Chapter 3.14

High Speed Optical Higher Order Neural Networks for Discovering Data Trends and Patterns in Very Large Databases

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ABSTRACT

This chapter describes the progress in using optical technology to construct high-speed artificial higher order neural network systems. The chapter reviews how optical technology can speed up searches within large databases in order to identify relationships and dependencies between individual data records, such as financial or business time-series, as well as trends and relationships within them. Two distinct approaches in which optics may be used are reviewed. In the first approach, the chapter reviews current research replacing copper connections in a conventional data storage system, such as a several terabyte RAID array of magnetic hard discs, by optical waveguides to achieve very high data rates with low crosstalk interference. In the second approach, the chapter reviews how high speed optical correlators with feedback can be used to realize artificial higher order neural networks using Fourier Transform free space optics and holographic database storage.

INTRODUCTION

The problem of searching very large financial or business databases consisting of many variables and the way they have previously changed over time in order to discover relationships between them is difficult and time consuming. One example of this type of problem would be to analyze, the movements of specific equity share values based on how they depend on other variables and, hence, to predict their future behavior. Trends and patterns need to be found within the time-series of the variable. In addition, the relationships and dependencies between the changes in the time-series of the chosen variable and other time-series need to be found bearing in mind that there may be time lags between them. For example, the value of a specific equity share may depend on the time history of other shares, the oil price, the exchange rates, the bank base interest rates, economic variables such as the UK retail prices index (RPI), UK consumer prices index (CPI), the mortgage rates. It may also depend on the weather behavior, the occurrence of natural and manmade disasters and tax and import duty changes. When the time history of all of these variables and many more for all countries is stored it results in a very large database which is slow to search and analyze.

Several terabyte RAID arrays of magnetic hard discs mounted in racks are in demand for storage and backup of crucial financial, business and medical data and to archive all internet web pages and internet traffic. Very impressive simulations of 8 million neurons with 6,300 synapses in the 1 TB main memory on an IBM Blue Gene L supercomputer having 4,096 processors each having 256 MB have recently been reported (Frye, 2007). However, the demand is for similar fast performance at somewhat lower cost and in a more compact system for office use. The speed at which very large databases can be searched is also becoming limited by the speed at which the copper interconnections on the printed circuit boards inside the racks can operate. As speeds approach 10 Gb/s (10,000,000,000 bits per second) the copper tracks act as aerials and broadcast microwaves to each other causing so much cross-talk interference that the systems cannot operate. The radiated signal also causes power loss so the signal cannot travel very far (Grözing, 2006). In addition, the square shaped pulses transmitted degrade due to dispersion and limited bandwidth of the copper tracks so that the emerging pulse is spread in time interfering with adjacent bits causing intersymbol interference (ISI). The solution here is to use optical technology as optical beams can travel next to one another without significant crosstalk interference and suffer much less loss and signal degradation. This solution is discussed in the first part of the chapter in which the copper tracks are replaced by optical waveguides, rather like optical fibers, but more amenable to mass manufacturing as part of the printed circuit board fabrication process.

Artificial Higher Order Neural Networks are particularly good at discovering trends, patterns, and relationships between values of a variable at one time and values of the same variable at another time. This is because they multiply elements of the input data, time-series, vector together to identify correlations and dependencies between the different elements. This may be carried out directly before entering the data into a neural network or may be performed by appropriate hidden layer neurons in the network. In either case, the main problem of Artificial Higher Order Neural Networks is that the number of possible element combinations increases much faster than the number of elements in the input vector. The calculation speed and storage capacity of computers limits the number of combinations and, hence, the number of elements in the input vectors that can be considered and so many of the possible inter-relationships cannot be found nor used. In another chapter by the same author in this book, it is shown how the number of combinations can be dramatically reduced by summing selections of them by forming a new input vector of the inner and outer product correlations and this even gives better performance than using the higher order multiples of the variables themselves. The act of calculating the inner and outer product correlations also discovers the relationships and dependencies between the time-series data set for one variable and that for another including the effect of time lags. Such inner and outer product