*Lab 11*

# Optical Flow

**Learning Objectives:**

- *By the end of this lab, students will be able to:*
- *Understand the concept of optical flow and its role in motion analysis.*
- *Apply dense optical flow techniques using the Farneback method.*
- *Track sparse feature points between frames using the Lucas-Kanade method.*
- *Visualize and interpret motion information in videos using OpenCV.*

## Theoretical Background:

### What is Optical Flow?

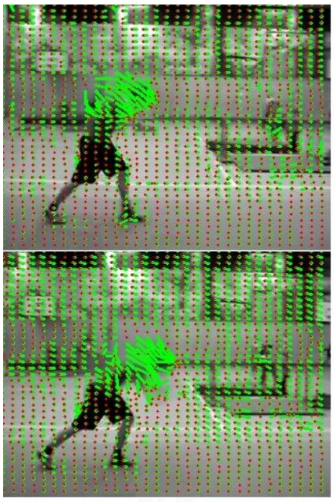
Optical flow is the pattern of **apparent motion** of objects, surfaces, and edges in a visual scene caused by the **relative motion** between an observer and the scene.

It provides information about:

- The **direction** in which pixels are moving.
- The **speed** of pixel movement.

Optical flow assumes (constraint):

- Brightness constancy: pixel intensity remains the same between consecutive frames.
- Small motion between frames.
- Smooth motion in neighboring pixels.



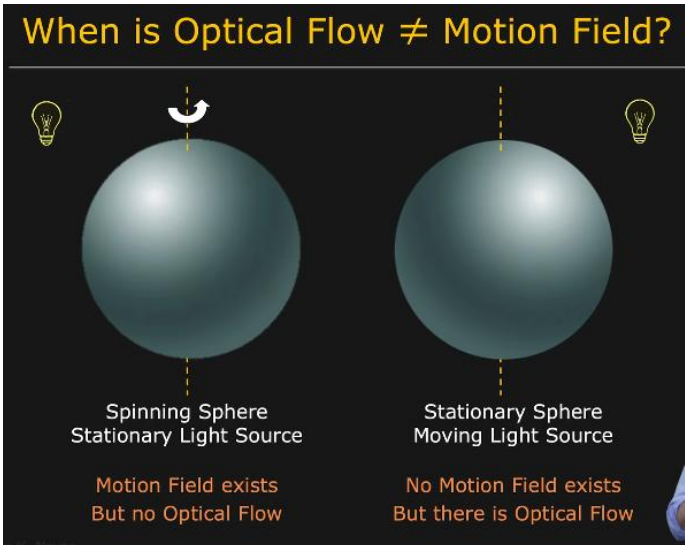
Optical flow vectors

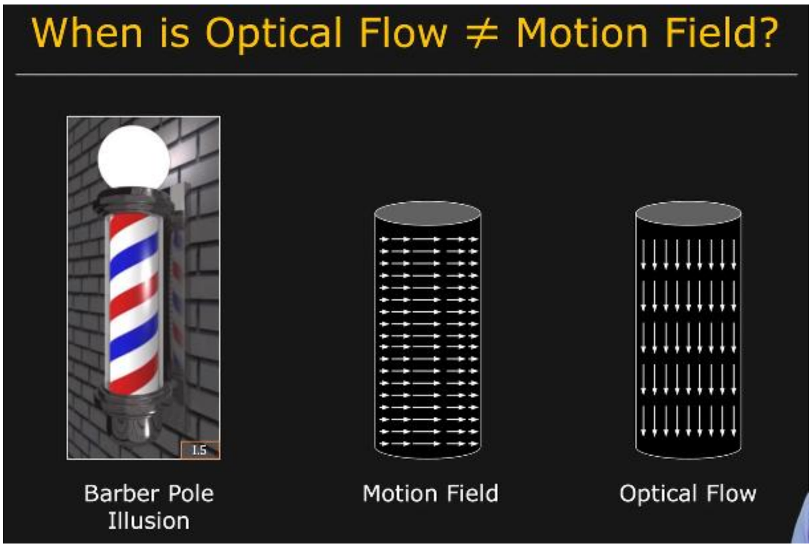
**What is the difference between (Optical flow and Motion field) ?**

***Motion Field:*** *The true physical motion of objects (or points) in the 3D world projected onto the 2D image plane.*

***Optical Flow:*** *The apparent motion computed from image intensity changes between two frames.*

**Ideally, Optical Flow = Motion Field, However Sometimes its not**




**Types of Optical Flow Estimation:**

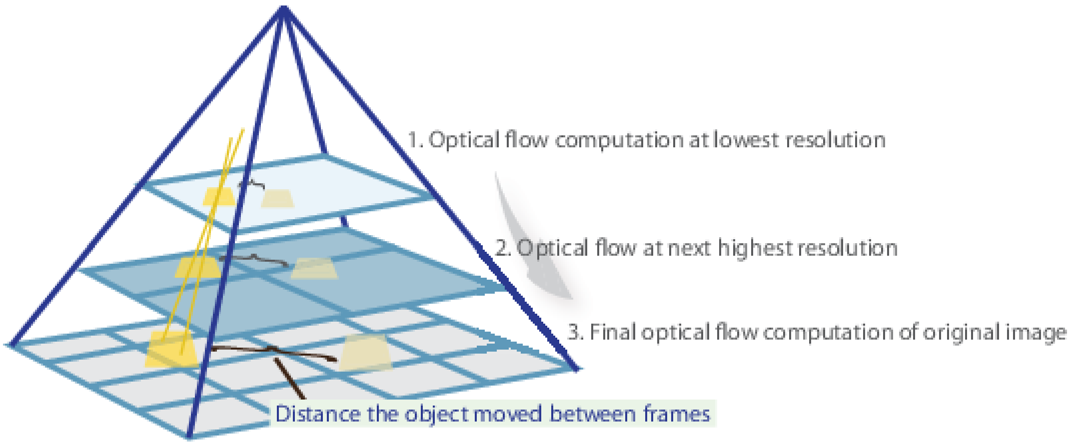
1. **Dense Optical Flow**:
    - Calculates motion vectors for **every pixel** in the frame.
    - Example method: **Farneback's method**.
    - Useful for capturing global motion fields.
2. **Sparse Optical Flow**:
    - Calculates motion vectors for **selected key points** (e.g., corners).
    - Example method: **Lucas-Kanade method**.
    - More efficient for tracking prominent features in videos.

(a) Sparse Optical Flow – Lukas Kanade

(b) Dense Optical Flow - Gunnar Farneback

## *Exercise 1: Dense Optical Flow with Farneback Method*

**Objective:**
Compute dense optical flow for all pixels between two consecutive frames.
**Method Overview:**
The Farneback algorithm approximates pixel neighborhoods with polynomials to estimate motion.




**Steps:**
**1.Read two consecutive frames from a video.**
**2.Convert both frames to grayscale**:

```
prev_gray = cv.cvtColor(prev_frame, cv.COLOR_BGR2GRAY)
next_gray = cv.cvtColor(next_frame, cv.COLOR_BGR2GRAY)
```

3.**Compute the dense optical flow**:

```
flow = cv.calcOpticalFlowFarneback(prev_gray, next_gray, None,
                                   pyr_scale=0.5, levels=3, winsize=15,
                                   iterations=3, poly_n=5, poly_sigma=1.2,
                                   flags=0)
```

**4.Visualize the**:
- Use color coding (hue for direction, brightness for magnitude).

**Farneback Function Parameters Overview:**

- pyr_scale: Image scale (<1) for pyramid building.
- levels: Number of pyramid layers.
- winsize: Window size for averaging.
- iterations: Iterations at each pyramid level.
- poly_n, poly_sigma: Parameters for polynomial expansion smoothing.
- flags: Optional flags like OPTFLOW_USE_INITIAL_FLOW or OPTFLOW_FARNEBACK_GAUSSIAN.

## *Exercise 2: Sparse Optical Flow with Lucas-Kanade Method*

**Objective:**
Track a set of selected points (features) between consecutive frames.
**Method Overview:**
The Lucas-Kanade method tracks points by solving motion equations over a small neighborhood.

**Steps:**
**1.Detect good features to track** in the first frame:

```
prev_pts = cv.goodFeaturesToTrack(prev_gray, maxCorners=100, qualityLevel=0.3,
minDistance=7)
```

**2.Compute the optical flow for these points**:

```
next_pts, status, err = cv.calcOpticalFlowPyrLK(prev_gray, next_gray,prev_pts,
None, winSize=(21,21), maxLevel=3,
            criteria=(cv.TERM_CRITERIA_EPS |
cv.TERM_CRITERIA_COUNT, 30, 0.01))
```

3. **Draw the tracked points**:
   - Draw lines or points to show how features have moved.

**Lucas-Kanade Function Parameters Overview**:

- `winSize`: Size of the search window.
- `maxLevel`: Number of pyramid levels.
- `criteria`: Termination criteria (max iterations or minimum movement).
- `flags`: Control behavior (e.g., use initial flow, get minimum eigenvalues).

## Key Differences Recap:

| Dense Optical Flow (Farneback) | Sparse Optical Flow (Lucas-Kanade) |
|---|---|
| Motion estimated for **every pixel.** | Motion estimated for **selected points** only. |
| More computationally expensive. | More efficient for tracking. |
| Useful for **global motion** analysis. | Useful for **tracking specific features** (e.g., corners, edges). |

**Additional reference:**

1. https://docs.opencv.org/3.4/d4/dee/tutorial_optical_flow.html
2. https://www.youtube.com/watch?v=WrlH5hHv0gE&t=237s&ab_channel=NicolaiNielsen-ComputerVision%26AI
3. https://www.youtube.com/watch?v=hfXMw2dQO4E&ab_channel=NicolaiNielsen-ComputerVision%26AI