Reinforcement Learning Neural Networks for Optical Communications

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A. Project Introduction

The objective of this work is to utilize neural networks to find new methods for optimizing high performance fiber-optic communication links. In typical broadband analog optical communication links, the dominant distortion comes from the transmitter. The electrical-to-optical transfer characteristics of both electro-optic external modulators and semiconductor lasers are nonlinear and create both odd and even-order harmonic distortions of the modulating signal. One cost-effective method to cancel device non-linearities in direct modulated lasers is by electronic predistortion. For our previous work, based on the simulated annealing learning algorithm utilized for neural network learning, a novel algorithm was developed to obtain the initial parameters of predistortion and laser circuits, and it has been used to linearize the Distributed FeedBack (DFB) semiconductor laser transmitters.

Because predistortion is not self-aligned for optimal performance, this type of transmitter would have to be re-adjusted in the field at various times. This re-adjustment is necessary in order to maintain optimal performance with variances in device performance due to drifting, aging, or possible changes in non-linearities when the bias point of the laser changes as derived from optical power feedback from a laser back facet monitor. The alternative to periodic hand-retuning the transmitter circuit is to use active techniques to monitor the transmitter performance and compensate the linearization from the measured performance.

An adaptive control system that is based on artificial neural networks is being developed to solve this problem and to fulfill the following goals:

- Obtain the initial predistorter parameter settings faster than the current approach; and
- Dynamically adjust the predistorter and the laser parameter settings to compensate for the changes within the system including those induced by the environment.

A major challenge for the design of the proposed adaptive control system is that the selected neural network architecture and the method of adjusting of the connection weights (i.e., learning rules) of the final-designed neural network must be capable of employing both of the following two learning algorithms:

- A learning algorithm to obtain the initial predistorter parameter setting such as simulated annealing or some deterministic learning algorithms.
- A novel reinforcement learning algorithm to achieve for on-line dynamic control.

B. Overall Progress

B.1 Stochastic Learning Approach

Different neural network architectures are being studied to use fast simulated annealing scheduling methods. Currently, the possible network architectures are the Boltzmann machine and the Mean-Field-Theory Machine.

The Boltzmann machine uses hidden and visible (i.e., inputs and outputs) neurons that are in the form of stochastic, binary-state units. It cleverly links the simulated annealing algorithm with a neural network. The Boltzmann machine offers several appealing features:

- Through training, the probability distribution of the network is matched to that of the environment;
- The network offers a generalized approach that is applicable to the basic issues of search, representation, and learning; and
- The network is guaranteed to find the global minimum of the energy function, provided that the annealing schedule in the learning process is performed slowly enough.

However, the original proposed annealing schedule is much too slow for all applications. In practice, a faster annealing schedule is used to produce reasonably good solutions, though not necessarily optimal. Research is being conducted for the best probability distribution as well as annealing scheduling that can be used on the neural network with an architecture similar or identical to the

Boltzmann machine.

The mean-field-theory machine is derived from the Boltzmann machine by analogy. Specifically, the stochastic binary-state neurons of the Boltzmann machine are replaced by deterministic analog ones. The end results is a new neural network that offers the following practical advantages:

- Being deterministic, the mean-field-theory machine is one to two orders of magnitude faster than the corresponding Boltzmann machine.
- It can be a strong candidate for implementation in analog VLSI form.

The major limitations of the mean-field-theory machine is that it is restricted to the simple gradient search; advanced optimization techniques such as the conjugate gradient method are of no value. Furthermore, the use of the mean-field-theory learning is restricted to neural networks with a single hidden layer.

B.2 Deterministic Learning Approach

For the supervised learning (deterministic learning) neural network, learning and testing data sets must be provided for the network to learn. These data sets contain the information about the relationships among the parameters of data link performance (e.g., laser, predistorter, etc.). Either empirical data or theoretical data are required to generate these learning and testing data sets. Feasibility studies for both of these two approaches have begun.

C. Current Problems

None.

D. Ongoing Work

Computer simulations are required to test the designed neural network architecture and learning rules. The following are the two essential test items:

- In relation to the available hardware input signals, what is the feasibility of the designed neural network architecture?
- How rapidly do the connection weights converge to the point corresponding to the global minimum?

According to the current research results, the most feasible network candidates for the computer simulations are:

- A network with an architecture similar or identical to the Boltzmann machine with faster annealing scheduling, such as the scheduling used in fast simulated annealing algorithm.
- A network similar to the mean-field-theory machine.

E. Fiscal Status

1.	Amount currently provided on contract:	$611,872.00
2.	Expenditures and Commitments to date:	$ 688.00
3.	Funds required to complete work:	$611,184.00