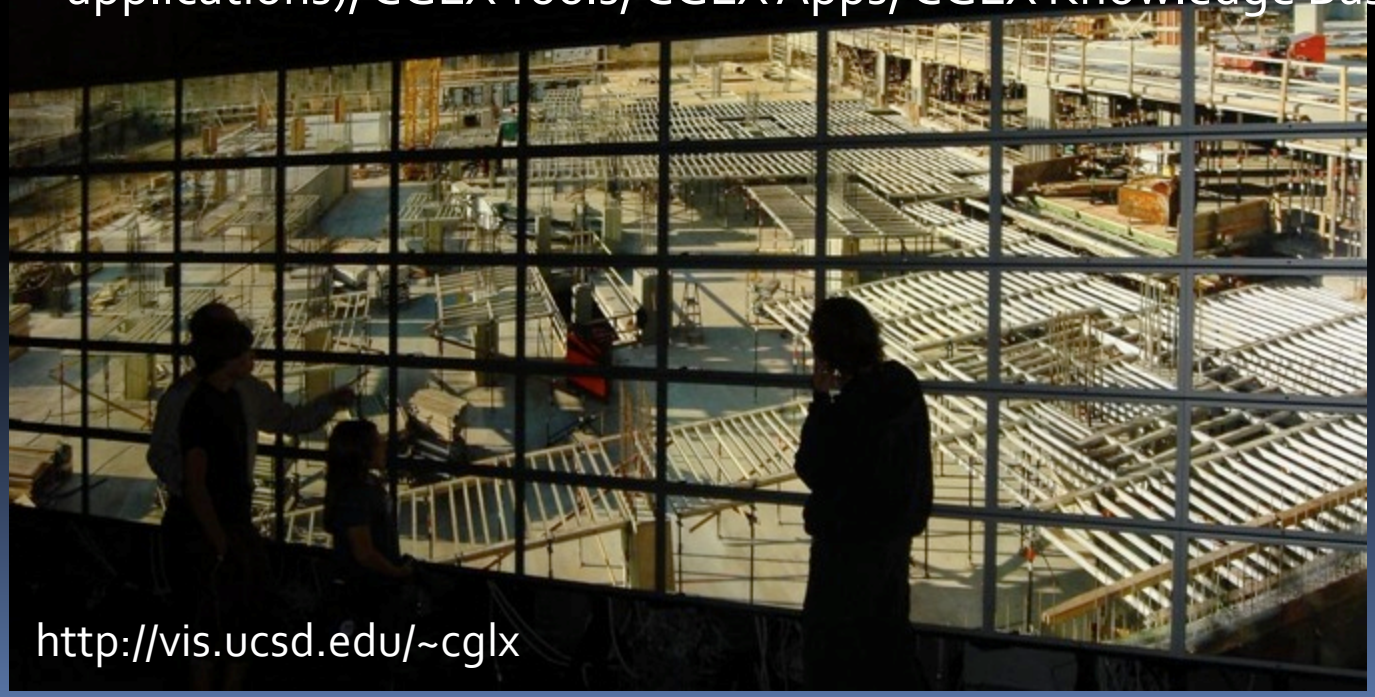
Frameworks

- SAGE, by EVL/UIC
  - High-resolution video streaming middleware via an extremely fast network
  - Use the virtual frame buffer similar to WireGL distributed rendering
  - Support multiple application windows execution
  - But, require very fast network for network streaming

http://www.youtube.com/watch?v=C99OMik3PHA
http://www.sagecommons.org/

Frameworks

- CGLX(Cross-Platform Cluster Graphics Library), by UCSD
  - 3D graphics parallel rendering framework for the development of large-scale, collaborative, multi-tile visualization systems
  - CGLX Core Engine API (Distributed parallel rendering of OpenGL applications), CGLX Tools, CGLX Apps, CGLX Knowledge Base



Frameworks

- DisplayCluster software, by TACC
  - Works in Linux and Mac OSX
  - Pixel Streaming (similar to SAGE)
  - Multiple interactive interfaces (Joysticks, Gamepad, iPhone/iPad/iTouch/Android devices, Microsoft Kinect gestures)
  - Scripting (via Python API)

http://www.tacc.utexas.edu/tacc-projects/displaycluster

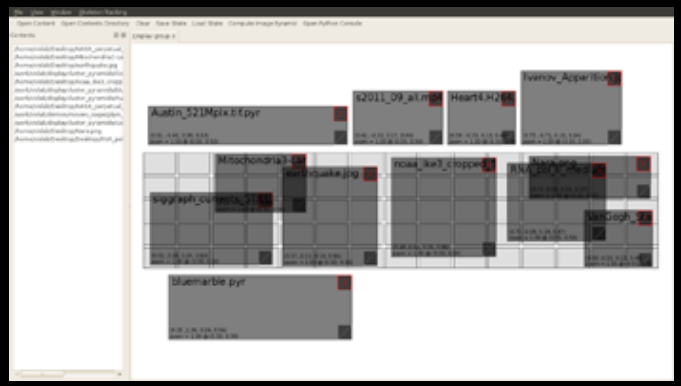
Frameworks

- iTILE Framework
  - Support the construction of interactive tiled display applications
  - Multiple application windows
    - Window manager
  - Various input device on cluster-based tiled display
    - Input processor using shared memory
  - Rendering synchronization and distributed data sharing
    - Message passing
    - Distributed shared memory
  - Tiled display configuration
    - Configuration script

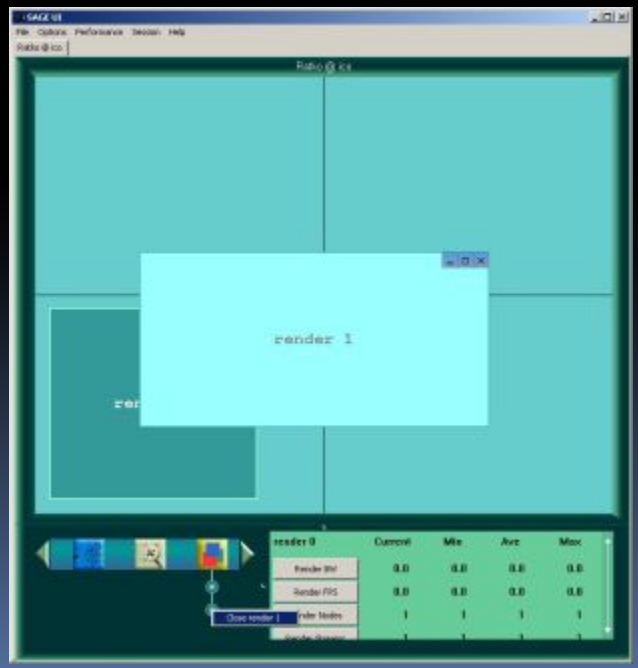
User Interactions

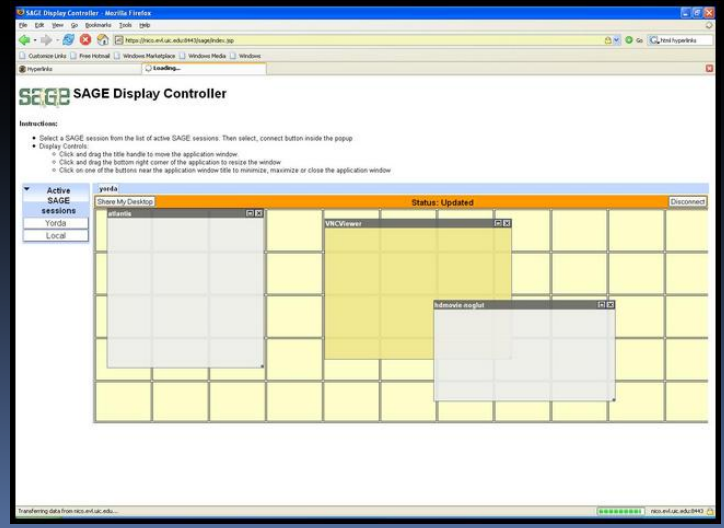
- Graphical User Interface
- Laser Pointer
- 3D Gyro Mouse (Wiimote, 3D wand, joystick, trackball, etc)
- Gesture (Kinect)
- Multi-touch
- Mobile Devices (PDA, Pad, etc)
- Physical Navigation
- etc (ChairMouse)

User Interactions: GUI



- DisplayCluster software GUI
- SAGE GUI
  - Cross-platform GUI window manager for SAGE (move, resize, maximize, minimize)
- SAGE web-based display controller





User Interactions: Laser Pointer

- LumiPoint: Multi-user Laser-based interaction on tiled display, by Stanford University

- Laser Pointer on tiled displays, by UC Davis

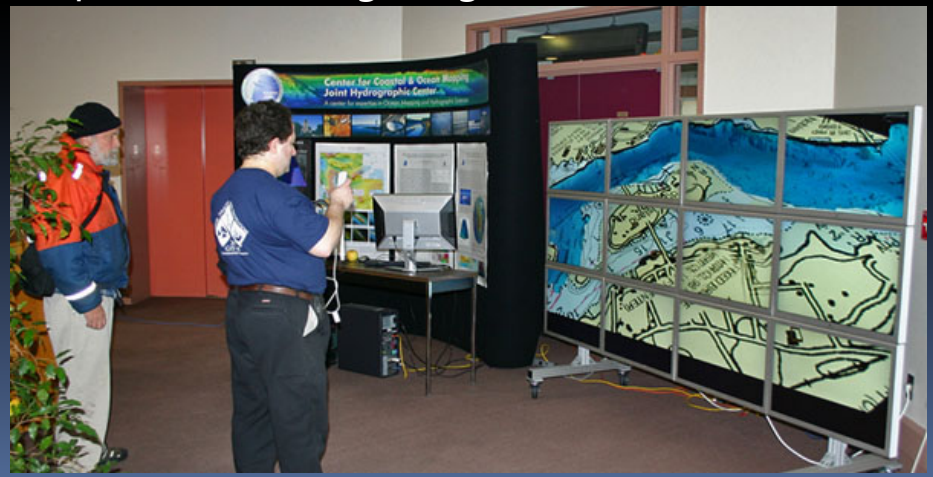
http://www.idav.ucdavis.edu/publications/print_pub?pub_id=856

User Interactions: 3D Gyro Mouse

http://www.helixsoft.nl/blog/?tag=tiled-display

- 3D Wand, joystick, trackball, Wiimote, etc

CCOM tiled display, showing Portsmouth, NH in GeoZui, controlled with Wiimote
http://schwehr.org/blog/archives/2009-08.html



SAGE Direct Interaction Manager (DIM)
http://renambot.lakephoto.org/2010/07/direct-wall-interaction-in-sage/

User Interactions: Gestures

User interaction using Kinect in DisplayCluster, TACC

- Using gestures and the Microsoft Kinect

Kinect for SAGE, by EVL/UIC
http://www.youtube.com/watch?v=oFQeszkCaPU

User Interactions: Multi-Touch

Fleet Commander

- Fleet Commander Game, on the Cyber-Common 20-foot wide multi-touch LCD wall by EVL/UIC.

http://www.youtube.com/watch?v=6V003TjB2Tw&feature=relmfu

- TACC's Multi-touch Display System (12.5 megapixel, 6 monitors, 32-touch point capability using PQLabs)

http://www.youtube.com/watch?v=MFNe1fv7P4k

User Interactions: Mobile Devices

http://wn.com/evltube?upload_time=all_time&orderby=published

- 20 Foot Virtual Canvas uses iPad as a palette and multi-touch for users to paint on the 20 ft virtual canvas, by EVL/UIC
- CGLXTouch, multi-user multi-touch devices (iPads, iPhone, mult-touch table) on high resolution tiled display, by UCSD

User Interactions: Physical Navigation

Multiscale interaction using physical navigation & PDA & vision wand on Gigapixel display, by Virgina Tech

- Physical navigation on high-resolution tiled display

Move to improve: Promoting physical navigation to user performance with large displays, by VT

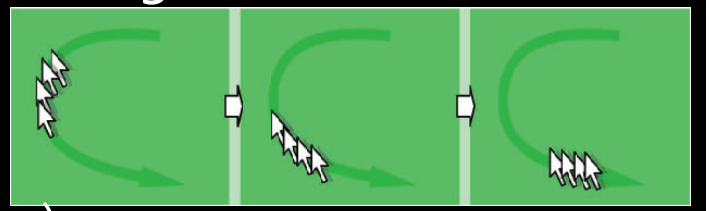
User Interactions: Chair Mouse

- Leveraging chair rotation for cursor movement on large high-resolution tiled display, by Virginia Tech

http://www.youtube.com/watch?v=xCDTl_gne_c&feature=youtu.be

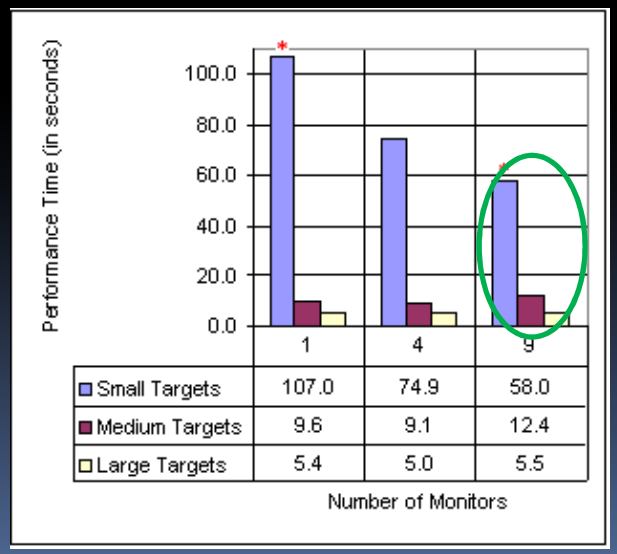
User Interaction Challenges

- Large Display User Experience, CGA 2005
  - Cursor tracking problem
    - High-density cursor
    - Auto-locator cursor
  - Distal access problem (target acquisition)
    - Missile mouse
    - Drag-and-Pop interaction
  - Bezel problem
    - Mouse Ether
    - OneSpace
  - Window management problem
    - StartAnywhere
    - WinCuts
  - Task management problem
    - GroupBar

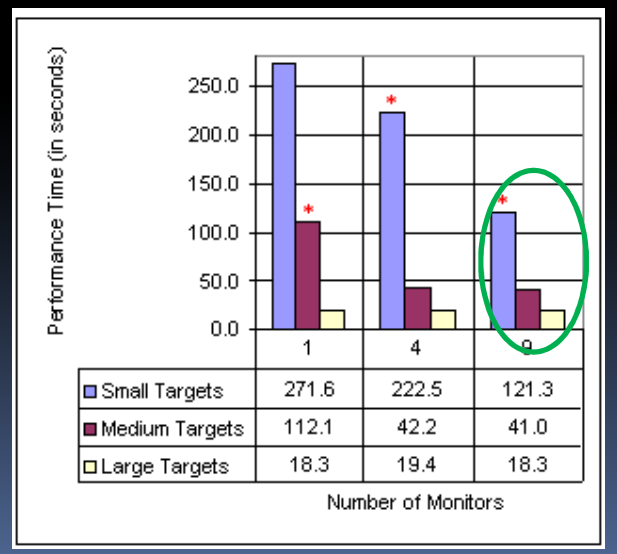


User Evaluations

- Effects of Tiled High-Resolution Display on Basic Visualization and Navigation Tasks, CHI2005
  - 3x3 tiled display (3840 x 3072 pixels) vs. 2x2 display (2560 x 2048) vs. 1 display (1280 x 1024)
  - Small target vs. Medium target vs. Large target
  - High-resolution display (with physical navigation, i.e., no pan-and-zoom virtual navigation) significantly improve performance time



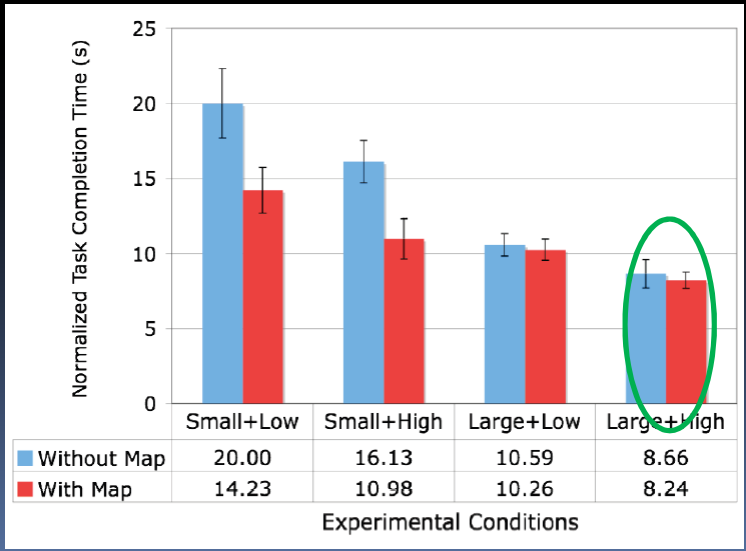
Find a single target task



Identify paired targets task

User Evaluations

- Increased Display Size and Resolution Improve Task Performance in Information-Rich Virtual Environments, GI2006
  - Small-size low-resolution vs. Small-size high-resolution vs. Large-size low-resolution vs. Large-size high-resolution display
  - Search task & Comparison task with/without Wayfinding aids in a 3D virtual environment



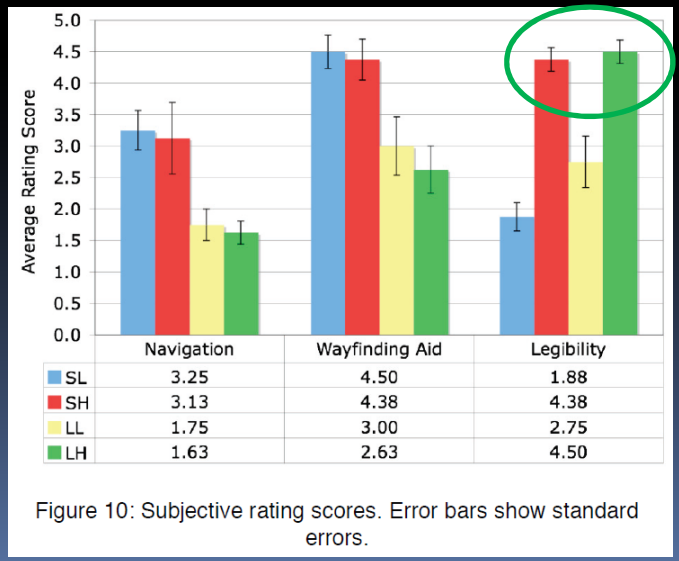


Figure 10: Subjective rating scores. Error bars show standard errors.

User Evaluations

- Move to Improve: Promoting Physical Navigation to Increase User Performance with Large Displays, CHI2007
  - Physical navigation (moving eyes, head, body) vs. virtual navigation (zooming, panning, flying using 3D gyro mouse) on tiled display
  - Navigation task & Search task & Pattern finding task
  - Increased physical navigation on tiled displays correlates with reduced virtual navigation and improved user performance

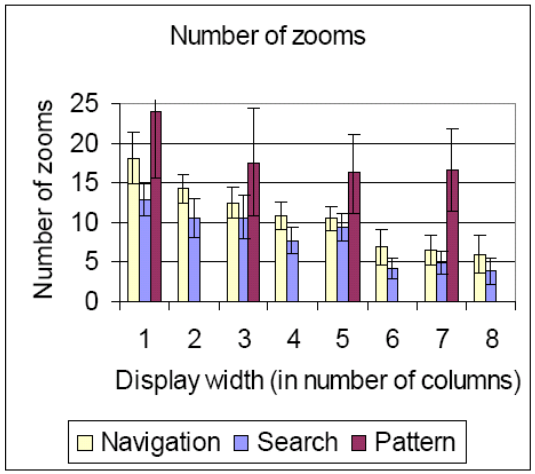


Figure 6. Average number of zooms (virtual navigation) for each task and display width.

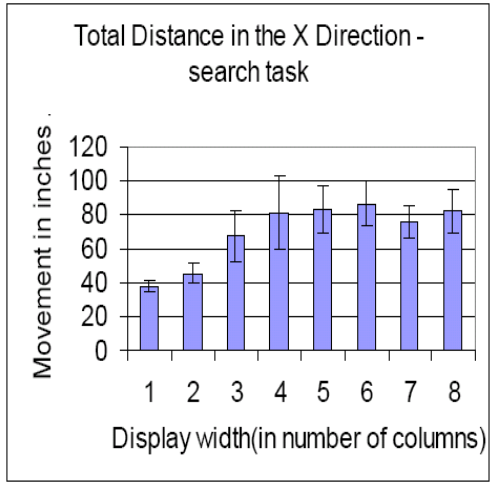


Figure 9. Average total X distance of participants in the search task.

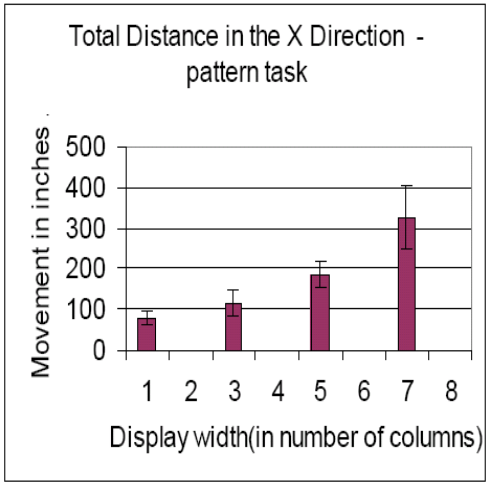
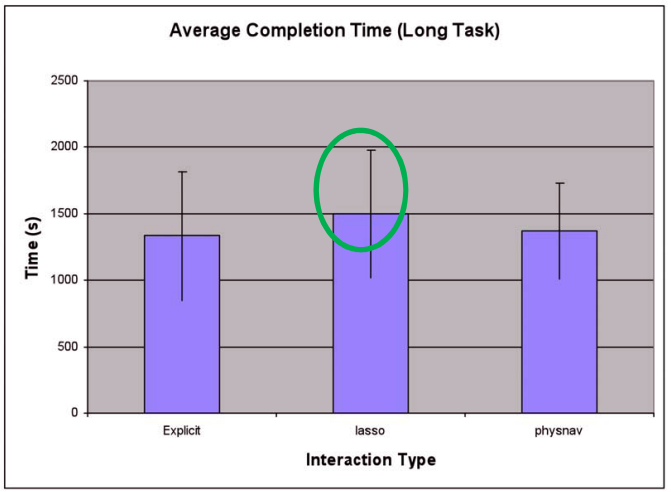
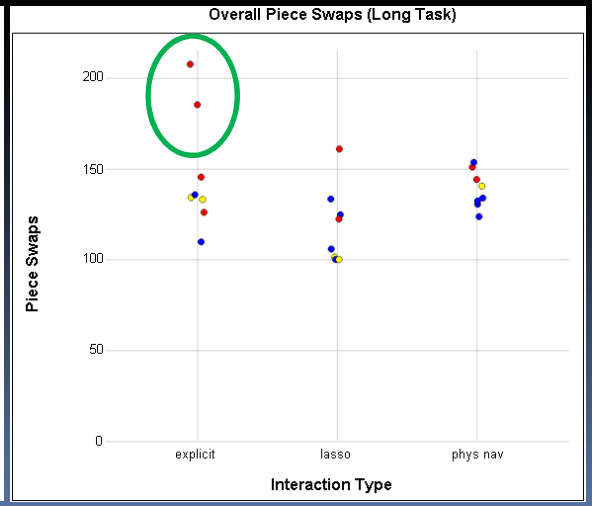


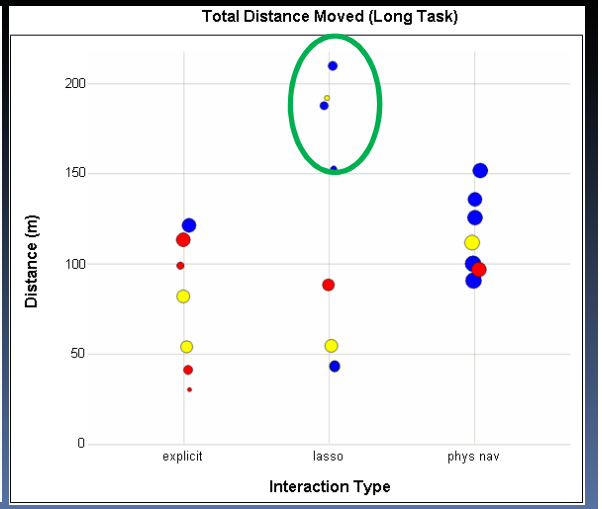
Figure 10. Average total X distance of participants in the pattern task.

User Evaluations

- A Multiscale Interaction Technique for Large, High-Resolution Displays, 3DUI 2009
  - Multiscale interaction (automatically changing the scale of 2D cursor according to the user's distance from the display) 4 levels
  - Physical navigation vs. Explicit (using menu on PDA) vs. Lasso (using VisionWand lasso gesture) interaction techniques
  - On multiscale interaction, physical navigation is natural to people although there is no significant difference on completion time among interaction techniques.

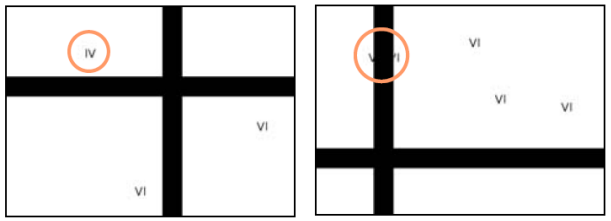






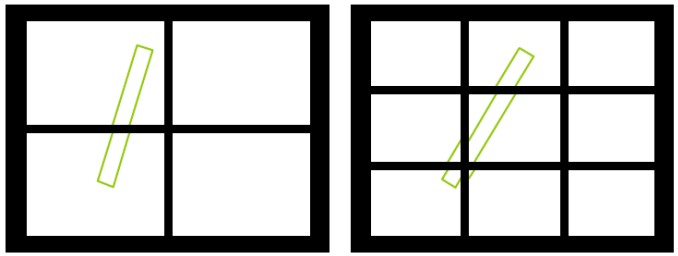
User Evaluations

- Effects of Interior Bezels of Tiled-Monitor Large Displays on Visual Search, Tunnel Steering, and Target Selection, CHI2010
  - 1x1 display vs. 2x2 tiled display vs. 3x3 tiled display
  - Visual search task & Tunnel steering task & Target selection task
  - Bezels are not detrimental to visual search performance but affect user's search strategies.
  - The presence of bezels hinders straight tunnel steering performance and also affects steering behaviors
  - The existence of bezels does not affect target selection performance



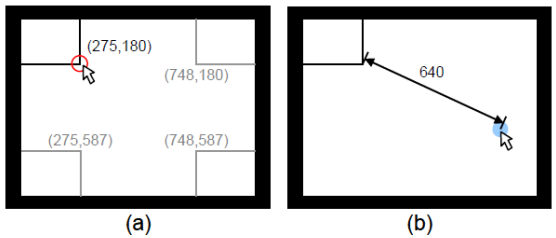
(a) (b)

Figure 3. Visual search: (a) task – to identify if an IV exists among VI's in a given image, (b) the symbol-split condition – symbols might be displayed apart across an interior bezel(s).



(a) (b)

Figure 5. Deflected straight tunnels in (a) [2×2] and (b) [3×3] tiled displays.

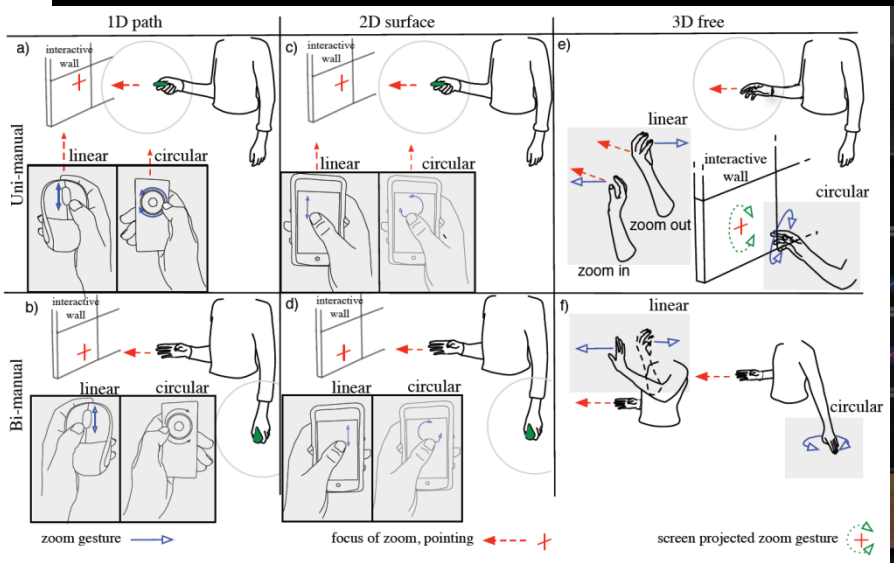


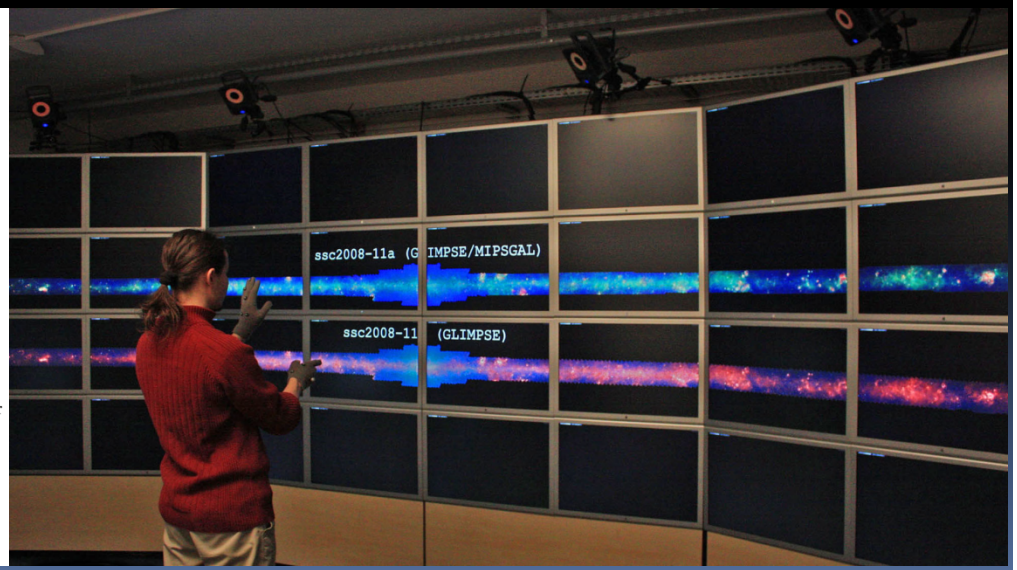
(a) (b)

Figure 9. Target selection task: (a) clicking the start circle at one of the four home positions to start a block of 10 trials, (b) clicking a target circle 640 pixels away from the start position (or previous target position).

User Evaluations

- Mid-air Pan-and-Zoom on Wall-sized Displays, CHI2011
  - One-hand vs. Two hands
  - Linear gesture vs. Circular gesture
  - 1D path vs. 2D surface vs. 3D free hand
  - Significant effects were obtained for all three factors: bimanual interaction, linear gestures and a high level of guidance(3D free hand) resulted in significantly improved performance.





Q & A