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 that solving application problems with computer algorithms.

Solving nonlinear matrix equations can be applied to extensive application problems - to get stationary vector for various queueing models, or to solve generalized eigenvalue problems in overdamped problems. Various direct methods also have been suggested to solve various nonlinear matrix equations. But, one iterative method can cover wider area of problems than one direct method. So, it is also an important issue researching accelerations of iterative methods. Until now, I have researched acceleration techniques of Newton’s method as advanced iterative methods.

While I was in the previous institute, I have dealt with many medical images from hospitals in Busan to distinguish existence of diseases or to detect some parts of body. To do this works, I have studied and applied convolutional neural network models for classification or segmentation.

# Current Research

### Iterative Method solving 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 like a quadratic matrix equation, a matrix polynomial equation, and an order-convex matrix equation. 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 solving matrix polynomial equations with Newton’s method. My colleagues and I plan to publish the analytical result of this problem.

### Medical Image Processing with Neural Network Models

I have been working on a project to build an algorithm searching normal pulmonary alveolus for trauma patients with lung CT data. In the trauma patient cases, pneumothorax and hemothorax in CT images does not always mean that they have lung diseases. The patients can have blood or air pocket in the thorax with damages from organs not lungs. It is very important to discern the blood or air pocket is from damages from lungs or not with only CT images.

In the institute where I worked, I participated the projects developing medical image processing algorithms with neural network models. One of the projects was developing eye disease distinguishing algorithm with fundus photographs. At that time, my role was to write the annual algorithm validation report. The other one was developing tooth numbering algorithm from mobile dental photos. In the project, I constructed two segmentation neural network models from a modified EfficientNet model and the U-net model.

From these experiences, I applied 3D filtering techniques to the volume calculation algorithm of the pneumothorax and hemothorax from damages from organs not lungs with the lung CT data. My coauthors in the hospital is comparing with the clinical data. This work is almost in the process finishing.

# Future Research

Moving forward, I plan to deal with two subjects. The first subject is to suggest various accelerated iterative method, especially Newton’s method, solving nonlinear matrix equations. A representative method to accelerate Newton’s method is giving appropriate scalar multiplication to the differences of each steps. One of methods finding the appropriate scalar is exact line searches. A disadvantage of exact line searches is that it takes too much calculation resources. On the other hand, in mathematical sense, it gives the most appropriate next step for each iteration. Moreover, for Newton’s method, there is a tendency that each difference of each step converges to a one-dimensional space from many experiments. So, I will give a proof of the tendency and show the efficiency of the method which applies only one time of exact line searches.

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 have dealt with many medical images like fundus, dental, and lung CT image data. But, I had less chances to deal with other data for example language data. Especially, I want to study about language processing models for SOV(Subject-Object-Verb) or agglutinative language like Korean language. There are many advanced natural language process algorithms for English. However, English and Korean have different language structure and history. So, I hope that I understand the differences of them and construct a model which is fit to Korean.

Through previous two subjects, I will research about efficient neural network models finding solutions of various nonlinear matrix equations. Iterative methods to find solutions of nonlinear matrix equations need a lot of calculation resources. The reason that I research about acceleration techniques for iterative methods also are which save resources like electric power or time. To overcome heavy resource problems with other techniques, I consider applying efficient neural network model to finding solutions. Of course, neural network models also have heavy resource problems. But, most heavy resources are needed when models are been in training process, and there are and will be many researches about increasing efficiency of neural models.