User-Centered Design and Evaluation of a Real-Time Battlefield Visualization Virtual Environment

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Outline

• Introduction
• “Dragon” VE application
• Usability evaluation methodologies
• Application of methodologies
• Results
• Conclusions
User-Centered Design & Evaluation

- Virtual Environments: from Mars
- Usability Engineering: from Venus
User-Centered Design & Evaluation

• Purpose of our research (basic):
  – Design a *usable* VE interface
  – *Evaluate* and *iteratively improve* VE user interface design

• Purpose of our research (meta-level):
  – Identify *general principles* and *most important parameters* of VE user interface design
  – Identify *effective techniques* for VE usability engineering
“Dragon” VE System

- VE for battlefield visualization
- Implemented on a Responsive Workbench
- Numerous iterations of UI design
Usability Engineering Methodologies

**Expert Heuristic Evaluation:**
assessment by UI design experts, to determine violated usability design guidelines

**Formative Evaluation:**
assessment with users, to iteratively determine and improve usability

**Summative Evaluation:**
assessment with users, to determine which among several design alternatives is “best”
Preliminary observational studies revealed **generic tasks**: navigation, object manipulation, object selection, object querying, query response, object aggregation.

Focus on **navigation** as fundamental to all other generic tasks.
Approach

- Dragon VE was instrumentable testbed for *heuristic* and *formative* work
- Developed scenarios of benchmark user tasks
- Extensive evaluations performed over nine-month period
- One to three users per evaluation cycle
- Based on results, iterate design
- Four major cycles of evaluation
Expert Heuristic Evaluation

• Experts assessed UI design
• Initially “free play”, then structured scenarios
• One or two other experts observing
• Guided by *framework of usability characteristics of VEs* [Gabbard & Hix 1999]
• Discovered and addressed usability problems:
  – *Poor mapping* of navigation tasks to flightstick buttons
  – *Missing functionality*
  – *Damping* of map movement in response to flightstick movement
  – Graphical and textual *feedback*
Formative Evaluations

• Six sessions; formal protocol; single user per session
• User first asked to use flightstick
• User then asked to perform scenarios
  – Time ranged from 20 minutes to more than one hour
  – Timed individual tasks; counted errors
  – Noted critical incidents
• Two evaluators (observers) in each session
• Four major iterations of Dragon UI design over one year
First Iteration Results: Virtual Sandtable

Based on real-world *sandtable metaphor*:
- exo-centric map manipulation

Utilized 5 DOF (x, y, z, h, p)

- Mapping of buttons to navigation tasks worked well
- Users wanted terrain-following capability, to “fly” over map
- Basic metaphor cumbersome
Second Iteration Results: Point & Go

Based on real-world *airplane metaphor*:

- ego-centric flying

One gesture moves anywhere on map

Utilized 6 DOF (x, y, z, h, p, r)

+ Attempted to avoid navigation modes
  - Single gesture to move around was not powerful enough to support diverse navigation tasks
  - Users wanted exo-centric rotate capability

Discovered *control vs. convenience* trade-off
Third Iteration Results: Modal

Based on combination of *flying* and *sandtable* metaphors

Each navigation task was *separate mode*

Utilized 5 DOF (x, y, z, h, p)

– Users found it cumbersome
– Too much control, not enough convenience
Fourth Iteration Results: Integrated Navigation

Based on combination of *flying* and *sandtable* metaphors

**Combined modes** mapped to flightstick buttons:

1) Pan & zoom \((x, y, z)\)
2) Pitch & heading \((h, p)\)
3) Exo-centric rotate & zoom \((y, h)\)

Fine-tuned damping and acceleration

+ Users found navigation to any location easy, and easy to switch among tasks
+ Achieved control vs. convenience compromise
Results: Significant Navigation Variables

- Identified 27 key variables that effect VE navigation → narrowed to 5 variables

<table>
<thead>
<tr>
<th>User Tasks</th>
<th>Virtual Model</th>
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<tbody>
<tr>
<td>1. navigation presets</td>
<td>15. mode switching</td>
</tr>
<tr>
<td>2. user scenarios</td>
<td>16. mode feedback</td>
</tr>
<tr>
<td></td>
<td>17. number of modes</td>
</tr>
<tr>
<td>Input Devices</td>
<td>18. visual navigation aids</td>
</tr>
<tr>
<td>3. navigation metaphor</td>
<td>19. dataset characteristics</td>
</tr>
<tr>
<td>4. navigation degrees-of-freedom</td>
<td>20. visual terrain representation</td>
</tr>
<tr>
<td>5. gestures to trigger actions</td>
<td>21. visual battlefield object</td>
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<td>6. speech input</td>
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<tr>
<td>7. number of flightstick buttons</td>
<td>representation</td>
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<tr>
<td>8. input device type</td>
<td>22. visual input device representation</td>
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<tr>
<td>9. movement deadspace</td>
<td>23. size of battlefield objects</td>
</tr>
<tr>
<td>10. movement damping</td>
<td>24. visual object relationship</td>
</tr>
<tr>
<td>11. user gesture work volume</td>
<td>25. map constrained vs. floating</td>
</tr>
<tr>
<td>12. gesture mapping</td>
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</tr>
<tr>
<td>13. button mapping</td>
<td>Presentation Devices</td>
</tr>
<tr>
<td>14. head tracking</td>
<td>26. visual presentation device</td>
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<td>27. stereopsis</td>
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Ongoing Summative Studies

• **Goal**: systematically examine five variables most likely to influence VE navigation

• **Summative Evaluation**: assessment with users, to statistically compare user performance with different UI designs

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<tr>
<th>Variable</th>
<th>Levels</th>
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<tbody>
<tr>
<td>1) stereopsis</td>
<td>absent</td>
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<tr>
<td>2) visual presentation device</td>
<td>virtual workbench</td>
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<tr>
<td>3) gesture mapping</td>
<td>controls rate</td>
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<tr>
<td>4) navigation metaphor</td>
<td>egocentric</td>
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<tr>
<td>5) head-tracking</td>
<td>absent</td>
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Conclusions

- Successful, cost-effective progression from **heuristic** to **formative** to **summative** evaluations

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<tr>
<th>Usability Evaluation Type</th>
<th>Associated Cost</th>
<th>Generality of Results</th>
<th>Precision of Results</th>
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<tbody>
<tr>
<td>Expert Heuristic Evaluation</td>
<td>Cheap</td>
<td>General</td>
<td>Low</td>
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<tr>
<td>Formative Evaluation</td>
<td>Expensive</td>
<td>Specific</td>
<td>High</td>
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<td>Summative Evaluation</td>
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