IIT Jodhpur

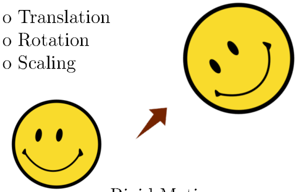
Biological Vision and Applications
Module 02-05: Motion Perception

Hiranmay Ghosh

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

What is the problem?

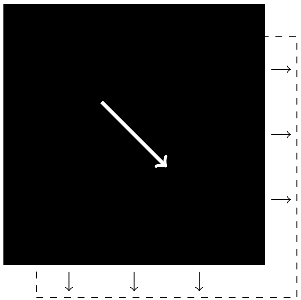
- An image is motion: $I(x, y, t)$
- The motion: $\vec{V}(x, y, t)$
- How to estimate $\vec{V}(x, y, t)$ from values of $I(x, y, t)$ observed over time
- Sometimes it is sufficient to detect motion
  - Measurement not necessary

Continuous and Discrete Motion

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

Intensity based scheme

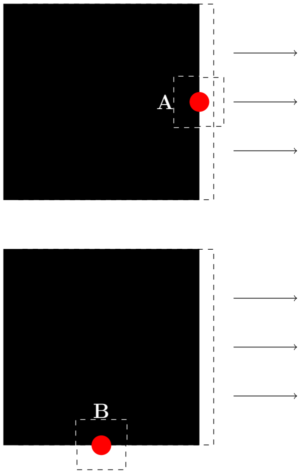
Basic Principle



- See the contour changing and infer motion
- Works well when there is significant intensity variation
  - Can be applied to object boundaries if there is a significant contrast between FG and BG

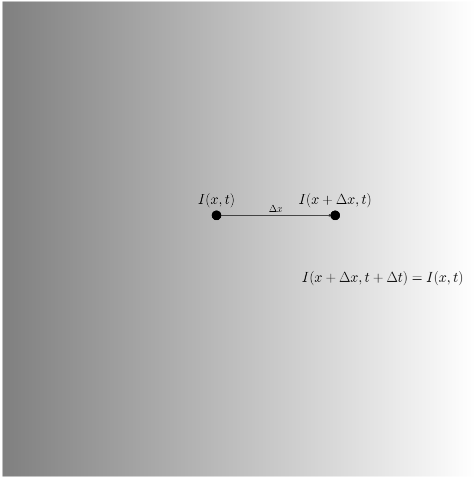
Estimating local motion

Aperture problem



- The motion can be perceived near point A
  - Intensity changes with time
- The motion cannot be perceived near point B
  - No intensity changes with time
  - Aperture problem

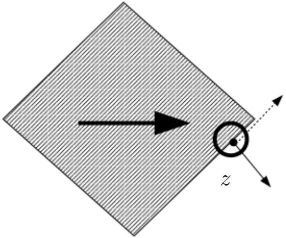
Gradient model of motion estimation



- $\Delta I = I(x+\Delta x, t) - I(x,t)$
- $\Delta x = \Delta I / \frac{\partial I}{\partial x}$
- $\Delta t = -\Delta I / \frac{\partial I}{\partial t}$
- $v = \frac{\Delta x}{\Delta t} = -\frac{\partial I/\partial t}{\partial I/\partial x}$

Gradient model of motion estimation

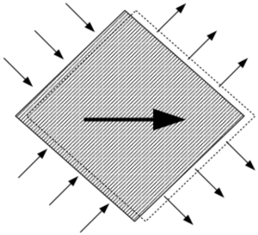
contd.



- Motion is estimated from the local gradients of the image intensity.
- The local velocity at z, in the direction of the spatial intensity gradient
- $v(z,t)_{\nabla I} = -\frac{I_t(z,t)}{|\nabla I(z,t)|}$
  - where
  - $I_t(z,t)$ represents the temporal gradient for local illumination change
  - $|\nabla I(z,t)|$ represents the magnitude of spatial gradient for local illumination change

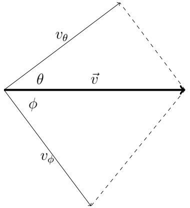
Rigid motion in image plane

Constant velocity assumption (translation only)



- The overall 2D motion of a rigid object can be estimated from the perceived motion at various points on the contour.

- Need minimum two points ($\theta \neq \phi$)
  - Let $\vec{V} = (v_x, v_y)$
  - $v_\theta = v_x.cos\theta + v_y.sin\theta$
  - $v_\phi = v_x.cos\phi + v_y.sin\phi$
  - Solve for v_x, v_y



Error resilience

Why we should observe at many points

- Minimize RMS error in

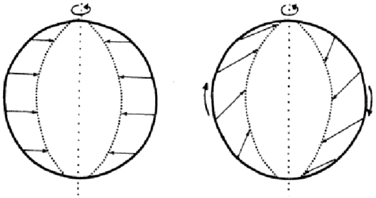
$$\begin{bmatrix} \alpha_1 & \beta_1 & -v_1 \\ \alpha_2 & \beta_2 & -v_2 \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ \alpha_n & \beta_n & -v_n \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ 1 \end{bmatrix} = 0$$

- where $\alpha_1 = cos\theta$, $\beta_1 = sin\theta$, $v_1 = v_\theta$ etc.
- Use Singular Value Decomposition (SVD)

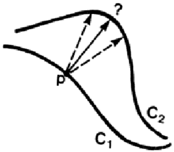
SVD through example

Ambiguity in motion estimation

More general cases



Motion in 3D

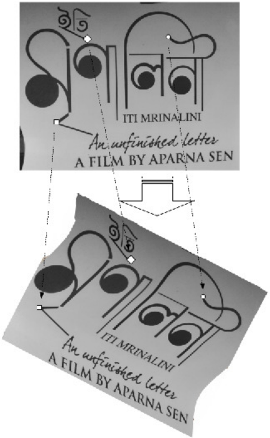


Elastic motion

- 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 02-05

End of Module 02-05