Question 3

(a) The images were taken

(b) Using the provided vlfeat library features and descriptors have been extracted.

- Each of the feature vectors is a 4-row vector: $\begin{cases} (f(1:2)) - location\ of\ the\ feature \\ f(3) - scale \\ f(4) - orientation \end{cases}$

- Each of the descriptor vectors is a 128 elements vectors, describing orientation histogram (for 8 orientations) for each of the 16 cells in the vicinity of the feature (16 * 8 = 128).

The vlfeat library allows the usage of customized parameters for feature extraction:

- Peak threshold
- Edge threshold

They define the threshold for a potential feature to be declared a feature. In our example, 57 features were extracted for #1 and 64 features were extracted for Image #2:
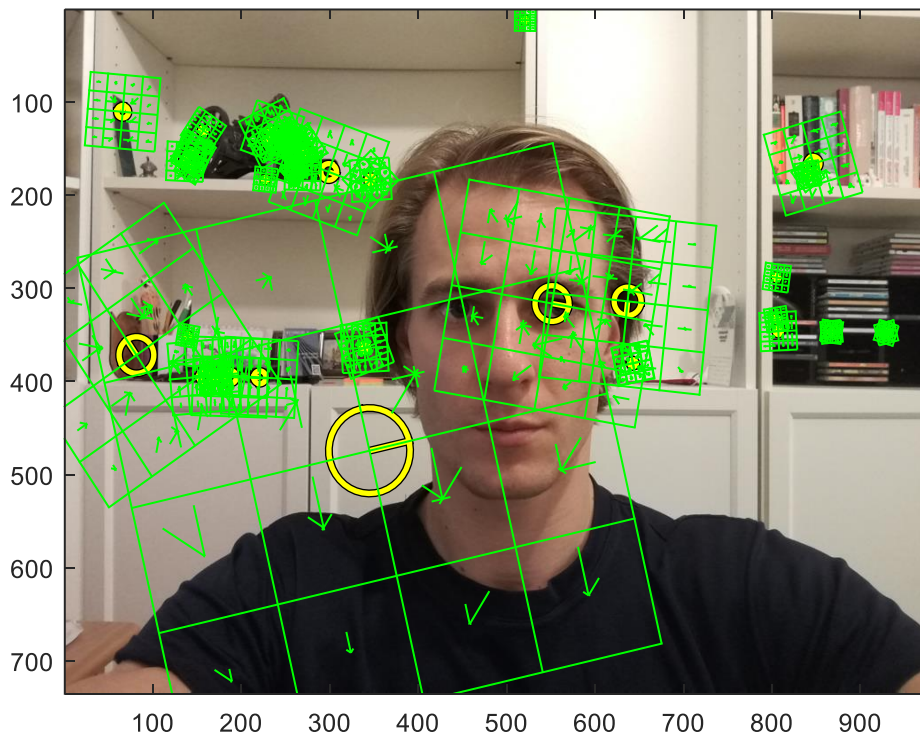

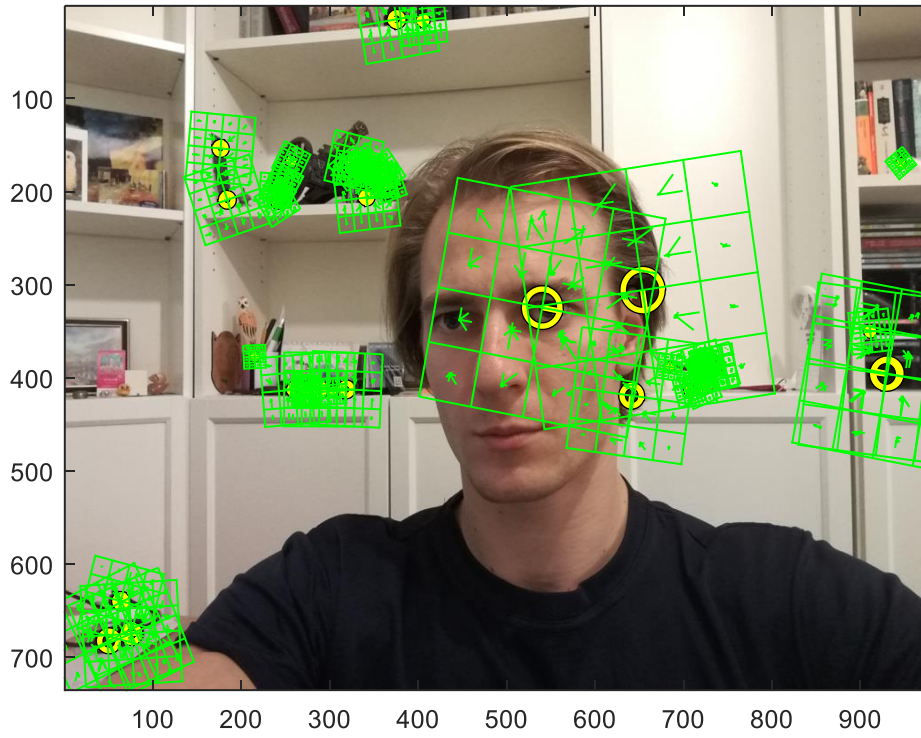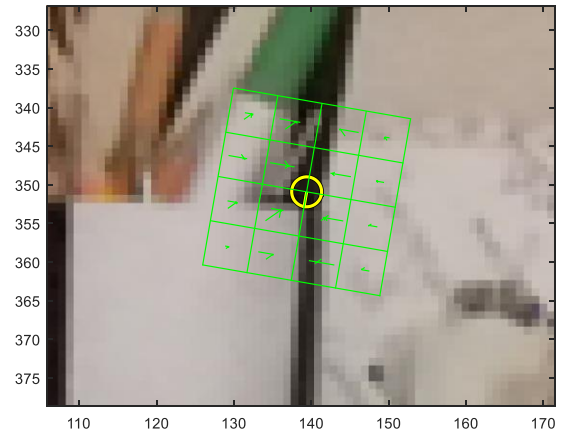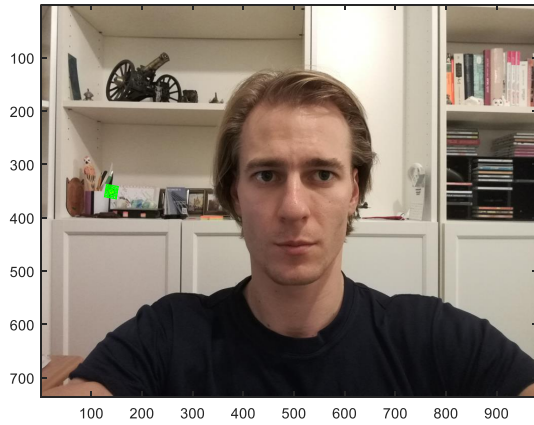*Figure 1   Image 1: 57 features detected*

Figure 2   Image2: 64 features detected

Scale and orientation for a representative feature: select arbitrary index 1. The feature 1 on Image1 is the following: (right image is the close-up)


The representative feature is then : $\begin{cases} x \\ y \\ scale \\ orientation \end{cases} = \begin{cases} 139.4 \\ 350.91 \\ 1.937 \\ 0.172 \end{cases}$; with scale =1.937 & orientation = 0.172

(c) The vlfeat library does possess the function for the feature matching, but since the question asks to perform the calculation as explained in class, the algorithm is written manually, while the library function helps us to validate the results. The algorithm for feature matching is the following:

1. Calculate the Euclidean distance from every feature descriptor (128 row vector) in Image 1 to every feature descriptor in Image 2.
2. For every feature in Image 1, find the minimum Euclidean distance out of Euclidean distances calculated to every feature in Image 2 (calculated in step 1)
3. Use the threshold parameter to validate this feature is "unique" enough. Meaning, the minimal Euclidean distance multiplied by threshold is still smaller than any other Euclidean distance to other features. Default value in vlfeat library is 1.5
4. If the condition in Step 3 holds, add this couple of matched features (their indexes) to the matched array.

The features matched by this way using a certain threshold (1.5) may be observed in the following image:
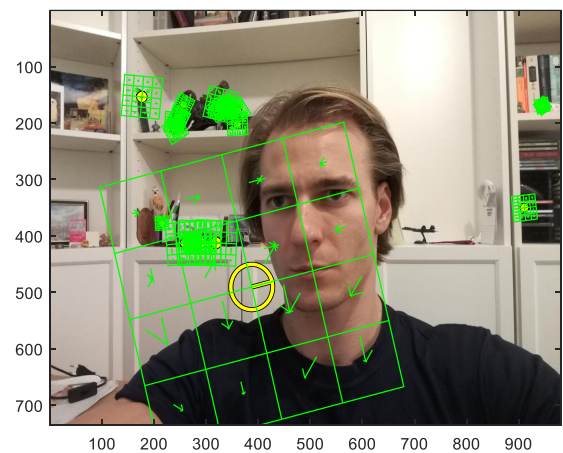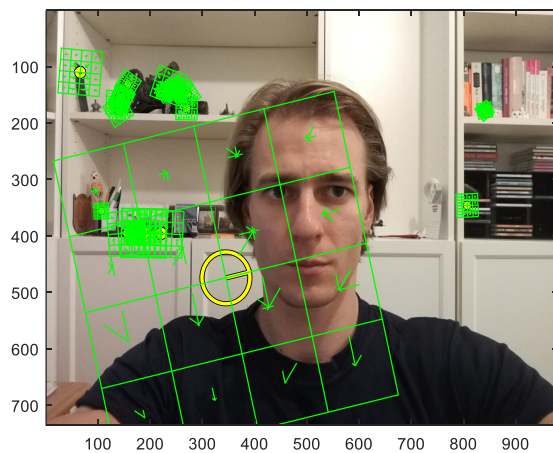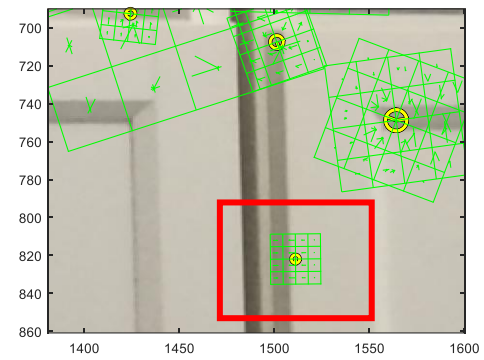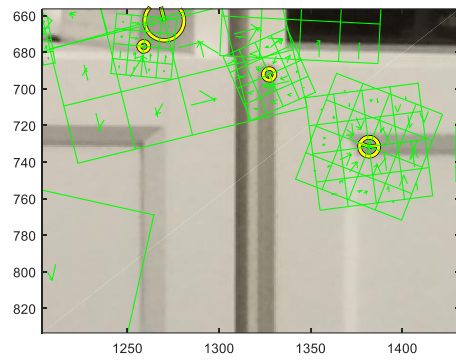

By the first look, it is indeed observable that those features are corresponding to each other. No outliers were found on this image, since the threshold parameters were set quiet to make the features amount small (for easier visual inspection).

In order to find the outliers, the higher resolution image was used, with smaller threshold parameters for feature extraction. As a result, in the following specific example, for Image 1 and 2 : 1188 and 1210 features were extracted, with 237 matches:
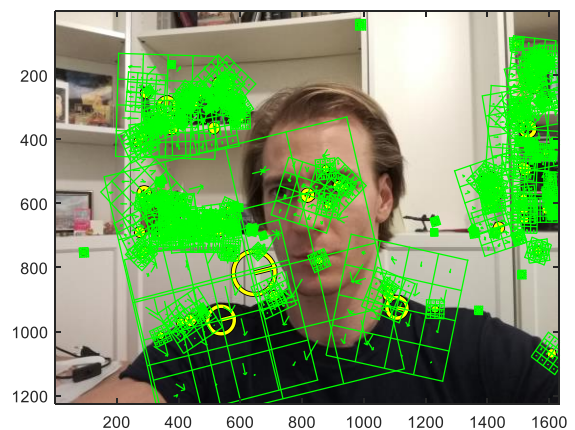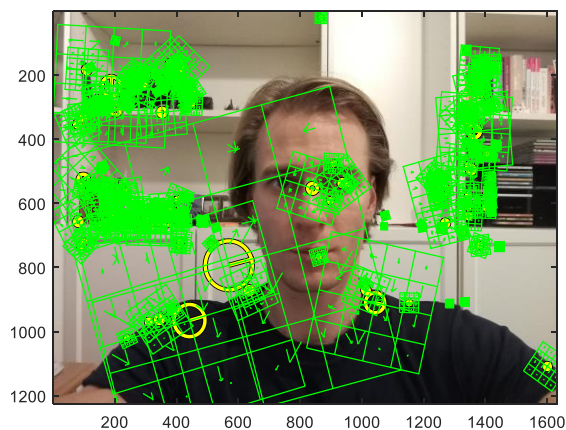
After the fast inspection, the following are the two examples of the outliers: (marked with red boxes)

Outlier 1 :

Outlier 2 :