

Development of Helmholtz of Gaussian Kernel for Edge Detection.

Yamuna N. Swamy and Phaneendra K. Yalavarthy.

1 Edge Detection: The role of Filter

Edge detection could be performed using a high pass filter or a bandpass filter. Laplacian filter is a high pass filter whose frequency response is as shown in Fig. 1.

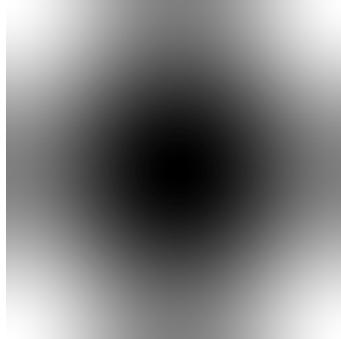


Figure 1: Frequency response of the Laplacian filter

Edge detection performed by enrolling a high pass filter is incompetent in eliminating the noise present in the image. A bandpass filter could aptly accomplish the task of edge detection by overriding the noise. The bandpass filter could be visualized as a tie-up of a high pass filter and a low pass filter as shown in the Fig. 2.

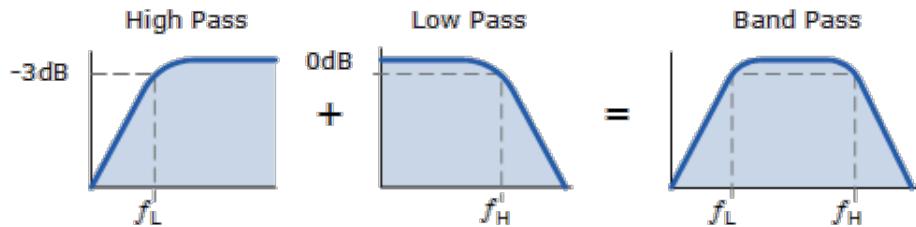


Figure 2: Visualization of a bandpass filter

Laplacian of Gaussian[LoG] is a bandpass filter, which is a conjunction of a Gaussian filter and a laplacian filter whose frequency response is shown in the Fig. 3(a). The LoG kernel's frequency response appears to be that of a doughnut shape, since the kernel blocks the lower frequencies corresponding to the smooth region and also very high frequencies corresponding to the noise. Additionally, the HoG kernel which is also a bandpass filter has a frequency response(shown in Fig. 3(b)) similar to that of a LoG, with an upper hand of imparting higher resistance to the noise present in the image. The roll off of the slope in the frequency response of the HoG filter is slightly sharper when compared to the LoG kernel

The term pertaining to $-k^2$ is contributing to make the passband of the HoG kernel slightly narrower compared to that of the LoG kernel. This allows the HoG kernel to perform as closely as possible to the intended design of the LoG filter only giving it an advantage of eliminating a few higher frequencies which the LoG kernel is incapable of doing. The HoG filter is capable of detecting all the true edges which the LoG kernel is expected to. In addition to this the HoG kernel is competent enough to ward off the slightly higher frequencies pertaining to noise. In Fig. 3(a) and (b) it is observed that the hole in the center of the doughnut shaped frequency

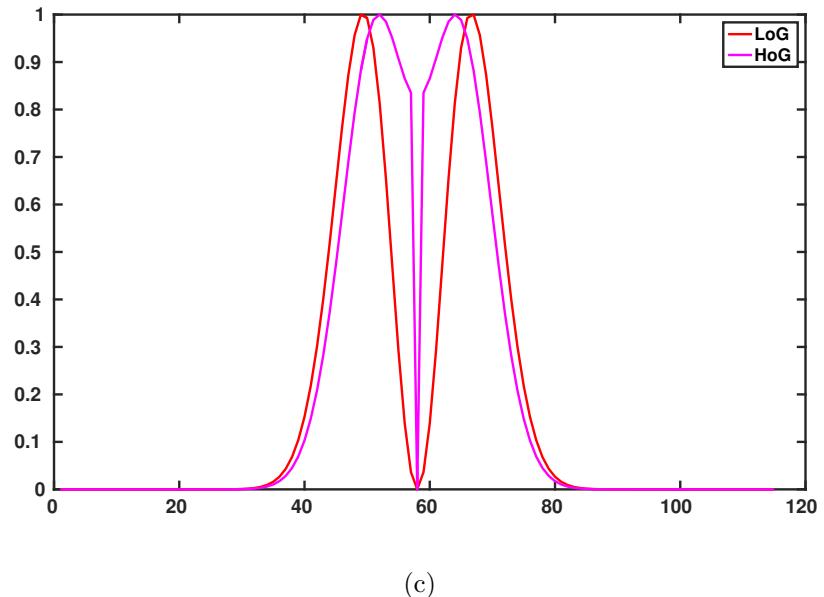
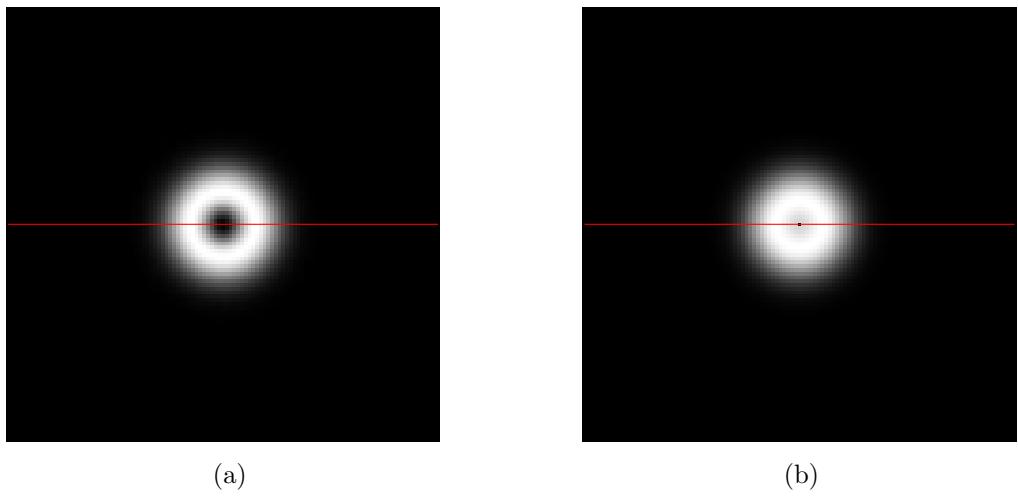
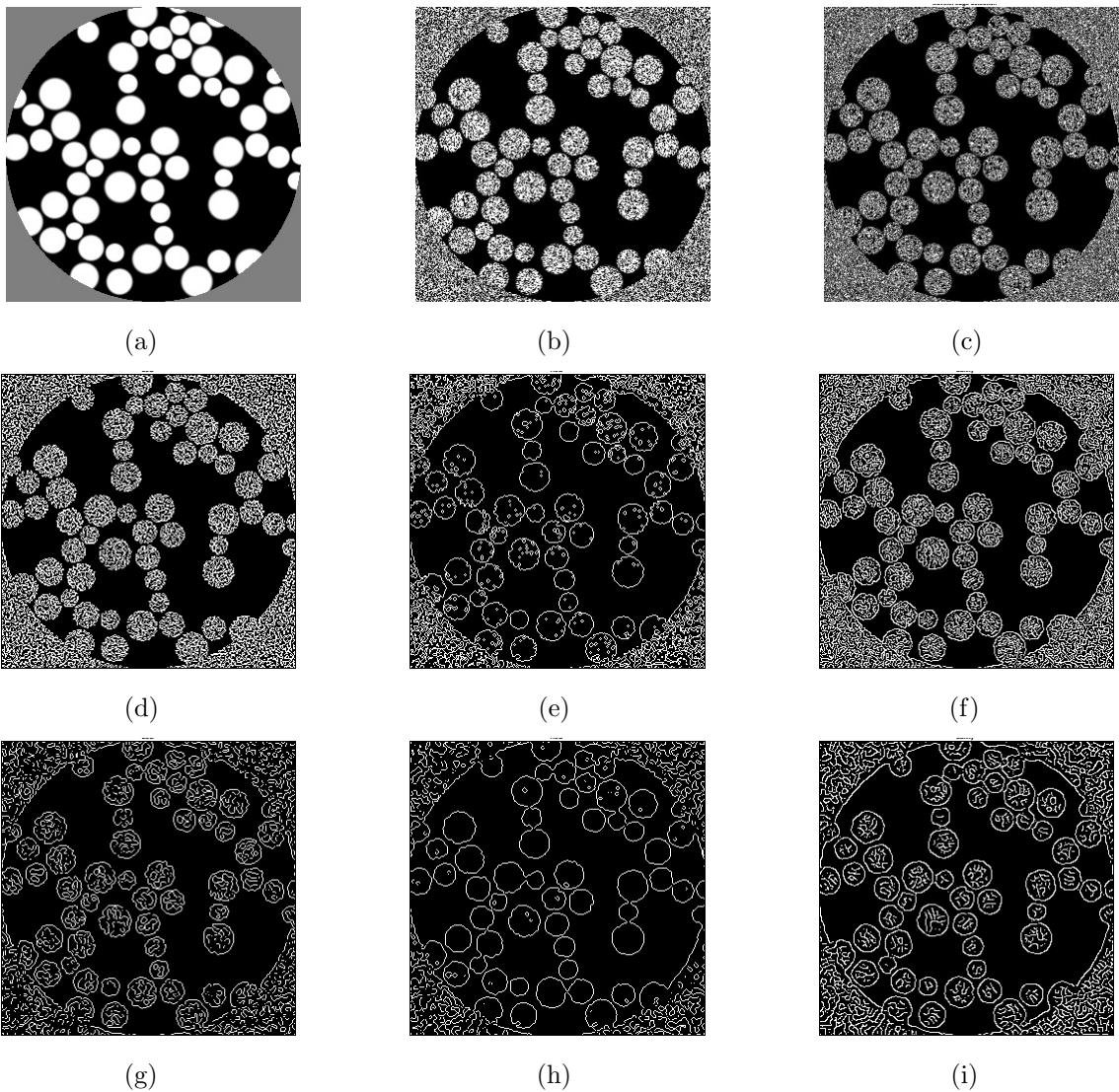


Figure 3: Frequency response two dimensional (a) LoG kernel (b) HoG kernel respectively. (c) profile plot of the red line under consideration

response of the HoG is smaller compared to that of the LoG, which proves that the HoG is sensitive to the 'intermediate higher frequencies' corresponding to the true edges and robust to 'very high frequencies' corresponding to the noise.

2 Performance of discussed Kernel based filter on example/natural Images

A complex image with random radii was chosen to evaluate the performance of the LoG and HoG detector. When the $\sigma=1$ (second row of figures Fig. 4(d-f)) the HoG detector showed more robustness to noise when compared with the LoG detector. As the value of σ increased though the LoG detector was more equipped to handle noise, the HoG detector outperformed the LoG detector in each case. When the σ value was equal to 3(fourth row of figures), both the detectors could remove the noise considerably but the HoG detector produced a binary image with closed contours when compared with the LoG detector.



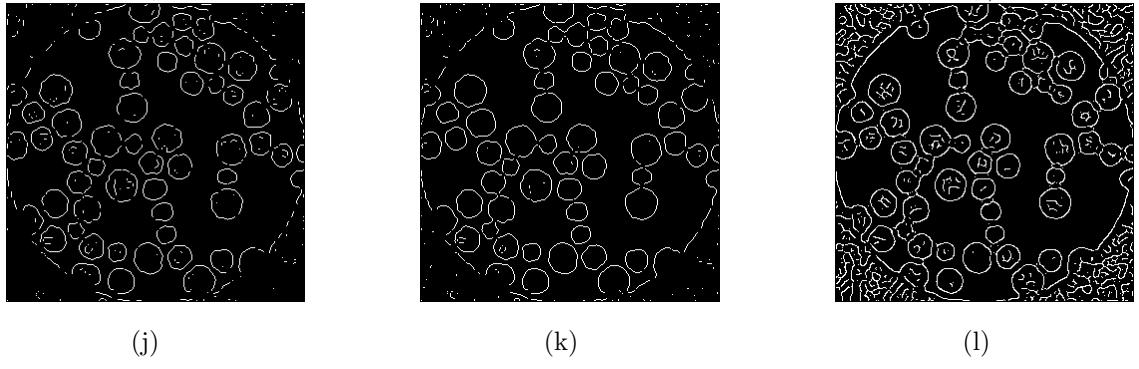


Figure 4: (a) The original image which has blobs of varying radius,(b) Noisy image, (c) Detected edges using wavelet based edge detector, (d,g,j) Detected edges using LoG kernel with varying values of $\sigma = 1, 2$ and 3 ; (e,h,k) Detected edges using HoG kernel with varying values of $\sigma = 1, 2$ and 3 ; (f,i,l) Detected edges using Canny edge detector with varying values of $\sigma = 1, 2$ and 3 .

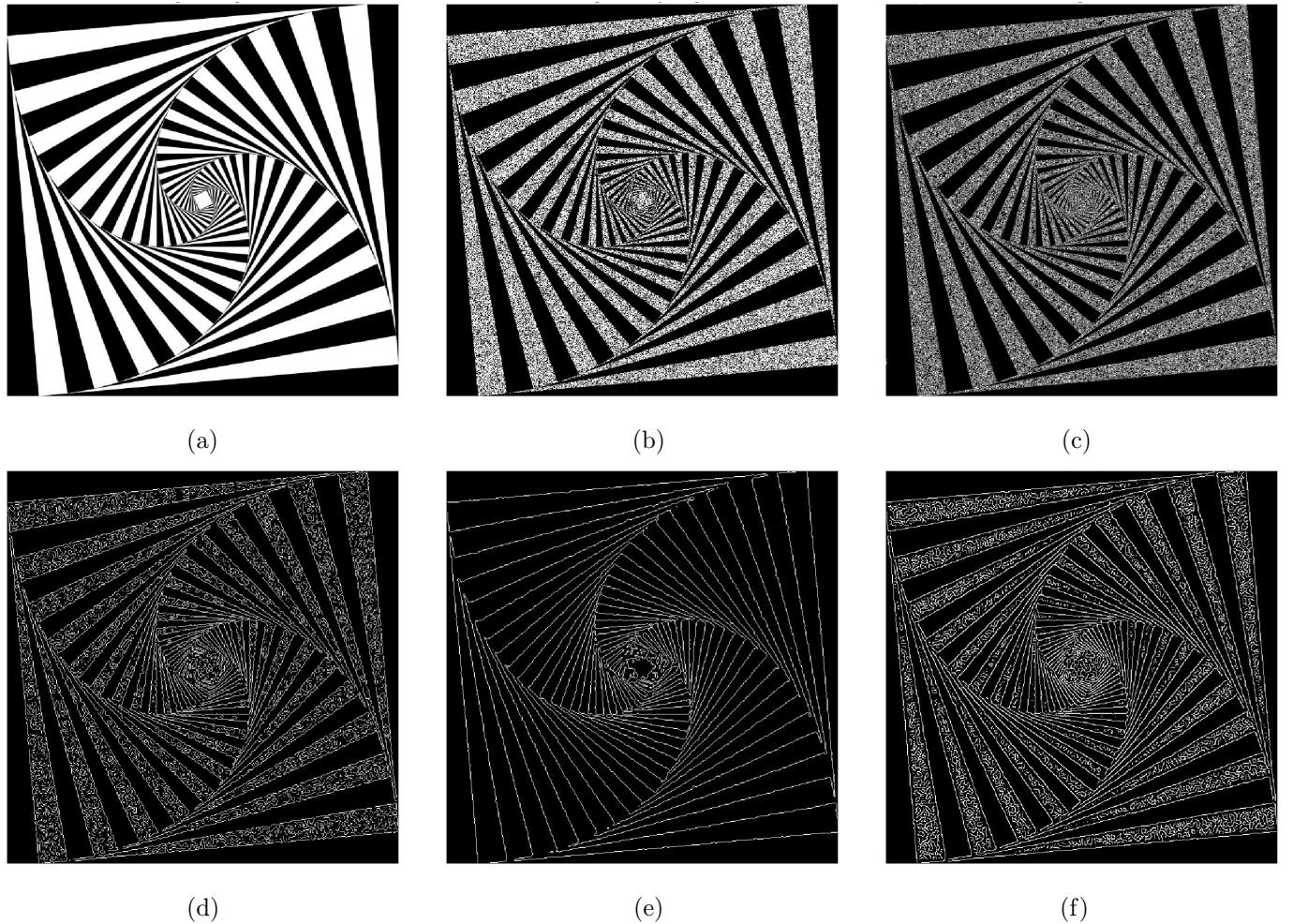
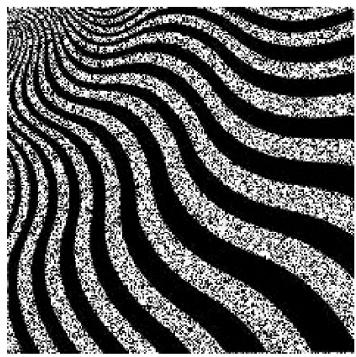


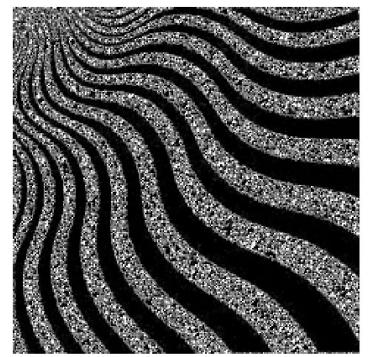
Figure 5: (a) The original image (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 8.5063dB, (c) Detected edges using using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 2$, kernel size = 78 and $k = 2/\sigma$ (f) Detected edges using Canny edge detector



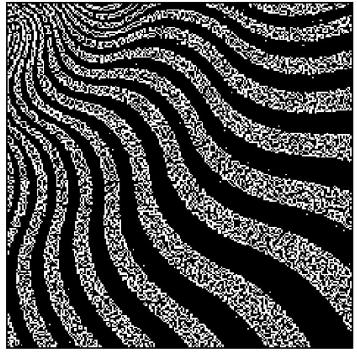
(a)



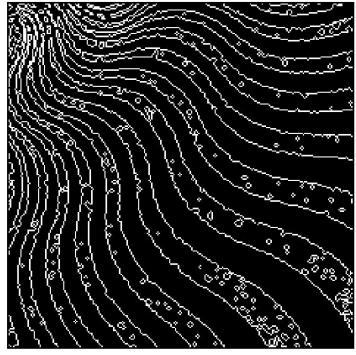
(b)



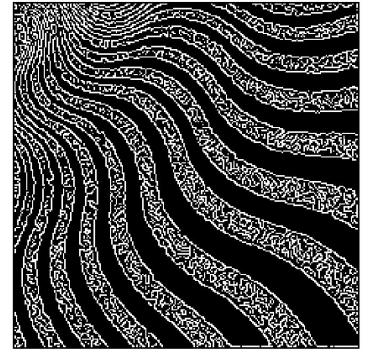
(c)



(d)



(e)



(f)

Figure 6: (a) The original image, (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 8.4660dB, (c) Detected edges using using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 1$, kernel size = 42 and $k = 2/\sigma$, (f) Detected edges using Canny edge detector.

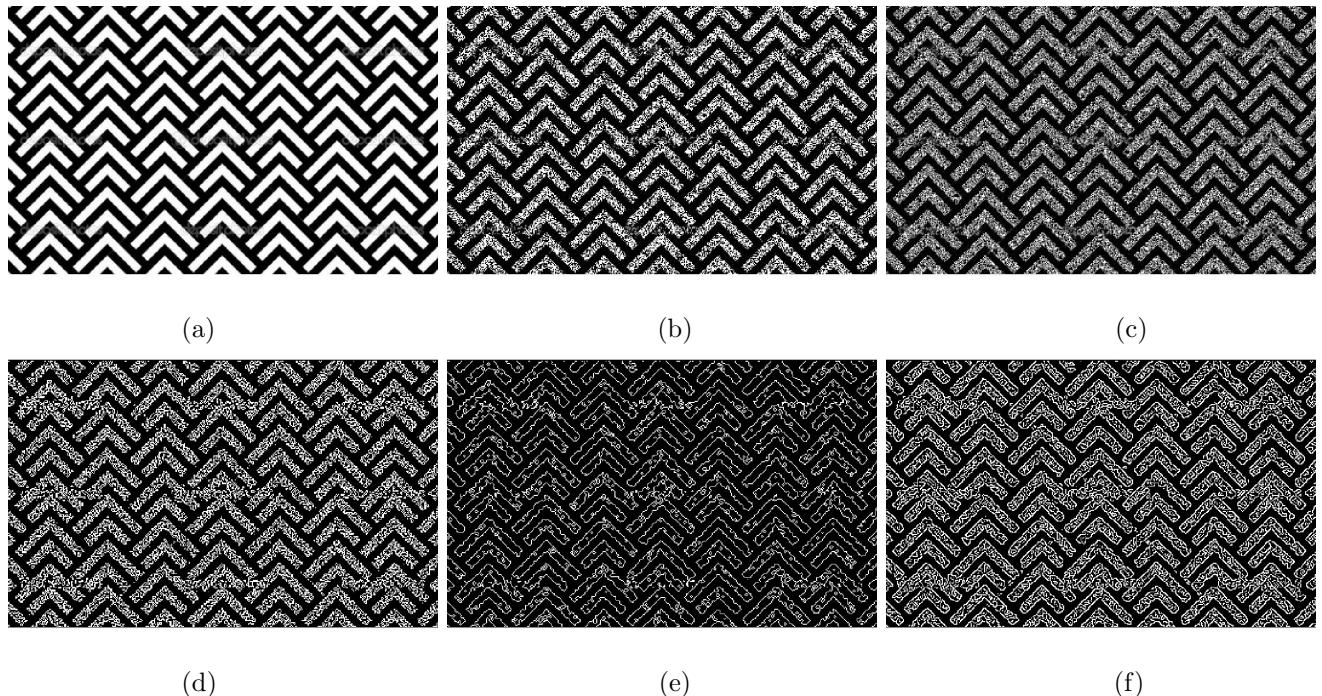


Figure 7: (a) The original image, (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 7.655dB, (c) Detected edges using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 1$, kernel size = 42 and $k = 2/\sigma$, (f) Detected edges using Canny edge detector.

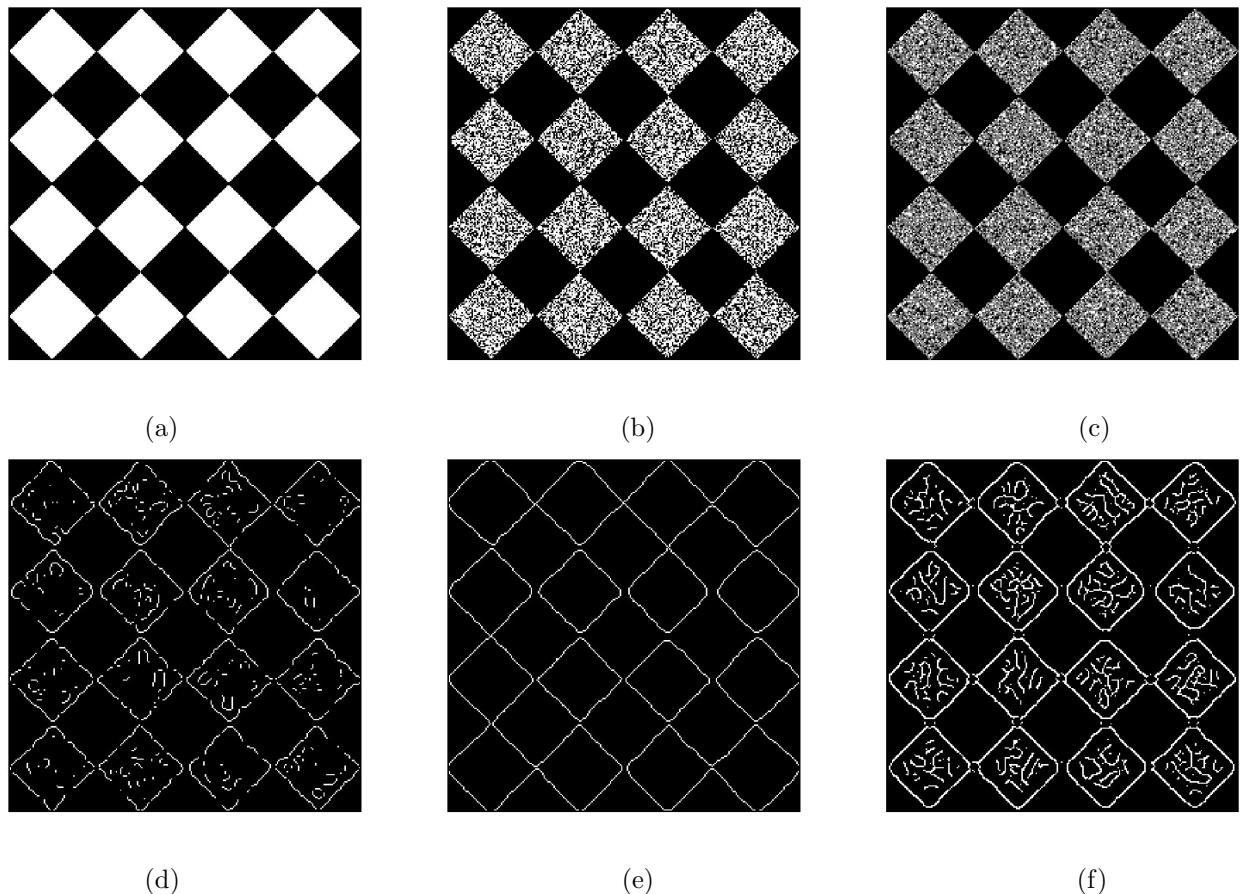


Figure 8: (a) The original image, (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 7.2620dB, (c) Detected edges using using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 3$, kernel size = 114 and $k = 2/\sigma$, (f) Detected edges using Canny edge detector.

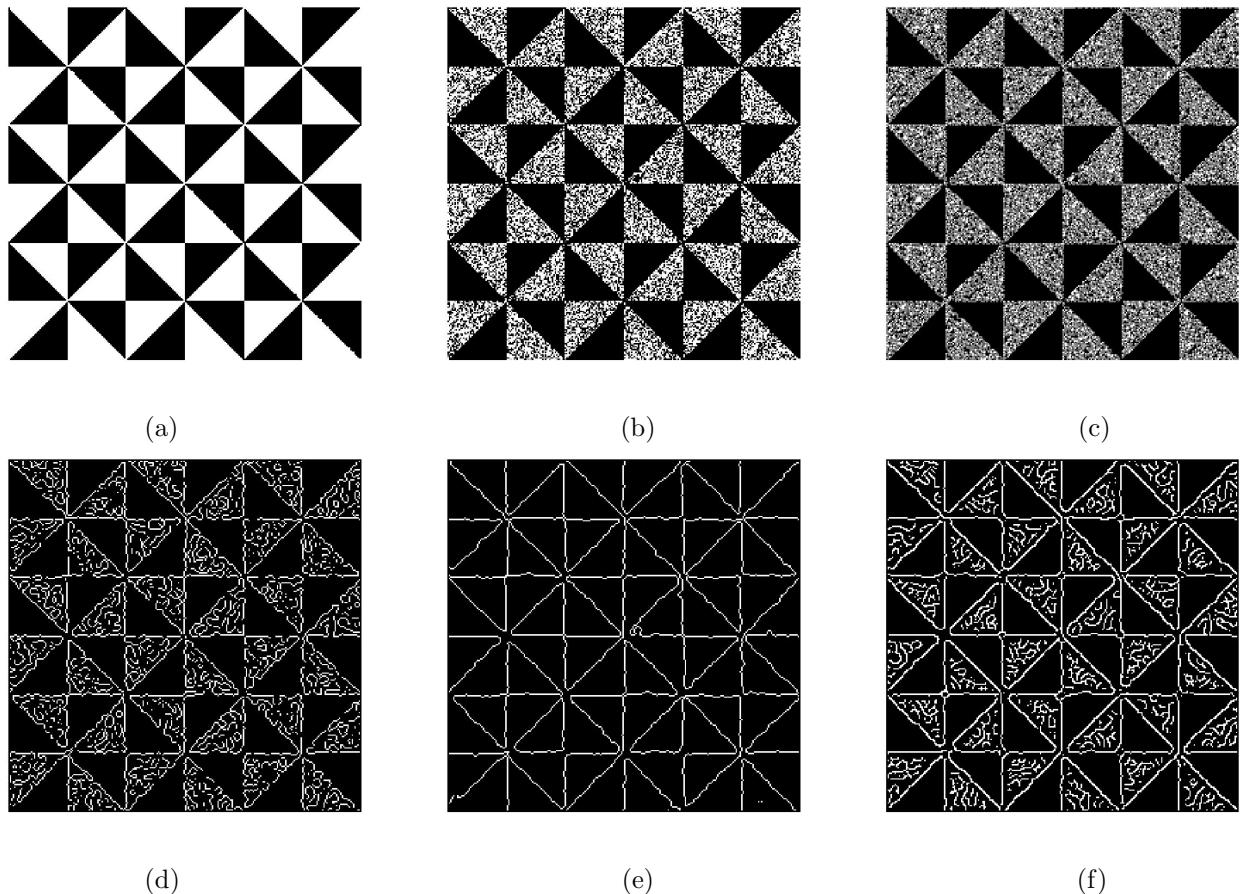
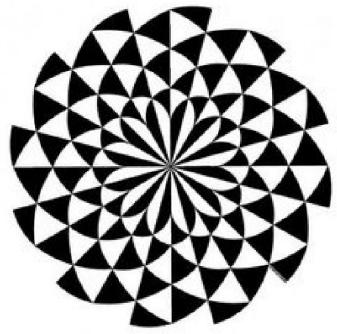
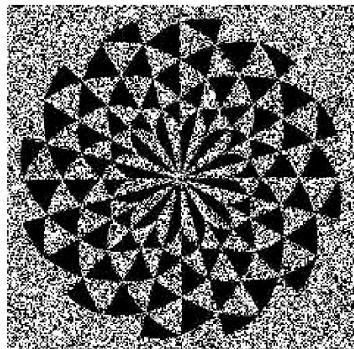


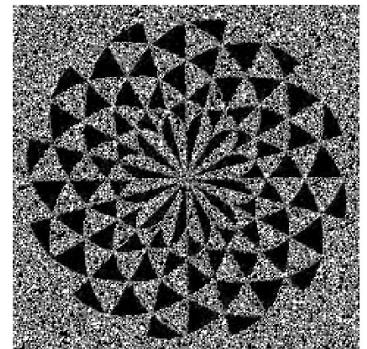
Figure 9: (a) The original image, (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 7.0907dB, (c) Detected edges using using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 2$, kernel size = 78 and $k = 2/\sigma$, (f) Detected edges using Canny edge detector.



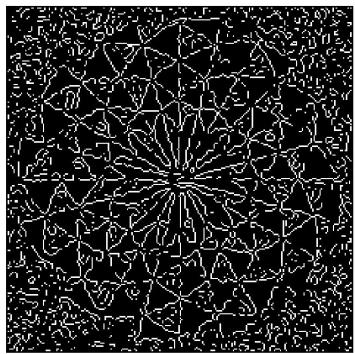
(a)



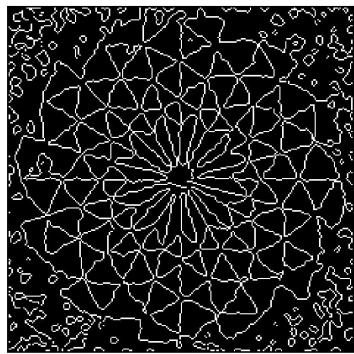
(b)



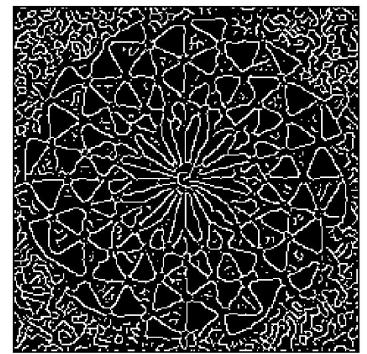
(c)



(d)



(e)



(f)

Figure 10: (a) The original image, (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 6.0502dB, (c) Detected edges using using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 2$, kernel size = 78 and $k = 2/\sigma$, (f) Detected edges using Canny edge detector.



Figure 11: (a) The original image, (b) Noisy image. Speckle noise of variance one was added yielding Peak SNR of 8dB, (c) Detected edges using using wavelet based edge detector, (d) Detected edges using LoG kernel, (e) Detected edges using HoG kernel. The filter parameters used are $\sigma = 1$, kernel size = 42 and $k = 2/\sigma$, (f) Detected edges using Canny edge detector.