ISCS 30.65-M1
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Submission 2: Denoising Autoencoders

A) Why is poisson distribution the ideal one to use to simulate noise for medical images? Why not gaussian or something else? Answer in terms of relevance of medical applications.

Poisson noise models the acquisition of photons on a photosite. The number of photons is random and depends on the illumination. The corresponding Poisson process has a mean equal to the illumination, which provides a realistic representation of noise present in medical images (Mazet, 2020).

Given that Poisson noise is dependent on photons and illumination, Poisson noise is then beneficial for medical equipment that have photon-counting detectors or low-dose imaging. Imaging modalities such as x-ray imaging rely on photon-counting detectors to capture images and the number of detected photons in those modalities follows a Poisson distribution because of the randomness of the interaction between the photons and the detector (Thakur et al., 2015). Simulating noise for medical images using poisson distribution can then accurately represent the statistical behavior of photon counting in the imaging modalities.

As mentioned earlier, Poisson noise is dependent on the illumination. For medical imaging, the illumination refers to the amount of radiation or energy incident on the imaging sensor. Radiation is essential for medical imaging because it is what is administered to patients so that medical professionals are able to create a digital image or film that shows the structures inside our body (e.g. bones, tissues, organs) (Centers for Disease Control and Prevention, 2019). Since radiation can bring harm to our bodies, lowering the dosage of radiation administered is essential (Thakur et al., 2015). However, it results in fewer photons being detected, which increases the noise levels. Poisson noise then accurately models the randomness and variability of photon detection so as to provide a realistic simulation of noise under conditions with reduced photon counts.

Poisson noise simulation is also valuable for those who are still training to be medical professionals. It is because being able to mimic the noise patterns that are present in actual imaging conditions can help them understand the effects of noise on image quality, diagnostic interpretation, and the limits of imaging modalities. Moreover, Poisson noise simulation can allow people to assess the performance of image processing methods, evaluate the impact of noise on diagnostic accuracy, and validate quantitative measurements obtained from medical images.

Although Gaussian distribution and others can still be applicable to some imaging modalities, we must note that Poisson distribution is a discrete distribution. By having a discrete nature, Poisson distribution can only take on a finite or countable number of values (Madiraju, 2023). It is why Poisson noise simulation is suited for photon-counting detectors and can accurately model the photon-counting nature of the imaging process. Lastly, compared to others, poisson distribution accounts for the randomness of the number of photons detected along with the illumination is distinct to poisson and captures the behavior of photons, making it more ideal to be used in medical images.

B) Which one performed the best? Why do you think this is the case?

	Lambda = 25	**Lambda = 50**	**Lambda = 75**
Median Filter	10.901243109658 dB	10.060125621700259 dB	9.006801031359451 dB
Mean Filter	10.9046997008307 dB	10.068582537096962 dB	9.018985582026184 dB
Bilateral Filter	10.922254519204891 dB	10.083412119518204 dB	9.030138604954717 dB
Gaussian Filter	10.90364058155884 dB	10.067562187324874 dB	9.018154051534141 dB
Autoencoder Model	13.2916 dB	11.3808 dB	10.0602 dB

Despite the variation in the value of lambda, the filter that managed to get the highest average PSNR value is the **autoencoder model**. It is because PSNR is the ratio of the maximum value of the pixel to the noise that affects the quality of the pixels (MathWorks, 2023). A higher PSNR translates to having a better quality of the reconstructed image. The autoencoder model is a deep learning algorithm that can be trained to learn the specific characteristics of the noise and the image content that traditional filters cannot do (Wang et al., 2020). Because of this, the autoencoder model is then capable of producing better quality images than traditional filters like the median filter, mean filter, bilateral filter, and the Gaussian filter.

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