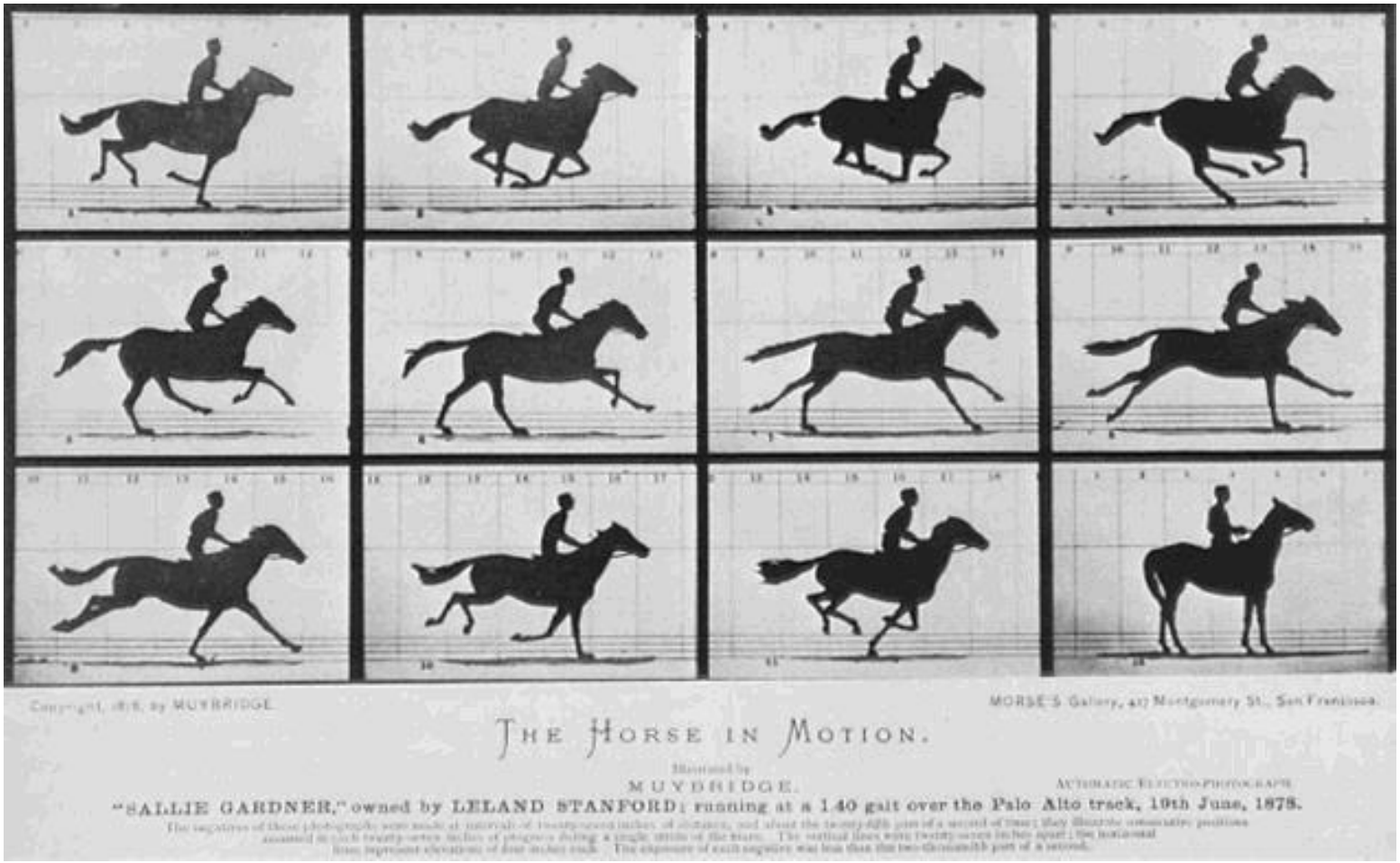
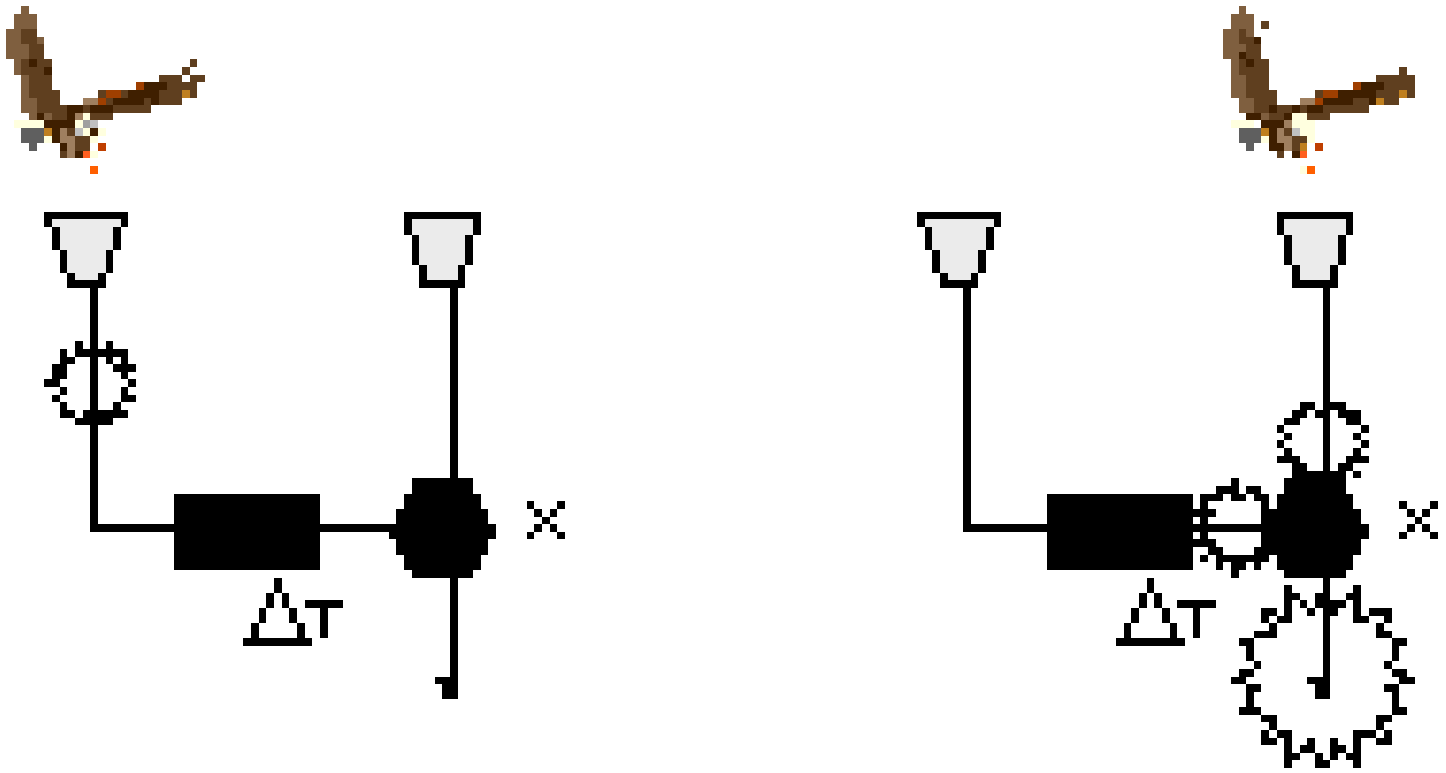
Human-machine interaction in virtual reality

Paul MacNeilage, Psychology
Eelke Folmer, Computer Science

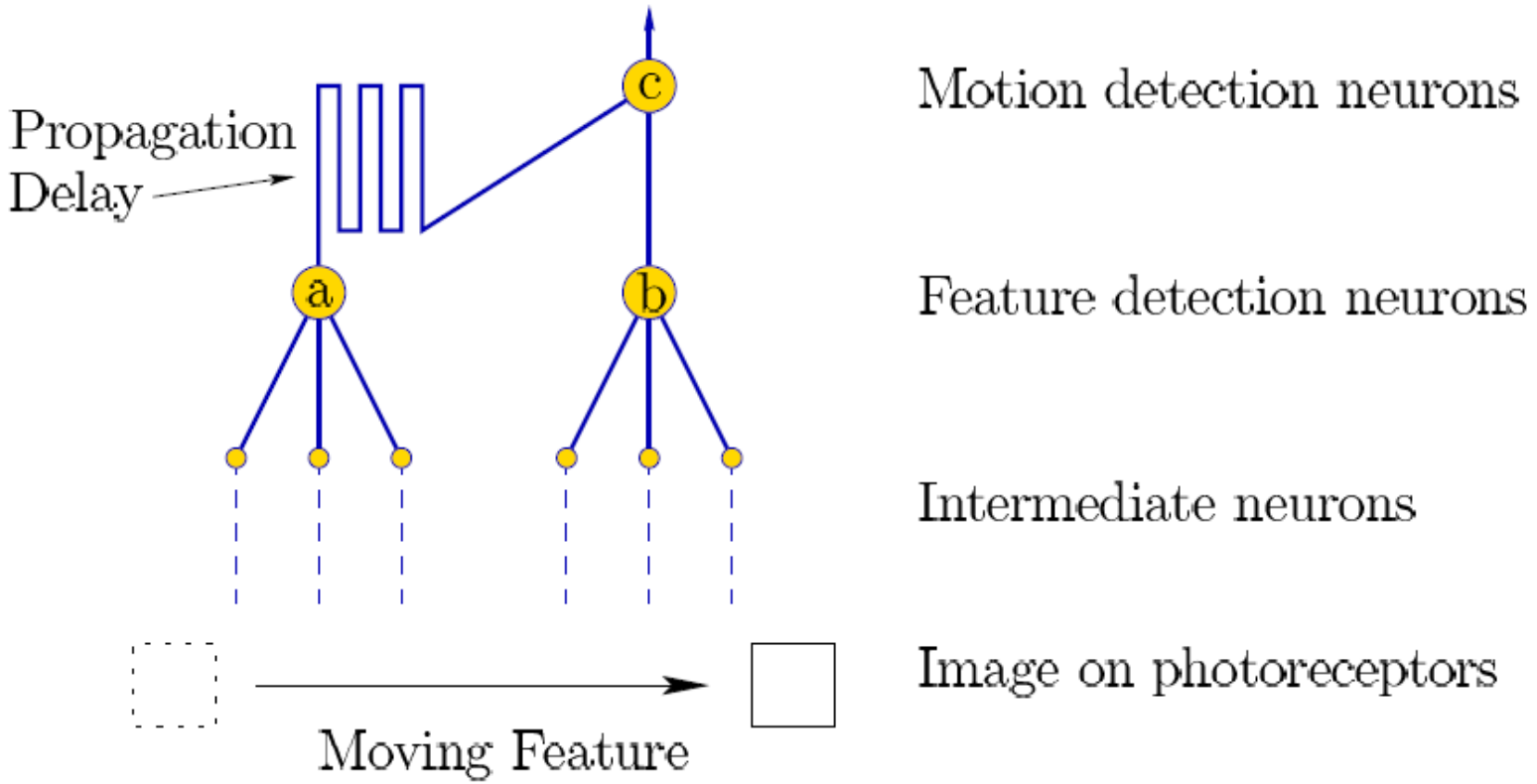
Motion is Change Detection



Reichardt Motion Detector

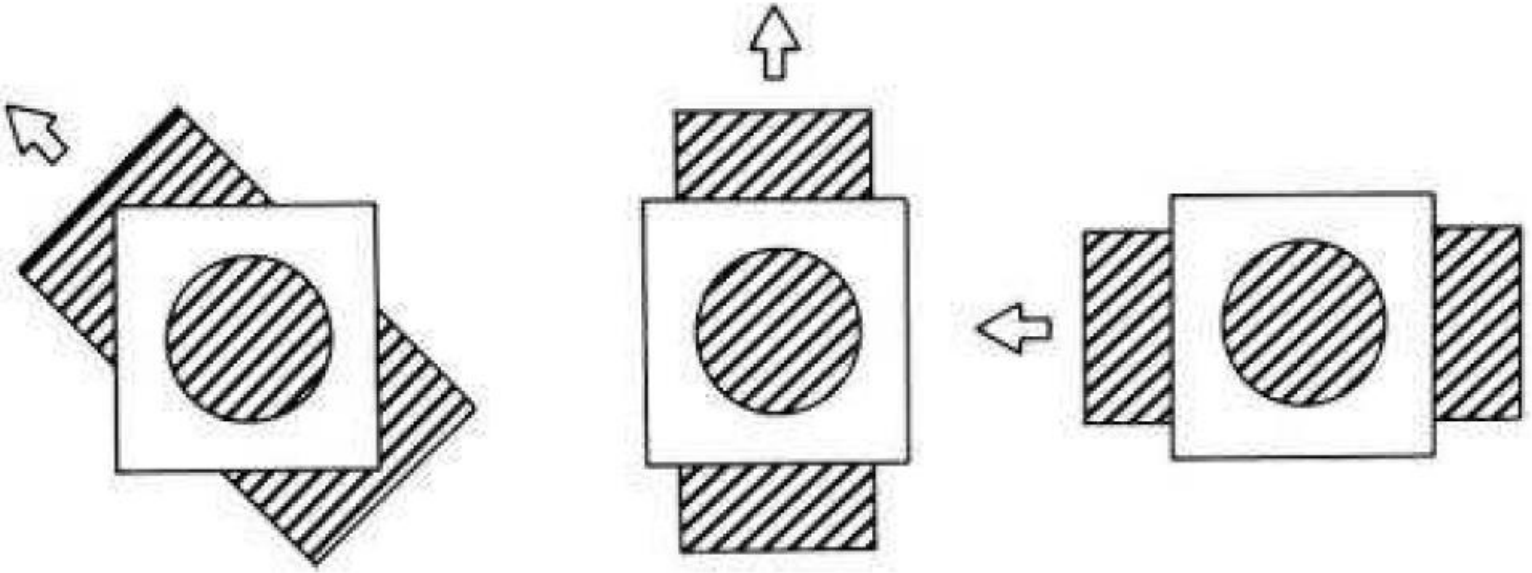


Reichardt Motion Detector



Aperture Problem

- Ambiguity of local motion signals

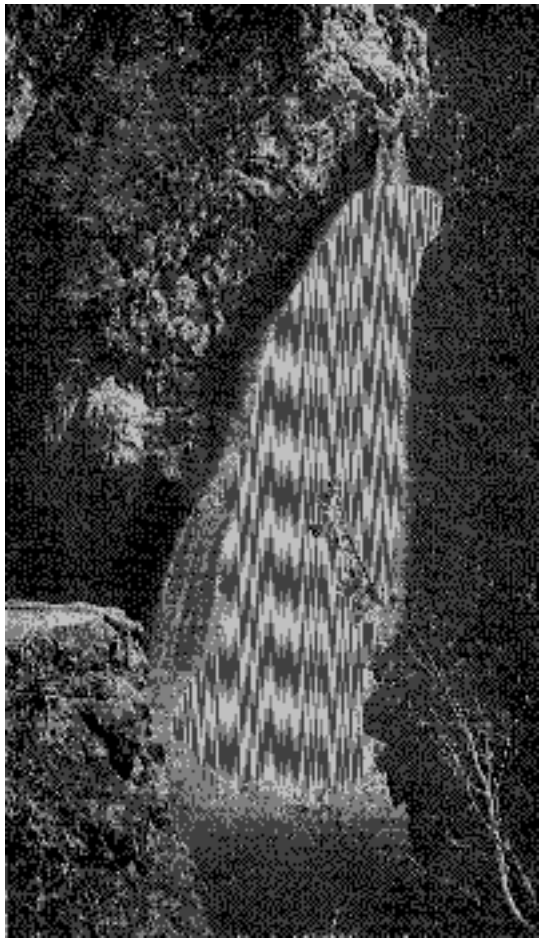


Adaptation

- Waterfall illusion

Motion Illusions

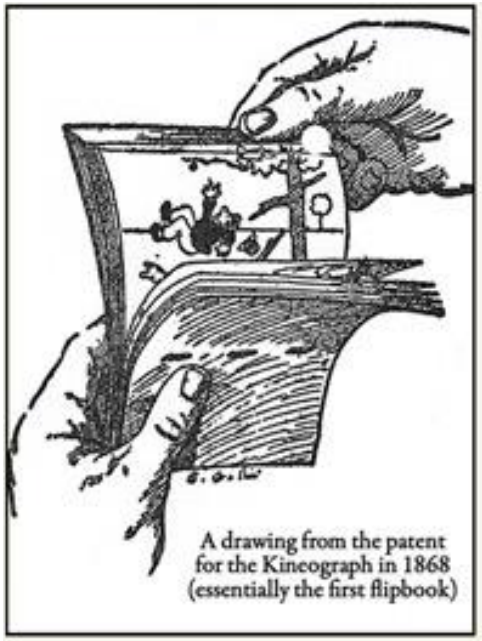
- Waterfall illusion
- Motion adaptation – dedicated mechanisms
- Motion is processed independent of position information



Apparent Motion

- When motion is perceived from a series of still images…

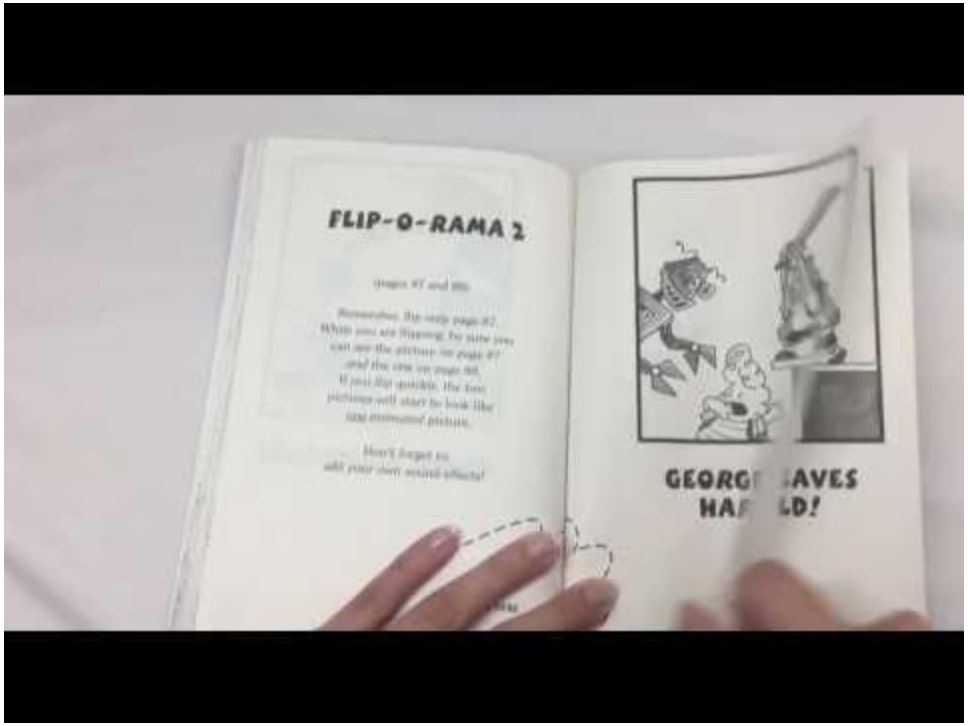
Zoetrope, 1833



Kineograph, 1868

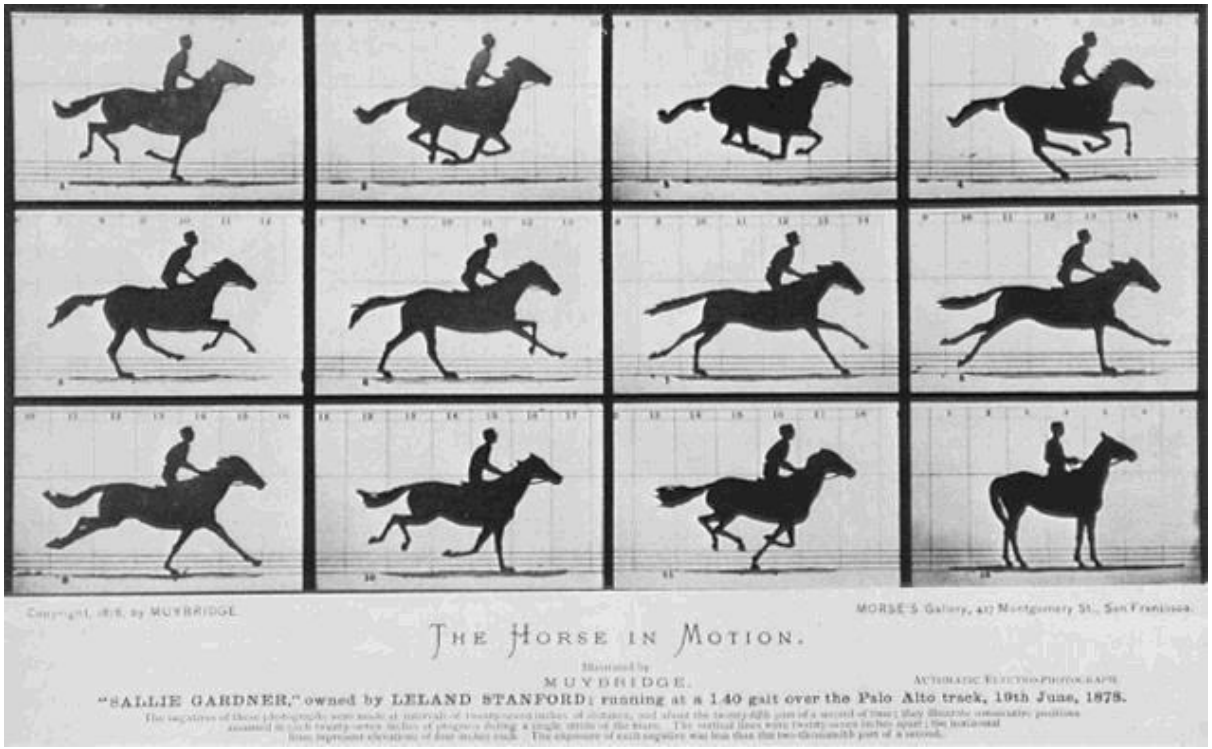
Apparent Motion

- Captain underpants – flip-o-rama



Apparent Motion

- When motion is perceived from a series of still images…

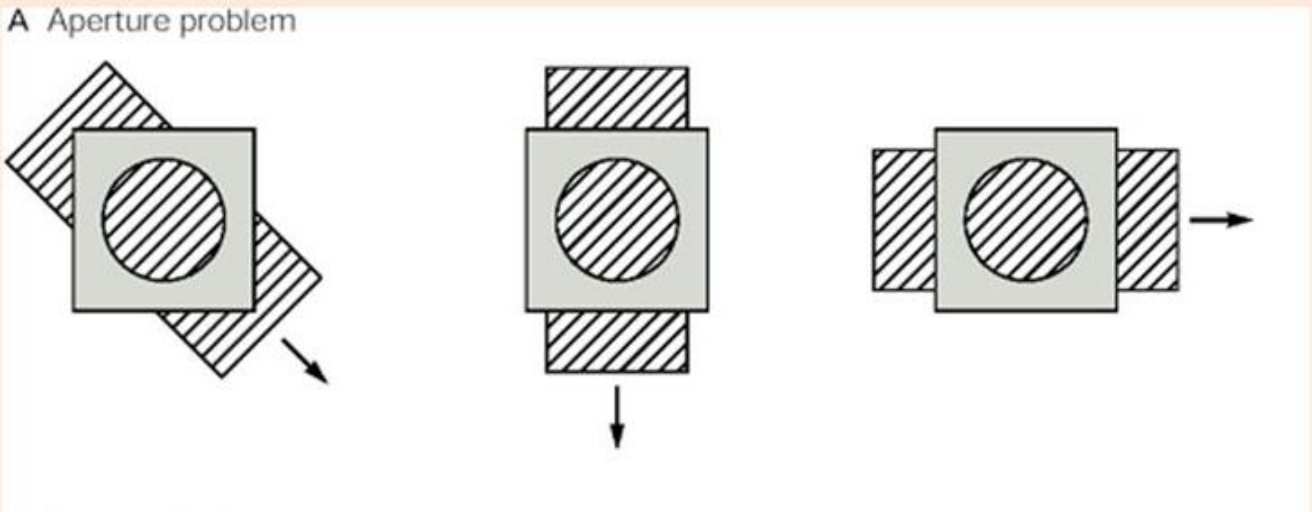


Video Link

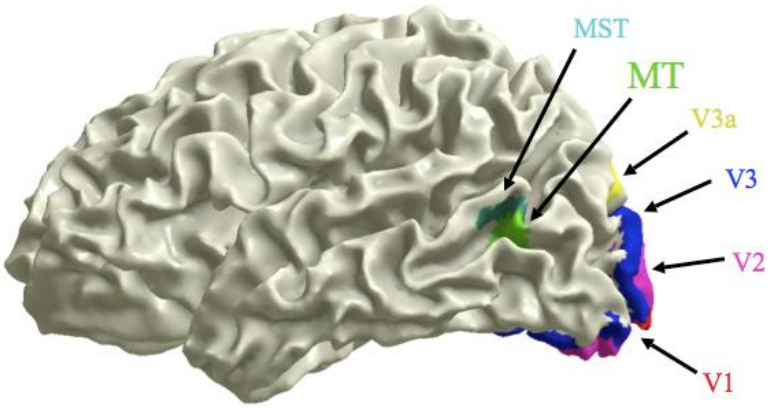
Frame Rates

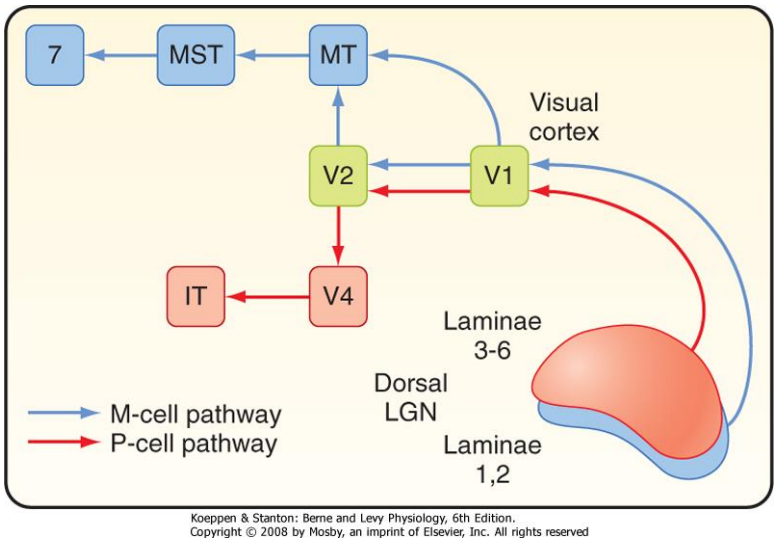
FPS	Occurrence
2	Stroboscopic apparent motion starts
10	Ability to distinguish individual frames is lost
16	Old home movies; early silent films
24	Hollywood classic standard
25	PAL television before interlacing
30	NTSC television before interlacing
48	Two-blade shutter; proposed new Hollywood standard
50	Interlaced PAL television
60	Interlaced NTSC television; perceived flicker in some displays
72	Three-blade shutter; minimum CRT refresh rate for comfort
90	Modern VR headsets; no more discomfort from flicker
1000	Ability to see zipper effect for fast, blinking LED
5000	Cannot perceive zipper effect

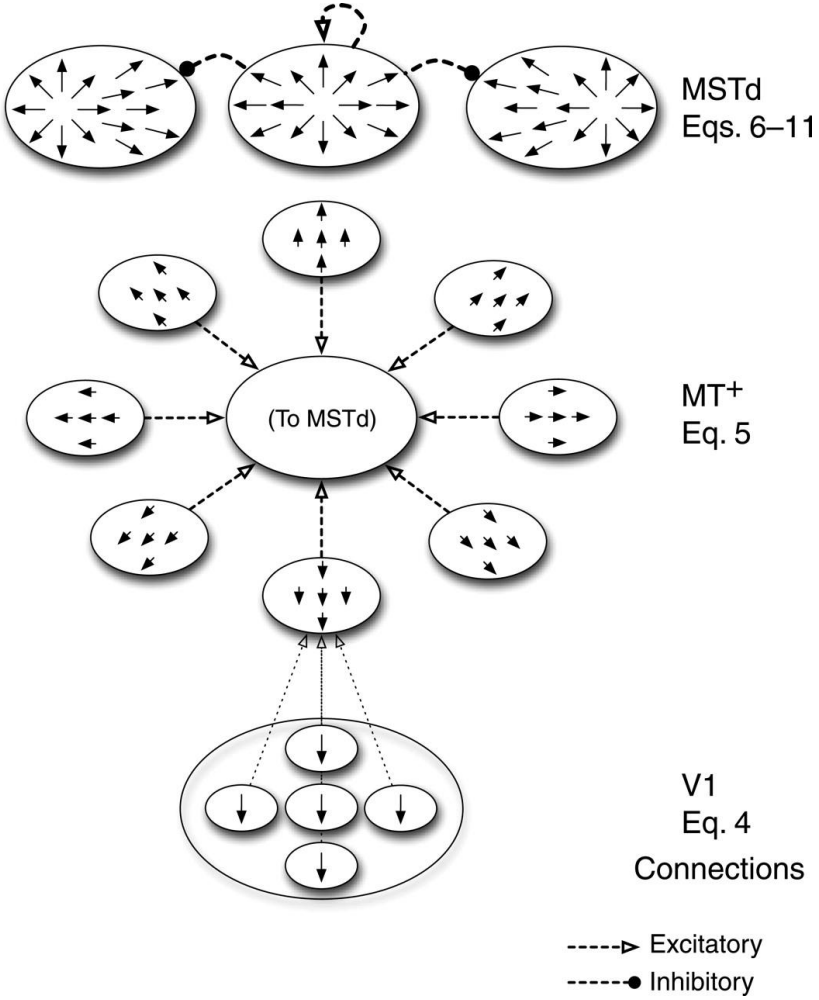
Hierarchical Motion Processing



Hierarchical Motion Processing

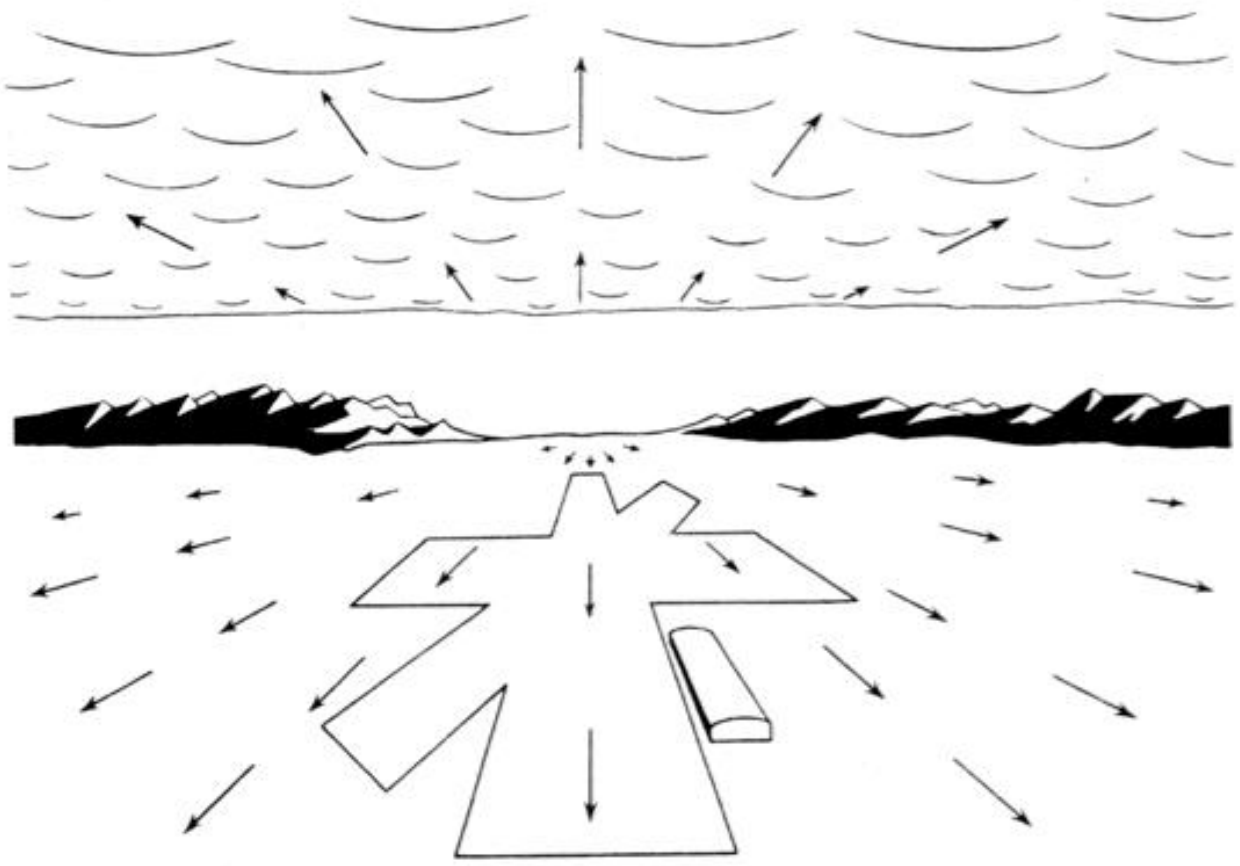






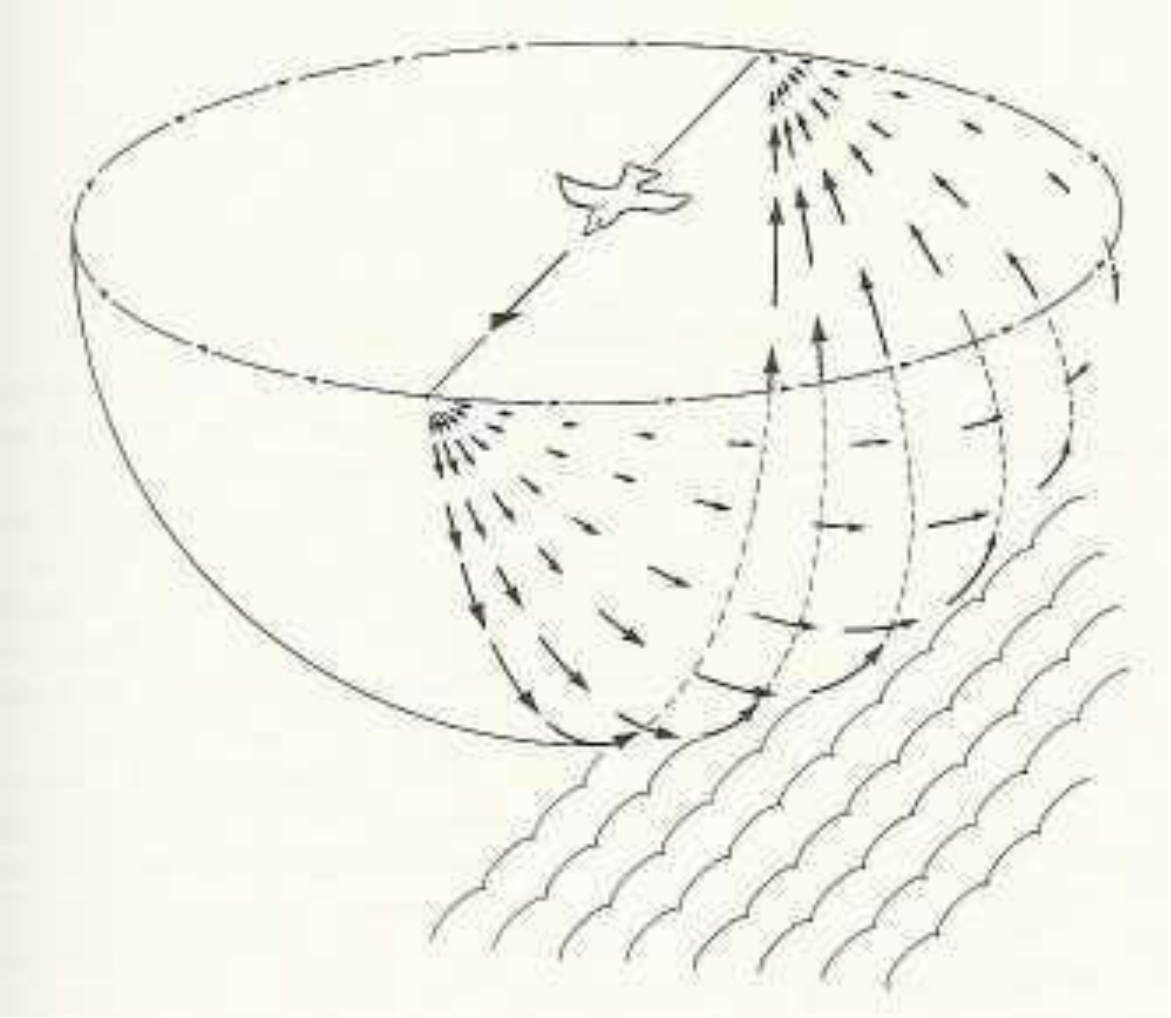
Journal of Vision January 2012, Vol.12, 20. doi:10.1167/12.1.20

Optic Flow



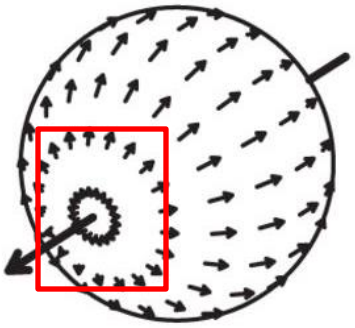
Gibson 1950

Optic Array

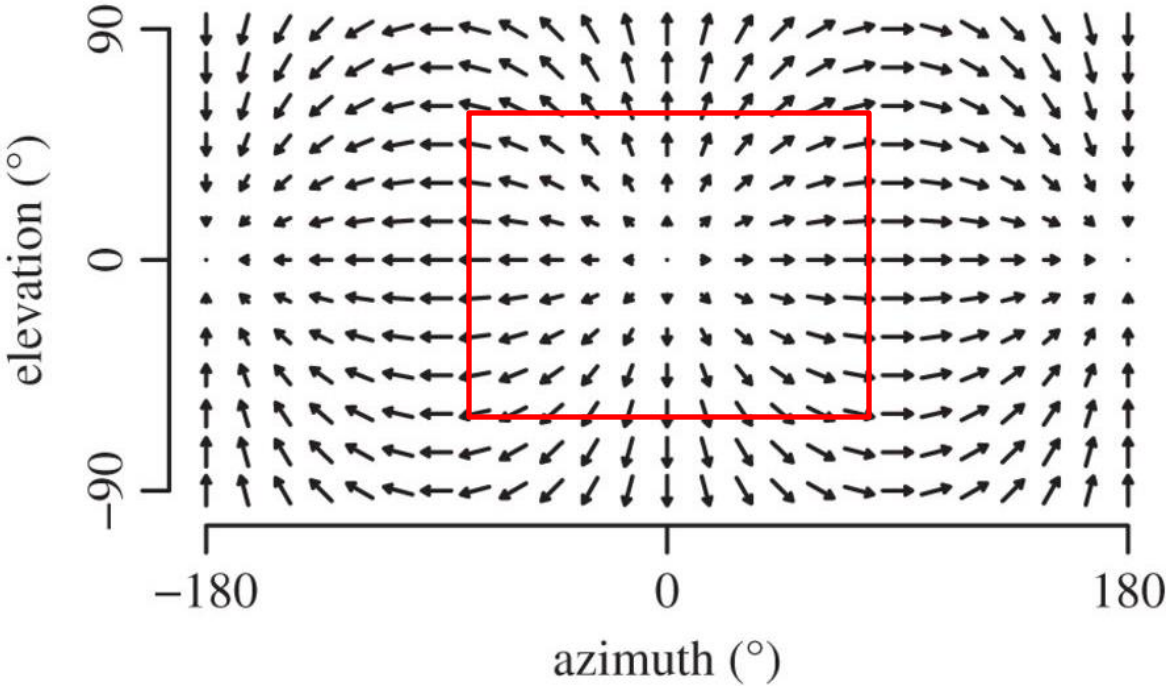


Gibson 1950

Linear Optic Flow

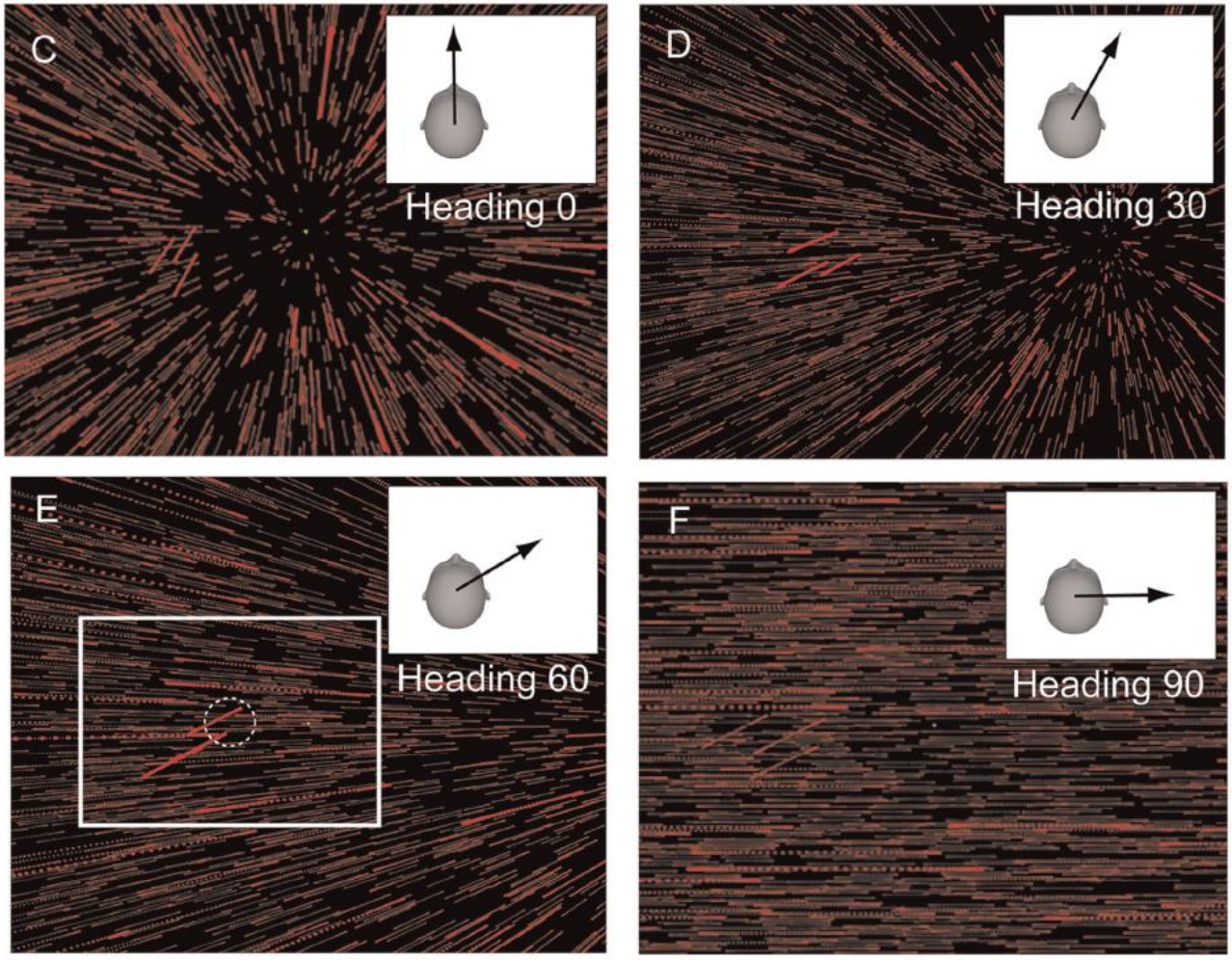


translation



Linear Optic Flow

- Heading
- FOE (Focus of Expansion)
- Radial Flow
- Laminar Flow



Scale Ambiguity of Linear Optic Flow

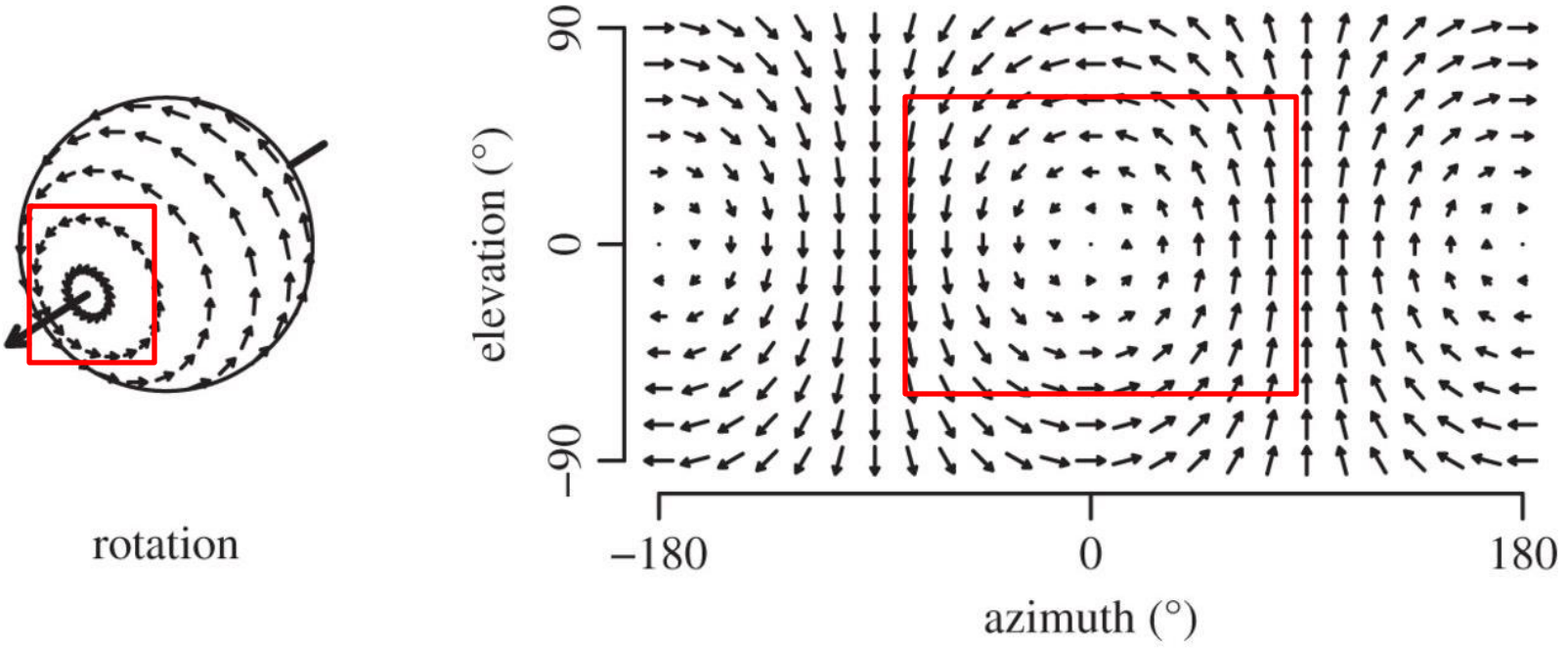
- Same optical flow can be generated…

Traveling fast through a large scene

Traveling slowly through a small scene

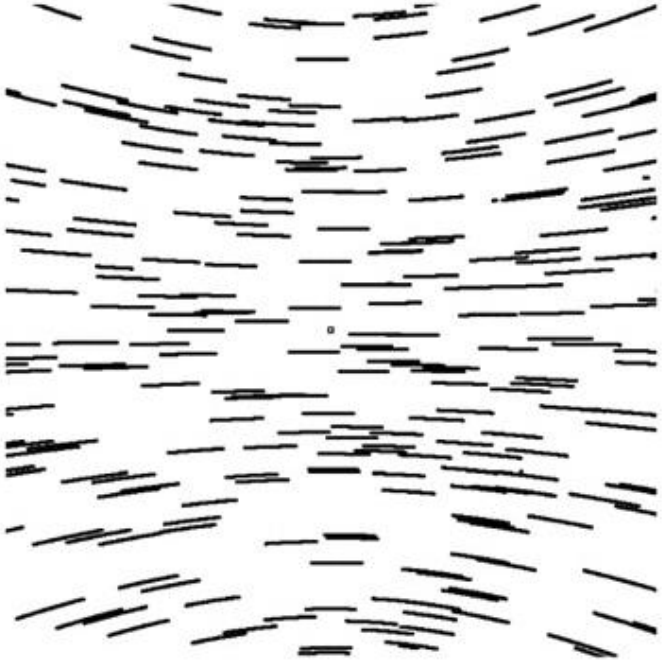
- Optic flow alone cannot tell how fast you are moving

Angular Optic Flow

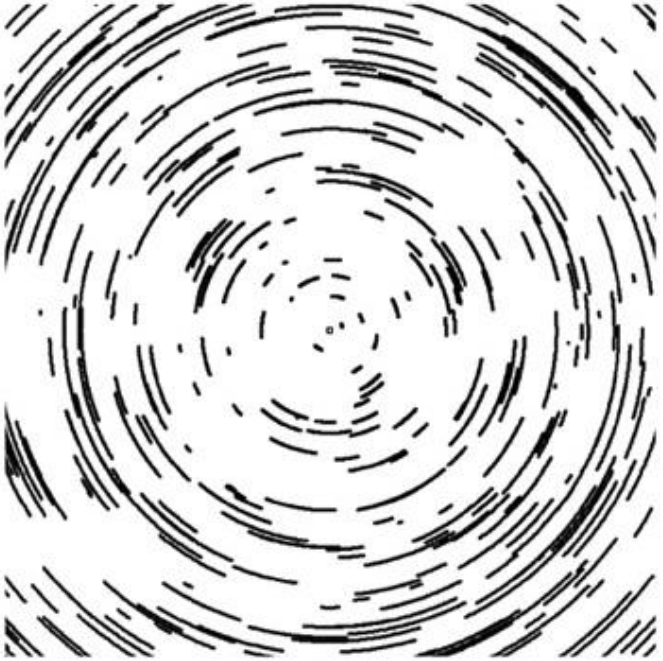


Angular Optic Flow

Laminar

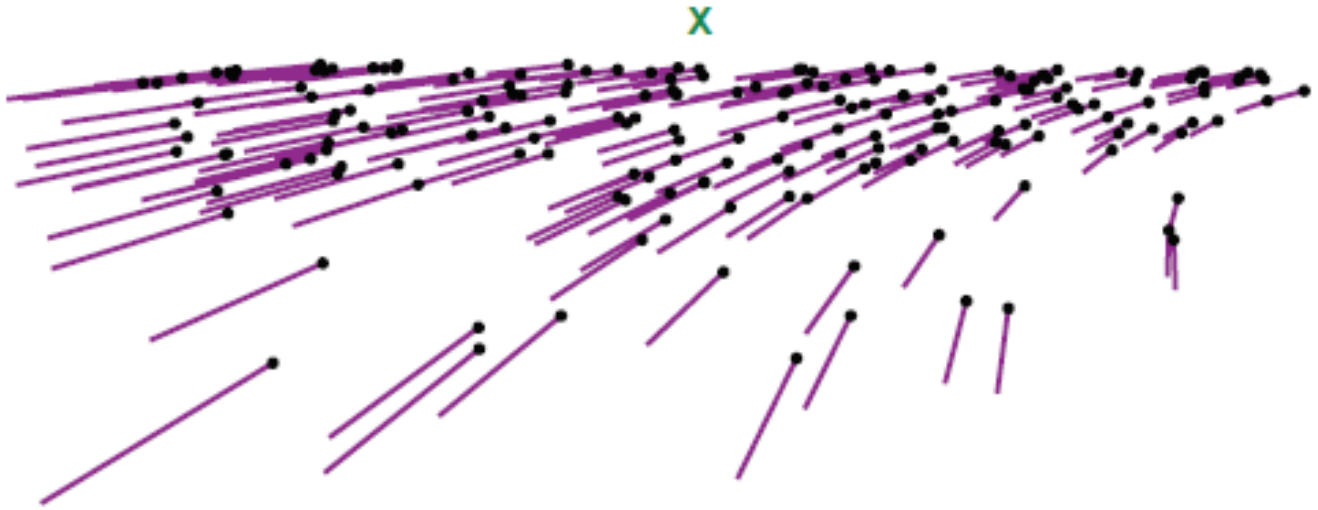


Radial



Linear + Angular Motion

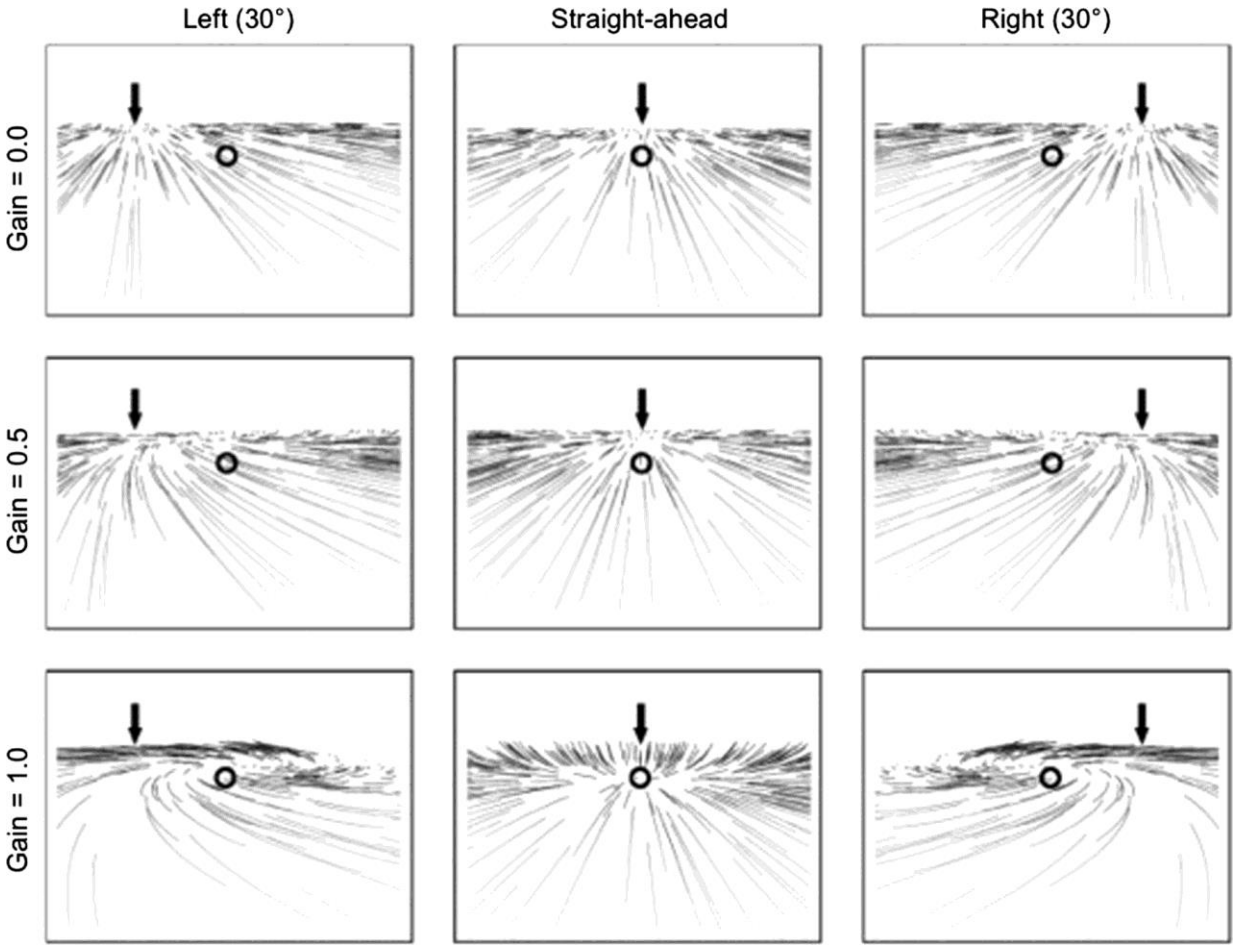
- Traveling on a curved path



Britten (2008) Annual Review of Neuroscience

Linear + Angular Motion

- Linear motion plus eye movement

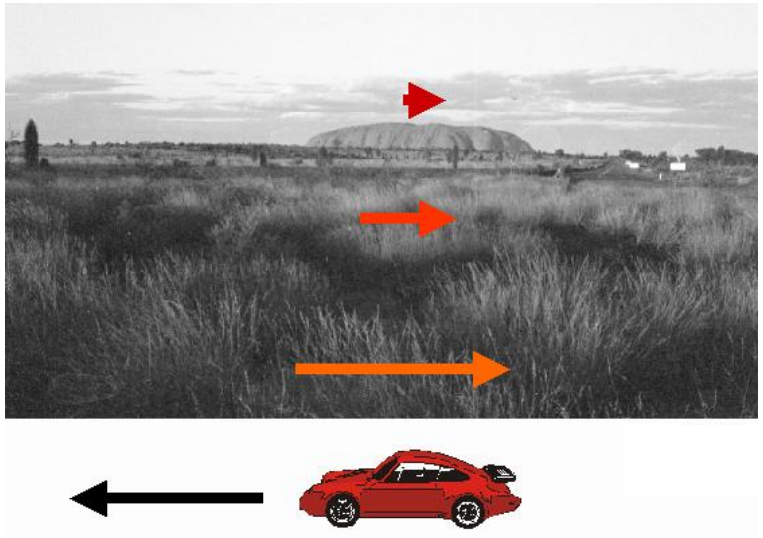


Kaminiarz, Schlack, Bremmer (2014)

Linear + Angular Motion

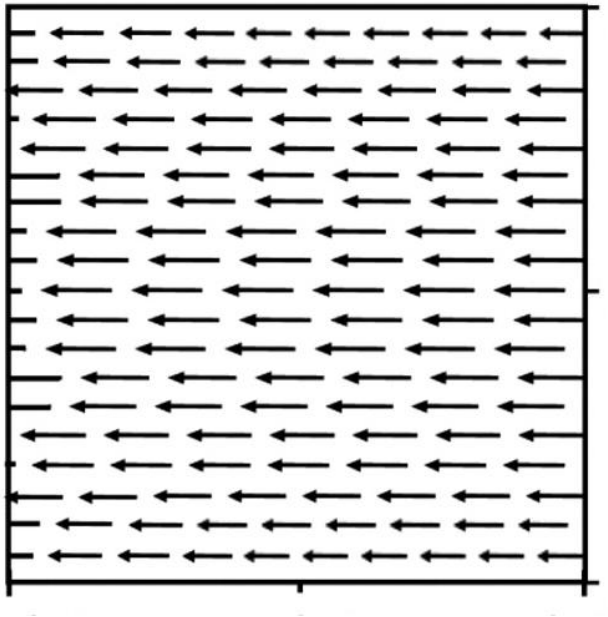
- Pursuit of point in scene adds rotational flow

Linear (self-motion)



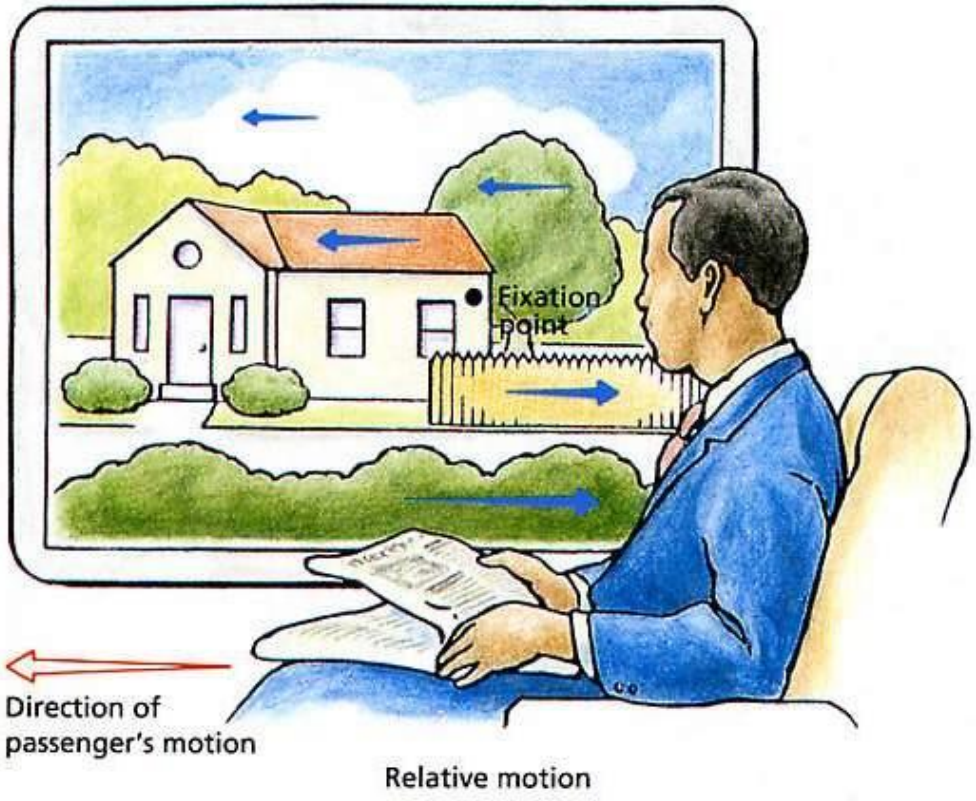
+

Angular (eye rotation)

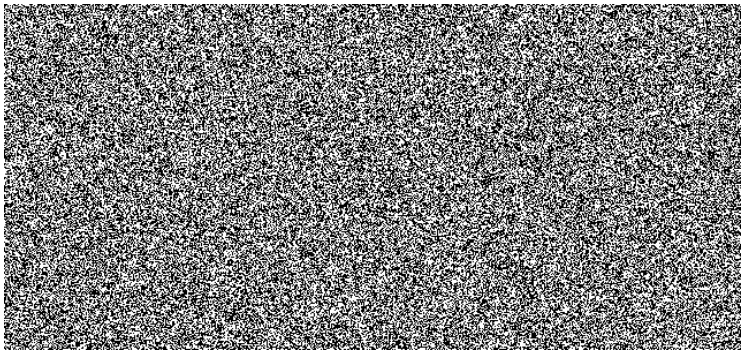


Linear + Angular Motion

- Classical example of motion parallax



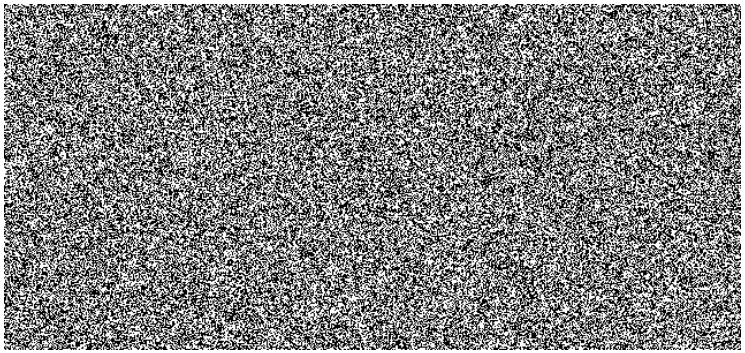
Ambiguity of Optic Flow



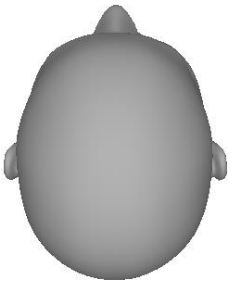
Eye Motion

Crowell, Banks, Shenoy, Anderson (1998) *Nat. Neuroscience*

Ambiguity of Optic Flow



Eye Motion

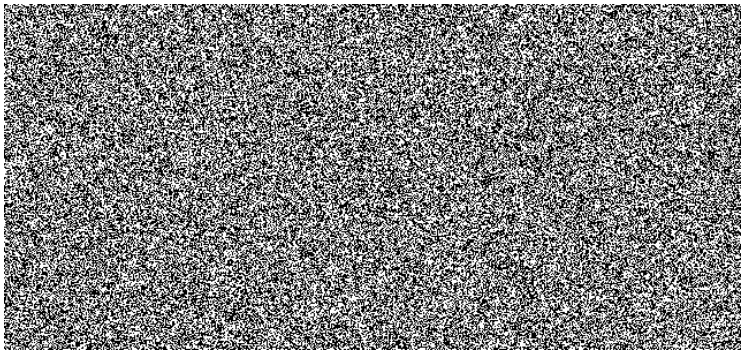


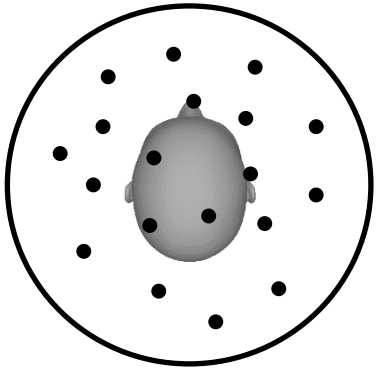
Head Motion

Crowell, Banks, Shenoy, Anderson (1998) *Nat. Neuroscience*

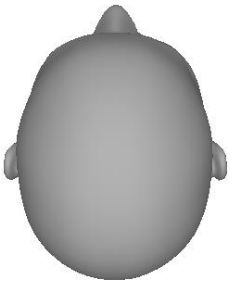
Ambiguity of Optic Flow

Eye Motion





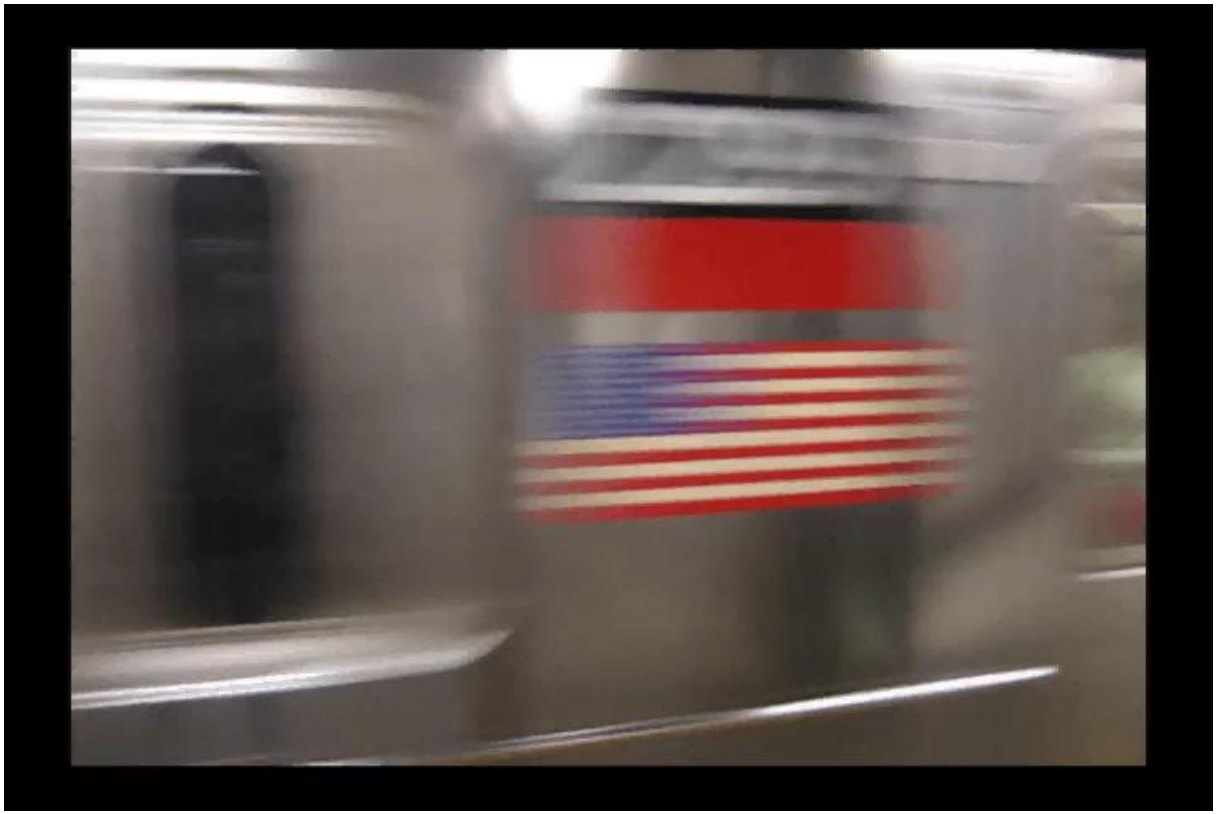
Environmental Motion



Head Motion

Crowell, Banks, Shenoy, Anderson (1998) *Nat. Neuroscience*

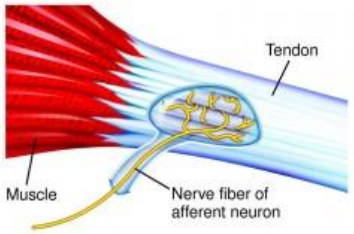
Self- versus Object Motion



How can you tell which?

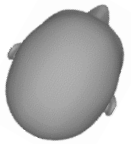
Motor Signals

Efference copy → Forward model of motor plant → **Prediction** of achieved movement

Proprioception → 

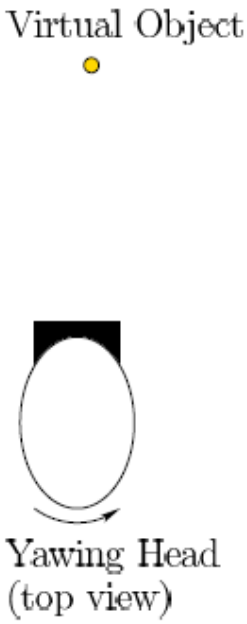
→ **Sensation** of achieved movement

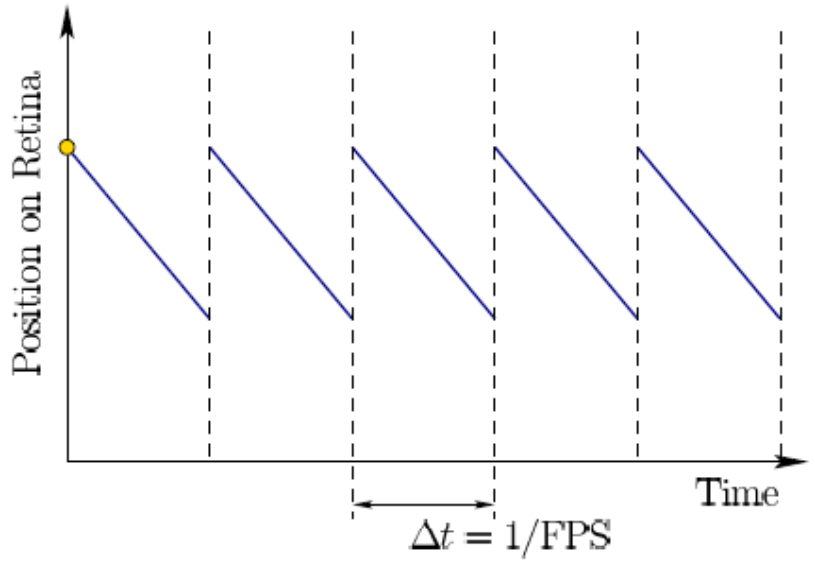
- Oculomotor (eye-in-head)
- Neck-motor (head-on-body)
- Locomotor (body-in-space)



Implications for VR

- Retinal slip during head turn with fixation

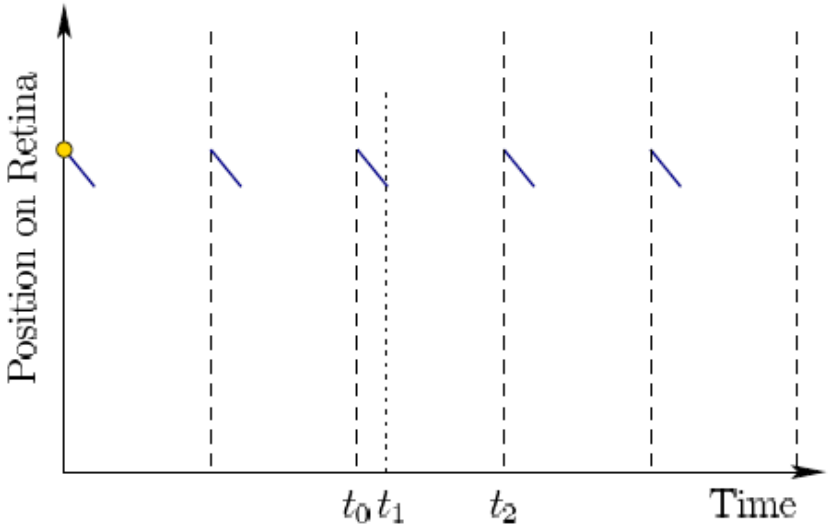


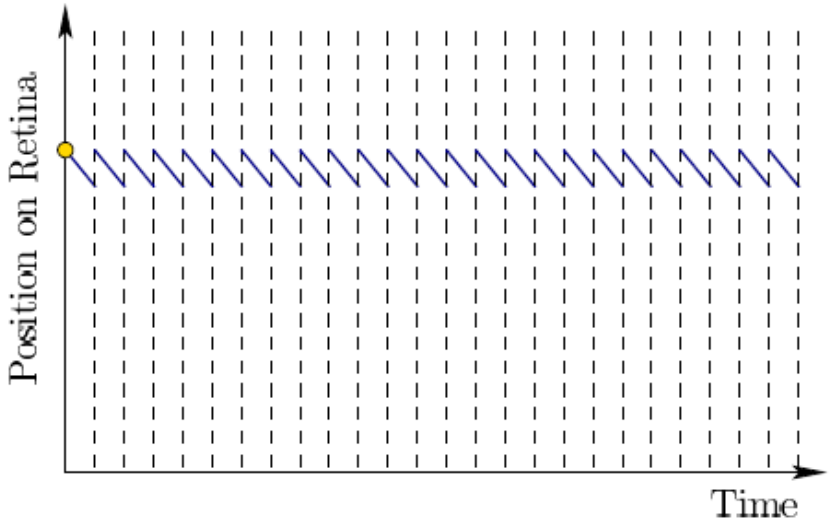


- Low fps; slippage leads to “judder”

Implications for VR

- Solution for judder





- Blank the screen between frames (low persistence)

Implications for VR

- Rendering self-motion:
  - Scale ambiguity of optic flow?
    - Include objects to scale the scene
  - Object vs self-motion
    - Large objects can confuse self-motion

Implications for VR

- Role of motor signals?
  - Perceiving motion while moving
  - Not well-studied

MORE TO COME