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');
addpath('./sift')
```

Note: There is a SIFT version for MAC users at the Canvas page.

Lab 1: The SIFT descriptor

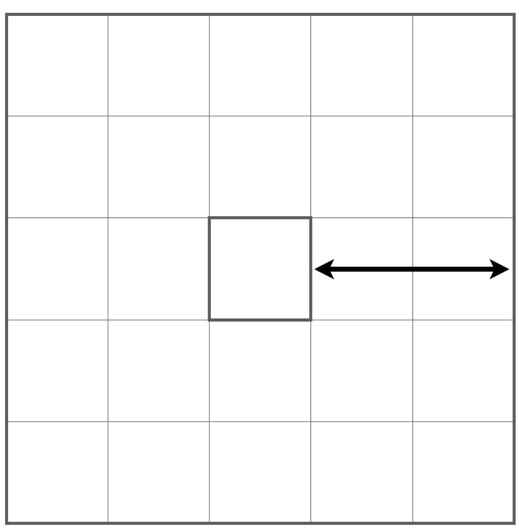
In this lab you will implement a SIFT-like descriptor and try it on some classification tasks. Keep your code well commented, both for your own sake and because it is required.

Ex 1.1

Make a function

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

that takes out a quadratic patch from the image centred at (x; y) with a range of +/- 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((11:100), 10, 9)
```

```
test_image = 10×9
    11    21    31    41    51    61    71    81    91
    12    22    32    42    52    62    72    82    92
    13    23    33    43    53    63    73    83    93
    14    24    34    44    54    64    74    84    94
    15    25    35    45    55    65    75    85    95
    16    26    36    46    56    66    76    86    96
    17    27    37    47    57    67    77    87    97
    18    28    38    48    58    68    78    88    98
    19    29    39    49    59    69    79    89    99
    20    30    40    50    60    70    80    90   100
```

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,3,4,2)
```

```
ans = 5×5
    12    22    32    42    52
    13    23    33    43    53
    14    24    34    44    54
    15    25    35    45    55
    16    26    36    46    56
```

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,2,4,2)
```

```
ERROR. Patch outside image border 0   1   2   3   4, 2   3   4   5   6
ans =
'ERROR. Patch outside image border'
```

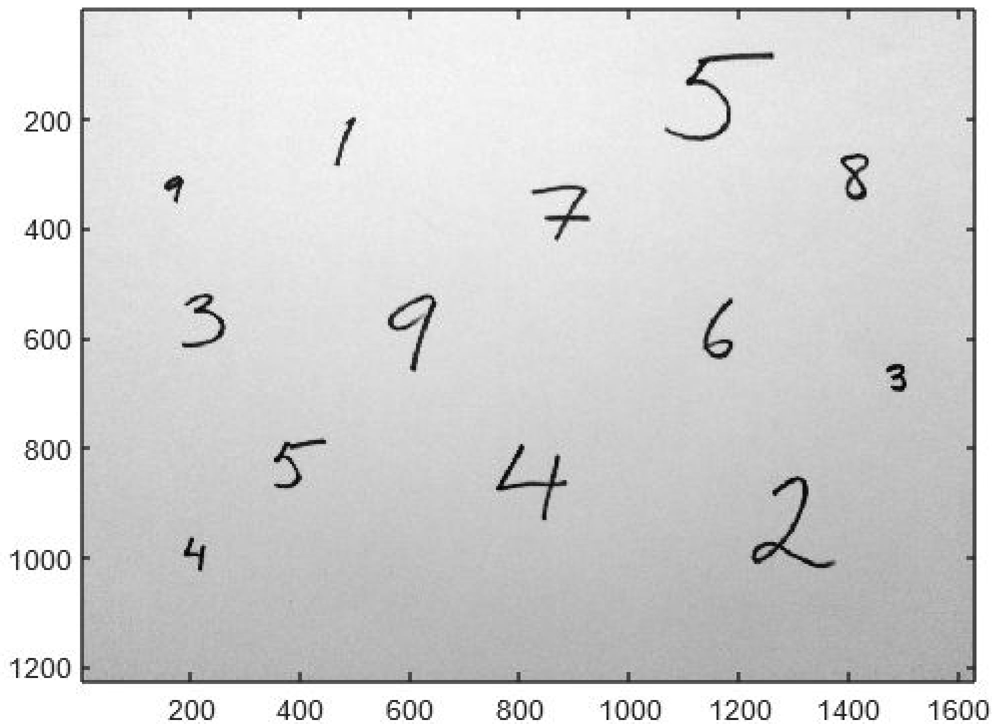
Gradient histograms

Ex 1.4

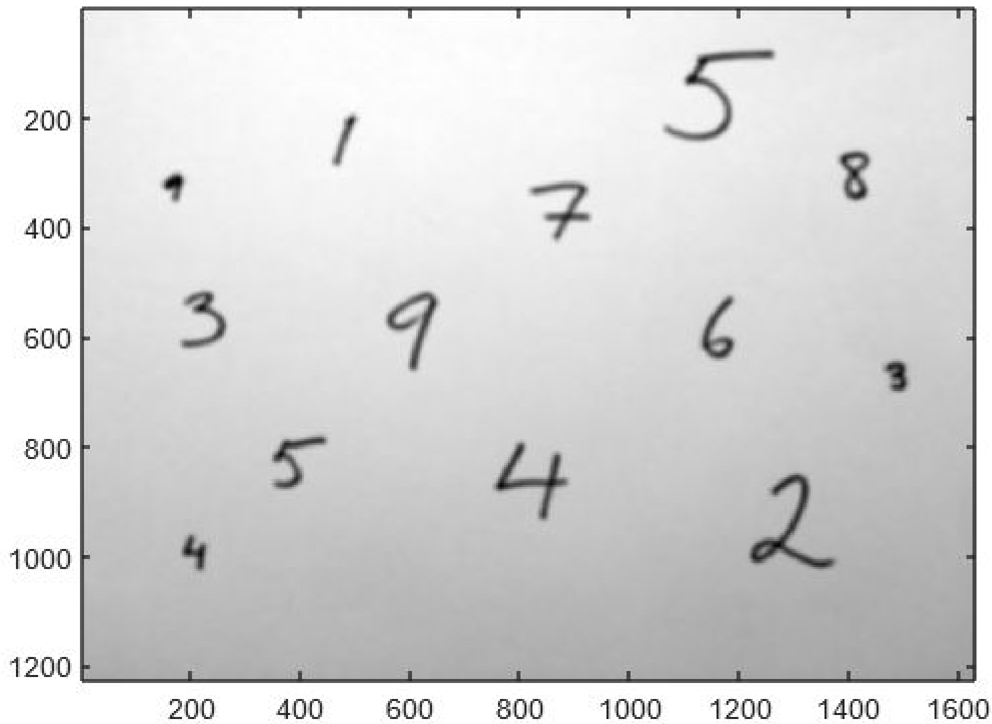
Create a Matlab function **gaussian_filter** that takes two arguments, one grayscale image and one number specifying a standard deviation. The output should be the image filtered with a Gaussian filter of the specified standard deviation. Example usage:

```
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 loose 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

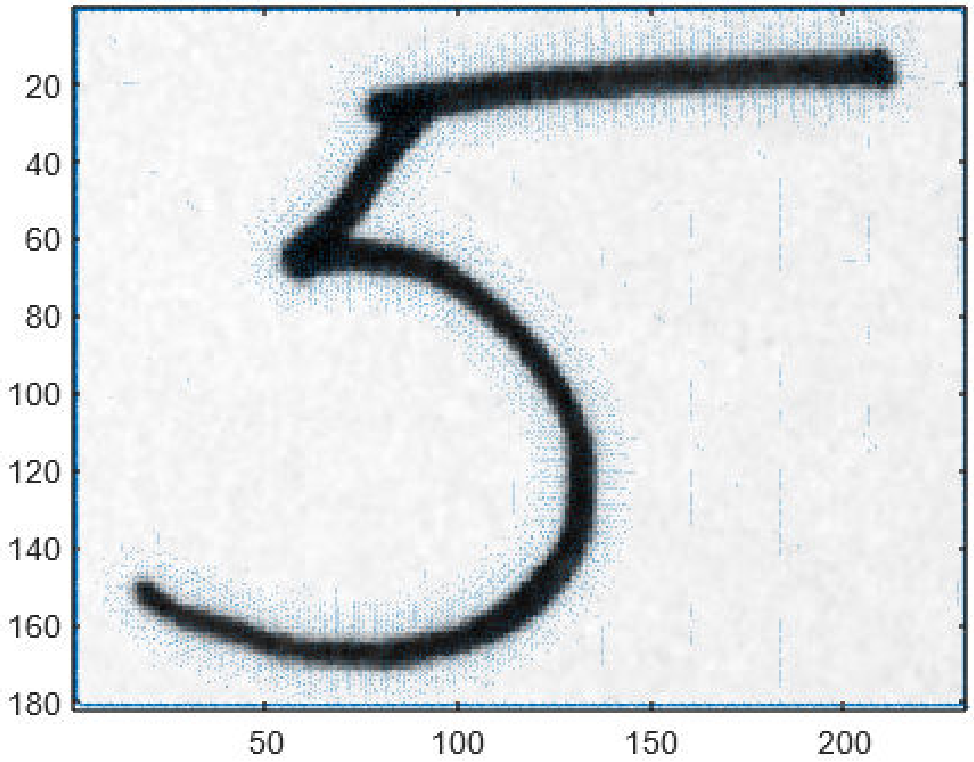
[grad_x, grad_y] = gaussian_gradients(img, std)

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.

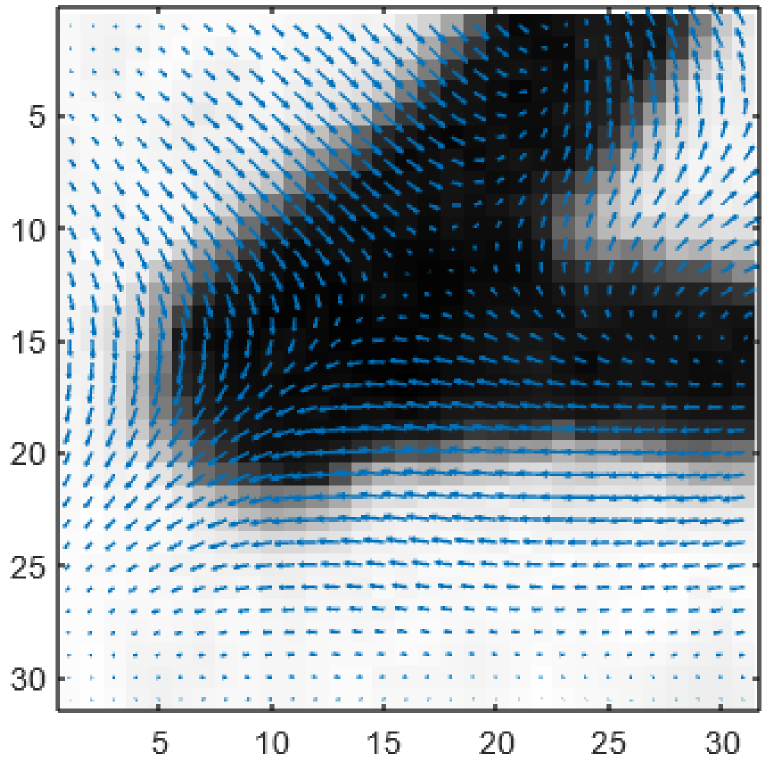
Ex 1.6

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.

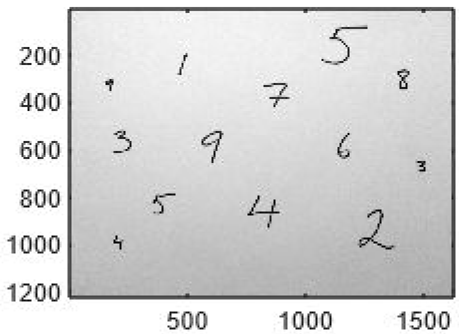
Ex 1.7

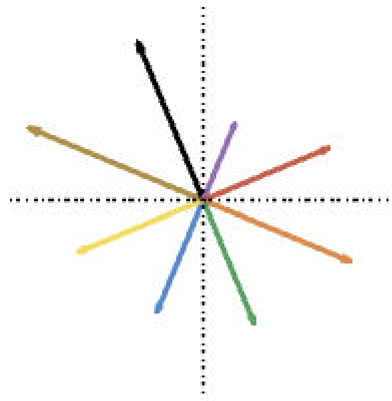
Make a function

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(img, 5);
```





A SIFT-like descriptor

Next, we will create a SIFT-like descriptor by computing gradient histograms for 3 x 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).

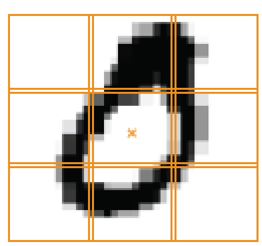


Figure: Example of patch placement. The x marks the coordinates in the argument position.

Ex 1.8

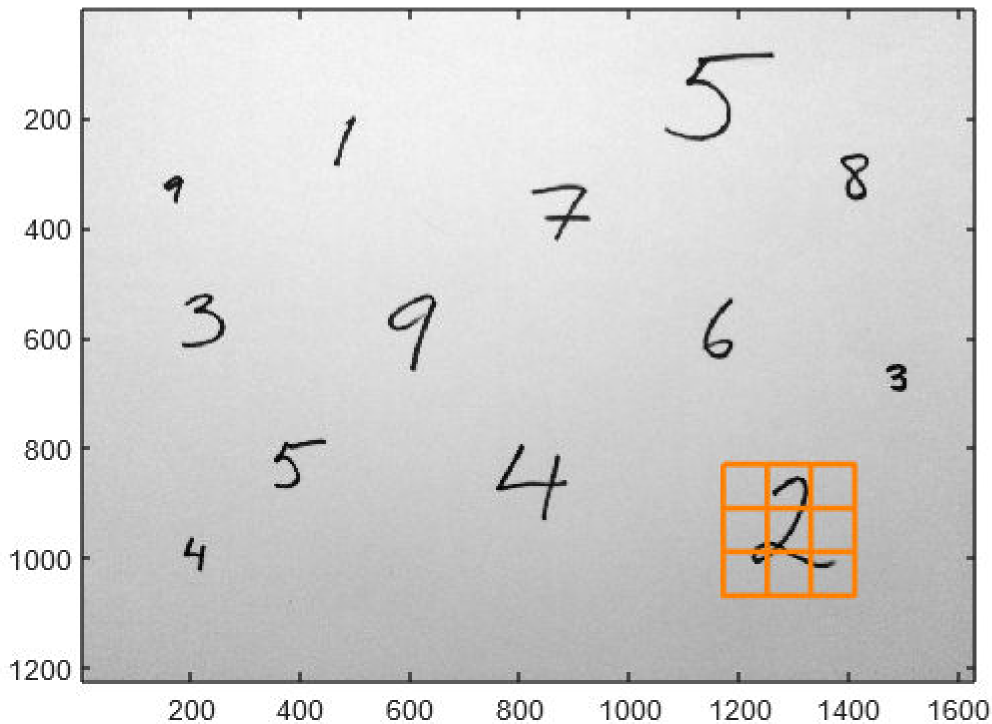
Make a function

region_centres = place_regions(centre, radius) that creates 3 x 3 square regions for the descriptor; see the above figure. The input radius specifies the radius of each region (as in Ex 1.1). The output should be an 2x9 array with the centre points of each region. Use the provided function

plot_squares(img, region_centres, 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]; radius = 80;
region_centres = place_regions(centre, radius);
plot_squares(img, region_centres, radius/2);
```



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 x 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 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 'descriptors'
digits_training(12)
```

```
ans = struct with fields:
         image: [39×39 double]
         label: 2
    descriptor: [72×1 double]
```

Ex 1.11

Make a function

label = classify_digit(digit_image, 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
```

```
INFO. Percentage correct: 66%
```

Ex 1.13

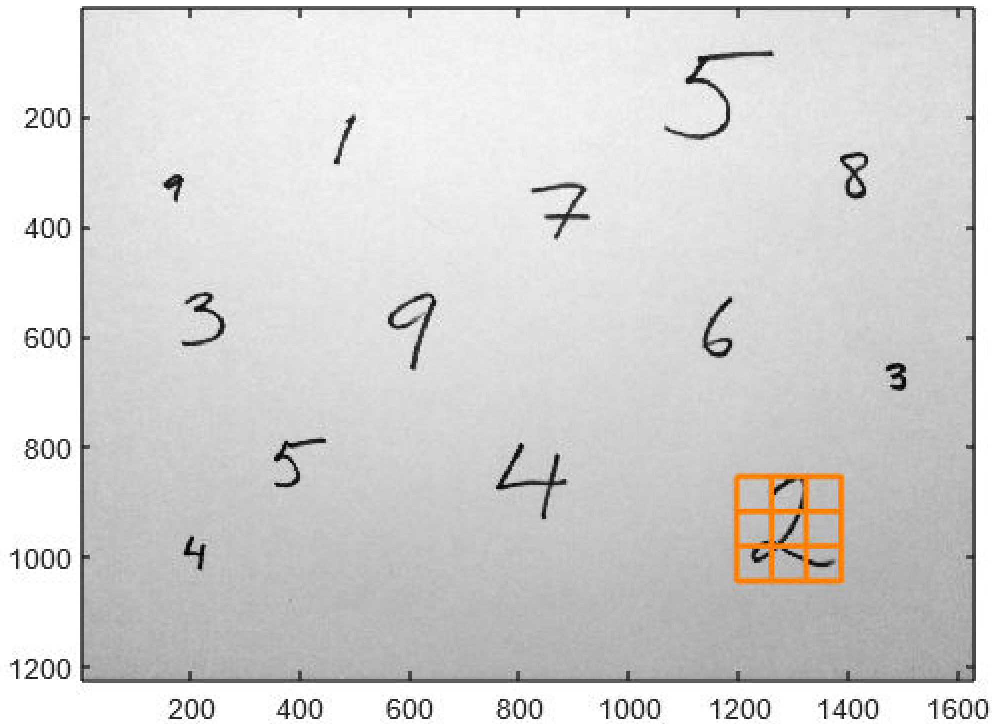
Try to classify a few of the large digits in **paper_with_digits.png**. For example there are digits at

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

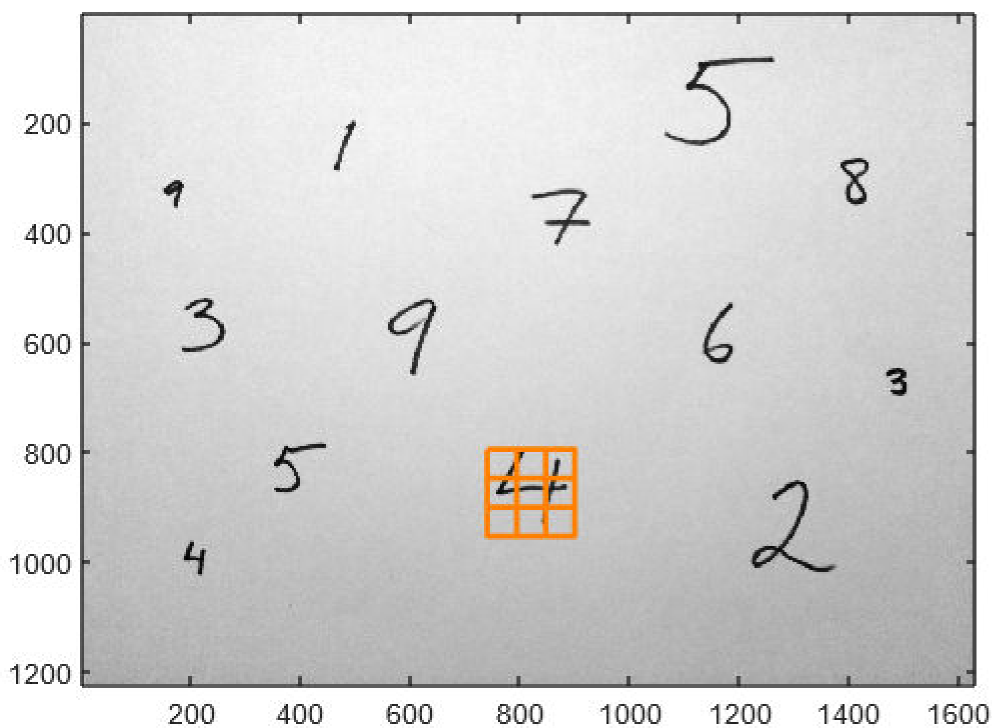
Note that you need to change the radius parameter. Does it work?

```
% Load image.
im = im2double(imread('paper_with_digits.png'));
im = mean(im, 3);
% Set centre and radius, then extract the region containing a digit.
region_centres = [1290; 950];
region_centres = [region_centres [820; 875]];
region_centres = [region_centres [220; 570]];
region_centres = [region_centres [170; 330]];
region_centres = region_centres';

region_radii = [96 80 60 40]; % Hard-coded patch radii

for n = 1:size(region_centres, 1)
    region_centre = region_centres(n, :);
    region_radius = region_radii(n);
    % Finally, get the label out of the region.
    region_w_number = get_patch(im, region_centre(1), region_centre(2), region_radius *
    centre = [int32(size(region_w_number, 1) / 2) - 1; int32(size(region_w_number, 2) /
    radius = (size(region_w_number, 1) / 3 - 1) / 2;
    label = classify_digit(region_w_number, digits_training, radius, centre);
    disp(['INFO. Classified patch [' num2str(region_centre(1)) '; ' num2str(region_cent
    figure, plot_squares(im, place_regions(region_centre, radius), radius / 2)
end
```

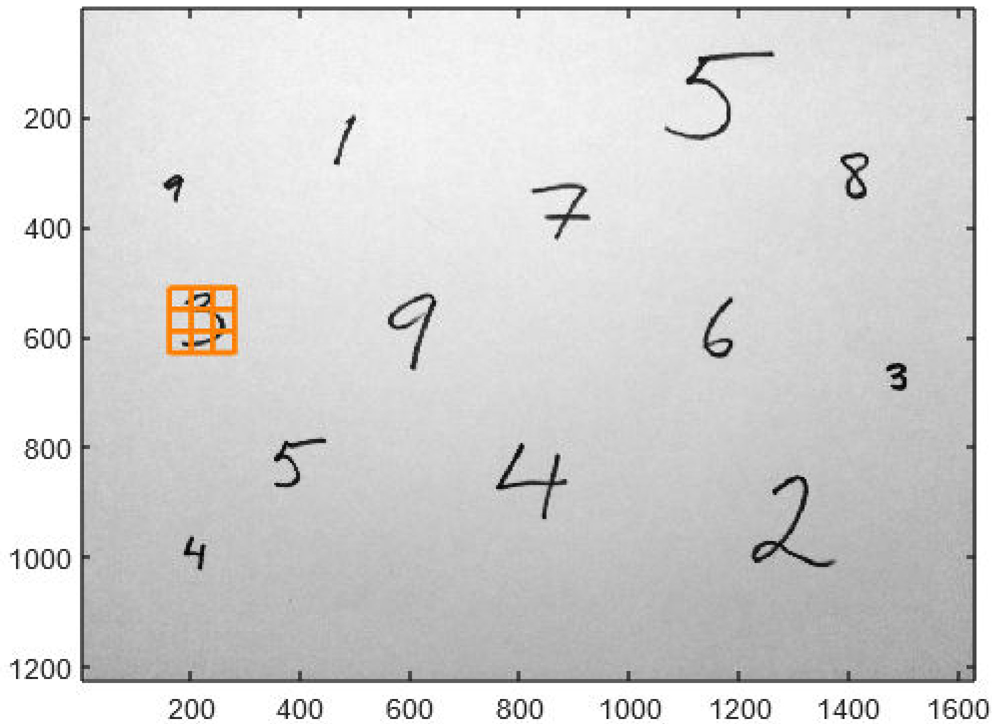
```
INFO. Classified patch [1290; 950] as 2, figure:
```



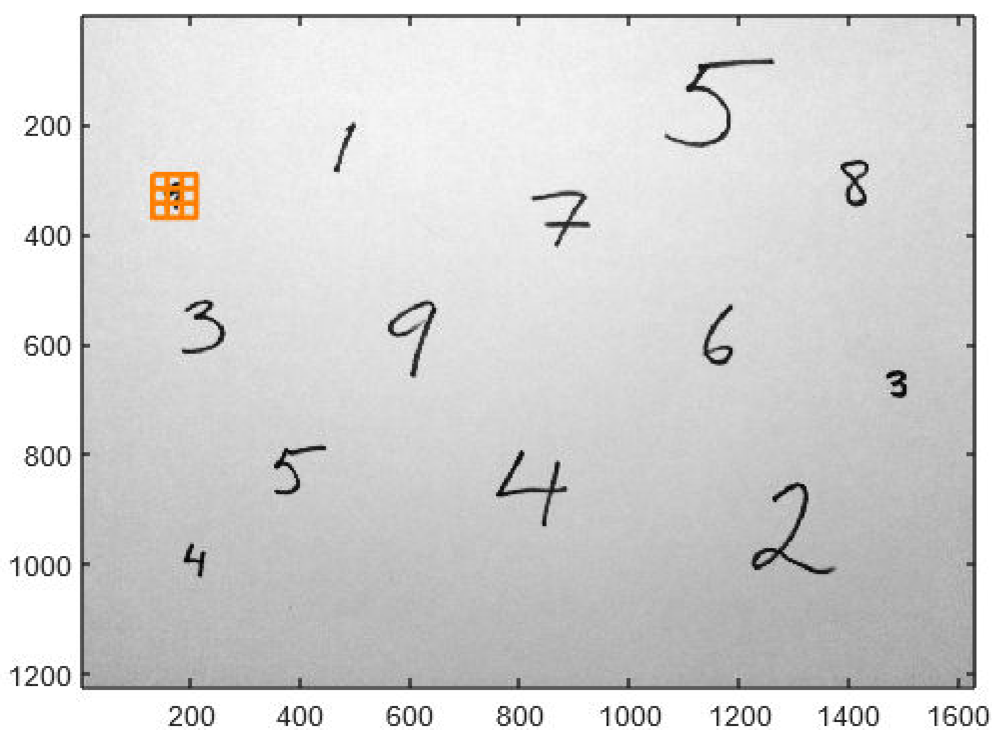
INFO. Classified patch [820; 875] as 4, figure:



INFO. Classified patch [220; 570] as 3, figure:



INFO. Classified patch [170; 330] as 9, figure:



Any ideas on how to set the parameter automatically?

Your answer:

Brainstormed idea on how to automatically determine the patch size:

1. Calculate the largest radius that fit the region
2. If any of the patches is empty, reduce the radius until all patches contain a 'piece' of the digit

Using the SIFT code from vlfeat

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

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

```
[coords, descriptors] = extractSIFT(img)
```

```
coords = 2×3
   25.7325   21.7342   21.7342
   19.8296   17.8698   17.8698
descriptors = 128×3 single matrix
         0         0         0
    0.0020         0         0
         0         0         0
         0         0         0
    0.0020         0         0
    0.2592         0         0
    0.0805         0         0
         0         0         0
    0.0039         0         0
    0.0039         0         0
      ⋮
```

```
% help extractSIFT
```

to compute positions and descriptors for the SIFT features in an image. (Make sure that the sift folder is in your path. If you still have problems running sift ask the lab assistant for help.)

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);

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

Ex 1.15

In **church_data.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.mat
feature_collection
```

```
feature_collection = struct with fields:
          names: {'goteborg'  'kalmar'  'lund'  'stockholm'  'uppsala'}
    descriptors: [128×18578 single]
         labels: [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

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 = double(rgb2gray(imread(['church_test/church',num2str(church),'.jpg'])));
    label = classify_church(im, feature_collection);
    disp(['Church n.' num2str(church) ' is ' manual_labels{church} ' and classified as
    correct = correct + strcmp(feature_collection.names{label},manual_labels{church});
end
```

```
Church n.1 is goteborg and classified as goteborg
Church n.2 is kalmar and classified as kalmar
Church n.3 is stockholm and classified as stockholm
Church n.4 is kalmar and classified as kalmar
Church n.5 is uppsala and classified as uppsala
Church n.6 is uppsala and classified as uppsala
Church n.7 is goteborg and classified as goteborg
Church n.8 is lund and classified as lund
```

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

In order to find the best parameters, I ran the classification over many combinations, as follows:

```
best_thr = 0;
best_ratio = 0;
best_correct = 0;

for i = 1:10
    for j = 1:10
        correct = 0;
        thr = i * 10;
```

```
        ratio = j * 0.1;
        for church = 1:10
            im = double(rgb2gray(imread(['church_test/church',num2str(church),'.jpg']))
            label = classify_church(im, feature_collection, thr, ratio);
            correct = correct + strcmp(feature_collection.names{label},manual_labels{ch
        end
        if correct > best_correct
            best_ratio = ratio;
            best_thr = thr;
            best_correct = correct;
        end
    end
end
best_thr
best_ratio
best_correct
```