Optical Crosstalk and Visual Comfort of a Stereoscopic Display used in a Real-Time Application

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17th October 2007
The UK’s national standards laboratory

A world-leading national measurement institute (top 3 among 54) for precise measurement techniques and standards

Over 600 specialists dedicated to providing measurement solutions
- Scientists
- Engineers
- Support staff

Owned by the dti, but privately operated by Serco (GOCO)

New state of the art laboratory
Professional and Consumer display applications.

Professional Identification of symbols & imagery

End User

Commercial / Consumer Visual performance that is better or same as competitors at same or lower cost

Display Product

Professional

Consumer

Visual performance that is better or same as competitors at same or lower cost

Mobile

ATC

Military Aircraft

Civil Aircraft

Automobile

PC

Information displays.

TV
Stereoscopic Displays

- Volumetric Displays first postulated in 1912
- 3D displays present the advantage of enhanced depth perception
- Mainstream use of prevented so far due to reports of user discomfort
- A common cause of eyestrain & nausea is optical cross-talk
Measurement of cross talk

\[ p = \frac{D}{\left(\frac{e}{d}\right)} - 1 \]

perceived depth (p)

Inter Pupillary Distance, e

Viewing Distance D
• An estimated two thousand major medical procedures make use of visual displays
• In principle surgeons agree that a stereoscopic view would enhance their visual experience
• Large scale uptake is prevented by visual discomfort during procedures that can take several hours
• One of the largest contributing factors is cross-talk
Aims

- Design a system inherently free of crosstalk into which controlled amounts of crosstalk can be introduced
- Design a set of tasks that fulfil a given criteria with possible medical relevance
- We look for the effects of cross-talk on task performance in real-time as opposed to still or pre-recorded images
Helmholtz Stereoscope

Virtual screens

PLAN

Left LCD

Right LCD

Mirrors

Mirror

Viewer

HELHMHOLTZ STEREOSCOPE
Helmholtz Stereoscope in the Laboratory
Capture and Task Region

Cameras mounted on adjustable stages.

Top rod fixed and bottom rod moved using a remote control via a stepper motor.

Two strips from a light box provide uniform illumination.
Introducing Crosstalk
Crosstalk Images

Main image from the right camera

Ghost image from the left camera

Left channel display

Right channel display
The photon counting system allows us to make accurate and repeatable measurements at the very low light levels present.

Typical luminance values:
- 2% Crosstalk < 3 Cdm$^{-2}$
- Comparison of different black levels ~ 0.2 Cdm$^{-2}$

These measurements are not possible using any commercially available system.
Definition of Crosstalk

Calculation of crosstalk:

\[ C = \frac{L_G - L_{BL}}{L_M - L_{BL}} \]

Where, \( L_M \) = Luminance of Main image, \( L_G \) = Luminance of Ghost image, \( L_{BL} \) = LCD background luminance.
Calibration of system for Crosstalk

Mixer Voltage vs Cross-talk for Left Channel

Voltage (V)

Cross-talk (%)

(3.39V, 20%)
(3.55V, 15%)
(3.76V, 10%)
(4.05V, 5%)
(4.31V, 2%)
Criteria

- Task Criteria
  - Simple enough to be of equal challenge to all users
  - Worst case scenario when crosstalk is introduced
- Subject Selection
  - Tested for near vision acuity, distance acuity, stereo acuity and colour vision
  - Questionnaire to probe how frequently subject uses 3D displays, computers, experiences headaches/eyestrain/nausea, and enthusiasm for new technology
• An artefact with a simple convex/concave profile with a random patterned surface was engineered
Ergonomics

• External factors of discomfort had to be reduced to a minimum
• Dimensions were configured to suit 97% of the population
• Adjustments to the chair and table height are easily controlled by the user electronically
Measurement Techniques

- Depth Object – we change both disparity and crosstalk
  - Can the user identify the convex/concave profile
  - Is there any hesitation in deciding the profile
- Aligning Rods – Set disparity to 10% and vary crosstalk
  - Can the user identify the relative start positions of the rods
  - Time taken to complete the alignment to user’s satisfaction
  - Galvanic Skin Resistance (GSR)
  - NASA Task Load Index (TLX) Questionnaire
  - Error in final alignment
Galvanic Skin Resistance

Example of a user’s GSR reading. Region A is a period of relaxation and region B is a period of induced stress.

Further consultation is planned with a psychologist to interpret this data.
## Depth Object Results 1

<table>
<thead>
<tr>
<th>Score</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Could not tell</td>
</tr>
<tr>
<td>1</td>
<td>Difficult (&gt; 4 seconds)</td>
</tr>
<tr>
<td>2</td>
<td>Hesitation (≤ 4 seconds)</td>
</tr>
<tr>
<td>3</td>
<td>No hesitation (less than one second)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disparity</th>
<th>Total scores across all crosstalk levels</th>
<th>Ratio of correct answers across all crosstalk levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>148</td>
<td>0.92</td>
</tr>
<tr>
<td>50%</td>
<td>135</td>
<td>0.80</td>
</tr>
<tr>
<td>75%</td>
<td>143</td>
<td>0.88</td>
</tr>
</tbody>
</table>
## Depth Object Results 2

<table>
<thead>
<tr>
<th>Crosstalk</th>
<th>Total scores across all disparity levels</th>
<th>Ratio of correct answers across all disparity levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>143</td>
<td>0.98</td>
</tr>
<tr>
<td>5%</td>
<td>108</td>
<td>0.90</td>
</tr>
<tr>
<td>10%</td>
<td>102</td>
<td>0.87</td>
</tr>
<tr>
<td>15%</td>
<td>73</td>
<td>0.70</td>
</tr>
</tbody>
</table>
## Rod Alignment Results

<table>
<thead>
<tr>
<th>Crosstalk</th>
<th>Average correct judgement of start positions</th>
<th>Average modulus of alignment error (mm)</th>
<th>Average completion time (s)</th>
<th>Average TLX Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>3.00</td>
<td>0.87</td>
<td>48.5</td>
<td>38</td>
</tr>
<tr>
<td>2%</td>
<td>3.00</td>
<td>1.15</td>
<td>33.1</td>
<td>47</td>
</tr>
<tr>
<td>5%</td>
<td>3.00</td>
<td>1.11</td>
<td>42.5</td>
<td>51</td>
</tr>
<tr>
<td>10%</td>
<td>2.57</td>
<td>1.60</td>
<td>43.3</td>
<td>57</td>
</tr>
<tr>
<td>15%</td>
<td>2.28</td>
<td>2.68</td>
<td>41.7</td>
<td>58</td>
</tr>
</tbody>
</table>
Conclusions

- We have developed a robust system for making traceable measurements of crosstalk on 3D images.
- We have not yet found any clear trend that varying the disparity affected the users’ judgement of depth in a predictable way.
- In these trials a decrease in task performance and increased workload was observed as crosstalk was increased.
Further Work

• Carry out a pilot study with surgeons and develop new tasks that both address the needs of a surgeon and better emulate a real scenario

• Test the importance of the background when crosstalk is introduced
Latest Set Up
Thank You

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