Qualcomm Augmented Reality Lecture Series – August 24, 2012
User Interfaces for Spatial Augmented Reality

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The Team

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- PhD's
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How Does Augmented Reality Technology Fit in the Commercial World?

- Training
- Design
- Manufacturing
- Logistics
- Medicine
- Reality
- Maintenance

How Does Augmented Reality Help?

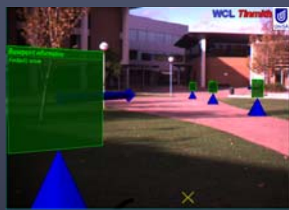
- Just in time information
- In situ visualisation of data
- Easier to understand information in context of the real world

What is Augmented Reality?

Like special effects in movies…

Augmented Reality

- Registered virtual information to physical world
- Provides extra information
- Allows users to see the unseeable
- Realtime



Presenting Augmented Reality Information


Projectors / Spatial Displays

Head Worn Displays

Handheld Devices

What Can You Do With AR?

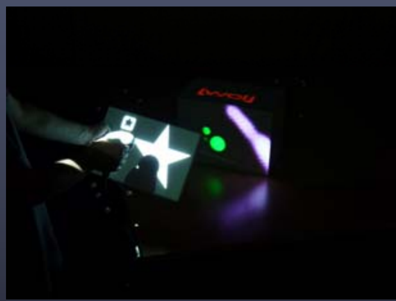
- Embed manuals in the physical world
- Visualise virtual artefacts in context of the environment
- Status information in situ with physical object
- Simulate future capability
- Physically and virtual embody future concepts

Barriers to AR

- Applications have been too complex.
- Visualisation have been too ambitious.
- Developers fight the current state of the art of technology.
- Lack of good user interface technology.

Spatial Augmented Reality

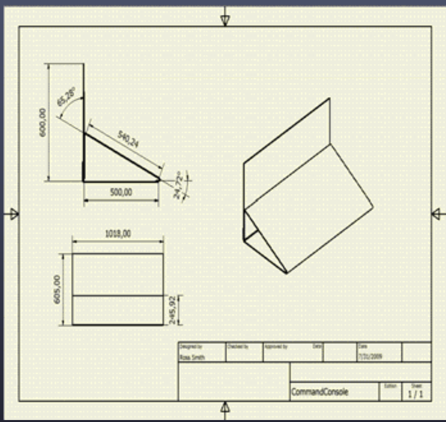
- Project *perspective correct* graphics onto objects in the real world
- Physical objects represented as 3D virtual models
- Can project onto movable objects by adding a tracking system

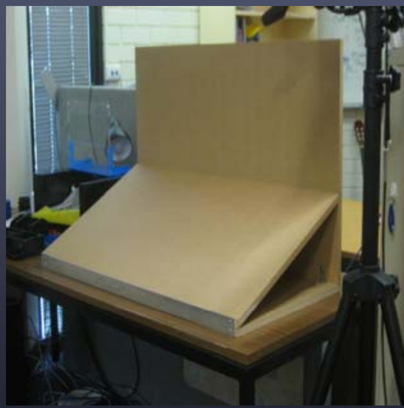


Spatial Augmented Reality in five easy steps

Ramesh Raskar, Greg Welch, Kok-lim Low Deepak Bandyopadhyay
Shader Lamps:
Animating Real Objects with Image-Based Illumination

Step One

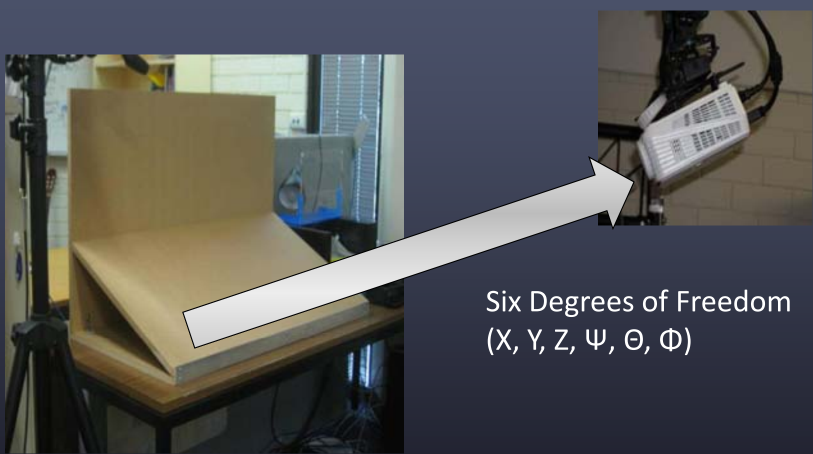




Step Two

Step Three

Step Four



Six Degrees of Freedom
(X, Y, Z, Ψ, Θ, Φ)

Step Five

Challengers for SAR User Interfaces

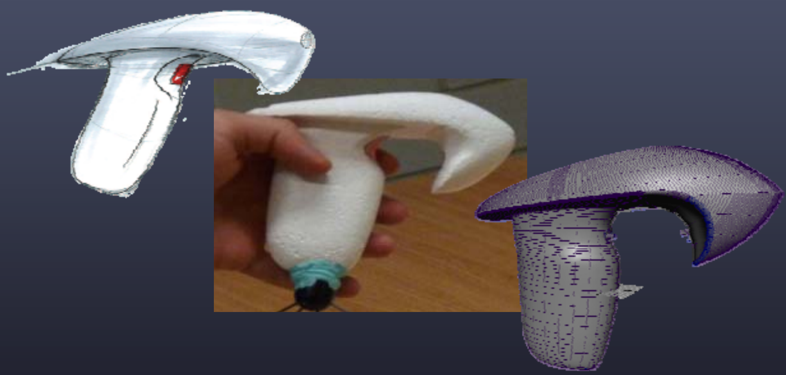
- Traditional UI technology does not map onto SAR
  - No mouse or keyboard
- Many virtual environment technologies do not map well onto SAR
  - All virtual information must be displayed on a physical surface, i.e. no floating menus.
- Need to rethink the user interface!

Opportunities for SAR User Interfaces

- Users do not have to wear a head mounted display
- The passive haptic nature of the display surfaces allows for better understanding of the physical/virtual visualisation.
  - Users can touch and interact with the display surface
- Naturally supports collaboration
  - all users are able to see the same virtual information

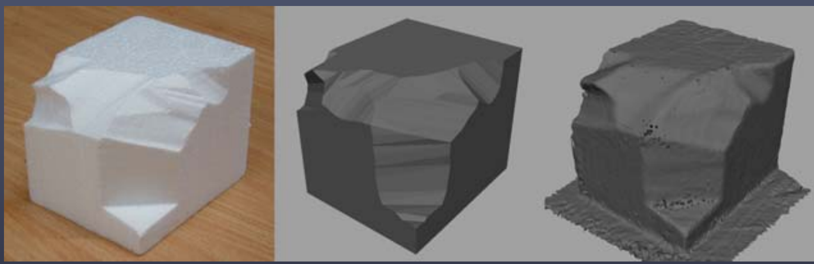
Augmented Foam Sculpting for Capturing 3D Models

- How can we make this process better?



Augmented Foam Sculpting for Capturing 3D Models

Evaluation
- Quality of Virtual Models



- Augmented Foam Sculpting compared to Polhemus FastSCAN
- 684 triangles vs. 81,925
  - Faces only added where cut occurs
- Accuracy currently limited to tracking system

Research Question

- How should users interact with large SAR systems?
- Where does the keyboard and mouse go?

Physical-Virtual Tools

- User interaction supported by physical tools
- Aim to take advantage of existing skills
- User feedback projected onto tools. Can overload tools with several tasks by changing projections
- No need for separate screens, HUD, etc.

(A very brief overview of) Related Work

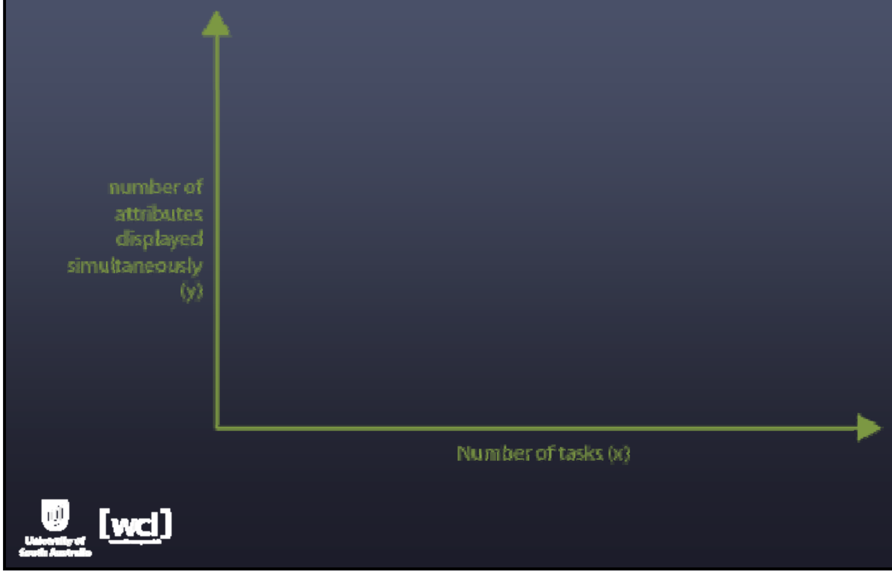
- Graspable & Tangible User Interfaces
  - Fitzmaurice et al. 1995, Ullmer& Ishii 1997
- Props used as handles to virtual objects
  - Spray Modeling (Jung et al. 2004)
  - Surface Drawing (Schwerdtfeger et al. 2008)
- VR input devices
  - Virtual Tricorder (Wloka& Greenfield 1995)
  - Personal Interaction Panel (Szalavri&Gervautz 1997)
- Shader Lamps (Raskar et al. 2001)

Digital Airbrushing with a Virtual Stencil

Digital Airbrushing with a Virtual Stencil

- Natural, two handed interaction
  - Takes advantage of existing airbrushing skills
- Work can be saved and modified later
- Virtual stencil is more flexible
  - Any shape can be used

The Within-System Tool Virtualisation Continuum



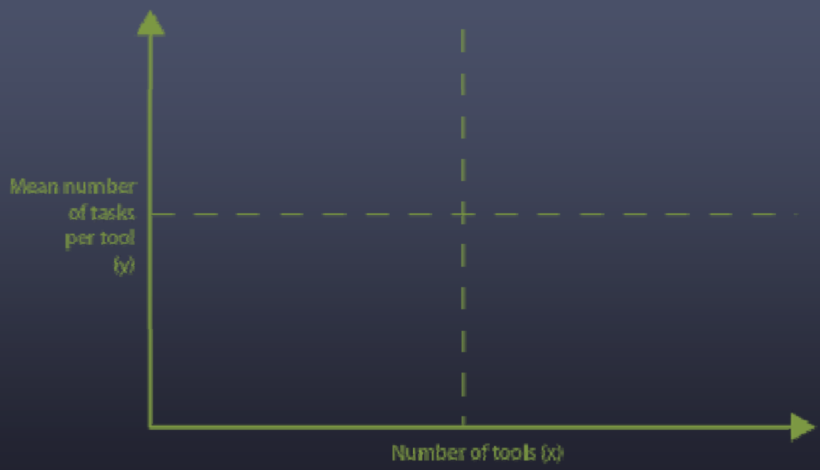
The Within-System Tool Virtualisation Continuum

- helps designers decide on the number of tools required, and the physical nature of these tools
- A *task* is the physical interaction required to achieve a goal (e.g. drawing a line)
- An *attribute* is a user changeable parameter for a task (e.g. line color)
- Overload tools with tasks that have the same or similar physical interactions

The Within-System Tool Virtualisation Continuum

- As a tool's position in the y-axis increases, should consider adding another tool with the same physical characteristics
- As a tool's position in the x-axis increases, should consider adding another tool with physical characteristics customized for a subset of the tasks

The Inter-System Tool Virtualisation Continuum



The Inter-System Tool Virtualisation Continuum

- Used to compare the relative complexity of user interfaces of different systems
- The complexity of user interface increases as the system moves away from the origin of the graph
- Systems in the lower left of the IS-TVC would have less complex user interfaces

Example Tools

Ray Gun Tool

- Digital Airbrushing
  - Color, paint flow, hardness, and spray angle attributes
- Virtual Laser Pointer
  - Color attribute
- Stencil Creation
- Command Entry
- **Placed (4,4) on WC-TVC**

Stylus Tool

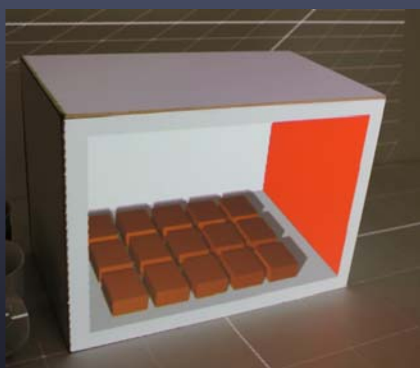
- Annotation
  - Pen color
- Stencil Creation
- Command Entry
- **Placed (3,1) on WC-TVC**

Foam Sculpting Tool

- Highly specialised tool
- Augmented Foam Sculpting
  - No attributes
- **Placed (1,0) on WC-TVC**

View-dependent Rendering

- Projecting onto surfaces
- Simple models - complex CAD data
- Holes, edges, silhouettes
- Virtual space
- View-dependent/ ”perspective correct” rendering



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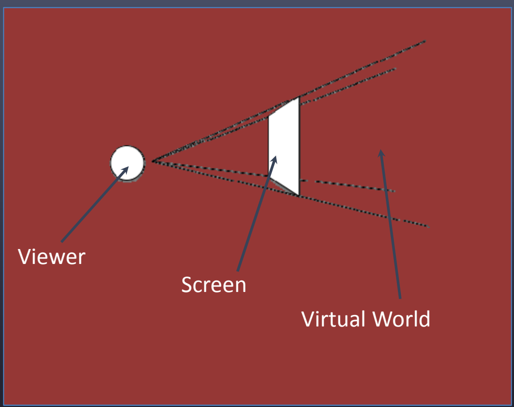
Three Things

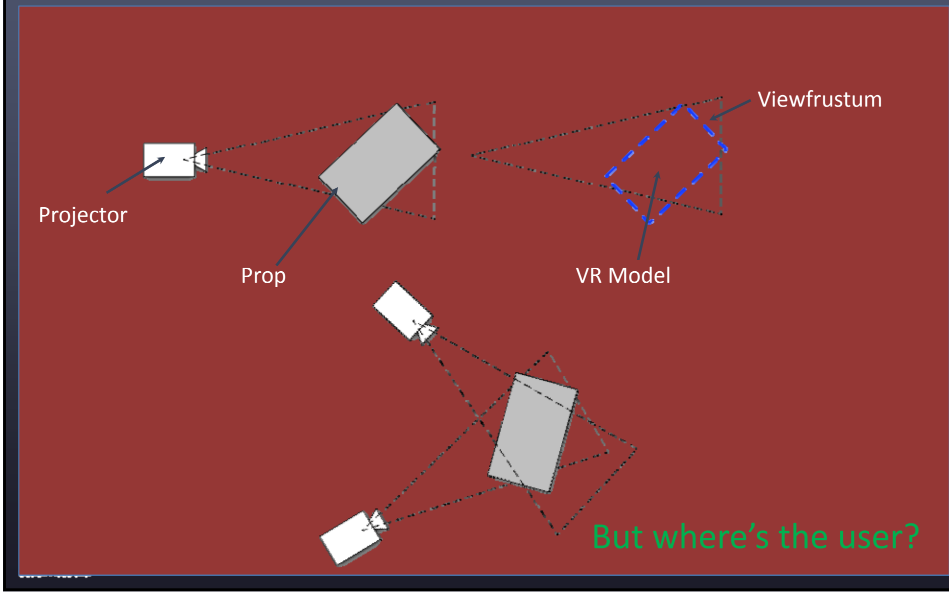
- How well can we trick the user in believing this illusion?
- View-dependent Rendering
- Depth Cues/Perception
- User study

(View-dependent) Rendering basics

- Traditional AR/VR:
  - View position is implicitly known
  - 'Window' into VR world
  - Pinhole camera
- Fishtank VR
- SAR?

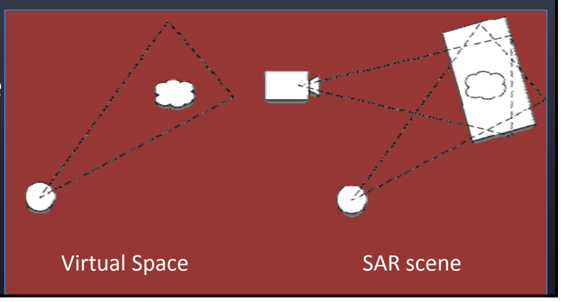


Rendering in SAR

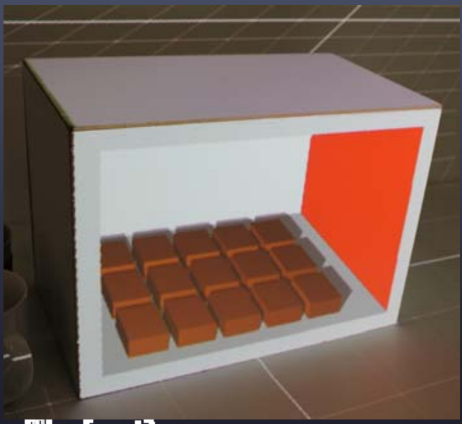


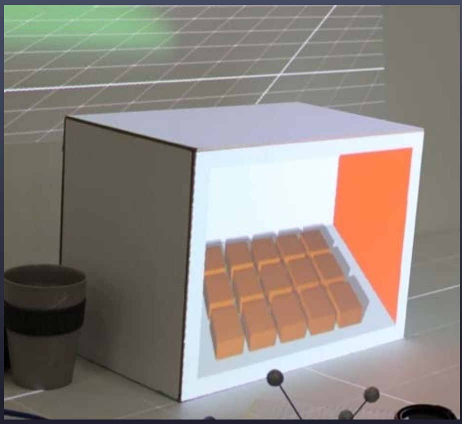
View-dependent Rendering Implementation

- View position != Render position
- Tracking
- Projected texturing
- Two-passes:
  - Render virtual space from user's position
  - Project as texture



View-dependent Rendering Results





Depth Cues/Perception

- Image is a 2D ‘plane’
- Depth and distance are inferred

Claude Lorrain - Seaport with the Embarkation of St. Ursula, 1641

Usable Depth Cues for SAR

- Perspective
- Occlusion

'automatically' provided by CG

- Shading
- Shadows
- Texturing

OpenGL settings

- Parallax ← Head-Tracking
- 'Thickness' ← Virtual-space

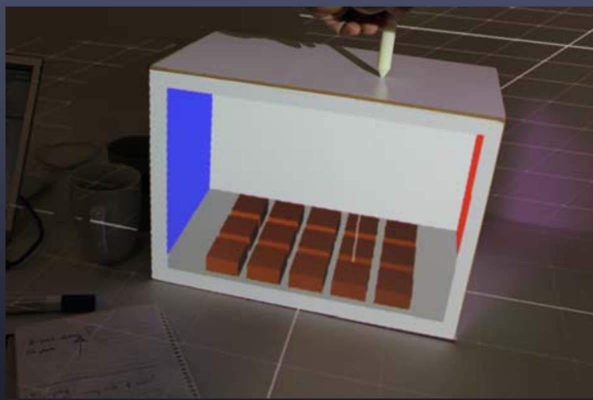
artificial depth cues

- Grid
- Selection Ray
- Blur

Measuring Depth Perception

- Desktop SAR
- ‘Empty’ box

- Selection task
- Ground truth



User Study (ongoing)

- 2 Boxes
- Many selections
- Combinations of depth cues

- Hypotheses:
- Parallax is strongest depth cue
- View-dependent Rendering at least ‘as good as the real thing’

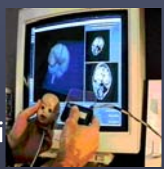
Results (shakycam)

Inspiration

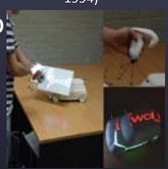
- What is TAM?
  - Architecture to enable ad-hoc definition of Tangible UIs (TUIs)
- Distinct separation of those who develop TUIs and those who use them
  - Individual development and usage stages – doesn't reflect real world use
- Why can't we just walk up to a system, pull out an object, and start interacting using it?

Tangible UIs

- Marble answering machine (Ishii, 2008a)
  - Physically instantiated virtual elements
- Dolls head prop (Hinckley et al., 1994)
  - Surgical visualization through spatial relationshi
- The Proximity Toolkit (Marquardt et. al, 2011)
  - Toolkit for abstracting proxemic relationships to programmatic events
- Physical-Virtual tools (Fjeld et al., 2002)
  - Physical tools to support virtual interactions



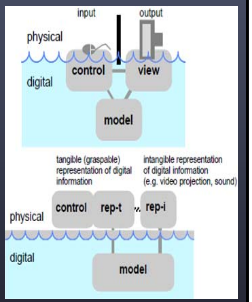
Dolls head (Hinckley et al., 1994)



PVT Spray Painting (Marner et al., 2009)

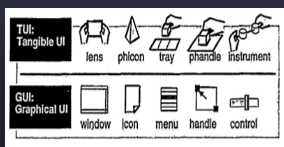
UI Theory

- CLI > GUI > NUI > Continuous NUI (Petersen and Stricker, 2009)
- Model-View Controller architecture used to enable GUIs (Olsen, 1998)
  - Needs to be modified for TUIs (Ullmer 2002)
- Current evaluation frameworks don't support adaptive UIs (Stary and Totter, 1997)



Interface Design

- Programming by Demonstration vs. Programming by Example (Halbert 1984)
  - "do what I did" vs. "do what I mean"
- Need to support trial-and-error exploration of interfaces (Sharlin et al., 2004)
- TUI equivalents of GUI concepts (Ullmer and Ishii, 1997)
- Time multiplexed vs. space multiplexed
  - Specificity vs. Generality
  - Strive for 1:1 ratio (Sharlin et al., 2004)



(Ullmer and Ishii, 1997)

Research Question

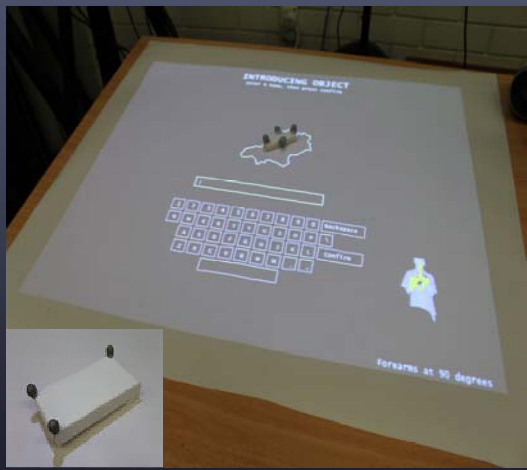
"How can we **introduce** previously **unknown tangible UIs** and **use** them to **effectively interact** with the system?"

Need to support range of devices - completely passive to organic

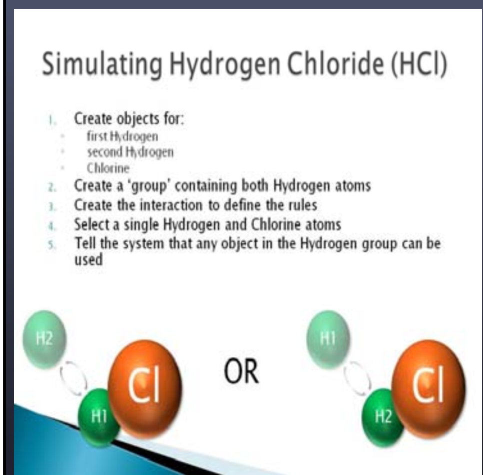
Implementation

- Gestures used for navigation
  - Wanted to avoid translating GUI into tangible realm
  - Allows entire system space to be 'blank' for user definition
- Kinect used for object detection and enabling touch interactions
- 6DOF IR tracking system used to track objects
- Introduce Objects > Define Properties > Define Interactions > Interact

Implementation



Using the System



Evaluation

- Participants watched video showing a single interaction being created
- Users could only watch the video once and had no additional materials aside from a 'gesture guide'
- Asked to create 3 simple 'war table' type scenarios to demonstrate system functionality

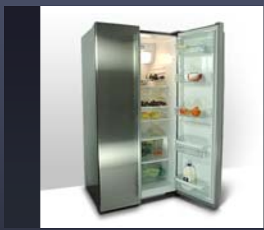
Results

- All participants completed all three stages
- Majority of users successfully completed the scenario in their first attempt
  – Indicates their expectations of the system matched the system's functionality
- Some participants confused over use of groups
- Gesture-based navigation was terrible

How do you design…

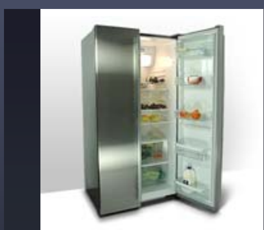
Appliances?

How do you design…


Appliances?


Operating Theatres?

How do you design…


Appliances?

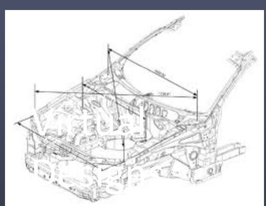

Operating Theatres?


Command and Control Rooms?

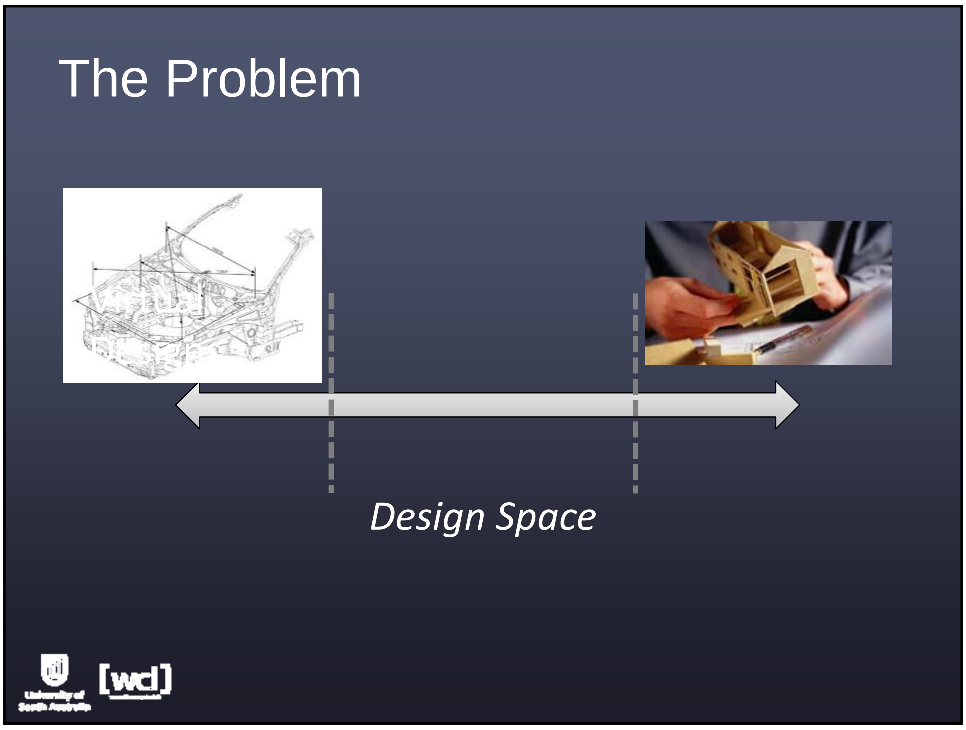
The Problem

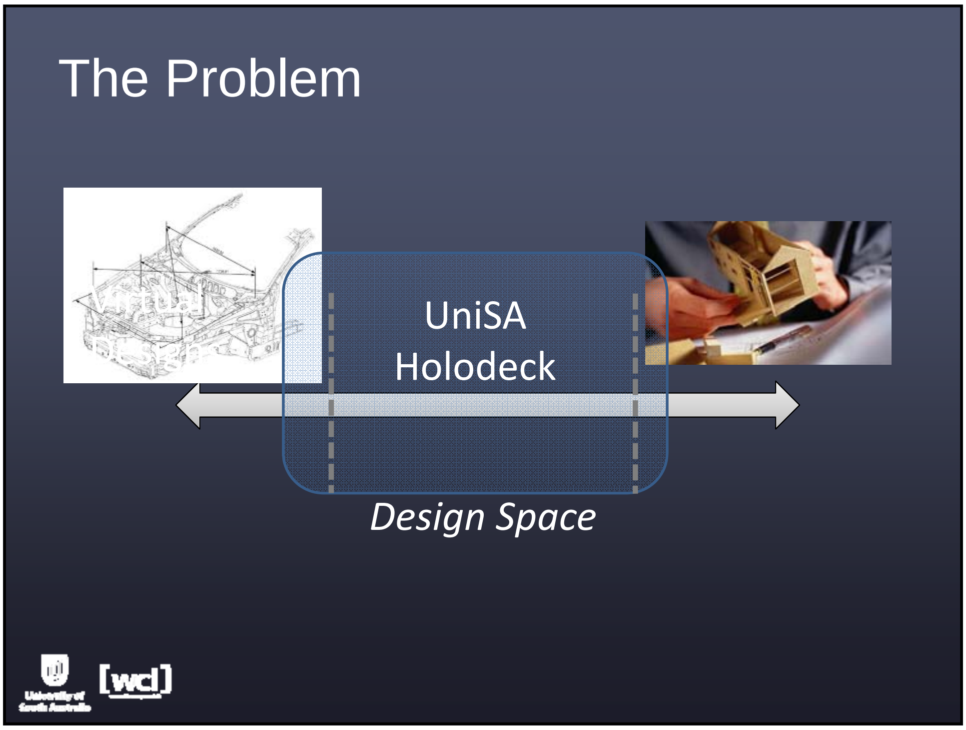
Design Space

The Problem

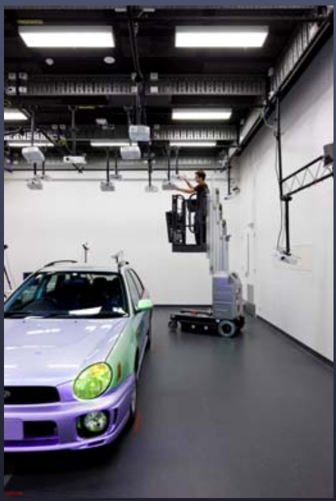


Design Space


The Problem
Design Space


The Problem
UniSA
Holodeck
Design Space

UniSA Holodeck



- 14m x 8.5m x 4m
- 44 Projectors
- High Performance Computing
- 40 Cameras
- Wide area tracking
- Automatic configuration
- External load-in

Command and Control Room Design

Spatial Augmented Reality for Design

- Command and control centres on submarines and ships
- Command centres for mining and gas operations
- Rapidly deployable command and control centres in the field
- Hospital operating theatres
- Any interior design problem

Benefits

- Natural manner for viewing designs
- Stakeholder buy-in for major decisions
- Early ergonomic measurements
- Interactive simulations of new technology

Current Industrial Projects

- GM Holden
  – Manufacturing and assembly
- Intel
  – Maintenance tasks
- Jumbo Vision
  – Design of control rooms

Questions?

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