EE367 - Project Proposal – Nicolas Friley

Denoising Very-Low-Radiation-Dose CT Images with Deep Learning

Motivation:

Computed tomography (CT) imaging is a great diagnostic tool to examine patients with possible internal injuries or trauma, clots, or other conditions. However, it exposes patients to ionizing electromagnetic radiation. The radiation dose is determined by tuning the x-ray tube current according to the size and weight of the patient. CT scans are usually reserved for tests where the valuable diagnostic information outweighs the risk represented by the radiations. The risk of developing cancer from exposure to x-ray radiation remains relatively small, but the risk remains difficult to assess and should be mitigated as much as possible. Additionally, low-dose CT scans are recommended to screen patients with a high risk of developing lung cancer based on their age, medical history, and smoking habits. While decreasing the radiation dose significantly would help mitigate the total radiation exposure, it would increase noise levels in CT images, making them less accurate and compromising the value of the diagnostic. Therefore, there is a need for developing an efficient denoising method that could enhance very-low-dose CT image quality. This project aims to address this challenge by utilizing a convolutional neural network (CNN) for denoising very-low-dose CT images.

Literature review:

To determine the lowest radiation dose while maintaining diagnostic accuracy in CT examinations, simulated low-dose CT scans with realistic noise levels are utilized. Fidelity testing is necessary, and a simple Poisson model is often sufficient for generating reasonably accurate low-dose images[1]. Ahn and Heo employed a simulation-based approach to obtain regular-dose and low-dose CT images from the same patients, and managed to efficiently remove CT noise patterns with a modified U-net architecture trained on extracted patches[2]. Additionally, researchers have developed AI software that utilizes the K-space Weighted Image Average algorithm for image reconstruction in CT scans used to assess brain damage in stroke patients. This software reduces radiation dose by 50-75% without compromising image quality or processing speed[3]. Another team proposed using conditional generative adversarial network (CGAN) to denoise CT scan images, improving over methods such as total-variation minimization and non-local means[4].

Project timeline:

1. Data collection: Ultra-low-dose CT images will be collected from clinical datasets. Because of their scarcity, these images will serve as testing data. Regular CT images will be collected from clinical datasets and will be added noise to mimic ultra-low-dose CT images which will serve as training data. (Week of 02/26)
2. Several CNN architectures will be surveyed to find the most well-suited for this denoising task. (Week of 02/26)
3. Data augmentation: The nature of the noise added to the regular CT images will be researched thoroughly, in order to generate realistic ultra-low-dose CT images. (Week of 02/26)

4. CNN training: The CNN will be trained on the training data to map the noisy input images to their corresponding denoised versions. (Week of 03/04)
5. Performance evaluation: Qualitative assessment will involve visually inspecting the denoised images and assigning a score based on overall image quality, ensuring no loss of detail associated to major visual features. Quantitative evaluation may include metrics such as signal-to-noise ratio (SNR) improvement, structure similarity index measure and residual noise autocorrelations. (Week of 03/04)
6. Report writing and project finalization. (Week of 03/11)

Citations:

1. Yu, Lifeng, et al. “Radiation Dose Reduction in Computed Tomography: Techniques and Future Perspective.” Imaging in Medicine, vol. 1, no. 1, Oct. 2009, pp. 65–84, www.ncbi.nlm.nih.gov/pmc/articles/PMC3271708/, https://doi.org/10.2217/iim.09.5.
2. Chulkyun Ahn, Changyong Heo, and Jong Hyo Kim "Combined low-dose simulation and deep learning for CT denoising: application in ultra-low-dose chest CT", Proc. SPIE 11050, International Forum on Medical Imaging in Asia 2019, 110500E (27 March 2019); https://doi.org/10.1117/12.2521539
3. “Two Monumental Milestones Achieved in CT Imaging.” National Institute of Biomedical Imaging and Bioengineering, U.S. Department of Health and Human Services, www.nibib.nih.gov/news-events/newsroom/two-monumental-milestones-achieved-ct-imaging. Accessed 22 Feb. 2024.
4. Author links open overlay panelHee-Joung Kim a b, et al. “Image Denoising with Conditional Generative Adversarial Networks (CGAN) in Low Dose Chest Images.” Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, North-Holland, 28 Feb. 2019, www.sciencedirect.com/science/article/abs/pii/S0168900219302293.