Histogram of Oriented Gradients (HOG)

CVPR ’05 Dalal and Triggs
Introduction

• Global features

• Sliding window

• Image subsampled to multiple sizes

• Normalized histograms
Steps

• Find horizontal and vertical gradients

• Gradient Magnitude and orientations

• Use a patch of 64 x 128

• Divide the image into blocks of 8 x 8 cells

• Slide over 2 x 2 block cells

• Quantize the gradient orientation into 9 bins by gradient magnitude

• Concatenate histograms into a feature of: \(15 \times 7 \times 4 \times 9 = 3780\) dimensions.
Gradients

\[
\nabla f(x, y) = \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} = \lim_{d \to 0} \frac{f(x + d) - f(x - d)}{2d}
\]

Filter Masks:

\[
\begin{array}{ccc}
-1 & 0 & 1 \\
0 & 0 & 0 \\
1 & 0 & 1
\end{array}
\]

Gradient Magnitude:

\[
g = \sqrt{g_x^2 + g_y^2}
\]

Gradient Orientation:

\[
\theta = \tan^{-1}\left(\frac{g_y}{g_x}\right)
\]
Blocks and Cells
Blocks and Cells

- 16 x 16 blocks with an overlap
- Total blocks: 15 x 7
- Each block is 2 x 2 of 8x8 cells
Quantize gradient orientations into 9 bins
Quantize gradient orientations into 9 bins

<table>
<thead>
<tr>
<th>Gradient direction</th>
<th>Gradient Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 35 5 10 64 0</td>
<td>2 5 4 85 2 0</td>
</tr>
<tr>
<td>57 85 160 0 120 65</td>
<td>106 12 13 77 3 6</td>
</tr>
<tr>
<td>22 45 90 145 30 18</td>
<td>37 86 48 180 12 37</td>
</tr>
<tr>
<td>12 4 134 6 75 57</td>
<td>108 3 87 33 81 27</td>
</tr>
<tr>
<td>43 30 23 5 119 14</td>
<td>23 54 11 186 19 114</td>
</tr>
<tr>
<td>67 57 98 11 9 77</td>
<td>7 210 19 33 24 12</td>
</tr>
<tr>
<td>3 11 23 54 78 90</td>
<td>112 4 34 9 3 12</td>
</tr>
</tbody>
</table>

Histogram bins
Concatenate Histograms

\[15 \times 7 \times 9 \times 4 = 3780\]