An Introduction to Augmented Reality

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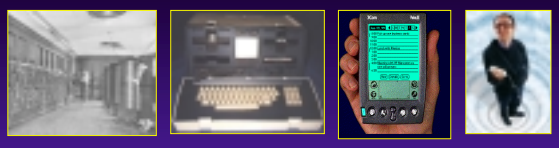
Tutorial Goals

- Introduction to the fundamentals of Augmented Reality (AR) technology
- To provide hands-on experience with Augmented Reality demonstrations
- An introduction to open-source software tools that can be used to build AR applications
- An overview of unexplored areas in the AR field that may prove fruitful domains for future research
- Have Fun !

A brief history of Time

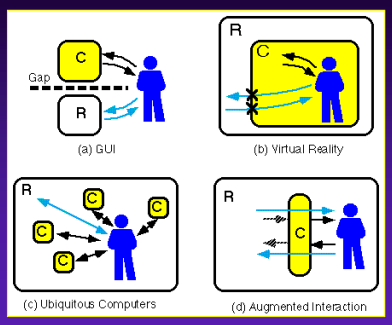
- Trend
  - smaller, cheaper, more functions, more intimate
- Technology becomes invisible
  - Intuitive to use
  - Interface over internals
  - Form more important than function
  - Human centered design

A brief history of Computing



- Trend
  - smaller, cheaper, faster, more intimate, intelligent objects
- Computers need to become invisible
  - hide the computer in the real world
    - Ubiquitous / Tangible Computing
  - put the user inside the computer

Invisible Interfaces



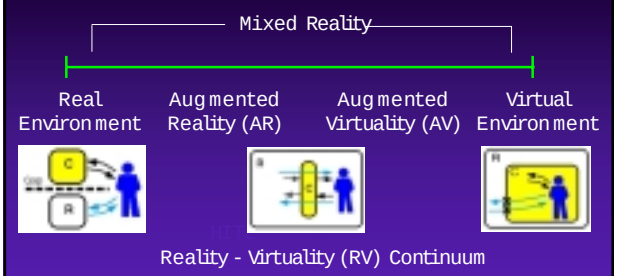
Show MR Lab Video

AR Concept Video

Augmented Reality

- Virtual Reality: Replaces Reality
  - Immersive Displays
- Augmented Reality: Enhances Reality
  - See-through Displays
- Characteristics
  - Combines Real and Virtual Images
  - Interactive in real-time
  - Registered in 3D

Milgram's Reality-Virtuality continuum

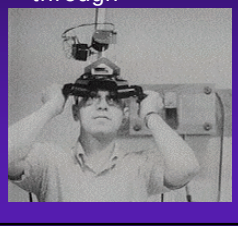


Adapted from Milgram, Takemura, Utsumi, Kishino. Augmented Reality: A class of displays on the reality-virtuality continuum

AR History

A Brief History of AR (1)

- 1960's: Sutherland / Sproull's first HMD system was see-through



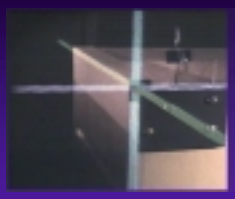
A Brief History of AR (2)

1970 - 80's: US Air Force Super Cockpit (T. Furness)

A Brief History of AR (3)

- Early 1990's: Boeing coined the term "AR." Wire harness assembly application begun (T. Caudell, D. Mizell).
- Early to mid 1990's: UNC ultrasound visualization

A Brief History of AR (4)



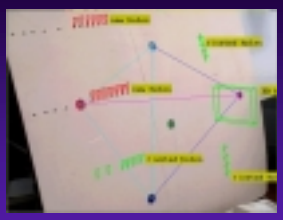

- 1994: Motion stabilized display [Azuma]
- 1995: Fiducial tracking in video see-through
- 1996: UNC hybrid magnetic-vision tracker

AR History (5)


- 1998: Dedicated conferences begin
- Late 90's: Collaboration, outdoor, interaction
- Late 90's: Augmented sports broadcasts
- 1998 - 2001: Mixed Reality Systems Lab

Applications

- Medicine
- Manufacturing
- Training
- Architecture
- Museum



Applications: medical

- "X-ray vision" for surgeons
- Aid visualization, minimally-invasive operations. Training. MRI, CT data.
  - Ultrasound project, UNC Chapel Hill.

Courtesy UNC Chapel Hill

Show Medical AR Video

Medical AR

Assembly and maintenance

Show CAD Video

Car Design

Applications: annotating environment

- Public and private annotations
- Aid recognition, “extended memory”
  - Libraries, maps [Fitzmaurice93]
  - Windows [Columbia]
  - Mechanical parts [many places]
  - Reminder notes [Sony, MIT Media Lab]
  - Navigation and spatial information access

Show CAD Video

Car Design

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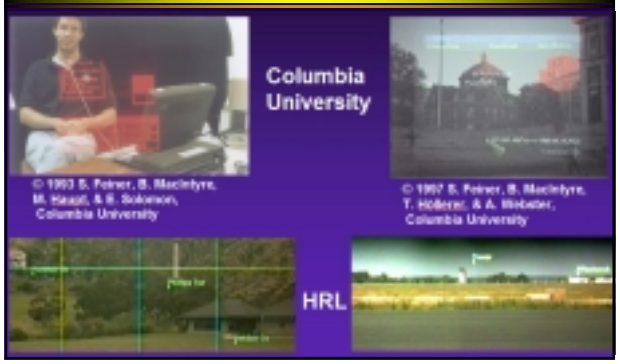
Annotation pictures



Building Labeling

Show Labeling Video

Building Labeling

Application: 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 is one company
    - http://www.pvi-inc.com/

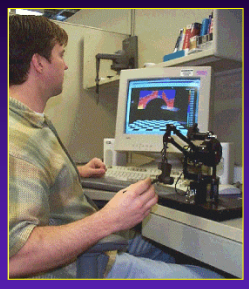
Broadcast Examples

AR Technology

- Key Technologies
  - Input
    - Input devices
    - Tracking technologies
  - Output
    - Display (visual, audio, haptic)
    - Image Generation

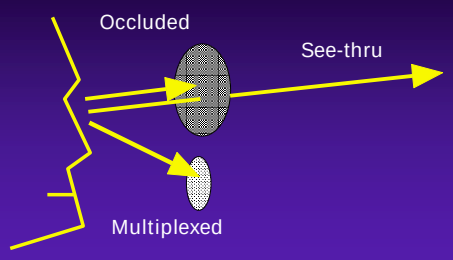
Other Types of AR

- Audio
  - spatial sound
  - ambient audio
- Tactile
  - physical sensation
- Haptic
  - virtual touch

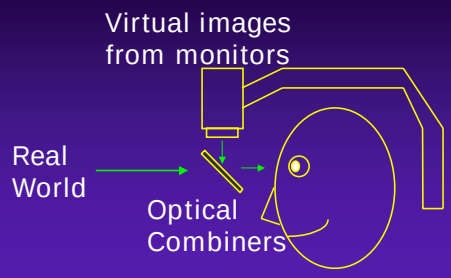


AR Displays

Types of Head Mounted Displays



Optical see-through head-mounted display

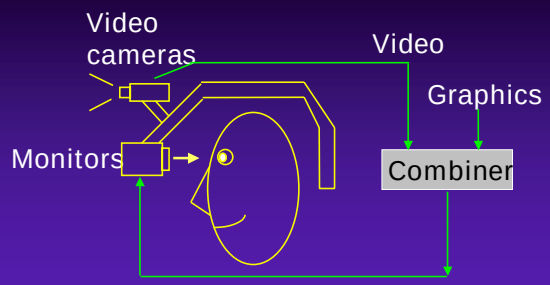


Optical see-through HMDs

Sony Glasstron

Virtual Vision VCAP

Video see-through HMD



Video see-through HMD

MR Laboratory's COASTAR HMD
(Co-Optical Axis See-Through Augmented Reality)
Parallax-free video see-through HMD

Strengths of optical AR

- Simpler (cheaper)
- Direct view of real world
  - Full resolution, no time delay (for real world)
  - Safety
  - Lower distortion
- No eye displacement (but COASTAR video see-through avoids this problem)

Strengths of video AR

- True occlusion (but note Kiyokawa optical display that supports occlusion)
- Digitized image of real world
  - Flexibility in composition
  - Matchable time delays
  - More registration, calibration strategies
- Wide FOV is easier to support

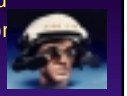
Optical vs. video AR summary

- Both have proponents
- Video is more popular today?
  - Likely because lack of available optical products
- Depends on application?
  - Manufacturing: optical is cheaper
  - Medical: video for calibration strategies

Eye-multiplexed viewer Virtual Vision Personal Eyewear

Virtual image inset into real world

Head Mounted Displays (HMD)



- Display and Optics mounted on Head
- May or may not fully occlude real wor
- Provide full-color images
- Considerations
  - Cumbersome to wear
  - Brightness
  - Low power consumption
  - Resolution limited
  - Cost is high?

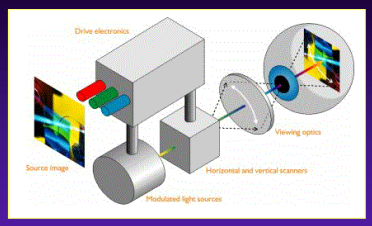
Sony Glasstron

- Color, 30 degrees FOV
- PLM-S700
  - SVGA - 800x600
- PLM-A55
  - 260x255 - NTSC
- SVGA, NSTC/PAL
- 11 W or 4 W
- $500 - $2000 US

MicroOptical

- Unobtrusive
- Monochrome
- 320x280 pixel
- See through
- 8 degree FOV
- $1500 US
- www.microopticalcorp.com

The Virtual Retinal Display

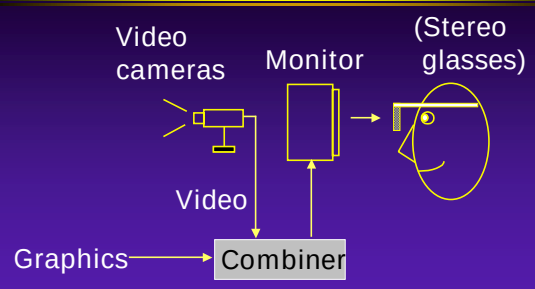


- Image scanned onto retina
- Commercialized through Microvision
  - Nomad System - www.mvis.com

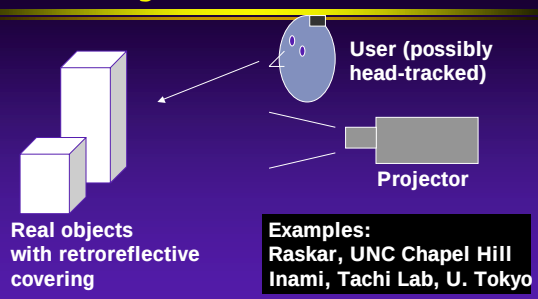
Nomad Display

Show Nomad Video

Video Monitor AR



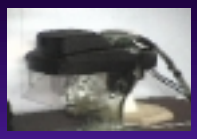
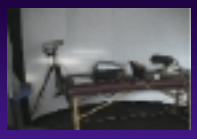
Projector-based AR



Example of projector-based AR

Ramesh Raskar, UNC Chapel Hill

Head Mounted Projector

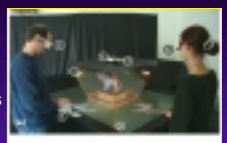
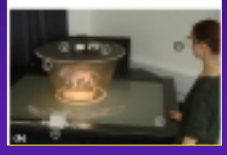

- Head Mounted Projector
  - Jannick Rolland (UCF)
- Retro-reflective Material
  - Potentially portable

Head Mounted Projector Demo

HMPD Video

Virtual Showcase

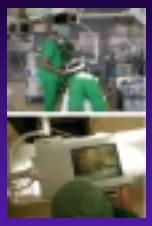
- Mirrors on a projection table
  - Head tracked stereo
  - Up to 4 users
  - Merges graphic and real objects
  - Exhibit/museum applications
- Fraunhofer Institute (2001)
  - Bimber, Frohlich

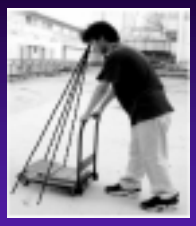
Virtual Showcase

Show Virtual Showcase Video

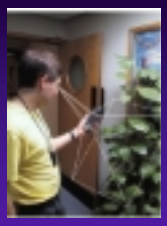
Alternate Displays



LCD Panel



Laptop

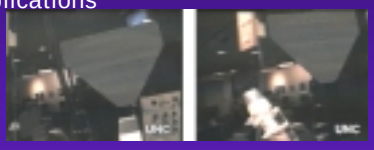


PDA

AR Tracking

The Registration Problem

- Virtual and Real must stay properly aligned
- If not:
  - Compromises illusion that the two coexist
  - Prevents acceptance of many serious applications



Registration Requirements

- Augmented Reality Information Display
  - Head Stabilized
  - Body Stabilized
  - World Stabilized

Increasing Registration &Tracking Requirements

- Advantages
  - overcomes display resolution limitations
  - allows use of innate spatial abilities
  - creates information enriched real environments

AR Information Spaces

Head Stabilized → Body Stabilized → World Stabilized

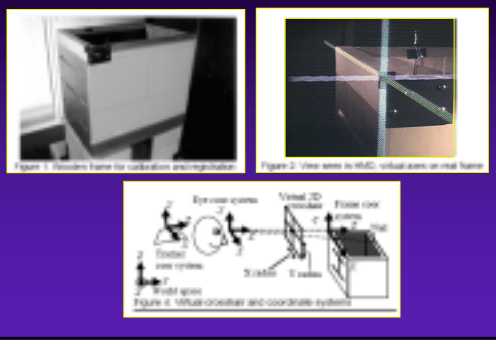
Sources of registration errors

- Static errors
  - Optical distortions
  - Mechanical misalignments
  - Tracker errors
  - Incorrect viewing parameters
- Dynamic errors
  - System delays (largest source of error)
    - 1 ms delay = 1/3 mm registration error

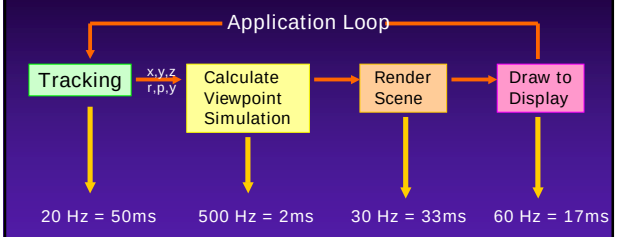
Reducing static errors

- Distortion compensation
- Manual adjustments
- View-based or direct measurements
  - [Azuma94] [Caudell92] [Janin93] etc.
- Camera calibration (video)
  - [ARGOS94] [Bajura93] [Tuceryan95] etc.

View Based Calibration (Azuma 94)



Dynamic errors

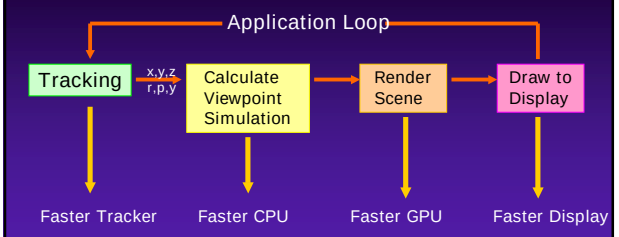


- Total Delay = 50 + 2 + 33 + 17 = 102 ms
  - 1 ms delay = 1/3 mm = 33ms error

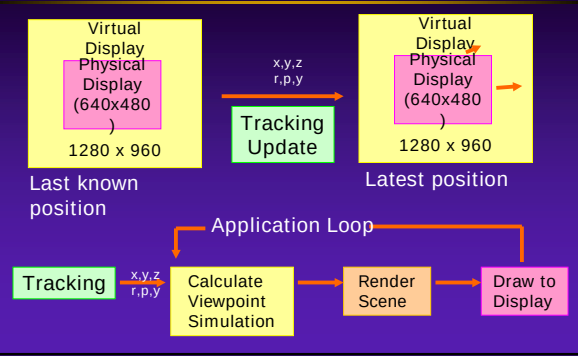
Reducing dynamic errors (1)

- Reduce system lag
  - [Olano95] [Wloka95a] [Regan SIGGRAPH99]
- Reduce apparent lag
  - Image deflection [Burbidge89] [Regan94] [So92] [Kijima ISMR 2001]
  - Image warping [Mark 3DI 97]

Reducing System Lag

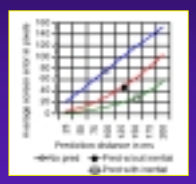


Reducing Apparent Lag



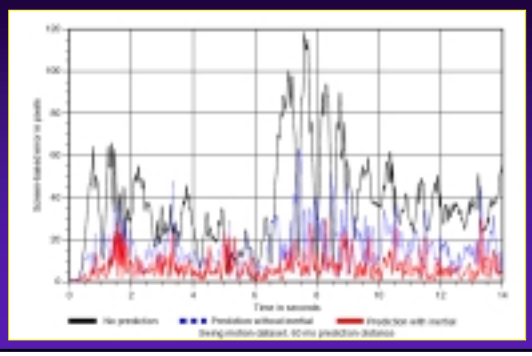
Reducing dynamic errors (2)

- Match input streams (video)
  - Delay video of real world to match system lag
- Predict
  - [Azuma94] [Emura94]
  - Inertial sensors helpful

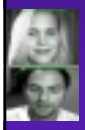


Azuma / Bishop 1994

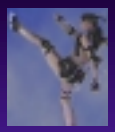
Predictive Tracking (Azuma 94)



Types of Trackers



- **Mechanical**
  - Armature with position sensors
- **Electromagnetic**
  - AC or DC field emmitors/sensors
  - Compass
- **Optical**
  - Target tracking (led, ping pong balls)
  - Line of sight, may require landmarks to work well.
  - Computer vision is computationally-intensive
- **Acoustic**
  - Ultrasonic
- **Inertial & dead reckoning**
  - Acceleration and impulse forces
  - Sourceless but drifts
- **GPS**
  - Outdoor Augmented Reality
  - Line of sight, jammable
- **Hybrid**



Hybrid Tracking

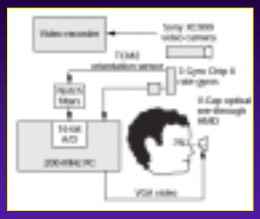
- AR Tracking Types
  - passive, active, inertial

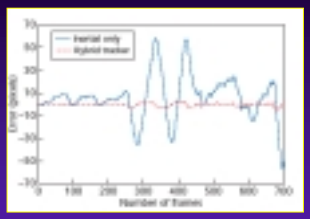
Active-Active	vision-magnetic
Active-Passive	magnetic-vision
Active-Inertial	vision-inertial, acoustic-inertial
Passive-Inertial	
Passive-Inertial	compass-inertial, vision-inertial
Inertial-Inertial	

Outdoor Hybrid Tracking

- Azuma (1999), Suya (1999)
- Combines
  - computer vision
    - natural feature tracking
  - inertial gyroscope sensors
- Both correct for each other
  - Inertial gyro - provides frame to frame prediction of camera orientation
  - Computer vision - correct for gyro drift

Outdoor AR Tracking System





You,Neumann, Azuma outdoor AR system (1999)

Tracking Wrap-up

- Tracking is a key problem to AR
- Registration error
  - Measures against static error
  - Measures against dynamic error
- AR typically requires multiple tracking technologies

AR Interaction

Interface Design Path

1/ Prototype Demonstration

2/ Adoption of Interaction Techniques from other interface metaphors

3/ Development of new interface metaphors appropriate to the medium

4/ Development of formal theoretical models for predicting and modeling user actions

AR Interfaces as 3D data browsers

- 3D virtual objects are registered in 3D
  - See-through HMDs, 6 DOF optical, magnetic trackers
  - "VR in Real World"
- Interaction
  - 3D virtual viewpoint control
- Applications
  - Visualization, guidance, training

AR interfaces as context based information browsers

- Information is registered to real-world context
  - **Hand held AR displays**
    - Video-see-through (Rekimoto, 1997) or non-see through (Fitzmaurice, et al. 1993)
    - Magnetic trackers or computer vision based
- Interaction
  - Manipulation of a window into information space
- Applications
  - Context-aware information displays

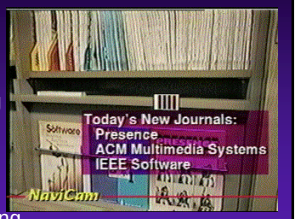
Rekimoto, et al. 1997

NaviCam

Show NaviCam Video

AR Info Browsers: Pros and Cons

- Important class of AR interfaces
  - Wearable computers
  - AR simulation, training
- Limited interactivity
  - Modification of virtual content is difficult
  - Virtual content authoring is difficult



Rekimoto, et al. 1997

3D AR Interfaces

- Virtual objects displayed in 3D physical space and can be freely manipulated
  - See-through HMDs and 6DOF head-tracking are required
  - 6DOF magnetic, ultrasonic, etc. hand trackers for input
- Interaction
  - Viewpoint control
  - Traditional 3D user interface interaction: manipulation, selection, adding, removing, etc.

Kiyokawa, et al. 2000

AR 3D Interaction

Show VLEGO Video

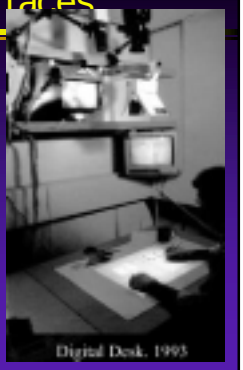
Pros and Cons

- Important class of AR interfaces
  - Entertainment, design, training
- Advantages
  - User can interact with 3D virtual object everywhere in space
  - Natural, familiar interaction
- Disadvantages
  - Usually no tactile feedback
  - HMDs are often required
  - ***Interaction seams***: user has to use different devices for virtual and physical objects

Oshima, et al. 2000

Augmented Surfaces and Tangible Interfaces

- Basic principles
  - Virtual objects are projected on a surface
    - back projection
    - overhead projection
  - Physical objects are used as controls for virtual objects
    - Tracked on the surface
    - Virtual objects are registered to the physical objects
    - Physical embodiment of the user interface elements
  - Collaborative



Augmented Surfaces

- Rekimoto, et al. 1998
  - Front projection
  - Marker-based tracking
  - Multiple projection surfaces
  - Tangible, physical interfaces + AR interaction with computing devices

Augmented Surfaces

Show Rekimoto Video

Tangible Interfaces (Ishii 97)

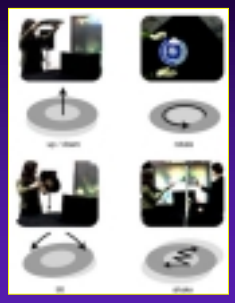
- Create digital shadows for physical objects
- Foreground
  - graspable UI
- Background
  - ambient interfaces

Tangible Interfaces

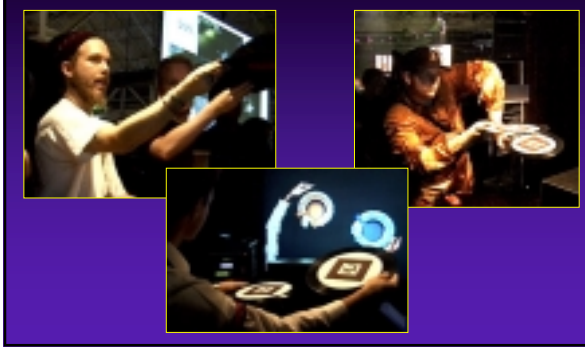
- Dangling String
  - Jeremijenko 1995
  - Ambient ethernet monitor
  - Relies on peripheral cues
- Ambient Fixtures
  - Dahley, Wisneski, Ishii 1998
  - Use natural material qualities for information display

ARgroove

- Collaborative Instrument
- Exploring Physically Based Interaction
  - Map physical actions to Midi output
    - Translation, rotation
    - Tilt, shake
- Time Multiplexed Interface
  - One physical object -> many commands



ARgroove in Use



Show ARgroove Video

ARgroove Video

Visual Feedback

- Continuous Visual Feedback is Key
- Single Virtual Image Provides:
  - Rotation
  - Tilt
  - Height

Lessons from Tangible Interfaces

- Physical objects make us smart
  - Norman's "Things that Make Us Smart"
  - encode affordances, constraints
- Objects aid collaboration
  - establish shared meaning
- Objects increase understanding
  - serve as cognitive artifacts

Limitations

- Difficult to change object properties
  - can't tell state of digital data
- Limited display capabilities
  - pinwheels = 1D, projection screen = 2D
  - dependent on physical display surface
- Separation between object and display
  - ARgroove

Orthogonal Nature of AR interfaces

	3D AR	Augmented surfaces
Spatial gap	No interaction is everywhere	Yes interaction is only on 2D surfaces
Interaction gap	Yes separate devices for physical and virtual objects	No same devices for physical and virtual objects

Back to the Real World

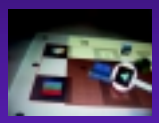
- AR overcomes limitation of TUIs
  - enhance display possibilities
  - merge task/display space
  - provide public and private views

- TUI + AR = Tangible AR
  - Apply TUI methods to AR interface design

Space vs. Time-multiplexed

- Space-multiplexed
  - Many devices each with one function
    - Quicker to use, more intuitive, clutte
    - Tiles Interface, toolbox

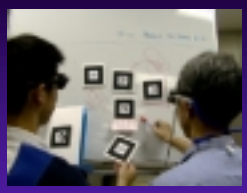
- Time-multiplexed
  - One device with many functions
    - Space efficient
    - VOMAR Interface, mouse



Tangible AR: generic interface semantics

- Tiles semantics
  - data tiles
  - operation tiles
    - menu
    - clipboard
    - trashcan
    - help
- Operation on tiles
  - proximity
  - spatial arrangements
  - space-multiplexed

Space-multiplexed Interface



Data authoring in Tiles

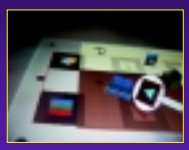
Tiles Video

Show Tiles Video

Proximity-based Interaction

Tangible AR: Time-multiplexed interaction

- Use of natural physical object manipulations to control virtual objects
- VOMAR Demo
  - Catalog book:
    - Turn over the page
  - Paddle operation:
    - Push, shake, incline, hit, scoop



Show VOMAR Video

VOMAR Video

Tangible AR: Pros + Cons

- Advantages
  - Seamless interaction with both virtual and physical tools
    - No need for special purpose input devices
  - Seamless spatial interaction with virtual objects
    - 3D presentation of and manipulation with virtual objects anywhere in physical space
- Disadvantages
  - Required HMD
  - Markers should be visible for reliable tracking

Wrap-up

- Browsing Interfaces
  - simple (conceptually!), unobtrusive
- 3D AR Interfaces
  - expressive, creative, require attention
- Tangible Interfaces
  - Embedded into conventional environments
- Tangible AR
  - avoids seams, but requires track-able objects

Designing AR Interfaces

AR Design Principles

- Interface Components
  - Physical components
  - Display elements
    - Visual/audio
  - Interaction metaphors

Tangible AR Design Principles

- Tangible AR Interfaces use TUI principles
  - Physical controllers for moving virtual content
  - Support for spatial 3D interaction techniques
  - Time and space multiplexed interaction
  - Support for multi-handed interaction
  - Match object affordances to task requirements
  - Support parallel activity with multiple objects
  - Allow collaboration between multiple users

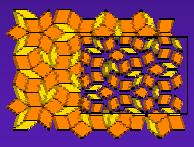
Design of Objects

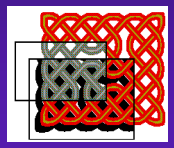
- Objects
  - Purposely built – affordances
  - "Found" – repurposed
  - Exiting – already at use in marketplac
- Make affordances obvious (Norman)
  - Object affordances visible
  - Give feedback
  - Provide constraints
  - Use natural mapping
  - Use good cognitive model

Case Study 1: 3D AR Lens

Goal: Develop a lens based AR interface

- MagicLenses
  - Developed at Xerox PARC in 1993
  - View a region of the workspace differently to the rest
  - Overlap MagicLenses to create composite effects

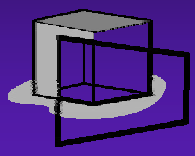




3D MagicLenses

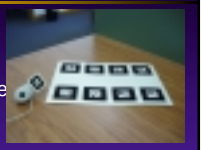
MagicLenses extended to 3D (Veiga et. al. 96)

- Volumetric and flat lenses



AR Lens Design Principles

- Physical Components
  - Lens handle
    - Virtual lens attached to real obje
- Display Elements
  - Lens view
    - Reveal layers in dataset
- Interaction Metaphor
  - Physically holding lens



3D AR Lenses: Model Viewer

- Displays models made up of multiple parts
- Each part can be shown or hidden through the lens
- Allows the user to peer inside the model
- Maintains focus + context

AR Lens Demo

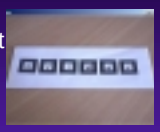
Show AR Lens Demo

AR Lens Implementation

Case Study 2: Occlusive Interfaces

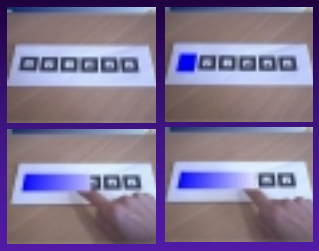
Goal: An AR interface supporting 2D input

- menu selection, 2D input



- Physical Components
  - Tracking sheet
- Display Elements
  - 1D or 2D virtual menu
- Interaction Metaphor
  - Find 2D input using occlusion

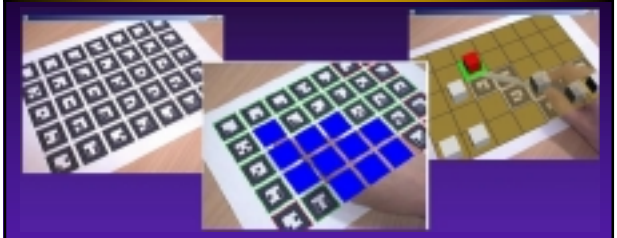
1D Occlusion-based Interaction



Check for occlusion of known markers

- Accurate 2D interaction
  - Buttons, sliders, grid input

2D Occlusion-based Interaction



Grid of tracking markers

- 2D interaction – moving virtual objects

AR Occlusion Demo

Show AR Occlusion Demo

Implementation

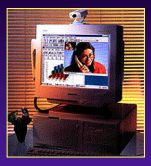
- Classify Markers
  - B = border, H = hybrid, I = interaction
- 3D camera pose calculation
  - Using visible markers
- 2D marker projection
  - Identify occluded markers

Collaborative Augmented Reality

Mark Billinghurst

Today's Technology

- Video Conferencing
  - lack of spatial cues
  - limited participants
  - 2D collaboration



Beyond Video Conferencing

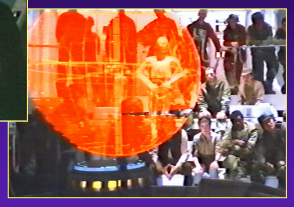
- 2D Interface onto 3D
  - **VRML**
- Projection Screen
  - **CAVE, WorkBench**
- Volumetric Display
  - **scanning laser**
- Virtual Reality
  - **natural spatial cues**

Beyond Virtual Reality

- Lessons from CSCW
  - Seamless
  - Enhance Reality
- Immersive Virtual Realit
  - separates from real world
  - reduces conversational cues

Collaboration in the Future ?

Remote Conferencing



Face to face Conferencing

Studierstube Demo

Video 1

Collaborative Augmented Reality

- Seamless Interaction
- Natural Communication
- Attributes:
  - Virtuality
  - Augmentation
  - Cooperation
  - Independence
  - Individuality

Face to Face Collaboration

Communication Cues

A wide variety of communication cues used.

Audio

- Speech
- Paralinguistic
- Paraverbals
- Prosodics
- Intonation

Visual

- Gaze
- Gesture
- Face Expression
- Body Position

Environmental

- Object Manipulation
- Writing/Drawing
- Spatial Relationship
- Object Presence

- Face-to-face collaboration
  - People surround a table
  - It is easy to see each other

- Computer supported collaboration
  - People sit side by side
  - It is hard to see each other

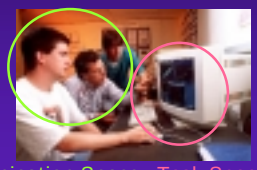
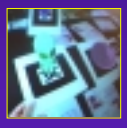


Table Top Demo

- Goal
  - create compelling collaborative AR interface usable by novices
- Exhibit content
  - matching card game
  - face to face collaboration
  - physical interaction



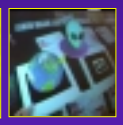


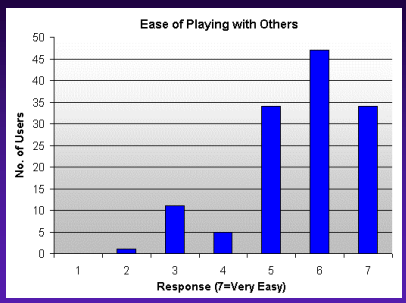
Table Top Demo

Video 2

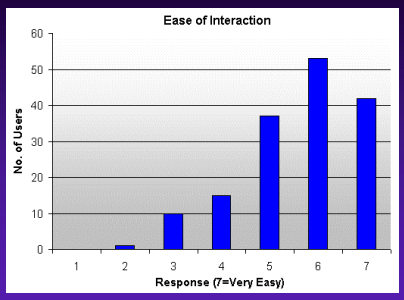
Results

- 2,500 - 3,000 users
- Observations
  - no problems with the interface
    - only needed basic instructions
  - physical objects easy to manipulate
  - spontaneous collaboration
- Subject survey (157 people)
  - Users felt they could easily play with other people and interact with objects
- Improvements
  - reduce lag, improve image quality, better HMD

Ease of Playing with Others



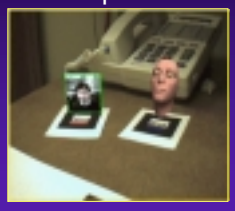
Ease of Interaction



Remote Collaboration

AR Conferencing

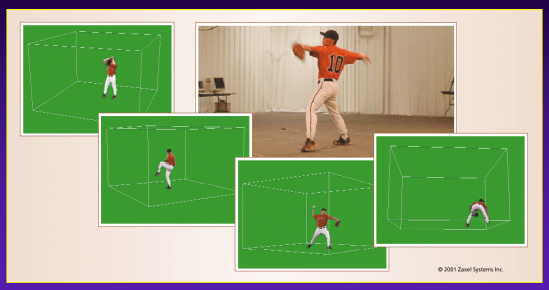
- Moves conferencing from the desktop to the workspace



AR Conferencing Video

Video 4

Virtual Viewpoint Generation



3D Live Video

Video 5

3D Live System

Lessons Learned

- Face to face collaboration
  - AR preferred over immersive VR
  - AR facilitates seamless/natural communication
- Remote Collaboration
  - AR spatial cues can enhance communication
  - AR conferencing improves video conferencing
  - Many possible confounding factors

Building Applications With ARToolKit

http://www.hitl.washington.edu/artoolkit/

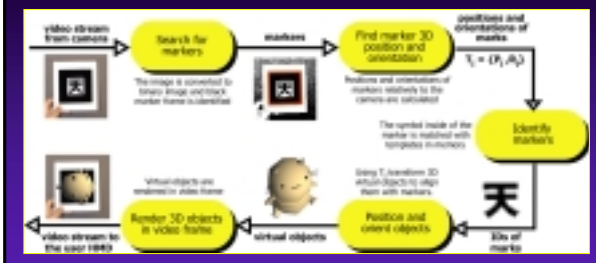
ARToolKit Characteristics

- Enabling technology
- Solves two significant problems in AR
  - Tracking
  - Interaction
- Tracking
  - Cheap vision based tracking
- Interaction
  - Object-based AR (Tangible AR)

Augmented Reality Demo

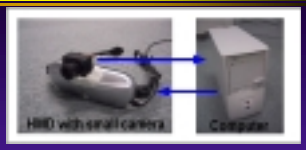
Show AR Demo

ARToolKit Tracking



ARToolKit - Computer vision based tracking libraries

Hardware

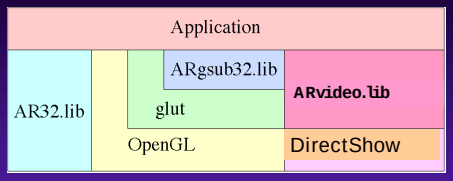


- Camera
  - 320x240+
- Computer
  - Pentium 500Mhz+
  - 3D graphics video card
  - Video capture card
- HMD (optional)
  - Video see-through or Optical see-through
  - Binocular or Monocular

Software

- ARToolKit : version 2.40 or later
  - libAR – tracking
  - libARVideo – video capturing
  - libARgsub – image drawing
- OS: Linux, IRIX, Windows
- Language: C

ARToolKit Structure

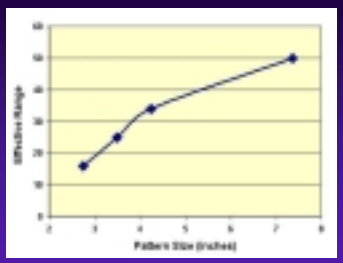


- Three key libraries:
  - AR32.lib – ARToolKit image processing functions
  - ARgsub32.lib – ARToolKit graphics functions
  - ARvideo.lib – DirectShow video capture class

Software (cont.)

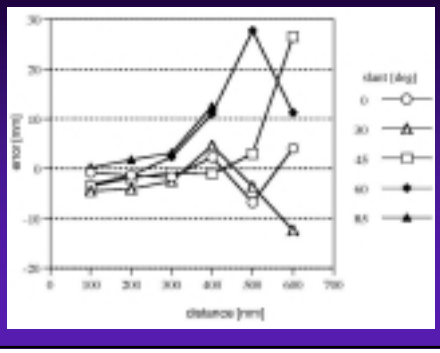
- Additional basic libraries
  - Video capture library (Video4Linux, VisionSDK)
  - OpenGL
  - GLUT
- Other useful libraries
  - Open VRML, Open Inventor, WTK, etc

Tracking Range with Pattern Size

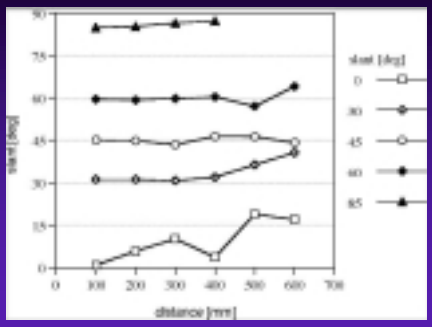


Rule of thumb – range = 10 x pattern width

Tracking Error with Range

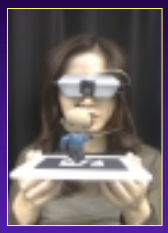


Tracking Error with Angle



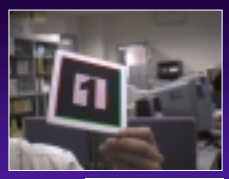
An ARToolKit Application

- Basic Outline
  - Step1. Image capture & display
  - Step2. Marker detection
  - Step3. Marker identification
  - Step4. Getting 3D information
  - Step5. Object Interactions
  - Step6. Display virtual objects

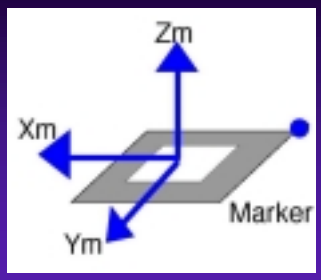


Making a pattern template

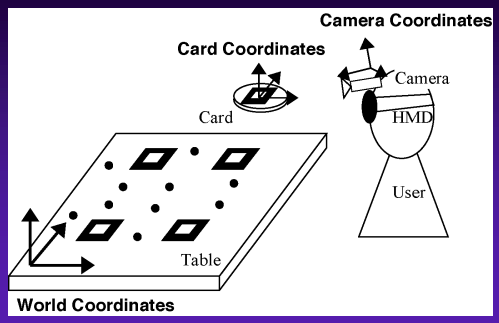
- Use of utility program:
  mk_patt.exe
- Show the pattern
- Put the corner of red line segments on the left-top vertex of the marker
- Pattern stored as a template in a file
- 1:2:1 ratio determines the pattern region used



ARToolKit Coordinate Frame



Tangible AR Coordinate Frames



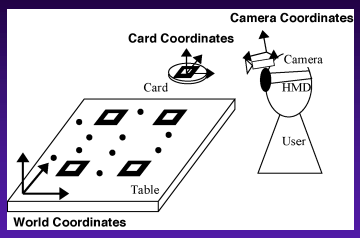
Local vs. Global Interactions

- Local
  - Actions determined from single camera to marker transform
    - shaking, appearance, relative position, range
- Global
  - Actions determined from two relationships
    - marker to camera, world to camera coords.
    - Marker transform determined in world coordinates
      - object tilt, absolute position, absolute rotation, hitting

Multi-marker Tracking

- Sample File – multiTest.c
- Multiple markers to establish a single coordinate frame
  - Reading in a configuration file
  - Tracking from sets of markers
  - Careful camera calibration

Paddle-based Interaction



Tracking single marker relative to multi-marker set

- paddle contains single marker

Research Directions

Mark Billinghurst

Advanced AR Interfaces

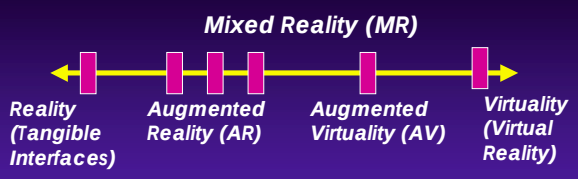
- Transitional Interfaces
  - MagicBook
- Hybrid User Interfaces
  - Desktop + AR combined
- Wearable Computing
  - Outdoor AR

Case Study 3: Transitional Interfaces

Goal: An AR interface supporting transitions from reality to virtual reality

- Physical Components
  - Real book
- Display Elements
  - AR and VR content
- Interaction Metaphor
  - Book pages hold virtual scenes

Milgram's Continuum (1994)



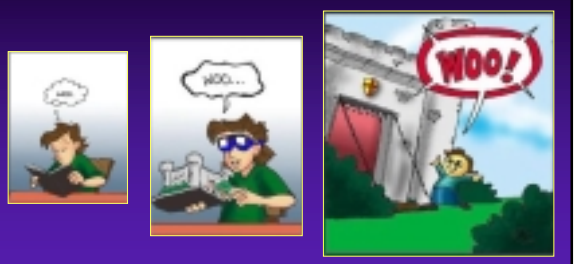
Central Hypothesis

- The next generation of interfaces will support transitions along the Reality-Virtuality continuum

Transitions

- Interfaces of the future will need to support transitions along the RV continuum
- Augmented Reality is preferred for:
  - co-located collaboration
- Immersive Virtual Reality is preferred for:
  - expriencing world immersively (egocentric)
  - sharing views
  - remote collaboration

MagicBook Metaphor



Show MagicBook Video

MagicBook Video

Features

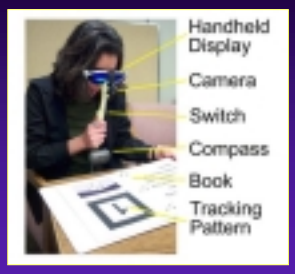
- Seamless transition between Reality and Virtuality
  - Reliance on real decreases as virtual increases
- Supports egocentric and exocentric views
  - User can pick appropriate view
- Computer becomes invisible
  - Consistent interface metaphors
  - Virtual content seems real
- Supports collaboration

Collaboration

- Collaboration on multiple levels:
  - Physical Object
  - AR Object
  - Immersive Virtual Space
- Egocentric + exocentric collaboration
  - multiple multi-scale users
- Independent Views
  - Privacy, role division, scalability

Technology

- Reality
  - No technology
- Augmented Reality
  - Camera – tracking
  - Switch – fly in
- Virtual Reality
  - Compass – tracking
  - Press pad – move
  - Switch – fly out

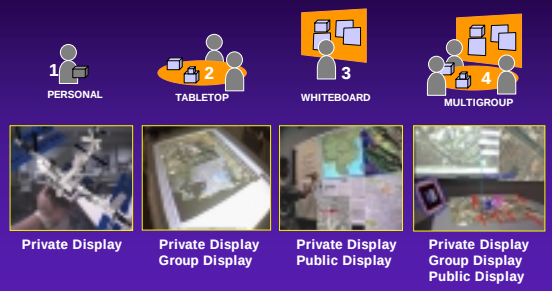


Case Study 4: Hybrid UI

Goal: To incorporate AR into normal meeting environment

- Physical Components
  - Real props
- Display Elements
  - 2D and 3D (AR) displays
- Interaction Metaphor
  - Use multiple tools – each relevant for the task

Hybrid User Interfaces



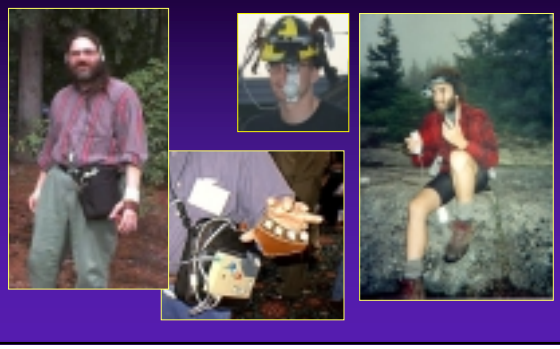
MagicMeeting

Show MagicMeeting Video

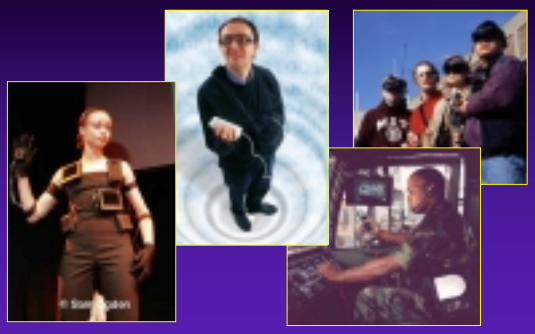
Design Ideas

- Use the most appropriate tools for any given task
  - Manipulate 2D text or images on a 2D PC or laptop
  - Manipulate 3D objects in 3D space
- Use the most appropriate displays
  - size, resolution, stereopsis
  - privacy vs sharing

Wearable Computing



The Cyborgs are Coming...



Attributes of Wearable Computing

The Wearable Computer

- A computer which is (Mann 97):
  - Eudaemonic
    - considered part of person
  - Existential
    - user has complete control
  - Ephemeral
    - always operating on minimal level
- Always part of you, Always accessible, Always on

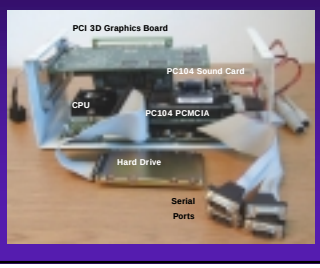
The Technology

- Computing
  - Belt or Backpack
- Displays
  - Head Mounted, LCD Panel, Audio
- Input Devices
  - Chording Keyboard, Speech, Camera
- Networking
  - Wireless LAN, Infra-Red, Cellular

Mobile AR – Hardware
Computing Platform

Columbia *Touring Machine*

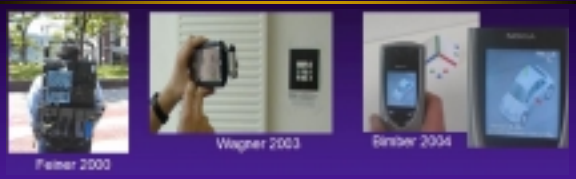
Example self-built working solution with PCI-based 3D graphics



Tinmith

Show Tinmith Video

Mobile AR



- Mobile AR platform changing
  - Backpack → Tablet PC → PDA → Phone
- Application challenges
  - What applications are enabled by a mobile phone AR interface?
- Interface challenges
  - Screen size, input, processing power

AR on a Cellphone

Show Bimber Video

Natural Feature Tracking

- Goal:
  - Overlay virtual imagery onto normal printed material (maps, photos, etc)
- Method:
  - AR registration based on matching templates generated from image texture

Natural Feature Tracking

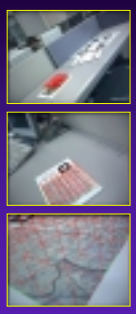
Natural Feature Tracking Video

Preparation

- Need set of feature points for template matching to work
- Automatic detection of best points
  - For each point in image, 50 x 50 pixel region tested for similarity with neighbors
  - Calculated for different resolution in

Tracking Method

- Iterative Tracking Process
  - Calculate camera pose from set of features in the image
  - Use template matching to find set of features in next frame
    - Dynamic template generation
  - Use normalized correlation value for template matching



Occlusion with See-through HMD

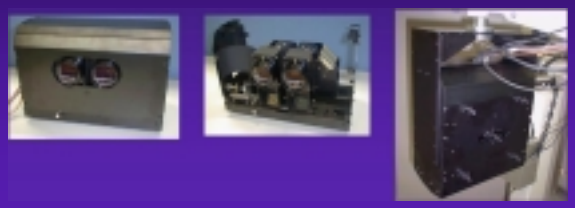
- The Problem
  - Occluding real objects with virtual
  - Occluding virtual objects with real

Real Scene

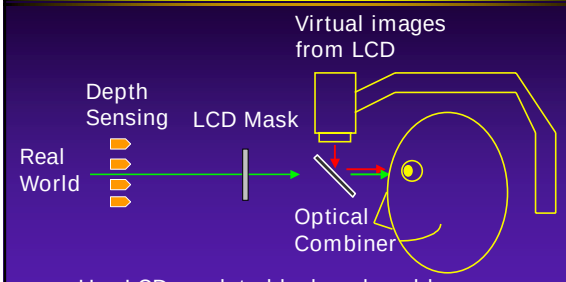
Current See-through HMD

ELMO (Kiyokawa 2001)

- Occlusive see-through HMD
  - Masking LCD
  - Real time range finding



ELMO Design



- Use LCD mask to block real world
- Depth sensing for occluding virtual images

ELMO Results

ELMO Demo

Show ELMO Video

More Information

Some starting points

- Jim Vallino's, Reinhold Behringer's pages:
  http://www.cs.rit.edu/~jrv/research/ar
  http://www.augmented-reality.org
- Ron Azuma's survey paper
  Azuma, Ronald. A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments 6*, 4 (August 1997), 355-385.

More starting points

- Survey Paper - Nov. 2001 IEEE Computer Graphics & Applications
  - **Azuma, Baillot, Behringer, Feiner, Julier, MacIntyre. Recent Advances in Augmented Reality.**
- Book
  Barfield and Caudell. *Fundamentals of Wearable Computers and Augmented Reality.* Lawrence Erlbaum Associates (2001). ISBN 0-8058-2901-6

Growth of Field

- New conferences
  - International Symposium on Mixed and Augmented Reality (ISMAR) - www.ismarConf.org
- Major Projects
  - Mixed Reality Systems Laboratory (Japan)
    http://www.mr-system.co.jp/
  - Project ARVIKA (Germany)
    http://www.arvika.de/
  - Ubicom Project (Delft University)
    http://www.ubicom.tudelft.nl

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