PHENOMENA OF MOTION PERCEPTION

1) What is motion? Apparent motion and real motion

2) Long-range motion

3) Korte's laws and figural affinity

4) Short- and long-range motion

→**Traveling Gaussian waves** (Grossberg and Rudd)

5) Fourier and non-Fourier stimuli

6) Gradient models (Marr/Ullman)

7) Energy models (Adelson/Bergen)

8) Correlation models (Reichardt; van Santen/Sperling)

UTILITY OF MOTION PERCEPTION

Nakayama, 1985: Tasks for which motion processing is useful:

1) Encoding 3-D shape
2) Perceiving time-to-collision
3) Segmentation
4) Proprioception
5) Control of eye movements
6) Pattern vision
7) Perception of moving objects

How these tasks are accomplished is (still) not well understood!

UNITS OF MOTION PERCEPTION

J. J. Gibson (1979) warns that our "first order" intuitions about the origins of spatiotemporal patterns of visual input in the environment may lead us astray.

Many assume that "the problem" of motion perception is one of successively, over time, inverting the projective correspondence between a patch of a physical surface and its projection on the retina.

However, many of our most vivid and ecologically pertinent experiences with motion -- particularly those involve with occlusion and disocclusion over time -- do not conform to such an analysis.

MOTION AS FUNDAMENTAL VISUAL MODALITY

Arguments for **motion as a fundamental visual modality**

(not just "derived" as displacement across time):

Motion aftereffects

Single-cell recordings

Random dot stimuli

http://www.bu.edu/smec/lite/perception/camouflage/color.html

Phi motion over distances irresolvable by static perception

http://psyclops.psych.purdue.edu/Magniphi/ARVODemo.html

Explore this great web site; learn how the **phi phenomenon** launched the **Gestalt revolution!**

MOTION NOMENCLATURE

Consider classical distinction of:

short-range **motion** vs. ***long-range*** **motion**

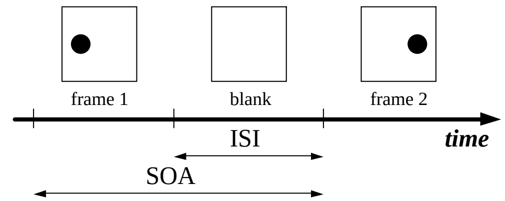
and the more “modern” usage:

first-order motion vs. ***second-order*** **motion**

NOTE:
First-order is ***not*** the same as short range.
Second-order is ***not*** the same as long-range.

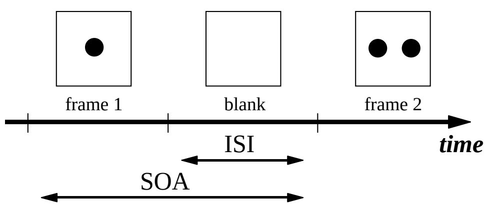
Let’s start with long-range motion!

LONG-RANGE MOTION PARADIGM



ISI: Interstimulus Interval
SOA: Stimulus Onset Asynchrony

EXNER (1875): MOTION AS A PRIMARY MODALITY



1) Simultaneous perception of motion in two directions rules out explanation by eye movements.

2) Motion is perceived for dot displacements that are below hyperacuity thresholds; therefore is not “derived” from displacement over time.

KORTE’S “LAWS” FOR LONG-RANGE MOTION

S: Spatial separation

ISI: Inter-Stimulus Interval

I: Stimulus energy (luminance)

For optimal apparent motion:

1) For fixed ISI: **S ~ I**

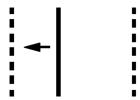
2) For fixed S: **I ~ 1 / ISI**

3) For fixed I: **S ~ ISI**

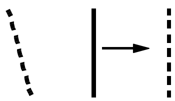
FIGURAL AFFINITY 1

Figural affinity in split apparent motion -- Ullman, 1979

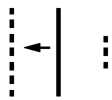
First frame: Second frame:



Closer is preferred.

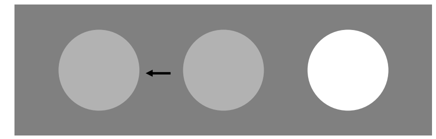


Same orientation is preferred.

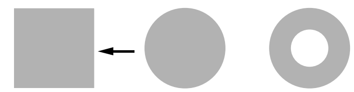


Same length is preferred.

FIGURAL AFFINITY 2

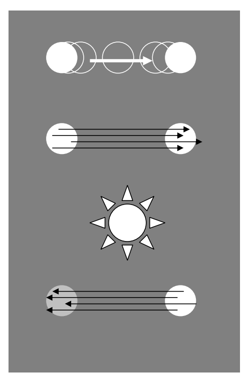


Same luminance is preferred.



Claim: Same topology is preferred. ???
Li, 19??

KINDS OF LONG-RANGE APPARENT MOTION



Beta: *Continuous ("optimal") motion* of a well-defined *object* across empty intervening space

Phi: Sense of ("pure") *motion without* a concurrent perception of *moving object*

Gamma: Apparent *expansion at onset* or *contraction at offset* of a single flash of light.

Delta: Beta or phi motion directed toward the first flash, when the *intensity of the second flash is sufficiently greater* than the first

Michael Bach

Check out "reversed phi" demo -- and more! -- at:

http://www.michaelbach.de/ot/mot_reverse-phi/index.html

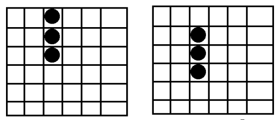
TWO-FLASH APPARENT MOTION DATA

Key facts:

A *single flash* (stationary) does *not* generate a motion percept (gamma motion aside).

Two or more properly timed and positioned *flashes do*.

A *change of ISI* (only) can *alter the global motion percept* qualitatively (e.g. Ternus effect)



Why is the *long-range influence of a single flash* -- which **must** exist -- *not* perceived as motion?

TRAVELING G-WAVES

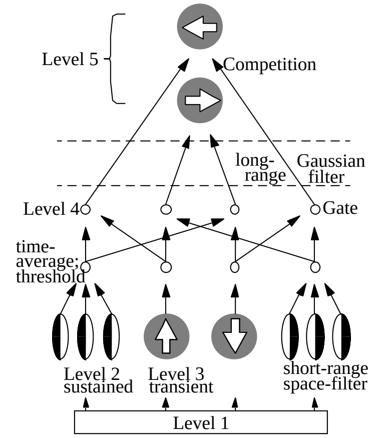
1) Contemplate the stages labeled "Level 1, Level 2, ..., Level 5" in the Grossberg & Rudd (1989) **Moving Oriented Contrast (MOC) Filter.**

2) Forget them.

3) Remember the "level-less" **long-range Gaussian filter,**

. . . whose traveling Gaussian (G) waves do all the work in long-range apparent motion.

G-waves are also implicated in the spatial deployment of *visual attention!*

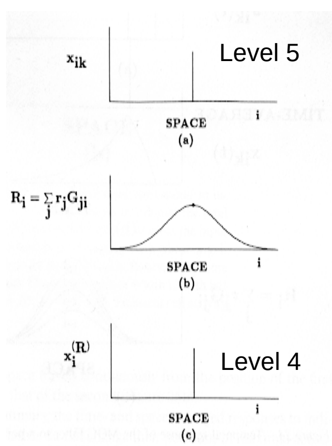


SINGLE FLASH SPATIAL PATTERN

If a single narrow *peak* is produced at Level 4, the *Gaussian filter* produces a *Gaussian profile*, which is then *sharpened* back to a single peak by a "winner-take-all" competition at Level 5.

Note 1: The width of the Gaussian varies, depending on the (size of) the *"scale"* considered.

Note 2: A Gaussian of any scale *changes amplitude over time.*

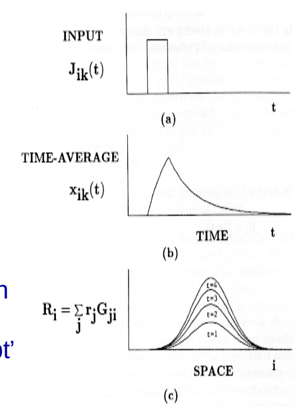


TEMPORAL PROFILE OF SINGLE FLASH

A single flash creates a characteristic *rapid increase toward saturation level* while ON and a corresponding *exponential decay* soon after it shuts OFF.

This **temporal profile** modulates the amplitude of the Gaussian signal.

Since the *peak* of the Gaussian *stays in place* regardless of amplitude, the model's "percept' is that ***nothing moves.***

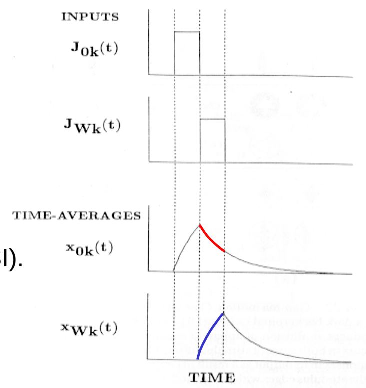


TEMPORAL PROFILE OF TWO FLASHES

If *two flashes* occur in rapid succession, the **"waning"** of the first signal may overlap in time with the **"waxing"** of the second.

Note: To produce apparent motion, it is not necessary that the temporal profiles of the stimulus "abut" (i.e. zero ISI).

ISI could be positive, or the flashes themselves could overlap in time somewhat.

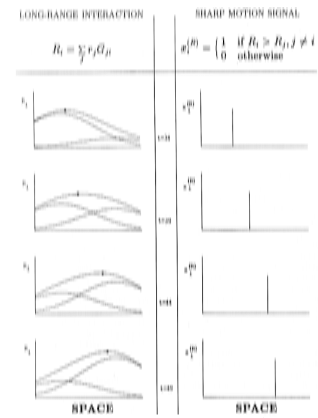


TRAVELING WAVE: LONG-RANGE MOTION

If the *Gaussian activity profiles* of two flashes overlap sufficiently in space and time, the sum of Gaussians produced by the waning of the first-flash Gaussian, combined with the waxing of the second-flash Gaussian, can produce a *single-peaked* ***traveling wave.***

The wave is then processed through a "choice" network.

The resulting motion percept is thus both *long-range* and *sharp*.



THE UNITS OF MOTION PERCEPTION

Issue: Are we first finding **features**, and then matching or tracking them over time?

OR

Are we extracting **"motion energy"** from the spatiotemporal optical arrangement before we conclude that anything is moving?

SHORT-RANGE MOTION DEMO

http://www.bu.edu/smec/lite/perception/camouflage/color.html

Note:

Absence of static information for form.

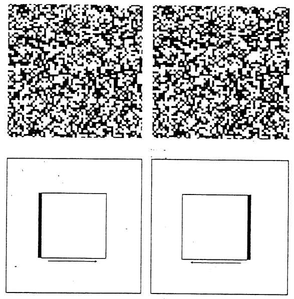
Accretion/deletion at edges of moving form.

Sharpness of perceptual edges.

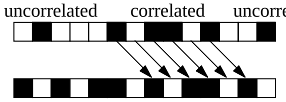
RANDOM DOT KINEMATOGRAMS: D-MAX

***"Short-range"** apparent motion occurs for stimuli composed of dense arrays of small elements (e.g. dots).*

frame 1 frame 2



uncorrelated correlated uncorrelated



Question: What is the "D-max" for "short-range" apparent motion?

I.e., what is the **largest tolerated displacement** for corresponding dots in a dense *kinematogram* for seeing motion (by "sensing" correlation across two frames)?

MOTION LONG AND SHORT

Table 1 from Cavanagh & Mather (1989) -- See Syllabus (principally after Anstis (1980) and Braddick (1980), with some additions).

Short-range	**Long-range**
Short spatial range (< 15 arc min) Braddick (1974) ["D-max"]	Operates over many degrees Kolers (1972)
Brief temporal range (80-100 ms ISI) Braddick (1974)	ISI up to 500 ms Mather (1989)
Motion aftereffect Banks and Kane (1972)	No motion aftereffect Papert (1964), Anstis (1980)
Not dichoptic Braddick, 1974	Dichoptic Shipley et al. (1945)
No response to colour Ramachandran and Gregory (1978)	Response to colour Ramachandran and Gregory (1978)
Low-level neural comparator	Responsive to higher-level correspondences that do not activate motion detectors
Passive motion response, velocity space computations Adelson and Movshon, 1982	Cooperative processes, inference

MAD (D-)MAX: THE REVENGE OF MULTIPLE SPATIAL SCALES

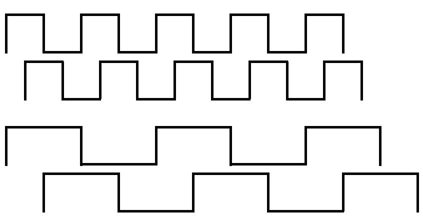
Later studies showed that D-max can be **much more than** 15 arc min if:

1) More than two frames are used, or
2) Low spatial frequencies are used

D-max can be thought of as (more like) 1/4 of the spatial "duty cycle" of a "balanced" periodic stimulus:

e.g.

vs.



frame 1
frame 2
frame 1
frame 2

FIRST-ORDER AND SECOND-ORDER STIMULI

First-order and **second-order** motion stimuli are sometimes referred to as **Fourier** and **non-Fourier** stimuli, respectively.

A **second-order motion stimulus** is one in which the "thing" that moves has the **same mean luminance** as a stationary background -- over a sufficiently large spatio-temporal averaging window.

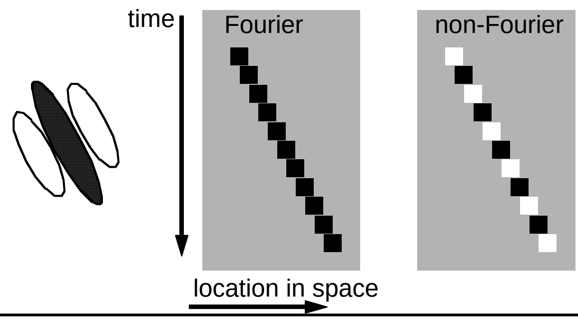
The local contrasts that make up the moving "thing" may themselves scintillate (change sign of contrast) so that no local element "persists" long enough to be tracked.

http://www.cnl.salk.edu/~maarten/demos/2nd.html

SECOND ORDER AGAIN

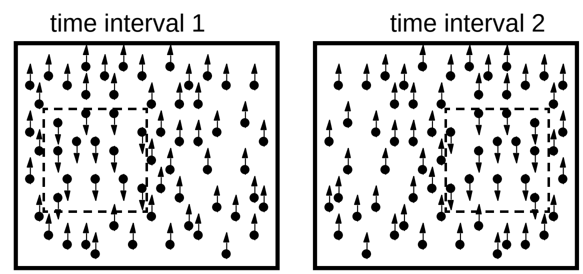
There are many kinds of **second order stimuli**
a.k.a. **"non-Fourier" stimuli**

What they have in common is that ***no* first-order detector**,
of sufficient "size" (in *space* for texture, in *space-time* for motion)
would respond to them . . . true if the mean luminance of the "black" and "white" squares on the right is the same as the luminance of the background.



SECOND SECOND-ORDER EXAMPLE

Another kind of second order motion:



Perceived motion of *"region of downward moving dots"* is to the right.

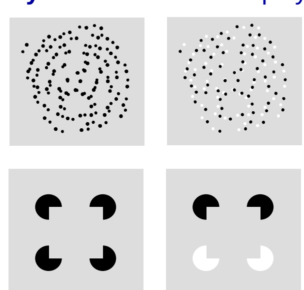
(The dashed boxes are not part of actual display;
dots disappear when they collide with virtual boundary.)

D-MAX REVISITED

Considering first-order and second-order stimuli, spatial scales, multiple frames vs. two frames, etc. . . .

D-max seems to be less of a fixed (retinal) quantity and more *dependent on stimulus characteristics* (e.g. contrast polarity, spatial frequency, **density** of elements in a display).

Consider analogies to static grouping "D-max":



SHORT AND LONG; FIRST AND SECOND

Cavanagh & Mather argue that *long-range* vs. *short-range* is less important than *first-order* vs. *second-order*, and that pools of detectors of either type could exist for different spatial scales.

Note that the diagram on the right includes (spatial) **gradient operators*** as front ends of **Reichardt-type** "delay and compare" units!