Human Factor and User Interface in Augmented Reality for Military Applications

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Military Benefits of AR

- Situation awareness
  - Pilots (head-up displays)
  - Dismounted infantry
  - Vehicles

- Team coordination
  - IFF and target communication
  - Formation and movement

- Training
  - Urban combat
  - Fire support team
Urban Skills Training

• Bridge to SAF system to include virtual friendly and enemy forces or civilians
• Room clearing task
  – Need to model environmental geometry and light
  – Issue of model fidelity
• Task: Room clearing
• Does training against virtual characters lead to better training than learning techniques in empty rooms?
Evaluation Strategy

- Use One-SAF Testbed to control computer-generated forces
- Two test groups: novice (scientists) and Corporals/Lance Corporals at MCB Quantico
- Pre-test & post-test against live forces; training type (AR, empty rooms) varied
- Single person “team” with threats placed in his area of responsibility within each room
Training Effectiveness Results

- Novices with AR training learned to look at the whole room
  - Those with empty rooms learned to look at less of the room
- Experts tended to fire more shots and take a little longer when training against AR
  - But only trends
- Subjective feedback
  - Liked idea and use of standard targets
  - Errors in sighting of weapon, OPFORs moved or disappeared, difficulties perceiving depth, trouble seeing real walls, uncomfortable wearing HMD

\[ F(1,12) = 11.998, \ p = 0.005 \]
\[ F = 2.85, \ p = 0.092 \]
\[ F = 2.81, \ p = 0.080 \]
Depth Perception in AR

• AR can present locations of troops in 3D
  – Visualizations of troops hidden by buildings
  – Breaks some depth cues, notably occlusion
• So a pre-requisite for troop location with AR would appear to be working “X-ray vision”
User Study Design

Two goals:
• Visualizations
• Indoor vs. outdoor
“X-ray vision” Metaphors
Does “X-ray vision” Work?
Registration Noise and Occluded Object Representation
Registration Noise and Occluded Object Representation
AR Distorts Basic Perception

- Limited resolution
  - Graphics
  - Real in video overlay AR

- Lower contrast
  - Both graphics and real, depending on the display optics/electronics

- Shifted colors
  - Both graphics and real, depending on the display optics/electronics
Contrast Sensitivity Study Design

• **Task:** identify which side of a square has an opening
  - Inspired by Landolt-C eye chart [Fidopiastis05]

• **Sixteen subjects**
  - All with normal or correct-to-normal vision
  - Twelve male / four female
  - Heavy computer users
  - Age \(21 - 39\); mean 27.6
  - Split into two pools...
Contrast Sensitivity Results

<table>
<thead>
<tr>
<th>Display</th>
<th>Res</th>
<th>h-FOV</th>
<th>Pix/°</th>
<th>Min/Pix</th>
<th>Snellen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor</td>
<td>UXGA</td>
<td>18.7°</td>
<td>85.5</td>
<td>0.70</td>
<td>20/15</td>
</tr>
<tr>
<td>nVisorST</td>
<td>SXGA</td>
<td>48.0°</td>
<td>26.7</td>
<td>2.25</td>
<td>20/45</td>
</tr>
<tr>
<td>Nomad</td>
<td>SVG</td>
<td>23.7°</td>
<td>33.8</td>
<td>1.78</td>
<td>20/35</td>
</tr>
<tr>
<td>Glasstron</td>
<td>SVG</td>
<td>28.1°</td>
<td>28.5</td>
<td>2.11</td>
<td>20/42</td>
</tr>
<tr>
<td>ARvision graphics</td>
<td>SVG</td>
<td>24.9°</td>
<td>32.1</td>
<td>1.87</td>
<td>20/38</td>
</tr>
<tr>
<td>real</td>
<td>NTSC</td>
<td>24.9°</td>
<td>25.7</td>
<td>2.33</td>
<td>20/47</td>
</tr>
</tbody>
</table>

Objective predictions

Measured contrast sensitivity function
Color Perception

- With no control over background, colors such as MILSTD2525c may not appear as intended
- Color matching task
- Measure objective change and subjective change
Objective Color Distortion

Blue = color meter
Gray = real
Magenta = Black background
Cyan = White background
Yellow = See-through

Glasstron

nVisorST

ARvision
Perceptual Color Distortion

Gray = real
Magenta = Black background
Cyan = White background
Yellow = See-through
This concept sketch shows information important for military personnel to establish and maintain SA: building and street labels, friendly (light rectangles) and enemy (dark square) icons, and a compass.
The Meissa software displays cues for SA and threat potential.

A command-and-control (C2) application might show icons for forces and live sensor (including camera) data over a mixture of satellite imagery and virtual terrain.
Information Filtering

Showing all information and labels in the database can overwhelm the user and prevent a Marine from achieving SA.

Information filter uses semantic keys and the concept of area of operations to limit the information shown, which enables the user in this case to discern the location of enemy tanks – spotted by another user – much more easily.
User Interaction

Early prototype of our wearable AR system from commercial components.
Artificial Intelligence

- Scripting
- Navigation system

- Two stage state machine
  - The top level state machine works at mission level.
    - Character actions when it receives a certain command.
    - Response when it encounters a certain event.
  - The secondary state machine
    - Low level animation sequence of the character
Open Research Questions

• Registration requirements
  – Situation awareness
  – Training

• Improvement in situation awareness

• Training effectiveness
  – More detailed studies
  – More training tasks

\[ t(22) = 5.252, p = 0.000 \text{ between Noise and Latency} \]
Required Improvements

• Are head-worn displays best?
  – Training: yes
  – Situation awareness: some of the time
• Increased FOV, resolution
• Multi-focus displays
• Optical see-through with occlusion
• Sensors for tracking
• Graphics processing for mobile devices
• AI for virtual forces
Conclusions

• AR is a promising method for military training and SA
  – Mixture of virtual objects and physical objects
  – Incorporate mission specific environmental models and digital opposing forces
  – More realistic than a pure virtual environment
  – More flexible training than pure physical settings
  – Reduced manpower to provide training

• But technology has not delivered on promise
  – Displays and tracking hardware have a long way to go
  – Interaction techniques need improvement
  – Human factors require deeper understanding to make these systems that people really want to use