7. Vision: Motion

I. Image motion and viewer/eye motion

Image-retina vs Eye-head motion

Eye movements
- Saccades
- Smooth pursuit
- Tremor, micro-saccades - stabilized image fading
- Optokinetic nystagmus
- Disjunctive eye movements (convergence/divergence)

Stabilizing the world - inflow (corollary discharge) vs outflow
- Saccadic suppression

II. Types of retinal image motion

Real vs apparent movement
- Phi motion
  - Korte’s laws: \((\text{distance} \propto \text{ISI}, \text{intensity} \propto 1/\text{ISI}, \text{intensity} \propto \text{distance})\)
  - Motion ‘strength’ in ambiguous displays
    - motion correspondence problem
    - Burt and Sperling - element shape doesn’t matter
    - Green - element spatial frequency (and orientation) content matters
    - Pantle and Picciano - element and group motion in the Ternus display,
      two motion systems
    - Ullman - correspondence strength minimal mapping model

Random dot cinematograms
- Braddick and others - short-range vs long-range motion
  - short-range properties:
    - short spatial range
    - brief temporal range
    - has a motion aftereffect
    - not dichoptic
    - weak color input
    - low-level comparator (as opposed to high-level correspondences, cooperativity and inference)

- Chang and Julesz - \(d_{\text{max}} \propto 1/f\) up to 5 cpd
- Cavanagh and Mather - generalized 2nd-order motion

Reversed-phi motion

III. Properties of motion channels

- Motion aftereffects
- Adaptation - direction-specific adaptation effects
- Summation: Levinson and Sekuler - no subthreshold summation across directions
- Masking - e.g. Ball and Sekuler - masking by directionally tuned noise
- Equiluminance
Motion capture
Chang and Julesz - In random dot cinematograms across neighboring regions
Ramachandran - Low spatial frequencies capture high

IV. Models of motion detection mechanisms
Barlow and Levick - ‘And-not’
Marr and Ullman - motion of zero crossings
Reichardt - auto-correlation detectors with motion opponency
Fennema and Thompson, Horn and Schunck - gradient model: \( v = -E_t/(E_x^2 + E_y^2)^{1/2} \)
Fourier models
Motion in the Fourier domain
Watson and Ahumada - motion in the frequency domain
Burr, Ross and Morrone - oriented spatiotemporal receptive field measured by masking
Adelson and Bergen
motion as orientation in space-time
motion energy
oriented spatiotemporal filters from separable quadrature pairs
reversed-phi - take 2
van Santen and Sperling - Elaborated Reichardt Detectors
aliasing - wagon wheels in film
spatiotemporal filtering to avoid aliasing
Watson and Ahumada
Linear motion units
Temporal frequency counters

V. Motion analysis
Velocity computation
The aperture problem - Wallach, Movshon et al.
Motion plaids - motion transparency and coherence
Intersection of constraints
Movshon et al. - IOC computation and MT
Hildreth - smoothness along contours
Nakayama and Silverman - moving curves and nonrigidity
Watson and Ahumada - frequency meter
Adelson and Bergen - code velocity by computing \( \frac{R - L}{S} \)
Heeger - fitting a plane through motion energy filter responses
Weiss/Adelson/Simoncelli - Bayesian ‘‘slow and smooth’’ approach
Second- and third-order motion
Chubb and Sperling
drift-balanced and micro-balanced stimuli
moving flicker
motion of random-phase textures
noise modulated by moving sine or square wave
two systems - with two different spatial CSFs
Lu and Sperling - 3rd-order motion of salience
Cavanagh
motion tracking
motion at isoluminance
leftward plus rightward moving gratings