3D User Interfaces for the Real World

Lecture #16: Augmented/Mixed Reality
Spring 2009
Joseph J. LaViola Jr.

Special thanks to Ivan Poupyrev

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

Image Copyright Sony CSL
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

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


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)

<table>
<thead>
<tr>
<th></th>
<th>3D AR</th>
<th>Augmented surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial gap</strong></td>
<td>No interaction is everywhere</td>
<td>Yes interaction is only on 2D surfaces</td>
</tr>
<tr>
<td><strong>Interaction gap</strong></td>
<td>Yes separate devices for physical and virtual objects</td>
<td>No same devices for physical and virtual objects</td>
</tr>
</tbody>
</table>

### 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
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)!!!