Research Statement and Contribution

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We live in a world where many objects cannot be imaged directly and hence rely on reconstruction algorithms to solve the corresponding inverse imaging problems. However, lots of information is contaminated or even lost when samples are collected by imaging devices, so that the resulting inverse problem is ill-posed and challenging to solve. As the recorded photon arrivals by the sensor are often assumed to follow Poisson distributions, algorithms for solving Poisson inverse problems are crucial. My previous research mainly tackles two applications where Poisson inverse problems arise: phase retrieval and single photon emission computerized tomography (SPECT).

For phase retrieval[1], my contributions are novel algorithms [1–3] that have faster convergence speed and lead to improved image reconstruction quality. For example, we propose modifications to the WF algorithm. My method determines the step size based on observed Fisher information and incorporates a quadratic majorizer into our majorize-minimize approaches. I demonstrate that our methods are effective and exhibit favorable convergence properties [3]. Furthermore, we explore cases involving measurements affected by a combination of Poisson and Gaussian noise. I propose the use of an innovative technique called "AWFS" which uses accelerated WF with a score function as a generative prior. Theoretical analysis is conducted to showcase the critical point convergence guarantee of our algorithm. Simulation results demonstrate that our approach enhances reconstruction quality in terms of both visual perception and numerical assessment.

For SPECT imaging[2], I develop a Julia toolbox [7] enables efficient modeling of SPECT forward-backward projectors with parallel computing and minimized memory allocations. This facilitates effective backpropagation during deep learning regularized iterative algorithm training, resulting in higher quality reconstructions compared to non-end-to-end methods. Moreover, I propose DblurDoseNet [8], a deep neural network for joint dosimetry estimation and image deblurring after SPECT reconstruction. It accurately estimates dose-rate distribution and compensates for SPECT resolution effects. Evaluations on phantoms and patients show that DblurDoseNet outperforms conventional dosimetry methods while being fast enough for real-time clinical use in radionuclide therapy dosimetry. Additionally, I propose a neural network with unsupervised learning to predict missing SPECT projections. Our method aims to decrease acquisition time by obtaining only a subset of all projections. Our method outperforms linear interpolation techniques used to predict missing projection views in terms of the achieved image reconstruction quality [10].

My PhD dissertation (updated version) can be accessed on Github.

Given the insights gained from my previous research, various avenues exist for further investigation and exploration in the future. These include investigating transfer learning techniques for SPECT images, such as tumor segmentation; exploring unsupervised methods for scatter correction in SPECT imaging, and incorporating Positron Emission Tomography (PET)-guided diffusion into the reconstruction of SPECT images. Similar methods can be employed to address 3D phase retrieval problems as well. I am excited to see explorations on these research directions and believe they have the potential to improve the accuracy and efficiency of algorithms for solving Poisson inverse problems.

[1] This part of work is based on [1–6].
[2] This part of work is based on [7–16].

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