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: (distance $\propto$ ISI, intensity $\propto$ 1/ISI, intensity $\propto$ 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 - $d_{max} \propto 1/f$ 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