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RECENT TRENDS IN XOR PROBLEM

Prof. Purushottam Das*, Prof. Shambhu Prasad Sah, Prof. Ankur Singh Bist
* Professor, Graphic Era Hill University, India
Professor, Graphic Era Hill University, India
Professor, KIET, Ghaziabad, India

ABSTRACT

Classification is an important issue in the field of computer science research. There are various methods for classification for complex problems. The level of accuracy depends on complexity of problem. Xor classification is an open problem and there are many approaches to solve it. In this paper we will discuss some recent techniques proposed in this direction.

KEYWORDS: XOR problem.

INTRODUCTION

The XOR Problem: Using Multi-Layer Perceptrons

The advent of multilayer neural networks sprang from the need to implement the XOR logic gate. Early perceptron researchers ran into a problem with XOR. The same problem as with electronic XOR circuits: multiple components were needed to achieve the XOR logic. With electronics, 2 NOT gates, 2 AND gates and an OR gate are usually used. With neural networks, it seemed multiple perceptrons were needed (well, in a manner of speaking). To be more precise, abstract perceptron activities needed to be linked together in specific sequences and altered to function as a single unit. Thus were born multi-layer networks.

Why go to all the trouble to make the XOR network? Well, two reasons: (1) a lot of problems in circuit design were solved with the advent of the XOR gate, and (2) the XOR network opened the door to far more interesting neural network and machine learning designs [1].

2. Solving the XOR problem and the detection of symmetry using a single complex-valued neuron

The XOR problem and the detection of symmetry problem, which cannot be solved with a single real-valued neuron (i.e. a two-layered real-valued neural network), can be solved with a single complex-valued neuron (i.e. a two-layered complex-valued neural network) with the orthogonal decision boundaries, which reveals the potent computational power of complex-valued neurons [2].

3. Weights optimization of Neural Network via improved BCO Approach

Feed forward neural Network (FNN) has been widely applied to many fields because of its ability to closely approximate unknown function to any degree of desired accuracy. Back Propagation (BP) is the most general learning algorithms, but is subject to local optimal convergence and poor performance even on simple problems when forecasting out of samples. Thus, authors have an improved Bacterial Chemotaxis Optimization (BCO) approach as a possible alternative to the problematic BP algorithm, along with a novel adaptive search strategy to improve the efficiency of the traditional BCO. Taking the classical XOR problem and *sinc* function approximation comparisons were implemented [3].

4. Kernel matrix completion by semi-definite programming

Authors consider the problem of missing data in kernel-based learning algorithms. Authors explain how semi-definite programming can be used to perform an approximate weighted completion of the kernel matrix that ensures positive semi-definiteness and hence Mercer's condition. In numerical experiments authors apply a support vector machine to the XOR classification task based on randomly sparsified kernel matrices from a polynomial kernel of degree 2. The approximate completion algorithm leads to better generalisation and to fewer support vectors as compared to a simple spectral truncation method at the cost of considerably longer runtime. Authors argue that semi-definite programming provides an interesting convex optimisation framework for

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machine learning in general and for kernel-machines in particular [4].

5. Solving the XOR and parity *N* problems using a single universal binary neuron

A universal binary neuron (UBN) operates with complex-valued weights and a complex-valued activation function, which is the function of the argument of the weighted sum. The activation function of the UBN separates a whole complex plane onto equal sectors, where the activation function is equal to either 1 or −1 depending on the sector parity (even or odd, respectively). Thus, the UBN output is determined by the argument of the weighted sum. This makes it possible the implementation of the nonlinearly separable (non-threshold) Boolean functions on a single neuron. Hence, the functionality of UBN is incompatibly higher than the functionality of the traditional perceptron. Authors arrived on new modified learning algorithm for the UBN, which shows that classical nonlinearly separable problems XOR and Parity *n* can be easily solved using a single UBN, without any network [5].

6. Analysis and study of perceptron to solve XOR problem

This approach explains the network structures and methods of single-layer perceptron and multi-layer perceptron. It also analyses the linear division and un-division problems in logical operation performed by single-layer perceptron. XOR is linear un-division operation, which cannot be treated by single-layer perceptron. With the analysis, several solutions exist to solve the problems of XOR. Single-layer perceptron is improved by multi-layer perceptron, functional perceptron or quadratic function [6].

7. Network: Computation in Neural Systems

A complete solution of the excitation values which may occur at the local minima of the XOR problem is obtained analytically for two-layered networks in the two most commonly quoted configurations, using the gradient back-propagation algorithm. The role of direct connections which bypass the two-layered system is covered in connection to the XOR problem and other related training tasks [7].

8. Bernoulli error measure approach to train feed-forward artificial neural networks for classification problems

The training of artificial neural networks usually requires that users define an error measure in order to adapt the network weights to achieve certain performance criteria. This error measure is very important and sometimes essential for achieving satisfactory solutions. Different error measures have been used to train feed-forward artificial neural networks, with the mean-square error measure (and its modifications). This approach shows that the Bernoulli error measure is very suitable for training feed-forward artificial neural networks to learn classification problems. The authors compare the Bernoulli error measure with the popular mean-square error measure in terms of error surfaces, adaptation rates and stability regions. The AND and XOR classification problems are used to illustrate the differences between the Bernoulli error measure and the mean-square error measure [8].

9. Generalized XOR Classification Solution Using Neural Networks Ensemble Based on Chaos Searching

Neural network ensemble (NNE) is a most powerful method for design of neural network. This approach incorporates chaos searching technologies into neural network ensemble methods and proposes a chaos-based NNE (CNNE) method. This proposed method maintains the characteristics that may enhance the generalization performance of neural networks and decrease the effects of multidimensional co-linearity and noise of sample. Chaos theory is adopted in the process of initialization of weight values in order to effectively guarantee the diversity of weight values of networks. The computational results on the generalized XOR problem show that the proposed method is superior to original neural network ensemble [9].

10. Adaptive particle swarm optimization algorithm based on feedback mechanism

To overcome premature of multi-modal function search by standard particle swarm optimization (SPSO) algorithm, a new adaptive particle swarm optimization (APSO) based on feedback mechanism was proposed. Considering the large lost in population diversity during the evolution, two parameters of population-distribution-entropy and average-distance-amongst-points were introduced into the proposed algorithm to balance the trade-off between exploration and exploitation. A linear function relationship between inertia weight and average-distance-amongst-points was established through analyzing the dynamic relationship between inertia weight value and population diversity, and this functional relationship was embedded into APSO. The testing results indicate that APSO has better probability of finding global optimum, accuracy and speed of convergence than SPSO when APSO is applied to the solution of exclusive OR (XOR) classification problem, and that APSO is more efficient in training neural networks than in that of SPSO [10].

11. Classification using hierarchical mixtures of experts

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There has recently been widespread interest in the use of multiple models for classification and regression in the statistics and neural networks communities. The hierarchical mixture of experts (HME) has been successful in a number of regression problems, yielding significantly faster training through the use of the expectation maximisation algorithm. In this approach HME is extended to the classification and results are reported for three common classification benchmark tests: exclusive-OR, N-input parity and two spirals[11].

12. Low voltage low power neuron circuit design based on sub-threshold FGMOS transistors and XOR implementation

In this approach, design of low-voltage low-power analog artificial neural network (ANN) circuit blocks by using subthreshold floating-gate MOS (FGMOS) transistors and a neuron circuit is implemented. The circuit blocks, four-quadrant analog current multiplier and FGMOS based differential pair, have been designed and simulated in CADENCE environment with TSMC 0.35µm process parameters. Using the proposed neuron circuits a neural network was realized. XOR problem was applied to test accuracy of the network [12].

13. On the solution of the XOR problem using the decision tree-based neural network

The decision tree-based neural network is introduced to combine neural networks with decision trees. Its key idea is using decision trees to form the structure of the neural network: to construct a decision tree and then convert the tree into a neural network. The decision tree and neural network for classification are similar and have equivalent property. Thereby a decision tree can be used to provide a systematic design method of neural network. Authors propose a new mapping between decision tree and neural network that can accurately specify the number of units, layers, connection and initial setting of parameters of neural network. Furthermore, authors quote two theorems to show that the mapping is reasonable. In this paper, Authors use the decision tree-based neural network to solve the XOR problem [13].

CONCLUSION

This paper tries to explain the network structures and methods for XOR problem. XOR is linear un-division operation, which cannot be treated by single-layer perceptron. With the analysis, several solutions are proposed in the paper to solve the problems of XOR. Various solutions are discussed to understand the concerned problem.

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