Contours, Saliency & Tone Mapping

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Visual Imaging in the Electronic Age
Lecture 15
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Receptive Fields
Receptive Fields

On center and off center retinal ganglion cells respond oppositely to light in the center and surround of their receptive fields. A strong response means high frequency firing, a weak response is firing at a low frequency, and no response means no action potential is fired.

http://en.wikipedia.org/wiki/Receptive_field
Three identical disks pasted onto the photograph appear as different shades in different locations.
Perception Edge Effects
The Eye Sees Contours

- Contours are so dominant in our visual perception that when we draw an object, it is almost instinctive for us to begin by sketching its outlines.
The Eye Sees Contours

• Contours are so dominant in our visual perception that when we draw an object, it is almost instinctive for us to begin by sketching its outlines.

• We see contours when there is a contrast, or difference, in the brightness or color between adjacent areas.
Rate of Discharge of nerve impulses produced by steady illumination of a single receptor, $A$, in the eye of the horseshoe crab *Limulus* is directly related to the intensity of the light. The nerve fibers from the receptor are separated by microdissection and connected to an electrode from an amplifier and a recorder.

Inhibition of receptor, $A$, steadily exposed to moderate illumination is produced when neighboring receptors, $B$, are also illuminated.

Lateral Inhibition in the eye of the horseshoe crab is strongest between receptors a short distance apart and grows weaker as the distance between receptors increases.

Observed Brightness Curve obtained by psychophysical measurements (*black line*) has two sharp flections, one corresponding to the bright band and the other to the dark band. Measurement of actual luminance (*colored line*) across a half-shadow region reveals that the effect lies in the beholder and is not an objective phenomenon.
Rapid Rotation of this disk will create the Cornsweet illusion. The white spur creates a local variation near the contour between the two zones that causes the apparent brightness of the inner zone to increase. In the same way the dark spur creates a local variation that causes the outer zone to appear darker. Except in the spur region the objective luminance of the disk when it is rotating is the same in both the inner and the outer region.

Source of Craik-O’Brien Effect can be demonstrated by covering the contour with a wire or string. When this is done, the inner and outer regions appear equally bright.

**Luminance** on both sides of the Craik-O’Brien contour is the same but the inside appears brighter. The human visual system may extrapolate (*colored curve*) from the maximum and minimum produced by inhibitory processes (*black curve at right*).

“Le petit déjeuner”
Paul Signac (1886-87)

This is a portion of his “Le petit dejeuner” (1886-1887). Note how the shadow is darker near the unshaded tablecloth and lighter next to the dark matchbox.

Contour and Contrast

Subjective Triangles

Subjective Triangles

Curved Subjective Contours are created by sectors with curved angles (left). Sectors with straight angles can create curved contours if angles are not aligned with one another.

Geometric Regularity

Saliency

Where do we look?

Where should we have high resolution?
The Significance of Movement-Sensitive Cells

The Significance of Movement-Sensitive Cells

The Significance of Movement-Sensitive Cells

A picture is viewed by an observer while we monitor eye position and hence direction gaze. The eye jumps, comes to rest momentarily (producing a small dot on the record), then jumps to a new locus of interest.

The Significance of Movement-Sensitive Cells

The Significance of Movement-Sensitive Cells

TONE MAPPING
Visual Adaptation

- Luminance (log cd/m²):
  - Starlight
  - Moonlight
  - Indoor lighting
  - Sunlight

- Range of illumination:
  - Scotopic
  - Mesopic
  - Photopic

- Displays:
  - Poor contrast
  - No color
  - Low acuity

- Good contrast
  - Good color
  - High acuity
The tone reproduction problem

- the absolute range of environmental illumination is *vast* (~10-12 log units)
- the dynamic range of scenes can be *large* (~3-4 log units)
- the absolute and dynamic ranges of display devices are *small* (~2.0-3.0 log units)
Threshold visibility – Weber’s Law

\[ \Delta L = kL \quad \text{Weber’s law} \]
Tone Mapping Look-up Tables

Value

Address

0 0 0 0 0 0 5 6 7
Original Lookup Table

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
</table>

Modified Lookup Table

| 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |

![Graphs showing original and modified lookup tables with corresponding input and output values.](image)
Original Image – Snake River
Modified Image
Dodging (Ansel Adams)

Burning

A technique for selective lightening of an area of a print by giving it additional exposure.

Usually accomplished by blocking the projected image, letting light fall only on the selected region.
Dodging

Holding back the light which reaches an area of an image during exposure to darken it.

Usually done with the hands or a dodging tool.
### Linear display response

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>6.7%</td>
<td>0.2%</td>
</tr>
<tr>
<td>13.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td>20%</td>
<td>0.6%</td>
</tr>
<tr>
<td>26.7%</td>
<td>0.8%</td>
</tr>
<tr>
<td>33.3%</td>
<td>1.0%</td>
</tr>
<tr>
<td>40%</td>
<td>1.2%</td>
</tr>
<tr>
<td>46.7%</td>
<td>1.4%</td>
</tr>
<tr>
<td>53.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td>60%</td>
<td>1.8%</td>
</tr>
<tr>
<td>66.7%</td>
<td>2.0%</td>
</tr>
<tr>
<td>73.3%</td>
<td>2.2%</td>
</tr>
<tr>
<td>80%</td>
<td>2.4%</td>
</tr>
<tr>
<td>86.7%</td>
<td>2.6%</td>
</tr>
<tr>
<td>93.3%</td>
<td>2.8%</td>
</tr>
<tr>
<td>100%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

The diagram shows a linear relationship between input and output values.
# Gamma 2.2 display response

| Input | 0%    | 0.3%   | 1.2%   | 2.9%   | 5.5%   | 8.9%   | 13.3%  | 18.7%  | 25.1%  | 32.5%  | 41.0%  | 50.5%  | 61.2%  | 73.0%  | 85.9%  | 100%   |
|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Output| 0     | 0.2    | 0.4    | 0.6    | 0.8    | 1      |        |        |        |        |        |        |        |        |        |

![Graph](image-url)
Gamma Curve

http://en.wikipedia.org/wiki/Gamma_correction#mediaviewer/File:GammaFunctionGraph.svg
Displaying high dynamic range scenes

10,000:1 dynamic range

before
linear mapping

after
visual mapping
Digital Image Manipulation

Filter Types

- **Box (Blurring)**
- **Triangle (Blurring)**
- **Gaussian (Blurring)**
- **“Hat” (Edge Sharpening)**
Compute the weighted average of the selected points.

Original Image

Blur Filter

Scale = 37


Blurred Image
Original Image - red channel

Sharpen Filter

Scale = 1

3 pixels

114 114 114
124 122 119
123 122 121

114(-1)+114(-1)+114(-1)+
124(-1)+122(9)+119(-1)+
123(-1)+122(-1)+121(-1)

147

Sharpened Image

147
Original Image - green channel

88 88 86
97 96 92
95 95 94

Sharpen Filter

\[
\begin{array}{ccc}
-1 & -1 & -1 \\
-1 & 9  & -1 \\
-1 & -1 & -1 \\
\end{array}
\]

Scale = 1

\[
\begin{align*}
88(-1) + 88(-1) + 86(-1) + \\
97(-1) + 96(9) + 92(-1) + \\
95(-1) + 95(-1) + 94(-1) &= \frac{129}{1}
\end{align*}
\]
Original Image - blue channel

Sharpened Image

3 pixels

150 150 137
164 [163] 150
156 154 148

Sharpen Filter

-1 -1 -1
-1 9 -1
-1 -1 -1

Scale = 1

150(-1)+150(-1)+137(-1)+
164(-1)+163(9)+150(-1)+
156(-1)+154(-1)+148(-1) = 258

150 150 137
[164] 255 150
156 154 148

255
End...