

Notes regarding lab format

We will use Matlab Livescript for this lab. Livescript allows switching between text and code cells.

You will find the entire lab manual in this file. Some exercises require you to write a text answer, others require you to write code. You should not define functions inside this file. Instead save functions to the functions folder and call them from the code cells in this notebook.

Your finished lab report should be a .zip-file containing your functions folder, and this livescript file. You should also provide a pdf of the result of running the live script (in the Live Editor, you can **export to pdf** under Save).

Since we need to access the functions and data folder the first step is to add the following locations to MATLAB's path.

```
addpath('./functions');  
addpath('./data');
```

Lab 1: The SIFT descriptor

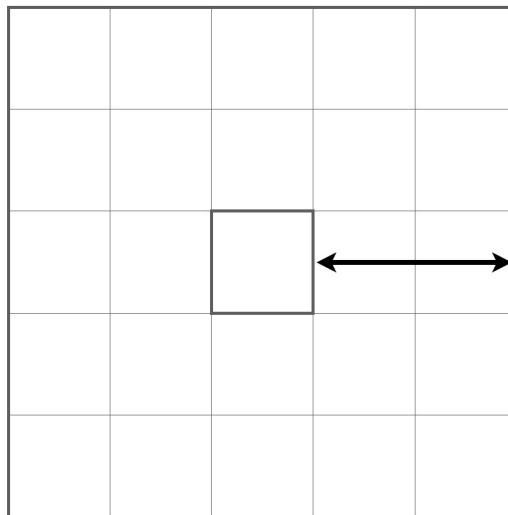
In this lab you will implement a SIFT-like descriptor and try it on some classification tasks. Keep your code well commented, both for your own sake and because it is required.

Ex 1.1

Make a function

```
patch = get_patch(image, x, y, patch_radius)
```

that takes out a square patch from the image centred at $(x; y)$ with a range of $+/- \text{patch_radius}$. (The figure below shows a patch with patch_radius of two pixels.) Make sure that your function works both for grayscale and color images.



Ex 1.2

Use

```
test_image = reshape((11:120), 10, 11)
```

```
test_image = 10x11
 11   21   31   41   51   61   71   81   91   101  111
 12   22   32   42   52   62   72   82   92   102  112
 13   23   33   43   53   63   73   83   93   103  113
 14   24   34   44   54   64   74   84   94   104  114
 15   25   35   45   55   65   75   85   95   105  115
 16   26   36   46   56   66   76   86   96   106  116
 17   27   37   47   57   67   77   87   97   107  117
 18   28   38   48   58   68   78   88   98   108  118
 19   29   39   49   59   69   79   89   99   109  119
 20   30   40   50   60   70   80   90   100  110  120
```

to create a test image with numbered pixels. Try extracting a few patches from this image to verify that your function works. Make sure that the x-variable corresponds to the column index and the y-variable to the row index.

```
get_patch(test_image,5,3,1)
```

```
ans = 3x3
 42   52   62
 43   53   63
 44   54   64
```

Ex 1.3

Modify **get_patch** so it returns an error with an informative error message such as

'Patch outside image border'

if the patch doesn't fit inside the image. Use the error function for this. Test with the following.

```
get_patch(test_image,5,3,2)
```

```
ans = 5x5
 31   41   51   61   71
 32   42   52   62   72
 33   43   53   63   73
 34   44   54   64   74
 35   45   55   65   75
```

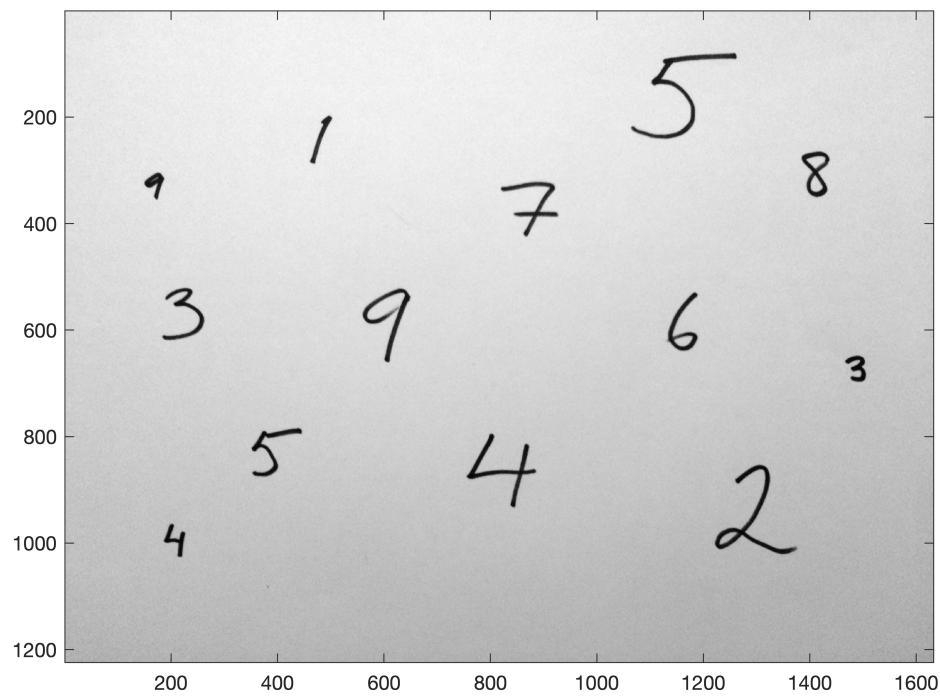
Gradient histograms

Ex 1.4

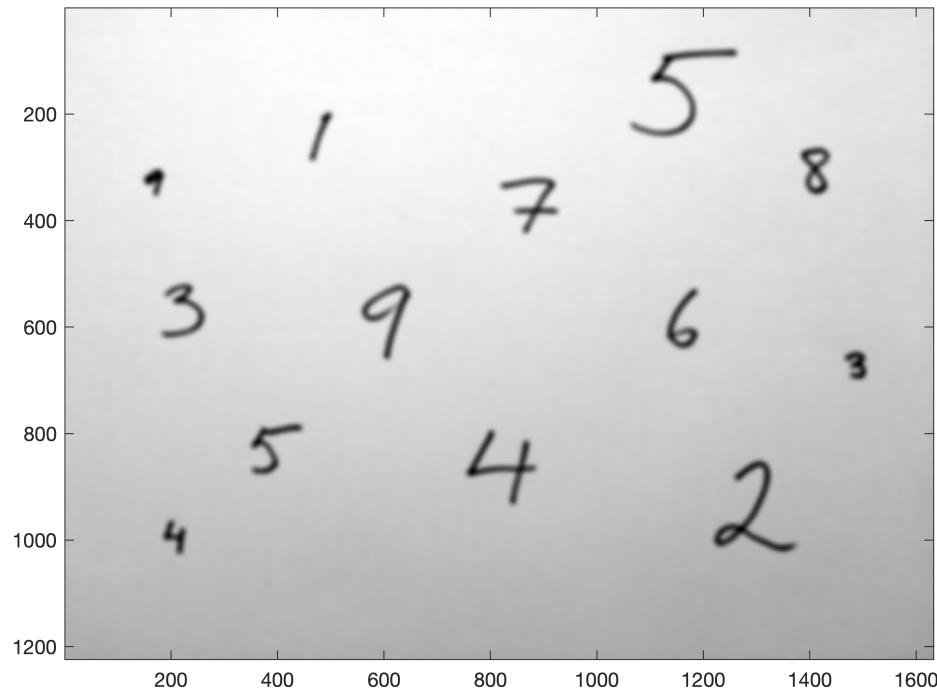
Create a Matlab function **gaussian_filter** that takes two arguments, one grayscale image and one number specifying a standard deviation. The output should be the image filtered with a Gaussian filter of the specified standard deviation. Example usage:

```
img = rgb2gray(imread('paper_with_digits.png'));
img = double(img); %convert from integer format to doubles
result = gaussian_filter(img, 5.0);
```

```
figure; imagesc(img); axis image; colormap gray;
```



```
figure; imagesc(result); axis image; colormap gray;
```



The filter size should be at least four standard deviations not to lose precision. Use **fspecial** to construct a Gaussian filter. It is a good idea to use the '**symmetric**' option with **imfilter**. (Do not use the built-in function for Gaussian filtering.)

Ex 1.5

Make a function

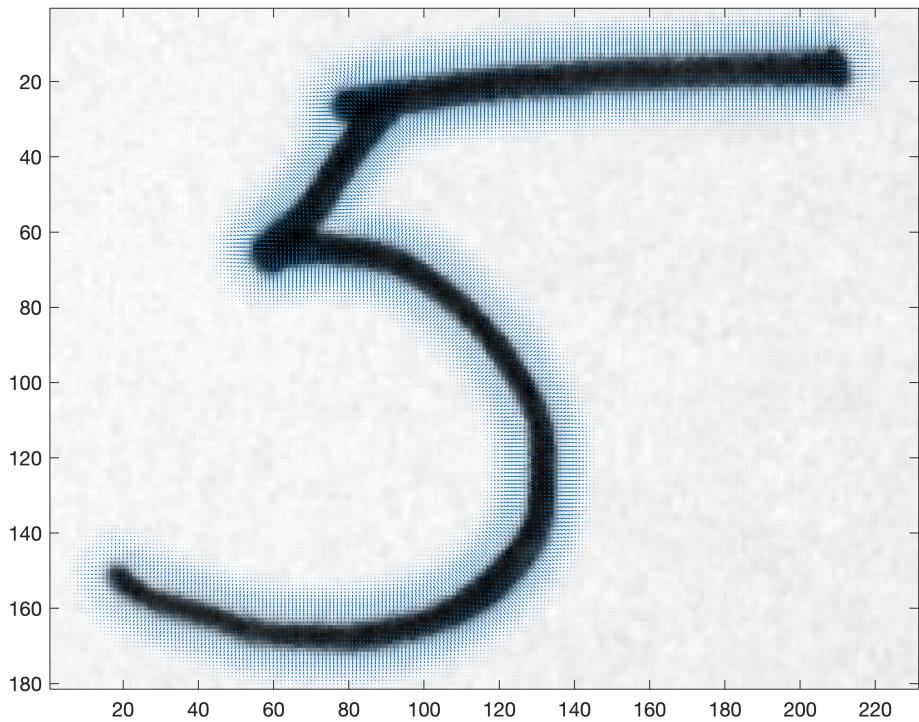
```
[grad_x, grad_y] = gaussian_gradients(img, std)
```

that takes a grayscale image and estimates both gaussian derivatives for each pixel. Use filtering with derivative filters and your function from the previous exercise. The output should be two matrices of same size as the input image. Be careful about the definition of x and y.

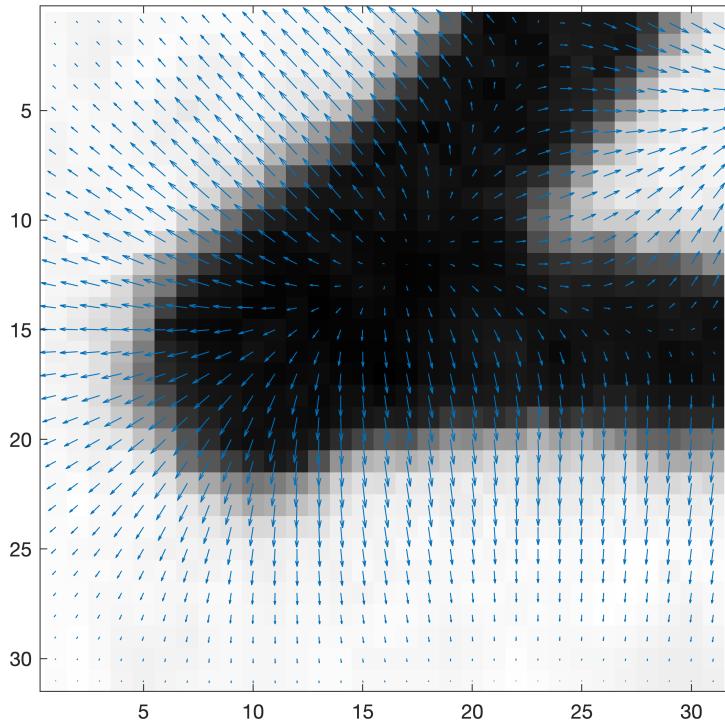
Ex 1.6

Plot your gradients in the image using

```
smallimg = img(70:250,1050:1280);
[grad_x, grad_y] = gaussian_gradients(smallimg, 5);
clf
imagesc(smallimg)
axis image
hold on
quiver(grad_x, grad_y)
```



```
clf
imagesc(smallimg(50:80,50:80))
axis image
hold on
quiver(grad_x(50:80,50:80), grad_y(50:80,50:80))
```



and verify visually that the gradients are correct.

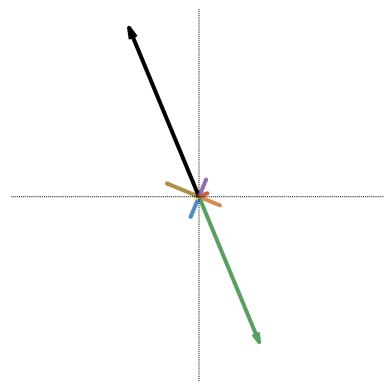
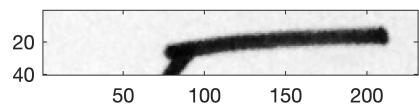
Ex 1.7

Make a function

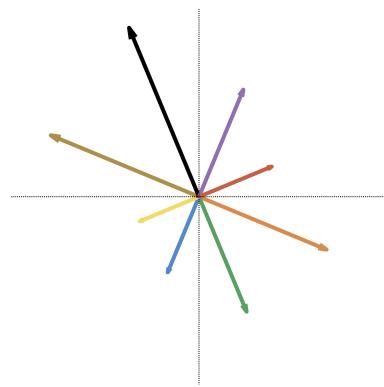
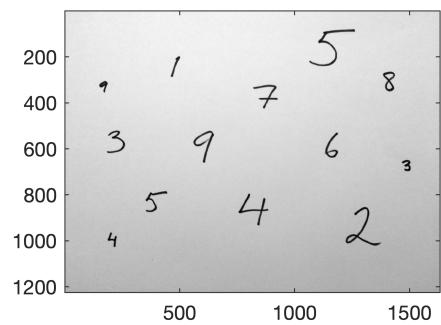
```
histogram = gradient_histogram(grad_x, grad_y)
```

that places each gradient into one of eight orientation bins. A useful function is **atan2** in Matlab. Use the bins and bin order from the lecture notes. The provided **plot_bouquet** lets you plot the histograms as a bouquet of vectors and might be helpful for debugging. It assumes that you have given all functions exactly the names suggested here and used the bin ordering from the lecture notes.

```
plot_bouquet (smallimg(1:40,:), 5);
```



```
plot_bouquet (img, 5);
```



A SIFT-like descriptor

Next, we will create a SIFT-like descriptor by computing gradient histograms for 3×3 regions and stacking them into a vector. The exact positions and sizes of the regions are not crucial. For example, you might choose whether to use overlapping regions or not. The figure below shows an example of how to place the nine regions. You can use the provided `paper_with_digits.png` as an example image. For example, there is a digit at (1290; 950).

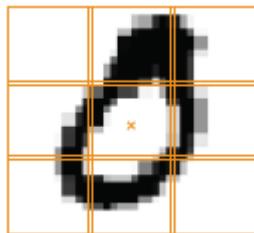


Figure: Example of patch placement. The x marks the coordinates in the argument position.

Ex 1.8

Make a function

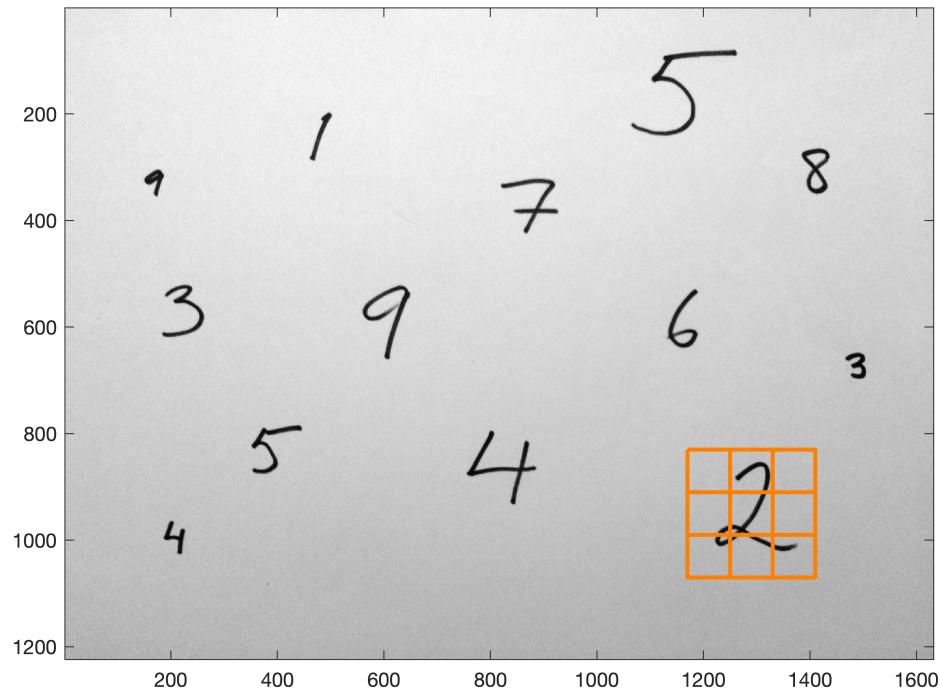
```
region_centres = place_regions(centre, radius)
```

that creates 3×3 square regions for the descriptor; see the above figure. The input radius specifies the radius of each square region (as in Ex 1.1). The output should be an 2×9 array with columns being the 2D centre points of the 9 regions. Use the provided function

```
plot_squares(img, region_centres, region_radius)
```

to plot your regions in an example image. Increasing the input radius with a factor K should scale the whole region pattern with a factor K.

```
centre = [1290;950]; r1 =40;  
region_centres = place_regions(centre, r1);  
plot_squares(img, region_centres, r1);
```



Ex 1.9

Make a function

```
desc = gradient_descriptor(image, position, radius)
```

that computes a SIFT-like descriptor at a certain position. The input radius controls the size of the regions just as in Ex 1.8.

- Compute gaussian gradients. Let the standard deviation be proportional to radius.
- Divide your gradients into 3×3 regions defined by **place_regions**.
- Compute a gradient histogram for the gradients from each region.
- Stack the histograms into a 72-vector.
- Normalize that vector to unit length.

Digit classification

In the file **digits.mat**, there are two lists of images, **digits_training** with 100 training images and **digits_validation** with 50 similar images. Our next goal is to classify each of the validation images by finding the most similar image in the training set and assuming that the query image has the same label.

Load the digit data by running

```
load digits.mat
```

The examples are stored in a struct array. To get image number 12 you write `digits_training(12).image` and to get its label you write `digits_training(12).label` .

Ex 1.10

Make a script **prepare_digits.m** that computes a descriptor for each digit in **digits_training**. You need to choose the position and radius parameters so that all the descriptor regions fit into the images. Store the descriptors in an appropriate place. A suggestion is to store the 12th descriptor in **digits_training(12).descriptor**.

```
prepare_digits;
%show 12th digit and its fields - there should be 'image', 'label' and 'descriptor'
digits_training(12)

ans = struct with fields:
    image: [39x39 double]
    label: 2
    descriptor: [0 0 0.1660 0.3078 0 0 0 0 0.0559 0.2149 0.2355 0.0115 0 0 0 0.0162 0.1898 0.1000 0 0]
```

Ex 1.11

Make a function

```
label = classify_digit(digit_image, position, radius, digits_training)
```

that computes a descriptor for the given digit image, goes through all the digits in `digits_training` to find the one with the most similar descriptor and outputs the label of that digit.

You can use **disp** to display text in matlab. For example

```
disp(['I am ' num2str(age) ' years old'])
```

will display your age, assuming that it is stored in the variable **age**.

Ex 1.12

Make a script **classify_all_digits.m** that runs **classify_digit** for each of the digits in **digits_validation** and displays the percentage of correct answers.

classify_all_digits

Correct classification: 66%

Ex 1.13

Try to classify a few of the large digits in `paper_with_digits.png`. For example there are digits at

[1290; 950] ; [820; 875] ; [220; 570] ; [170; 330]

Note that you need to change the radius parameter. For each digit, plot the appropriately sized grid of regions and print the digit it was classified as.

```
%Your code here

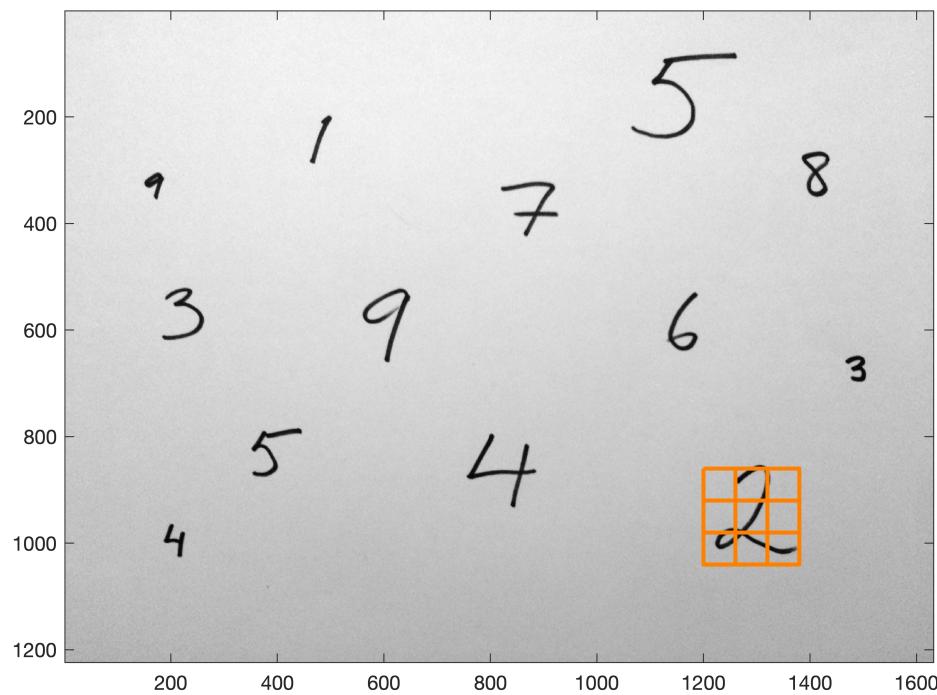
% Positions of the digits
pos1 = [1290; 950]; % 2
pos2 = [820; 875]; % 4
pos3 = [220; 570]; % 3
pos4 = [170;330]; % 9

% Appropriate radii for the digits
r1 = 30;
r2 = 30;
r3 = 20;
r4 = 10;

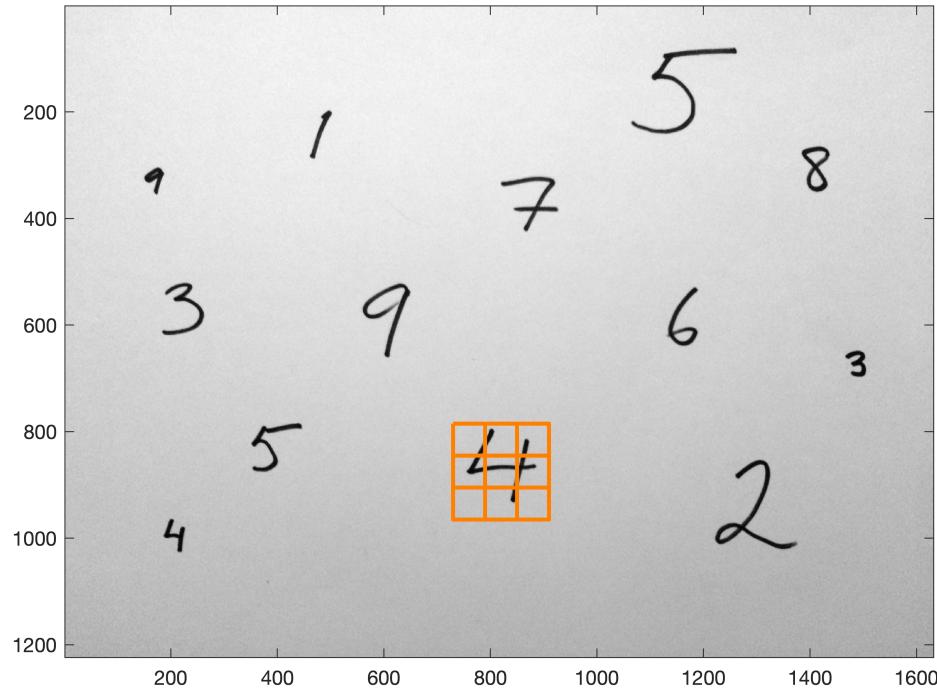
% Gather in vectors
pos = [pos1 pos2 pos3 pos4];
r =[r1 r2 r3 r4];

% Iterate over digits and classify them
for i=1:length(r)
    label = classify_digit(img, pos(:,i), r(i), digits_training)
    region_centres = place_regions(pos(:,i), r(i));
    figure()
    plot_squares(img, region_centres, r(i));
end

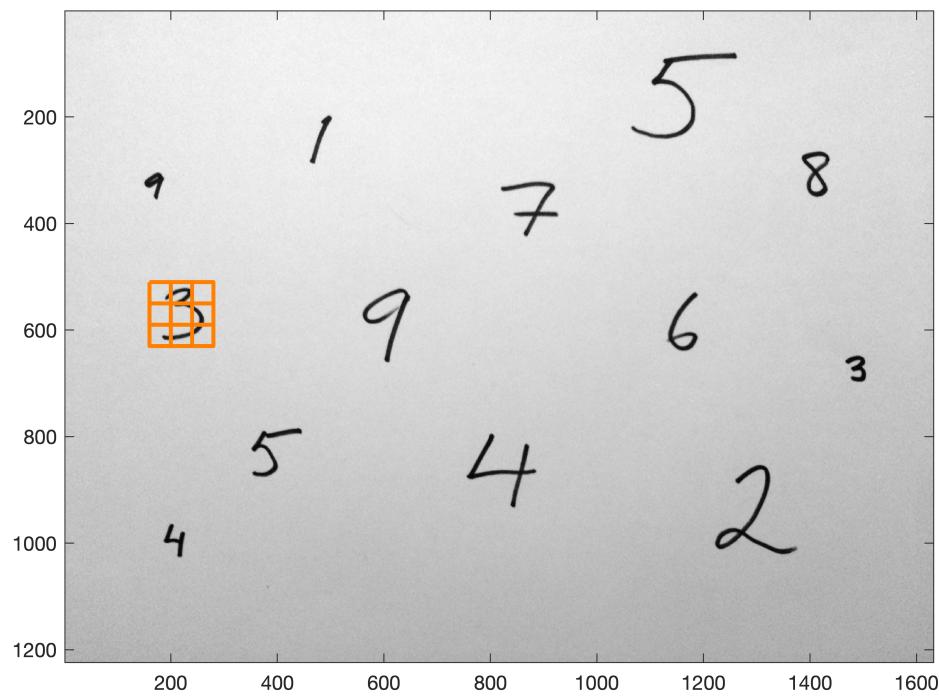
label = 2
```



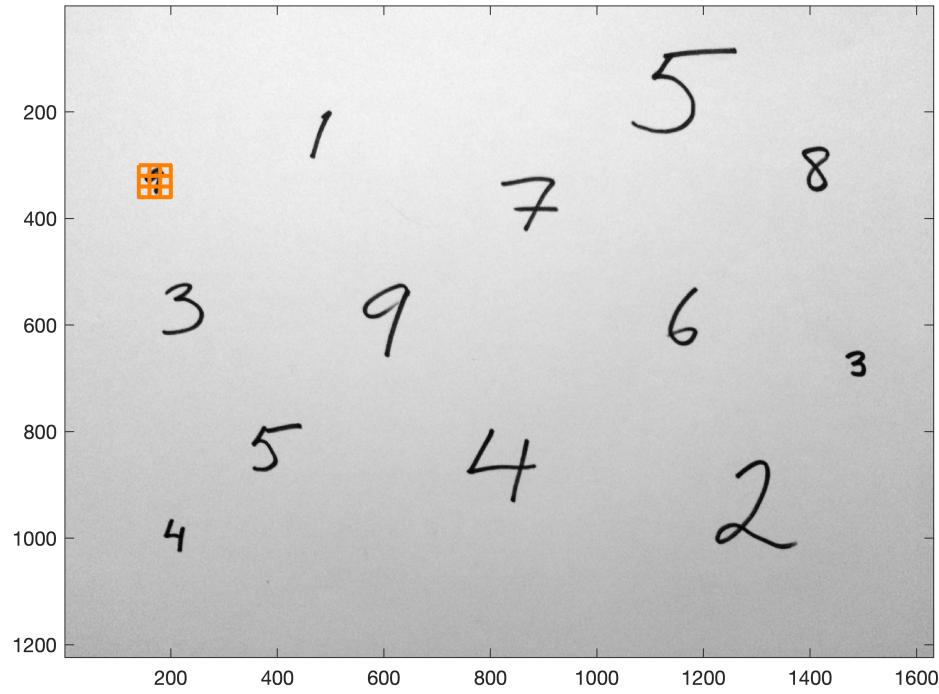
label = 4



label = 3



label = 9



Describe any one idea on how to set the radius parameter automatically?

Your answer:

On way to automate the radii would be to find where the rate of change for the gradient diminishes, i.e where it transitions from foreground to background.

Do this:

Start of with a small radius, determine the gradient and hessian of the patch in that radius. If the hessian is above a wanted value α , increase the radius.

Repeat the steps until the hessian gets below the wanted value α . At this point, the rate of change in the gradient is sufficiently low that we may assume that we are now transitioning between foreground and background.

However, it is difficult to say whether this approach will converge for any given α ... It may work in the digits case since there is a clear distinction between foreground and background, but it may not work for other examples where the foreground and background may be indistinguishable.

/ Nicholas Granlund

Using the SIFT code from Computer Vision toolbox

To speed things up a bit, we will use the SIFT descriptor from the CV toolbox in the next few exercises.

It is written in C, so it is much more efficient than your Matlab implementation. Use

```
points = detectSIFTFeatures(img);  
[features, validPoints] = extractFeatures(img,points);
```

to compute positions and descriptors for the SIFT features in an image.

Ex 1.14

To prepare for the next exercise, try to work out how to use the built-in function **matchFeatures**. To match descriptors using the Lowe criterion with threshold 0.7, add the following options:

```
corrs = matchFeatures(descs_1, descs_2, 'MatchThreshold', 100, 'MaxRatio', 0.7);
```

Ex 1.15

In **church_data_matlab.mat** there is a collection of stored feature points, **feature_collection**. This is a struct with a 128 x N-array **feature_collection.descriptors** containing descriptors and a 1 x N array of labels **feature_collection.labels**

```
load church_data_matlab.mat  
feature_collection
```

`feature_collection.labels`

The labels indicate what church the feature was collected from. The link between labels and church names is given by `feature_collection.names`.

Make a function

```
label = classify_church(image, feature_collection)
```

that tries to classify a new image by computing feature points for the new image, matching them to the features in the list and letting each match vote for the correct church.

Try classifying all ten provided church images in **church_test**. How many do you get right? (Note: It should be possible to get all of them right!) The correct labels are stored in **manual_labels.mat**.

```

load church_test/manual_labels.mat;
correct = 0;
for church = 1:10
    im = rgb2gray(imread(['church_test/church',num2str(church),'.jpg']));
    label = classify_church(im, feature_collection);
    disp(['Church is ' manual_labels{church} ' and classified as ' feature_collection]);
    correct = correct + strcmp(feature_collection.names{label},manual_labels{church});
end

```

Church is goteborg and classified as goteborg
Church is kalmar and classified as kalmar
Church is stockholm and classified as stockholm
Church is kalmar and classified as kalmar
Church is uppsala and classified as uppsala
Church is uppsala and classified as uppsala
Church is goteborg and classified as goteborg
Church is lund and classified as lund
Church is lund and classified as lund
Church is stockholm and classified as stockholm

```
disp(['Correctly classified churches: ', num2str(correct)]);
```

Correctly classified churches: 10