[p4]

Physical fields are tensor quantities which vary in time and/or space axes. They are very common in our daily life, such as temperature field, gravitational field, electromagnetic field. It’s essential to understand the distribution of field patterns in scientific research and engineering problem for accurate predictions of relative phenomena as well as the development of related devices. Therefore, I want to do research on this topic.

The traditional method to obtain the field pattern is to solve field equations that contain the information of a specific field. For example, for electromagnetic field patterns, one needs to solve Maxwell equations of electrodynamics. This method costs a lot of computational resources as field equations have the form of multivariable and partial differential equations.

But in this research, I found a potential method to get the field patterns and predict parameters, which can save much time and computation.

[p5]

The waveguide consists of two parts: core and cladding. The core refractive index is greater than the cladding refractive index so light can be confined in the core and propagate along the waveguide. The theory of this part has been introduced briefly in proposal presentation, I would not go over it.

For this research, all we need to know is. The electromagnetic field consists of magnetic field and electric field. The electromagnetic field pattern has transverse electric (TE) mode and transverse magnetic (TM) mode, they are classified based on the dominant component in the pattern. The mode pattern plays an important role in investigating behaviors of optical waveguides.

[p6]

To build the model and predict the parameters successfully, I need to understand my input data the field pattern completely first. I started analyzing from a clearer part, that is predicting the field patterns using RNN.

Model: 3 RNN hidden layers with 64, 96, and 224 neurons in each layer and 1 output layer with 1024 neurons. This model is built In Keras, the SimpleRNN layer is a fully connected RNN layer and the Dense layer is a fully connected layer. The SimpleRNN layer accepts 3-dimension data and outputs 2-dimension or 3-dimension results.

The magnetic field pattern can be obtained by using the same model (an interchange of the width and height of the optical waveguide) because of the symmetry property of the optical waveguide. So, we only need to consider the dominant component of the field pattern.

[p7]

After fully understanding the field pattern and the parameters, I build CNN model and consider it by inversing the output and the input. The cross section of the optical waveguide is discretized into a set of pixels, which contains the field values. I used pooling after convolution, like two convolutions and one pooling. After that, I straighten the matrix that we get into a vector. Putting vectors in fully connected layer, and using softmax. Finally, we can get the output. For this model, I choose mean squared error as the loss function, and Adam as my optimizer, batch size = 32 and epochs = 500.

[p8]

The input dataset is obtained by taking one quarter of the field pattern, and discretizing the pattern into tiny pixels. The output dataset consists of geometrical parameters of the optical waveguide: width of the waveguide w and height of the waveguide h. w varies from 0.1 to 1.2 and same as h.

There are 2500 samples, so I divide the dataset into 3 parts: training data, testing data and validation data, with 1600 samples, 500 samples and 400 samples, respectively.

[p10]

These results show my analysis on field patterns prediction by RNN, and the experiment of prediction on waveguide parameters by Convolutional neural networks. Y scale is set at log value. We can see from left figure, no changes show before 450 epochs, but there is a huge drop around epoch 480, and after that the loss tends to be gentle. In the right figure, the training loss and the validation loss seems to be similar, and both of them have a gentle fall.