# Histogram of Oriented Gradients (HOG)

**What is HOG?**  
HOG (Histogram of Oriented Gradients) is a feature descriptor used in computer vision and image processing for object detection. It captures edge and gradient structure that is characteristic of local shapes in images.

**What is a Feature Descriptor?**  
A feature descriptor is a representation of an image or part of an image that describes its important characteristics, such as texture, shape, or gradient patterns, to be used in machine learning models or computer vision algorithms.

**Steps Involved in HOG Feature Extraction**

**Step 1: Grayscale Conversion**  
Convert the color image to grayscale to simplify the process:

* HOG works on intensity, not color.
* Input image becomes a 2D array of pixel values.

**Step 2: Compute Gradients (Gx, Gy)**  
Detect edge information in the image using gradients:

* Use filters like Sobel to compute gradients.
* For each pixel:
  + Gx = I[x+1, y] - I[x-1, y]
  + Gy = I[x, y+1] - I[x, y-1]

**Step 3: Compute Magnitude and Orientation**

* For each pixel:
  + Magnitude = sqrt(Gx² + Gy²)
  + Orientation = atan2(Gy, Gx) in degrees (0°–180° for unsigned angles)

**Step 4: Divide Image into 8×8 Cells**

* For a 64×128 image:
  + (64/8) × (128/8) = 8 × 16 = 128 cells
* Each cell:
  + Size = 8×8 pixels
  + Computes a histogram of gradient directions
  + 9 bins (0° to 180° in steps of 20°)
  + Each pixel votes to a bin based on its magnitude and orientation

**Step 5: Normalize Using 16×16 Blocks**

* A block = 2×2 cells = 16×16 pixels
* Slide the block over the image with a stride of 8 pixels (overlapping blocks)
* Each block:
  + Contains 4 cells × 9 bins = 36 values
  + Normalize the 36×1 feature vector:

k = sqrt(sum([x\*\*2 for x in V]) + epsilon) # Prevent division by zero

V\_normalized = V / k

**Step 6: Concatenate All Block Features**

* Vertical blocks: (128 - 16) / 8 + 1 = 15
* Horizontal blocks: (64 - 16) / 8 + 1 = 7
* Total blocks = 15 × 7 = 105 blocks
* Each block contributes 36 features
* Final HOG descriptor = 105 × 36 = **3780 features**

This final feature vector is used for image classification and detection tasks.

**Advantages of HOG**

* Robust to small changes in pose and lighting
* Effective for detecting objects like humans and vehicles
* Easy to implement and interpret

**Disadvantages of HOG**

* Not rotation invariant
* High dimensional feature vector
* Limited performance on complex or cluttered scenes

**Applications of HOG**

* Human detection
* Vehicle detection
* Face recognition
* Pedestrian tracking
* Surveillance systems