Augmented Reality
Mixed Reality

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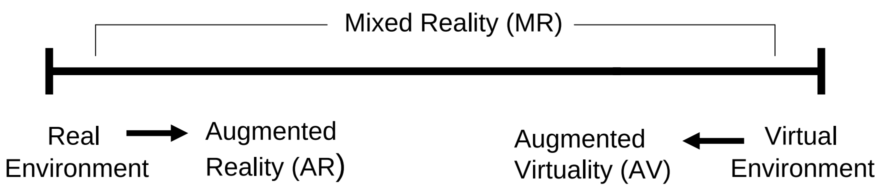
Augmented Reality and Virtual Reality

- Virtual Reality
  - Totally immersive environment
  - Visual senses are under control of system (sometimes aural and proprioceptive senses too)
- Augmented Reality
  - System augments the real world scene (supplements reality, instead of completely replacing it)
  - User maintains a sense of presence in real world
  - Needs a mechanism to combine virtual and real worlds, i.e., registration

Reality-Virtuality Continuum



Miligram coined the term "Augmented Virtuality" to identify systems which are mostly synthetic with some real world imagery added such as texture mapping video onto virtual objects.

Augmented Reality

- Ronald Azuma (1997)
- "In contrast with virtual reality, which refers to a situation in which the goal is to immerse a user in a completely synthetic environment, augmented reality refers to a situation in which the goal is to supplement a user's perception of the real world through the addition of virtual objects."
- Blends real and virtual, real-time interactive, registered in 3D
- Enhance perception of and interaction with real world
- Potential for productivity improvements in real-world tasks
- Relatively new field; many problems to be solved

Mixed Reality

- Paul Milgram and Fumio Kishino (1994)
- “Mixed reality is a term that has been used to refer to the entire spectrum of situations that span the continuum between virtual reality and actual reality. Mixed reality includes augmented reality, augmented virtuality, and other mixed configurations.”

Augmented Virtuality

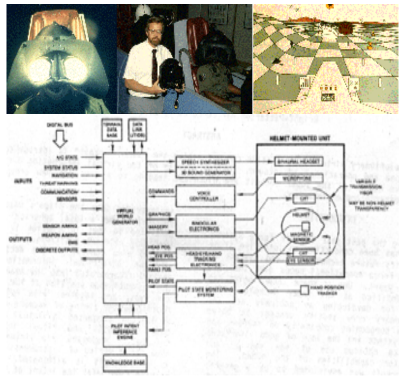
- A system in which real multi-sensory input is provided, which supplements the visually presented virtual environment
- Directing the smell of coffee grounds to a user when she/he passes near a coffee maker in the virtual environment
- Turning on a heat lamp over the user when she/he approaches a spot in the virtual environment that is exposed to full sun
- Turning on a fan in front of the user when she/he approaches a spot in the virtual environment that is exposed to wind

AR History

- 1960s – First See-Through HMD (Ivan Sutherland)
- 1970-80s – US Air Force Super Cockpit (Thomas Furness)
- Early 1990s
  - Boeing coined the term “Augmented Reality.”
  - Wire harness assembly application (T. Caudell, D. Mizell).
- Early to mid 1990s – UNC ultrasound visualization
- 1994
  - Motion-stabilized AR display (Azuma)
  - First motion-stabilized AR display that works outdoors and achieves tighter registration than any previous outdoor AR system.
- 1995 – Fiducial tracking in video see-through AR
- 1996 – UNC hybrid magnetic-vision tracker
- Late 1990s – Collaboration, Outdoor applications
- 2000 – Augmented sports broadcasts

AR History

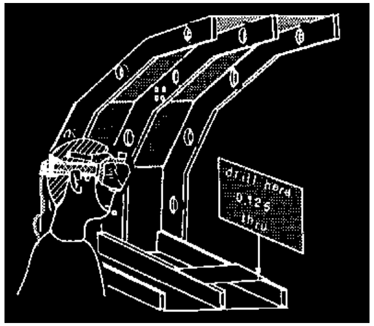
Surtherland’s “Ultimate Display”



Furness’ “Super Cockpit”, a simulated virtual cockpit

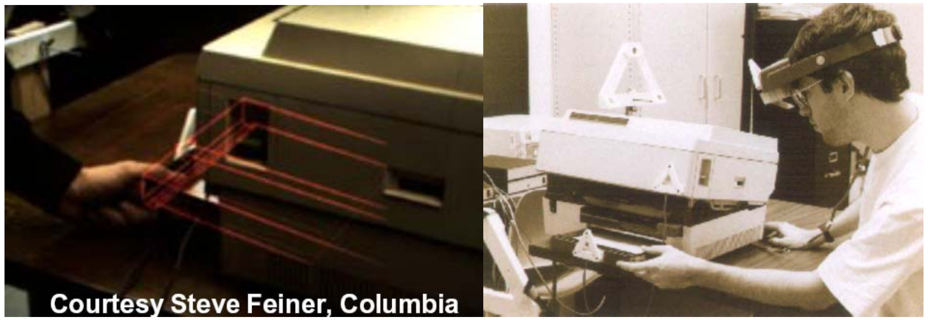
AR History – Assembly and maintenance

Layout Diagrams for the wire bundles appear "superimposed" on the layout board



Boeing HUDSET (Heads-up Display See-through head-mounted display)

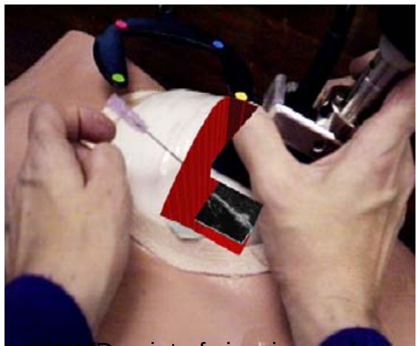
AR History – Assembly and maintenance



Assembly, maintenance, and repair of printer @ Columbia University

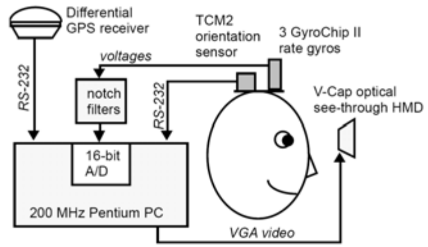
AR History – Medical training

Video See-through Augmented Reality HMD built on the basis of a Sony Glasstron LDI-D100 device



HMD point of view image from a 1996 AR guidance experiment @ UNC, Ultrasound project

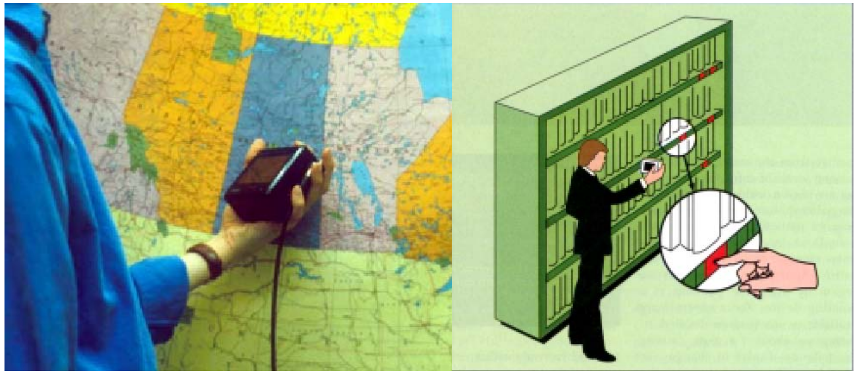
AR History – Annotating environment



AR History – Annotating environment

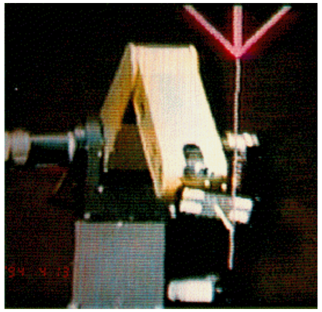
Touring Machine, a Mobile Augmented Reality Systems project - Campus information system @ Columbia University

AR History – Annotating environment

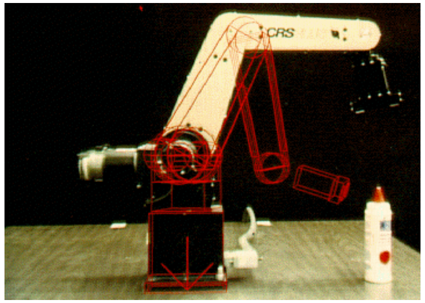


Augmenting maps, libraries, etc - Chameleon @ U of Toronto [Fitzmaurice93]

AR History – Robot control

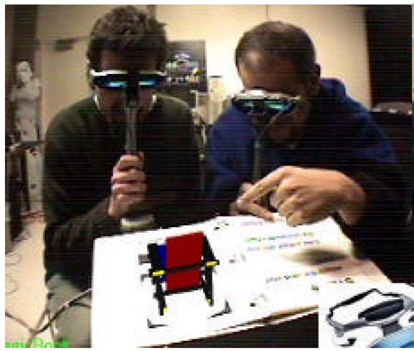


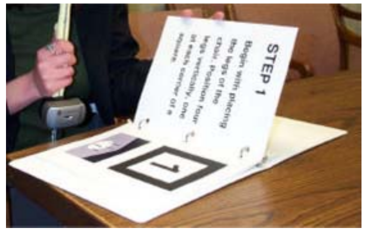
Robotic path planning, previewing - Virtual Pointer in space for the robot to follow



Remote manipulation
ARGOS (Augmented Reality through Graphic Overlays on Stereovideo) @ U. of Toronto

AR History – Collaboration





Use AR to allow users to collaborate inside the same real environment, in the Magic Book Project [Billinghurst]

AR History – Broadcast augmentation

Adding virtual content to live sports broadcasts
- First down line in American football
- Hockey puck trails
- Virtual advertisements
- National Flags in swimming lanes in 2000 Olympics

Commercial application - Princeton Video Image

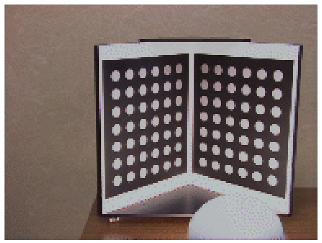
Combining the Real and Virtual Worlds

To combine real and virtual world, we need:

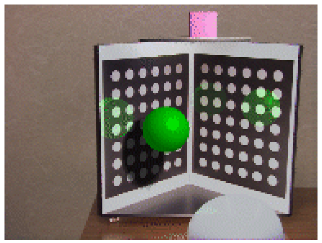
- Precise models
- Locations and optical properties of the viewer (or camera) and the display
- Calibration of all devices
- To combine all local coordinate systems centered on the devices and the objects in the scene in a global coordinate system

Combining the Real and Virtual Worlds

- Register models of all 3D objects of interest with their counterparts in the scene
- Track the objects over time when the user moves and interacts with the scene



Real world



Real world with virtual objects and inter-reflections and virtual shading

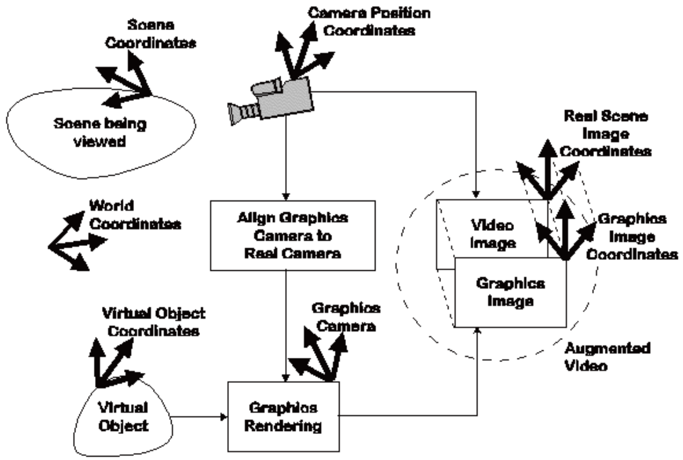
Realistic Merging

To create realistic merging, we need:

- Objects to behave in physically plausible manners when manipulated
- Occlusion
- Collision detection
- Shadows

- All of this requires a very detailed description of the physical scene

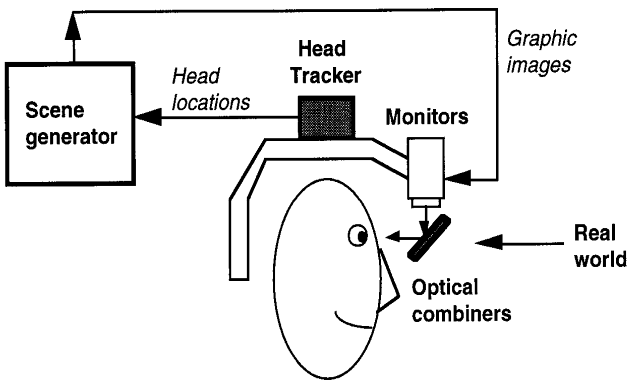
Components of an AR System



Augmented Reality Technology

- Augmented reality systems often involve the use of head mounted displays
- There are two main categories of HMD-based AR systems
  - Optical See-Through
  - Video See-Through
- However, some augmented reality systems involve the use of projectors or other display devices instead of HMDs.
  - Monitor-based
  - Projection-based
  - Head-Mounted Projective Display (HMPD)
  - Hand-held Augmented Reality

Optical See-Through Display



Optical See-Through Display

Kaiser Electro-Optics Sim Eye XL 100A

AddVisor 150™

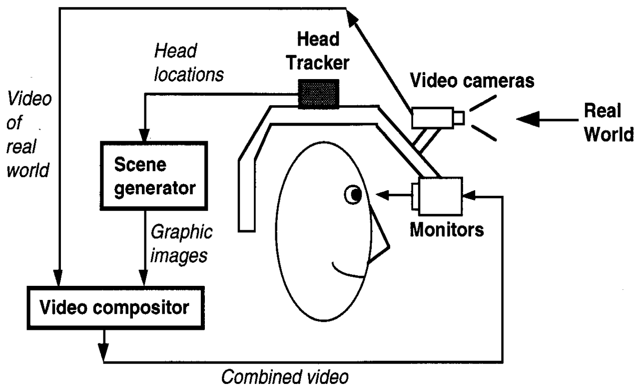
Optical See-Through Display

- An optical see-through head mounted display works by placing optical combiners in front of the user's eyes
- These combiners are partly **transmissive** allowing the user to see through them, and partly **reflective**, allowing the user to see in them the reflection of virtual images portrayed on miniature displays in their line of sight

Advantages of Optical See-through HMD

- Simpler & cheaper
- Direct view of real world
  - Full resolution
  - No time delay (for real world)
  - Safety
  - Lower distortion
- No eye displacement
  - Video see-through HMD creates an offset between cameras and real eyes
  - But, COASTAR video see-through display avoids this problem

Video See-Through Display



Video See-Through Display

Work done by Jannick Roland, Frank Biocca @ UNC

Video See-Through Display

- A video see-through head mounted display uses miniature cameras to capture the view of the world that would be seen by each eye
- The video images of the real world are then combined with the computer-generated images of the virtual world, to create augmented-reality images that can be displayed on a traditional (non see-through) HMD

Advantages of Video See-Through HMD

- True occlusion
  - But, ELMO optical display that supports occlusion
- Digitized image of real world
  - Flexibility in composition
  - Real and virtual view delays can be matched
  - More registration, calibration strategies
- Wide field of view is easier

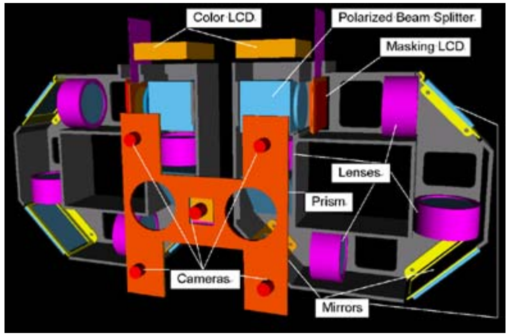
Video Composition for Video See-Through Display

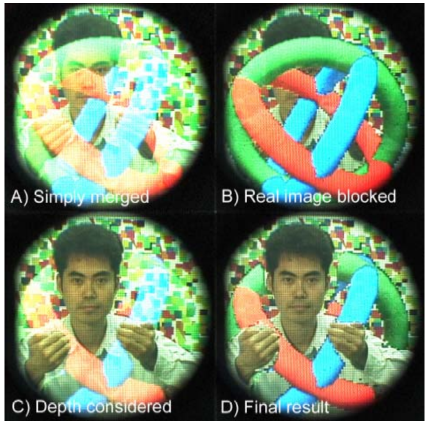
- The real and virtual images can be combined using a **chroma key (blue screen)** approach:
  - The background in the virtual images is defined to be a particular color that doesn't appear in the virtual objects
  - Pixels in the background color are replaced by pixels from the registered real world images
  - Used for special effects
- This results in the virtual objects being superimposed over the real world images (regardless of depth)

Video Composition for Video See-Through Display

- A better approach is to perform a **depth-composite** of the real and virtual images, allowing closer objects to occlude farther objects regardless of their provenance (real world or virtual world)
- Combine real and virtual images by a pixel-by-pixel depth comparison
- This requires having information about the depth at each pixel in the real world image

ELMO Occlusion-Capable Optical See-Through HMD





Kiyokawa, Billinghurst, Campbell, Woods, ISMAR 2003

COASTAR (Co-Optical Axis See-Through Augmented Reality) Video See-Through HMD

MR Laboratory & Canon

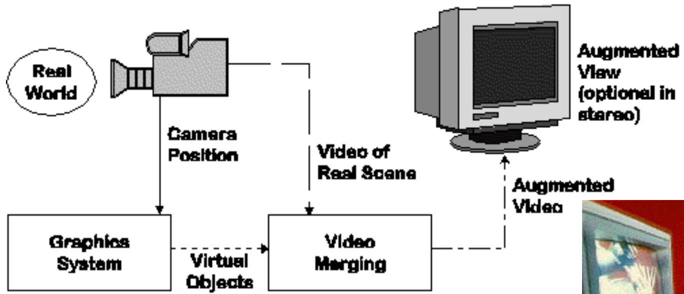
Optical vs. Video See-Through HMD

A view from a Optical See-Through HMD

A view from a Video See-Through HMD

Monitor-based Augmented Reality

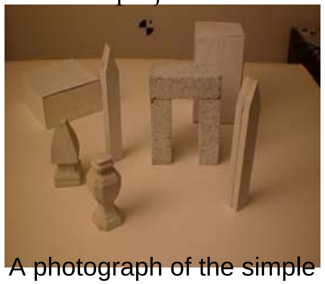
- Simplest available
- Less feeling of being immersed in the environment



ARGOS @ U. of Toronto

Projector-based Augmented Reality

- Shader Lamps: Table-Top Spatially Augmented Reality [UNC]
  - The architectures are white bricks and wooden/paper blocks with textures projected from two DLP projectors mounted on the ceiling

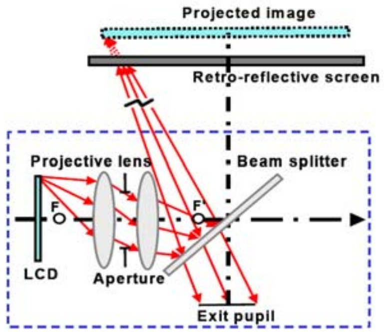


A photograph of the simple physical model, made up of white diffuse surfaces

The physical model illuminated to create an illusion of a tabletop with colorful objects

Head-Mounted Projective Display

- SCAPE (Stereoscopic Collaboration in Augmented and Projective Environments) [UIUC]
  - a hybrid environment involving both projective and optical see-through head-mounted displays



Hand-held Augmented Reality Display

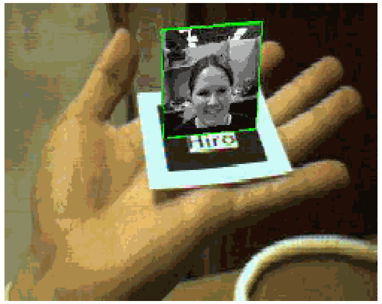
- Augmented Reality using consumer Cell Phones or PDA
  - PhoneGuide: Museum guidance supported by on-device object recognition on mobile phones
  - Video See-Through AR and Optical Tracking with cell phones

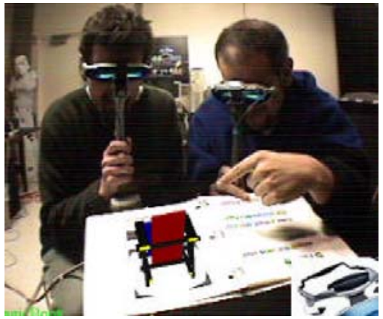
AR Tracking

- Tracking is significantly more difficult in AR than VR
- Indoor AR tracking:
  - Inertial trackers, such as Intersense IS-300
  - UNC Hi-Ball optical tracker using multiple IR sensors to track IR sources mounted on the ceiling
- Outdoor AR tracking:
  - Global Positioning Satellites (GPS),
  - Hybrid tracking using vision and inertial gyroscope sensors
- Improving tracking using estimation and prediction

AR Tracking

- Shared Space project @ HITLab, UW
  - Vision-based (fiducial) tracking for collaborative applications
  - Targets are placed on square tiles and virtual images appear over the tiles in a see-through HMD
  - AR Toolkit





Registration Problem

- Virtual and Real must stay properly aligned
- If not, compromises illusion that the two coexist & prevents acceptance of many serious applications
- Accurate registration is difficult
  - Sensitivity of visual system
  - Many sources of error
- Augmented reality information display
  - Head-stabilized
  - Body-stabilized
  - World-stabilized

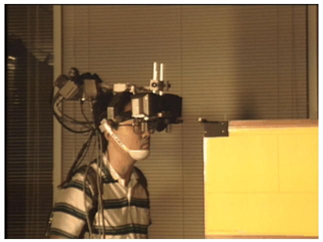
Increasing Registration & Tracking requirements

Sources of Registration Errors

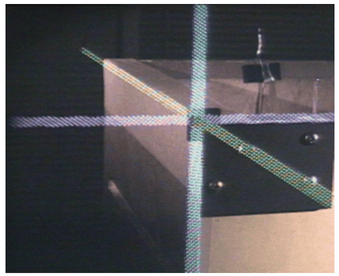
- Static errors
  - Optical distortions
  - Mechanical misalignments
  - Tracker errors
  - Incorrect viewing parameters
- Dynamic errors
  - System delays (largest source of error)

Reducing Static Errors

- Distortion compensation
- Manual adjustments
- View-based or direct measurements
- Camera calibration



View-based calibration [Azuma 94]



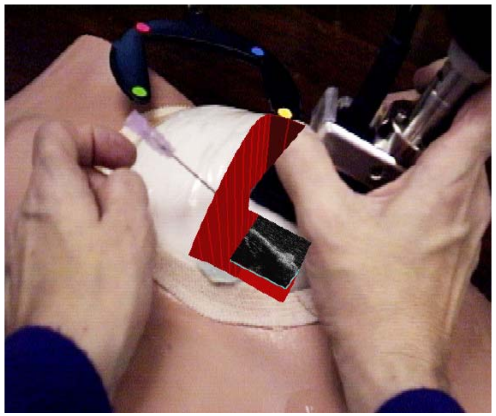
Reducing Dynamic Errors

- Dynamic errors (i.e., delay in application loops)
  - Tracking, e.g. 20 Hz = 50 ms
  - Calculate viewpoint simulation, e.g. 500 Hz = 2 ms
  - render scene, e.g. 30 Hz = 33 ms
  - draw to display, e.g. 60 Hz = 17 ms
  - Total delay = 102 ms (i.e., 1 ms delay = 33 ms error)
- Reduce system lag
  - Faster tracker, faster CPU, Faster GPU, Faster display
- Reduce apparent lag
  - Image deflection
  - Image warping
- Match input streams
  - Delay video of real world to match system lag
- Predictive tracking

AR Interaction

- AR Interfaces as 3D data browsers
  - 3D virtual objects are registered in 3D
  - 3D virtual viewpoint control interaction
- AR interfaces as context-based information browsers
  - Information is registered to real-world context
  - Manipulation of a window into information space
  - But, difficult to modify or author virtual contents
- AR 3D interfaces
  - Virtual objects displayed in 3D real world and can be freely manipulated
  - Use can interact with 3D virtual object everywhere in space
  - But, usually no tactile feedback & lack of seamless interaction for virtual and physical objects
- Augmented surfaces
  - Images are projected on a surface
  - Physical objects can be used as controls for virtual objects

AR Interfaces as 3D data browsers



UNC Ultrasound Project

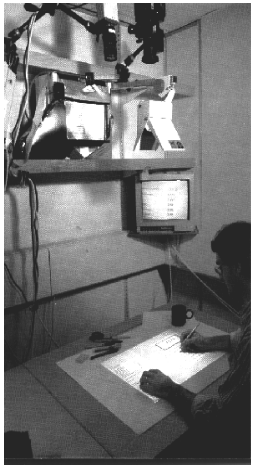
AR Interfaces as context-based information browsers

NaviCam [Rekimoto95]

Collaborative 3D AR Interfaces

AR Hockey interface @ MR System Laboratory [Kiyokawa 2000] allows two users to play a game of air hockey using a virtual puck.

Augmented Surfaces



DigitalDesk @ Georgia Tech

Augmented Reality Kitchen @ MIT Media Lab

Digilog Book

Digilog Book – Temple Bell @ GIST

Digilog Book - Unjusa @ GIST

Reference

- Ronald Asuma (1997) "A Survey of Augmented Reality", Presence: Teleoperators and Virtual Environments, 6(4):355-385.
- http://www.cs.unc.edu/~raskar/Tabletop/images.html
- http://portal.acm.org/citation.cfm?id=964697
- http://www.uni-weimar.de/~bimber/research.php
- http://www.vrlogic.com/html/keo/sim_eye_xl100a.html
- http://products.saab.se/PDBWeb/ShowProduct.aspx?ProductId=1097&MoreInfo=true
- http://www.cs.brown.edu/stc/resea/sciviz/research_S7.html
- http://erie.nlm.nih.gov/~yoo/pubs/93-021.pdf
- http://www1.cs.columbia.edu/graphics/projects/mars/touring.html
- http://midag.cs.unc.edu/pubs/papers/MICCAI01-rosenthal-AugReality.pdf
- http://www.dgp.toronto.edu/~gf/Research/Chameleon/ChameleonResearch.htm
- http://vered.rose.utoronto.ca/people/david_dir/CHI93/CHI93.full.html
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