Research Statement

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Overview

My areas of interest are image processing, inverse problems, and deep learning. The goal of my research is to apply advancements in machine learning techniques to standing challenges in computational imaging and image processing and, to develop algorithms for such problems as well as improving the current methodology.

Tremendous progress has been made in deep learning research in recent years, and the developed techniques have been applied to various areas in image processing. While these advances are promising, it is not straightforward to apply them for many challenges in the industry. My research is focused on adapting iterative algorithms and deep learning methods for specific inverse problems that have solutions with significant drawbacks or remain unsolved with current literature.

Research Contributions

Improvement in an Iterative Reconstruction by Combining two Inverse Models [1]: In this research, we addressed the so-called ptycho-tomography problem and introduced a 3D reconstruction method that uses gradient descent. 3D nanoscale computational imaging is crucial for a variety of applications, such as failure analysis of integrated circuits or observation of crack propagation. 3D Ptychography overcomes the resolution limitation of lens-based imaging methods, and it is significant to get high-resolution reconstructions. Here, we re-design the inverse problem and solve the ill-posedness of the problem by exploiting the redundancy in the forward model, which makes the reconstruction to be easily accessible via gradient descent. Then, we apply our gradient descent algorithm to show significant improvements over the state-of-the-art methods. As this work shows, before the application of deep learning methods, defining the problem properly and constructing the inverse problem correctly is as critical as the method used, and this experience may come in handy for various applications at Roku.

Covid-19 Detection using Chest X-Ray Images [2]: Implementation of classification networks are usually simpler in many areas. However, effects of Covid-19 in chest imaging are rather subtle and classification of positive Covid-19 x-rays becomes harder. In this work, we have developed classification networks with different specifications to detect different aspects of findings in the lungs. Due to the small amount of training data available, networks are pre-trained on a general chest x-ray dataset and fine-tuned with clinical images from Northwestern University. To ensure to get the best accuracy, networks are ensembled via a probabilistic approach and the resulting model performed similar to a consensus of experienced thoracic radiologist which allow the method to be used as a pre-screening tool in hospitals. This project shows the importance of creating out-of-the-box ideas using known methods for challenging tasks, where this point of view may be helpful for many areas as well as the problems encountered at Roku.

Physics-Based Deep Image Prior Approach to Computed Tomography [3]: Computed tomography has been studied well, and various methods have been developed to get the 3D image of a structure. However, in some cases, the whole structure cannot be scanned, resulting in an ill-posed problem, namely missing-wedge. Unlike the traditional methods, we approach the challenge with a physics-based deep network and solve it without training with the inspiration from "Deep Image Prior". That is, we construct a generative network taking projections as the input and modifies the 3D output to minimize the loss between the input projections and results of the physical projection model of the output. This approach does not require any training data as it transforms the projections into 3D reconstruction directly using a combination of fully connected and convolutional layers. To incorporate the regularization for noise, we have self-trained the network in an Alternating Direction Method of Multipliers (ADMM) framework. The results show significant improvement of reconstructions in a noisy environment over traditional methods. In applications using physical as can be found at Roku, incorporating physical model into a network would result in improvements in the output of the model.

Improving X-Ray Imaging Method through Regularization and Automatic Position Correction [4]: In this project, we improve an x-ray imaging method by decreasing dependency on exact measurements via regularization and learned position correction. X-Ray Ptychography is a nanometer imaging method with high resolution, and it requires precise projections. However, equipment is usually not precise in the nanometer domain, and resulting reconstructions generate significant errors. We have approached the problems in the reconstruction method and improved the results via two methods: incorporating regularization via image priors and correcting position via automated self-learning. In this approach, learned scan positions generate more quality with the help of regularization. We show that the resulting improvements are significant compared to the existing methods in the literature. As the data acquisition is not perfect most of the time, fixing these issues will lead to better applications of the methods employed, and I will be excited to apply these techniques if I encounter similar issues during my Roku internship.

Future Work and Collaboration with Roku

Image processing field has a broad range of applications in current technology. In the last decade, deep learning has taken a crucial part in many applications in this field. Although deep learning is widely used, it is still in its early stages; many of them can be and will be improved significantly, whereas some of them are still far from possible deep learning applications.

I have been in the image and video processing field with a focus on inverse problems for several years. In recent projects, my focus has shifted towards the applications of deep learning in new inverse imaging fields and towards the improvements on the current challenges. My intention is to continue working on the application of machine learning methods to various existing problems in this field, and Roku is a well-suited environment for me to pursue this goal.

In many applications, with the background knowledge of the traditional methods, significant improvements can be made to deep learning compared to experimental applications. Roku has been in the image processing field for a long time, and many of the well-studied methods in image processing can be applied to deep learning methods currently being employed in its products. If I am given the chance, I desire to work on specific inverse problems in computational imaging or image processing at Roku, where the methods can be improved by using the well-studied image processing literature

References

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[3] **S. Barutcu**, S. Aslan , D. Gursoy, A. K. Katsaggelos, "Computed Tomography reconstruction via Deep Image Prior and Alternation Direction Method of Multipliers," *Nature - Scientific Reports (In review).*

[4] P. Shedligeri, **S. Barutcu**, F, Schiffers , P. Ruiz, A. Katsaggelos, O. Cossairt, "Improving Acquisition Speed of X-Ray Ptychography through Spatial Undersampling and Regularization," *Proceedings of the IEEE International Conference on Image Processing (ICIP)(In review).*