The Interactive “Silk” Effect: Utilizing Semi-Transparency in Human Computer Interaction

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Introduction: 3D Visual Interfaces

- 3D Graphics, Animation, CAD
- Information Visualization
- Virtual Environments
- Teleoperation / Telerobotics
Forms of 3D displays

- Immersive, head mounted display - VR
- Desktop, monitor based, “fish tank” VR
- Large screen (or Table) projection system
- Augmented Reality
  - Merging virtual with real
  - Optical see-through
  - “wearable” computers
  - Stereovideo + Stereographics
  - System calibration
  - Perceptual calibration (cue conflict)
3D Cues and Technologies

Perceptual Cues

- Interposition
- Stereopsis
- Perspective
- Shadow
- Motion Parallax
- Active Movement
- *Semi-transparency?*
# 3D Cues and Technologies

## Perceptual Cues
- Interposition
- Stereopsis
- Perspective
- Shadow
- Motion Parallax
- Active Movement
- Semi-transparency?

## Interface Techniques
- Hidden surface removal
- Stereoscopic Shutters
- Perspective Projection
- Lighting Model
- Rotation, motion
- Head Tracking
- Alpha blending
Research Questions

- Does semi-transparency indeed provide depth cue?
- Can it be utilized in HCI?
- How much performance improvement?
- Relative strength
Experimental Task

- Virtual Fishing
- 3D dynamic target acquisition
- Essential element in 3D interaction - Locating objects in depth
Experimental Task

- Input Device
A fish in front of the silk cursor
Experimental Task

- A fish behind the silk cursor
Experimental Task

- A fish partially inside of the silk cursor
Experimental Task

- A fish completely inside of the cursor
Experimental Task

Wireframe cursor
Experimental Design

- **Experimental Conditions**

<table>
<thead>
<tr>
<th>Display</th>
<th>Cursor</th>
<th>Silk</th>
<th>Wireframe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereoscopic</td>
<td>StereoSilk</td>
<td>StereoWire</td>
<td></td>
</tr>
<tr>
<td>MonoSilk</td>
<td>MonoWire</td>
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<td></td>
</tr>
</tbody>
</table>

- Balanced within-subject

- 12 subjects x 2 cursor types x 2 display modes
  x 5 tests x 15 trials
Performance Measures

- Trial Completion Time
- Error Rate
- Error Magnitude
- Subjective Evaluation
Task Completion Time

- **Significant factors:**
  - Cursor type
  - Display mode
  - Cursor type and Display interaction

- **Ranking (best to worst):**
  - StereoSilk
  - MonoSilk
  - StereoWire
  - MonoWire

Trial completion time (sec)

![Graph showing trial completion time with Silk and Wireframe modes for Stereo and Mono.]
Error Rate

Fish missed (%)

- **Significant factors:**
  - Cursor type
  - Display mode
  - Cursor type and Display interaction

- **Ranking (best to worst):**
  - StereoSilk
  - MonoSilk
  - StereoWire
  - MonoWire
Error Magnitude

- Significant factors:
  - Cursor type
  - Display mode

- Ranking (best to worst):
  - StereoSilk
  - StereoWire
  - MonoSilk
  - MonoWire

- Post hoc analysis:
  - MonoSilk vs. StereoWire: $p = 0.16$
  - Other pairs significant
Learning Effects

- Speed accuracy trade-off w.r.t. learning
## Subjective Preference

<table>
<thead>
<tr>
<th></th>
<th>Very Low</th>
<th>Low</th>
<th>OK</th>
<th>High</th>
<th>Very High</th>
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<tbody>
<tr>
<td>StereoSilk</td>
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<td>3</td>
<td>9</td>
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<tr>
<td>MonoWire</td>
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<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Number of subjects in cells)

- Consistent with performance measures:
  - StereoSilk - MonoSilk - StereoWire - MonoWire
Partial Occlusion Depth Cue

- Semi-transparency does not obscure objects.
- Semi-transparency as qualitative/relational depth cue.
- Quantitative/continuous information can be enhanced through *interaction* (moving through object).
Models of 3D Performance

- Combining multiple sources of information
- Additive model (Bruno and Cutting, 1988)
- Multiplicative model (Sollenberger and Milgram 1993)

This experiment:
- Time and Error: Multiplicative
  - dominance of semi-transparency.
- Error magnitude: Additive
Applications

“Silk Hand”
Telerobotics
- Movie and Video
- Information Visualization

“Cone Tree”

“Spiral Calendar”

(Card, Robertson, Mackinlay, Pirolli, 1991, 1994)
- Surgical Visualisation

(Hinckley, Pausch, Goble, Kassell 1994)
6 DOF Tracking

- Tracking with six degree-of-freedom (Zhai, Milgram 1993)
- 2.5 Interfaces

- "Tool glass and magic lenses"
- 2.5 Interfaces

- "SilkWidgets"
Zhai, Buxton, Milgram:


http://vered.rose.toronto.edu/people/shumin_dir/SILK/silk.html