Answers to questions in Lab 2: Edge detection and Hough transform

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Program DD2423

Instructions Complete the lab according to the instructions in the notes and respond to the questions stated below. Keep the answers short and focus on what is essential. Illustrate with figures only when explicitly requested. Good luck!

Question 1

What do you expect the results to look like and why? Compare the size of dxtools with the size of tools. Why are these sizes different?

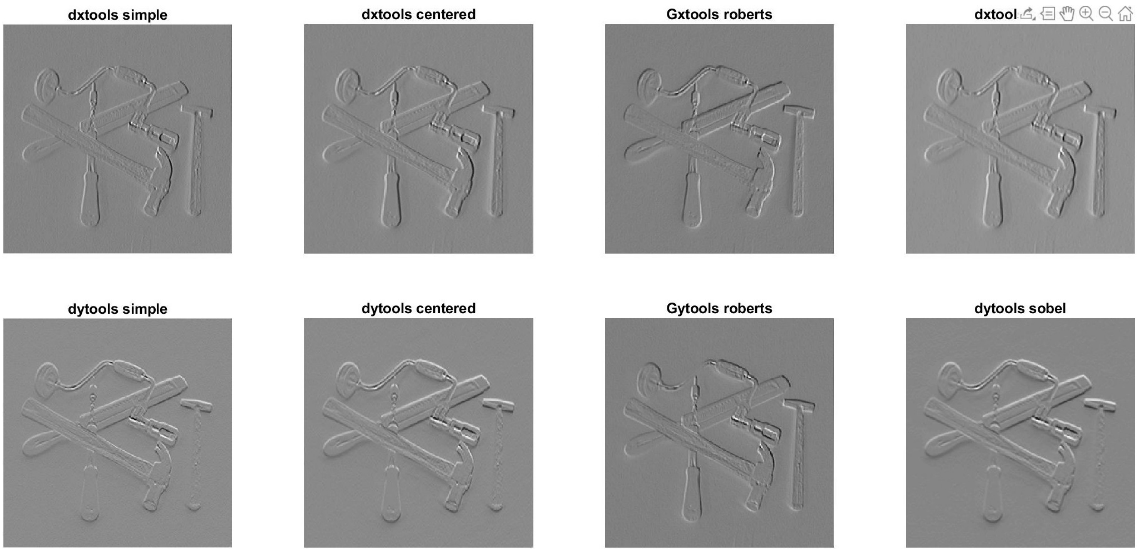

Figure 1: Illustration of 4 difference operators

Answers

- It was expected that the results highlight edges in the image because we compute derivatives that are sensitive to color variations.
- The sizes of *dxtools* and *tools* are different because for derivative at one point, we need points that are following or preceding it, but we do not have it for borders, so when using the **valid** parameter of the *conv2* function, convolution is computed without zero-padded edges, making the result size smaller.
- x-wise partial derivative shows horizontal variations (so vertical lines are better detected), y-wise partial derivative shows vertical ones (so horizontal lines are better detected, see Figure.1).
- the color of the edges are determined by the direction of the derivative. We can see that with convolution, x-wise partial derivatives are computed from right to left and y-wise from bottom to top.

- roberts operator shows the diagonal edges
- sobel operator works like x-wise and y-wise derivatives, but the edges are more pronounced and smoother

Question 2

Is it easy to find a threshold that results in thin edges? Explain why or why not!

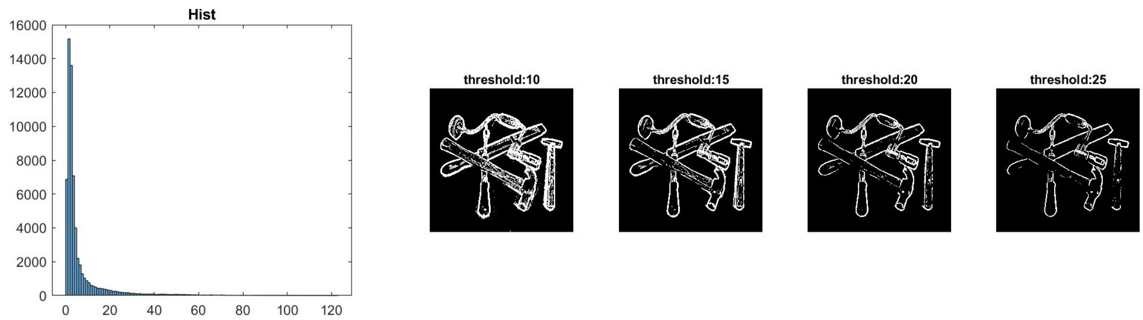

Figure 2: Histogram (left), and different thresholded results of the gradient magnitude.

Answers Using histogram and comparing different thresholds on the *tools* image (see Figure.2), 20 seems a reasonable threshold that keeps most of the tools edges. We can get thiner lines with a threshold of 38 but the hammer handles are not visible.

As we can see in Figure.2, it is not easy to find thin edges as using threshold we get strong response for all magnitudes above the threshold, which results in thick edges if threshold is low, and often missing edges if threshold is too high. This is observed no matter what difference operator is used.

Question 3

Does smoothing the image help to find edges?

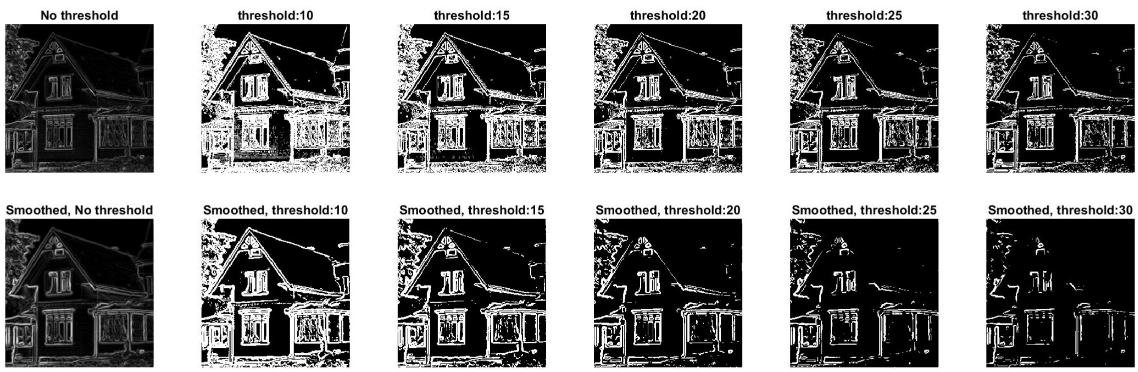

Figure 3: Thresholded magnitudes on not smoothed (first row) vs smoothed image (second row)

Answers As shown in Figure.3, using Gaussian smoothing does not seem to help to find edges though it helps removing the noise (leafs on the left side). But it also remove important thin edges like the top of the roof.

From this we can conclude that we need to find the right balance in how much we smooth the image so that we get rid of noise but still keeping important information.

Question 4

What can you observe? Provide explanation based on the generated images.

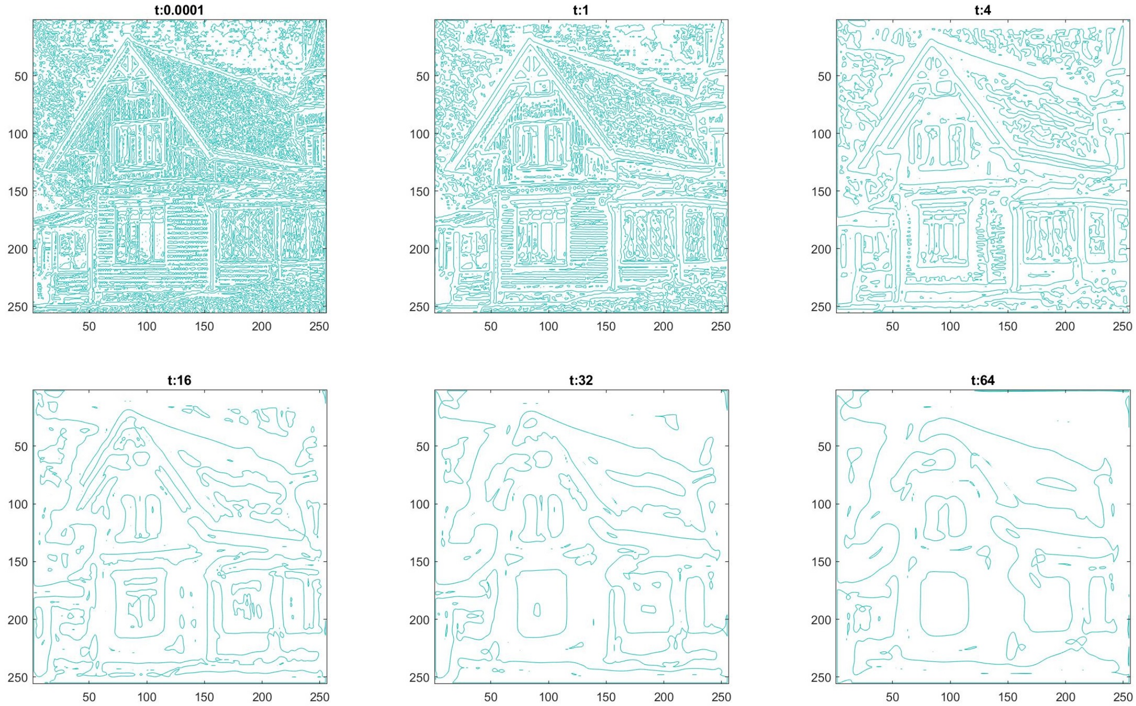

Figure 4: Zero-crossings of $\tilde{L}_{vv}$ on *house* image, for different scales.

Answers Figure.4 shows the zero-crossings of the second order derivative $\tilde{L}_{vv}$ of L, i.e. points where the gradient magnitude (L_v) is at a local extrema. The larger t (gaussian smoothing variance, i.e. the more smoothed the image), the sparser zero-crossings are and the more they seem distorted (as the edges get smoother and smoother).

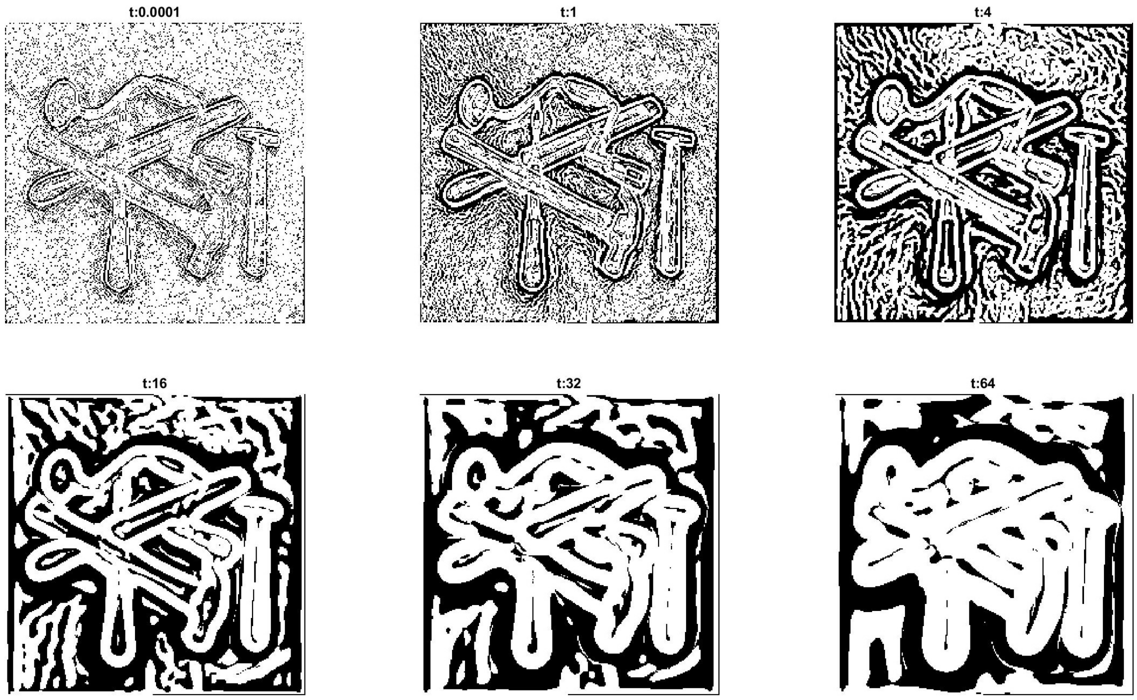

Figure 5: Sign of $\tilde{L}_{vvv}$ on 'tools' image, for different scales.

Figure.5 illustrates the effect of the sign of the third order derivative $\tilde{L}_{vvv}$ of the smoothed image L. The image is white where $\tilde{L}_{vvv} < 0$, we can see it matches both edges and some other points throughout the image. We also observe that as t increases (i.e. the image get smoother) the response patterns gets wider (as edges get smoothed).

Question 5

Assemble the results of the experiment above into an illustrative collage with the subplot command. Which are your observations and conclusions?

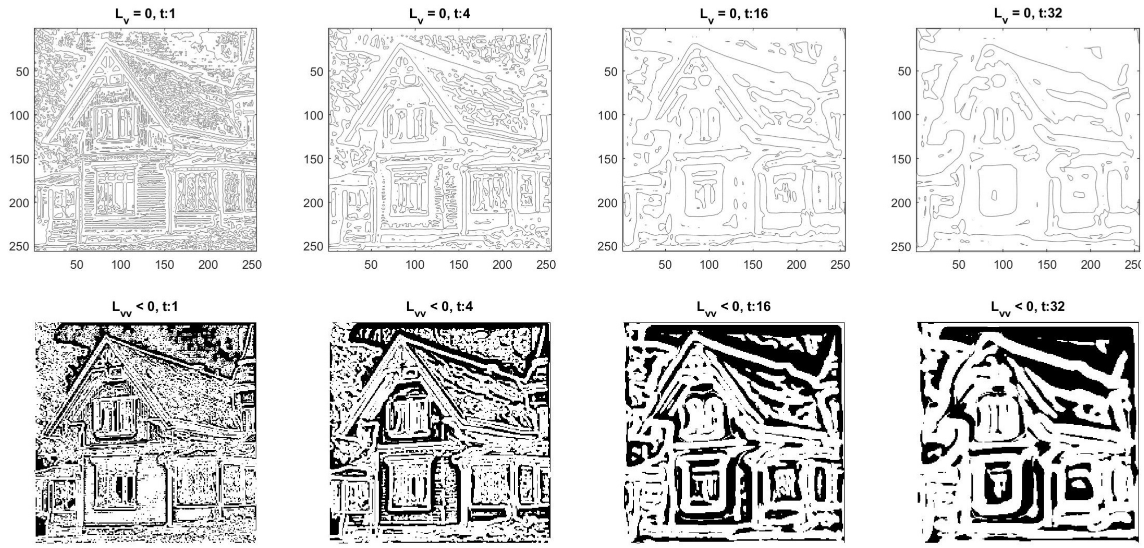

Figure 6: Illustration of both constraints $\tilde{L}_{vv} = 0$ (first row) and $\tilde{L}_{vvv} < 0$ (second row) on 'house' image, for different gaussian smoothing variances.

Answers By studying Figure.6 we can conclude that we could combine he constraints $\tilde{L}_{vv} = 0$ and $\tilde{L}_{vvv} < 0$ to obtain good results for edges (obtaining local maxima of gradient magnitude, i.e. the edge points we want).

Question 6

How can you use the response from Lvv to detect edges, and how can you improve the result by using Lvvv?

Answers We first compute zero crossing curves from $\tilde{L}_{vv}$, then improve the result by masking it with constraint $\tilde{L}_{vvv} < 0$ to get local maximas of the gradient magnitude.

Question 7

Present your best results obtained with extractedge for house and tools.

Answers Figure.7 shows our best results with *extractedge*:

- Tools: $\sigma = 8.0, threshold = 26$
- House: $\sigma = 4.0, threshold = 7$

Question 8

Identify the correspondences between the strongest peaks in the accu-mulator and line segments in the output image. Doing so convince yourself that the implementation is correct. Summarize the results of in one or more figures.

Answers Figure.8 shows our results for the *triangle* test image and matching responses in the Hough space.

Figure 7: Our best results with *extractedge* on the 'tools' and 'home' images.

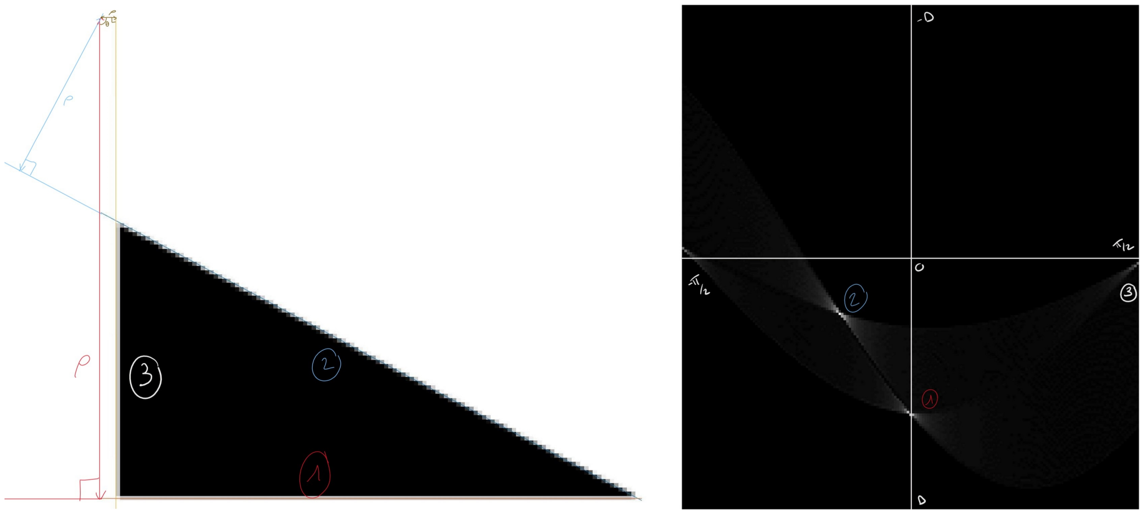

Figure 8: 3 best matching lines for the *triangle* test image (left) and corresponding Hough space (right)

Question 9

How do the results and computational time depend on the number of cells in the accumulator?

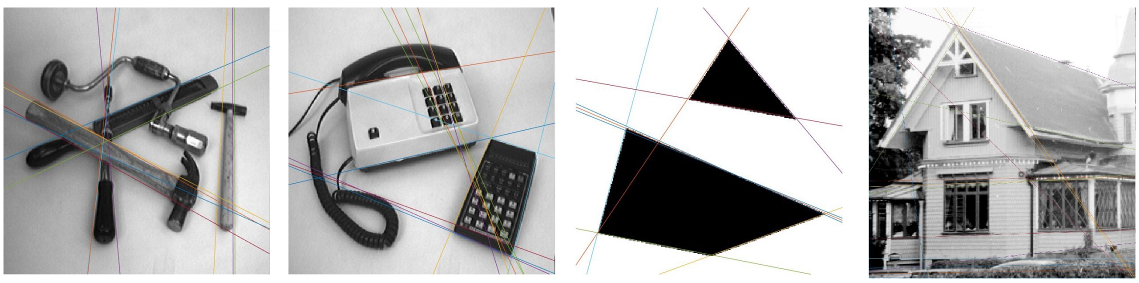

Figure 9: Results for *tools*, *phone*, *houghtest* and *home* images

Answers The computational times also increases with the number of cells in the accumulator since the function *houghline* as we implemented it has a complexity of $O(N^2 n.ntheta.nrho)$ for an image of size NxN.

As the number of cells increases, so does the accuracy, but we tend to get multiple responses for a single line. For small number of cells some edge lines cannot be found.

Figure.9 shows our result on different images with a reasonable number of cells in the accumulator.

Question 10

How do you propose to do this? Try out a function that you would suggest and see if it improves the results. Does it?

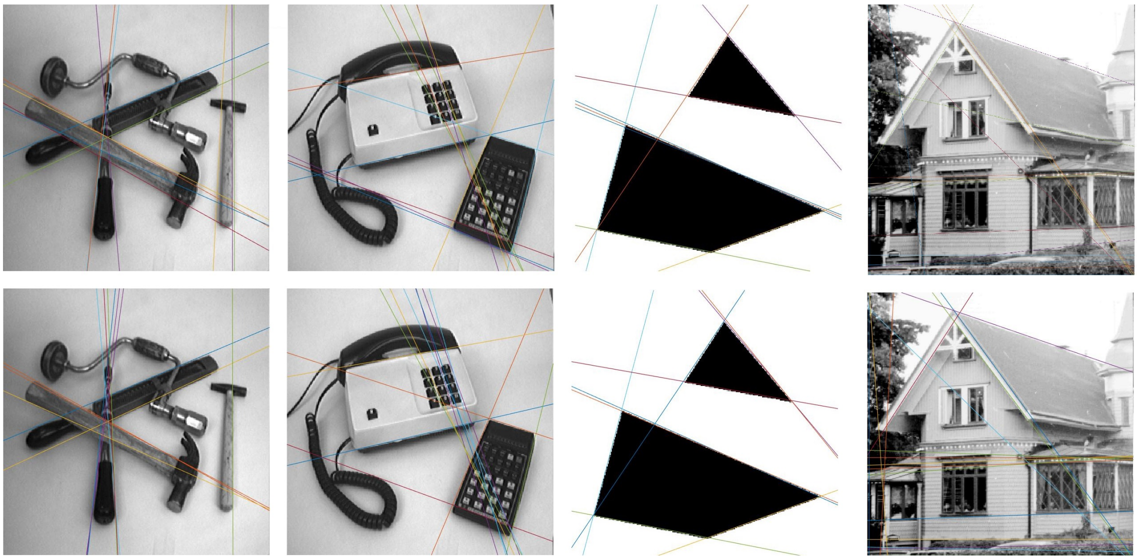

Figure 10: Comparison between $\Delta S = 1$ (1^{st} row) and $\Delta S = log(mag)$ (2^{nd} row) for *tools*, *phone*, *houghtest* and *home* images

Answers We thought of 2 intuitive ways of setting the accumulator increment to a function of the gradient magnitude. The first one is to update the accumulator linearly with the magnitude with a factor 1 (i.e. $\Delta S = mag$). The second one is to increment the accumulator using the *log* of the magnitude (i.e. $\Delta S = log(mag)$). Figure.10 shows that the log does not really improve our results, but it helps finding edges with lower gradient magnitude.