Gaussian Notch Median Filter

Tiffany French

What does the Gaussian Notch Median Filter Do?

- The Gaussian Notch Median Filter removes periodic or quasi-periodic noise from an image through frequency domain filtering.
- The algorithm:
  - Takes an image, then produces a fast fourier transform of that image.
  - Iterates over the image, pixel by pixel, through a local window, excluding an nxn area around the zero frequency peak.
  - When a peak is found, it is suppressed with an nxn Gaussian surface to reduce the peaks, and thereby, the noise in the image.

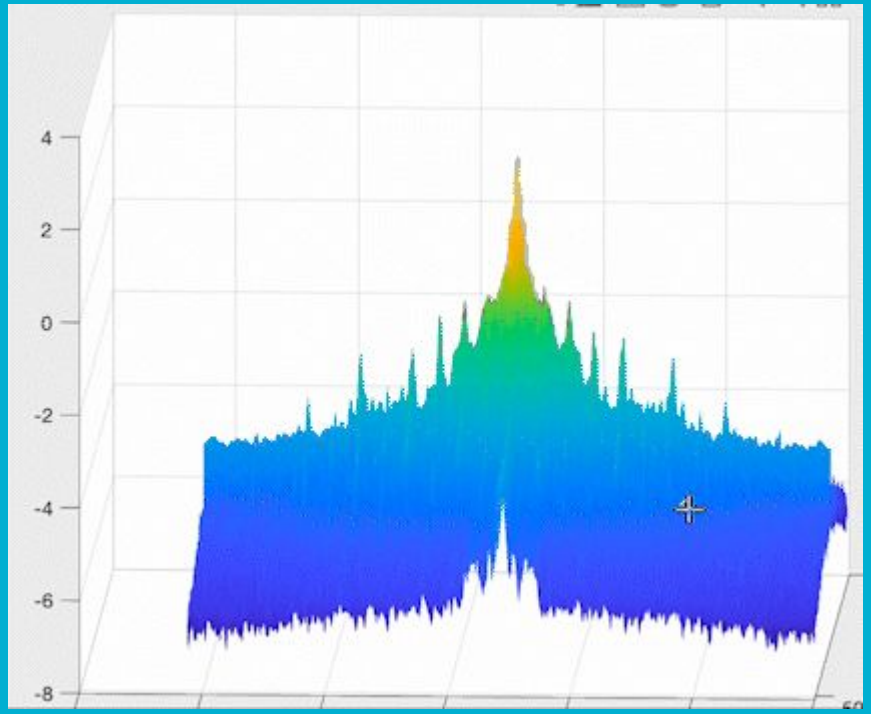
Examples of Periodic Noise

Why Do We Need to Filter in the Frequency Domain?

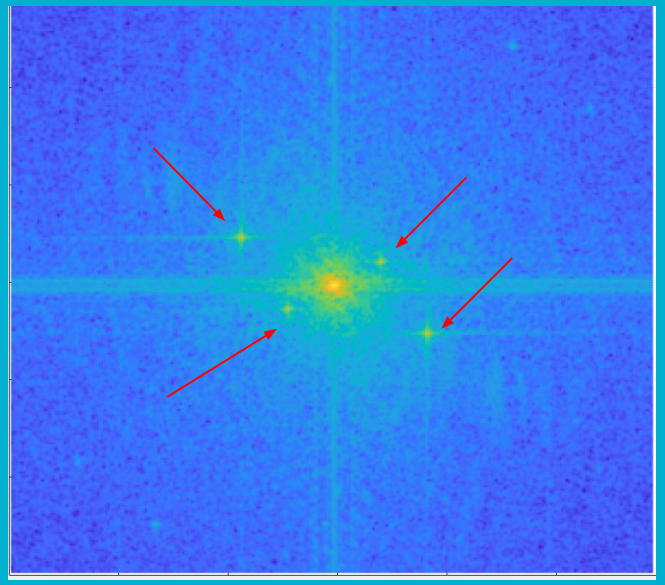
- We can address greater trends in our noise in the frequency domain, and the noise is repetitive so it acts more like a wave, than random noise.
- The frequencies are often very high in magnitude, compared to the rest of the values, so we can easily identify the noise.
- The limitations of this are that some noise cannot be completely eliminated, if there are many, smaller peaks, as there is a predetermined amplitude (the threshold) that would only correct frequencies that fall within that limit.

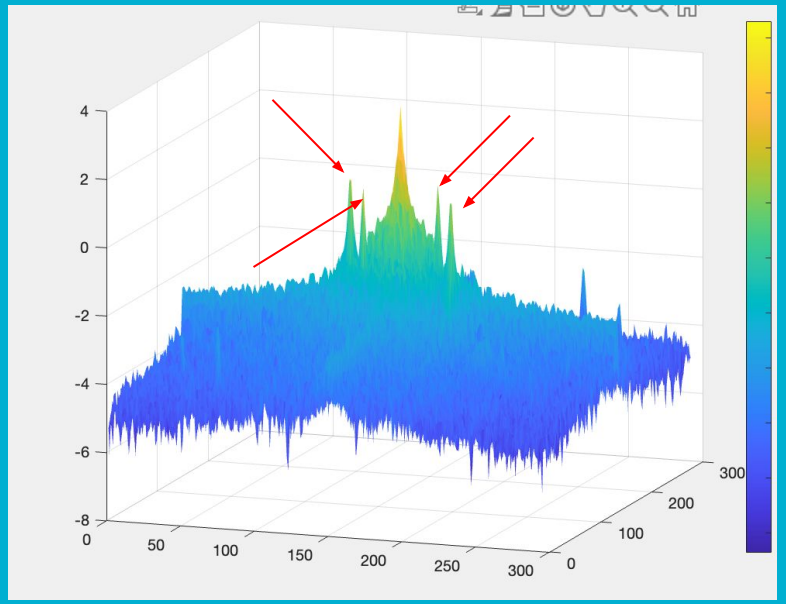
Zero Frequency Peaks: Explained

- Each sinusoidal/quasi-sinusoidal function creates two corresponding peaks in opposite quadrants of the transform.
- Their position is determined by their frequency: if closer to the DC frequency at the center, it is a lower-frequency function.



Fourier Transform to Expose Peaks

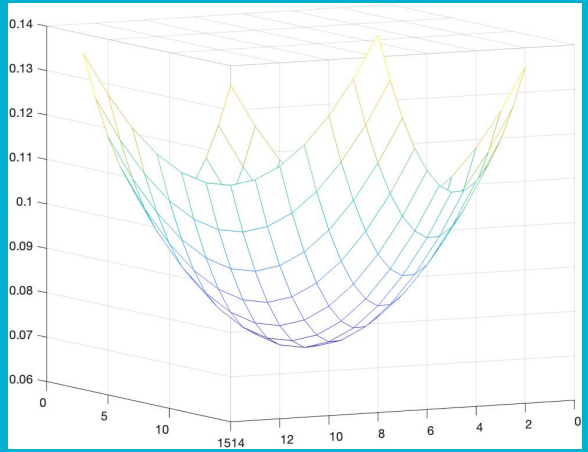




Create Gaussian Surface

$$\{G(u,v)\} = 1 - e^{-B\left[\left(u^2 + \left\lfloor \frac{n-1}{2} \right\rfloor^2\right) + \left(v^2 + \left\lfloor \frac{n-1}{2} \right\rfloor^2\right)\right]} \; ; \; u = -\left\lfloor \frac{n}{2} \right\rfloor, \ldots, \left\lfloor \frac{n}{2} \right\rfloor ; v = -\left\lfloor \frac{n}{2} \right\rfloor, \ldots, \left\lfloor \frac{n}{2} \right\rfloor ; B < 1$$

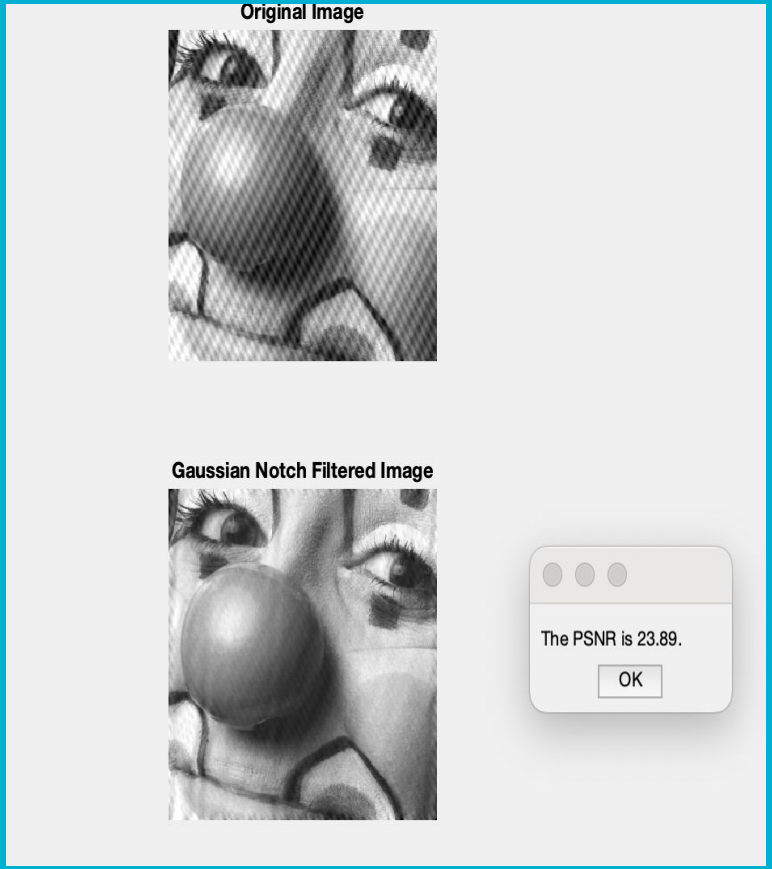
```
%%%%%%%Surface Params%%%%%%%%%%
edge = floor(n/2); %this is how you get the floor div.
e = 1; %scaling coefficient
g = zeros(n);
center = ceil(n/2);
k1 = floor((n-1)/2);
%%%%%%%create surface%%%%%%%%%%
for u = -edge:edge % this is floor division of -n/2
    for v = -edge:edge% this is floor division of n/2
        g(u+center,v+center) = 1-e * exp(-B*((u^2+k1^2) + (v^2+k1^2)));
    end
end
figure('name','Gaussian Surface')
mesh(g)
```



Experiments & Results

Image 1

- With parameter fine tuning the following provided the best results:
  - Window: 15
  - Scaling Coefficient: .001
  - Threshold: 7



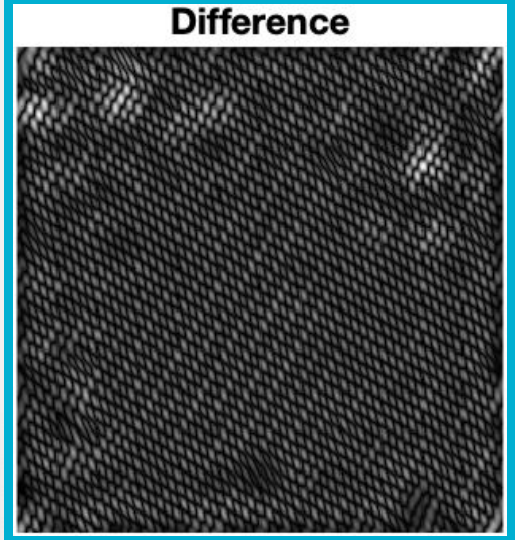
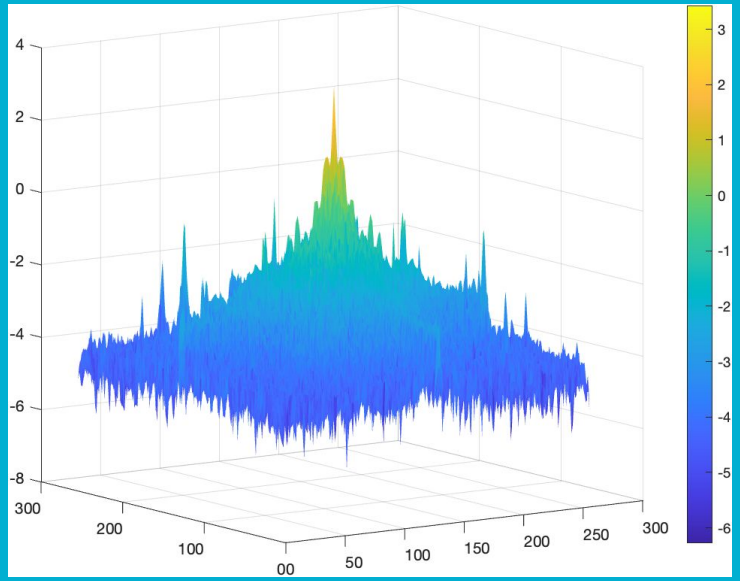


Image 2

- With parameter fine tuning the following provided the best results:
  - Window:5
  - Scaling Coefficient: .001
  - Threshold: 3



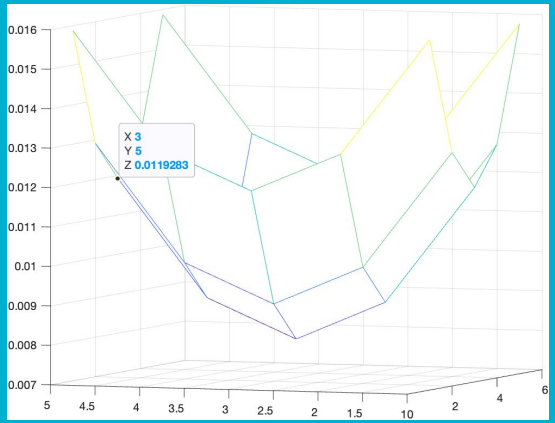
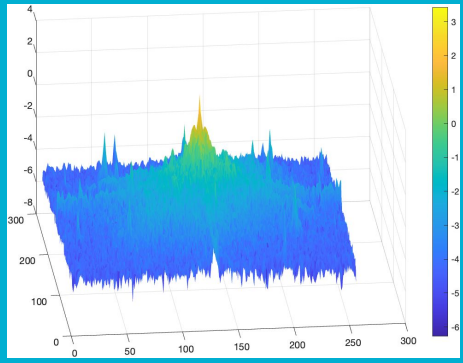


Image 2

- With parameter fine tuning the following provided the best results:
  - Window:5
  - Scaling Coefficient: .001
  - Threshold: 3



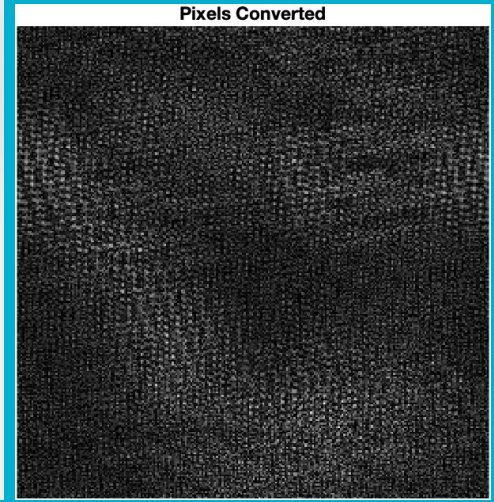
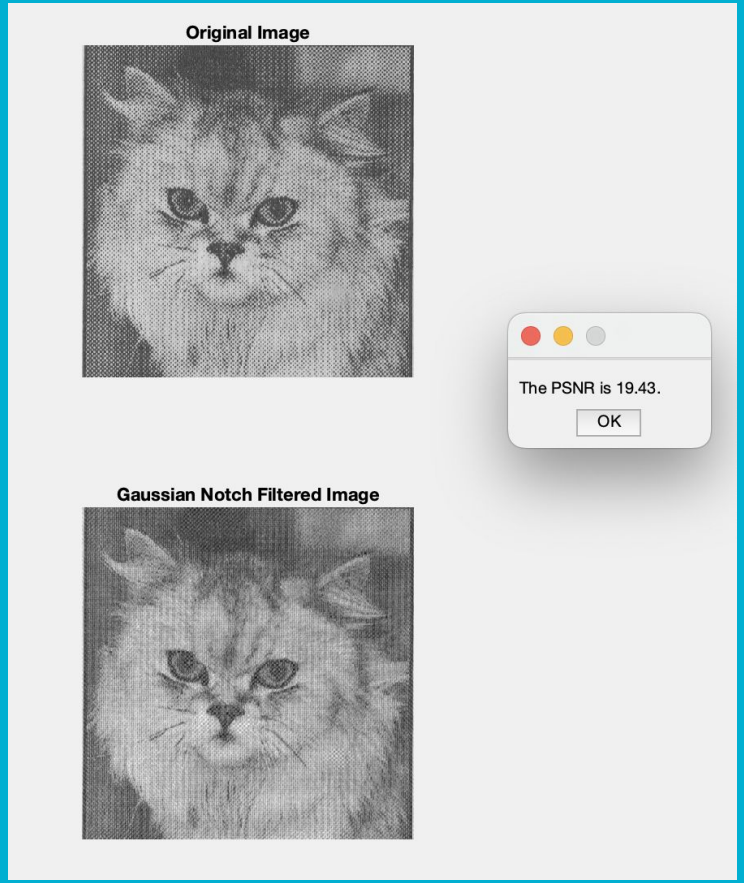
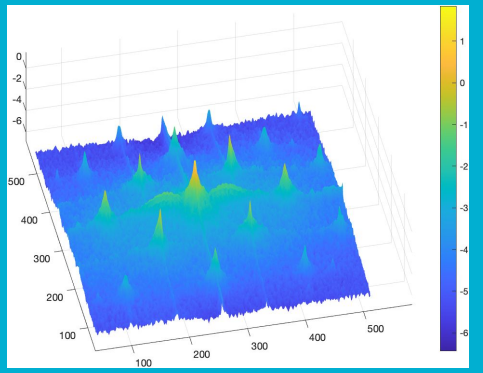


Image 3

- With parameter fine tuning the following provided the best results:
  - Window:3
  - Scaling Coefficient: .001
  - Threshold: 3





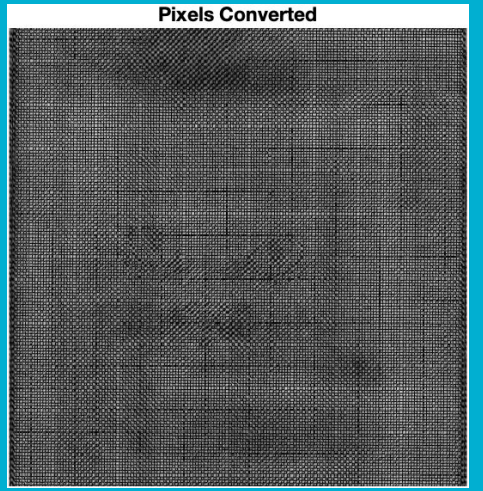
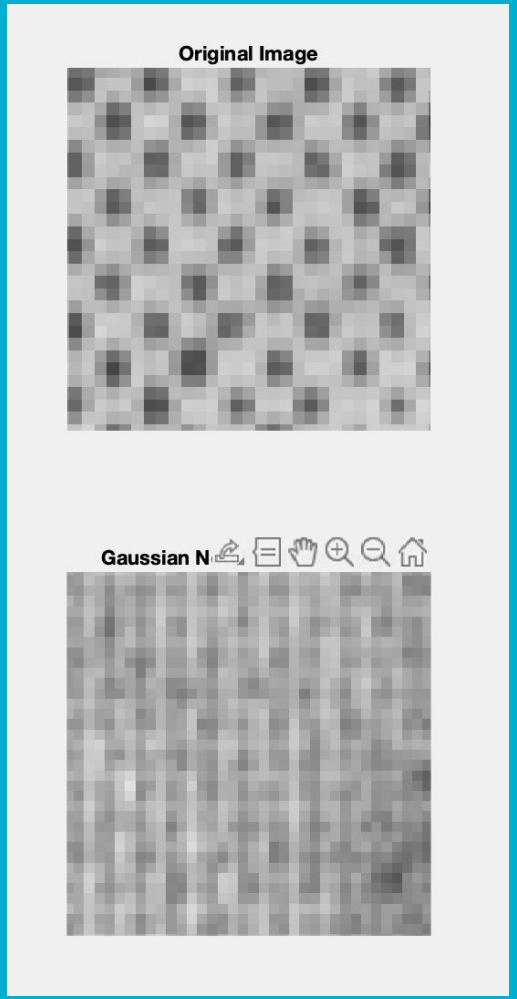


Image 3

- With parameter fine tuning the following provided the best results:
  - Window:3
  - Scaling Coefficient: .001
  - Threshold: 3



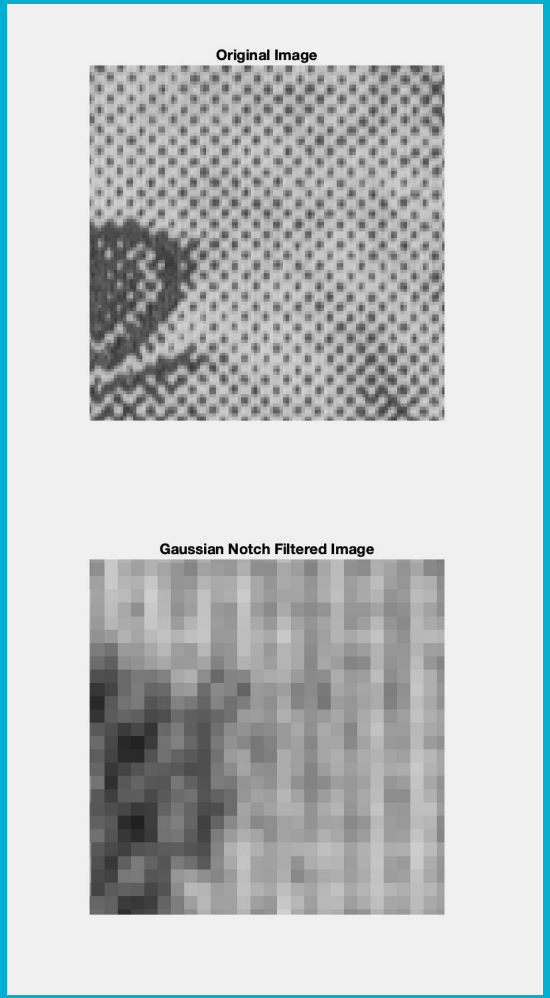
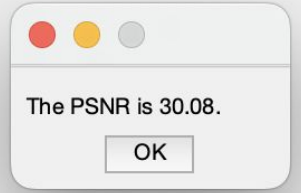


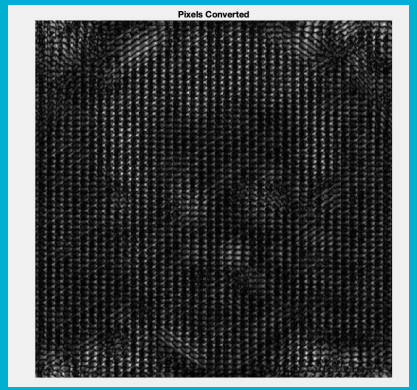
Image 4

- With parameter fine tuning the following provided the best results:
  - Window:19
  - Scaling Coefficient: .001
  - Threshold: 9

Original Image

Gaussian Notch Filtered Image





CONCLUSION

- Tests conducted on various images proved that it gives an effective result in getting an improved image with a good PSNR value.
- We would like to focus more on parameter tuning, as some of the images lost edges, in addition to noise with filtering.

Sources Cited

Ketenci and Gangal

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Justin Varghese , Saudia Subash , Kamalraj Subramaniam and Sridhar K P

https://www.researchgate.net/publication/339818026_Adaptive_Gaussian_Notch_Filter_for_Removing_Periodic_Noise_from_Digital_Images

Aizenberg & Butakoff: A windowed Gaussian notch filter for quasi-periodic noise removal