The Reconstruction of Shape with 3-Step Modeling Strategy

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Summary. Three step modeling strategy is newly developed to improve the performance of Artificial Neural Network through Knowledge Based Techniques. This strategy provides not only more accurate results but also time efficiency especially in complex modeling problems. In this study the reconstruction of shape obtained from measurements of scattered electromagnetic fields is considered. Multi Layer Perceptron is chosen for realization of Artificial Neural Networks. In order to demonstrate the efficiency of three step modeling, the reconstruction of shape for two different geometries are considered.

1 Introduction

Artificial Neural Network (ANN) is a well known approach in modeling problems where only input-output data is available. Data generation, number of neurons and number of iterations are important features that effect the accuracy of ANN. Since for complex modeling problems it is difficult to have input-output necessary data, modeling is hardly applicable for such problems.

Knowledge Based Techniques were developed to reduce complexity of modeling problem by using the knowledge about the considered problem [2,4]. Three step modeling strategy further improves the efficiency of knowledge based techniques. This strategy uses same training data and same number of neurons, but generates more accurate results and less time consuming than the conventional ANN modeling.

In this work, the main contribution over [1] is to use MLP as ANN structure. MLP, Prior Knowledge Input (PKI) [4] and Prior Knowledge Input with Difference (PKI-D) [2] are used in first (M-1), second (M-2) and third (M-3) steps of 3-step modeling strategy [1], respectively. In order to show the efficiency of the method inverse scattering problem is considered.

2 3-Step Modeling Strategy

3-step modeling strategy provides gradual improvements during modeling. For this purpose, it firstly utilizes ANN structure. After training process is completed, this model is named model-1 (M-1). M-1 generates prior knowledge for PKI model. PKI utilizes response of M-1 and complexity of modeling problem is reduced via this prior knowledge. After training process is completed, this model named model-2 (M-2). Finally PKI-D utilizes M-2 response both at input and output. Therefore M-2 is used to reduce complexity and it narrows the output range using difference between original response and M-2 response.

Each step uses same number of iterations and total number of iterations and neurons are the same as in conventional ANN model. This strategy gradually improves accuracy during three steps and total time consumption is always less than using conventional ANN model.

Modeling steps and necessary formulations of 3-step modeling strategy are given as follows:

- **Step-1:**
  Training ANN and calculate training response
  $x_{M-1} = f_{ANN}\left(Y_f\right)$
- **Step-2:**
  Training ANN using extra knowledge Y_{M-1} and calculate training response
  $x_{M-2} = x_{PKI} = f_{ANN}\left(Y_f, x_{M-1}\right)$
- **Step-3:**
  Training ANN using extra knowledge Y_{M-2}
  $x_{M-3} = x_{PKI-D} = f_{ANN}\left(Y_f, x_{M-2}\right) + x_{M-2}$
- **Test error:**
  Calculate test data using $M-1$, $M-2$ and $M-3$ and find test error for 3-step modeling

$$Mean\ Error = \frac{1}{N} \times \sum_{i=1}^{N} \frac{|X_{original,i} - X_{method,i}|}{X_{original,i}}$$

$$Max\ Error = \max_i \left\{ \frac{|X_{original,i} - X_{method,i}|}{X_{original,i}} \right\}$$

After training process is completed for 3-step modeling as shown in Fig.1, each model is used to calculate test error. This error performance is useful to compare this strategy with conventional modeling technique.

3 Inverse Scattering Problem

The direct scattering problems investigate the scattering fields for a given object. On the other hand, the aim of inverse scattering problems is to find out the properties of an object, such as shape, electromagnetic parameters, position for given scattered fields. Five Fourier coefficients (one of them is real others are complex) are used as inputs and 10 complex values obtained by measurement points in Fig.2 are used as outputs of the original model [3]. In this

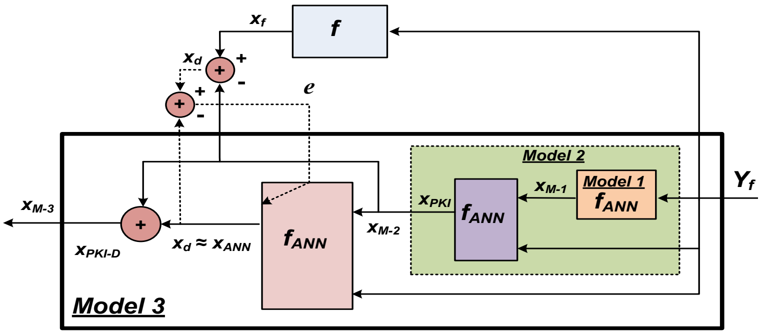

Fig. 1. 3-step modeling of inverse scattering problem.

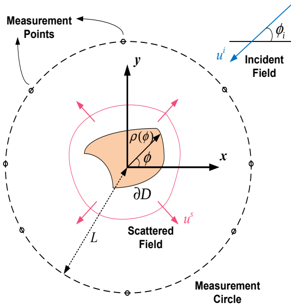

Fig. 2. Geometry of scattering problem.

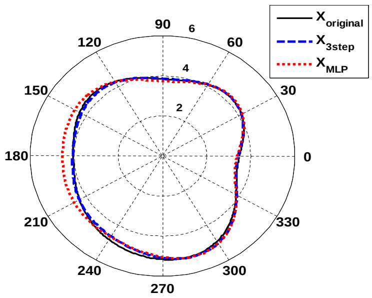

Fig. 3. The comparing original shape with the shape reconstruction of 3-step model and MLP-ANN model for geometry-1.

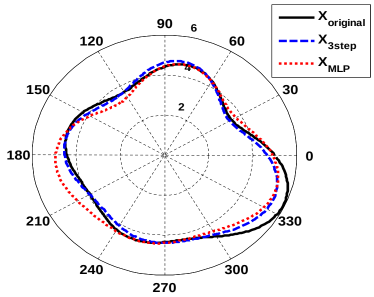

Fig. 4. The comparing original shape with the shape reconstruction of 3-step model and MLP-ANN model for geometry-2.

work, number of neurons and number of iterations are chosen 60*60 for conventional ANN modeling and 15*15, 20*20, 25*25 for the first, second and third step of 3-step modeling strategy. In total conventional ANN and 3-step modeling use same number of iterations and neurons. The geometry of inverse scattering problem is shown in Fig.2. Time consumption is 1.95 sec in M-1, 2.215 sec in M-2 and 2.231 sec in M-3.Total time consumption of 3-step modeling (6.396 sec) is less than conventional ANN's (20.187 sec). To compare test results of 3-step modeling and conventional ANN, 5 randomly generated geometry are obtained. Original shape, the reconstruction of shape obtained from 3-step modeling and conventional ANN are given together in Fig.3 for $geometry-1$ and Fig.4 for $geometry-2$.

4 Conclusion

Although 3-step model utilizes same number of iterations and number of neurons as conventional ANN, it generates more accurate results (mean error: %3.7) in less time than conventional structure (mean error: %4.2). This efficiency is based on knowledge based strategy in 3-step modeling. This work demonstrates the efficiency of this strategy for inverse scattering problem as well.

References

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