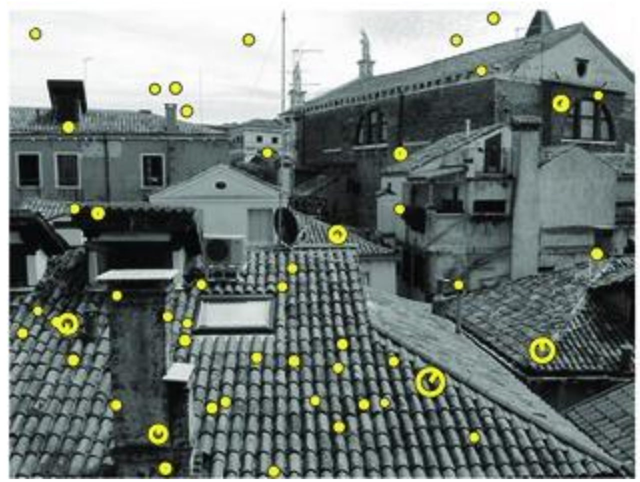
Matlab Tutorial.
Session 2.
SIFT



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Sift purpose

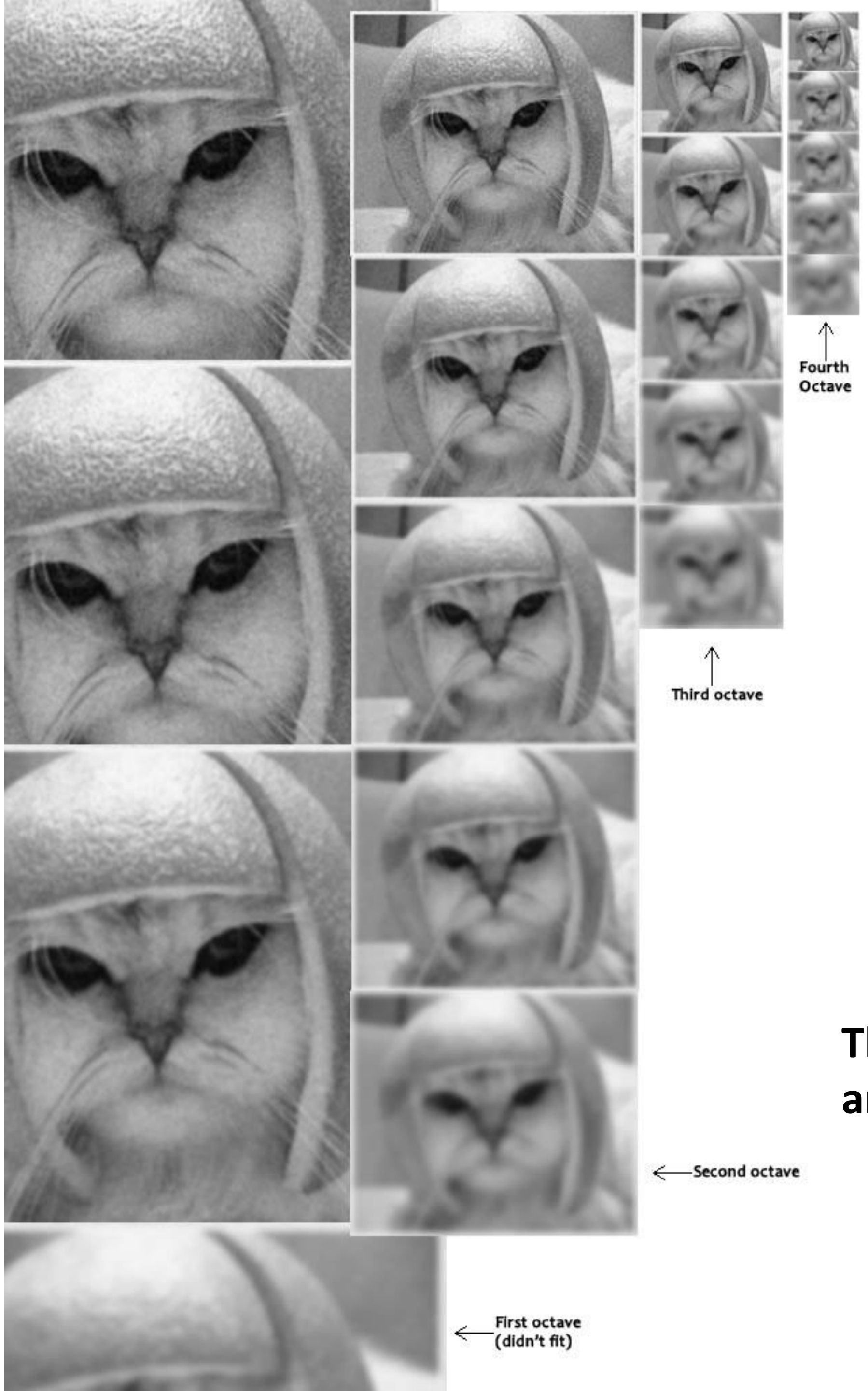
- Find and describe interest points invariants to:
  - Scale
  - Rotation
  - Illumination
  - Viewpoint

Do it Yourself

- Constructing a scale space
- LoG Approximation
- Finding keypoints
- Get rid of bad key points (A technique similar to the Harris Corner Detector)
- Assigning an orientation to the keypoints
- Generate SIFT features

*http://www.aishack.in/2010/05/sift-scale-invariant-feature-transform/2/

Construction of a scale space



SIFT takes scale spaces to the next level. You take the original image, and generate progressively blurred out images. Then, you resize the original image to half size. And you generate blurred out images again. And you keep repeating.

The creator of SIFT suggests that 4 octaves and 5 blur levels are ideal for the algorithm

Construction of a scale space (details)

- The first octave
  - If the original image is doubled in size and antialiased a bit (by blurring it) then the algorithm produces more four times more keypoints. The more the keypoints, the better!
- Blurring

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y)$$

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$$

- Amount of Blurring

octave \ scale →				
0.707107	1.000000	1.414214	2.000000	2.828427
1.414214	2.000000	2.828427	4.000000	5.656854
2.828427	4.000000	5.656854	8.000000	11.313708
5.656854	8.000000	11.313708	16.000000	22.627417

The Convolution of Two Gaussian Distributions

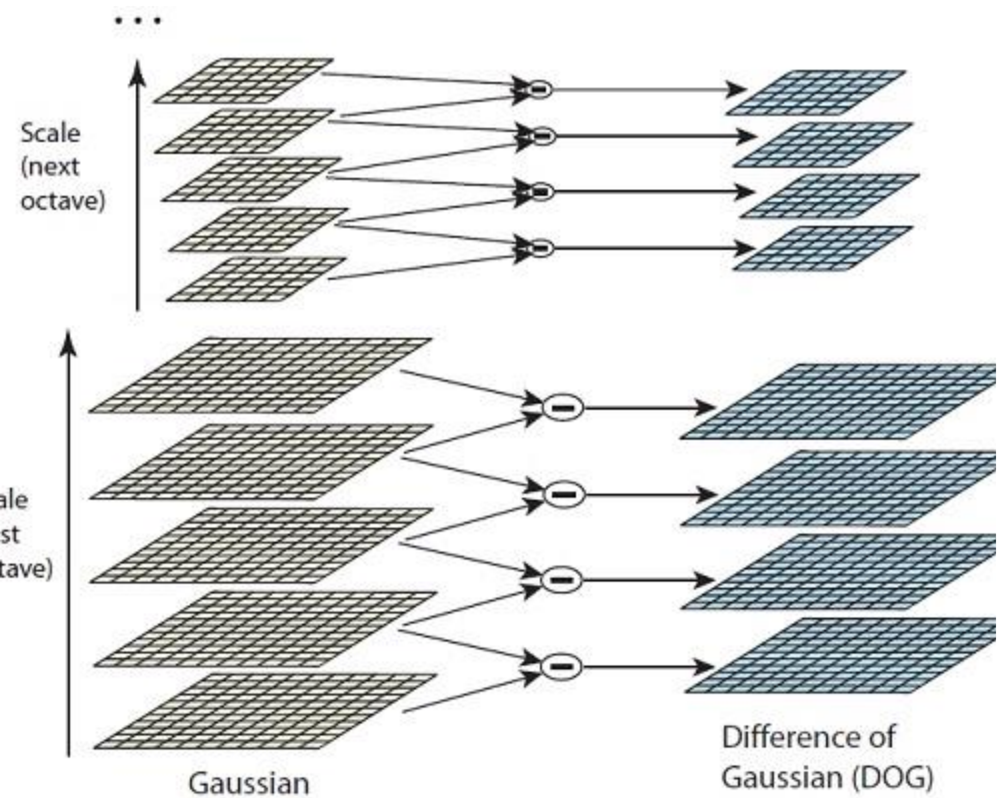
- http://tina.wiau.man.ac.uk/docs/memos/2003-003.pdf

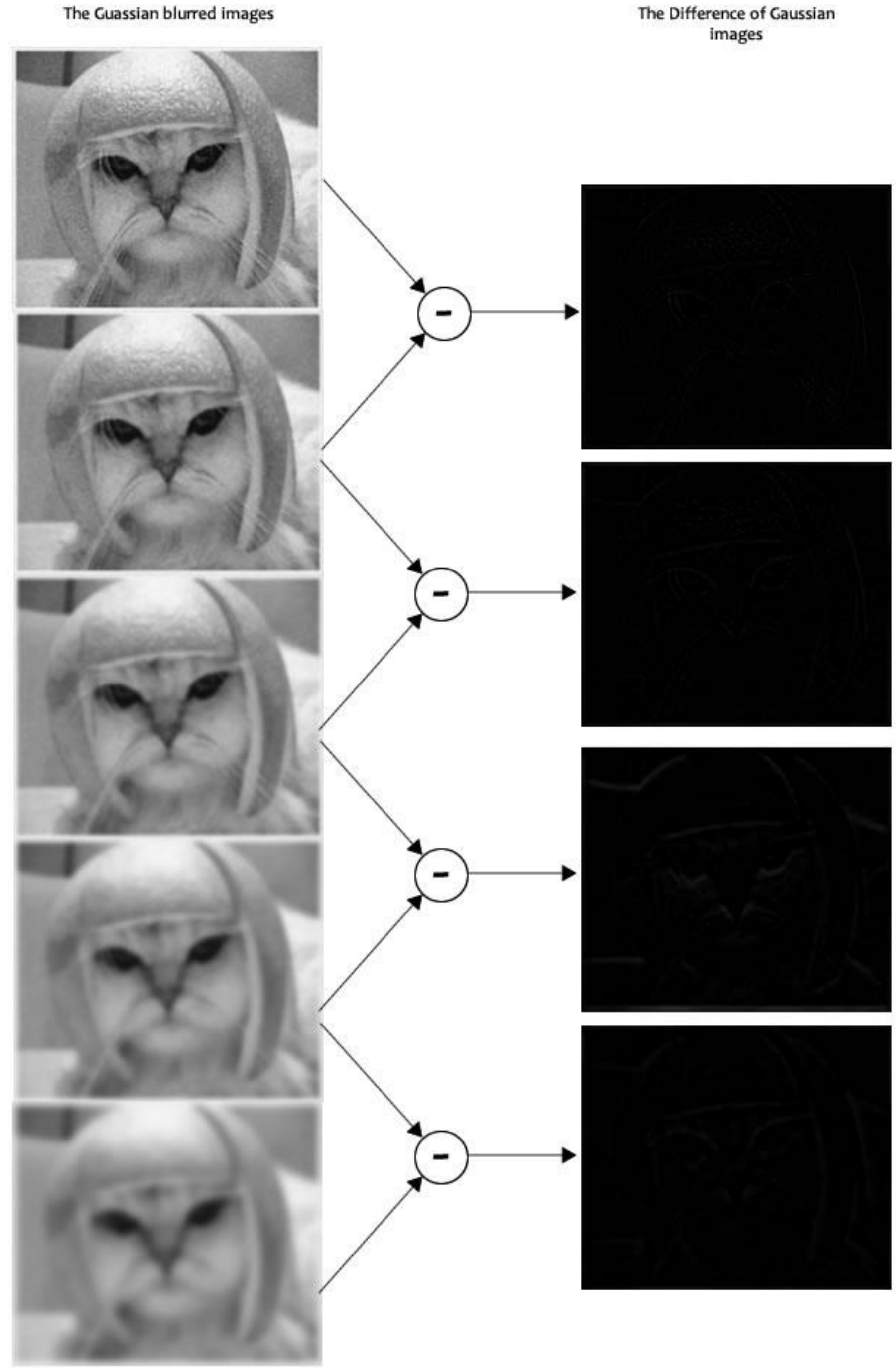
$$\mu_{f\otimes g} = \mu_f + \mu_g \quad \text{and} \quad \sigma_{f\otimes g} = \sqrt{\sigma_f^2 + \sigma_g^2}$$

0

Chose k=sqrt(2) means : $\sigma_f = \sigma_g$

LoG approximation





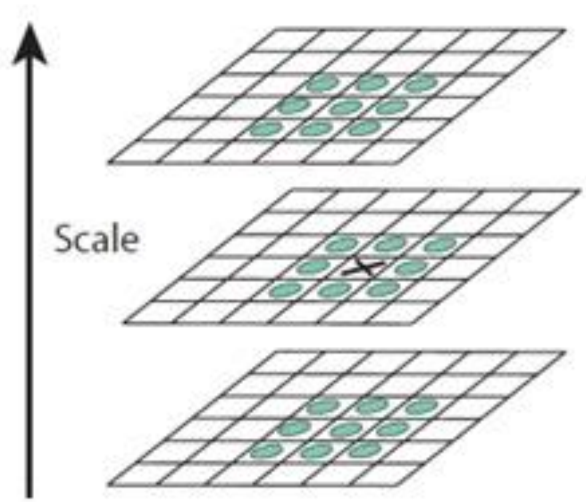
$$G(x, y, k\sigma) - G(x, y, \sigma) \approx (k-1)\sigma^2 \nabla^2 G.$$

Matlab Implementation !

```
% %%% Create first interval of the first octave %%%%%
init_image=impyramid(gauss_filter(image1,antialiassigma,4*antialiassigma),'expand');
gaussians(1)={gauss_filter(init_image,sigmavalue,4*sigmavalue)};

 % %%% Generates all the blurred out images for each octave %%%%
% %%%           and the DoG images                  %%%%
for i=1:num_octaves
   sigma=sigmavalue;    %reset the sigma value
   for j=1:(num_intervals+2)
       sigma=sigma*2^((j-1)/2);     %Assign a sigma value acording to the scale
       previmage=cell2mat(gaussians(j,i));  %Obtain the previous image
       newimage=gauss_filter(previmage,sigma,4*sigma);  %apply a new smoothing
       dog=previmage-newimage;  %calculate the difference of gaussians

       %save the results
       gaussians(j+1,i)={newimage};
       dogs(j,i)={dog};
   end

   %Build the  init image in the next level
   if(i<num_octaves)
       lowscale=cell2mat(gaussians(num_intervals+1,i));
       upscale=impyramid(lowscale,'reduce');
       gaussians(1,i+1)={upscale};
   end
end
```

Finding keypoints

- a) Locate maxima/minima in DoG images

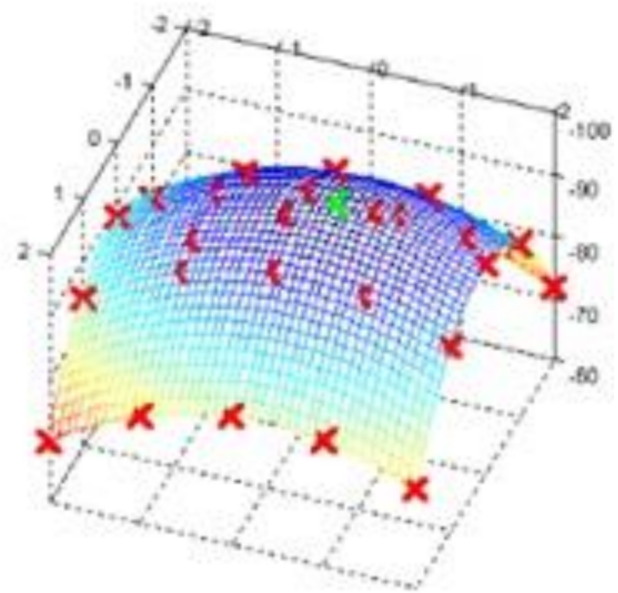


Matlab Implementation

```
for i=1:num_octaves
   for j=2:(num_intervals+1)
      % Obtain the matrices where to look for the extrema
      level=cell2mat(dogs(j,i));
      up=cell2mat(dogs(j+1,i));
      down=cell2mat(dogs(j-1,i));

      [sx,sy]=size(level);

      %look for a local maxima
      local_maxima=(level(2:sx-1,2:sy-1)>level(1:sx-2,1:sy-2)) & ( level(2:sx-1,2:sy-1) > level(1:sx-2,2:sy-1) ) & (level(2:sx-1,2:sy-1)>level(1:sx-2,3:sy)) & (level(2:sx-1,2:sy-1)>level(2:sx-1,1:sy-2)) & (level(2:sx-1,2:sy-1)>level(2:sx-1,3:sy)) & (level(2:sx-1,2:sy-1)>level(3:sx,1:sy-2)) & (level(2:sx-1,2:sy-1)>level(3:sx,2:sy-1)) & (level(2:sx-1,2:sy-1)>level(3:sx,3:sy)) ;
      local_maxima=local_maxima & (level(2:sx-1,2:sy-1)>up(1:sx-2,1:sy-2)) & ( level(2:sx-1,2:sy-1) > up(1:sx-2,2:sy-1) ) & (level(2:sx-1,2:sy-1)>up(1:sx-2,3:sy)) & (level(2:sx-1,2:sy-1)>up(2:sx-1,1:sy-2)) & (level(2:sx-1,2:sy-1)>up(2:sx-1,2:sy-1)) & (level(2:sx-1,2:sy-1)>up(2:sx-1,3:sy)) & (level(2:sx-1,2:sy-1)>up(3:sx,1:sy-2)) & (level(2:sx-1,2:sy-1)>up(3:sx,2:sy-1)) & (level(2:sx-1,2:sy-1)>up(3:sx,3:sy)) ;
      local_maxima=local_maxima & (level(2:sx-1,2:sy-1)>down(1:sx-2,1:sy-2)) & ( level(2:sx-1,2:sy-1) > down(1:sx-2,2:sy-1) ) & (level(2:sx-1,2:sy-1)>down(1:sx-2,3:sy)) & (level(2:sx-1,2:sy-1)>down(2:sx-1,1:sy-2)) & (level(2:sx-1,2:sy-1)>down(2:sx-1,2:sy-1)) & (level(2:sx-1,2:sy-1)>down(2:sx-1,3:sy)) & (level(2:sx-1,2:sy-1)>down(3:sx,1:sy-2)) & (level(2:sx-1,2:sy-1)>down(3:sx,2:sy-1)) & (level(2:sx-1,2:sy-1)>down(3:sx,3:sy)) ;

      %look for a local minima
      local_minima=(level(2:sx-1,2:sy-1)>level(1:sx-2,1:sy-2)) & ( level(2:sx-1,2:sy-1) > level(1:sx-2,2:sy-1) ) & (level(2:sx-1,2:sy-1)>level(1:sx-2,3:sy)) & (level(2:sx-1,2:sy-1)>level(2:sx-1,1:sy-2)) & (level(2:sx-1,2:sy-1)>level(2:sx-1,3:sy)) & (level(2:sx-1,2:sy-1)>level(3:sx,1:sy-2)) & (level(2:sx-1,2:sy-1)>level(3:sx,2:sy-1)) & (level(2:sx-1,2:sy-1)>level(3:sx,3:sy)) ;
      local_minima=local_minima & (level(2:sx-1,2:sy-1)>up(1:sx-2,1:sy-2)) & ( level(2:sx-1,2:sy-1) > up(1:sx-2,2:sy-1) ) & (level(2:sx-1,2:sy-1)>up(1:sx-2,3:sy)) & (level(2:sx-1,2:sy-1)>up(2:sx-1,1:sy-2)) & (level(2:sx-1,2:sy-1)>up(2:sx-1,2:sy-1)) & (level(2:sx-1,2:sy-1)>up(2:sx-1,3:sy)) & (level(2:sx-1,2:sy-1)>up(3:sx,1:sy-2)) & (level(2:sx-1,2:sy-1)>up(3:sx,2:sy-1)) & (level(2:sx-1,2:sy-1)>up(3:sx,3:sy)) ;
      local_minima=local_minima & (level(2:sx-1,2:sy-1)>down(1:sx-2,1:sy-2)) & ( level(2:sx-1,2:sy-1) > down(1:sx-2,2:sy-1) ) & (level(2:sx-1,2:sy-1)>down(1:sx-2,3:sy)) & (level(2:sx-1,2:sy-1)>down(2:sx-1,1:sy-2)) & (level(2:sx-1,2:sy-1)>down(2:sx-1,2:sy-1)) & (level(2:sx-1,2:sy-1)>down(2:sx-1,3:sy)) & (level(2:sx-1,2:sy-1)>down(3:sx,1:sy-2)) & (level(2:sx-1,2:sy-1)>down(3:sx,2:sy-1)) & (level(2:sx-1,2:sy-1)>down(3:sx,3:sy)) ;

      extrema=local_maxima | local_minima;
   end
end
```

Finding keypoints

- b) Find subpixel maxima/minima



$$D(\mathbf{x}) = D + \frac{\partial D}{\partial \mathbf{x}}^T \mathbf{x} + \frac{1}{2}\mathbf{x}^T \frac{\partial^2 D}{\partial \mathbf{x}^2}\mathbf{x}$$

Get rid of bad key points

- Removing low contrast features

If the magnitude of the intensity (i.e., without sign) at the current pixel in the DoG image (that is being checked for minima/maxima) is less than a certain value, it is rejected

- Removing edges

Tr (**H**) = **Dxx + Dyy**

Det(**H**) = **DxxDyy - (Dxy)2**

$$\mathrm{R} = \mathrm{Tr}\,(\mathbf{H})^2 \,/\, \mathrm{Det}\,(\mathbf{H})$$

- If the value of R is greater for a candidate keypoint, then that keypoint is poorly localized and hence rejected.

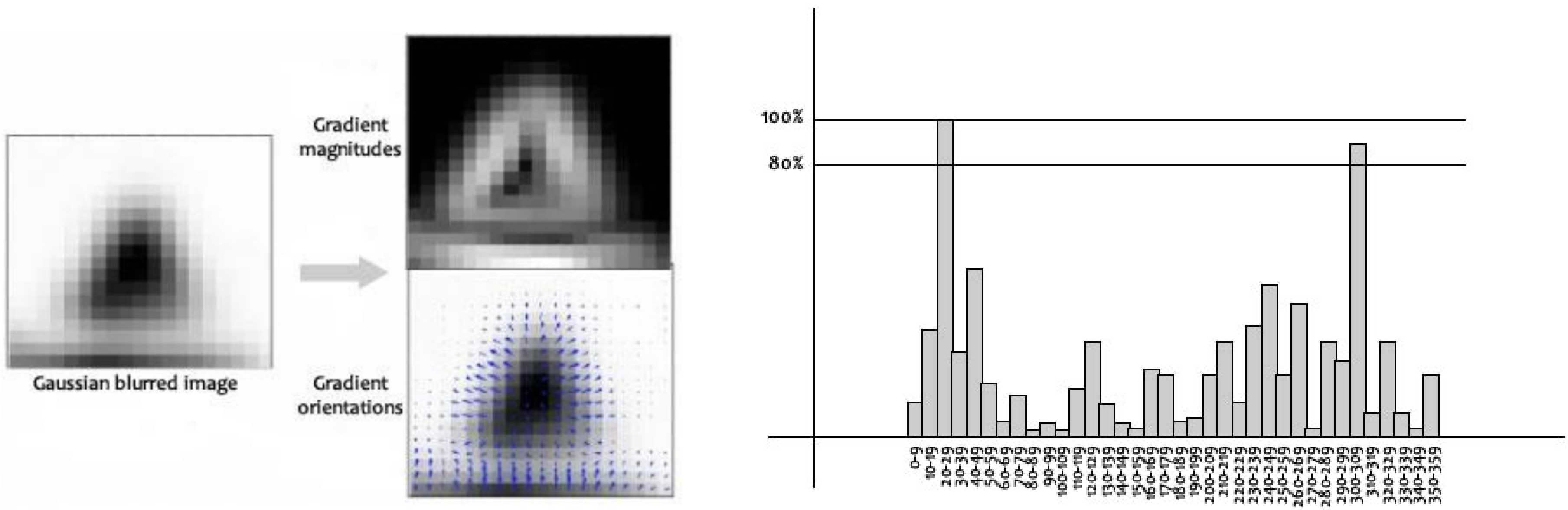
$$H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix}$$

$$\frac{D_{xx} + D_{yy}}{D_{xx}D_{yy} - (D_{xy})^2} < \frac{(r+1)^2}{r}$$

Matlab Implementation

```
%indices of the extrema points
    [x,y]=find(extrema);
    numtimes=size(find(extrema));

    for k=1:numtimes
      x1=x(k);
      y1=y(k);
      if(abs(level(x1+1,y1+1))<contrast_threshold)    %low contrast point are discarded
        extrema(x1,y1)=0;
      else   %keep being extrema, check for edge
        rx=x1+1;
        ry=y1+1;
        fxx= level(rx-1,ry)+level(rx+1,ry)-2*level(rx,ry);   % double derivate in x direction
        fyy= level(rx,ry-1)+level(rx,ry+1)-2*level(rx,ry);   % double derivate in y direction
        fxy= level(rx-1,ry-1)+level(rx+1,ry+1)-level(rx-1,ry+1)-level(rx+1,ry-1); %derivate inx and y direction
        trace=fxx+fyy;
        deter=fxx*fyy-fxy*fxy;
        curvature=trace*trace/deter;
        curv_threshold= ((r_curvature+1)^2)/r_curvature;
        if(deter<0 || curvature>curv_threshold)   %Reject edge points
          extrema(x1,y1)=0;
        end
      end
    end
```

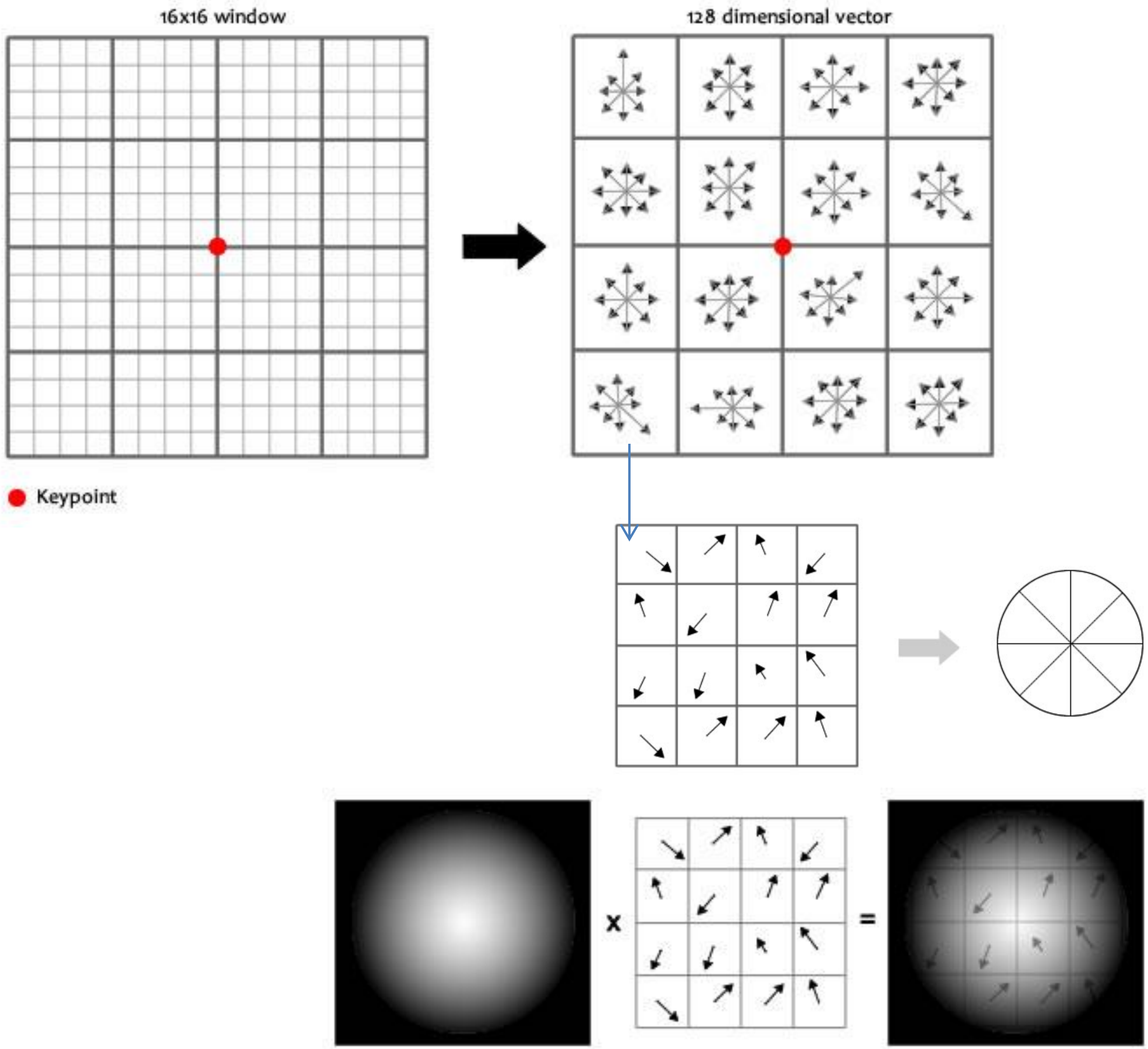
Assigning an orientation to the keypoints



$$m(x,y) = \sqrt{(L(x+1,y) - L(x-1,y))^2 + (L(x,y+1) - L(x,y-1))^2}$$

$$\theta(x,y) = \tan^{-1}((L(x,y+1) - L(x,y-1))/(L(x+1,y) - L(x-1,y)))$$

Generate SIFT features



Generate SIFT features

- You take a 16×16 window of “in-between” pixels around the keypoint. You split that window into sixteen 4×4 windows. From each 4×4 window you generate a histogram of 8 bins. Each bin corresponding to 0-44 degrees, 45-89 degrees, etc. Gradient orientations from the 4×4 are put into these bins. This is done for all 4×4 blocks. Finally, you normalize the 128 values you get.
- To solve a few problems, you subtract the keypoint’s orientation and also threshold the value of each element of the feature vector to 0.2 (larger than 0.2 becomes 0.2) (and normalize again).

Testing the detector

- i=imread('groceries_gray.jpg');
- sift(i,3,5,1.1)

Vl_feat

- The VLFeat open source library implements popular computer vision algorithms including SIFT, MSER, k-means, hierarchical k-means, agglomerative information bottleneck, and quick shift. It is written in C for efficiency and compatibility, with interfaces in MATLAB for ease of use, and detailed documentation throughout. It supports Windows, Mac OS X, and Linux

Vl_feat

- Download vl_feat from http://www.vlfeat.org/
- run('VLFEATROOT/toolbox/vl_setup')

- Permanent setup
  - To permanently add VLFeat to your MATLAB environment, add this line to your startup.m file:
  - run('VLFEATROOT/toolbox/vl_setup')

Extracting frames and descriptors

```
pfx = fullfile(vl_root,'data', 'roofs1.jpg') ;
I = imread(pfx) ;
image(I) ;
I = single(rgb2gray(I)) ;
[f,d] = vl_sift(I) ;
perm = randperm(size(f,2)) ;
sel = perm(1:50) ;
h1 = vl_plotframe(f(:,sel)) ;
h2 = vl_plotframe(f(:,sel)) ;
set(h1,'color','k','linewidth',3) ;
set(h2,'color','y','linewidth',2) ;
h3 = vl_plotsiftdescriptor(d(:,sel),f(:,sel)) ;
set(h3,'color','g')
```

Basic Matching

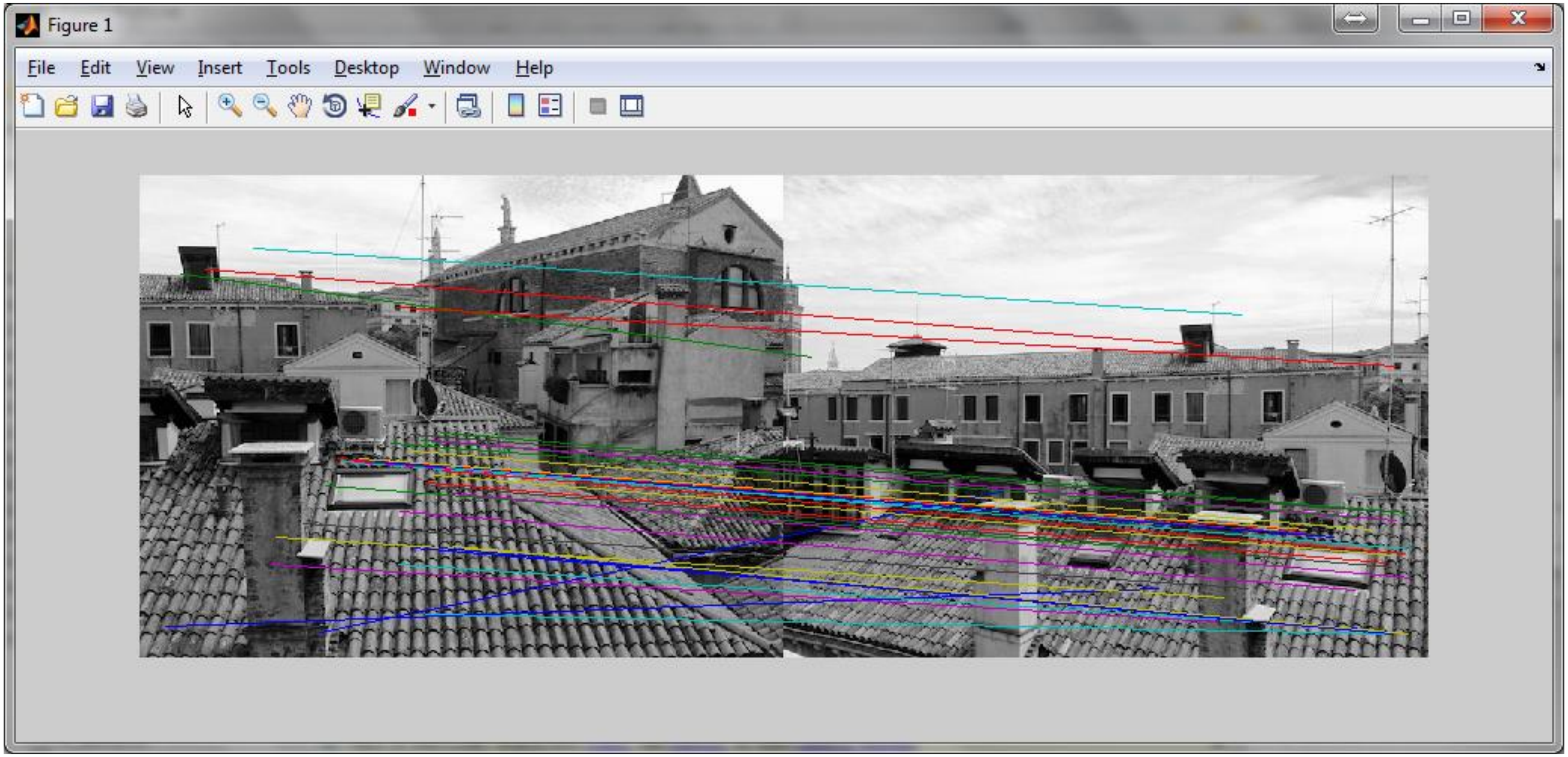
```
pfx = fullfile(vl_root,'data', 'roofs1.jpg') ;
I = imread(pfx) ;
figure; image(I) ;
Ia = single(rgb2gray(I)) ;

pfx = fullfile(vl_root,'data', 'roofs2.jpg') ;
I = imread(pfx) ;
figure, image(I) ;
Ib = single(rgb2gray(I)) ;
```

```
[fa, da] = vl_sift(Ia) ;
[fb, db] = vl_sift(Ib) ;
[matches, scores] = vl_ubcmatch(da, db) ;
```

Visualization

```
m1= fa (1:2,matches(1,:));
m2=fb(1:2,matches(2,:));
m2(1,:)= m2(1,:)+size(Ia,2)*ones(1,size(m2,2));
X=[m1(1,:);m2(1,:)];
Y=[m1(2,:);m2(2,:)];
c=[Ia Ib];
imshow(c,[]);
hold on;
line(X(:,1:3:100),Y(:,1:3:100))
```

Visualization



Custom frames

- The MATLAB command vl_sift (and the command line utility) can bypass the detector and compute the descriptor on custom frames using the Frames option.
- For instance, we can compute the descriptor of a SIFT frame centered at position (100,100), of scale 10 and orientation -pi/8 by
- fc = [100;100;10;-pi/8] ;
- [f,d] = vl_sift(I,'frames',fc) ;
- fc = [100;100;10;0] ;
- [f,d] = vl_sift(I,'frames',fc,'orientations') ;