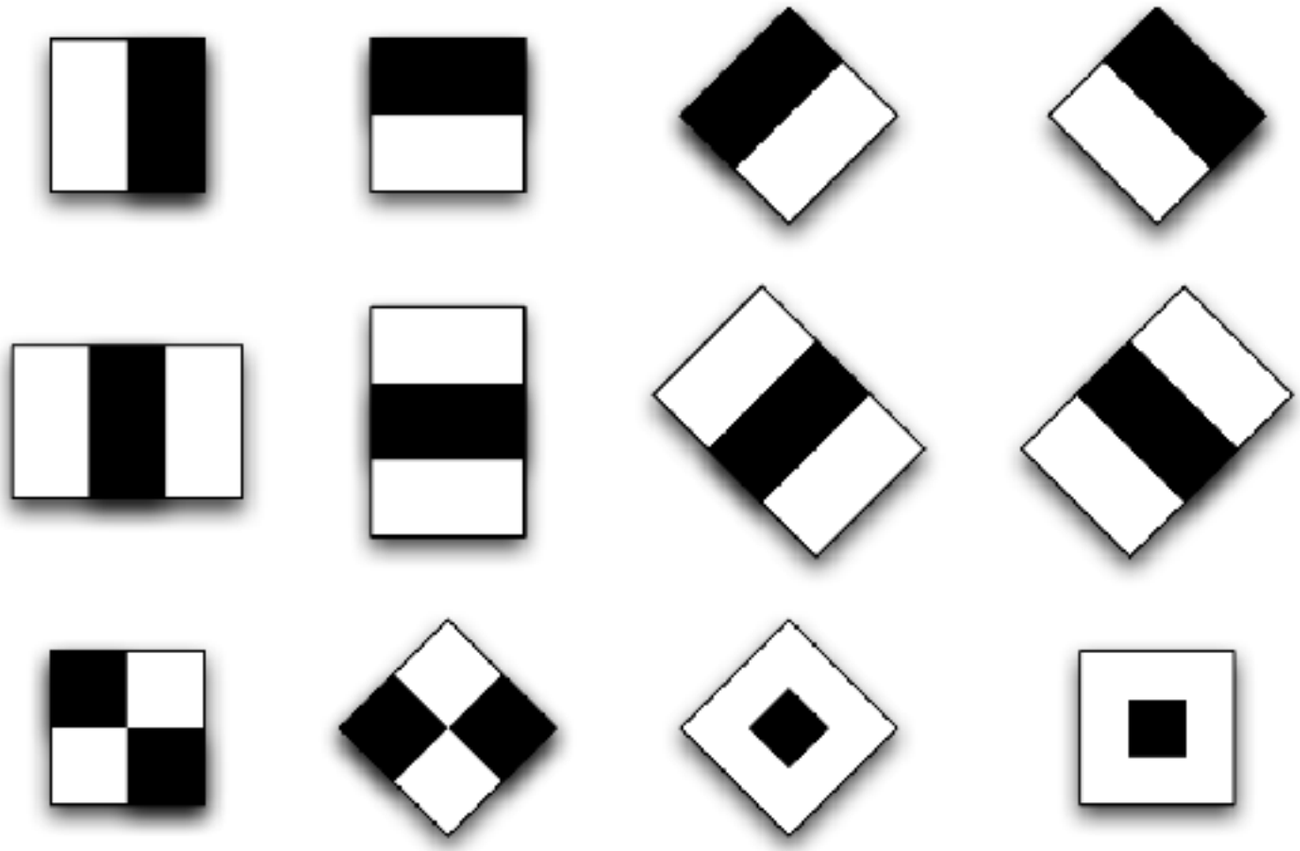
Haar Wavelets

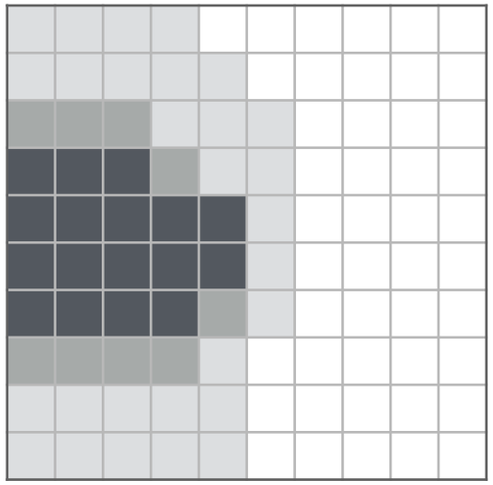
(actually, Haar-like features)

Use responses of a bank of filters as a descriptor

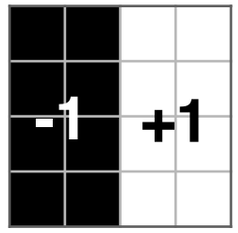


Haar wavelet responses can be computed with filtering

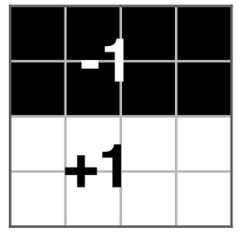
image patch



Haar wavelets filters



d_x



d_y

Haar wavelet responses can be computed
efficiently (in constant time) with integral images

Integral Image

original image

$I(x, y)$

1	5	2
2	4	1
2	1	1

$A(x, y)$

1	6	8
3	12	15
5	15	19

integral image

$$A(x, y) = \sum_{x' \leq x, y' \leq y} I(x', y')$$

Integral Image

original image

$I(x, y)$

1	5	2
2	4	1
2	1	1

$A(x, y)$

1	6	8
3	12	15
5	15	19

integral image

$$A(x, y) = \sum_{x' \leq x, y' \leq y} I(x', y')$$

Can find the **sum** of any block using **3** operations

$$A(x_1, y_1, x_2, y_2) = A(x_2, y_2) - A(x_1, y_2) - A(x_2, y_1) + A(x_1, y_1)$$

What is the sum of the bottom right 2x2 square?

$$A(x_1, y_1, x_2, y_2) = A(x_2, y_2) - A(x_1, y_2) - A(x_2, y_1) + A(x_1, y_1)$$

$I(x, y)$

1	5	2
2	4	1
2	1	1

image

$A(x, y)$

1	6	**8**
3	12	15
5	15	**19**

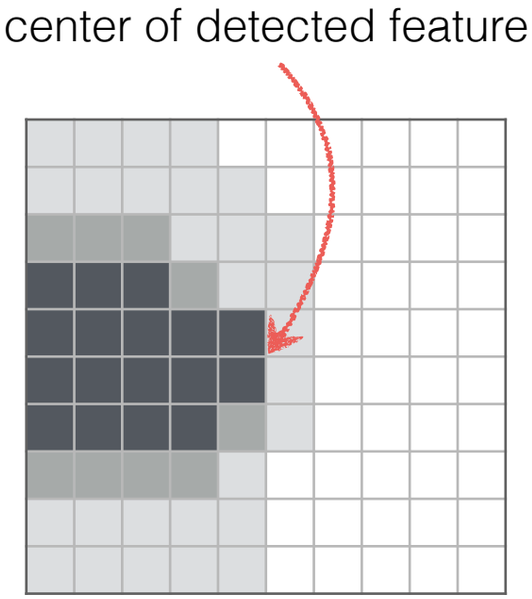
integral image

$$\begin{aligned} A(1,1,3,3) &= A(3,3) - A(1,3) - A(3,1) + A(1,1) \\ &= 19 - 8 - 5 + 1 \\ &= 7 \end{aligned}$$

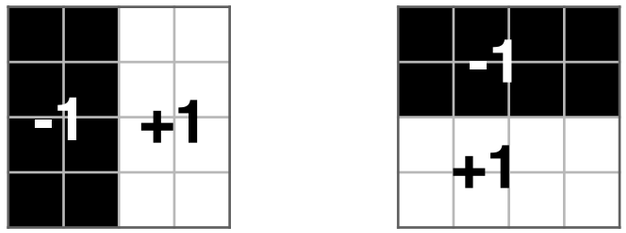
SURF

(‘Speeded’ Up Robust Features)

Compute Haar wavelet response at each pixel in patch



Haar wavelets filters



d_x d_y

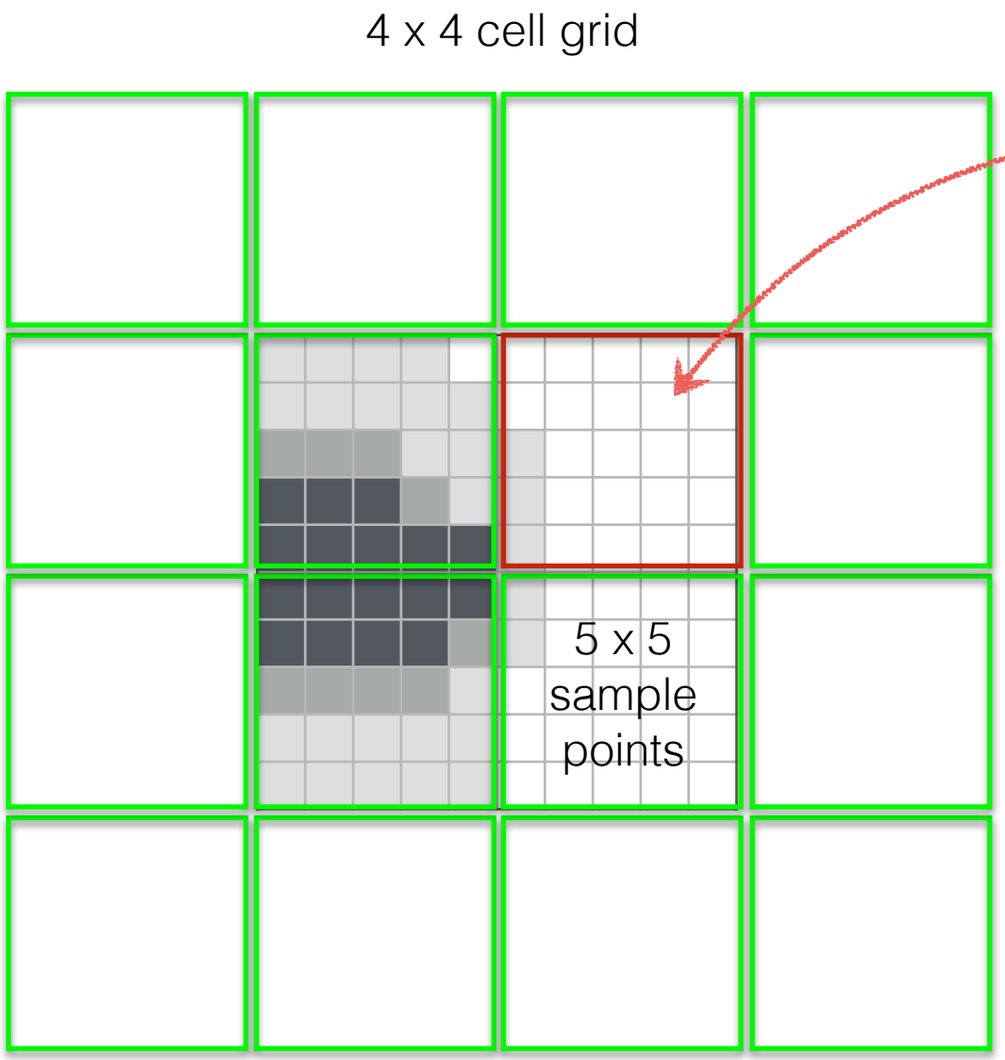
(Gaussian weighted from center)

How would do you compute the filter response?

Filtering using a sliding window can be slow
Haar wavelets are just sums over blocks
Use integral images for efficiency (6 operations)

SURF

(‘Speeded’ Up Robust Features)

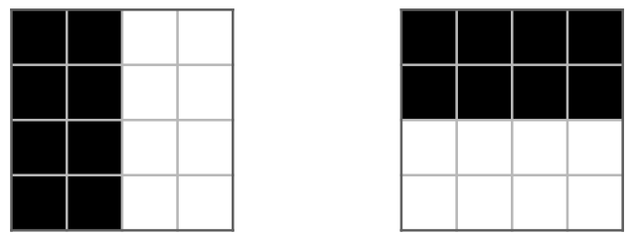


Each cell is represented by 4 values:

$$\left[\sum d_x, \sum d_y, \sum |d_x|, \sum |d_y|\right]$$

Haar wavelets filters

(Gaussian weighted from center)

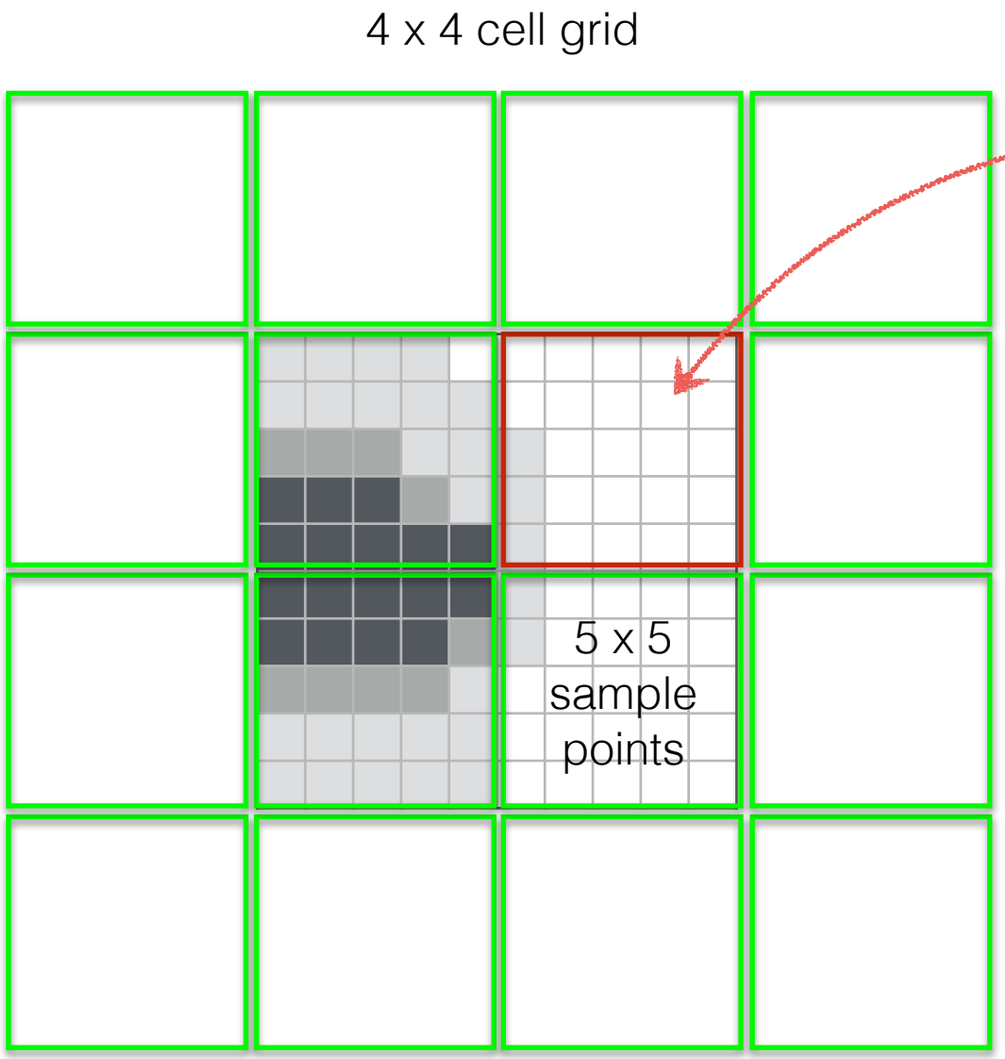


d_x d_y

How big is the SURF descriptor?

SURF

(‘Speeded’ Up Robust Features)

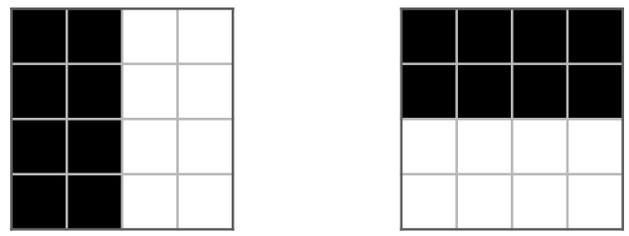


Each cell is represented by 4 values:

$$\left[\sum d_x, \sum d_y, \sum |d_x|, \sum |d_y|\right]$$

Haar wavelets filters

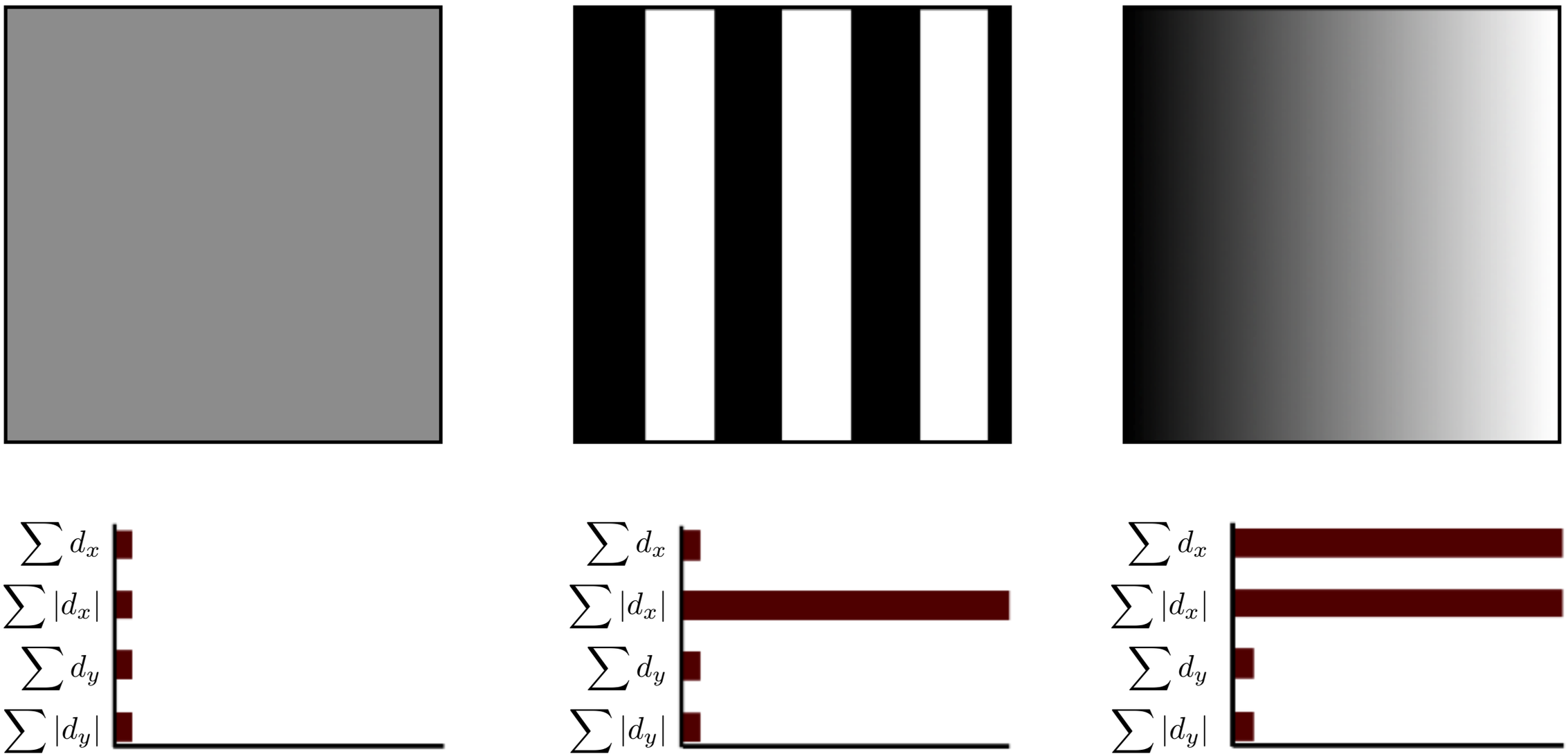
(Gaussian weighted from center)



d_x d_y

How big is the SURF descriptor?

64 dimensions


$\sum d_x$
$\sum |d_x|$
$\sum d_y$
$\sum |d_y|$

BRIEF

BRIEF: binary robust independent elementary features, Calonder, V Lepetit, C Strecha, ECCV 2010

Randomly sample pair of pixels a and b.
1 if a > b, else 0. Store binary vector.

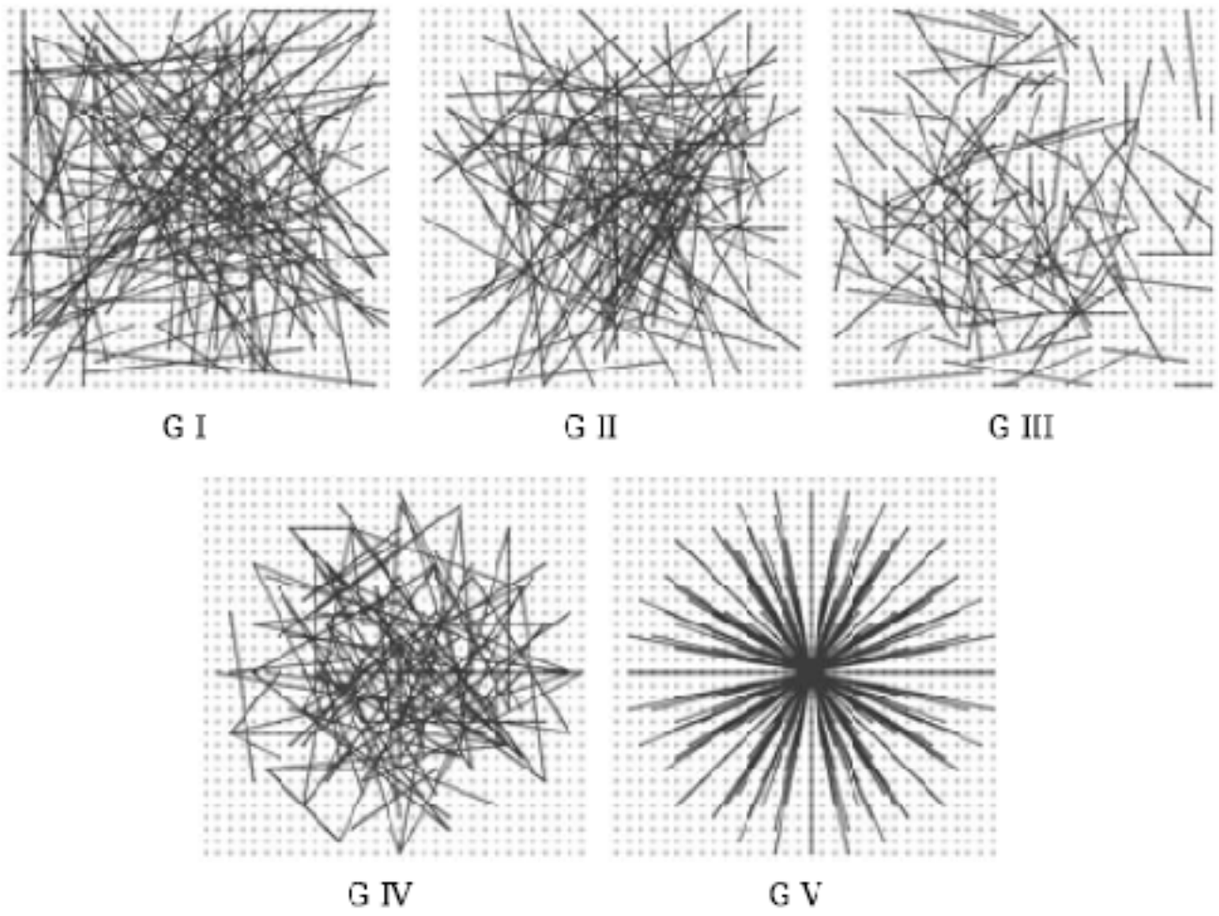


Fig. 2. Different approaches to choosing the test locations. All except the righmost one are selected by random sampling. Showing 128 tests in every image.