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

Virtual Reality: Replaces Reality
- Immersive Displays

Augmented Reality: Enhances Reality
- See-through Displays

Augmented Reality: Characteristics
- Combines Real and Virtual Images
- Interactive in real-time
- Registered in 3D

AR Concept Video

Augmented Reality (AR) and Virtual Reality (VR) Continuum

Adapted from Milgram, Takemura, Utsumi, Kishino.
Reality-Virtuality (RV) 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)


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

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
Medical AR

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

Applications: annotating environment

- Public and private annotations
- Aid recognition, “extended memory”
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  - Windows [Columbia]
  - Mechanical parts [many places]
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Annotation pictures

Building Labeling
**Building Labeling**

- 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

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**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

- Occluded
- See-thru
- Multiplexed

Optical see-through head-mounted display

- Virtual images from monitors
- Real World
- Optical Combiners
**Optical see-through HMDs**

- Sony Glasstron

**Video see-through HMD**

![Diagram of video see-through HMD]

- Video cameras
- Monitors
- Video
- Graphics
- Combiner

**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 world
- 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

Video cameras → Monitor → (Stereo glasses)

Graphics → Combiner

Projector-based AR

Real objects with retroreflective covering

User (possibly head-tracked) → Projector

Examples:
Raskar, UNC Chapel Hill
Inami, Tachi Lab, U. Tokyo

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
- 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 (Azuma94)
Dynamic errors

Total Delay = 50 + 2 + 33 + 17 = 102 ms

1 ms delay = 1/3 mm = 33 ms error

Reducing dynamic errors (1)

- Reduce system lag
  - [Olan095] [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

Last known position

Latest position
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

Types of Trackers

- Mechanical
  - Armature with position sensors
- Electromagnetic
  - AC or DC fields
- Optics
  - Target tracking (led, ping pong balls)
  - Line of sight, may require landmarks to work well
- Computer vision is computationally intensive
- Acoustic
  - Sound waves
- Inertial & dead reckoning
  - Acceleration and impulse forces
- GPS
  - Outdoor Augmented Reality
  - Line of sight, jammed
- 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

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

**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.

**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


Kiyokawa, et al. 2000

Oshina, 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

**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**
**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**

<table>
<thead>
<tr>
<th>Spatial gap</th>
<th>3D AR</th>
<th>Augmented surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>No interaction is everywhere</td>
<td>Yes interaction is only on 2D surfaces</td>
<td></td>
</tr>
</tbody>
</table>

| 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, clutter
    - 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

VOMAR Video

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
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

![Diagram of AR Interface Components](image)
**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 marketplace

- Make affordances obvious (Norman)
  - Object affordances visible
  - Give feedback
  - Provide constraints
  - Use natural mapping
  - Use good cognitive model

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**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 object

- **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
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

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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 Reality
  - 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

A wide variety of communication cues used.
- Audio
  - Speech
  - Paralinguistic
  - Paraverbals
  - Prosodics
  - Intonation
- Visual
  - Gaze
  - Gesture
  - Face Expression
- Environmental
  - Object Manipulation
  - Writing/ Drawing
  - Spatial Relationship
  - Object Presence

Communication Space

Table Top Demo

- 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

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**
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](image)

**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
An ARToolKit Application

- Basic Outline
  - Step 1. Image capture & display
  - Step 2. Marker detection
  - Step 3. Marker identification
  - Step 4. Getting 3D information
  - Step 5. Object Interactions
  - Step 6. 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
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

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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

Mixed Reality (MR)

- Reality (Tangible Interfaces)
- Augmented Reality (AR)
- Augmented Virtuality (AV)
- Virtuality (Virtual Reality)

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:
  - experiencing 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

PERSONAL

TABLETOP

WHITEBOARD

MULTIGROUP

Private Display

Private Display

Private Display

Private Display

Group Display

Public Display

Group Display

Public Display

Show Magic Meeting 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

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

Columbia Touring Machine
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

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

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

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
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

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Book

International Symposium on Mixed and Augmented Reality (ISMAR) - www.ismarConf.org

Mixed Reality Systems Laboratory (Japan) http://www.mr-system.co.jp/
Project ARVKA (Germany) http://www.arvka.de/
Ubicom Project (Delft University) http://www.ubicom.tudelft.nl
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