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 which is to solve 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 obtained from 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 to the 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 a 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 orgran other than the lungs. It is an important issue to correctly judge whether the trapped air or the pooled blood is 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 with 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 application of 3D filtering techniques for the volume calculation algorithm of the pneumothorax and hemothorax from injury of organ other than the lungs with the lung CT data. Applying the techniques, the algorithm can distinguish the pneumothorax and hemothorax between from lung injury and injury to organs other than the lungs. My coauthors in the hospital compared with the clinical data. This work is almost done.

# 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, solving nonlinear matrix equations. It is well known that giving appropriate scalar multiplication to the differences of each step is a representative technique to accelerate Newton’s method. One of the techniques finding the appropriate scalar is exact line searches. A disadvantage of exact line searches is that it requires too many computing resources. On the other hand, in the mathematical sense, there is an advantage that it gives the most appropriate next step for each iteration. Moreover, with, I guess that there is a tendency that the sequence of differences between each Newton step converges to a one-dimensional space. So, I plan to give a proof of the tendency and to show the efficiency of the technique which applies only one time of exact line searches on middle part of existing Newton sequence.

It is the second subject to study about deep learning models and apply them to applied problems. In the institute where I worked, almost of my missions were applying deep learning models for processing medical images. So, I dealt with many medical images like fundus, dental, and lung CT images. But, I had less chances to process other data like language data. In particular, I want to study about language processing models for SOV(Subject-Object-Verb) and agglutinative language like Korean language. There are many natural language processing algorithms for English. However, English and Korean have different language structure and history. So, I hope that I understand the differences of them and I develop a model which is fit to Korean.

?I will research about finding 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 are which save resources like electric power or time. As another technique, I consider developing a new neural network model to discover an efficient technique finding solutions. In fact, some researchers of DeepMind published an article “Discovering faster matrix multiplication algorithms with reinforcement learning.” So, I will develop a new model discovering acceleration techniques with my background of solving nonlinear matrix equations and the paper.