20 Questions: Grand Challenges in VE and 3D UI Research
1. Can we build systems that immerse all of the user’s senses?

- Visual: almost certainly
- Auditory: yes, noise-canceling headphones
- Haptic: very difficult, but possibly
- Olfactory: ??
- Gustatory: ??
- Vestibular, Kinesthetic: ??
- Direct display to the brain?
2. Can we completely remove the encumbrances in 3D interfaces?

- Approaches to input/tracking
  - Wireless transmission
  - Vision-based
- Approaches to output/display
  - Displays in the world
  - Displays and display generators worn by user
- Autostereoscopic displays: no glasses
3. Will "true 3D" displays ever become practical?

- Solve accommodation-convergence mismatch
- Multiple independent viewpoints
- Large-scale?
4. What are the best mappings between devices, tasks, interaction techniques, and applications?

- Huge potential for empirical research
- Examples from our group:
  - How should the WIM technique change to be used in the CAVE?
  - What navigation strategies do users adopt in fully- vs. semi-immersive displays?
  - Which VE displays are the most useful for decision-making tasks in the construction industry?
Interaction technique questions
5. What travel techniques will allow users to navigate effectively through multiple scales?

- Multi-scale VEs (e.g. human body, solar system) will be common
- Don’t want users to have to explicitly set scale or speed
- Need to maintain spatial orientation
6. Can we build usable hands-free 3D interfaces?

- Input from:
  - Speech (including “tone”)
  - Head movements
  - Eye movements
  - Facial expression
  - Bio-sensors
  - BRAIN
7. How can users enter, edit, and mark up symbols efficiently in 3D UIs?

• Largely unexplored area
• Lots of potential applications, as VEs become used for “real-world work”
• Techniques from mobile computing
• Novel techniques specifically for VEs
8. How can MR interaction techniques allow seamless interaction in both the real and virtual worlds?

- Tangible interfaces for AR/MR interaction:
  - Have no spatial gap
  - Have no interaction gap
  - BUT, they re-introduce limitations of the real world

- Can we do “magic” interaction with real objects in AR/MR?
9. Can we provide integrated interaction techniques for multiple tasks?
10. How should interaction techniques be optimized for specific domains?

- Consider properties, constraints, task requirements of the domain
- Example: object creation in architecture/construction
- How much specificity is worthwhile?
Design and development questions
11. How do we create a seamless 3D UI from a given set of 3D interaction techniques?

- Integration problem: the sum of 3 usable techniques is not necessarily a usable UI
- Example: HOMER and pointing steering
- Requires precise description of techniques
- Integrated techniques may help
12. What does an effective 3D UI development environment look like?

- Description language for 3D interaction techniques, UIs?
- Non-programming approach - choose a set of techniques from a menu
  - Requires solution to integration problem
- Example: iDesign
13. Can we build software systems that allow 3D UIs to migrate intelligently between platforms?

- Different displays, devices, etc. imply different UIs
- Ideal: specify a generic UI, and have the system create specific UIs for each platform
- Example: migrate Virtual Habitat UI from HMD to CAVE platform
14. How should abstract information be managed in 3D UIs?

- VEs need to represent more than perceptual, spatial information
- IRVEs add abstract information
- Challenges:
  - Database
  - Display / layout
  - Access / interaction
15. How can multiple users collaborate effectively in a 3D UI?

• Issues:
  - Awareness
  - Communication
  - Floor control
  - Cooperation

• How does a single-user 3D UI migrate to a collaborative 3D UI?
Evaluation questions
16. What specific heuristics or guidelines should we use to evaluate 3D UIs?

- **Generic level:** Nielsen’s heuristics
- **Mid-level:** General VE guidelines (like those in the book)
- **Specific level:** Guidelines for one type of 3D UI (e.g. IRVEs)

- Existing work shows that specificity can improve evaluation, but at what cost?
17. How can we effectively evaluate MR applications?

• With optical see-through displays, it’s impossible for the evaluator to see exactly what the user sees!

• Possible solutions:
  - Video see-through
  - Evaluator has own tracked display
  - Simulate AR with VR
Million dollar questions
18. Can we quantify the real benefits of 3D UIs?

• VEs: “A solution looking for a problem”
• We need proof that the use of VEs has measurable benefit relative to other platforms
• AND, that these benefits are greater than the associated costs
Existing approaches to quantify the benefits of immersion

- “Practical” studies (e.g. Arns)
  - High “ecological validity”
  - Not generalizable - only applies to specific systems tested

- Controlled studies (e.g. Pausch)
  - Generalizable
  - Can provide statistical evidence
  - BUT, how to separate components of immersion?
CAVE-based method for quantifying benefits of immersion

<table>
<thead>
<tr>
<th>No head-based rendering</th>
<th>1 wall, no head tracking</th>
<th>4 walls, no head tracking</th>
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</thead>
<tbody>
<tr>
<td>Small field of regard</td>
<td>Large field of regard</td>
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<tr>
<td>Full head-based rendering</td>
<td>1 wall, head tracking</td>
<td>4 walls, head tracking</td>
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19. Will there ever be a standard 3D UI?

- Standards would increase usability between applications
- Standards may actually decrease the potential usability of individual applications
- Depends on “mass market” applications
  - If VEs are only used in niche applications, no need to standardize
  - If VEs are to be used by the general population, standardization will probably follow
20. What is the “killer app” for VEs/3D UIs?

• Killer app: an application that requires a particular technology, and is so useful that it justifies the technology on its own

• GUIs: spreadsheet (VisiCalc)

• Internet: web browser (Mosaic)

• VEs/3D UIs:
  - Entertainment?
  - Teleconferencing?
  - Design?

• BUT, the success of VEs/3D UIs does NOT depend on a killer app