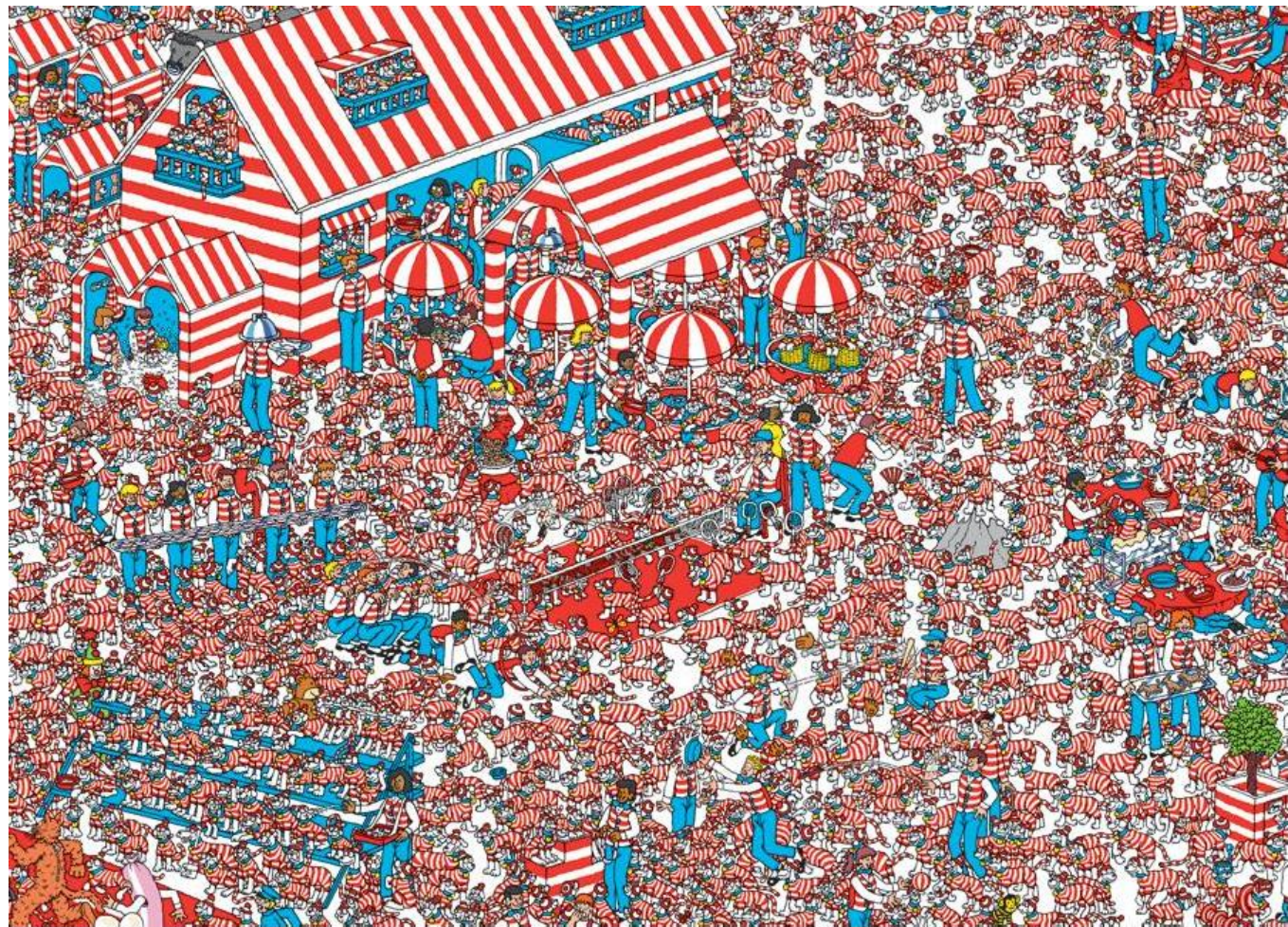


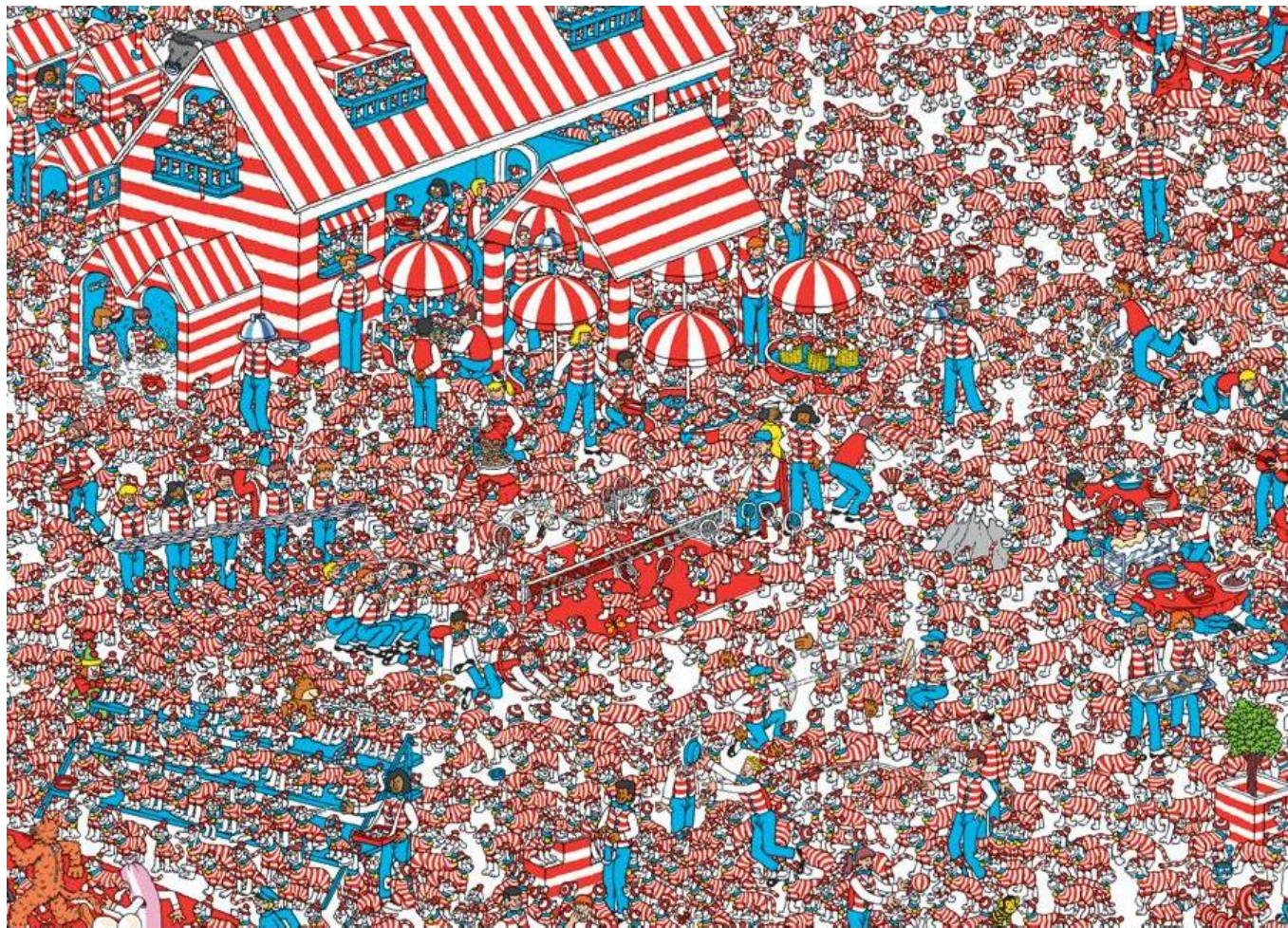


HISTOGRAM OF ORIENTED GRADIENTS

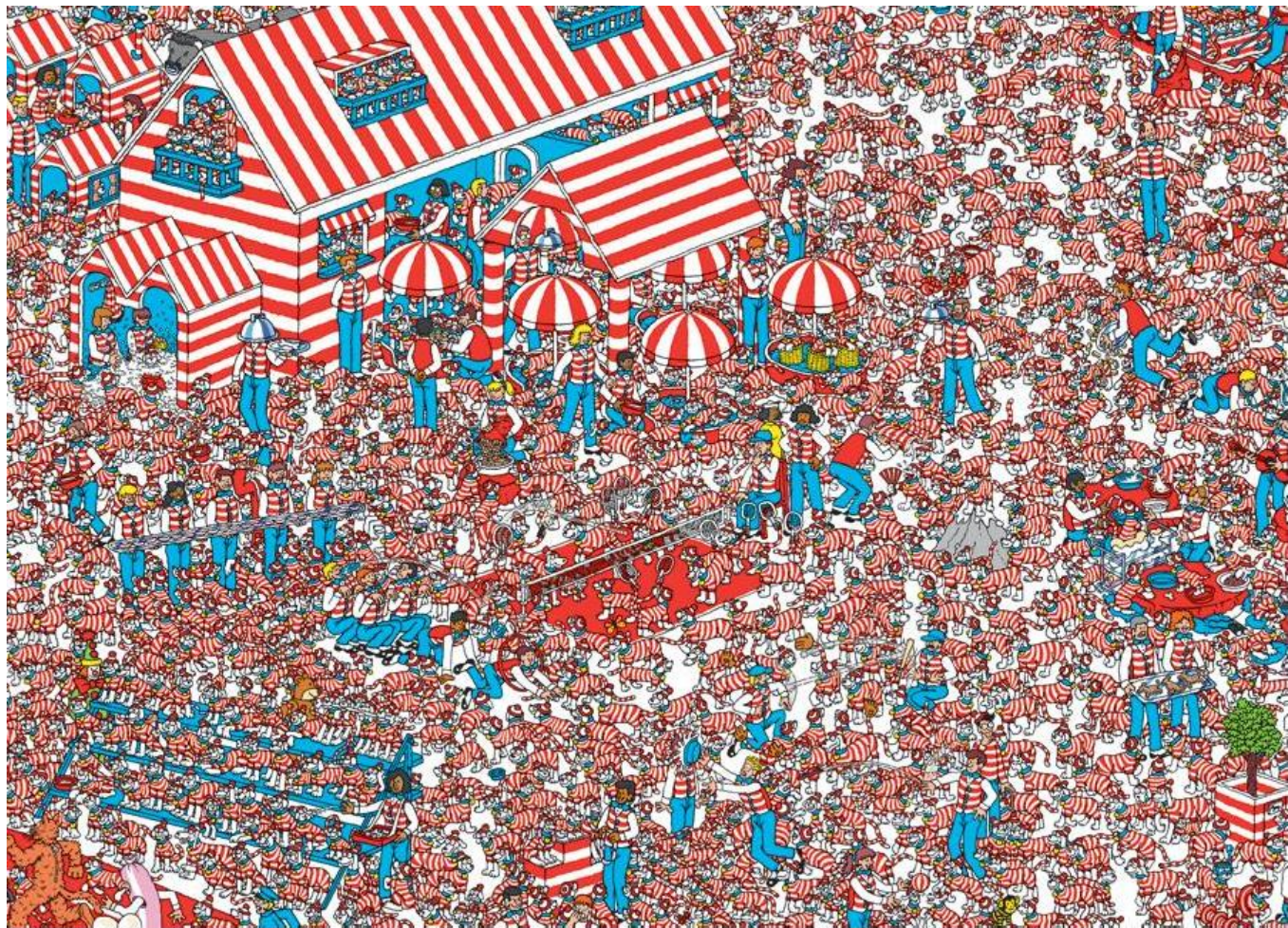
HYUN SOO PARK







20	35	21
53	22	23
22	34	32
22	56	55
45	11	13



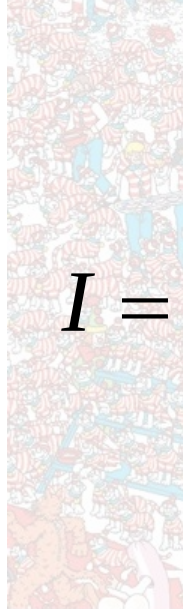
20	35	21
53	22	23
22	34	32
22	56	55
45	11	13

20
53
22
22
45
.
.
55
13

$J =$

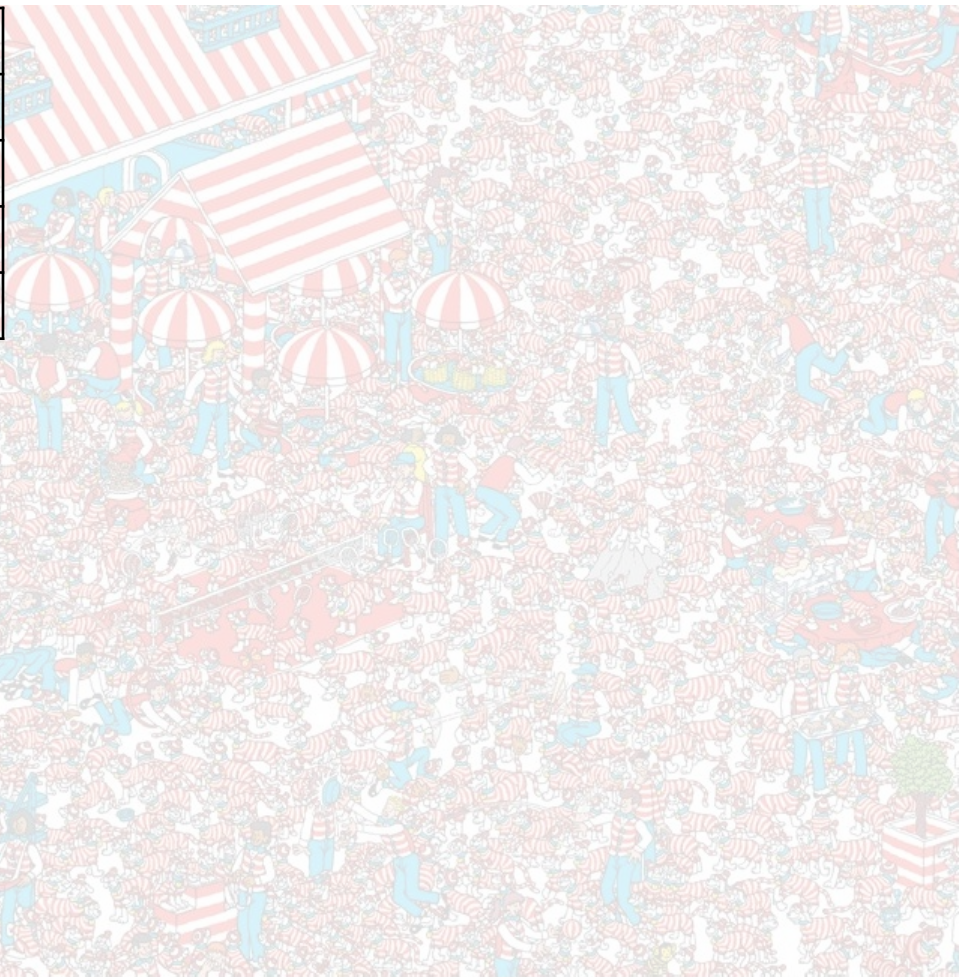


11	13	34
34	24	21
64	55	64
68	45	25
80	31	45



$I =$

11
34
64
68
80
.
.
25
45



20	35	21
53	22	23
22	34	32
22	56	55
45	11	13

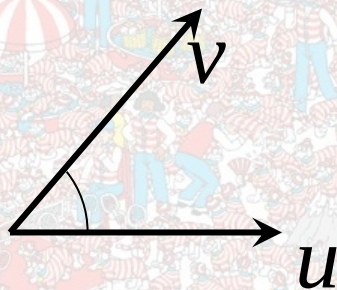
$J =$

20
53
22
22
45
.
.
55
13



11	13	34
34	24	21
64	55	64
68	45	25
80	31	45

CORRELATION == DOT PRODUCT



I =

11
34
64
68
80
.
.
25
45

$$\frac{u \cdot v}{\|u\| \|v\|} = \cos \theta$$



20	35	21
53	22	23
22	34	32
22	56	55
45	11	13

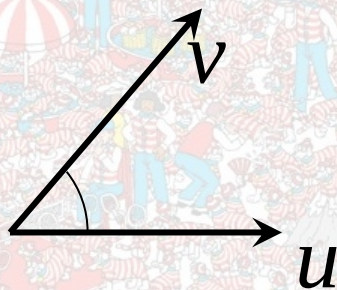
J =

20
53
22
22
45
.
.
55
13



11	13	34
34	24	21
64	55	64
68	45	25
80	31	45

CORRELATION == DOT PRODUCT



I =

11
34
64
68
80
.
.
25
45

$$\frac{u \cdot v}{\|u\| \|v\|} = \cos \theta$$



20	35	21
53	22	23
22	34	32
22	56	55
45	11	13

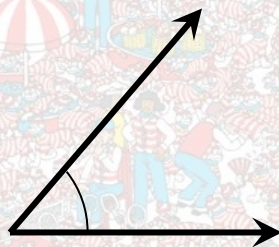
J =

20
53
22
22
45
.
.
55
13



11	13	34
34	24	21
64	55	64
68	45	25
80	31	45

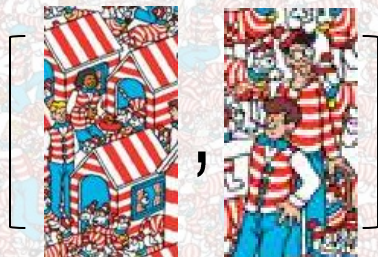
CORRELATION == DOT PRODUCT



I =

11
34
64
68
80
.
.
25
45

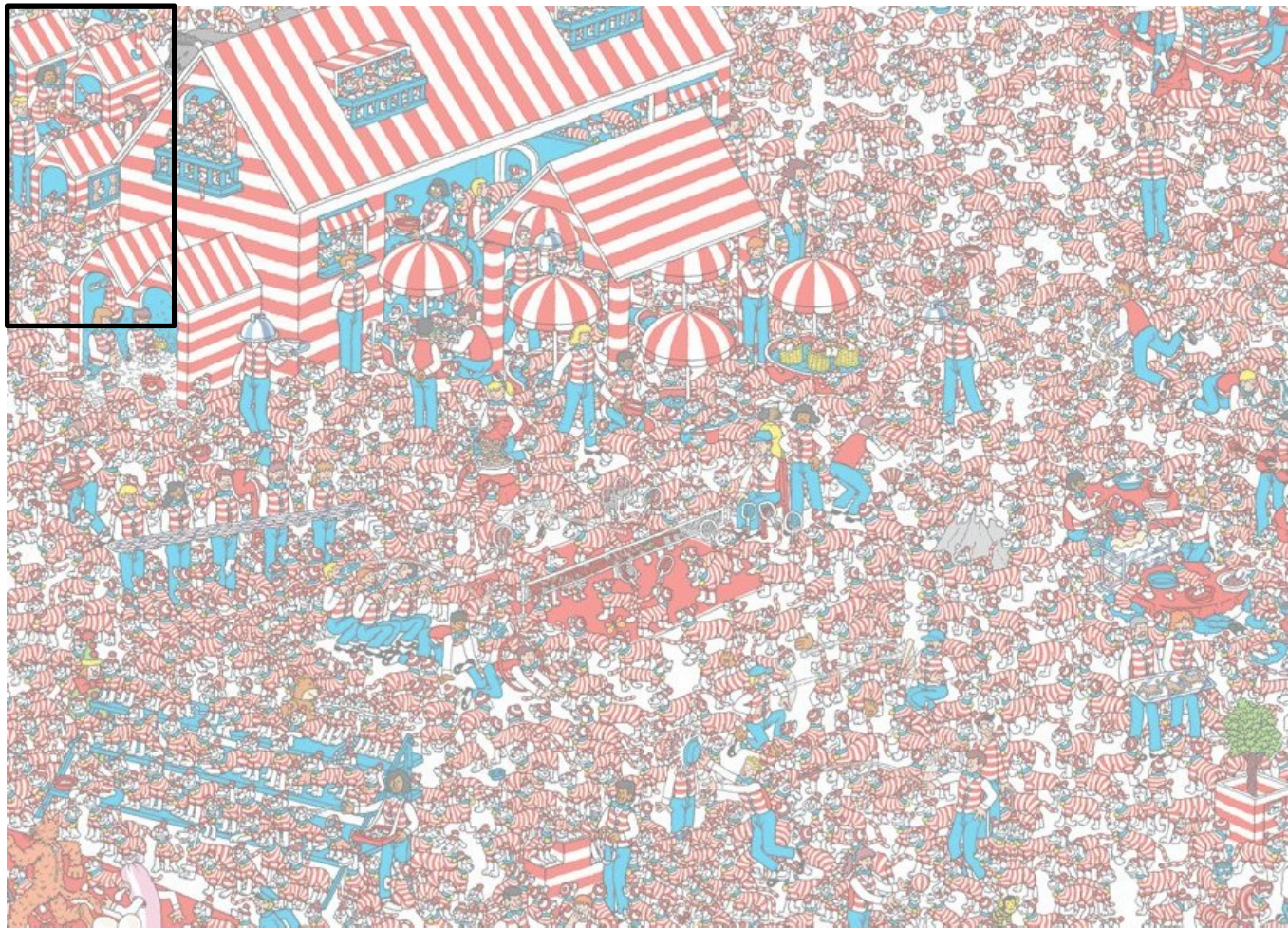
Corr



20	35	21
53	22	23
22	34	32
22	56	55
45	11	13

J =

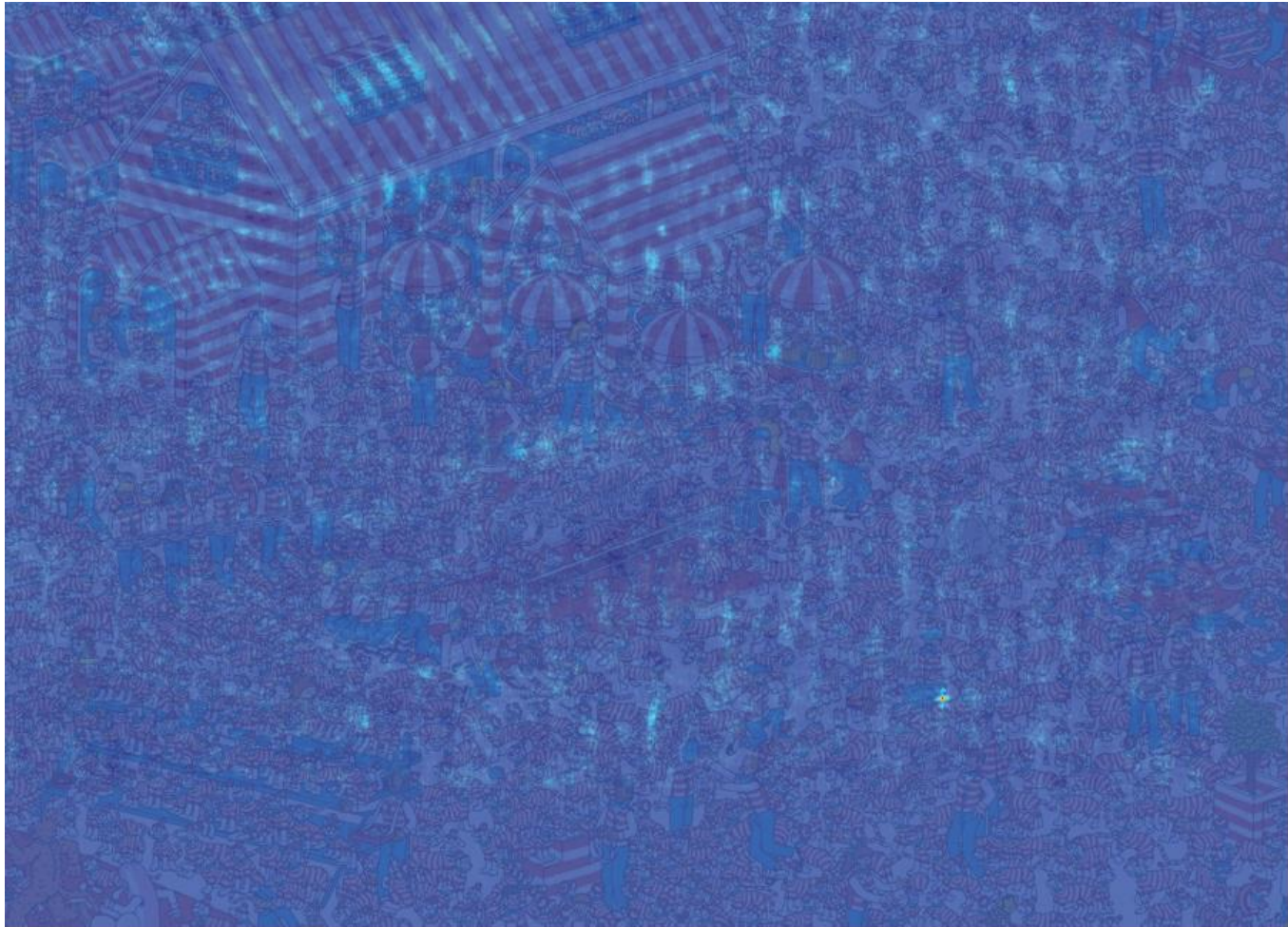
20
53
22
22
45
.
.
55
13

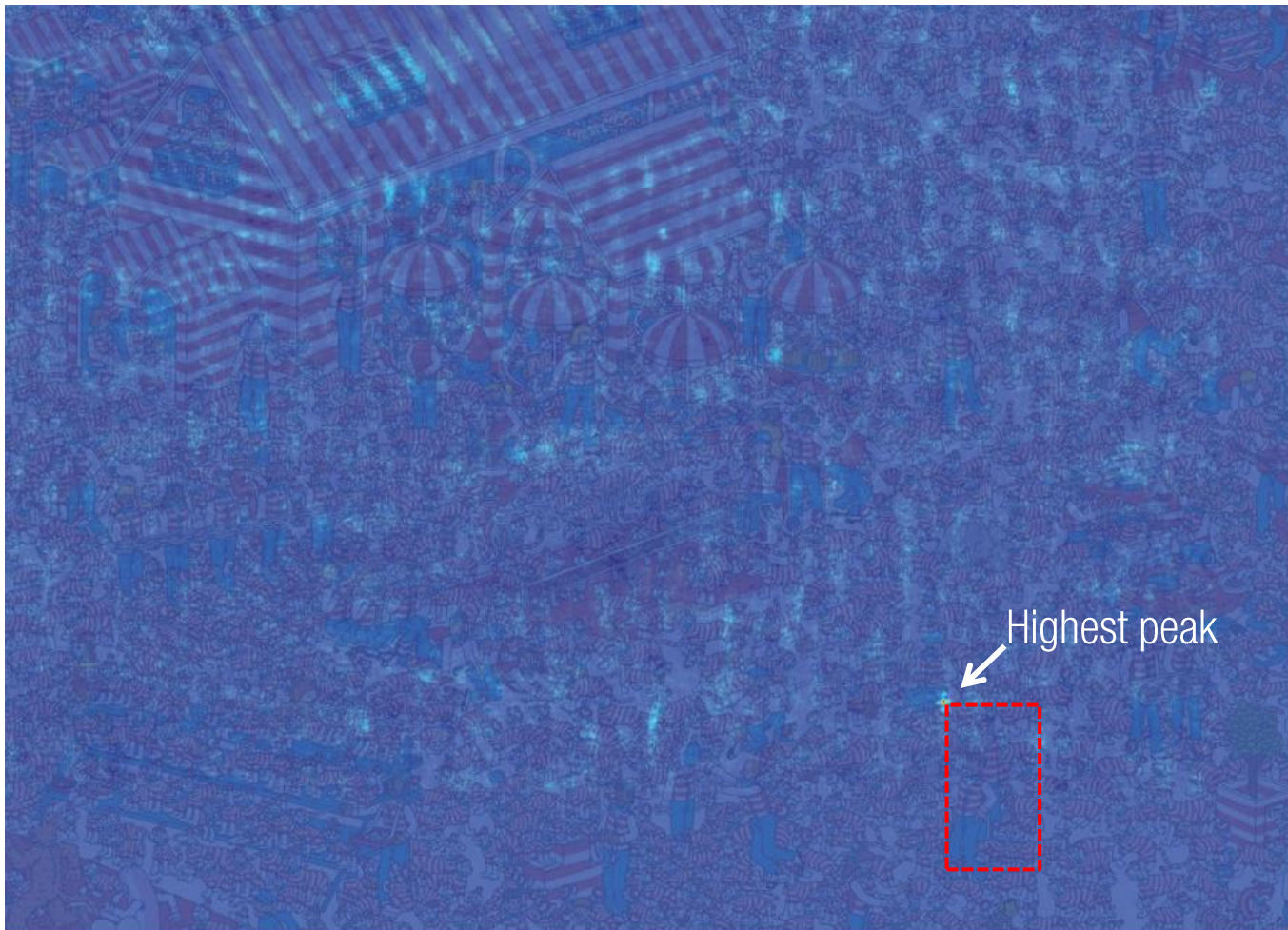


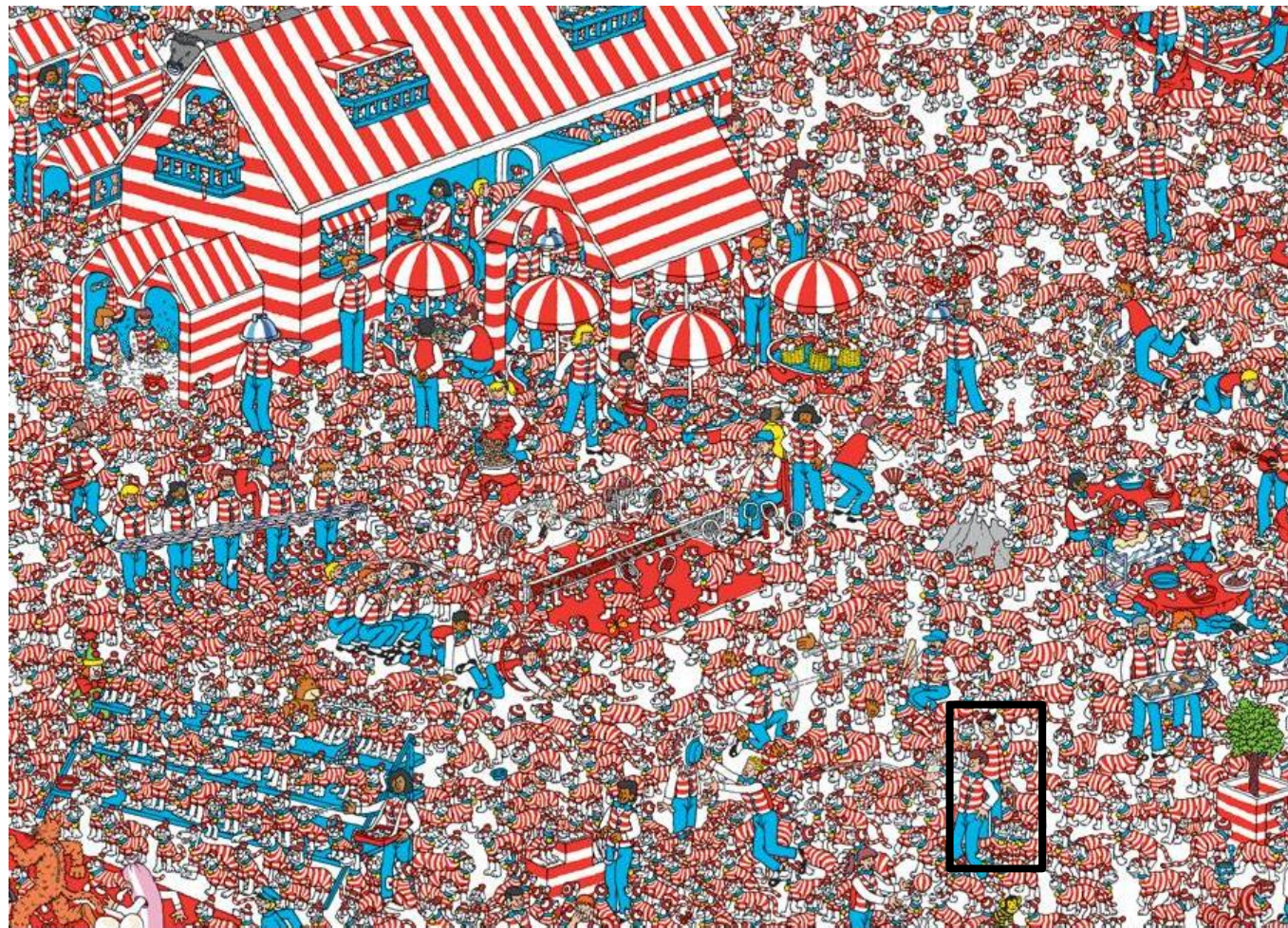
20	35	21
53	22	23
22	34	32
22	56	55
45	11	13

20
53
22
22
45
.
.
55
13

$J =$







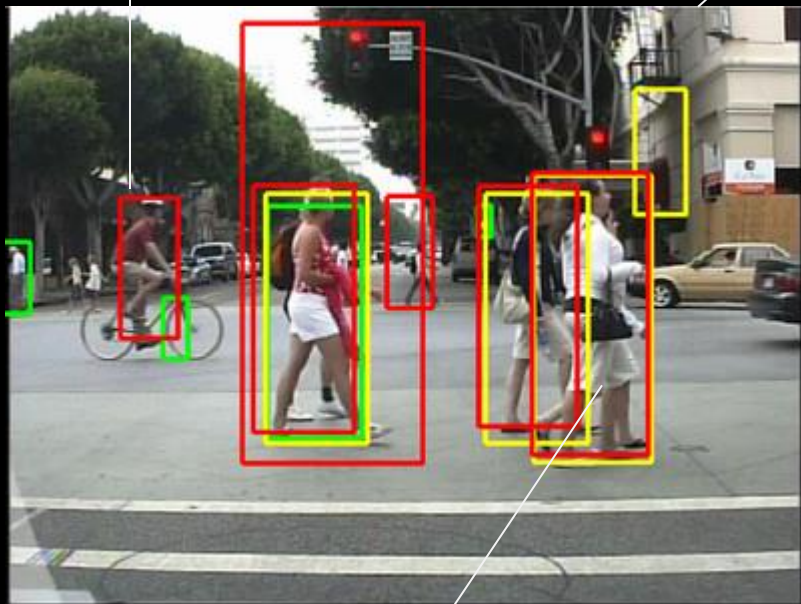
Assumptions:

- + Exactly same shape (no occlusion, no illumination change)
- + Exactly same size
- + Exactly same orientation
- + Exactly same viewpoint



Views

Different illumination



Occlusion

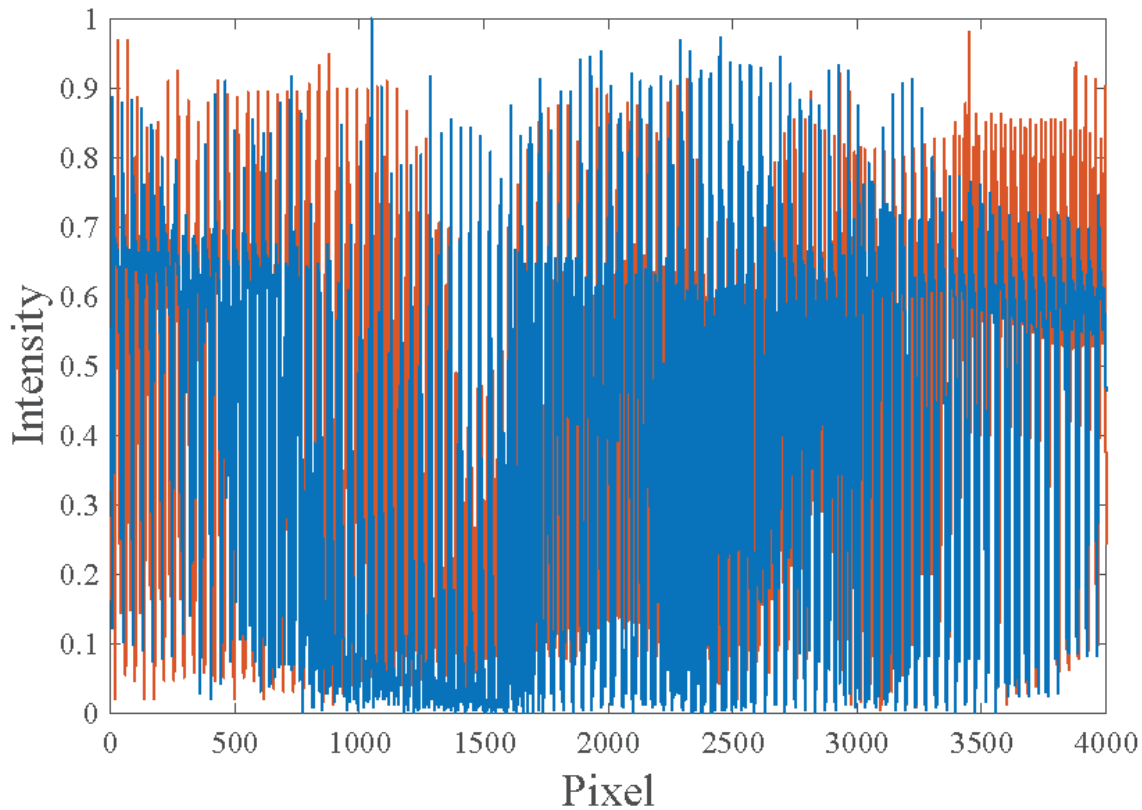


Various poses

PIXEL INTENSITY CORRELATION



Corr = 0.24

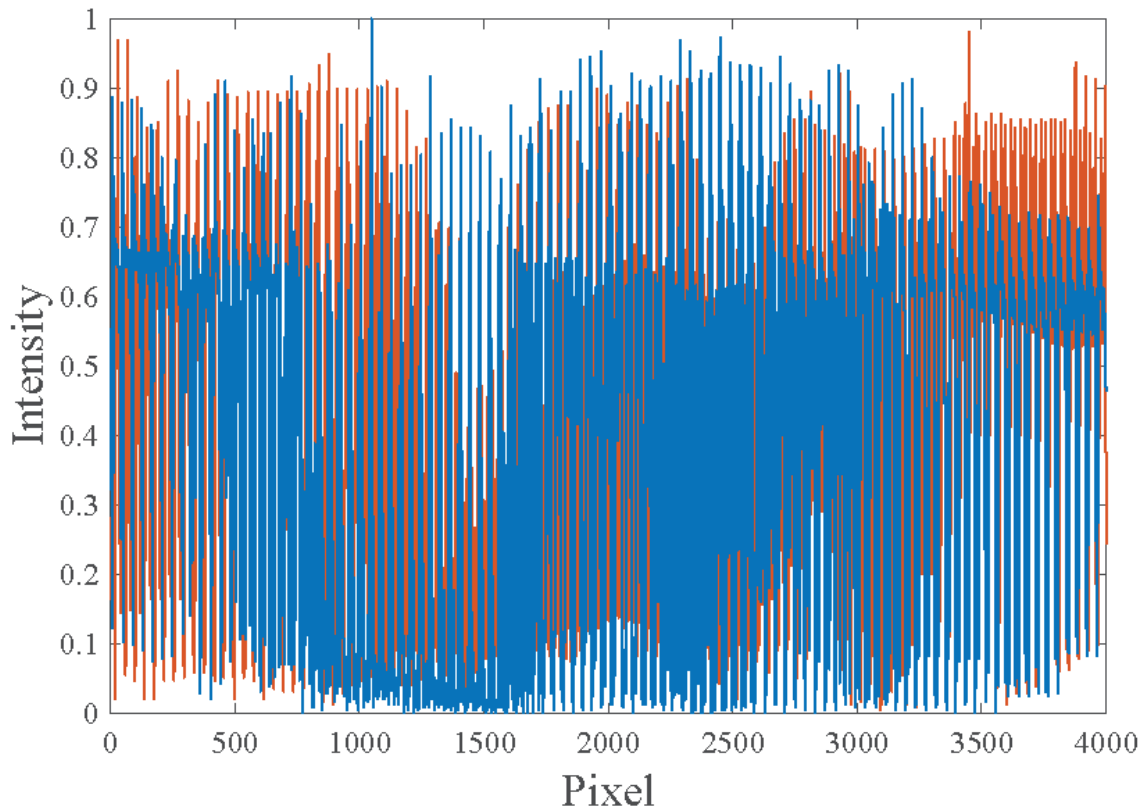


PIXEL INTENSITY CORRELATION

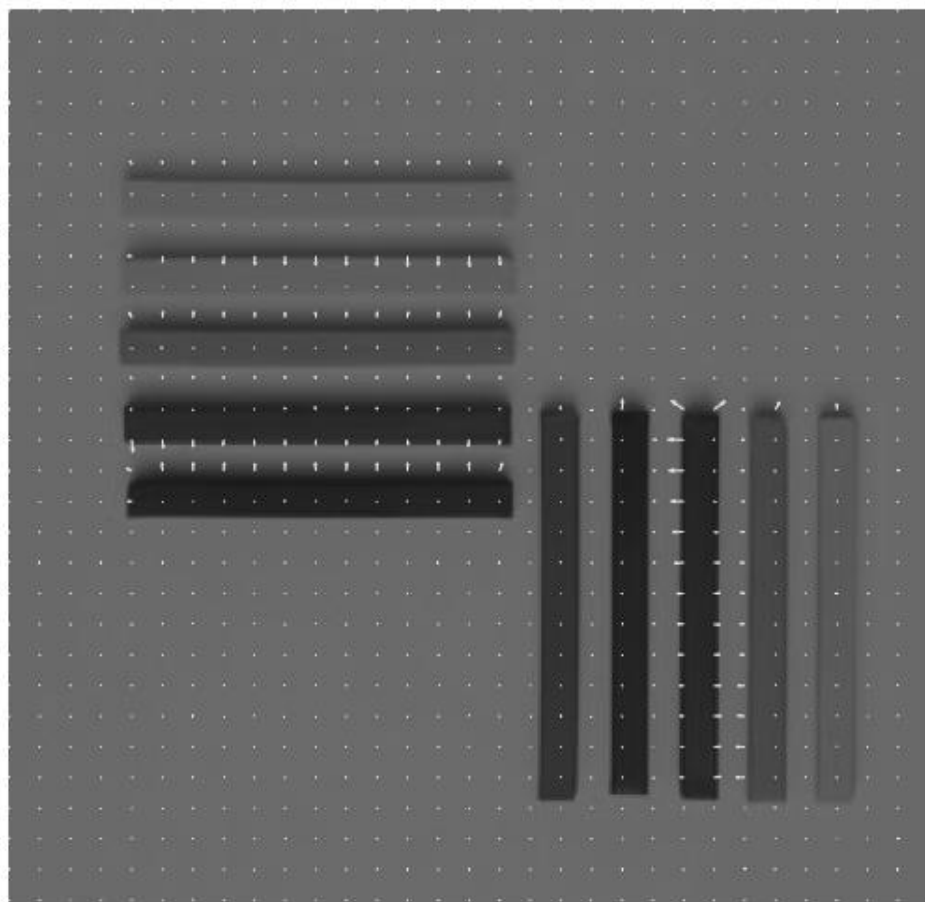
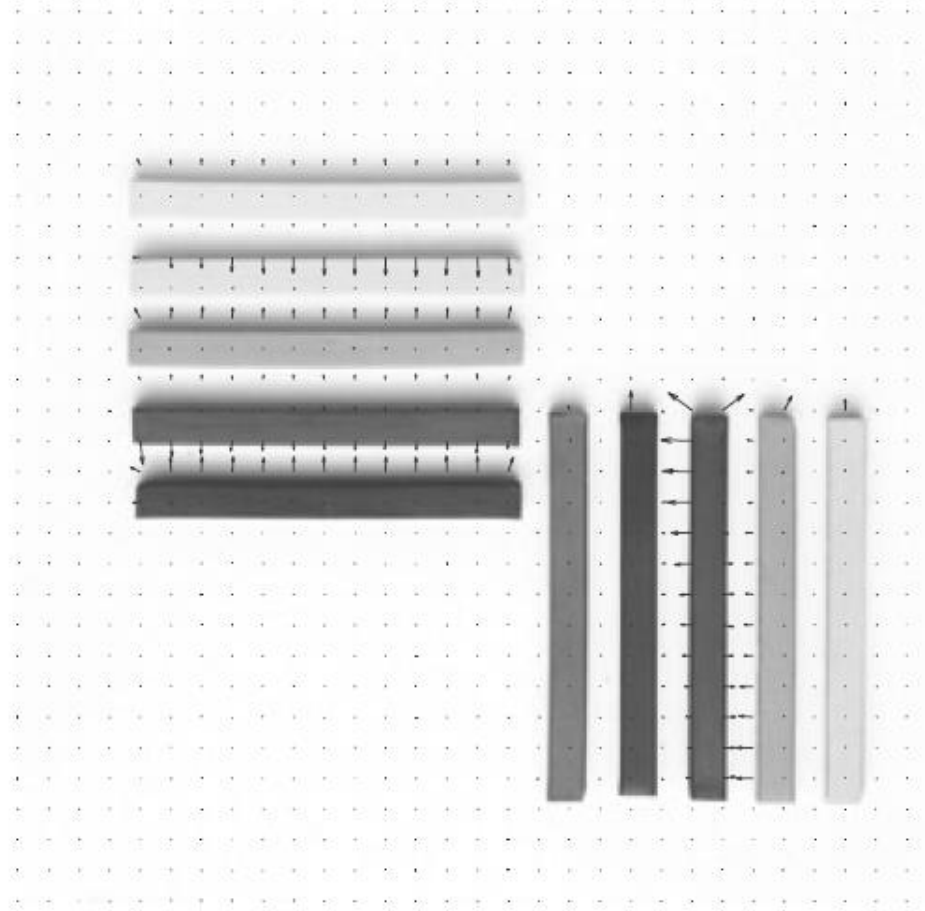


Corr = 0.24

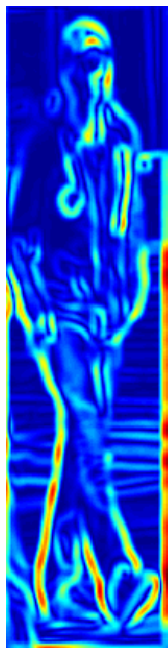
Corr = 0.31



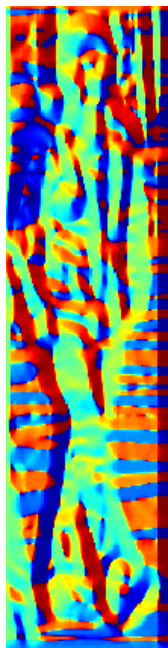
RECALL: ILLUMINATION INVARIANT GRADIENT



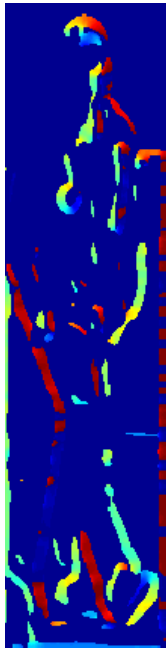
GRADIENT



$$\|\nabla I\|$$

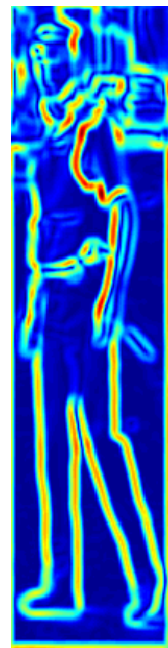


$$\angle \nabla I$$

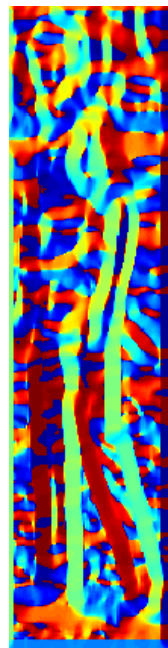


$$\angle \nabla I$$

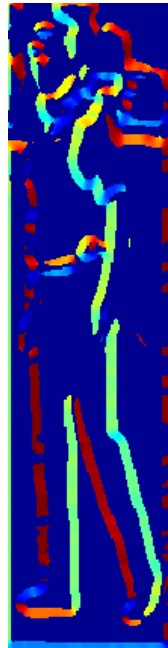
with mag thr.



$$\|\nabla J\|$$



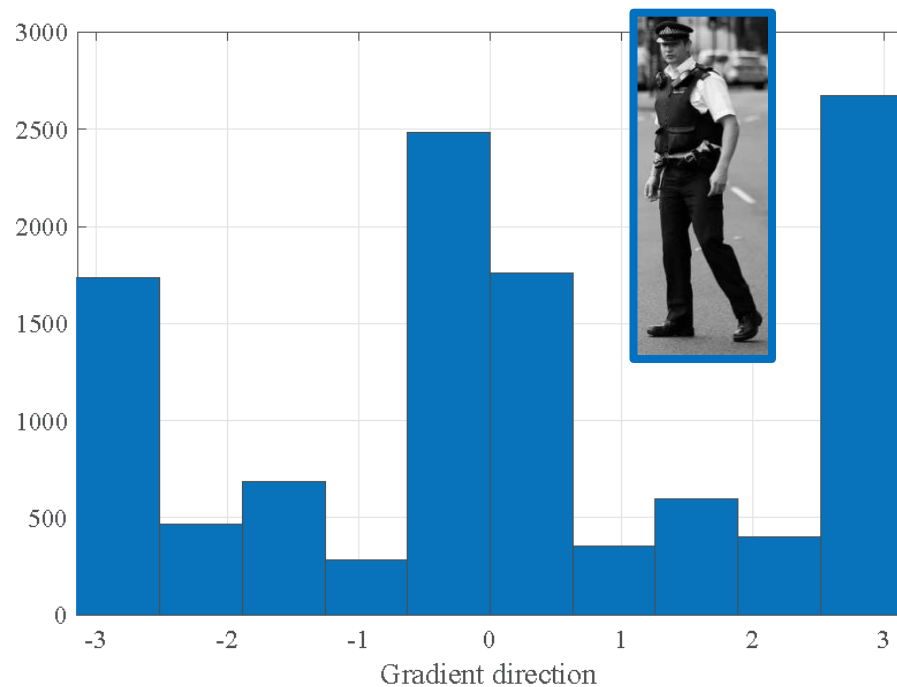
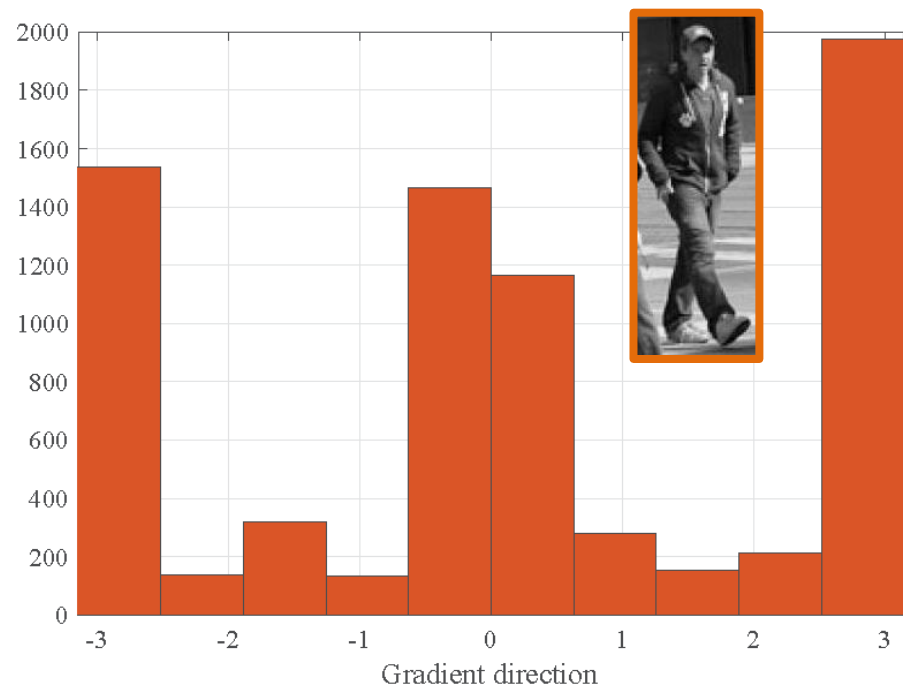
$$\angle \nabla J$$



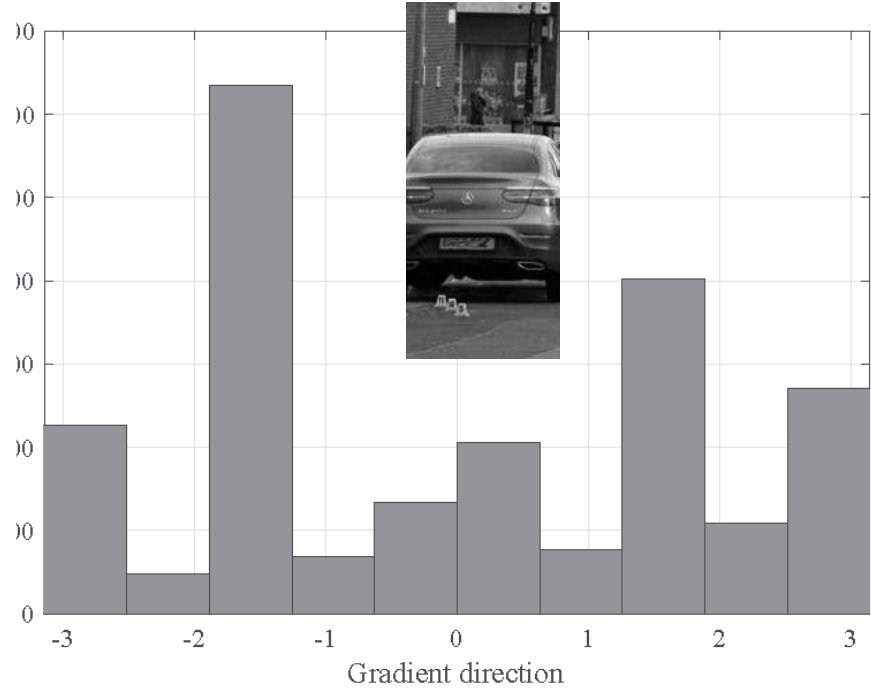
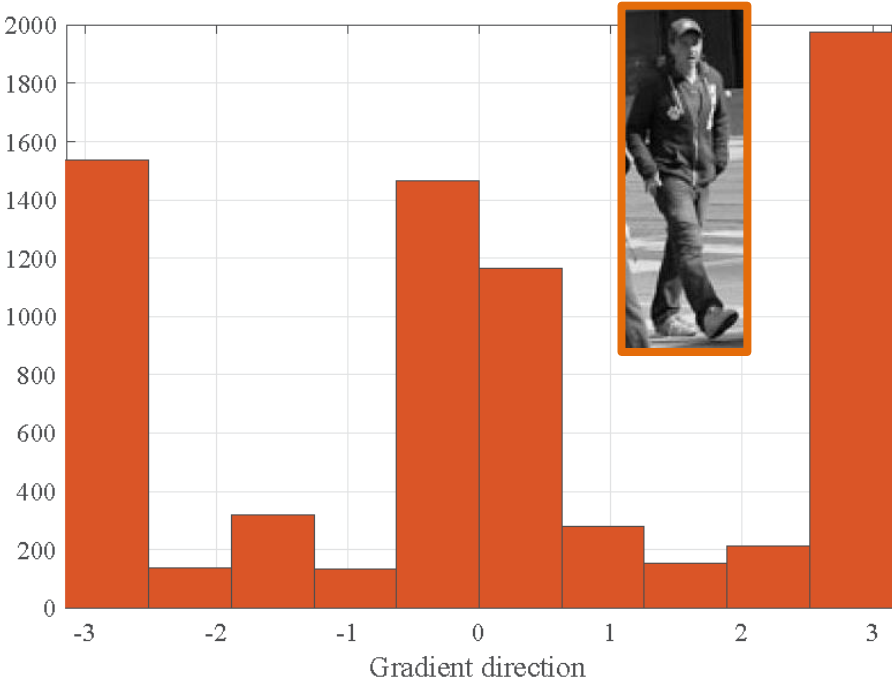
$$\angle \nabla J$$

with mag thr.

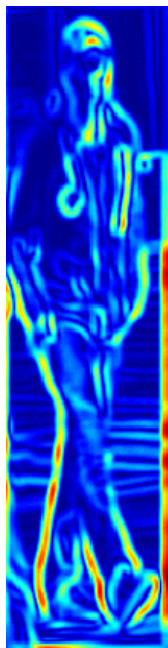
GRADIENT DISTRIBUTION (HISTOGRAM OF GRAD. DIRECTION)



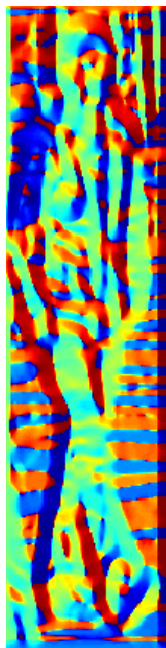
GRADIENT DISTRIBUTION (HISTOGRAM OF GRAD. DIRECTION)



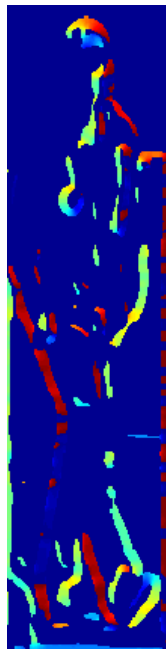
GLOBAL GRADIENTS



$$\|\nabla I\|$$

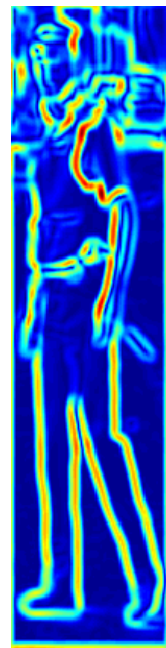
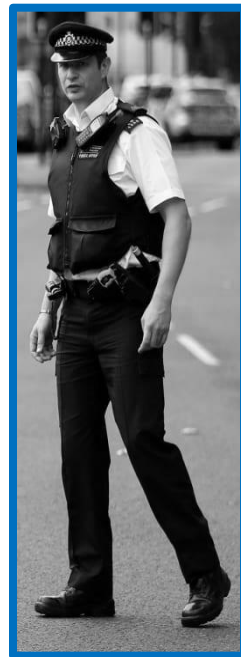


$$\angle \nabla I$$

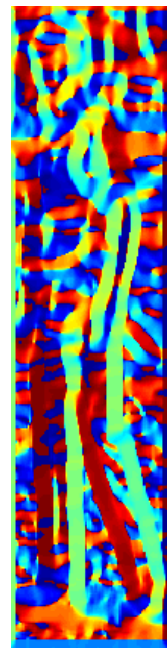


$$\angle \nabla I$$

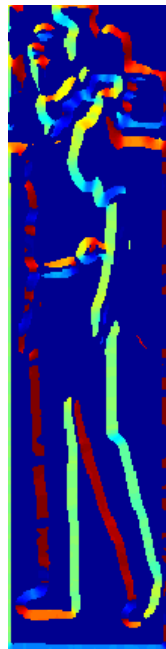
with mag thr.



$$\|\nabla J\|$$



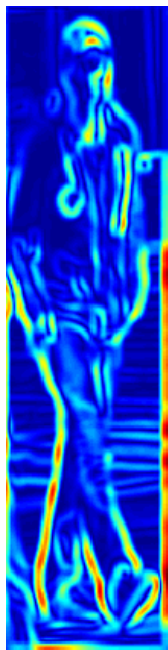
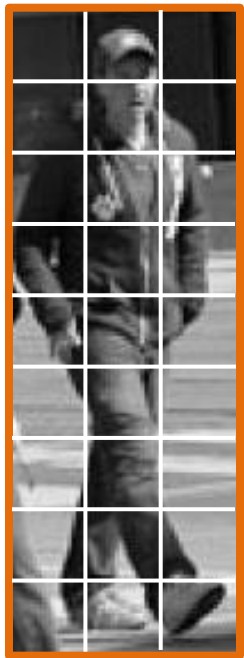
$$\angle \nabla J$$



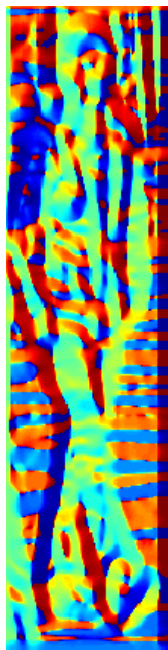
$$\angle \nabla J$$

with mag thr.

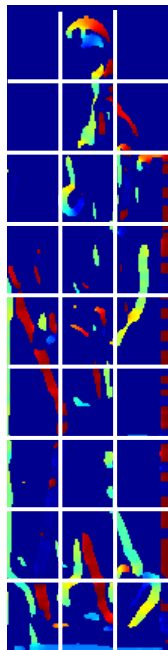
LOCAL GRADIENTS



$$\|\nabla I\|$$

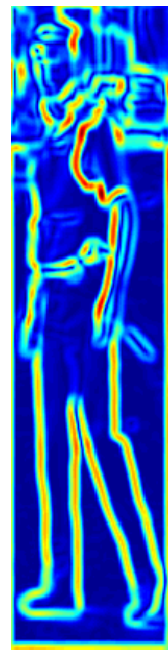
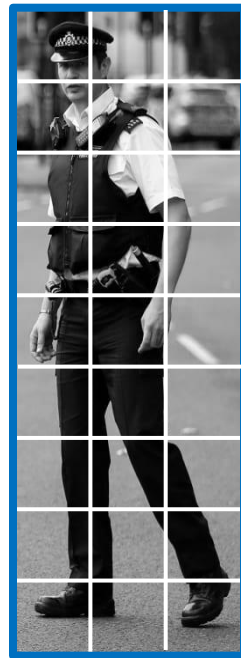


$$\angle \nabla I$$

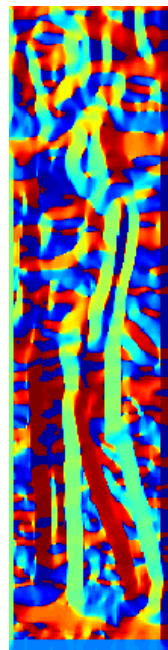


$$\angle \nabla I$$

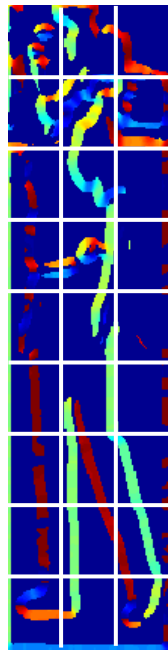
with mag thr.



$$\|\nabla J\|$$



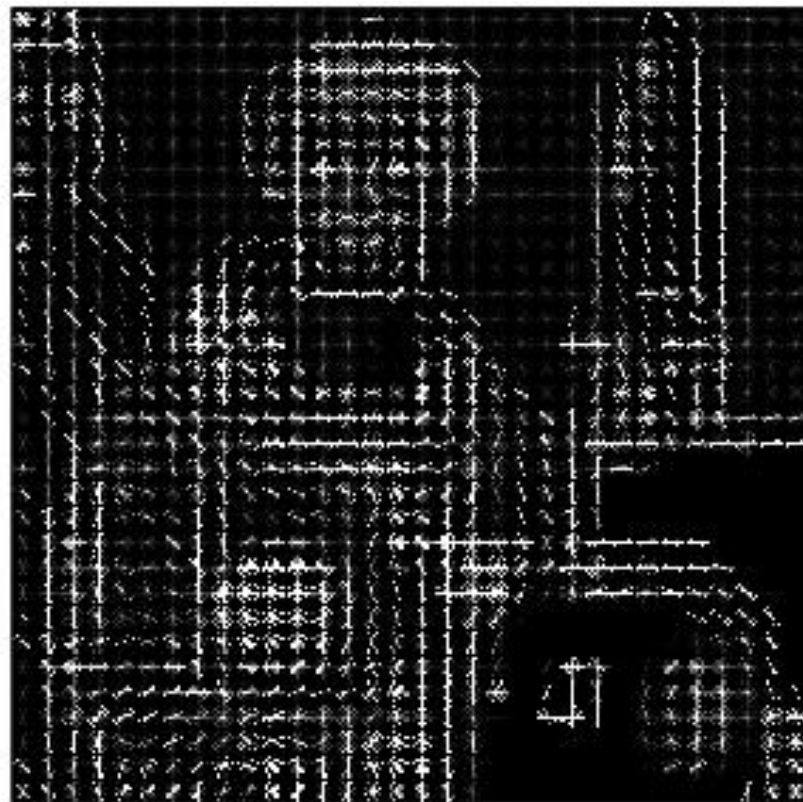
$$\angle \nabla J$$



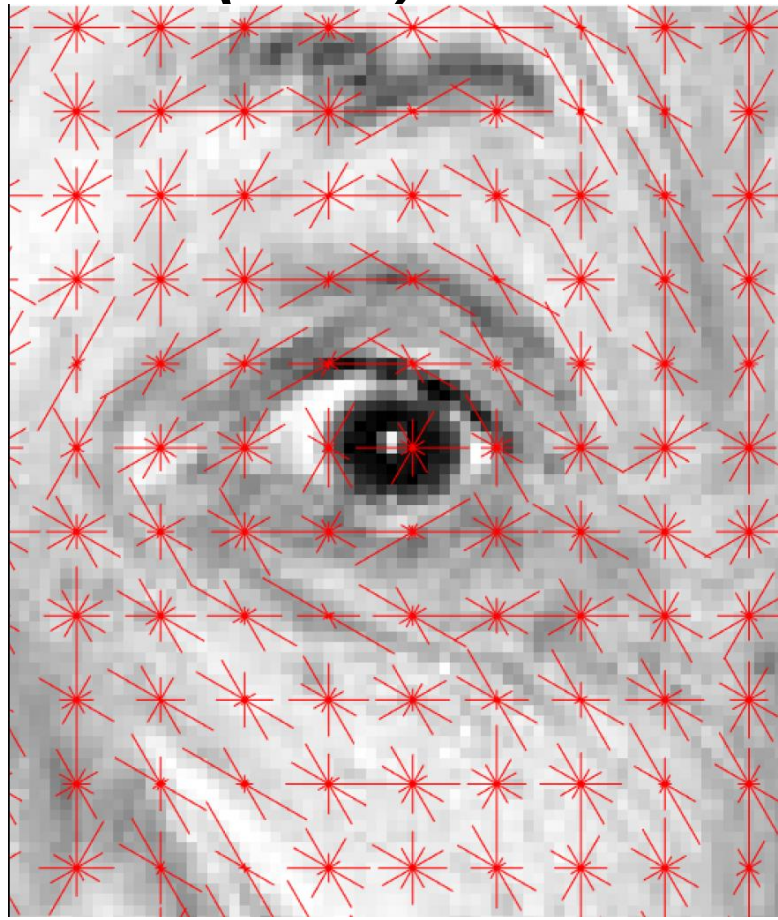
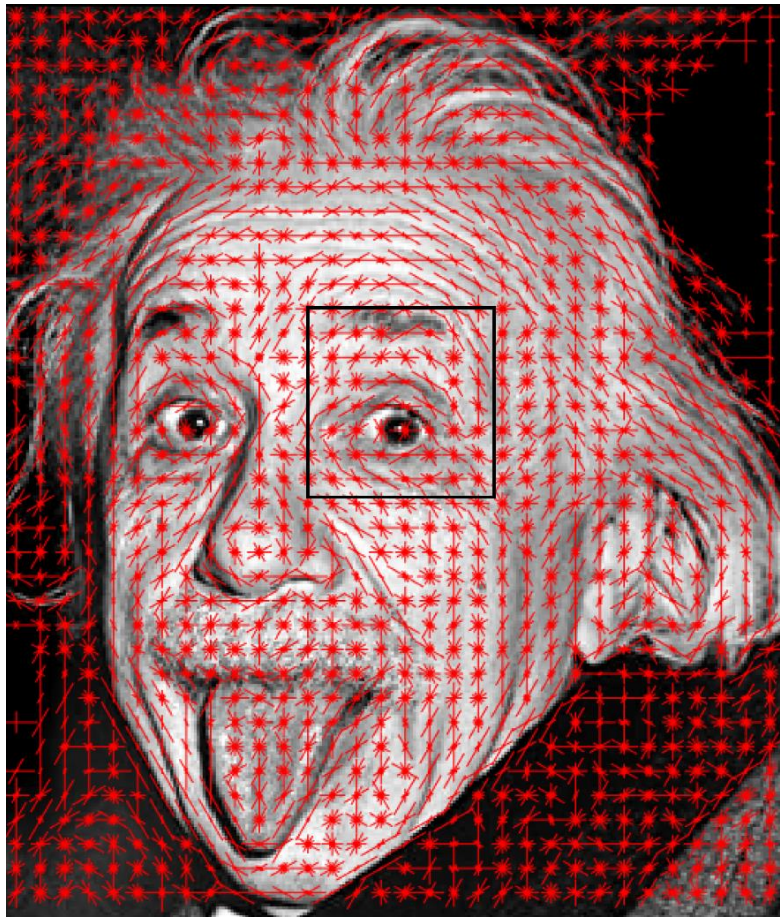
$$\angle \nabla J$$

with mag thr.

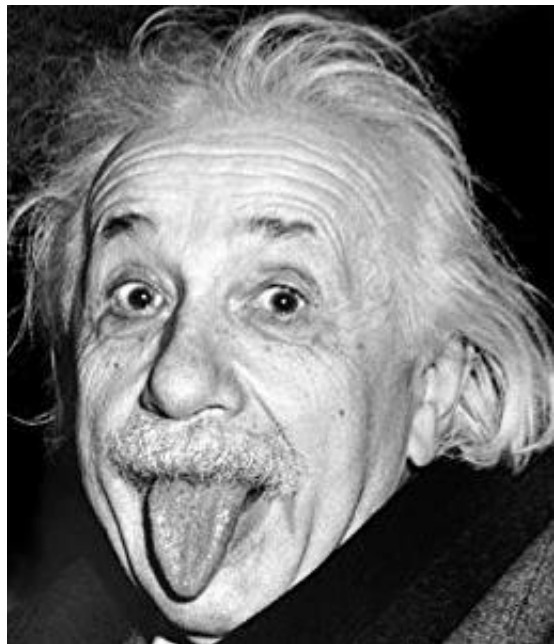
HISTOGRAM OF ORIENTED GRADIENTS (HOG)



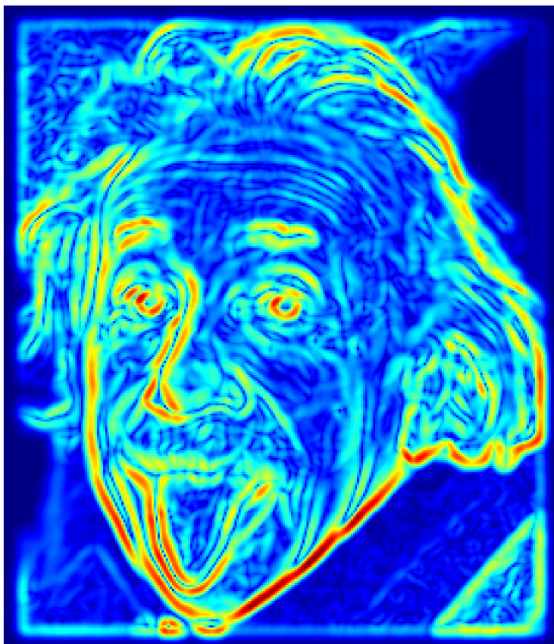
HISTOGRAM OF ORIENTED GRADIENTS (HOG)



GRADIENT IMAGE



I

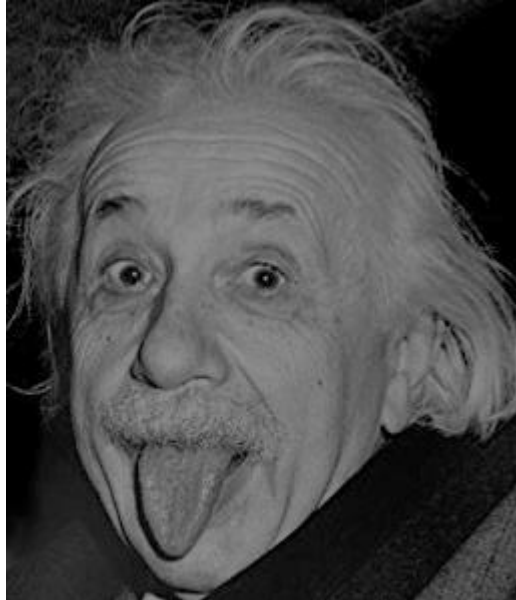


$\|\nabla I\|$

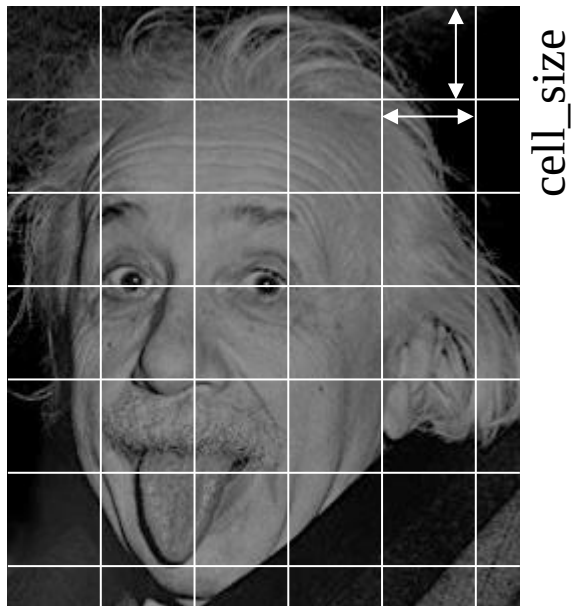


$\angle \nabla I$

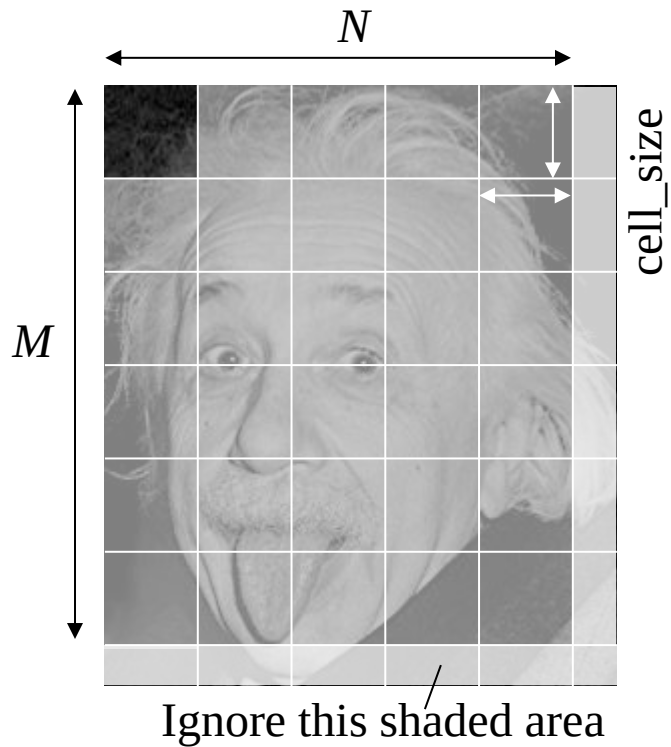
ORIENTATION BINNING



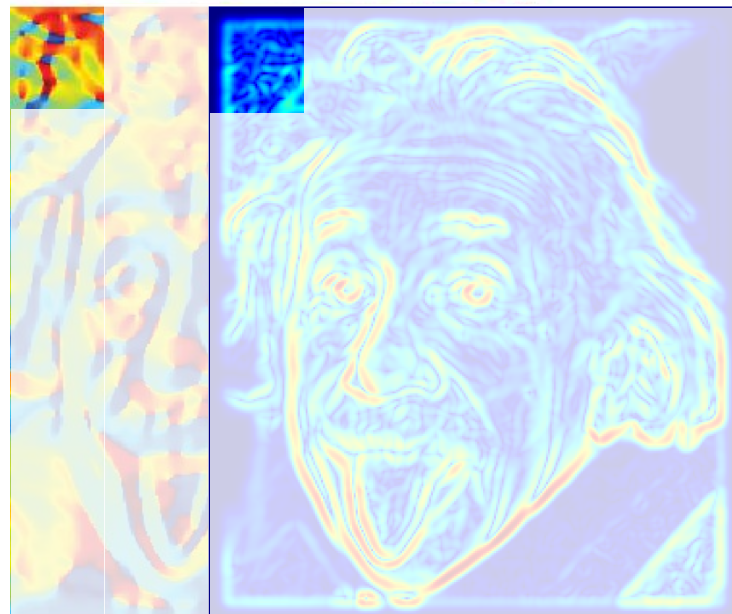
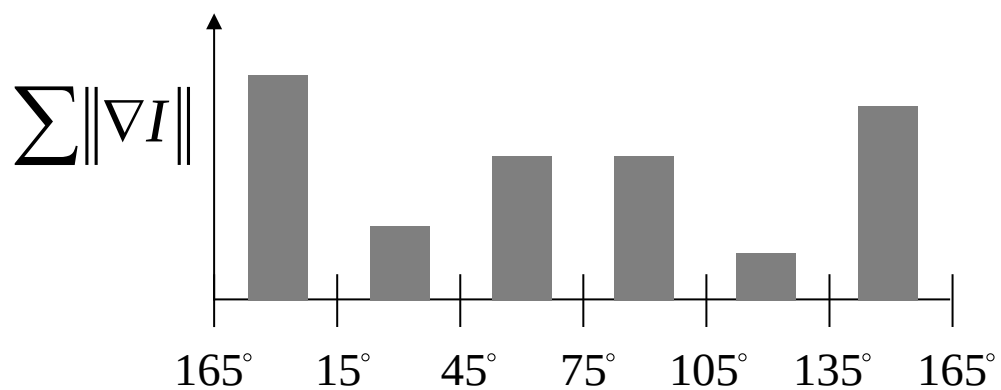
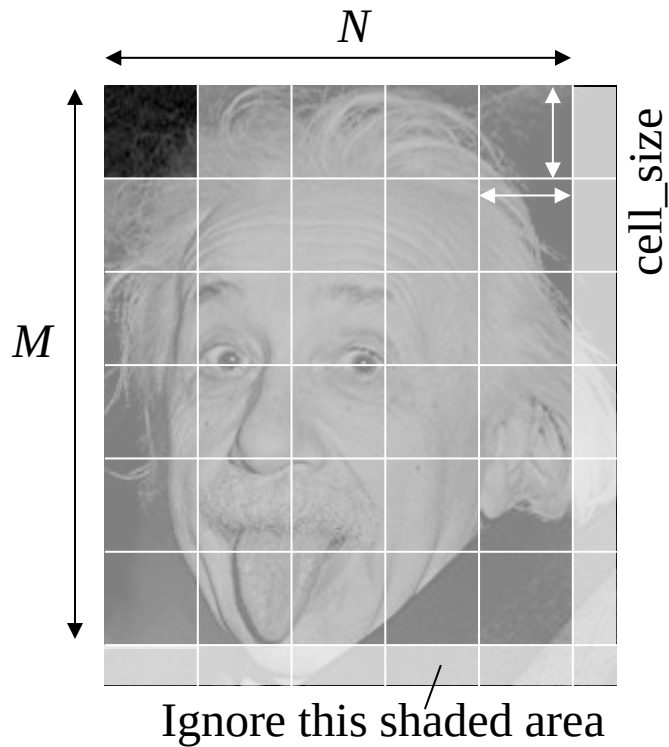
ORIENTATION BINNING



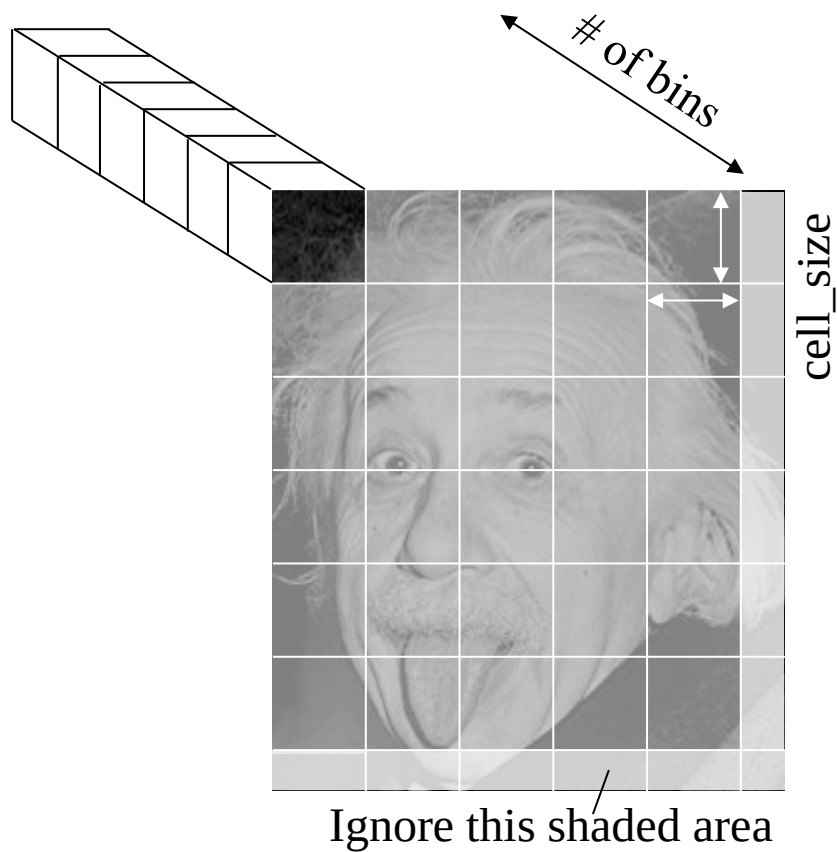
ORIENTATION BINNING



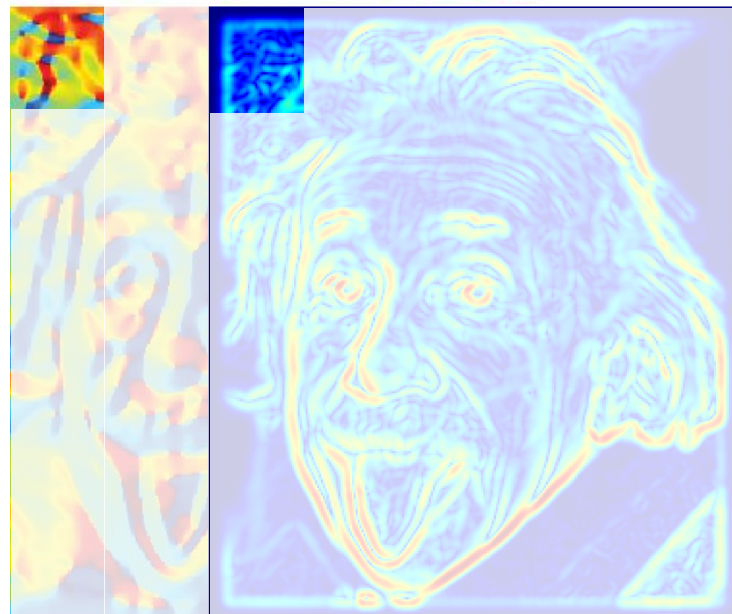
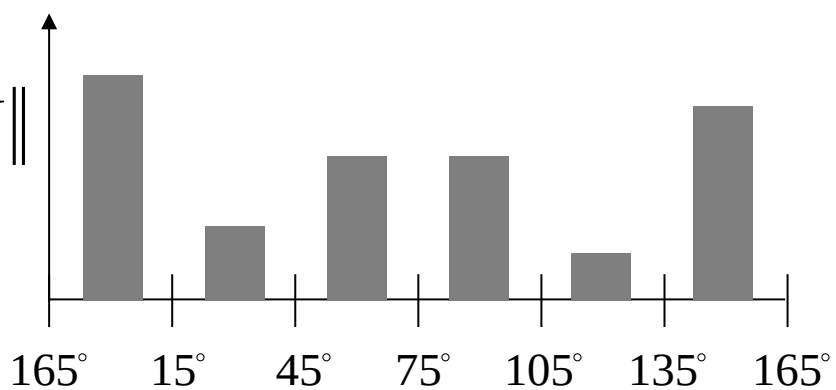
ORIENTATION BINNING



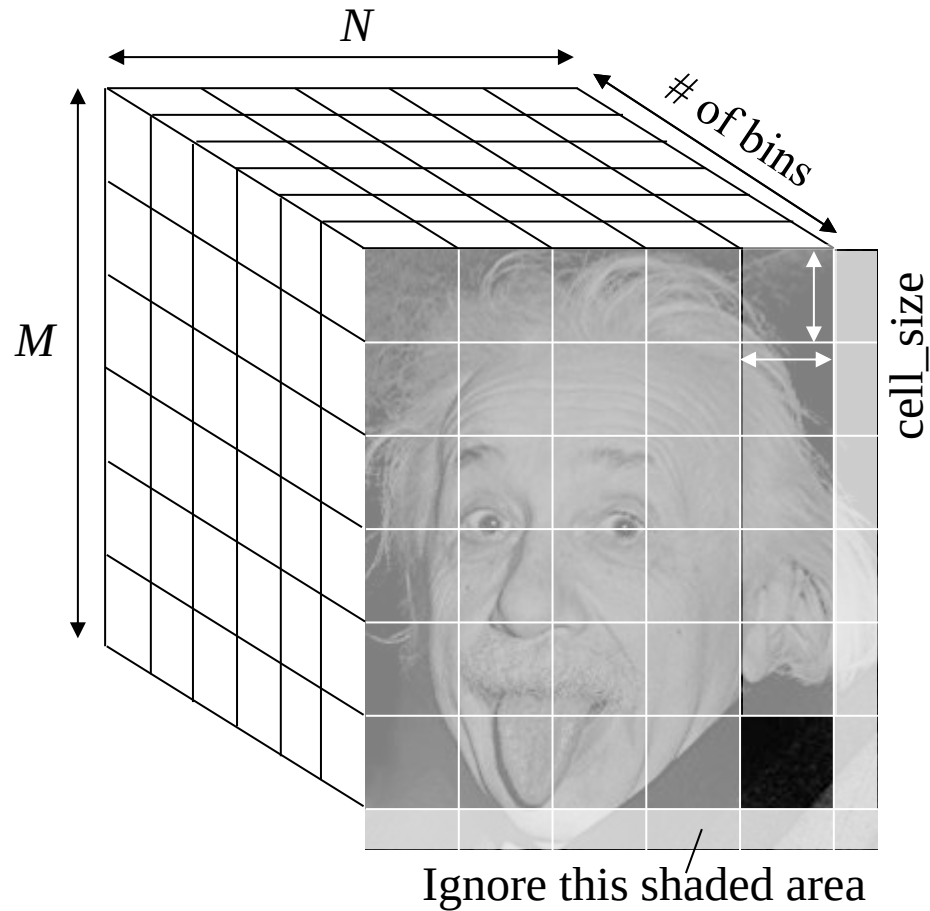
ORIENTATION BINNING



$$\sum \|\nabla I\|$$

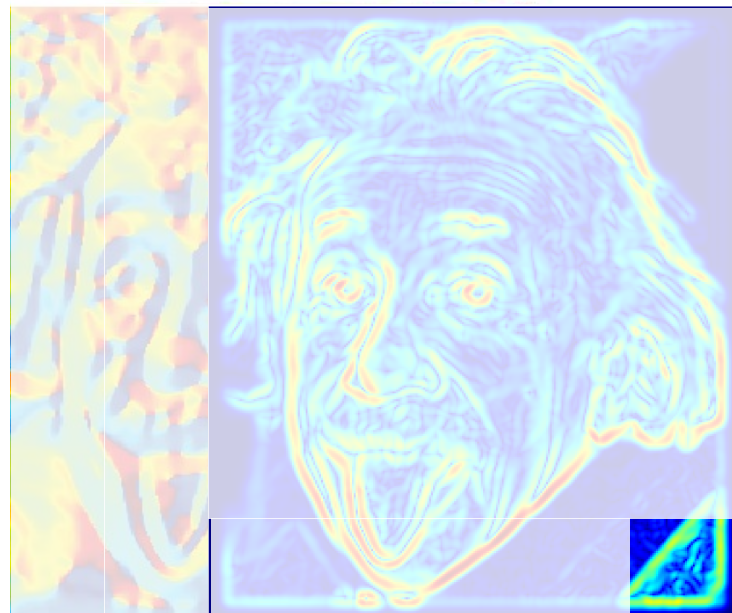


ORIENTATION BINNING

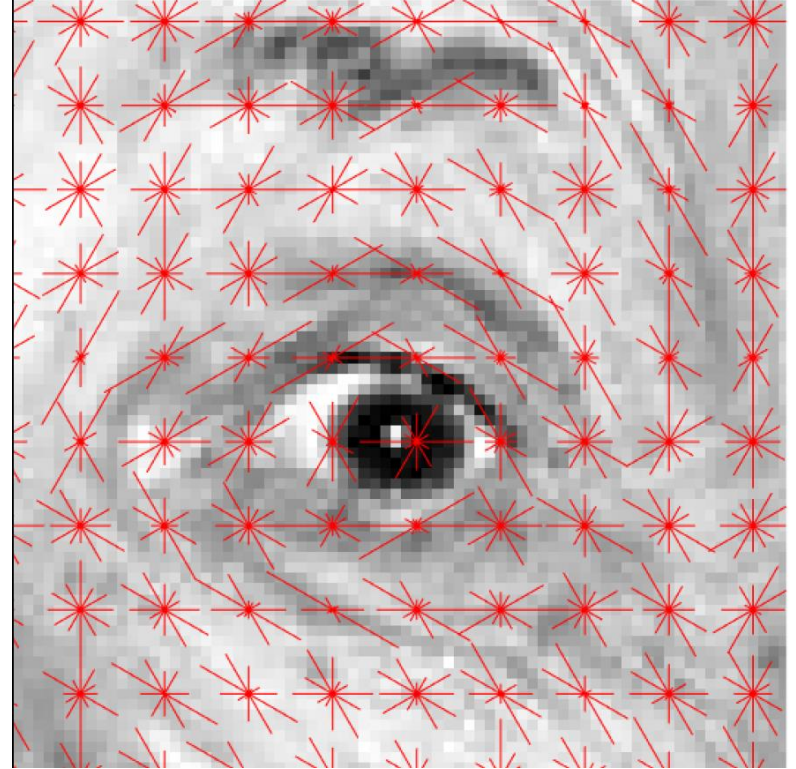
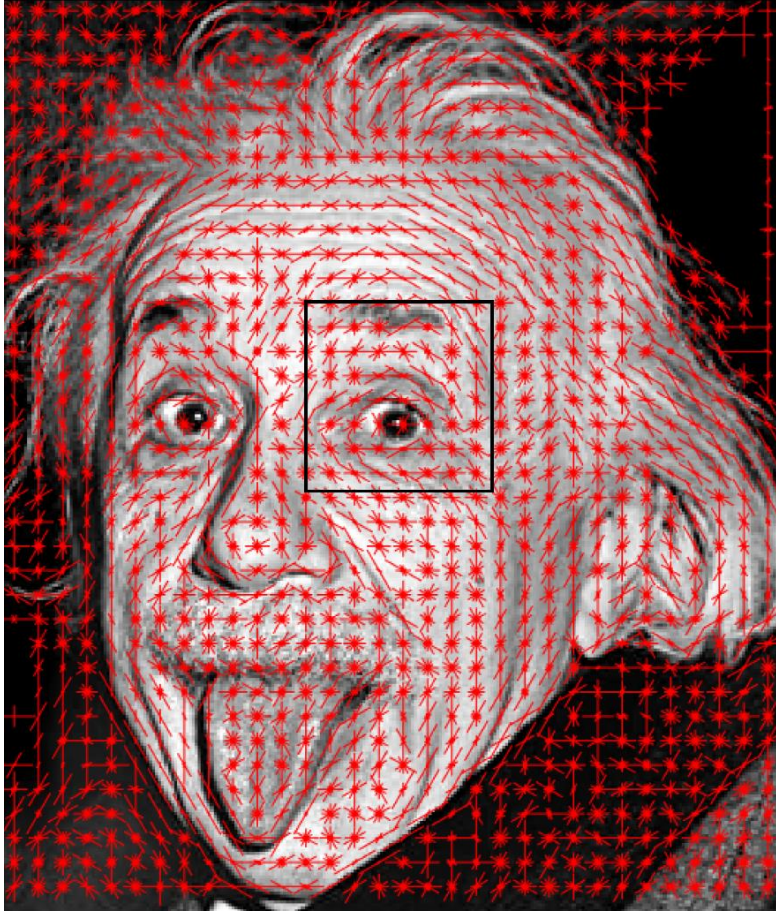


$$\sum \|\nabla I\|$$

165° 15° 45° 75° 105° 135° 165°

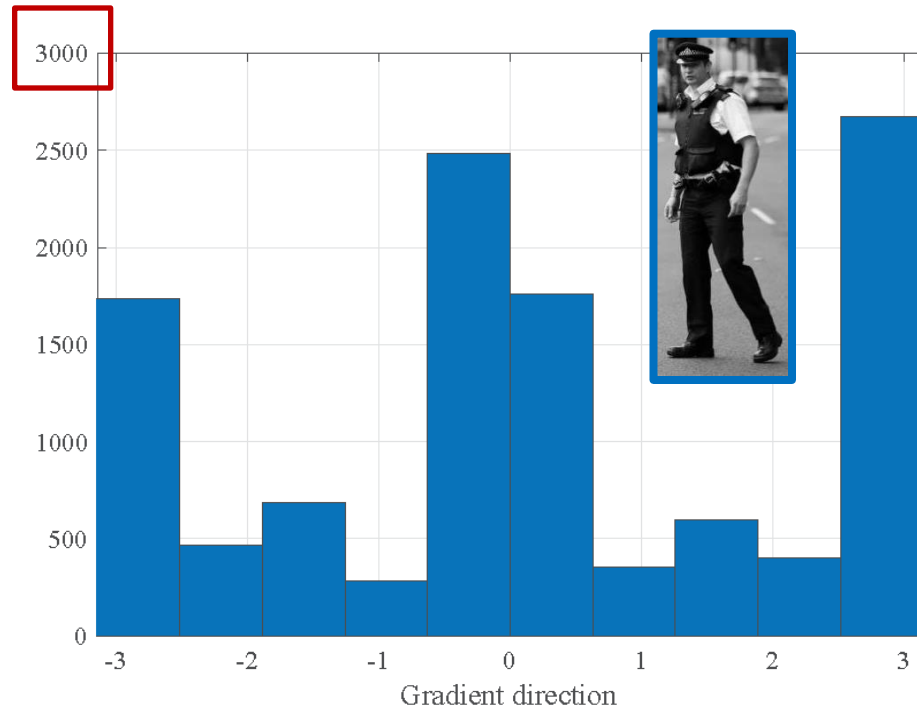
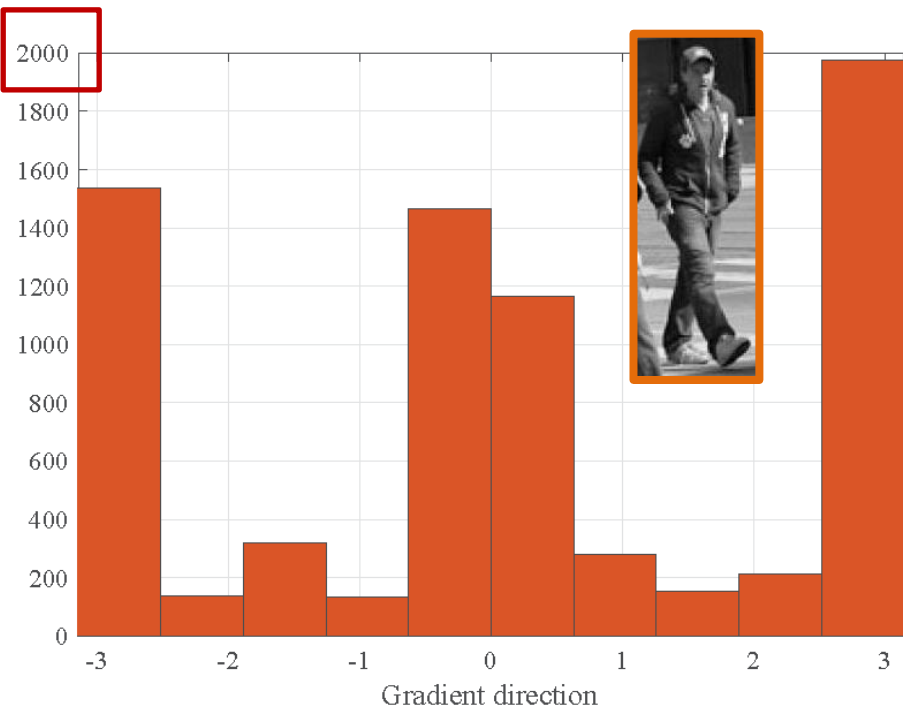


HISTOGRAM OF ORIENTED GRADIENTS (HOG)

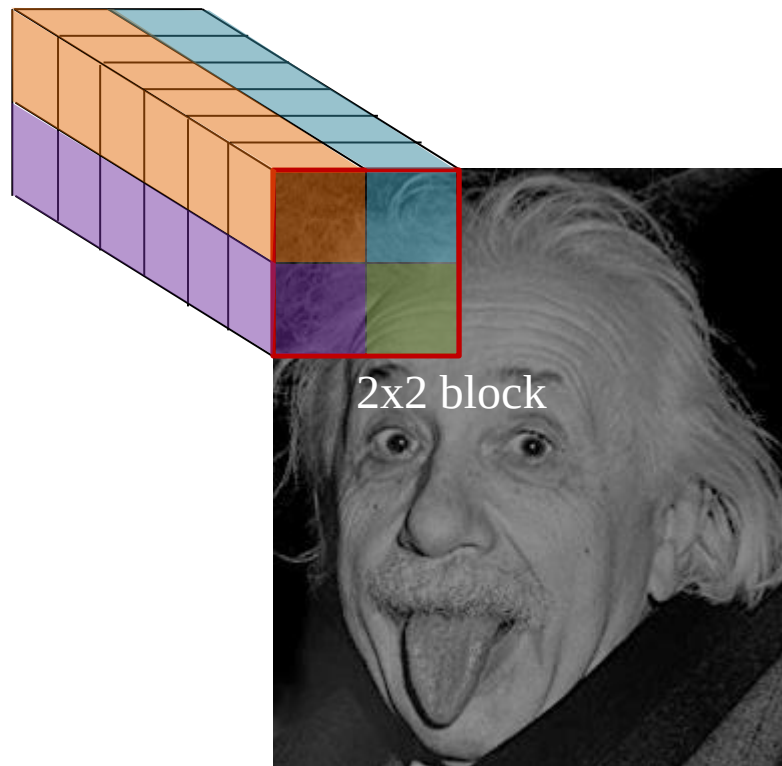
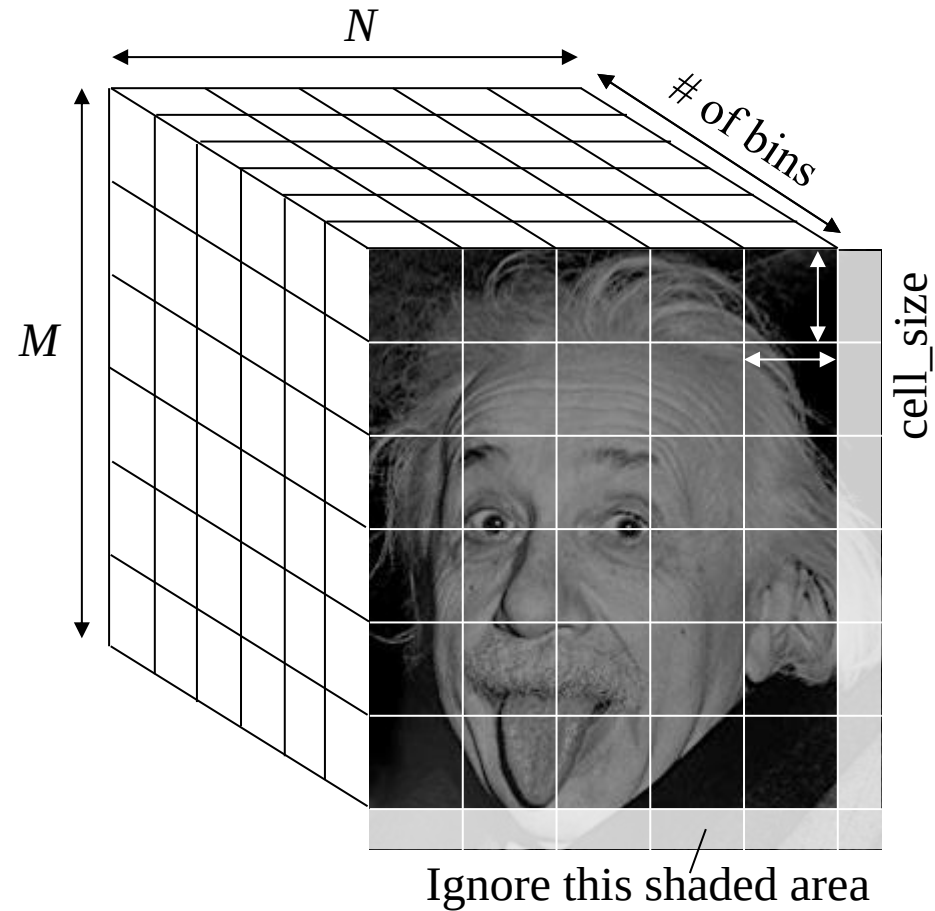


For visualization purpose, line perpendicular to the gradient directions are drawn.

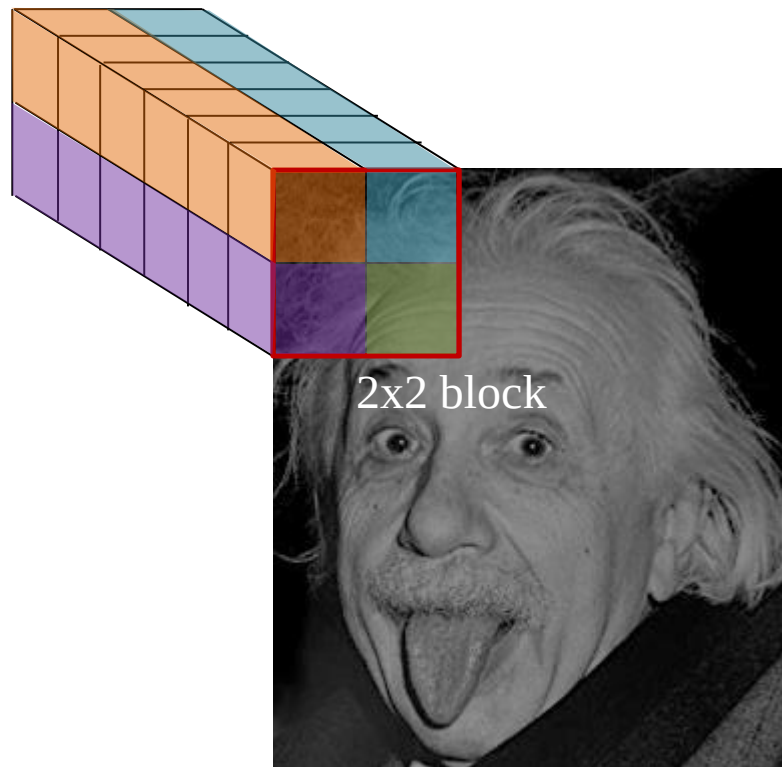
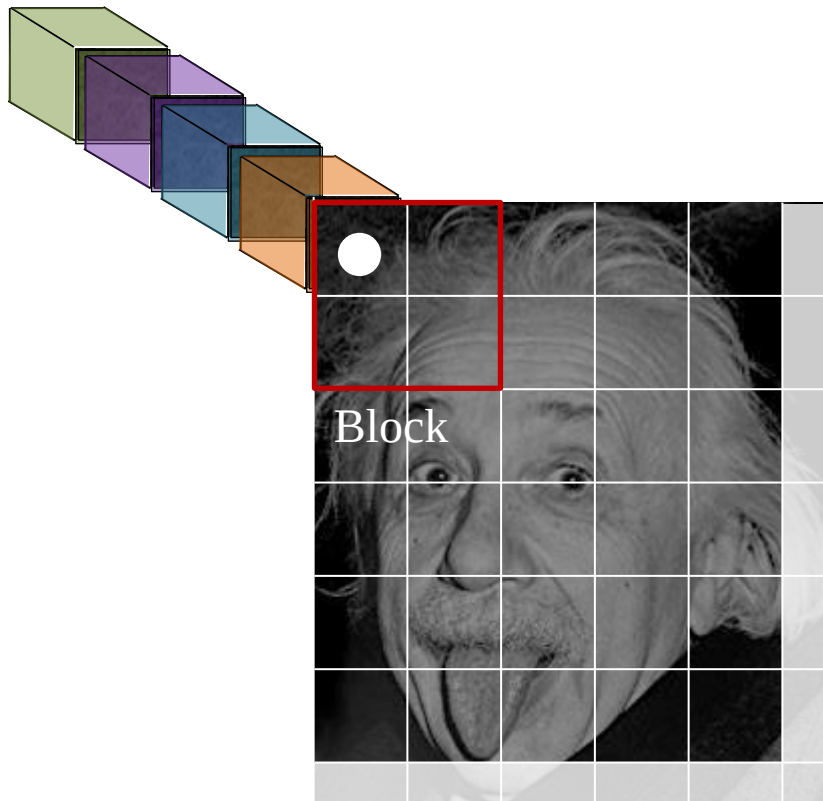
RECALL: SCALE



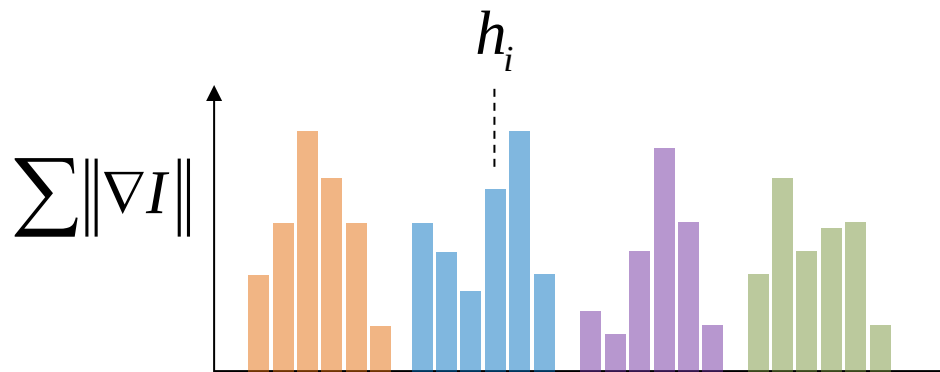
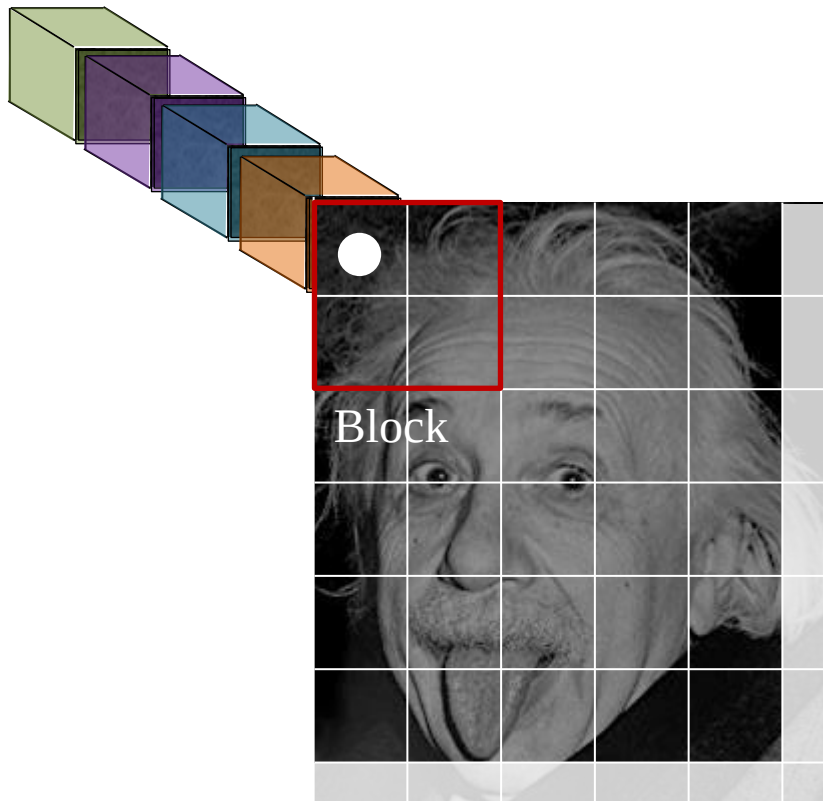
BLOCK NORMALIZATION



BLOCK NORMALIZATION

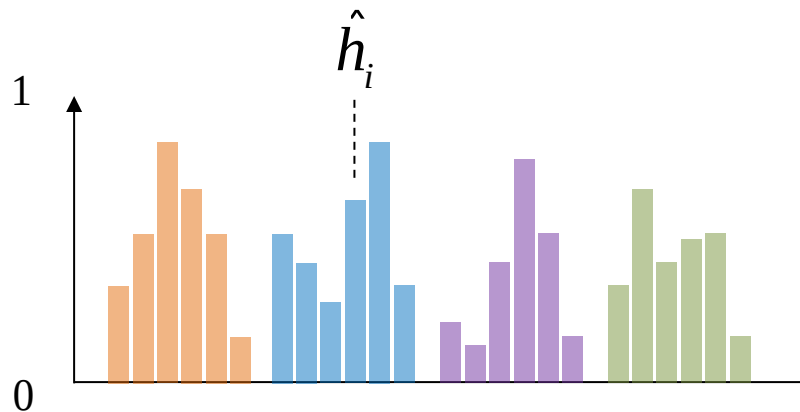
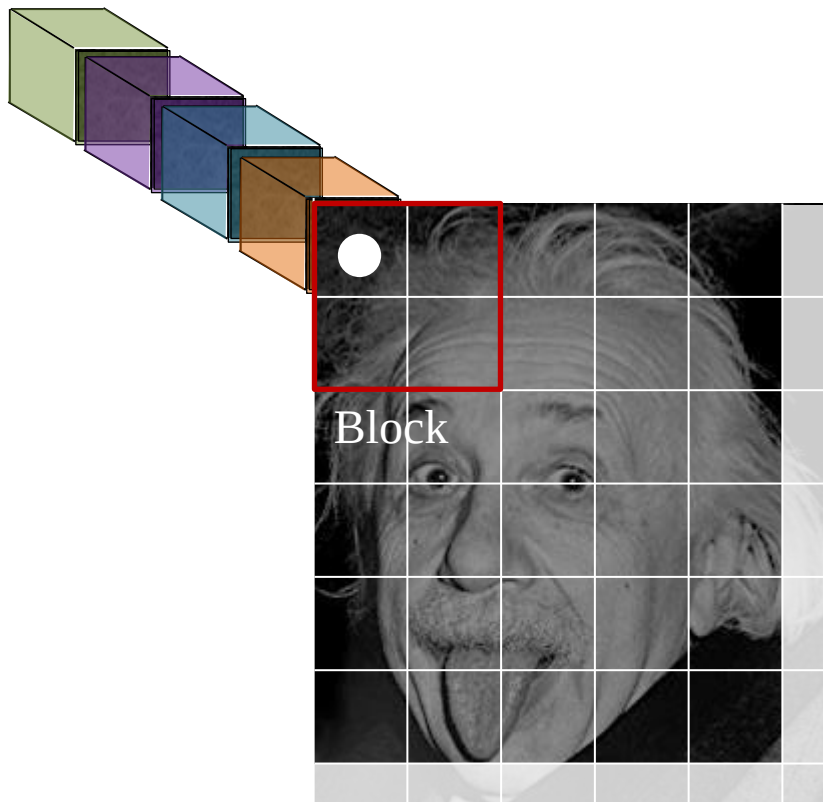


BLOCK NORMALIZATION



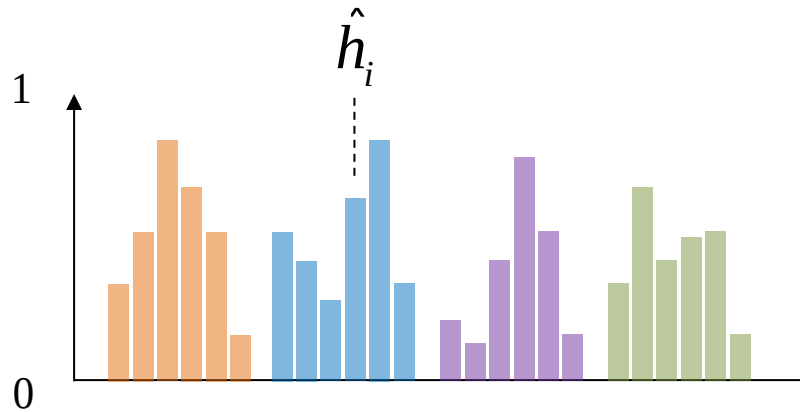
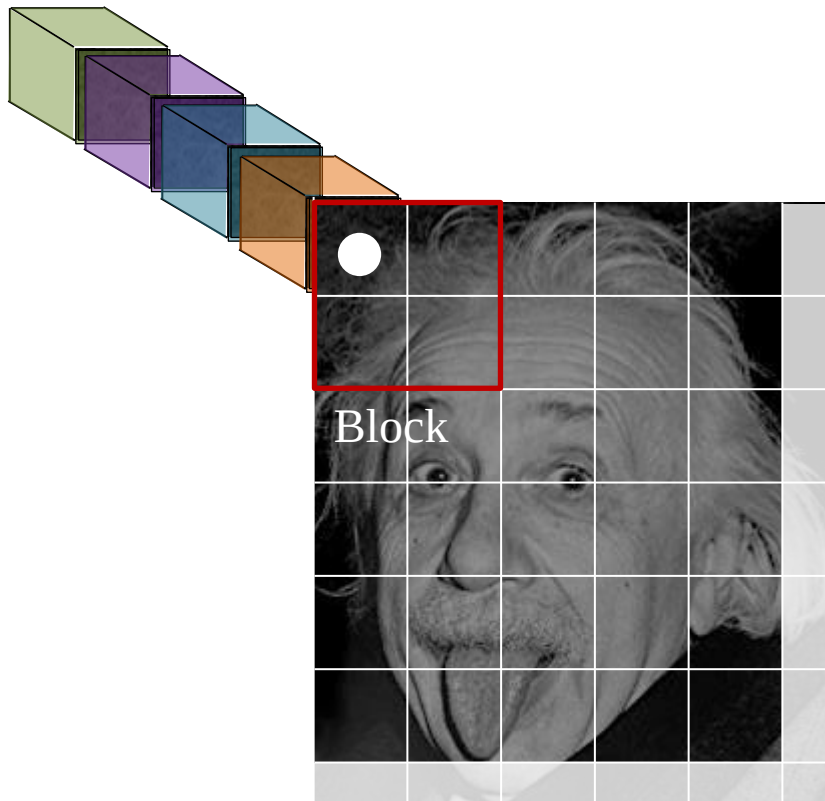
$$\hat{h}_i = \frac{h_i}{\sqrt{\sum_i h_i^2}}$$

BLOCK NORMALIZATION



$$\hat{h}_i = \frac{h_i}{\sqrt{\sum_i h_i^2}}$$

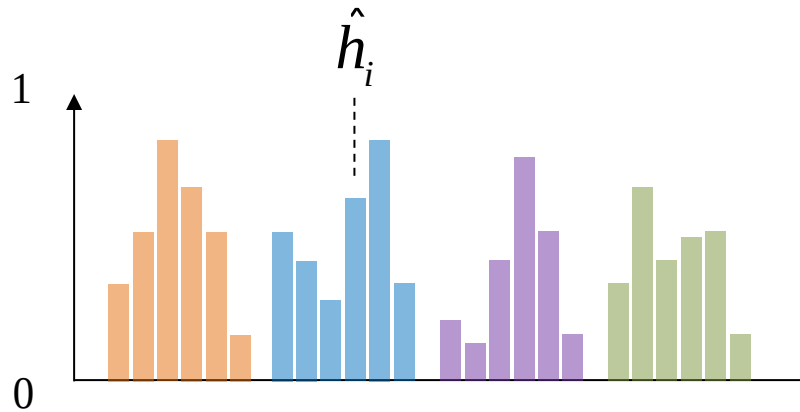
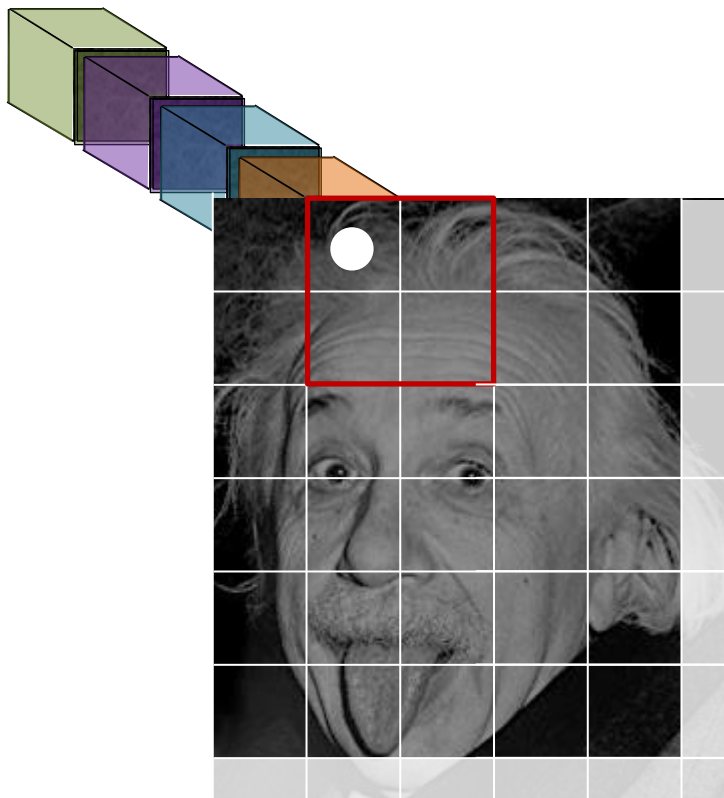
BLOCK NORMALIZATION



$$\hat{h}_i = \frac{h_i}{\sqrt{\sum_i h_i^2 + e^2}}$$

Preventing division by zero

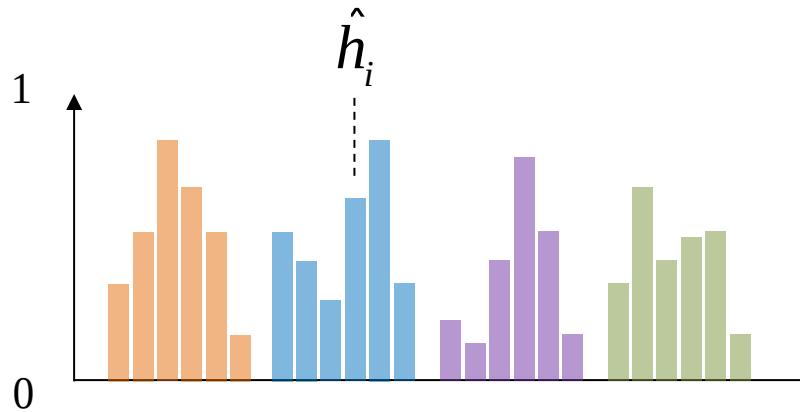
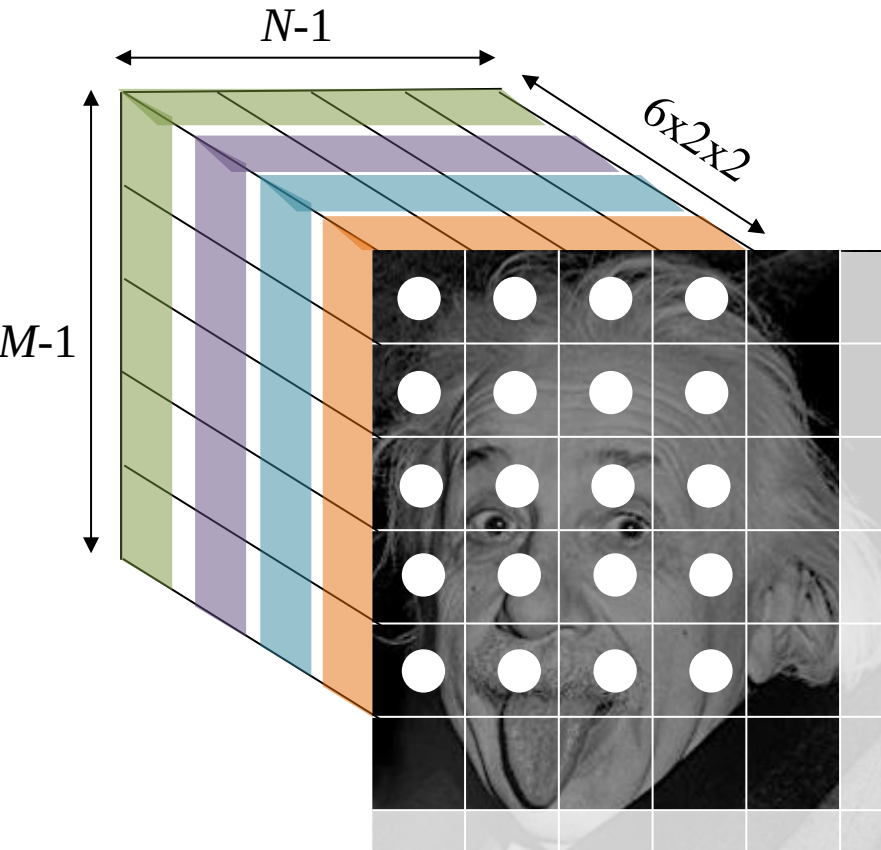
BLOCK NORMALIZATION



$$\hat{h}_i = \frac{h_i}{\sqrt{\sum_i h_i^2 + e^2}}$$

Preventing division by zero

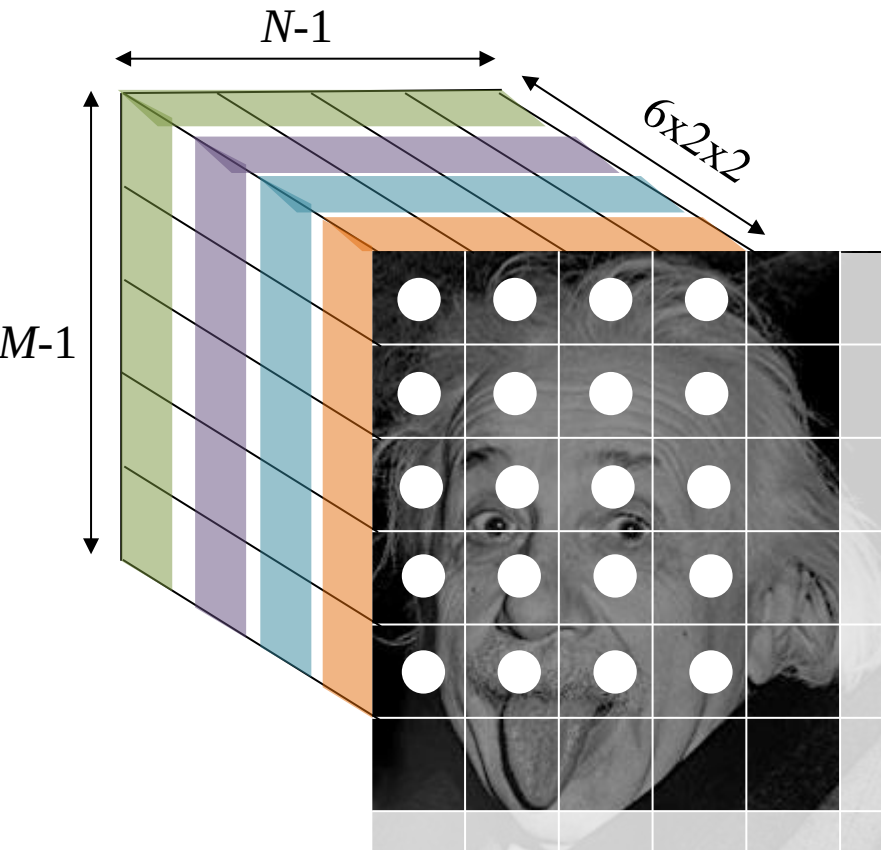
BLOCK NORMALIZATION



$$\hat{h}_i = \frac{h_i}{\sqrt{\sum_i h_i^2 + e^2}}$$

Preventing division by zero

VECTORIZATION

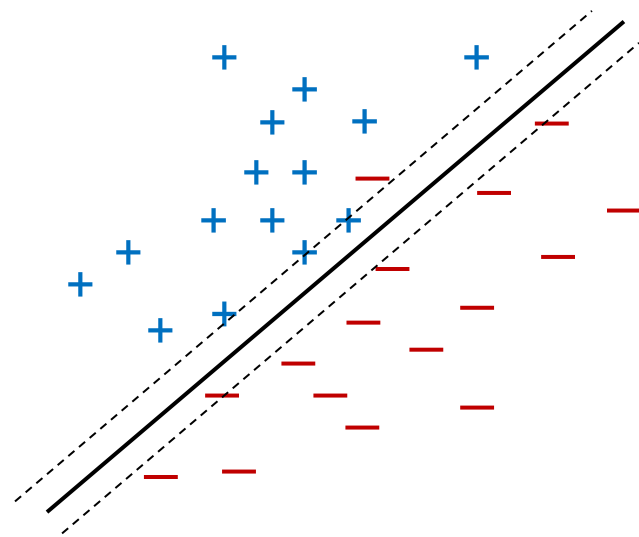


$\mathbf{X} =$



Feature descriptor of image I

OBJECT RECOGNITION WITH HOG

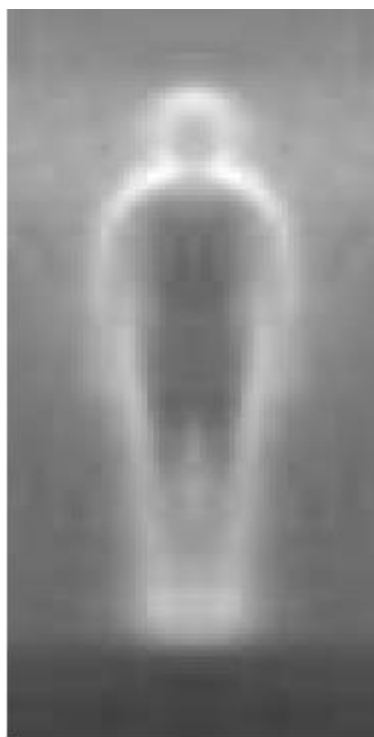


Max margin SVM classifier

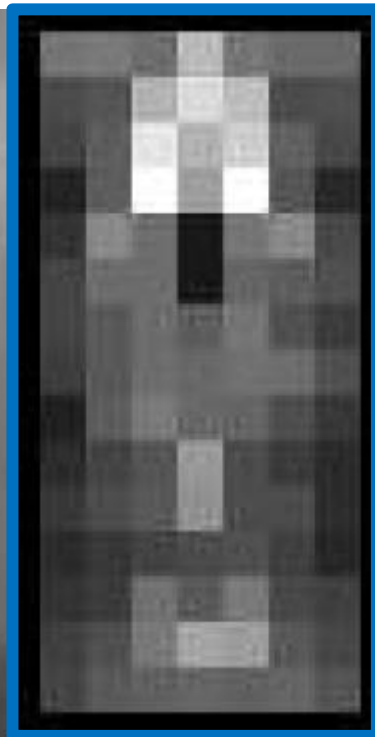
$$\mathbf{x} \cdot \mathbf{w} + \mathbf{b} > 0 \quad \text{Positive D.}$$

$$\mathbf{x} \cdot \mathbf{w} + \mathbf{b} < 0 \quad \text{Negative D.}$$

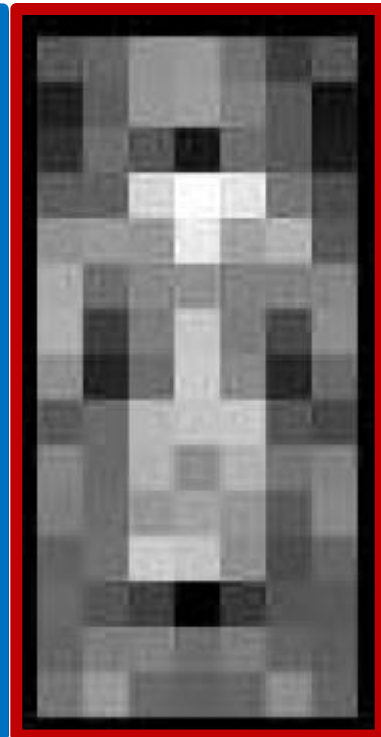
OBJECT RECOGNITION WITH HOG



Average pedestrian

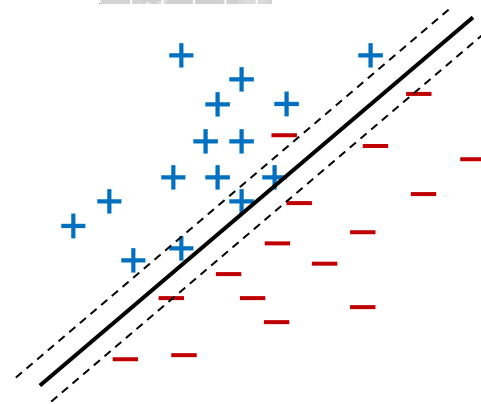
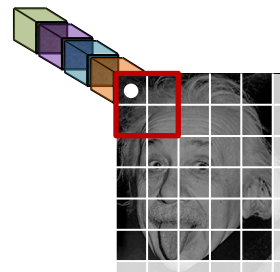


Positive



Negative

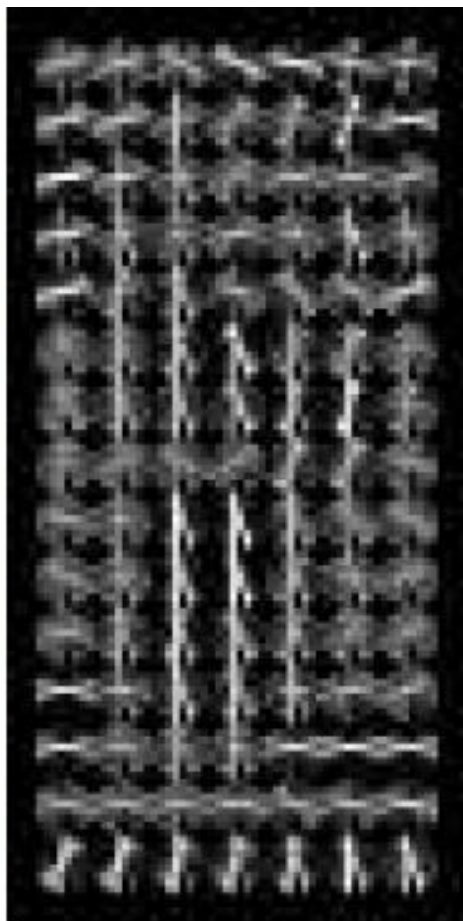
Maximum +/- SVM weight on each block



Max margin SVM classifier

$$\mathbf{x} \cdot \mathbf{w} + \mathbf{b} > 0 \quad \text{Positive D.}$$

$$\mathbf{x} \cdot \mathbf{w} + \mathbf{b} < 0 \quad \text{Negative D.}$$



HOG

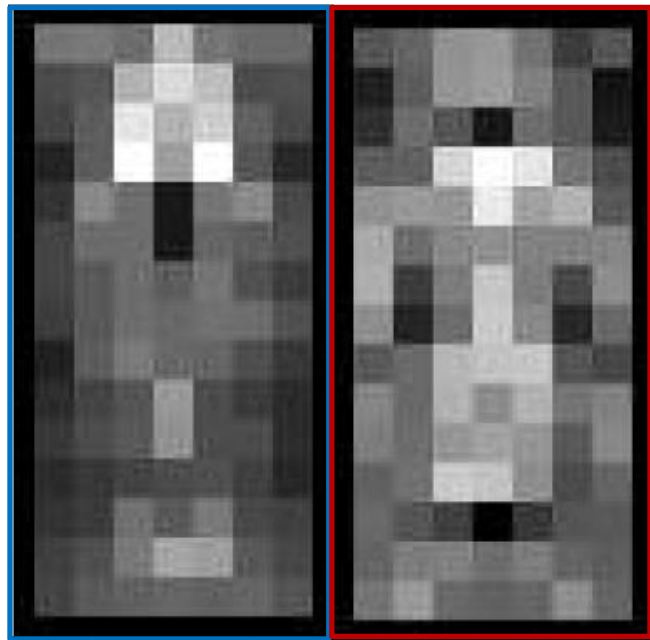


HOG weighted by
pos. SVM weight

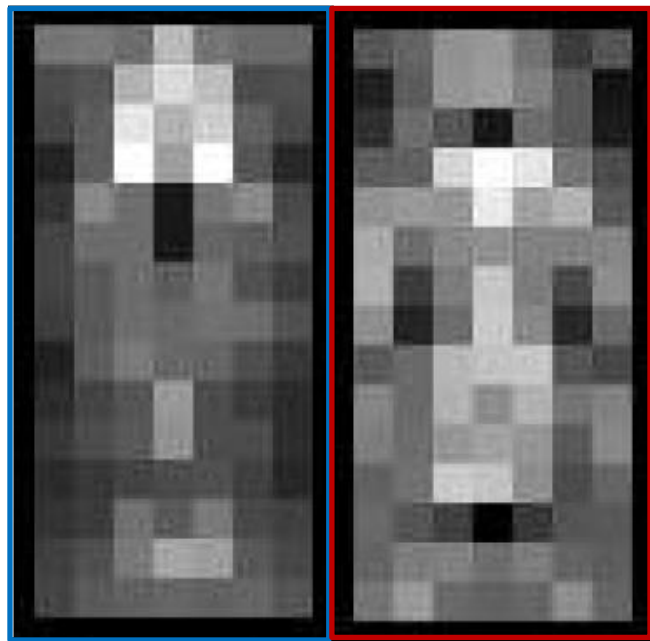


HOG weighted by
neg. SVM weight

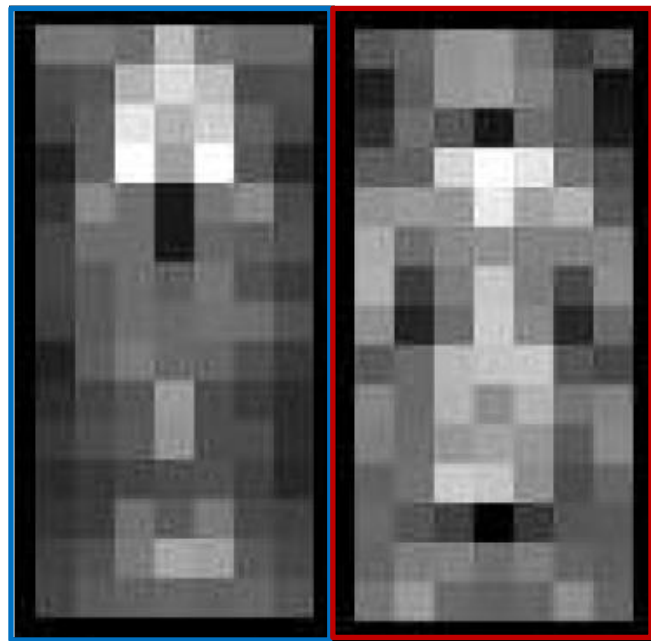
OBJECT RECOGNITION WITH HOG



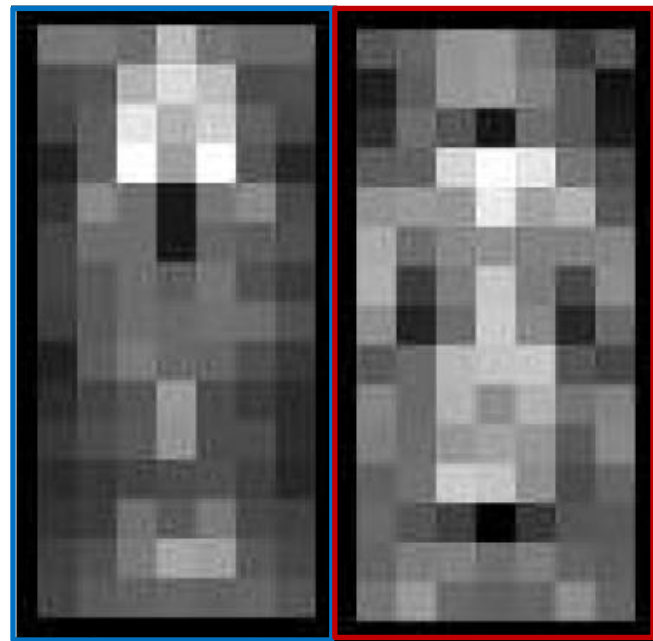
OBJECT RECOGNITION WITH HOG

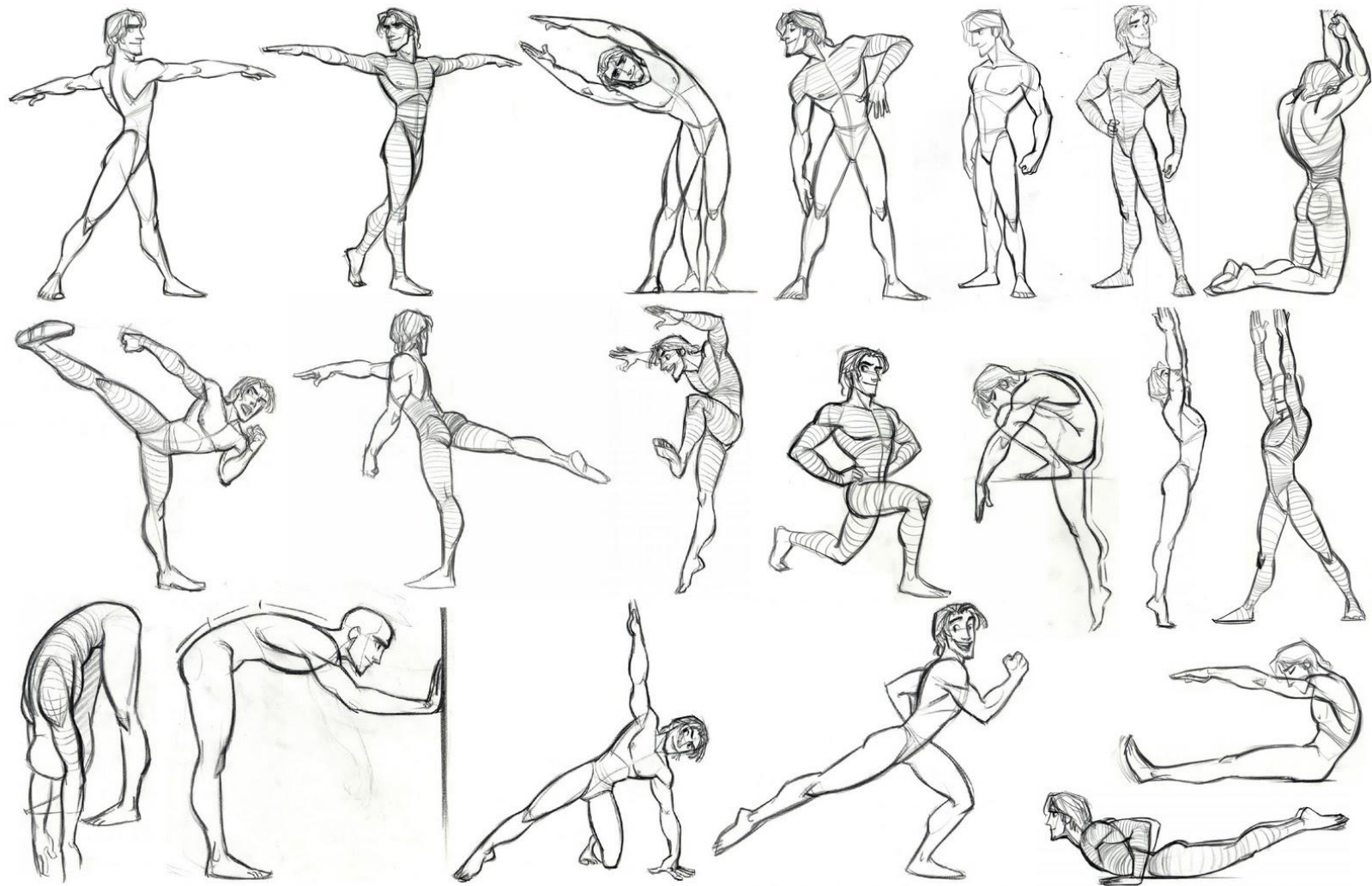


OBJECT RECOGNITION WITH HOG

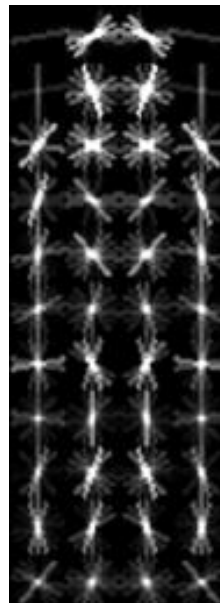
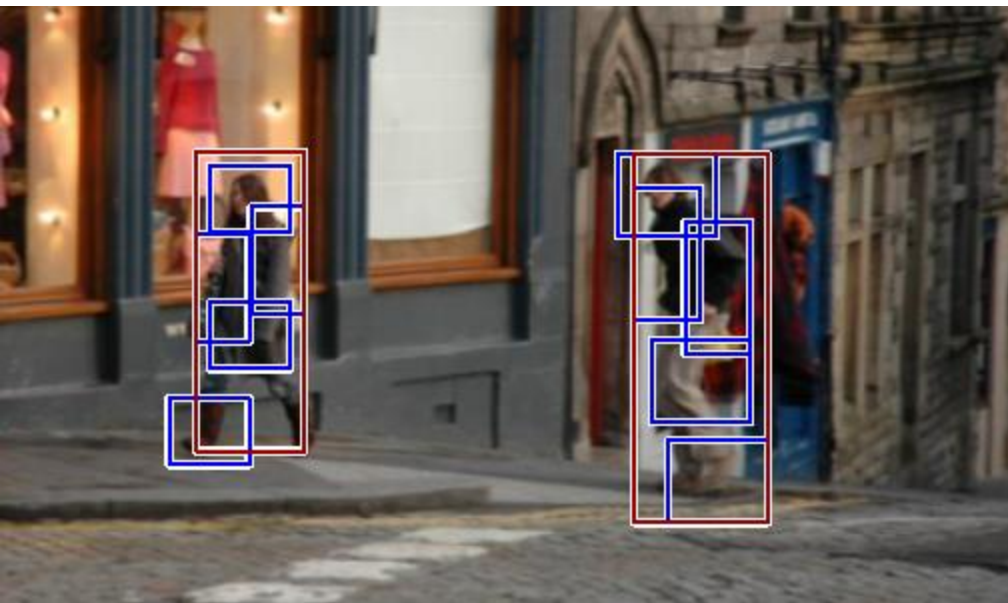


OBJECT RECOGNITION WITH HOG





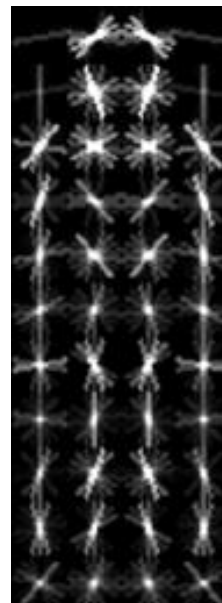
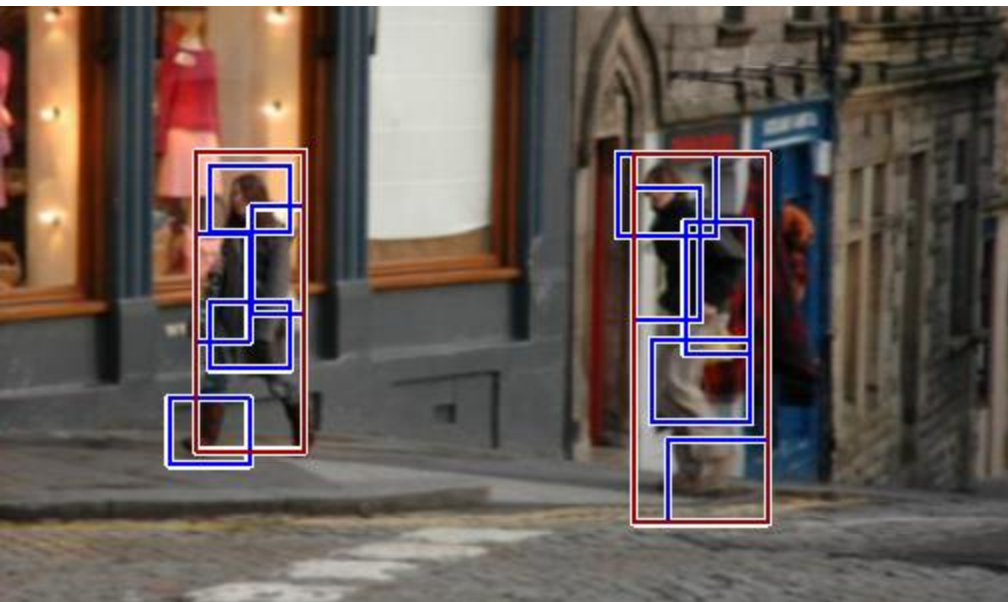
HOG EXTENSION: DEFORMABLE PART MODEL (DPM)



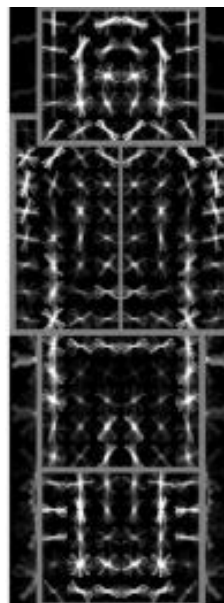
Root filter



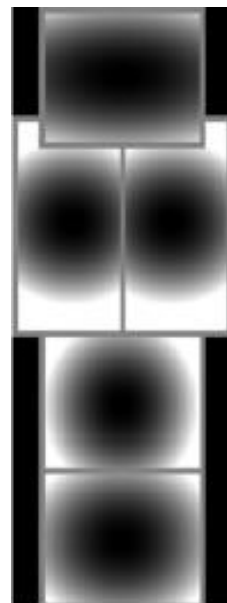
HOG EXTENSION: DEFORMABLE PART MODEL (DPM)



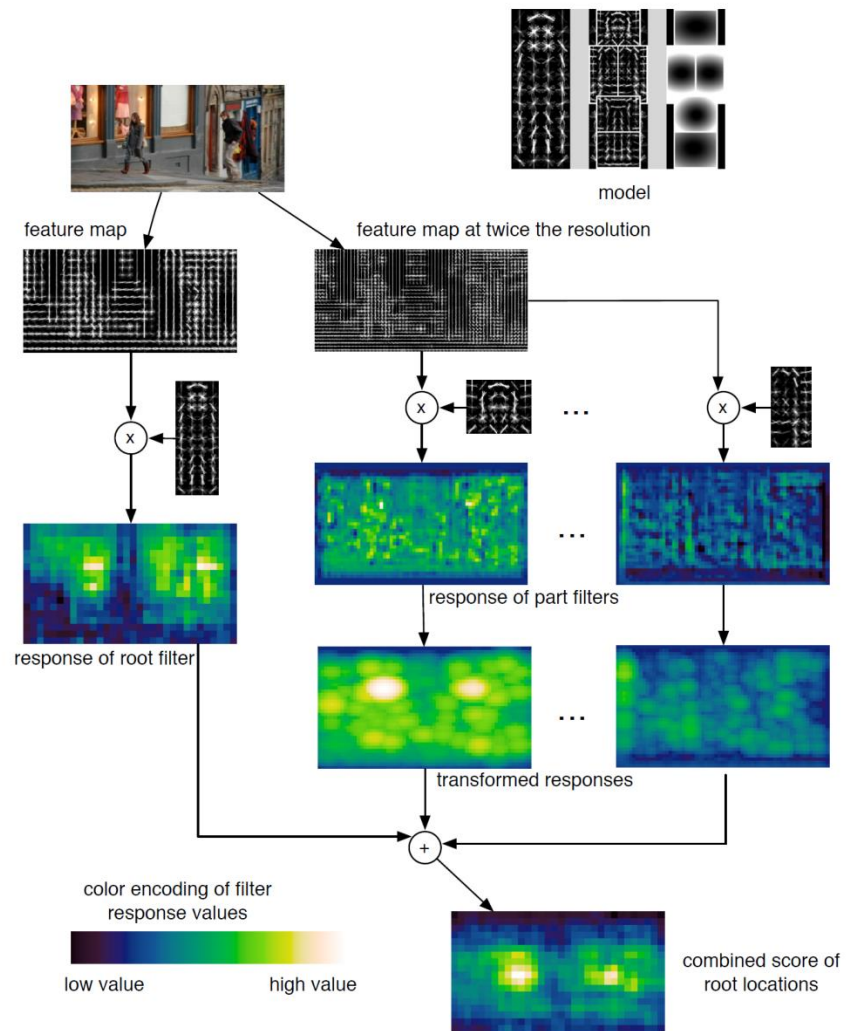
Root filter



Part desc.

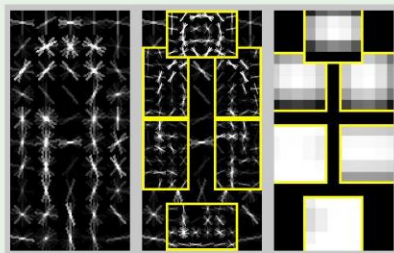


Deformation

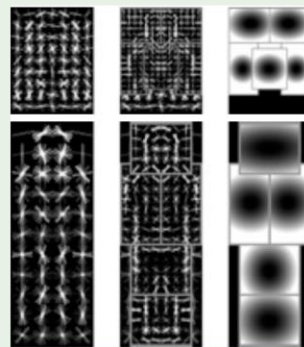




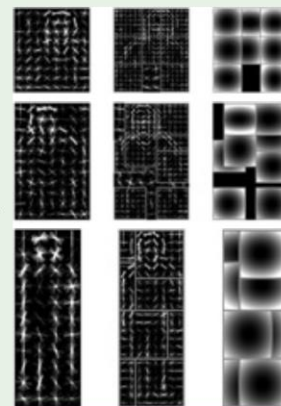
[DT'05]
AP 0.12



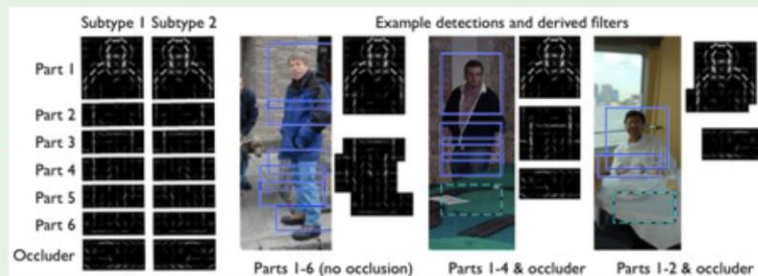
[FMR'08]
AP 0.27



[FGMR'10]
AP 0.36



[GFM voc-release5]
AP 0.45



[GFM'11]
AP 0.49

AUTONOMOUS DRIVING

Vehicle and pedestrian detection (HOG+SVM)

<https://www.youtube.com/watch?v=itmV7druy9Y>

<https://www.youtube.com/watch?v=NpjixVTNmyw>

<https://www.youtube.com/watch?v=XRYFqd8ygXI>