lecture 14

Psychophysics 2: Noise
- ideal observers e.g. contrast sensitivity
- image motion
- surface slant
- binocular disparity (not covered)

Thursday, Oct. 29, 2015

Recall image contrast from last lecture
.... but now add noise

noise present noise not

\[ I(x, y) = I_0 + \Delta I \cdot \cos\left(\frac{2\pi}{N} k_0 x\right) + n(x, y) \]

Take Fourier transform...

\[ \hat{I}(k_x, k_y) = \hat{I}_0 \cdot \hat{S}(k_x, k_y) + n(k_x, k_y) \]

\[ \hat{S}(k_x, k_y) = \frac{\hat{I}_0 \cdot \hat{S}(k_x, k_y) + n(k_x, k_y)}{\Delta I \cdot \cos\left(\frac{2\pi}{N} k_0 x\right)} \]

How would an ideal observer decide which of the two images has the "signal" (of some unknown frequency \( k_0 \))?

Example: ideal observer

if

\[ \max_{k > 0} \left| \frac{\hat{I}(k)}{\hat{I}_0} \right| > \max_{k > 0} \left| \frac{\hat{I}(k)}{\hat{I}_0} \right| \]

then return "I1"
else return "I2"

http://www.cim.mcgill.ca/~langer/546/MATLAB/contrastSensitivityIdealObserver.m

I_0 = 100, k_0 = 6 (These don’t matter for ideal observer, why not?)
standard deviation of noise is 3, N = 512 (These matter. Why?)
Recall image motion

true velocity

normal velocity (perceived)

Recall lecture 11: motion constraint equation

\[ O = \frac{\partial f}{\partial x} v_x + \frac{\partial f}{\partial y} v_y + \frac{\partial f}{\partial t} \]

What if there is noise?

add noise here

Interesting case:
Intersection of constraints solution is upwards (and to the right), even though the normal velocities are both downward (and to the right).

Example task:
adjust an arrow to indicate the perceived direction of motion

unique solution

NOT unique solution

When signal to noise ratio is low (low contrast lines, or large noise), the perceived direction of motion is downward to the right.

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Example: surface orientation from "texture"

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Surface orientation can be estimated using these "cues":
- size gradient
- density gradient
- foreshortening of texture elements (aspect ratio)

For regular texture such as on the previous slide, these estimates are quite accurate.
What about for more natural random textures?

Q: How do we perceive orientation?
A: No foreshortening, no size and density gradient.

Perceived orientation is given by foreshortening and (to a lesser extent) size gradient.
Focus and density may provide info too.

Foreshortening and size provide less information when the shapes of the texture elements is random.

Which cues are used to estimate surface orientation here?

Using artificial random textures such as below, one can investigate formally the cues that are used to perceive surface orientation. namely size, density, foreshortening.

Example task

Given two images (reference and test) of a textured surface, decide if the test has greater or lesser slant than the reference.

The threshold \( \Delta \theta \) is called the "just noticeable difference" (JND).

Many studies have compared the strengths of size ("perspective"), density, and shape ("compression") cues. In each of the above 8 examples, each cue is either present or not.

In the last two decades, many studies have used probability models. By changing the variability (noise) in each cue, one can affect the reliability of the cue. One can also compare human performance to that of an ideal observer.

Let's look at this idea for perception of surface orientation (slant) from texture.
Example: when all three cues are present, $\Delta \theta$ threshold is larger (performance is worse) when $\theta_{ref}$ is small i.e. when surface has small slant.

The same is true for ideal observers.

Note: humans perform worse than ideal.

Terminology: “slant” $\theta$ (usually $\sigma$) versus “tilt” $\tau$.

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**Oral Presentations Papers ....**

**CUE COOPERATION AND BEYOND METHODS**

- “The pragmatic expert assumption is a framework for visual perception” Procedures 1967, Nature 214, 487-490
- “Natural scene statistics predict the subjective contributions of human motion perception” J. Vision 2015
- “Natural scene statistics predict the subjective contributions of human motion perception” J. Vision 2015
- “Motion and shape perception in animal models” in “M. van Ee, J. Andrews, T. Brain (eds) 2009
- “Human and animal motion perception” in “M. van Ee, J. Andrews, T. Brain (eds) 2009
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1. Visual processing and function in simple visual mechanisms
2. Multi-dimensional Fourier transforms
3. Multidimensional signal processing techniques
4. Image formation and 3D scene reconstruction
5. Visual and perceptual representations
6. Image analysis and pattern recognition
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