Biological Vision and Applications
Module 02-03: Motion perception

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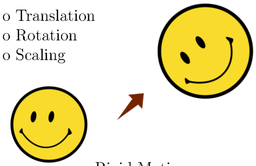
Why motion detection is important

- Distinguish objects of interest (foreground) from the background
- Determine change of location (where) of the objects of interest with time

Rigid, Elastic and Fluid Motion

- **Rigid motion** is where the moving object does not change shape
- **Elastic motion** is where the moving object changes shape with some continuity
- **Fluid motion** is where the continuity is not there

o Translation
o Rotation
o Scaling



Rigid Motion

Elastic Motion

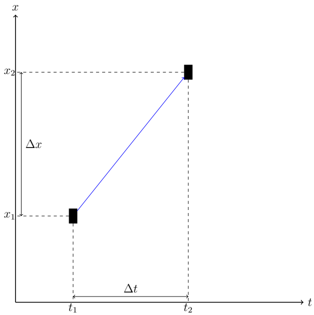
- We shall mostly talk about rigid motion

Continuous and Discrete Motion

- Human observers can distinguish two types of motion: Continuous and Discrete
  - For perception of continuous motion, an object need not move continuously over the retinal field
  - Examples: Alternately blinking festive lights, movie / TV
- There are two stages of motion detection
  - Short range (60 - 100ms, 10 - 15' of visual arc): Based on local intensity changes
    - Local contrasts: early vision
    - Continuous motion
  - Long range (400ms): Based on token matching
    - Object recognition: late vision
    - Discrete motion
- We shall talk about short range motion detection first

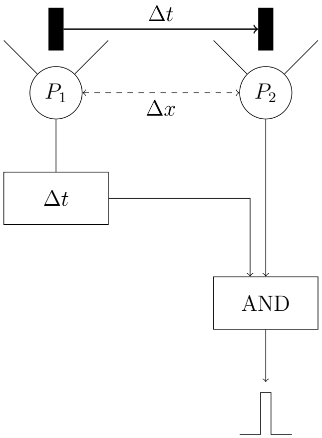
Motion is a correspondence problem

- An image in motion: $I(x, y, t)$
- The motion: $\vec{v}(x, y, t)$ – How to estimate from values of $I(x, y, t)$ over t ?
  - Sometimes it is sufficient to detect motion



- Detecting motion
  - Same object appears at (x_1, t_1) and at (x_2, t_2)
  - If for some (t_1, t_2), $(x_1 \neq x_2)$
- Measuring motion
  - Velocity $v = \frac{\Delta x}{\Delta t}$

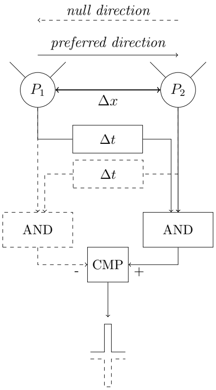
Reichardt model for motion detection

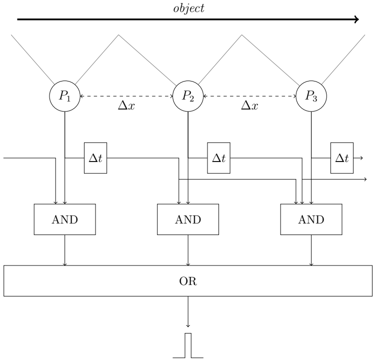


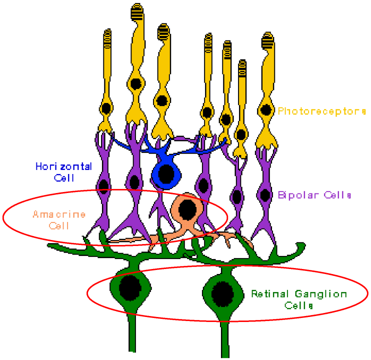
- Reichardt model
  - Eyes of house-flies
- Obvious limitations
  - Motion can be detected in one direction only
  - Motion can be detected only when $v \approx \frac{\Delta x}{\Delta t}$
  - Noise may induce false positives / negatives

Reichardt model for motion detection

Addressing the limitations







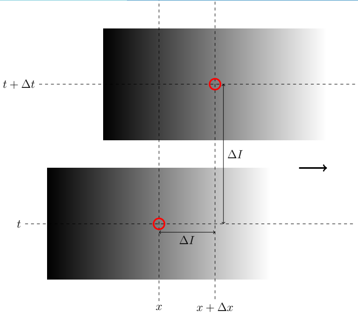
Intensity based scheme

Estimating local motion

- See the contour changing and infer motion
  - Works when there is a significant intensity (or color) variation

Aperture problem: Motion can be perceived in the direction of intensity change only

Gradient model of motion estimation



$$I(x,t) = I(x+\Delta x, t+\Delta t)$$

$$\Delta I = I(x+\Delta x, t) - I(x,t) = \tfrac{\partial I}{\partial x}\Delta x$$

$$\Delta I = I(x+\Delta x, t) - I(x+\Delta x, t+\Delta t)$$

$$\approx I(x,t) - I(x, t+\Delta t) = -\tfrac{\partial I}{\partial t}\Delta t$$

$$v_x = \tfrac{\Delta x}{\Delta t} = -\tfrac{\partial I/\partial t}{\partial I/\partial x}$$

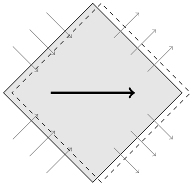
$$v(z,t)_{\nabla I} = -\tfrac{I_t(z,t)}{\nabla I(z,t)}$$

where

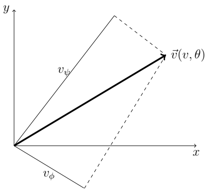
$v(z,t)_{\nabla I}$ = the local velocity at z, in the direction of the spatial intensity gradient
$I_t(z,t)$ = the temporal gradient for local illumination change
$\nabla I(z,t)$ = the spatial gradient for local illumination change

Rigid motion in image plane

Constant velocity assumption (translation only)



- The overall 2D motion can be estimated from the perceived motion at various points on the contour.
- Use many points for error-resilience



Given v_ϕ, v_ψ, $v = ?, \theta = ?$

$$v_\phi = v.cos(\theta - \phi)$$
$$v_\psi = v.cos(\theta - \psi)$$

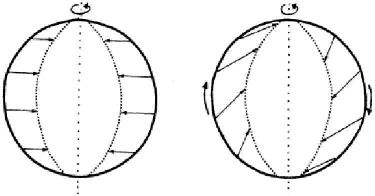
Solve for v and θ

$$v.cos(\theta - \phi_1) = v_1$$
$$v.cos(\theta - \phi_2) = v_2$$
$$v.cos(\theta - \phi_3) = v_3$$
$$\dots$$
$$\dots$$
$$v.cos(\theta - \phi_n) = v_n$$

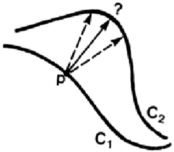
- SVD through example

Ambiguity in motion estimation

More general cases



Motion in 3D

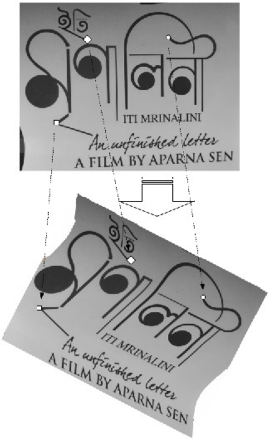


Elastic motion

- Sources of information loss
  - Projection of 3D object to 2D image
  - Projection of movement to intensity variation
- $\vec{V} = v_{\perp}.\vec{u}_{\perp} + v_{\top}.\vec{u}_{\top}$ ($v_{\top}$ cannot be estimated)
- Assumption on additional constraints are needed to estimate $v_{\top}$

Token based method

Motivated by higher level perception (token recognition)



- Tokens (distinctive points) are identified in the scene
  - Feature points (SIFT, SURF, etc.) can be used
- Tokens are tracked over time
  - Motion at tokens are estimated
  - Motion at other points interpolated

Token based method

(Continued)

- Depends of successful tracking of tokens
- Not an easy problem
  - Appearance of tokens may change
  - Two tokens are similar
- Tokens may be confused with each other during motion
- Additional domain-specific constraints need to be imposed
  - Relative geometry of tokens are maintained
  - Tokens have moved minimum distance
- Sometimes leads to illusion
  - A fan or a bicycle wheel appears to rotate in the opposite direction

Quiz

Quiz 02-03

End of Module 02-03