HCI Research in Augmented Reality

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A New User Interface Paradigm

- Beginnings in 1960’s, then into research labs, and since 2005 in commercial applications
- Driven by improvement in display and tracking technologies
- Information is integrated into the user’s view of the real world
- No standard input devices
- Towards an invisible interface
Definition

- Characteristics for AR system [Azuma, 97]
  - Combines real and virtual objects in a real environment
  - Registers (aligns) real and virtual objects with each other
  - Runs interactively and in real time
Mixed Reality Continuum

- Reality–Virtuality continuum [Milgram & Kishino, 94]

  - In AV and VE/VR the surrounding environment is virtual, in AR the surrounding environment is real
  - Other AR variants: mediated reality, e.g., diminished reality

\[\text{AR} \neq \text{VR}\]
Diminished Reality
AR Advantages

- Simplifying and enhance people’s lives by integrating virtual information in their surroundings
- Enhances people’s perception and interaction with the world
- Substitute missing senses
  - Example, augmenting the sight of blind users or users with poor vision by the use of audio
Building Block of AR Systems

- Technologies
- Authoring tools
- Interaction techniques
- Applications
- Usability and experiences
Technologies

• Display technologies
  • Show virtual objects overlaying the real world in 3D space
  • Head mounted, spatial, handheld displays [Bimber & Raskar, 05]

• Tracking (and registration) technologies
  • To register virtual objects in 3D space and track user input
  • Track the (a) scene (b) the user’s 6DOF viewpoint (head and/or eyes), (c) the user’s hands/body for input, and (d) input devices
Head Mounted Displays

- Optical see-through (glasses or contact lenses)
  - Direct and better view of the world, safer
- Video see-through
  - Occlusion, wider field of view, better registration and calibration, no perceived delays
- Advantages: hands free interaction
- Disadvantages: wearing it (socially and physically), brightness
Spatial and Handheld Displays

• Spatially aligned displays or projectors
  • Can be wearable
  • Advantages: provide public displays and project on irregular surfaces
  • Disadvantage: brightness, focus, resolution, FOV, and contrast

• Handheld displays

• Other displays: haptic, tactile and audio

[Mistry et al., SIGRAPH 09]
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>HMD Video see-through</th>
<th>HMD Optical see-through</th>
<th>Projectors</th>
<th>Handheld</th>
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<tbody>
<tr>
<td><strong>Pros.</strong></td>
<td>visual control, sync., less dependent on environment</td>
<td>more natural perception</td>
<td>displays directly onto physical objects’ surfaces</td>
<td>portable, widespread, powerful, camera, tracking</td>
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<tr>
<td><strong>Cons.</strong></td>
<td>camera and processing, unnatural perception</td>
<td>time lag, jitter of virtual image</td>
<td>(+/-) not user dependent</td>
<td>small display</td>
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Tracking and Registar Technologies

- Track the user’s viewpoint 6DOF (X, Y, Z, Roll, Pitch, Yaw) and update the appearance of virtual objects

- Register virtual objects in 3D and reduce lag

- Inertial sensors
  - Compasses, accelerometers, gyroscope, etc.

- Active sensors
  - GPS, Wifi, magnetic, ultrasonic, mechanical

- Optical/visual tracking
  - Marker-based, e.g., fiducial
  - Markless-based (infrared or camera), e.g., computer vision methods and depth cameras

[Reitmayr et al., AUIC ’03]
[Heller et al., CHI ’14]
Tracking Criteria and Challenges

- **Criteria**
  - Accuracy, tethering, cost, 6DOF, nosiness, resolution/range

- **Challenges**
  - Jitter, occlusion, brightness, user and environment changes, latency, ease of calibration

- **Choice of tracking technology depends on AR System** (fixed/mobile, indoor/outdoor)
Authoring Tools

- Tracking libraries, e.g., ARToolKit, Vuforia (mobile), FLARToolKit (web browser)
- 3D rendering engine for designing virtual objects
- IDE for design AR scenes
- Compete systems, e.g., AMIRE, BuildAR, Metaio Creator
- Visual programming: AR to design AR, e.g., iaTAR [Lee et al., 04] use real objects to design AR scenes
AR Systems and Experiences

• Categorising AR systems help make design deacons regrading the display, tracking technology, input technique and application

• Outdoor AR
  • Information browsers and navigation

• Indoor location based AR

• Handheld AR

• Web based AR

• Carmigniani and Furht categorized AR systems into five categories
  • Fixed indoor systems, fixed outdoor systems, mobile indoor systems, mobile outdoor systems, and mobile indoor and outdoor systems
AR Interaction

• Interaction tasks
  • 2D tasks: text entry, selection, position, and quantify [Foley]
  • 3D tasks: navigation, pointing and selection, manipulation (drag, rotate, scale), and data input [Bowman]

• Input devices
  • Tangibles, heterogeneous devices (other displays), specially designed devices

• Input modalities
  • Gestures, speech, eye tracking, brain signals

• Techniques or Metaphors
Viewpoint Control

• Using basic 2D and 3D tasks
• Used in navigation apps, information browsers, guidance interfaces
• Manipulate the view of the AR environment but not the content
Free 3D Hand Interaction

- Track 6DOF of user head and hand
- Manipulate virtual objects in 3D space
- Natural interaction
- No tactile feedback
Multimodal Input

• Multimodal free hand and speech to control 3D virtual objects

• Experimental setup (Wizard of Oz) [Lee & Billinghurst, 08]
  • Tasks: change object color, location, and shape
  • IV: speech only, gesture only, multimodal
  • DV: time, error, preference

• Results
  • Multimodal was faster, and more preferred, with no difference in error count
  • Speech is good of quantity and modal commands, e.g., change color
  • Gestures are good for quality and spatial manipulation
Handheld Finger Tracking

• Compared finger tracking with touch input on mobile devices for a grab-move-place gesture [Hürst et al., 13]

• Finger tracking was slower and less accurate
  • Nature of interaction (grab vs. tap)
  • Reduced feedback (tactile and visual) when the user is reaching out to the virtual object
  • Absolute position of virtual objects in 3D

• A simple buzzer on the finger tips can provide valuable haptic feedback when finger tips intersect with virtual objects [Buchmann et al., 04]
Handheld Hand Tracking

- Compared hand tracking with touch input on mobile devices for 3D manipulation tasks [Bai et al., 14]

- 3D gesture are slower but more preferred
  - Touch 3 axis moments faster than locating object in 3D space and 1 spatial movement for scaling and translation
  - No significant differences in placement errors
  - 3D easy to learn but causes physical stress

Task completion time (error bar: SE).
Handheld Device Interaction
Tangible AR

- Combine TUI with AR
- User physical objects to control virtual objects
- 1:1 or 1:* physical virtual mapping

[Kawashima et al., ISMAR 01]
Natural Interface

- Interfaces for treatment exposure (Kinect) [Corbett-Davies et al., 13]
- Model the scene
- Track the body
- Apply physical simulation engine on virtual objects
Applications
Applications

- Entertainment
- Marketing
- Medical
- Maintenance and assembly
- Training
- Museums guides
- Navigation

[Bichlmeier et al., ISMAR 07]

[Anderson et al., UIST 13]
Augmented Foam Sculpting for 3D Model Capture

Michael R. Marner  Bruce H. Thomas

wearables.unisa.edu.au
Training Apps

[Anderson et al., UIST '13]
Museum and Exhibit Navigators

- Rich information
- On the move
- Support several languages
- No need to wait in line
Geographic and Navigation Information Systems

• Augmented Maps
  • Represent the environment in a more natural and representative fashion

• Augmented Territories
  • Augment the environment itself to enhance users’ interaction
    • Sea navigation
    • Road navigation
  • Augmenting underground constructions
  • Indoor navigation
User Evaluation
User Evaluation

• A problem in AR research: not many user-based experiments
  • Technology is still not perfect
  • Depends on human perception, ergonomics, and attention models
  • Difficult to conduct in a well-controlled manner that is repeatable and reliable (On-off prototypes and variability)
  • Lack of suitable methods for evaluating AR interfaces
  • Who is the user? What problem are we solving? Who can evaluate the system?
Usability Tests vs. User Studies

• Usability tests
  • Learnability, Efficiency, Memorability, Errors, and Satisfaction (Nielsen)
  • Early on in the research project, using e.g., think aloud method or heuristic evaluation
  • Allow for rapid iterative design
  • Cannot be generalized

• User studies to answer research questions
  • For example, user interaction (efficiency or accuracy), behaviour, collaboration, ergonomics, performance, experience, etc
  • Incremental knowledge
User-based Studies in AR

- Based on work conducted by Swan and Gabbard VR 05, most AR user evaluations fit into one of four categories:
  - Low-level tasks: understanding human perception and cognition in AR contexts
  - User task performance: how AR technology could impact underlying tasks
  - Examine user interaction and collaboration
  - System usability
Evaluation Methods in AR

• Objective measurements
  • Measured numbers, reliable and repeatable, e.g., completion time, accuracy, object position

• Subjective measurements
  • Subjective judgment of people, e.g., from questionnaire and rankings

[Knörlein et al., ISMAR 09]
Evaluation Methods in AR

• Qualitative analysis
  • Data is gathered through observations and interviews

• Non User-Based techniques
  • Such as cognitive walkthroughs or heuristic evaluations with experts

• Informal testing
  • Reporting observations gathered during demonstration

[Morrison et al., CHI 09]
“The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.”

–Ivan Sutherland in 1965
Referenced Literature 1/2


Referenced Literature 2/2


