SPATIAL AUDIO FOR AUGMENTED REALITY

Mark Billinghurst
mark.billinghurst@unisa.edu.au

July 14\textsuperscript{th} 2016
Augmented Reality

1. **Combines Real and Virtual Images**
   - Both can be seen at the same time

2. **Interactive in real-time**
   - The virtual content can be interacted with

3. **Registered in 3D**
   - Virtual objects appear fixed in space

Pokemon GO ..

- Handheld AR, touch input, GPS/compass sensors
How We Look to Pokemon GO …
Hololens

- Head Mounted Augmented Reality
  - Speech, gesture input, stereo view
How We Look to Hololens
2 Eyes + 2 Ears = AR Spatial Interface

- **Visual interface**
  - See through HMD has ~ 30° – 90° Field of View
- **Audio interface**
  - Binaural headphone has 360° Field of Hearing
Wearable Spatial Audio Interfaces

- Previous research
  - Audio only interfaces
    - Navigation, visually disabled, gaming, mobile UI
- Little work in Hybrid Interfaces
  - Small wearable display + spatial AR
Benefits of Adding Spatial Audio to AR

• Cognitive
  • More information display without additional cognitive load
    • Different visual/auditory systems

• Information
  • Simultaneous information display using multiple modalities
  • Use appropriate modality for information

• Interface
  • Overcome limitations of limited visual display
    • Small screen size, Divided attention
  • Increase interface design options
Example AR Applications of Spatial Audio

• **Information Presentation**
  - Wearable information space (Billinghurst 1999)
  - Attention Redirection (Barde 2016)

• **Remote Collaboration**
  - Wearable AR conferencing (Billinghurst 1998)
  - Hybrid conferencing spaces (Bleeker 2013)

• **Location Based Audio**
  - High Street Stories (Lee 2013)

• **Authoring/Annotation**
  - Audio Stickies (Langlotz 2013)
  - Augmented Sound Reality (Dobler 2002)
Wearable Information Spaces (1998)

- Exocentric wearable information space
  - See through HMD
  - Wearable computer
  - Spatial audio/visual cues
  - Body stabilized information displays

User Evaluation

- **Task**
  - Finding target icon on pages of icons

- **Conditions**
  - Head stabilized vs. body stabilized
  - Additional spatial audio/visual cues for guidance

- **Results**
  - Body stabilized 30% faster performance
  - Spatial audio reduces search time by further 35%
  - No difference between spatial audio/visual cues
Attention Redirection (2016)

- Use dynamic spatial audio cues to direct attention
  - Audio moving in direction of target position
- Experimental Test
  - Divided attention task (wearable screen, projection screen)
  - Use no cue, static audio, dynamic moving spatial cue
  - Directing user attention to one of four target positions

Experimental Results

- Dynamically moving audio cue significantly reduces onset time
  - 30-40% faster than static audio cue for targets out of view
  - Up to 50% faster than no audio cue
Wearable AR Conferencing (1998)

**Concept**
- mobile video conferencing
- spatial audio/visual cues
- body-stabilized data

**Implementation**
- see-through HMD
- head tracking
- static images, spatial audio

User Evaluation

- Speaker discrimination task
  - 1, 3, 5 speakers saying almost same phrase at same time
  - Spatial vs. non-spatial cues

- Results
  - Spatial performance significantly better, more highly rated
  - Even simple spatial visual cues (radar display) produced improvement
Using HHD and HMD (2013)

- Use tablet to interact with AR conf. people
- Exo-centric view of conference space
- AE Spatial audio gives sense of direction

Location Based - High Street Stories (2013)

- Christchurch 2011 earthquake
  - Destroyed High Street, historical heart of city

- High Street Stories
  - Mobile AR app with minimal visual cues
  - Geolocated spatial audio cues – stories from locals
  - See http://www.highstreetstories.co.nz/
Location Based Information

- High Street Stories Interface
  - Map + AR View (GPS, compass interface)
  - Virtual tags showing geo-located stories
  - Spatial audio browsing based on viewpoint
  - Click to play complete story, view images
Demo Video
Authoring - Audio Stickies (2013)

- Mobile AR browser
  - Outdoor AR, GPS/compass tracking, panorama tracking
- User’s can add spatial audio annotations
  - Precise placement of spatial audio notes

Building Annotation

- Use mobile AR to view virtual buildings on site
  - View alternative AR designs
- Viewer can add audio comments
  - Simple tap and record interface
- Users can browse audio notes of others
  - Only play audio clips when in view
Demo Video
User Feedback

• 30 users tried system
  • 4 AR buildings viewed and commented on
  • Tested in two cities (Dunedin, Graz)

• Main feedback
  • Audio annotations seen as very useful
  • System easy to learn and use
  • Usable in noisy natural environment
  • Spatial audio supported discrimination between notes
  • Audio clutter an issue
Augmented Sound Reality (2002)

- Wearable interface for placing spatial audio cue
  - Virtual icons representing audio cues
  - 3D stylus for direct manipulation of sound sources
  - Viewing on stereo video see-through HMD
  - Spatial audio playback

Lessons Learned

• Spatial audio helps with information presentation
  • Out of view information, multimodal presentation

• Spatial audio can direct user attention
  • Dynamic audio cues

• Spatial audio cues can improve AR conferencing
  • Speaker discrimination, localization, social presence

• Tools can be developed for spatial audio authoring
  • Recording, manipulation audio cues

• Spatial audio enables richer AR experiences
  • Engages more sensors, reduces cognitive load
Directions for Future Research

- **User interface metaphors**
  - How to interaction with hybrid interfaces?
  - How to present information between modalities?

- **Collaborative Interfaces**
  - Using spatial audio for sharing communication cues
  - Recording and sharing spatial audio

- **Applications/Tools**
  - Which AR applications should use spatial audio?
  - AR spatial audio development tools

- **Technology**
  - Using headphones vs. bone conducting transducers/other tech.
  - Spatial audio algorithms (individual HRTF vs. generic HRTF, etc)
Conclusions

• AR is becoming commonly available
  • Handheld, head mounted

• Spatial audio can significantly improve AR experience
  • User interface
  • Information presentation
  • Remote collaboration

• However there are still significant areas for research
  • User interface, algorithms, collaboration, applications, etc