Effective Approach for Truss Optimization Using Deep Learning Based on Multi – Classification

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EFFECTIVE APPROACH FOR TRUSS OPTIMIZATION USING DEEP LEARNING BASED ON MULTI – CLASSIFICATION

Mehriniso Zokhirova

Abstract

Since deep learning is providing an effective way to train systems and gaining high performance, it is being transforming action in various fields. This study defines the deep learning approach for structural analysis and its predictions for exploring optimum design variables. The basic originality of this work is training dataset and prediction of design variables in the case of two types of truss structures. In order to train the neural network, various numbers of sets and classes are created for 10 bar and 25 bar trusses. In this case, implementation of this experiment involves two manners: regression and multi-classification. By these two manners, the power of deep learning for truss optimization is determined without using any structural analyzers and algorithms.

Key words: neural network, multi-classification, truss optimization, regression.

Introduction

The increase of interest in neural networks is obviously according to their conveniences for learning; make decision, and having summaries by partial information. These features related to human brain’s processes which other computer technologies have failed to pretend. As a result, one of the names that deep learning has gone by is Artificial Neural Network (ANN) and it is inspired by the biological brain. ANNs includes many nonlinear computational elements that form the network nodes, connected by weighted interconnections. Today, deep learning is the most attractive field for all spheres of engineering. In this paper, three neural networks is trained step by step in order to show developed methods of deep learning to structural optimization problems, and also illustrates results. We demonstrate innovative methods for training using hyperparameters and dropout algorithms in structural analysis in the case of ten bar truss problem. This work provides the information using more hidden layers with dropout on each layer and suitable activation functions for chosen problem. The key features in this study are: neural network using linear regression algorithm and classification. Also, dependence of input data in achieving better accuracy is described by numerical implementation.

Neural Network

By looking its history, it is known that deep learning is a quite novel promotion in neural network (NN) programming with representation of methods in training deep NNs. Primarily NN with more than two layers is called deep neural network. The term of NN firstly introduced by McCulloch and Pitts (1943) who derived theorems of models in neural systems similar to biological structures. The previous model of NN was called perceptron which contains of a single layer of neurons connected by weights. Rosenblatt (1958) discovered the algorithm called back propagation but it was slow with increasing of layers. Until 1984, NN could not be effectively trained and Hinton was the first researcher for well-trained complex NN.

Numerical Implementation

In this part, numerical calculations demonstrated by the library Keras (Cholet, 2015) in Python 3.6. This process includes three neural network trainings: two classification and one regression neural networks. The goal of previous NN is determine the candidates for areas by predicting on given conditions and Feed forward neural network is defined with two hidden layers. In this case input variables are stresses of each element and output is cross sectional areas of members and each output has three or more choices depending on number of classes. Figure 1 defines the training accuracies in the case of various number of hidden layers. As it is shown NN with two and three hidden layers insists almost
the same accuracy. For our training, NN with two hidden layers is chosen for reducing time.

![Figure 1: Accuracy for training sets with (10-200-10), (10-200-400-10), and (10-200-400-600-10) architectures after 1000 epochs representing comparisons different number of hidden layers and neuron](image)

### Constraints

<table>
<thead>
<tr>
<th>Member</th>
<th>3 classes</th>
<th>5 classes</th>
<th>4 classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>σᵢ ≤ σᵧ</td>
<td>σᵢ ≤ σᵧ</td>
<td>uᵢ ≤ δ</td>
</tr>
<tr>
<td></td>
<td>NN Analysis</td>
<td>NN Analysis</td>
<td>NN Analysis</td>
</tr>
</tbody>
</table>

| A₁ | 9 | 9 | 30 | 30 |
| A₂ | 1 | 1 | 10 | 10 |
| A₃ | 9 | 9 | 30 | 30 |
| A₄ | 5 | 5 | 10 | 10 |
| A₅ | 1 | 1 | 10 | 10 |
| A₆ | 1 | 1 | 10 | 10 |
| A₇ | 9 | 9 | 20 | 20 |
| A₈ | 5 | 5 | 10 | 10 |
| A₉ | 5 | 5 | 20 | 20 |
| A₁₀| 1 | 1 | 10 | 1 |

Weight(lb) 1954.23 1954.23 1852.41 1852.41 6654.7 6654.7 6057.61 5.581

![Figure 2: Predictions by neural network with the results satisfactory and unsatisfactory for constraints.](image)

By overlapping, satisfactory results looks less on this figure. But the percentage of satisfactory results varies between 50% to 70%. The comparison of Analysis and NN solution for ten bar truss is shown in Fig. 3.

### Conclusion

According to recent papers and researches, deep learning approach on structural analysis is getting relevant. In this work, we indicated a neural network as a potential tool for truss optimization without using structural analyzers. Three neural network models are examined. Firstly, by multi classification neural network we can easily predict the optimum areas by using tanh, relu, sigmoid activation functions in training part. In the case of classification problem, binary cross entropy was used with Adam optimizer. For avoiding overfitting, dropout was applied to each hidden layer. We trained the datasets of three, five and nine classes which three classes dataset showed best accuracy. Secondly, neural network using regression provides a model which serves for predicting stresses. Then using two neural networks we created the dataset for training next neural network network.
which allows to predict the areas including minimum weight and satisfaction for stress constraints.

In future, deep learning approach in truss optimization can show better performance than structural optimization tools by its time consuming and accurate results by dependence on the problem.

**References**