PROCEEDINGS
OF THE

FIRST WORKSHOP ON
NEURAL NETWORKS:
ACADEMIC/INDUSTRIAL/NASA/DEFENSE

WNN-AIND 90

February 5-6, 1990
Auburn University Hotel and Conference Center, Auburn, Alabama

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Center for Commercial Development of Space Power and Advanced Electronics
Auburn University, AL 36849-5320

With the requested cooperation of:

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INNS International Neural Network Society

IEEE Auburn branch

The Society for Computer Simulation

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PREFACE

Neural Networks: Academic/Industrial/NASA/Defense

During the past two decades, the profile of applications oriented systems modeling has evolved tremendously. Tasks and capabilities have expanded to utilize computers and to realize techniques originally confined to the paper and pencil speculative realm. Insights into why these expansions were needed and directions for future efforts may be gleaned from a review of the literature and conversations with experienced researchers. Examples of future directions with potential commercial applications are found in this proceedings.

First, the Neural Network Possibilities and Challenges section covers some background material and potential. Next, some applications examples are presented in the section on Pattern Recognition - Trends and Predictions. Engine diagnosis is covered in the Health Monitoring - Space Shuttle Main Engine (SSME) section. The Power Systems section covers fundamentals and goals. Next, Manufacturing and Robotics sections look further into commercial applications. Composite Systems and Environments sections cover the integration of neural networks into a research environment and blending them with supportive techniques. The Implementations section papers cover the physical environment and computer implementation aspects of obtaining a working neural network system. Finally, the Perspectives section contains panel discussion material and more food for thought.

Next year's workshop plans are underway. Extensions of work presented here and comments on it are welcome for WNN-AIND 91!

MARY LOU PADGETT
WNN-AIND 90 Program Chairman

First Workshop on

NEURAL NETWORKS: ACADEMIC/INDUSTRIAL/NASA/DEFENSE WNN-AIND 90

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Robotics support was provided by Dr. John Hung and Dr. Steve Hung. Power systems support came from Dr. Gerald Sheble, Electrical Engineering, Auburn University. Manufacturing support was provided by Dr. J. T. Black and Dr. B. C. Jiang, Advanced Manufacturing Technical Center, Auburn University and Aerospace Engineering was represented by Dr. J. E. Cochran.

Hard work by many individuals has enhanced the quality of this proceedings. Names of attendees are included to further encourage technical interchange among WNN participants, all of whom have ideas and solutions contributing to the value of the workshops - this year and next!

TABLE OF CONTENTS

PREFACE iii

PROGRAM COMMITTEE iv

NEURAL NETWORK POSSIBILITIES AND CHALLENGES

Overview of Advanced Architectures Research and Development Activities in the Software Technology Branch 3
Robert Savely, Robert Lea, Robert Shelton, James Villarreal, and Lui Wang
Lyndon B. Johnson Space Center

The Quest for Synthetic Intelligence 15
John M. Murphy
Westinghouse Science & Technology Center

Neural Networks for Classification and Regression 45
Robert J. Marks II
Interactive Systems Design Laboratory

Some Theoretical Upperbounds on the Capacity of Neural Networks 51
E. Fiesler, H. J. Caulfield, and A. Choudry
University of Alabama in Huntsville

Fault Tolerance in Neural Networks 59
Heng-Ming Tai
University of Tulsa

The Logical Limitations of Neurocomputing 67
J. Michael Spector
Air Force Human Resources Laboratory/IDC

PATTERN RECOGNITION - TRENDS AND PREDICTATIONS

Detection of Unresolved Air Targets with Neural Nets 81
Joe R. Brown, Sue Archer, and Mark R. Bower
Martin Marietta Electronic Systems

Neural Net Applications of Signal Processing, Pattern Recognition, and Real-Time Intelligent Processing 87
Lt. Steven Anderson
Air Force Systems Command Weapons Laboratory

Time Series Forecasting using Neural Networks vs. Box-Jenkins Methodology 95
Zaiyong Tang, Chrys de Almeida, and Paul A. Fishwick
University of Florida

Effect of using Peak Amplitudes of ERP Signals for a Class of Neural Network Classification 101
S. DasGupta, M. Hohenberger, and M. Mazzara
Temple University
L. Trejo
NPRDC

A Barrels Organization for Data Fusion and Communication in Neural Network Systems 115
Kevin D. Reilly and Mark F. Villa
University of Alabama, Birmingham

HEALTH MONITORING - SPACE SHUTTLE MAIN ENGINE (SSME)

The Application of an Unsupervised Parameter Estimation Technique to Determine Space Shuttle Main Engine (SSME) Operational Status 125
D. Charern, J. Pooley, and W. Teoh
SPARTA, Inc.
J. Jones and J. McBride
NASA Marshall Space Flight Center

Employment of Neural Network Methodology and Spectral Error Estimation to Space Shuttle Main Engine (SSME) Health Monitoring (HM) 133
Mark Tillman, John Pooley, and William Teoh
SPARTA, Inc.
M. Whitley, G. Lyles, and F. D. Bachtel
NASA Marshall Space Flight Center

Integration of Partial Correlation Analysis with Neural Network Methology to Effect a Diagnostic Procedure for the Space Shuttle Main Engine (SSME) 141
Jeff Roberts, John Pooley, W. Teoh
SPARTA, Inc.
M. Whitley, G. Lyles, and F. D. Bachtel
NASA Marshall Space Flight Center

POWER SYSTEMS

Tutorial on Associative Computing with Artificial Neural Networks in Electric Power Systems Engineering 151
Dejan J. Sobajic and Yoh-Han Pao
Case Western Reserve University and AIWARE, Inc.

Power System Fault Classification Using Neural Networks 229
C. C. Alexion and N. L. Ovick
Westinghouse Electric Corporation

MANUFACTURING

The Neural Network Approach to Optimization Problems: A Review 241
Chi-Ming Chang, Lousiana Tech University
Heng-Ming Tai, University of Tulsa
Tai-Lang Jong, Texas Tech University

Electronic Component Recognition in Automated PCB Assembly Using Neural Networks 247
Cihan H. Dagli and Mahesh Vellanki
University of Missouri-Rolla

Neural Network Diagnosis of Multi-Fault Conditions in Electronic Circuit Boards 261
Brenda J. Kagle and John H. Murphy
Westinghouse Science and Technology Center

ROBOTICS

Autonomous Fuzzy Grasping Force Controller with Neutral Networks for Manipulator Hand 279
Yasuhiko Dote and James C. Hung
University of Tennessee

Application of Neural Networks for Telerobotics as Applied to the Space Shuttle 285
C. R. Parten, Accurate Automation Corporation, The University of Tennessee, Center for Neural Engineering Applications, The University of Tennessee at Chattanooga
R. M. Pap, Accurate Automation Corporation, The University of Tennessee, Center for Neural Engineering Applications
C. T. Harston, Accurate Automation Corporation, The University of Tennessee, Center for Neural Engineering Applications
A. J. Maren, Accurate Automation Corporation, The University of Tennessee, Center for Neural Engineering Applications, The University of Tennessee Space Institute
M. L. Rich, Accurate Automation Corporation
C. Thomas, Accurate Automation Corporation, Covenant College

A Neural Network Simulator to Control a Lunar Lander 303
Neill Kipp and Paul H. Smith III
Florida State University

COMPOSITE SYSTEMS

The Transmission of Knowledge Between Neural Networks and Expert Systems 311
David C. Kuncicky
Florida State University

Hybrid Intelligent Perception System: Intelligent Perception through Combining Artificial Neural Networks and an Expert System 321
C. W. Glover and Philip F. Spelt
Center for Engineering Systems Advanced Research

Heuristic Link Networks 333
Kingsley Kerce and Frank Mueller
Florida State University

ENVIRONMENTS

A General Purpose Simulation Environment for Multiplexed, Multilayered Neural Networks 341
N. Kaul, L. W. Massengill, and S. L. Shelby
Vanderbilt University

Simulated Neural Network Development 345
Troy Henson, Wendy Huxhold, and Dan Bowman
IBM Corporation

A Feed-Forward, Back-Propagation, User Friendly, Neural Network Simulator for the IBM PC and Compatibles. An Excellent Neural Network Research Tool. 347
Michael E. Manausa
Florida State University

IMPLEMENTATIONS

A Practical, Non-VLSI Neural Network 351
David E. VandenBout and Thomas K. Miller III
North Carolina State University

The DAP as a Neuron Simulator 361
Joseph Yadegar and Rex Thanakij
Active Memory Technology, Inc.

The Use of an Advanced Hybrid Computation System for Rapid Prototyping of Neural Network Paradigms 383
Leslie D. Canney and Erich Nold
Martin Marietta Corporation

Limitations of a Real-Time Analog, Parallel Implementation of the Outstar Pattern Learning Neural Network 391
Erich Nold, Leslie Canney, and Micheal Georgiopoulos
Martin Marietta Corporation and the University of Central Florida

Simulation of Neural Networks in Ada: Signal Processing and Process Control Applications 403
Alex Abraham, Prashant Gharpure, M. J. Niccolai, and Jeff Loeb
University of South Alabama

Design a Parallel Processing System for Backpropagation Training 411
Chwan-Hwa Wu, R. M. Thomas, W. S. Neely, M. L. Padgett, and T. A. Roppel
Auburn University

PERSPECTIVES

Perspectives on Neural Networks 435
Raymond F. Askew
Auburn University

Advanced Sensors/Neural Networks 437
T. A. Roppel
Auburn University

Perspectives on Neural Network Patent Law 439
David Bendel Hertz
University of Miami

A Tri-Service Neural Network Overview and a Naval Surface Warfare Center Perspective 443
Lois J. Reid and E. June Glass
Naval Surface Warfare Center

Application of Neural Network and its Future 459
S. DasGupta
Temple University

A Progress Report for a Working Group on Neural Networks in Robotic Systems 467
John Y. Hung
Auburn University

Report from the Working Group on Hybrid Systems 471
Susan Hruska
Florida State University

Neural Networks -- Why Listen and Learn? 475
Robert Pap, Accurate Automation Corporation
Ralph Kissel and Dave Meeks, NASA Marshall Space Flight Center
Steve Anderson, Kennedy Air Force Base
Troy Henson, IBM
David Bendel Hertz, University of Miami
Mary Lou Padgett, Auburn University

LIST OF ATTENDEES 481

AUTHOR INDEX 511

NEURAL NETWORK POSSIBILITIES

AND CHALLENGES

Overview
of
Advanced Architectures Research and Development Activities
in the
Software Technology Branch

Robert Savely, Branch Chief, Robert Lea, Robert Shelton, James Villarreal, and Lui Wang

Software Technology Branch/PT4
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Introduction

The purpose of this Research and Development activity is to evaluate and develop state-of-the-art software architectures or techniques which might be used to solve NASA's engineering problems. Development of these technologies may be in the form of building and providing tools to facilitate the general use of the technology, construct demonstrations which illustrate the potential uses of the technology, or enhancing of an existing technology to better suit the needs of NASA's advanced programs. Activity in this area includes investigations into such technologies as artificial neural systems, fuzzy logic, parallel processing, genetic algorithms, man-machine interfaces, and approaches to machine vision.

Artificial Neural Systems (ANS)

The STB has maintained several research initiatives in the field of artificial neural systems. Our preliminary efforts began with the publication of a Neural Network Survey in 1987. Two major software products for simulation and a number of applications have evolved since its inception.

Neural Network Simulation Tools

The Transputer-based Work Station

Due to the extreme computational demands which arise in training of ANS, a neural network work station was designed and built to be hosted by a network of Transputers. This work station software is currently in the process of being released to Cosmic Computing. The work station was designed to allow for the simulation of a wide range of neural network architectures. There is a sophisticated graphics interface to allow the user to visualize the progress of the network toward convergence. The network of 40 Transputers yields the performance of a super-computer at a fraction of the cost.

NETS

NETS (Network Execution and Training System) is a portable C-based simulation of the popular back-propagation neural network which can run on most computers. NETS is intended as a tool for anyone interested in exploring the use of neural networks. It is easy to use, but sufficiently rich in features that it has been used extensively in support of our in-house research. NETS is also available through Cosmic. NETS is currently in use at 288 government sites.

New Tools for ANS Research

Space-Time Neural Networks(STNN)

A spin-off of a project to monitor space shuttle main engine performance with neural networks resulted in the development of an innovative neural network architecture especially useful at sequence discovery and nonlinear filtering. This neural network borrows concepts from associative memory and filtering techniques. In its present form, the STNN dynamics adapt and learn sequences of finite lengths. Currently, efforts are underway to extend the STNN to sequences of arbitrary lengths. It is anticipated that this network will result in the issuance of a patent .

Faster Training Algorithms

A major barrier to the use of artificial neural systems is the potentially large amount of processing power required to accomplish the training process. Therefore much research is directed toward the improvement of training methods. This research has resulted in some break-through results which are now described.

The Difference Optimized Training Scheme for the Neocognitron Neural Network (DOTS)

The neocognitron is an artificial neural model which was intended to simulate some of the functions of the optic nerve and visual cortex. As originally conceived, the network would "learn" to recognize objects by repeated exposure, a process which often required hundreds of passes to achieve satisfactory results. The DOTS algorithm partitions the training images into a large number of possible templates, and intelligently selects a a small collection of templates which describe the training data. From these templates, the synaptic connection strengths may be easily constructed. The time requirements for DOTS are much less than those for the iterative algorithm.

Accelerated Training Method for the Back-Propagation Neural Network

The back-propagation network has become an extremely popular tool for modeling complex functions and pattern recognition. For large networks, the standard training algorithm may be extremely time-consuming if for no other reason, because the network may have thousands of weights to be determined. The accelerated training algorithm exploits the fact that the input weights for the network (often the vast majority) can be represented as a linear combination of the input vectors. This representation of the input weights can result in a big reduction in the number of optimization variables which must be considered, and thus in a significant savings of time. The degree of effectiveness of the algorithm is strongly dependent on the particular problem under consideration.

Pre-Processing Tool

Often the data which would be natural to present to a neural network is highly redundant. In such a case, an orthogonal basis is extracted from the vectors which comprise the input space. Vectors having the greatest information content are extracted first, and it is possible to determine when there is no benefit in extracting more vectors. The input vectors are projected along the orthogonal basis vectors and the projection coefficients are given to the network instead of the original input. For the problem which suggested the development of this tool, it was able to replace a network with over 15,000 weights with a network having 19 weights. The savings in training and execution times is apparent.

Applications

Our anticipated applications for neural networks will be as pattern classifiers, content addressable memories and general non-linear adaptive models. The use of neural networks as part of computer vision systems for inspection, retrieval and rescue is contemplated. Prototype networks have been built, trained and tested on several hard problems including finding concentration from reading IR spectrograms, prediction of solar activity, speech synthesis from text, and computer vision applications.

A joint STB and Life Sciences Directorate project is currently underway to investigate the uses of neural network technology to discover specific sites in the central nervous system which are key for the maintenance of posture. The network will be used to analyze posture platform data collected from patients with lesions in the central nervous system and post and pre flight data from astronauts. it is hoped that neural networks will be able to formulate the appropriate correlations in the data. The STB recently acquired a commercial neural network simulator from SAIC to support this project.

A part of the Advanced Software Development Workstation (ASDW)* project team is currently investigating the use of simple artificial neural networks for indexing and retrieving extremely large numbers of information objects, especially reusable software parts. An object's name and attributes, i.e., its characteristics, are stored in an associative memory, which is a content-addressable memory that functions as a simple two-layer neural network. Specifically, the associative memory is very similar to a Kohonen self-organizing feature map. Currently, the associations between all of the names and attributes are loaded directly into the associative memory, and the resulting topology of associations is identical to that of a trained neural network. However, work is underway to develop a weight-adjusting algorithm for the associations that will give more weight to those attributes and names that are retrieved most frequently by each user. In this way, the associative memory (neural network) can be trained to be more responsive to each individual user. Results thus far are very encouraging and indicate that the use of an associative memory for information indexing and retrieval is very efficient and fast.

[*The ASDW is researching and developing the technologies required to support CASE (Computer Aided Software Engineering) with the emphasis on those advanced methods, tools, and processes that will be of benefit to support all of NASA and DOD. Immediate goals are to provide research and prototype tools that will provide near term productivity increases in projects such as the SSE (Software Support Environment), the SSCC (Space Station Control Center), and FADS (Flight Analysis and Design System) which is used to support the STS. Goals also include providing technology for future SSE and operational systems by adding knowledge based system support to all phases of information systems development, evolution, maintenance, and operation.]

Funding

Other than two Director's Discretionary Funding projects, funding for neural network technology has been difficult to acquire. However, STB has been successful with the use of the SBIR program to fund two neural network related projects:

1) Netrologic (San Diego, CA) is investigating the use of neural network technology for the monitoring of the space shuttle main engine (SSME) for failures. This is a full-scale example of a data fusion problem in that data from many different kinds of sensors must be reduced to obtain an estimate of the system's health. During launch, several SSME sensor readings are monitored by Booster Officers in the MCC. Applying data fusion to this system would, in a sense, "fuse" all sensor readings into a smaller, manageable number and allow the utilization of all the sensor readings in place of the 5 currently monitored. Classification into nominal and faulty engine behaviors would be determined from actual SSME test and launch data.

2) Martingale Research Corporation (Allen, TX) is developing a new neural network architecture called the Parametric Avalanche which is designed to implement a solution to the general stochastic filtering problem for non-linear systems in arbitrary noise. This neural network should see applications in the: 1) Tracking and control of nonlinear dynamical systems, such as spacecraft docking maneuvers, 2) Multi-sensor integration for monitoring of complex power systems, 3) and the control of large articulated space structures.

Measuring Effectiveness and Reliability

Our method for evaluating the performance of a neural network model is inherited from traditional validation procedures used for other modeling techniques (i.e. least squares, polynomial fitting, trigonometric series expansions). Where sufficient data exists, it is split into a training set and a test set. The training set is used to adapt the coefficients in the network.