



A Study on Quantum Inspired Hybrid Neural Networks Model

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Abstract— Quantum Neural Networks is one of the new concept which exploits the advantages of both traditional neural networks and concept of quantum computation. A simple hybrid three layer quantum neural networks model is studied, which is composed of both quantum and traditional neurons. The weight of the quantum neuron is quantum bits and its transforming function is an inner product operator. The input and output layers are composed of traditional neurons and hidden layer is composed of quantum neurons. This hybrid model takes the advantages of inbuilt parallelism, high efficiency of quantum computation and non linear computation of traditional neural networks.

Keywords— Quantum neural networks, Quantum neuron, Hybrid neural network, Quantum computing, Quantum bits

I. INTRODUCTION

Benioff and Feynman [1,2] first proposed the concept of quantum computation. Shore [3] developed the first quantum algorithm for very large integer factorization and then L.K. Grover [4] proposed a quantum algorithm which searches a marked state in an unordered list. As a result quantum computation drew the attention worldwide and became a challenging research field. The three most important soft computing tools of artificial intelligence, which are neural networks, Fuzzy logic and evolution calculation, have much comparability with quantum computation. Therefore, the combination of them would bring a remarkable change in the field of computation. Quantum computers have inherent parallelism and large memories. Utilising these potentials of quantum computation, quantum neural network [14] can be the next natural step in the evolution of neuro-computing system. At present some research is carried out using combination of quantum computation and evolution calculation, however, quantum neural computation needs more effort. Many researchers have proposed different prototypes for quantum neural networks similar to traditional neural networks. S.C. Kak [5] introduced quantum neural networks for the first time. Gupta and Gia [6] have revealed that both the quantum neural network and traditional neural network have almost the same computational power. Lewestein [7] proposed a quantum perceptron, where a unitary operator is used to map inputs to outputs instead of classical weights. S.C. Kak has suggested the use of quantum concepts in artificial neural networks for cognitive modelling, but these are only theoretical in nature and demand the need of quantum neural networks. Quantum learning was proposed by Chrisley [8], but he does not make any simulation of it. Menneer and Narayanan [9, 10] have extended Chrisley's model for single pattern quantum neural networks. Ezhov [11] argues that a quantum neural network based on single pattern networks is consistent with the parallel universe interpretation of quantum mechanics. Xiao and Cao [12] have proposed a quantum neural network model based on quantum and classical neurons. Mischczak [13] has shown ways for preparing initial quantum state based on probabilities. In this paper a study is done on the construct of a hybrid quantum neural model corresponding to traditional feed forward network model

II. HYBRID QUANTUM NEURAL NETWORKS MODEL

A. QUANTUM NEURON MODEL

An artificial neuron has four basic characteristics namely input, weight, transform function and output. Input and output are the outer attribute of the neuron where as weight and transform functions are the inner attributes. Hence different neuron models can be achieved by modifying the types of weight and the transform function. In this paper a study is done on the neuron model where the weight is represented by qubits and the transform function by inner product operator. This type of quantum neuron carries a group of one qubit gates that adjust the phase of weight qubits. The quantum neuron model is presented in Fig. 1.

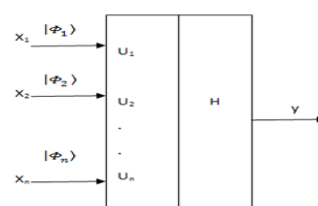


Figure 1 Quantum Neuron Model

In this model the weight is represented by qubit $|\Phi_i\rangle$, where a qubit is defined as follow:

$$|\Phi_i\rangle = \alpha_i |0\rangle + \beta_i |1\rangle, (i = 1, 2, \dots, n) \quad (1)$$

Here α_i and β_i are complex numbers and $|\alpha_i|^2$ and $|\beta_i|^2$ are the probabilities that the qubit will be found in the $|0\rangle$ and $|1\rangle$ respectively and satisfy the normalization condition as follow:

$$|\alpha_i|^2 + |\beta_i|^2 = 1, (i = 1 \dots n) \quad (2)$$

The numbers α_i and β_i that satisfy equation (2) are called the probability amplitudes of the qubit and thus the qubit can also be described by the probability amplitudes as $[\alpha_i, \beta_i]^T$.

Suppose $X = (x_1, x_2, \dots, x_n)^T$ is the input real vector, y is a output real number and $W = (w_1, w_2, \dots, w_n)^T$ is the weight matrix where w_i is probability amplitudes vector of qubit, $|\Phi_i\rangle (i = 1 \dots n)$.

Here x_i is real number w_i is m-dimensional real vector i.e. $w_i = (w_{i1}, w_{i2}, \dots, w_{im})^T$.

The product of X and W is defined as follow:

$$XW = \sum_{i=1}^n x_i w_i \quad (3)$$

Where $x_i w_i$ are the product of a scalar and vector quantity.

The input and output relation of the quantum neuron can be described as follow:

$$y = H(XW) = C \cdot (XW) = C \cdot \sum_{i=1}^n x_i |\Phi_i\rangle \quad (4)$$

Here H is an inner product operator and defined as $H(X) = C \cdot X$ and $C = (1, 1)^T$.

This operator which is a transform function transforms the input of quantum neuron to a real number. U_i is a quantum rotation gate to adjust the phase of the $|\Phi_i\rangle$.

B. Hybrid Quantum Neural Networks Model

The quantum neural network structure is the same as the traditional artificial neural network which consists of input layer, output layer and hidden layers. Quantum neural network is described as the model in which all the input, output and linked weights for each layer are qubits. Hence, hybrid quantum neural networks can be defined as the combination of both quantum neurons and traditional neurons. Since quantum neural transform function is a linear operator, the nonlinear mapping is restricted in case of pure quantum neural networks. Therefore, hybrid quantum neural networks can exploit both the powerful computing of quantum neural networks and nonlinear mapping capability of the traditional neural network. Hybrid quantum neural networks model is presented in Fig. 2. This hybrid model consists of three layers where the input layer and output layer contains n and m traditional neurons respectively and the hidden layer contains p number of quantum neurons. The input and output relation of the hybrid model can be described as follow:

$$y_i = g \left(\sum_{j=1}^p v_{ij} \left(C \cdot \sum_{k=1}^n (x_k |\Phi_{jk}\rangle) \right) \right) \quad (5)$$

Where $i = 1, 2, \dots, m$; $j = 1, 2, \dots, p$; $k = 1, 2, \dots, n$ and v_{ij} is the linked weight between the ith neuron in output layer and the jth neuron in hidden layer, g is Sigmoid function or Gauss function.

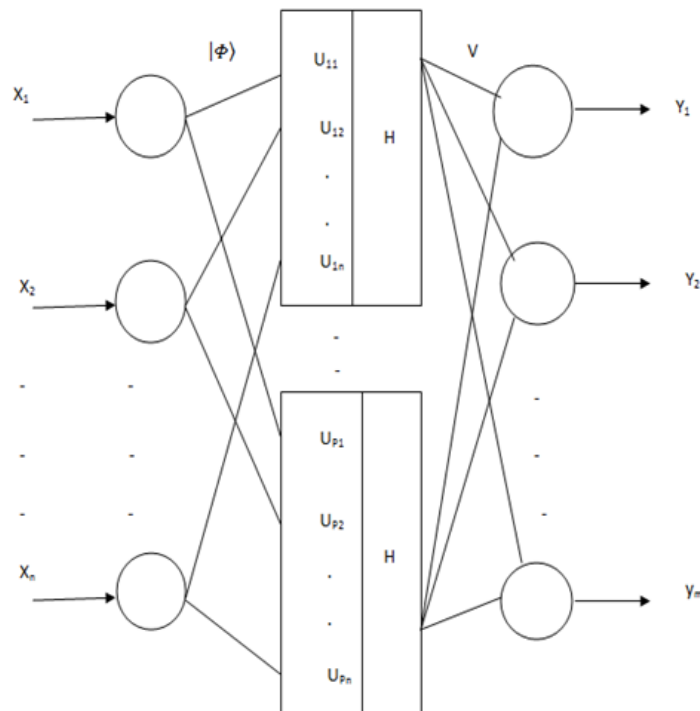


Figure 2 Hybrid Quantum Neural Network Model

III. CONCLUSION

In this paper, a study is done on a simple hybrid quantum neural network of three layer architecture. This hybrid nature of neural network can exploit the advantages such as parallelism and high computing power of quantum computing and non linear computation of traditional neural networks. In this model the weights are replaced by qubits and transform function by inner product operator.

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