3D User Interfaces for the Real World

Lecture #16: Augmented/Mixed Reality

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Joseph J. LaViola Jr.

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Definitions

- **Augmented reality**: Refers to a system in which the user views and acts within an *enhanced* version of the real world. The enhancements are virtual (computer-generated), and can include objects or information.
- **Mixed reality**: Refers to a system that combines real and virtual objects and information.

Mixed Reality Continuum

Mixed Reality (MR)

Reality ⟷ ***Augmented Reality (AR)*** ⟷ ***Augmented Virtuality (AV)*** ⟷ ***Virtuality***

Milgram (1994)

AR/MR Application Areas

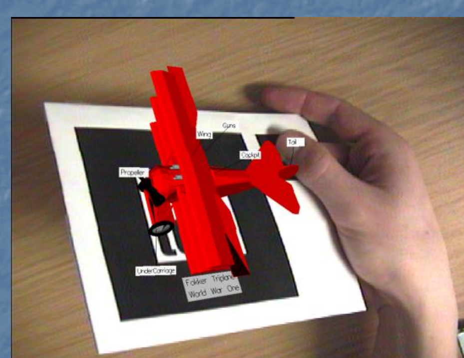
- Maintenance
- Training
- Tourism / Cultural heritage
- Design / construction
- Battlefield information display
- Entertainment

AR/MR Technology - Displays

- See-through HMDs:
  - Video see-through
  - Optical see-through
- Handheld displays
- Projection

AR/MR Technology - Tracking

- Optical / vision-based tracking
  - AR toolkit
  - ensures portability
  - large number of tracked objects
- Registration and low latency are *crucial* for AR systems



AR/MR technology - Tracking

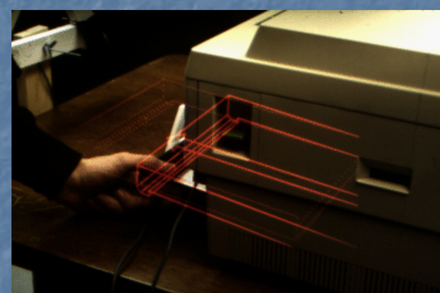
- Sourceless inertial orientation tracking
- GPS position tracking
  - enables mobile outdoor AR
- Markerless tracking

Mobile outdoor AR

- “Backpack systems”
- User wears/carries:
  - Computer
  - HMD
  - Inertial tracker
  - GPS unit/antenna
  - Input device(s)

Mixed Reality Interfaces

- Azuma (1997)
  - combine real and virtual objects
  - interactive in real time
  - virtual objects are registered in 3D physical world



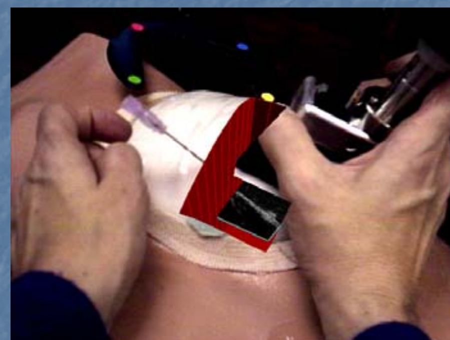
KARMA, Feiner, et al. 1993

Challenges in AR Interfaces

- Conflict between real world and virtual
  - not neatly separated anymore
- Limitations of displays
  - precise, fast registration & tracking
  - spatially seamless display
- Limitations of controllers
  - precise, fast registration & tracking
  - spatially seamless interactivity

AR Interfaces as 3D Information Browsers (I)

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



State, et al. 1996

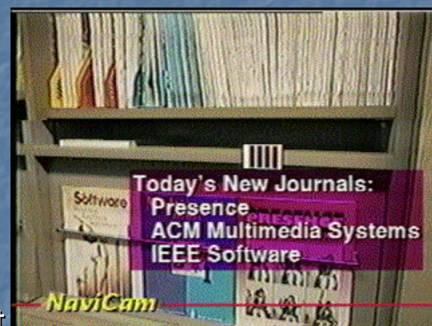
AR Interfaces as Context-Based Information Browsers (II)

- 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

AR Info Browsers (III): Pros and Cons

- Important class of AR interfaces
  - wearable computers
  - AR simulation, training
- Limited interactivity
  - modification and authoring virtual content is difficult



Rekimoto, et al. 1997

3D AR Interfaces (I)

- Virtual objects are displayed in 3D space and can be also manipulated in 3D
  - see-through HMDs and 6DOF head-tracking for AR display
  - 6DOF magnetic, ultrasonic, or other hand trackers for input
- Interaction
  - viewpoint control
  - 3D user interface interaction: manipulation, selection, etc.

Kiyokawa, et al. 2000

3D AR Interfaces (II): Information Displays

- How to move information in AR context dependent information browsers?
- InfoPoint (1999)
  - hand-held device
  - computer-vision 3D tracking
  - moves augmented data between marked locations
  - HMD is not generally needed, but desired since there are little display capabilities

Khotake, et al. 1999

3D AR Interfaces (III): Pros and Cons

- Important class of AR interfaces
  - entertainment, design, training
- Advantages
  - seamless spatial interaction: User can interact with 3D virtual object everywhere in physical space
  - natural, familiar interfaces
- Disadvantages
  - usually no tactile feedback and HMDs are often required
  - interaction gap: user has to use different devices for virtual and physical objects

Tangible interfaces and augmented surfaces (I)

- 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

Digital Desk. 1993

Tangible Interfaces and Augmented Surfaces (II)

- Graspable interfaces, Bricks system (Fitzmaurice, et al. 1995) and Tangible interfaces, e.g. MetaDesk (Ullmer'97):
  - back-projection, infrared-illumination computer vision tracking
  - physical semantics, tangible handles for virtual interface elements

metaDesk. 1997

Tangible Interfaces and Augmented Surfaces (III)

- Rekimoto, et al. 1998
  - front projection
  - marker-based tracking
  - multiple projection surfaces
  - tangible, physical interfaces + AR interaction with computing devices

Augmented surfaces, 1998

Tangible Interfaces and Augmented Surfaces (IV)

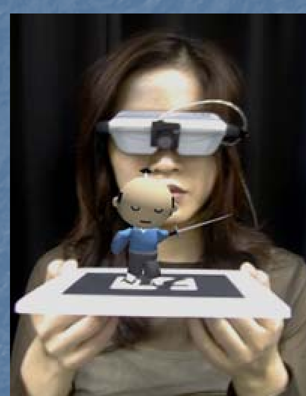
- Advantages
  - seamless interaction flow – user hands are used for interacting with both virtual and physical objects.
  - no need for special purpose input devices
- Disadvantages
  - interaction is limited only to 2D surface
  - spatial gap in interaction - full 3D interaction and manipulation is difficult

Orthogonal Nature of AR Interfaces (Poupyrev, 2001)

	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

Tangible AR interfaces (I)

- Virtual objects are registered to marked physical "containers"
  - HMD
  - video-see-through tracking and registration using computer vision tracking
- Virtual interaction by using 3D physical container
  - tangible, physical interaction
  - 3D spatial interaction
- Collaborative



Shared Space, 1999

Tangible AR (II): Generic Interface Semantics

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

Tiles, 2001

Tangible AR (III): Space-Multiplexed

Data authoring in Tiles (Poupyrev, et al. 2001). Left, outside view of the system; right, view of the left participant.

Tangible AR (IV): Time-Multiplexed Interaction

Data authoring in WOMAR interfaces (Kato et al. 2000). The user can pick, manipulate and arrange virtual furniture using a physical paddle.

Tangible AR (V): AR - VR Transitory Interfaces

- Magic Book (Billinghurst, et al. 2001)
  - 3D pop-up book: a transitory interfaces
    - augmented Reality interface
    - portal to Virtual Reality
    - immersive virtual reality experience
    - collaborative

Augmented Reality

Virtual Reality

Tangible AR (VI): Conclusions

- 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

Interfaces for Mobile Outdoor AR

- Devices must be handheld
- No tracking or limited tracking for devices
- Interaction at-a-distance
- Tinmith project

Challenges in AR/MR

- Occlusion and depth perception
- Text display and legibility
- Visual differences between real and virtual objects
- Registration and tracking
- Bulky HMDs and other equipment

Next Class

- Paper presentations begins
- Final project proposals due Friday (3-21-08)!!!