Sang-hyup Seo

Research Statement

Current Objectives

My research interests are in developing advanced iterative methods to solve nonlinear matrix equations and applying neural network models to solve industrial problems. Through these interests, I want to reach my research objective of solving application problems with computer algorithms.

Algorithms to solve nonlinear matrix equations can be applied to extensive application problems – to estimate the stationary vectors for various queueing models, or to solve generalized eigenvalue problems in overdamped problems. Although there exist various direct methods to deal with nonlinear matrix equations, an iterative method can cover wider area of problems than a direct method. Therefore, it is also important to advance the performance of iterative methods. Until now, I have studied the acceleration techniques of Newton's method which is one of the advanced iterative methods.

While I was in the previous institute, I dealt with several types of medical images provided by hospitals in Busan to distinguish existence of diseases or to detect parts of the body. To accomplish these tasks, I trained myself with convolutional neural network models for classification or segmentation and applied these techniques utilizing clinical data.

Current Research

Iterative Methods to solve nonlinear matrix equations

Currently, I am working on the acceleration technique of Newton's method by applying algebraic transposition on the given matrix polynomial equation.

In particular, my research has focused on Newton's method and variations of the method to find specific solutions of nonlinear matrix equations such as quadratic matrix equations, matrix polynomial equations, or order-convex matrix equations. The goal is to enhance the computational efficiency of the existing Newton's methods in terms of calculation time or number of iterations.

It is known that solutions of quadratic matrix equations can be obtained faster when first applying algebraic transposition and then solving the modified equation with the fixed-point iteration method. My idea is to apply this technique to solve matrix polynomial equations using Newton's method. My colleagues and I plan to publish the analytical result of this problem.

Medical Image Processing with Neural Network Models

While I was a postdoctoral researcher, I had a chance to lead the project to build an algorithm to identify normal pulmonary alveolus for trauma patients using lung CT data. In the cases of trauma patient, having pneumothorax and hemothorax in CT does not always mean that they have lung diseases. The patients can have trapped air or pooled blood in the thorax from injury of organ other than lungs. On that account, it is an important issue to correctly judge whether the trapped air or the pooled blood is originated from lung injury or not using CT images.

In the institute where I worked, I participated in the projects to develop medical image processing algorithms utilizing neural network models. One of the projects was to develop eye disease diagnosis algorithm with fundus photographs. Back then, I submitted the annual algorithm validation report for 2 years. The other one was to develop tooth numbering algorithm with dental photos taken from mobile devices. In the project, I developed two segmentation neural network models of customized EfficientNet model and the U-net model.

From these works, I experienced the application of 3D filtering techniques for the volume calculation algorithm of the pneumothorax and hemothorax using lung CT data of the patients who have lung injuries and other patients who have injuries in other organs. Applying 3D filtering techniques, the algorithm successfully distinguished pneumothorax and hemothorax caused by lung injury from those which was brought by other injuries. Currently the work is in its final stage and under the process of validation conducted by medical experts.

Future Research

Moving forward, I plan to deal with two subjects. The first subject is to develop various accelerated iterative method, especially Newton's method to solve nonlinear matrix equations. A well-known strategy in the acceleration of Newton's method is giving appropriate scalar multiplication to the differences of each step. To find the appropriate scalar, the technique of exact line search can be used. A disadvantage of exact line searches is in that it requires too many computing resources. On the other hand, in mathematical sense, there is an advantage that it gives the most appropriate next step for each iteration. Going through several simulation experiments, I gained an insight that there is a tendency that the sequence of differences between each Newton step converges to a one-dimensional space. As a next step, I plan to give a proof of the tendency and show the efficiency of the technique which applies only one time of exact line searches on the middle part of existing Newton sequence.

As a second subject, I will keep studying deep learning models and exert them to tackle industrial problems. In the institute I previously worked, my task was to apply deep learning models to process medical images. Consequently, I dealt with various types of medical images like fundus, dental, and lung CT images. In a future, I wish to have a chance to process other types of data including language data. In particular, I would like to study language processing models for SOV(Subject-Object-Verb) and agglutinative language like Korean language. Although there exist many natural language processing algorithms for English, as English and Korean have different language structure and history, I wish to understand the difference of them and develop a model which fit to Korean.

As a final goal, I hope to find solutions of various nonlinear matrix equations with neural network models. To find solutions of nonlinear matrix equations with iterative methods, we need a lot of computing resources. The acceleration techniques for iterative methods save resources such as electric power or time. On that account, I am going to develop a novel neural network model aiming to discover an efficient technique to find solutions. In fact, some researchers of DeepMind published an article entitled "Discovering faster matrix multiplication algorithms with reinforcement learning." With my background of solving nonlinear matrix equations, I believe I can develop a new model to advance acceleration techniques.