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D. Marchette

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Neural networks have undergone a resurgence of late, due to the work of Hopfield, Grossberg and others. They have the potential for applications in a wide range of areas, including signal processing, image processing, planning, control, and data fusion. In this paper we will address the applications being explored at NOSC. ~~We will also describe our~~ experiences with two neural network products currently being marketed: the Hecht-Nielsen Anza Neurocomputer and the SAIC Sigma-1 Neurocomputer.

The projects will be grouped by the NOSC branch. In each case a point of contact will be given, though of course there may be others working on each project. From the wide range of problems being addressed, it is clear that the Navy has a strong interest in neural networks, and believes that they are well suited to a wide range of applications. The authors are in Code 421, and as such have complete knowledge of the neural network research ongoing in Code 421. The descriptions of the work being done elsewhere at NOSC are based on varying degrees of interaction. For many, first hand knowledge of the research is present. The authors are in fact working directly with many groups outside their own code. For others, the interaction is not as thorough. In any case, the interested reader should contact the specific group indicated for a more in depth discussion of the work described herein.

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EXPERIENCE WITH NEURAL NETWORKS AT NAVAL OCEAN SYSTEMS CENTER

by

David Marchette
and
Carey Priebe
Architecture and Applied Research Branch
Code 421
Naval Ocean Systems Center
San Diego, Ca 92152

INTRODUCTION

Neural networks have undergone a resurgence of late, due to the work of Hopfield, Grossberg and others. They have the potential for applications in a wide range of areas, including signal processing, image processing, planning, control, and data fusion. In this paper we will address the applications being explored at NOSC. We will also describe our experiences with two neural network products currently being marketed: the Hecht-Nielsen Anza Neurocomputer and the SAIC Sigma-1 Neurocomputer.

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Command and Control Department

Information Systems Division

Code 421: Architecture and Applied Research Branch

Data fusion is of great interest to the Navy, although the description of data fusion is quite nefarious. There are two aspects of data fusion being explored via neural networks in code 421: Hull-to-emitter correlation (hulltec) and situation assessment.

Hulltec involves determining the origin of a signal from parameters measured from the signal. Neural networks have been developed which compare favorably with traditional methods of hulltec. A backpropagation network was used initially, but a new architecture has been developed which allows the network to learn the statistical distribution of the signals.

The problem of situation assessment is quite different. Here the system is given reports from several sources and must determine the events of interest that are taking place in the area. An unclassified version of this is being explored in which a sentry robot incorporating several types of sensors on a mobile platform is required to determine when an intruder has entered its area. This involves the fusion of data from several different types of sensors as well as different sensors within each type. Both these problems require the system to be able to store and recall patterns and sequences and to do recognition based not on static data but on time varying data. A network with this capability has been developed.

The above network is being tested on a speech recognition task: isolated word recognition. The system must recognize the word being spoken from the waveform. The eventual goal is to expand this research to speaker independent word recognition and continuous speech recognition.

A network to do translation invariant pattern recognition is also being developed. The goal is a system that can recognize a hand printed character in any position within the field of view, and to recognize multiple characters within the field of view. Two approaches are being explored: a simulation of Fukushima's Neocognitron is being developed, and a similar system using gaussian feature detectors is also being explored. An adaptation of this system will be employed in the robot described above to allow attention focussing.

<u>Advanced C^2 Technologies Division</u>
<u>Code 441: Human Factors and Speech Technology Branch</u>

Steve Luse and his coworkers have two neural network projects in the area of speech processing. The first involves determining the optimum configuration of a backprop network as a preprocessor for speech. The network parameters that are being investigated are number and size of hidden layers. The second project involves using Hecht-Nielsen's spatiotemporal network to recognize isolated spoken digits. This project, like their other network project, is involved with determining the utility of the given architecture for the problem, rather than constructing an architecture to solve the problem. As could be expected, the network's performance on test digits ranged from mediocre to very good.

Code 444: Artificial Intelligence Technology Branch

A project similar to our character recognition problem is being undertaken by Chris Haupt. Here, the problem is to categorize images from Inverse Synthetic Aperture Radar. Chris is looking at several approaches, ranging from traditional correlation techniques to a variation of code 421's temporal processing system. In addition to the image problem, he is working on an implementation of Hopfield's temporal sequence recognizer, and this will be used to compare and contrast with code 421's temporal system.

Marine Sciences and Technology Department

Solid State Electronics Division
Code 551: Design and Development Branch

In an attempt to address both the problem of slow simulations and the need for delivery systems, Pat Shoemaker and his coworkers are designing and fabricating a neural network chip which will implement the weight changes in silicon. The architecture chosen for implementation is the backpropagation model. The weights will be stored in variable resistors and the system will allow modification of these weights using the generalized delta backpropagation rule. After learning, the weights can be "frozen" to allow the chip to be fielded in an application where learning is not appropriate after the initial training. When the environment in which the chip is operating changes, the chip can be retrained to handle the new information.

ASW Department

ASW Technology Division
Code 633: Research Branch

Chaos is a hot topic in physics, and Adi Bulsara and his colleagues have taken their expertise in this field and are working on applying it to neural nets. The project intends to look at the mathematical models of biological neurons and study the conditions under which chaos will occure in the system. Future work will include the study of small networks of these neurons. Different models of the neuron will be explored and simulated, and an analytical description of the onset of chaos will be attempted.

ASW Systems Engineering Division
Code 652: Fleet Support Branch

Steve Speidel has worked on a neural network architecture to do adaptive beamforming. He is currently proposing a project to use a network to interpret sequences of multipath sound reflections in terms of reflector position.

ASW Analysis and Simulation Division
Code 663: Modeling and Analysis Branch

Bob Bologna and his colleagues have investigated the utility of both the backpropagation and the adaptive resonance paradigms for acoustic signal processing. They currently have no funded project using neural nets, but are active in teaching the technology to new employees under the New Professional program.

Surveillance Department

Signal and Information Processing Division
Code 731: Information Processing and Display Branch

Curt Goodhart and his coworkers have been studying the backpropagation network. They have been applying it to the problem of identifying transients in an acoustical signal.

Engineering and Computer Sciences Department

Ocean Engineering Division
Code 943: Undersea AI and Robotics Branch

This branch is working with an underwater teleoperated vehicle testbed, which allows researchers to add functionallity such as sensors, processors and software to increase its autonomy. Neural networks are being applied to the vision system. Using a model of the early visual system, Mike Blackburn and his associates are building a visual processor for motion detection. The rational for this is that in the ocean, things that move tend to be interesting, and so a system that can detect and identify moving objects is of value for a free swimming or tethered vehicle.

Neurocomputers

One of the drawbacks of neural network research is the processing requirements of the simulations. Often, networks must be applied to "toy" problems because the time required in simulation is too great to deal with the scaled up problem. This can be a serious drawback, as it is often nontrivial to scale a solution up from a "toy" problem. One of the ways that industry is addressing this problem is to produce add-on boards for existing systems, so called "neurocomputers", which give the new system greater processing power. We have had experience with two systems which provide a coprocessor board and network software packages. Both systems will also offer languages to better access their hardware, but these languages are not yet available.

Our experience with "netware" packages is that they are of limited use to a researcher. The limitations imposed by the packages we have used are such that they are quickly abandoned for more flexible C programs. In our experience, no one network architecture is suitable for most problems. In fact, one often has to piece together ideas from several different architectures, or invent a whole new paradigm for each problem. The so called "netware" packages we are familiar with do not do this.

The Hecht-Nielsen ANZA Neurocomputer comes with a netware package of several popular networks. The networks are packaged as a C library of functions, and some demo programs. The functions allow the programmer to create nets, initialize weights, tune a few parameters of the paradigm to fit the problem, and run the network. Since these functions are called from a C program, any preprocessing can be done within the C program. However, this preprocessing must be done on the host machine, in our case a PC-AT clone without a math coprocessor (the system provided by HNC). The demo programs have graphic displays, but these graphics functions are not a part of the netware package and must be purchased separately.

The networks within the ANZA package are too limited to be of much use, in our opinion. For example, the backpropagation network is limited to a single hidden layer, while it can be shown that some problems require two hidden layers. Also, the activation function for the backprop net is constrained to be linear or sigmoid, though there are reasons to choose other activation functions for some problems.

The SAIC Sigma-1 Neurocomputer comes with a netware package (ANSim) of twice the number of networks as the ANZA. The packages run within Microsoft Windows, and the user is able to tune the parameters of the networks using mouse and keyboard. Over all, the networks in this package are more flexible than the HNC system, but they are more cumbersome to use if pre- or post-processing is desired. The ANSim system also comes with graphic displays that allow the user to view weights, errors, etc on the screen. This is useful, but since the source is unavailable, the user must use the predefined graphics, which is not always what is needed.

Overall, we find systems of this type to be of limited use. The ANSim software would be best for a first time user, particularly someone with little or no programming experience. The HNC netware is a step in the right direction for researchers, but the networks are too limited to be of much use.

The only projects at NOSC that could use these software systems are the ones that chose to investigate a particular network paradigm. Here the purpose is more to become familiar with the technology and its limitations than to solve a particular problem. From our experience, any real world problem requires a hybrid system, rather than a particular network paradigm.

On the hardware side, not much can be said at this time. The ANZA is a 68020 coprocessor board which cannot be accessed except through the netware package. Again, a full featured language has been promised, but a simple C compiler would in our opinion be a minimum requirement to make the hardware accessable to the researcher. A C compiler is available from the company that makes the ANZA board, but it did not arrive in time to be included in this review. The SAIC board has had some delays and we have been told that it will be ready for release in the next few weeks. The board will come with a C compiler and has (according to SAIC) a 20 Mflop processor. The SAIC system comes packaged in a Wyse 80386 machine, and without the board it performs at close to the speed of the ANZA board. The ANZA can also be purchased with a 386 system.

Conclusions

Neural networks are being applied to a wide range of problems here at NOSC. They have been found to be a flexible and useful tool for many types of signal processing. It is our experience that most of the architectures available can do a fair job on most problems, but that a network architecture can often be designed to fit the problem, and that these networks can do as well or better than traditional methods. The technology is young and very promising. The inherent parallelism and fault tolerance make it a very attractive tool for many applications.

Often, the biggest problem with a neural network solution to the problem is the processing time required of simulations. Industry is starting to produce some impressive coprocessor boards that may help with the simulation processing load. In our experience, the important factor in these products is the speed and memory capacity of the hardware, and the languages available for the board, since the field is too young for the software packages to be of much use. NOSC and others are producing chips which will take advantage of the parallelism of the system and allow real time processing.