Assignment 1

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ELL715 Assignment
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Note: The code is available at `https://github.com/mohit1997/DIP_Assignment3`

1 Problem 1

Take an 8-bit gray scale image of some buildings and perform the following operations using MATLAB/Python to estimate the edges using:

1. Laplacian filter with and without diagonal terms
   (a) Apply Laplacian in x and y direction separately
   (b) And than jointly
2. Roberts cross gradient operator
3. Sobel gradient operator
4. High-boost filtering

Use different size operators to find the suitable size. Combine these operators to define your best edge detection operator for your image. Comment on the results and give the motivation and reason out your best edge detection operator.

Solution:

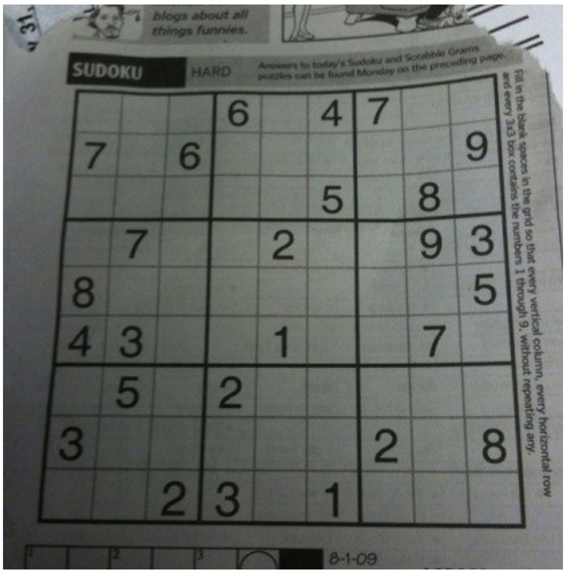

Figure 1: Original Image

To detect edges and analyze the directional gradients in specific directions and then several ways of merge them, we take image of a Sudoku which can highlight the benefits of different edge detectors. Since

the image resolution is low (400×400) and edges are thin, the kernels with dimensions 3×3 give the best performance. Larger Kernel give rise to pseudo edges rising from the varying lighting/brightness of the image rather than dominant intensity changes corresponding to horizontal and vertical lines as well as the boundaries of the digits.
Figure 1 contains the original image,

Figure 2 contains the first three parts of the problem, and compares the mentioned edge detection methods which are: directional laplacians, joint laplacians with and without diagonal terms, robert cross gradient operator and sobel operator.

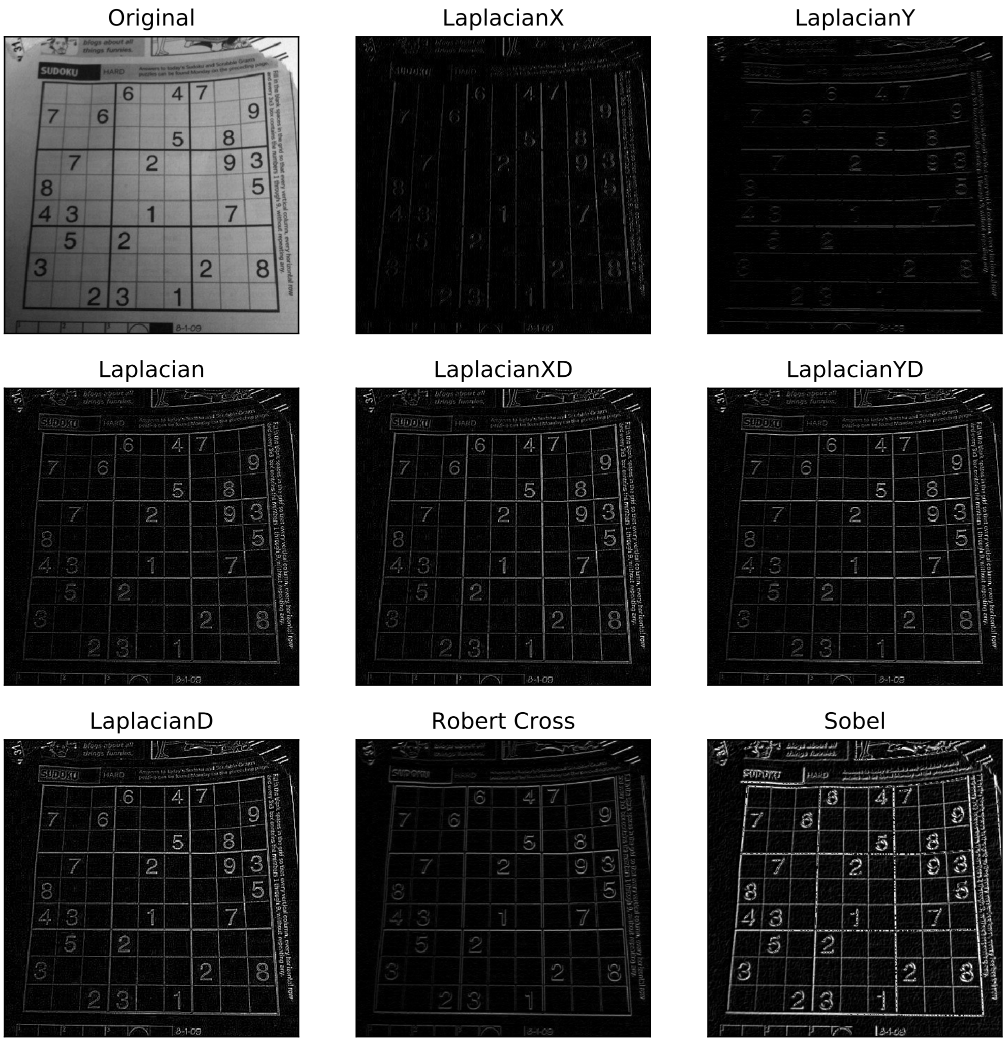

Figure 2: Comparison of edge detection algorithms like Laplacian without diagonal terms *(Laplacian)*, with diagonal terms *(LaplacianD)*, directional laplacians *(LaplacianX, LaplacianY)*, directional laplacians with diagonal terms *(LaplacianXD, LaplacianYD)*, Robert cross gradient operator *(Robert Cross)* and Sobel operator *(Sobel)*.

Figure 11 contains variation of kernel size of the sobel operator. The directional edge information is combined using the modulus operator i.e. by summing their absolute values. We can observe that with bigger kernels, edges start to spread out and become more prominent, the overall brightness of the image also increases.

Figure 4 highlghts the highboost filtering over the original image. In brief, highboost filtering is done by creating a mast the low frequencies removed. After that this mask is scaled and added to the original image to amplify the high frequency components of the image. It doesn't directly give the images but rather highlights the edge information significantly. We use a gaussian kernel for filtering in the low frequencies followed by scaled addition of the corresponding mask formed. We can see in the figure 4, with standard deviation 5.0 and $k = 5$, we are able to highlight all the desired edges.

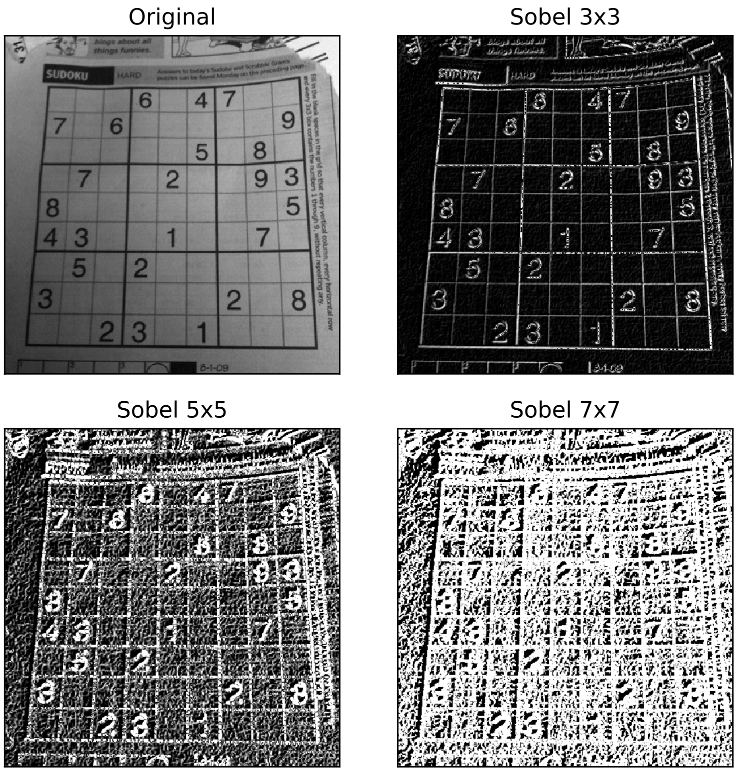

Figure 3: Output of different sizes of sobel operators post convolution over the original image..

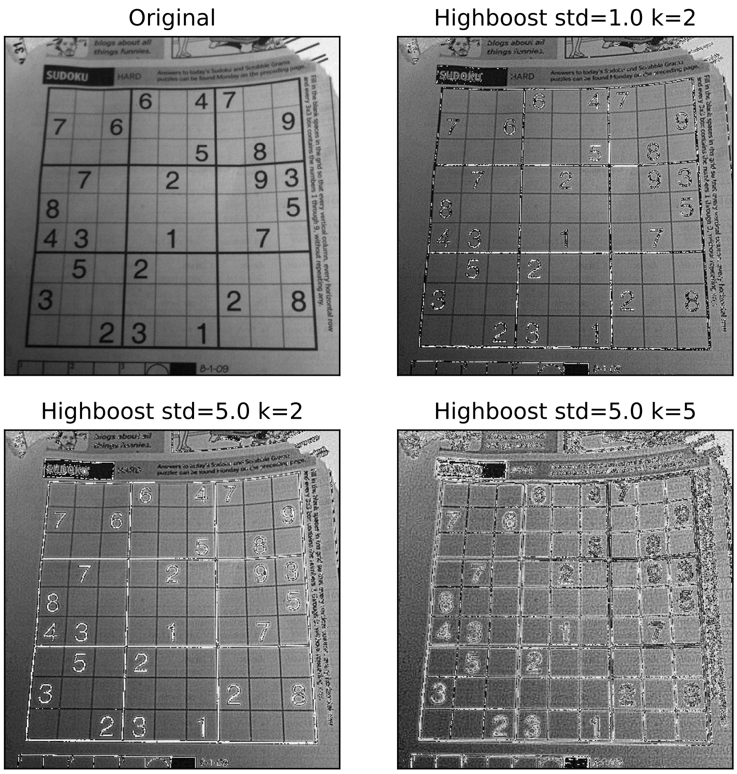

Figure 4: High Boost filtering with gaussian kernel of specified standard deviation being used to create mask and adding the mask scaled by k.

Note: We use 5×5 sized kernel for gaussian blurring. All other sizes lead to insignificant variation with standard deviation thereby reducing the averaging effect of the kernel.

For best edge detection, we will combine the laplacian, sobel and robert cross gradient with highboost filtering. Figure shows the comparison of these three methods post highboost filtering. We use a highboost filtering with gaussian kernel of $\sigma = 1.0$ in both dimensions and $k = 1$ with a kernel size 5×5

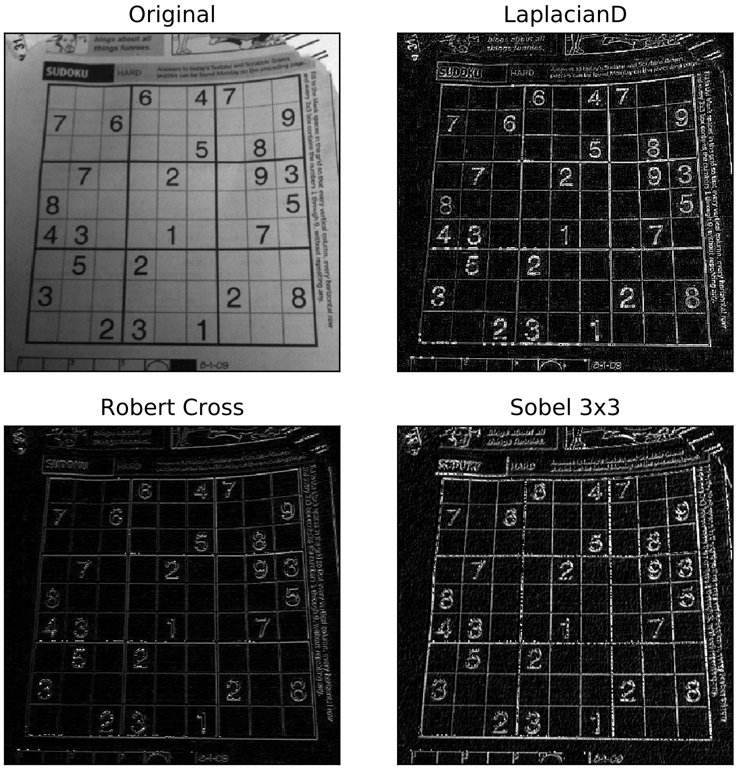

Figure 5: Best edge detection technique for the chosen image comprising of highboost filtering followed by a standard edge detection method. We compare Laplacian with diagonal terms *(LaplacianD)*, Robert Cross Operator *(Robert Cross)* and Sobel Operator *(Sobel)*.

Best Edge Detector: From the above image we can see that Laplacian with diagonal terms intially gave the cleanest form of edge detection approach, bu the intensity at some of the edges varied. But after highboost filtering we are getting even intensities at all of the desired edges as expected. Hence this forms the best edge detector for our case. Robert cross gradient suffers with low intensities even after highboost filtering. Sobel operator performs decently well almost at par with Laplacian. The problem with Sobel operator is that it detects noise as edges too hence capturing undesired information.

2 Problem 2

Extract two consecutive frames from a video clip, detect the changes in these over time(take snapshots). Can you use this information for edges detection?

Solution: We take a synthetic video of a man walking in plain green background. This is done so as to see whether theoretically it is possible to get edges from consecutive frames of a video. *Video Courtesy: Varun Srivastava*

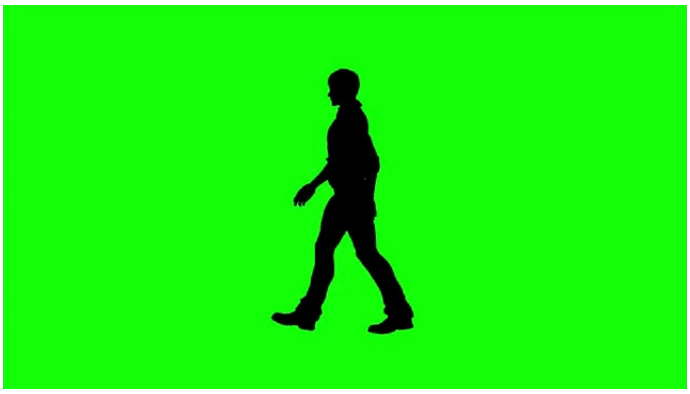

Figure 6: A randomly extracted frame from the chosen synthetic video

We take twenty five consecutive frames of the video as shown below to be processed for detecting the human boundary.

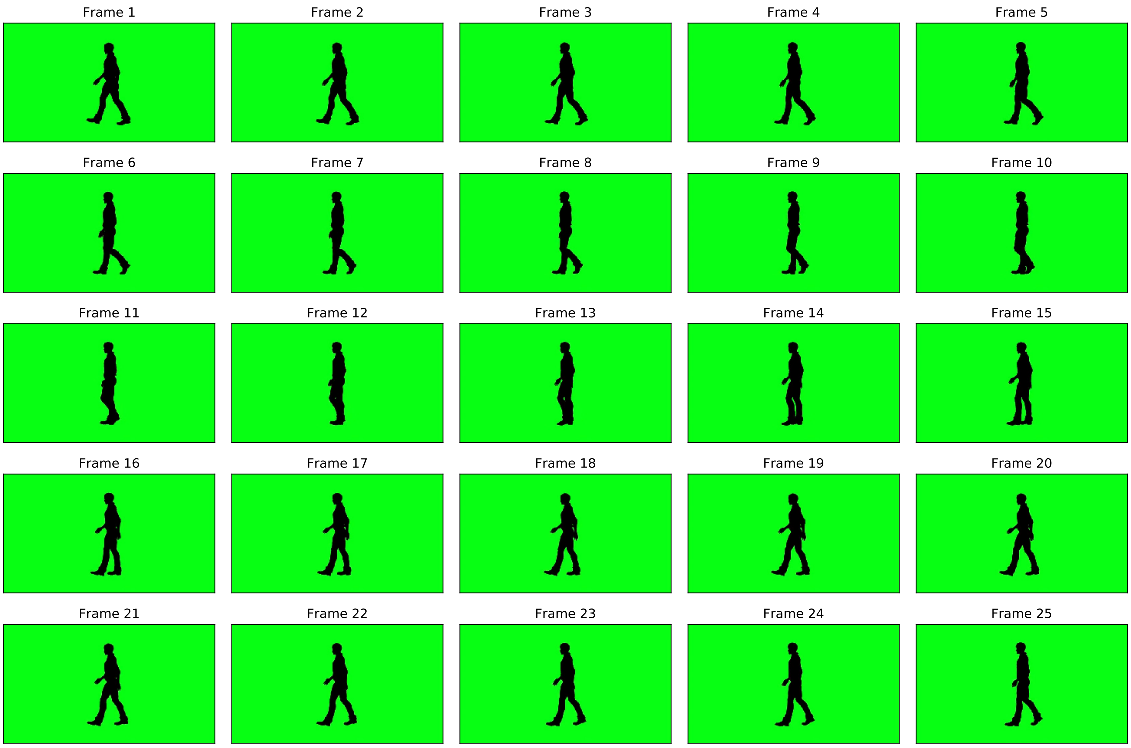

Figure 7: Left: Original Image $f(x, y)$, Middle: Scaled and Translated $g(x, y)$, Right: Rotated anticlockwise $h(x, y)$

The following transformations are applied on the frames above to generate frames in figure 8:

1. Define $\Delta g_n(x, y) = g_{n+1}(x, y) - g_n(x, y)$, where $g_n(x, y)$ is a frame enumerated in figure 7
2. Add all three channels of $f_n(x, y) = \sum_{i=1}^{3} \Delta g_n(x, y)_{ith\ channel}$ to intensify from the gradients in each of the three components.

3. The image obtained is then thresholded as $f_n(x,y) \rightarrow 0,\ if\ f_n(x,y) < T$ and $f_n(x,y) \rightarrow 255,\ if\ f_n(x,y) \geq T$, where T is the threshold. We use $T = 50$ for generating figure 8

The above process results in edges separating foreground and background. It helps to filter in all the high frequencies by taking a forward difference in consecuitve frames of video. All the boundaries of object translating or moving in any direction result in amplification of pixel intensities in the delta of frames. Hence, highlighting the desired edges which form the boundary of human figure in the video chosen for the demonstration.

Figure 8: Left: Original Image $f(x,y)$, Middle: Scaled and Translated $g(x,y)$, Right: Rotated anticlockwise $h(x,y)$

3 Problem 3

Noise effect. Add salt and pepper noise of 0 , 10, 30, 60dB SNR to the above image

1. Apply the best edge detection filter.
2. Apply the best edge detection filter after removing the noise by:
   (a) Harmonic Filter.
   (b) Median Filter.
   (c) Optimal/Adaptive Median Filter.

Solution:

1. **Part 1**: Figure 9 contains addition of salt and pepper noise of various SNR (dB) values onto to the original image. We add S&P noise by replacing the original image with a intensity of zero or two hundred twenty five (255). The probability of this replacement is controlled using SNR provided.

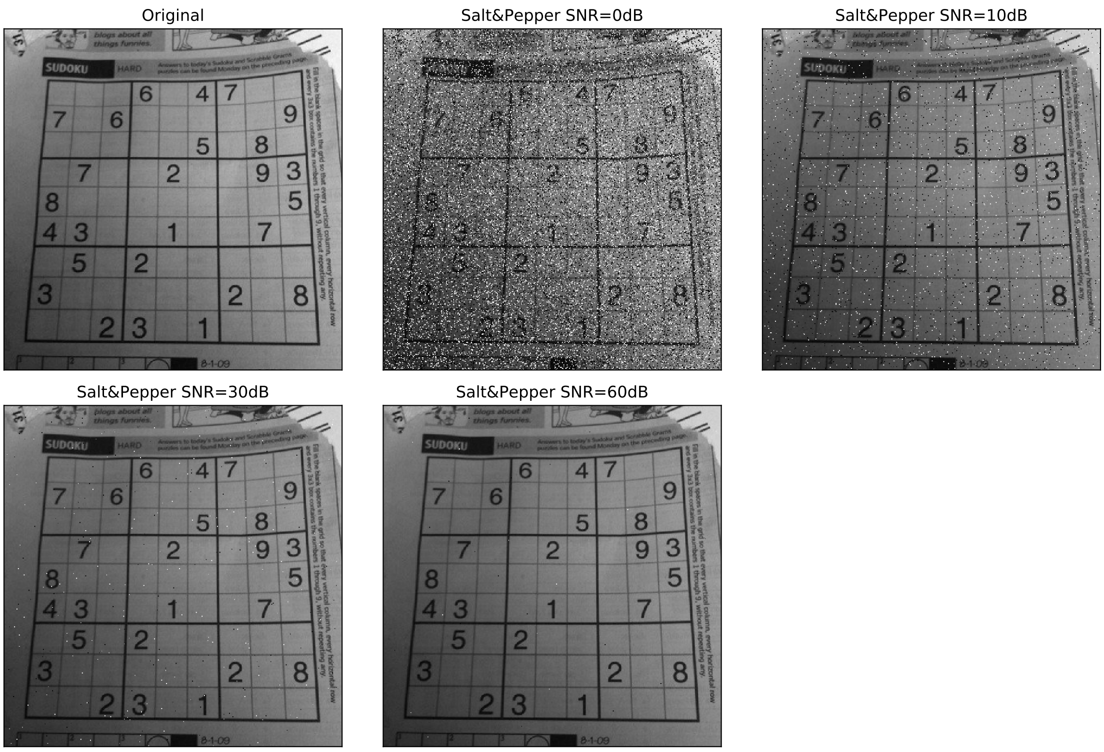

Figure 9: Adding S&P noise to the image for the various SNRs provided.

We observe that highboost filtering make the problem more difficult by enhancing the S&P noise which lies in the high frequency component of the image. Therefore we directly use the Laplacian and Sobel Operator here. At different SNRs, different methods look pleasing to the eye. Hence we leave it to the discretion of the evaluator to judge which method is better at what SNR. Sobel gives high intensity on edges, where as Laplacian gives low intensity, therefore is relatively robust to S&P noise as well. Below is the comparison of two methods (figure 10 and 11),

2. **Part 4**: We apply three varieties of filters Harmonic Mean, Median Filter and Adaptive Median Filter. We first show a comparison of the three filters and then choose the best of them, and find the best edge detection algorithm using the filter intially.

   We can see that **adaptive median filter** works best even at $SNR = 0dB$ whereas harmonic filter fails. Harmonic filters work only for salt type noise and fail for pepper noise.

   We show in figure 13 the laplacian operator with diagonal elements after applying adaptive mean filter followed by highboost filtering. We see that there is almost no perceptual difference in the edges obtained, which makes it the best edge detection technique which is robust to S&P Noise.

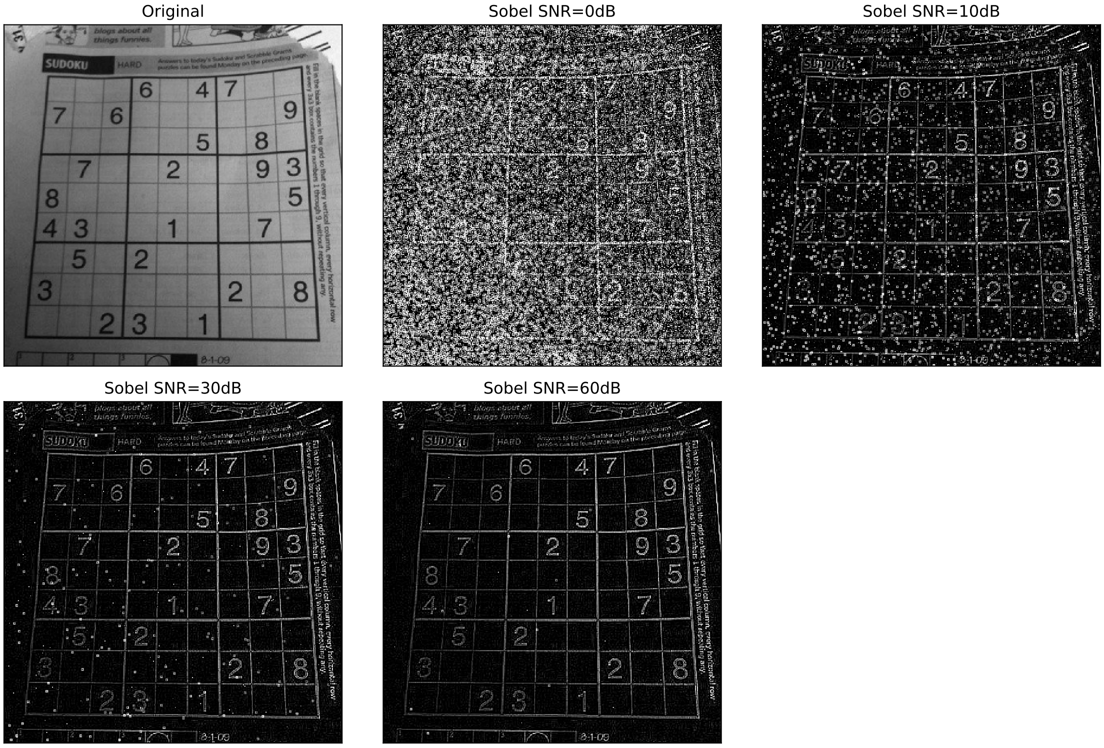

Figure 10: Laplacian Operator with diagonal elements on to the images affected by S&P noise

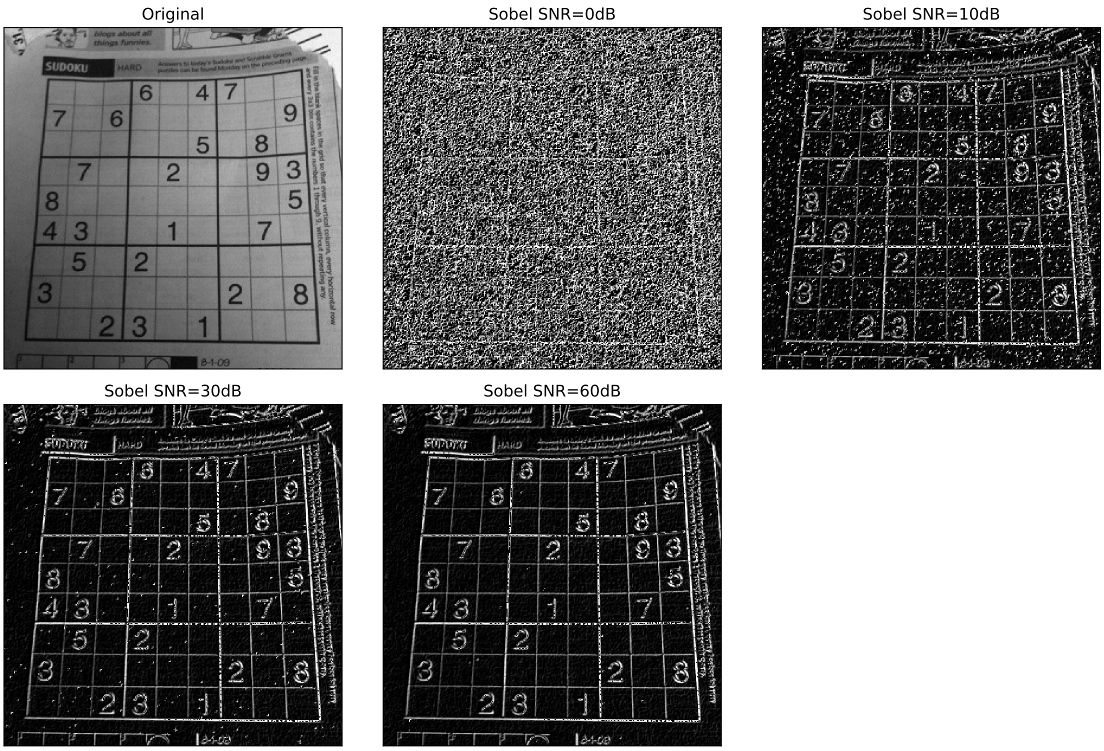

Figure 11: Powers of an Image (2, 3, and 4)

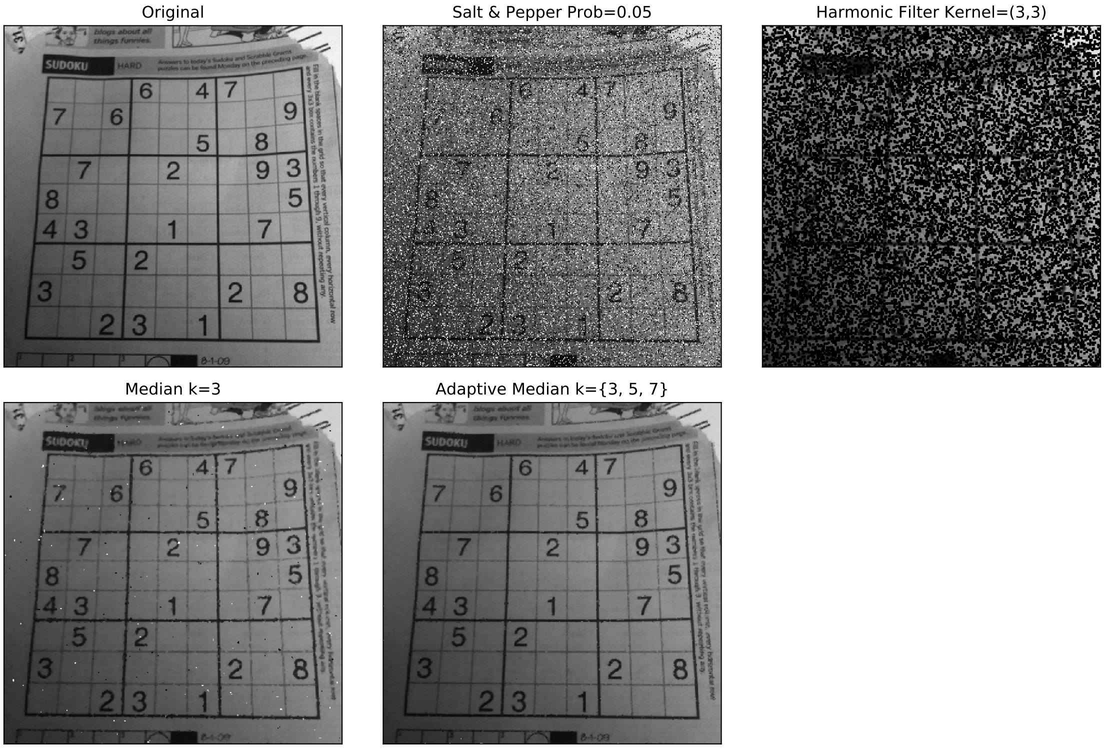

Figure 12: Comparison of different filters provided

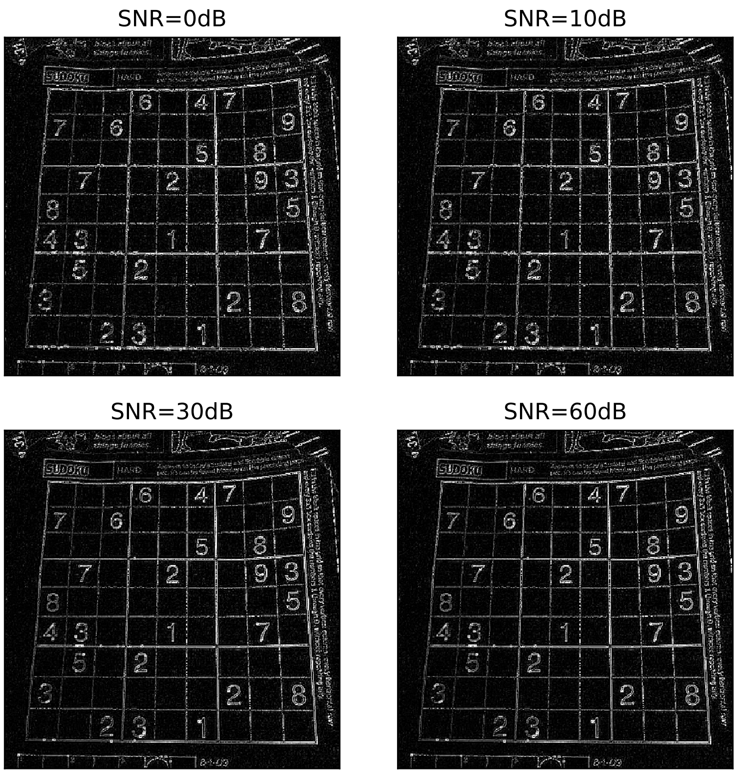

Figure 13: Comparison of different edge detectors post filtering