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* SURF: Speeded Up Robust Features

Before SURF paper was released many other detectors were also being used at that time such as:

→ Harris corner detection
→ LoG
→ SIFT

The SIFT approach was hugely successful but the only downfall was its 128 dimension descriptor which is quite large to tell features of an image.

So researcher ~~find it~~ found it difficult working with SIFT and came up with SURF.

Before we dive into SURF, we see the following insights.

→ Hessian-based detectors are more suitable and repeatable than their Harris-based counterparts.
→ Using the determinant of the Hessian matrix rather than its trace, seems advantageous as it fires less on ill-localised structures.
→ High dimensionality of SIFT is a drawback.

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* Now let's see the general overview of the approach:

- **Detector**
  - → Based on the Hessian matrix
  - → Uses a further approximated DoG
  - → Uses integral image

- **Descriptor**
  - → Describes a distribution of Haar-wavelet responses within the interest point neighbourhood.
  - → Only use 64 dimensions
  - → Introduced a new indexing step that is based on sign of the laplacian.

Before going into deep methodology, we first see what is integral images:

1	5
2	4

image

→

0	0	0
0	1	6
0	3	12

Integral image

Integral image formula: $ii(x,y) = \sum_{x' \le x, y' \le y} i(x', y')$

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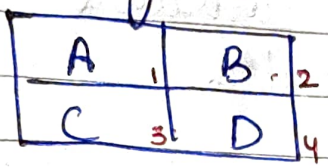
Integral image at location (x,y) contains the sum of pixels above and to the left of (x,y), inclusive.

So suppose we need to create an integral image; for that



So, the formula is for 2x2 image:

$4 = A+B+C+D$

$2 = A+B$

$3 = A+C$

$1 = A$

This leads to faster feature detection.

For this the researchers add box filters to detect features, this uses complexity of O(1) to compute the features.

The convolution with box filter of an image can be easily calculated with the help of integral images, and it can done in parallel for different scales. Also, the SURF rely on determinant of Hessian matrix for both scale and location.

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Hessian Matrix (add on topic)

Hessian matrix or Hessian in mathematic, is a square matrix of second-order partial derivatives of a scalar-valued function, or scalar field. It describes the local curvature of a function of many variables.

Corner is identified by its large variation in both x ~~and~~ and y directions.
We can build, hessian matrix that state the variation (derivative) in x, y and xy direction.

Let 'p' is a pixel in the image 'I'
Hessian matrix is defined as follows:

$$H = \begin{bmatrix} I_{xx}(p) & I_{xy}(p) \\ I_{xy}(p) & I_{yy}(p) \end{bmatrix}$$

where $I_{xx}(p)$ is the second derivative of image in x direction at point 'p'.

$I_{yy}(p) \Rightarrow$ 2nd derivative of image in y direction at pt. 'p'.

$I_{xy}(p)$: partial derivative in x & y at 'p'