Human Visual Perception
relevant to
3D-TV

Wa James Tam
Communications Research Centre Canada
An understanding of Human Visual Perception is important for the development of 3D-TV
Communications Research Centre Canada (CRC) is the primary federal laboratory for R&D in advanced telecommunications in Canada.
Stereovision

Stereo Interocular Deficiencies

Object-motion & Visual Comfort

Surrogate Depth Maps
What underlies 3D-TV?

Depth from Disparity Processing by the Human Visual System
Horizontal Disparity
Changing Horizontal Disparities
Two Types of Disparities

Uncrossed Disparity

Crossed Disparity
Differences/Implications

Stereo deficiency
Performance
Visual comfort
Visual display
Who can benefit from 3D TV?

Stereo Deficiencies
6% vs. 30%
Display Duration and Depth Discrimination
Apparatus

Test Set-up
Front or Back?
Left or Right?
**Depth Discrimination**

- Front/back?
- Left/Right closer?
  - 0.25 deg & 0.125/0.375 deg

**Dynamic tracking (PEST)**

- Duration varied
  - 20 – 1000 msec

- 100 viewers
- 8 Estimates each
Results

Prevalence of stereo-deficiency assessed using two different tasks

- Is the square in-front or behind?
- Which square is closer?
Results breakdown

PERCENTAGE STEREO-DEFICIENT
(Left/Right Depth Discrimination)

n=100

- Any stereo-deficiency
- Stereo-anomalous: uncrossed
- "Stereo-blind"
- Stereo-anomalous: crossed

Percentage of Viewers

0 200 400 600 800 1000
Display Duration (ms)
Hours watching TV
Inter-pupillary separation

IPD Distribution

Percentage of Viewers

Inter-pupillary Distance (mm)

n=100
Conclusion

Individuals vary along a continuum in their ability to process stereoscopic depth information.
Inter-ocular Averaging

How can bandwidth be reduced?
3D-TV
Interocular masking of blur in one eye

Julesz ’71
3D-TV
Asymmetrical Quality
Subjective evaluation of Image Quality

For different extents of asymmetry in image quality
Continuous Quality Scale

EXCELLENT
GOOD
FAIR
POOR
BAD
Subjective Assessment

Original

Severe

Blur

Image Quality

Level of Low-Pass Filtering

Extent of Asymmetry (Low-Pass Filtering)
Subjective Assessment

Original

Coarse

Blocky artifacts

Extent of Asymmetry (Quantization)
3D-TV

Viable
Conclusion

Asymmetrical coding with cross-switching at scene cuts is a viable method for bandwidth savings.
Motion & Visual Comfort

How might visual comfort be affected by stereoscopic objects in motion?
Motion in Depth
Display
Visual Comfort

Disparity Magnitude (minutes of arc)

Visual Comfort

Very Comfortable
Comfortable
Mildly Uncomfortable
Uncomfortable
Externel Uncomfortable

21 Viewers
Visual Comfort

![Graph showing visual comfort levels at different velocities (slow, medium, fast). The y-axis represents visual comfort levels ranging from Very Comfortable to Extremely Uncomfortable, while the x-axis represents velocity in cm/sec. The graph indicates a decrease in comfort as velocity increases.]
Horizontal Motion

Crossed Disparity
Display

Uncrossed Disparity
Visual Comfort

![Graph showing visual comfort levels for different sequence types.]

- Very Comfortable
- Comfortable
- Mildly Uncomfortable
- Uncomfortable
- Extremely Uncomfortable

Sequence Type:
- Crossed
- Uncrossed
- Cross&Uncross

21 Viewers
Visual Comfort

Disparity Magnitude (minutes of arc)

Very Comfortable
Comfortable
Mildly Uncomfortable
Uncomfortable
Extremely Uncomfortable

21 Viewers
Visual Comfort

The diagram illustrates the relationship between visual comfort and velocity, measured in degrees per second. The x-axis represents velocity with categories of Slow, Medium, and Fast. The y-axis shows visual comfort with levels from Very Comfortable to Extremely Uncomfortable. The graph indicates that as velocity increases, visual comfort decreases, with a noticeable trend towards discomfort at higher velocities.
Aside from disparity, object motion can significantly influence visual discomfort.
Surrogate Depth Maps

How to create 3D contents from 2D?
2D-to-3D Conversion Technique

Object segmentation and horizontal shifting
2D-to-3D

Another Approach

Depth Maps
2D + Depth

Multiple views for autostereoscopic displays
Advantages

bandwidth-efficient, multiple images & viewpoints
Create Depth Maps using information from 2D source images
Make use of human visual perception for 2D-to-3D conversion
Depth Filling/Interpolation
Depth Surface Perception

The region surrounded by a disparate boundary tends to take up the same depth as its boundary.
First Study
Sparse Depth Maps
Cones
Meal
Meal

Full

Edge

Boundary
Double-stimulus
Continuous Quality Scale

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Surrogate Depth Maps

Clearly different but functionally equivalent in a critical way

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New Method based on the gray level intensities of a colour component
Components of Colour Image

4:2:2 Component Digital Video

Y' Luma

B'-Y' Chroma

R'-Y'
Components of Colour Image
Components of Colour Image

![Colour Image Components]

- **Y**: Luminance Component
- **C_B**: Blue Difference Component
- **C_R**: Red Difference Component
Experimental Study

Surrogate Depth Maps

based on colour component

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Test sequences
Ten eight-second video clips
ITU-601 format (720x480, 30fps)
Camera Test
Confetti
Flowerpot
Red Leaves
Street Organ
Trapeze
Tulips
Waterslide
Single-stimulus Continuous Quality Scale

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Single-stimulus Continuous Quality Scale
Depth Results

Image Depth Quality

1. Aquarium
2. Camera Test
3. Confetti
4. Crowd
5. Flower Pot
6. Red Leaves
7. Street Organ
8. Trapeze
9. Tulips
10. Waterslide
Visual Comfort Results

Image Visual Comfort

Video Sequence

Visual Comfort Rating

- 2D
- 3D
- CONVERTED-3D

Video Sequence:
1. Aquarium
2. Camera Test
3. Confetti
4. Crowd
5. Flower Pot
6. Red Leaves
7. Street Organ
8. Trapeze
9. Tulips
10. Waterslide
How can it possibly “work”?

- **Natural Images**
- Foreground-background separation
- **Shading within objects**
- Visual experience

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Depth reversal
Familiarity information

http://www.kyb.mpg.de/bu/demo/index.html
Surrogate Depth Maps can be useful for 2D-to-3D conversion
Summary

1. Stereopsis  (& disparity type)

2. Stereoscopic deficiencies  (& display duration)

3. Inter-ocular averaging  (& bandwidth reduction)

4. Object motion  (& visual comfort)

5. Surrogate depth maps  (& 2D-to-3D conversion)
Take Home Message
Human Visual Perception can be exploited for 3D-TV
Human Visual Perception is an active process

Thanks!
Half Colour
Half Colour
Sony GDM-F500
21” CRT monitors
4H viewing distance
Field-sequential Stereo
Subjective Assessment

- Depth Quality
- Visual Comfort

21 Viewers