Report of Anton Maksimov (antonma), Task 2 "Local features" on ETHZ course "Computer Vision".

1. Detection, figures 1 – 36.

   (a) To compute gradient maps we use convolution (function `conv2`) of patterns $(-0.5, 0, 0.5)$ and $(-0.5, 0, 0.5)^\top$ for X and Y axis correspondingly and use only pixels which are distanced from boundary for at least one pixel.

   (b) Using filtering (function `imgaussfilt`) of zero matrix 3x3, but with unity in the center, we prepare weighting matrix representing 2D 0-mean gaussian PDF with $\sigma =$ `sigma`:
   `w = imgaussfilt([0,0,0;0,1,0;0,0,0], sigma);`
   After that we compute matrix M for every pixel and calculate element of the Harris response function C using formulas for trace and determinant with eigenvalues:

   $$C(i,j) = \underbrace{\lambda_1\lambda_2}_{det(M(i,j))} - k\underbrace{(\lambda_1+\lambda_2)}_{Tr(M(i,j))},\ k \in [0.04, 0.06]$$

   (c) We consider as point of interest these, which have Harris response function more than threshold T and which have the maximum of this function in 3x3 neighborhood.

   (d) To check which set of parameters (sigma, k, threshold) is the best, we construct tables with images (listed in the following pages, figures from 1 36) showing locations of detected corners (in captions are written (sigma, k, threshold)).

   It could be seen, than results with bigger `sigma` produce less errors and densely placed points along the edges, so from suggested in `extractHarris.m` values we choose $\sigma = 2$.

   For threshold the best look pictures with $T = 3 \cdot 10^{-6}$ — enough points but not too much dense groups and agglomeration along lines, with more threshold it is too much errors.

   k in suggested interval doesn't play a big role with selected `sigma` and `threshold`, so we just choose 0.05.

   Resulting used parameters: $(\sigma = 2,\ k = 0.05, T = 3 \cdot 10^{-6})$.

   Issues:

   i. points along edges are often detected, especially if the contrast between half-planes is big. It is bad for consequent matching, as they all have more or less the same neighborhood, so it's better to set up parameters to minimize this effect.

   ii. detected points near the upper-left corner of pictures are due the artifacts on the images (e.g. black line on top of the house's image), but these points will be deleted during extraction of patches.

2. Description and matching, figures 37 – 41.

   (a) First we extract patches of 9x9, excluding points with Manhattan distance less than 4 pixels, collecting indexes of these points and in the end deleting then from keypoints-array:

```
if ((x > 4) && (y > 4) && ((n_x - x) > 3) && ((n_y - y) > 3))
number = number + 1;
descriptors(number,:,:)  = img(x-4:x+4, y-4:y+4);
else
bad_keypoints = [bad_keypoints, i];
end
```

(b) Reshape 9x9 patches to 1x81 and compare them using `pdist2` with the `squareuclidian` distance, producing distance matrix with dimensions — numbers of patches from the first and the second images.

(c) We implemented all three suggested methods to match points. In the «mutual» in order to optimize program we used array of flags showing if patch from the second image already has found patch from the first and we shouldnt́ compare it when iterating over patches from the first image.

Results show, that indeed «mutual» (find patches that are the closest for both of them) and «ratio» (use patches which have big difference between distances to the best and the second closest patches in comparison) work much better as just «one-way» method, because they select subset of point using sensible conditions.

We can estimate quality of matching just counting ratio of the not horizontal (as images are roughly just translated horizontally in joint comparison image) lines in the resulting matching-images to the horizontal ones. It can be seen, that the number of right matchings decreases a little, but the number of false matchings decreases from 11 to 5 and 1 using «one-way»–«mutual»-«ratio» methods, what significantly changes frequency of error.

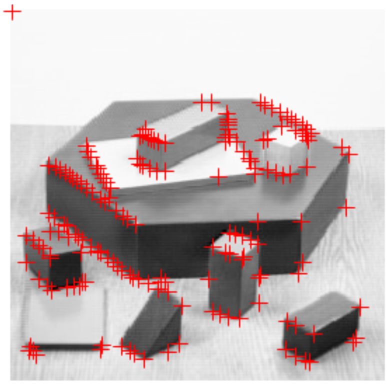


Figure 1: 1, 0.04, $1 \cdot 10^{-6}$

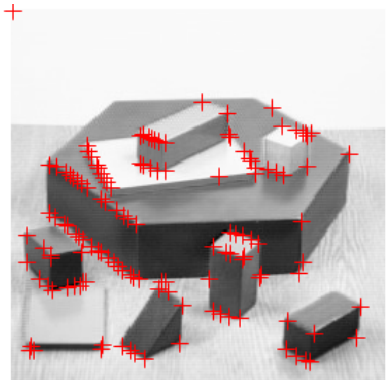


Figure 2: 1, 0.04, $3 \cdot 10^{-6}$

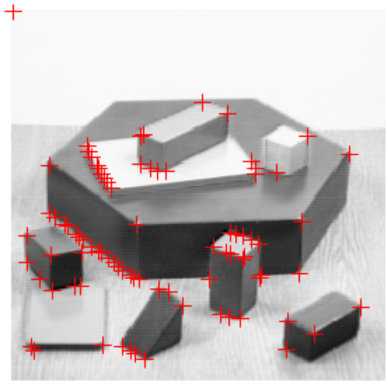


Figure 3: 1, 0.04, $7 \cdot 10^{-6}$

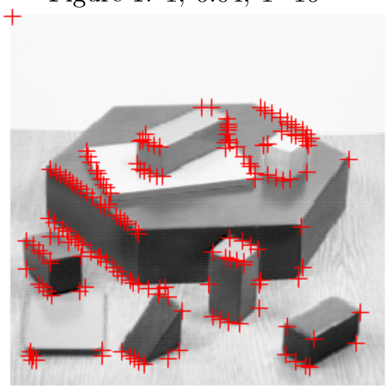


Figure 4: 1, 0.05, $1 \cdot 10^{-6}$

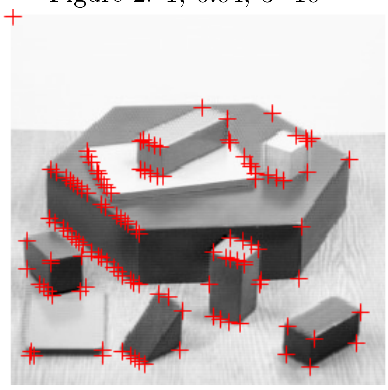


Figure 5: 1, 0.05, $3 \cdot 10^{-6}$

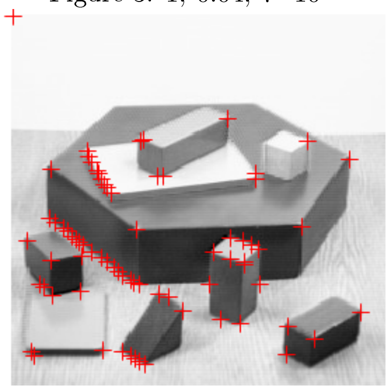


Figure 6: 1, 0.05, $7 \cdot 10^{-6}$

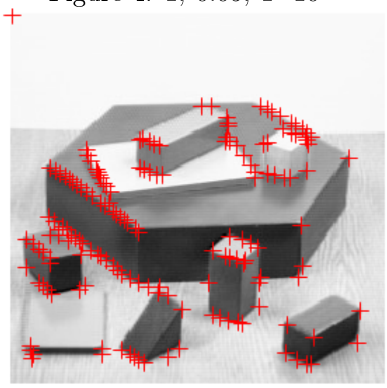


Figure 7: 1, 0.06, $1 \cdot 10^{-6}$

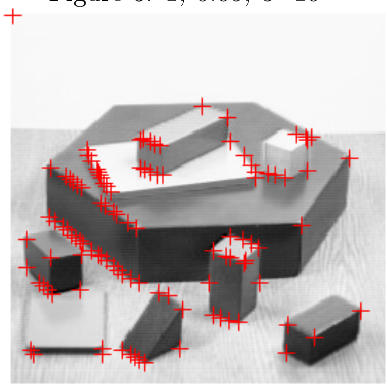


Figure 8: 1, 0.06, $3 \cdot 10^{-6}$

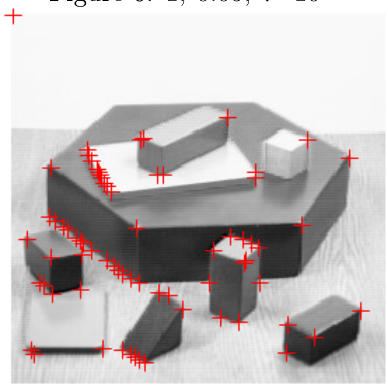


Figure 9: 1, 0.06, $7 \cdot 10^{-6}$

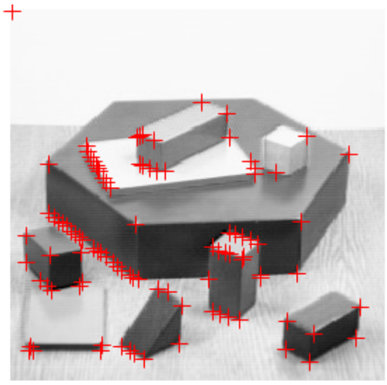


Figure 10: 2, 0.04, $1 \cdot 10^{-6}$

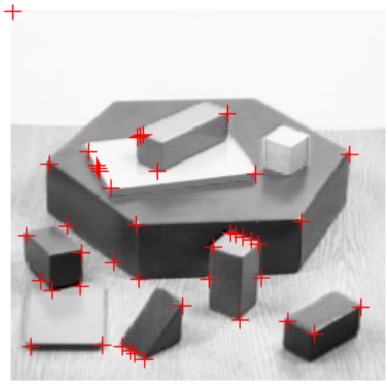


Figure 11: 2, 0.04, $3 \cdot 10^{-6}$

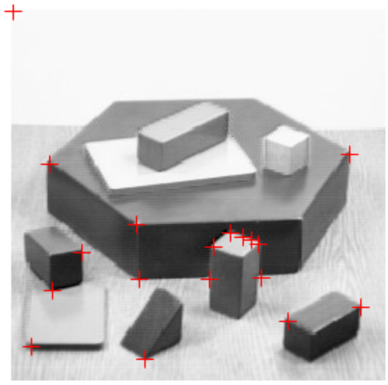


Figure 12: 2, 0.04, $7 \cdot 10^{-6}$

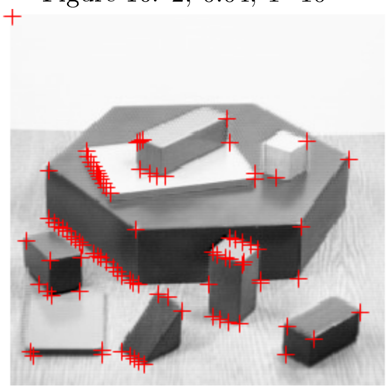


Figure 13: 2, 0.05, $1 \cdot 10^{-6}$

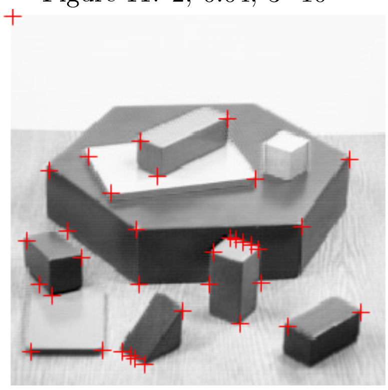


Figure 14: 2, 0.05, $3 \cdot 10^{-6}$

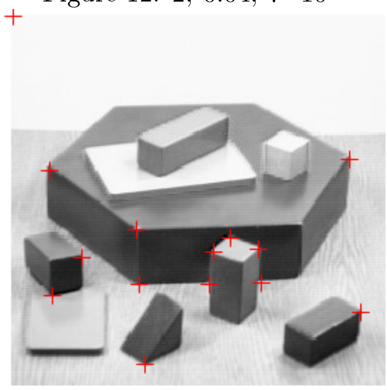


Figure 15: 2, 0.05, $7 \cdot 10^{-6}$

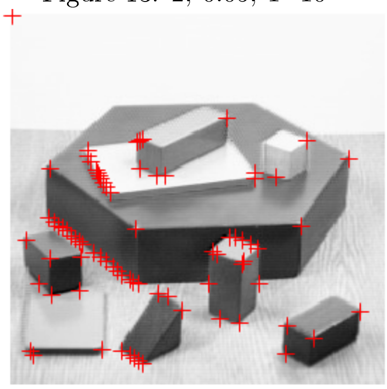


Figure 16: 2, 0.06, $1 \cdot 10^{-6}$

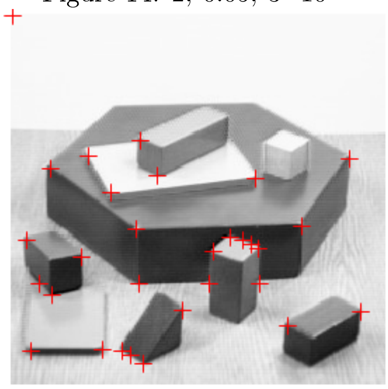


Figure 17: 2, 0.06, $3 \cdot 10^{-6}$

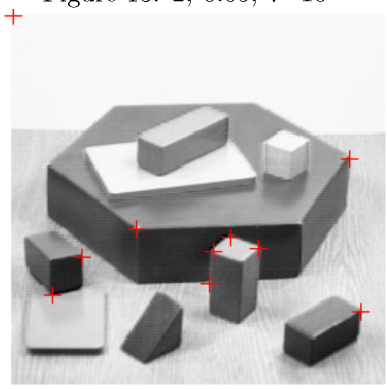


Figure 18: 2, 0.06, $7 \cdot 10^{-6}$

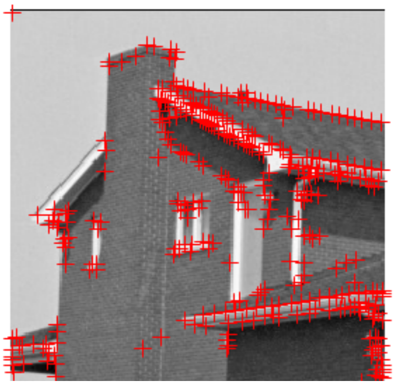


Figure 19: 1, 0.04, $1 \cdot 10^{-6}$

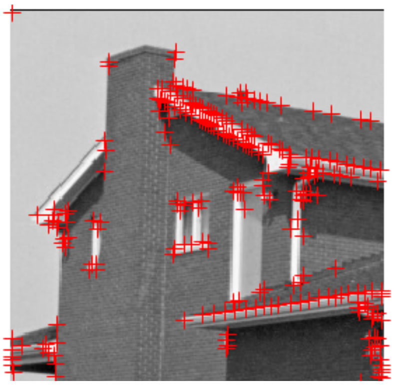


Figure 20: 1, 0.04, $3 \cdot 10^{-6}$

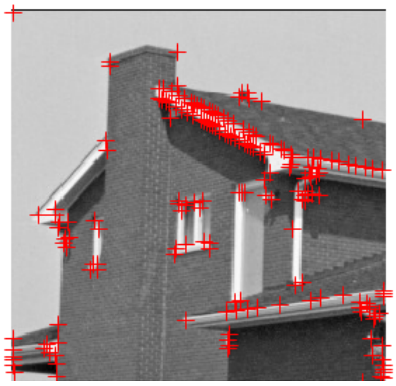


Figure 21: 1, 0.04, $7 \cdot 10^{-6}$

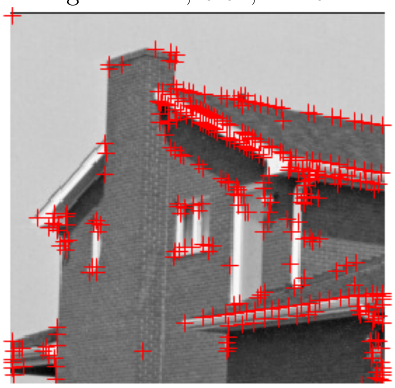


Figure 22: 1, 0.05, $1 \cdot 10^{-6}$

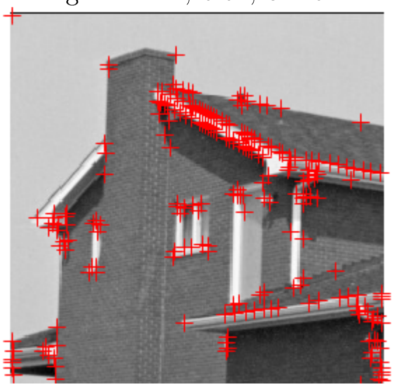


Figure 23: 1, 0.05, $3 \cdot 10^{-6}$

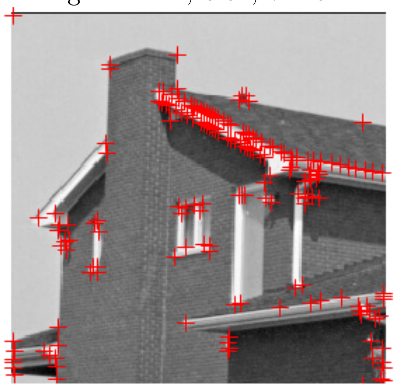


Figure 24: 1, 0.05, $7 \cdot 10^{-6}$

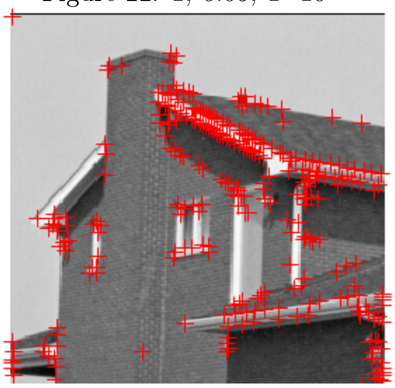


Figure 25: 1, 0.06, $1 \cdot 10^{-6}$

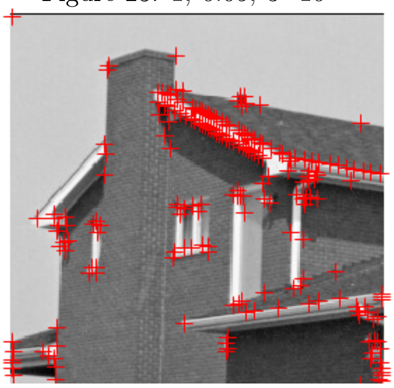


Figure 26: 1, 0.06, $3 \cdot 10^{-6}$

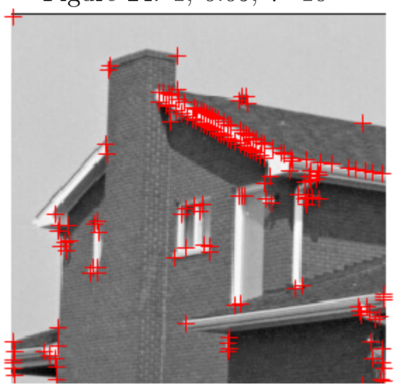


Figure 27: 1, 0.06, $7 \cdot 10^{-6}$

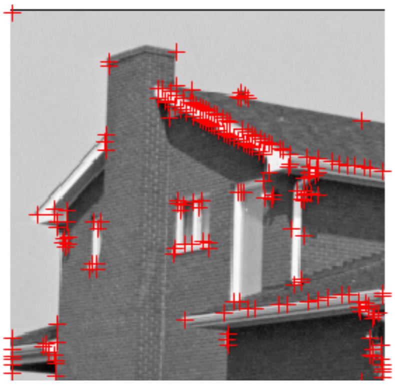


Figure 28: 2, 0.04, $1 \cdot 10^{-6}$

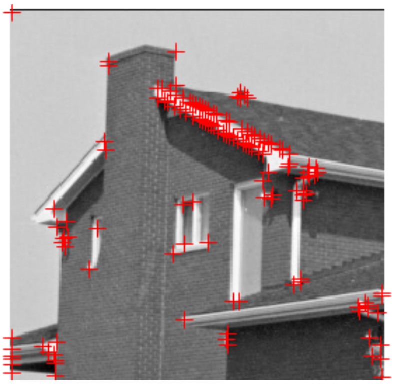


Figure 29: 2, 0.04, $3 \cdot 10^{-6}$

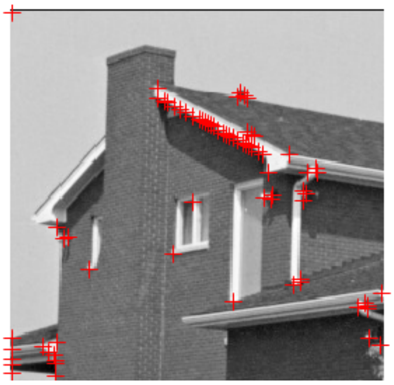


Figure 30: 2, 0.04, $7 \cdot 10^{-6}$

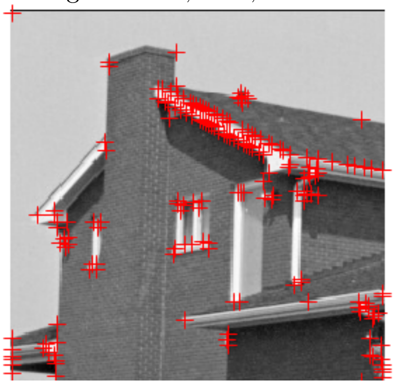


Figure 31: 2, 0.05, $1 \cdot 10^{-6}$

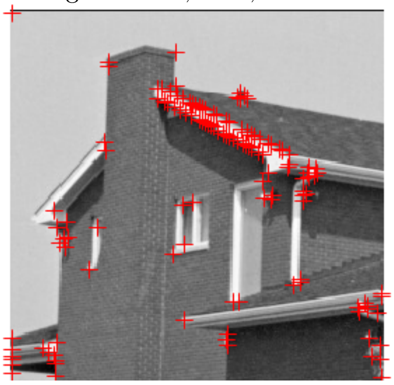


Figure 32: 2, 0.05, $3 \cdot 10^{-6}$

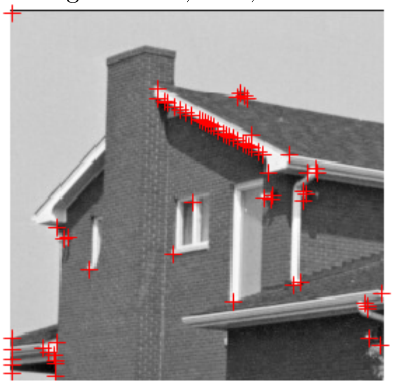


Figure 33: 2, 0.05, $7 \cdot 10^{-6}$

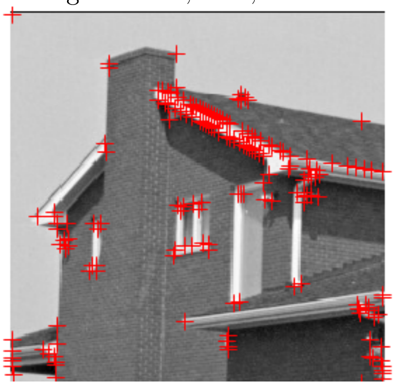


Figure 34: 2, 0.06, $1 \cdot 10^{-6}$

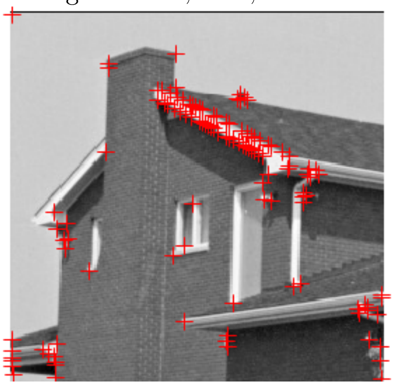


Figure 35: 2, 0.06, $3 \cdot 10^{-6}$

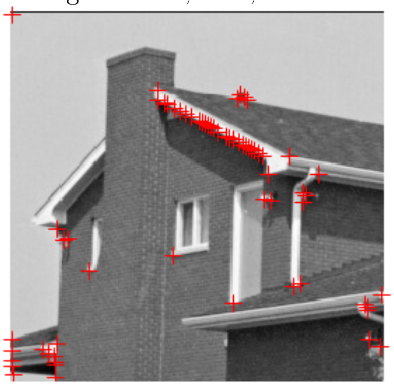


Figure 36: 2, 0.06, $7 \cdot 10^{-6}$

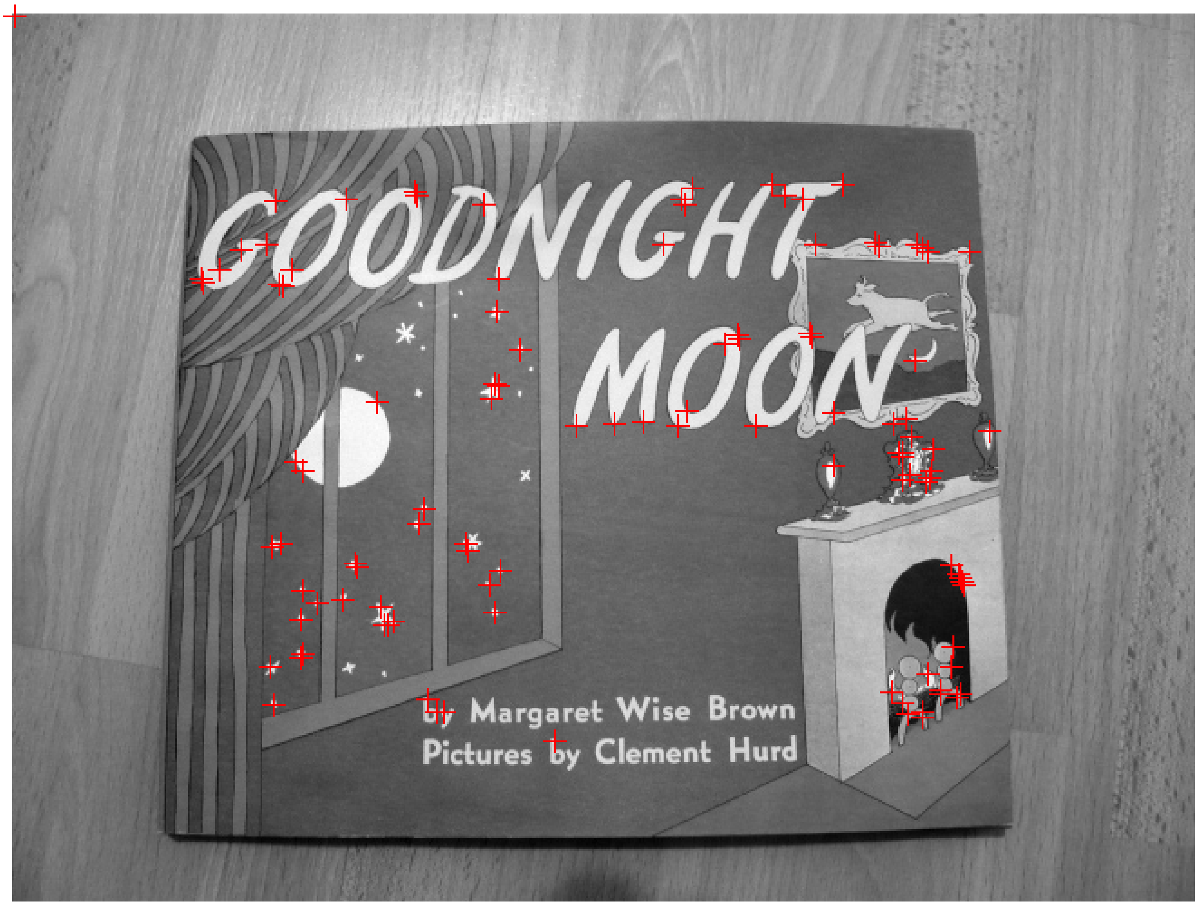
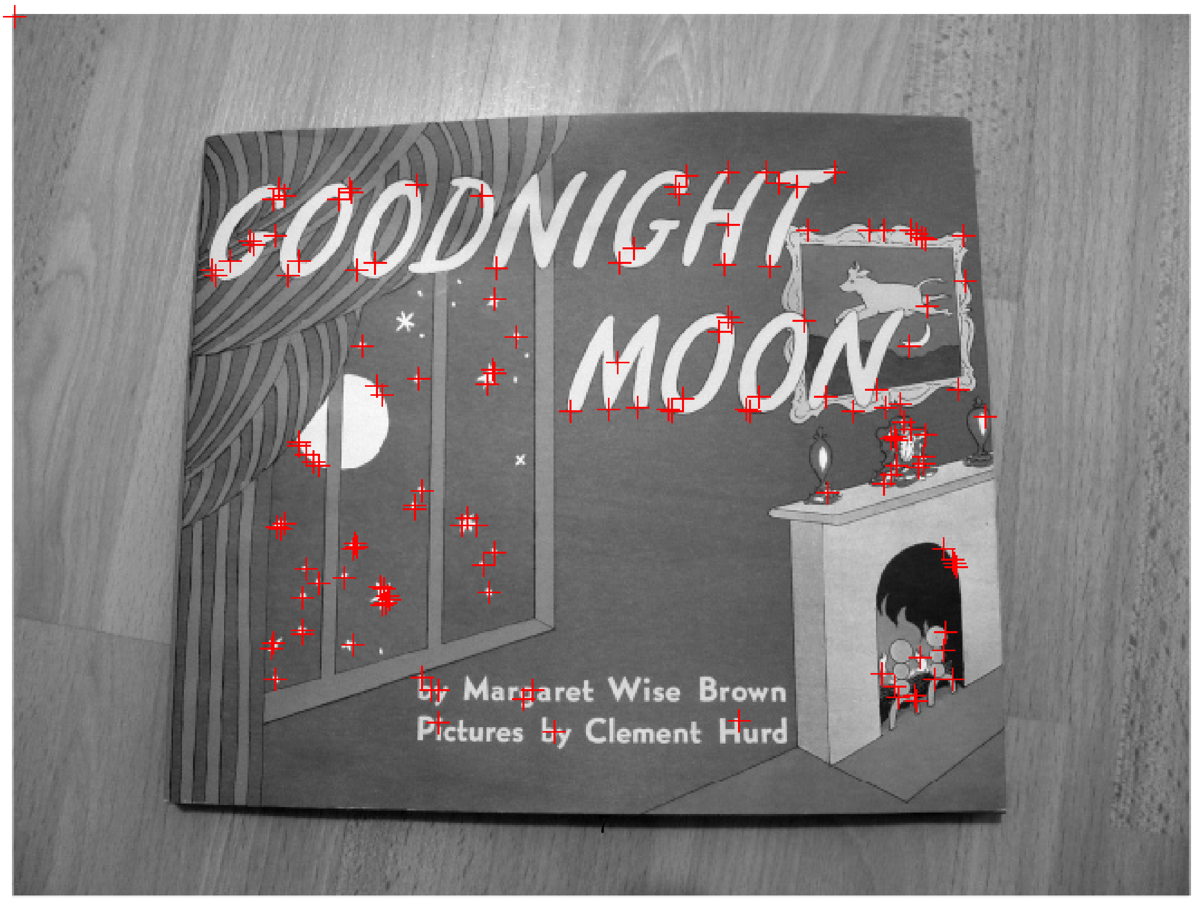


Figure 37: Points of interest using ($\sigma = 2,\ k = 0.05, T = 3 \cdot 10^{-6}$)



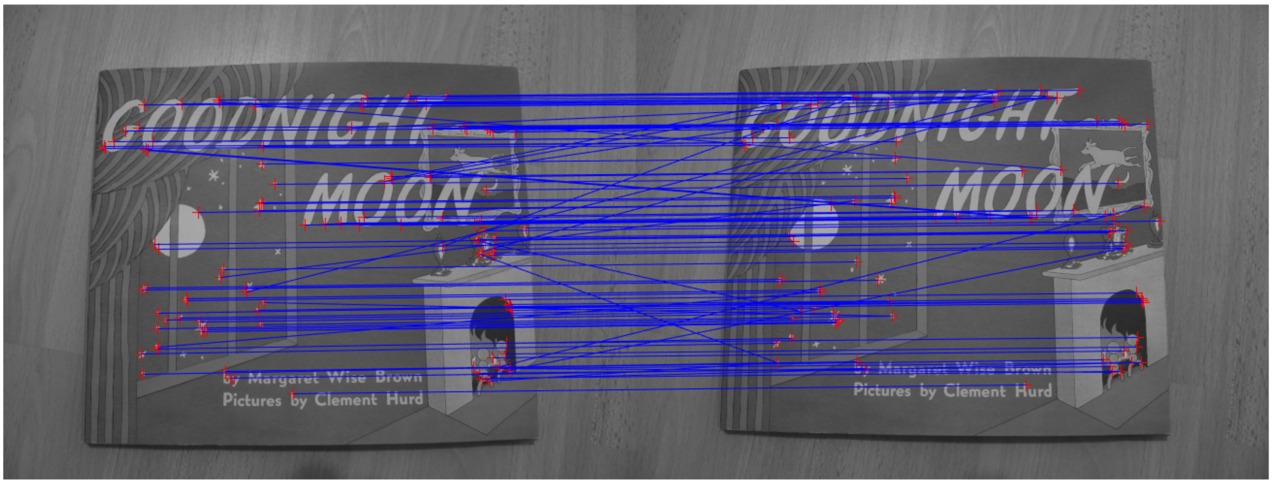


Figure 39: «One-way» matching

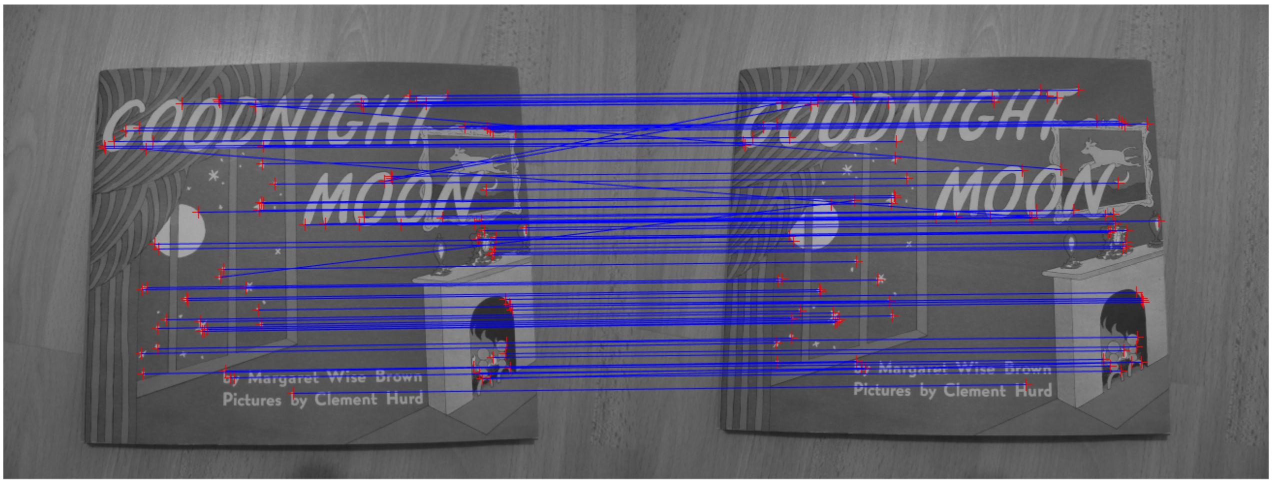


Figure 40: «Mutual» matching

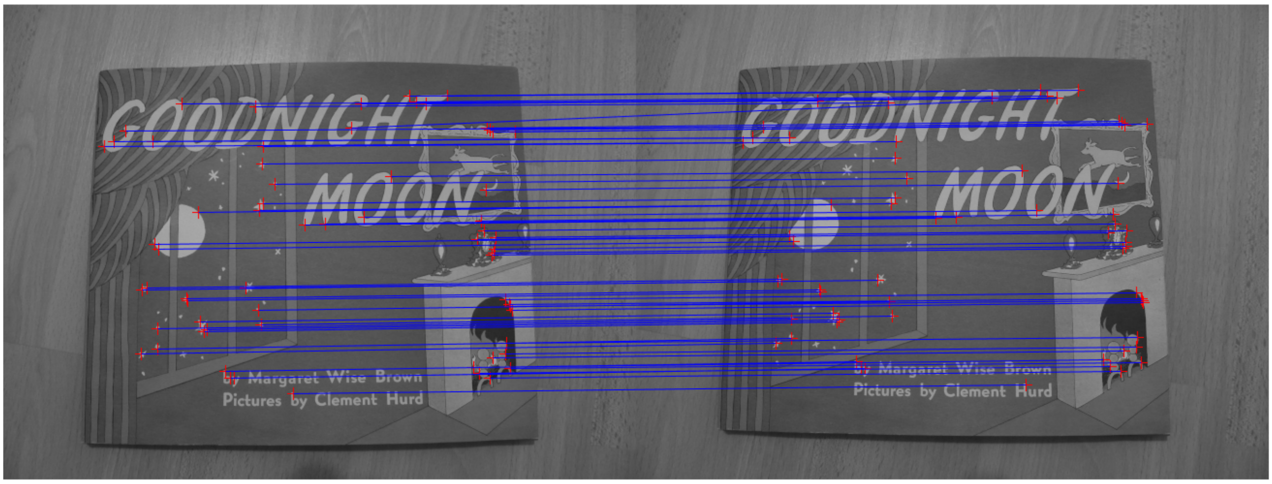


Figure 41: «Ratio» matching with ratio 0.5