

# Lecture Notes in Computer Science

540

Edited by G. Goos and J. Hartmanis

Advisory Board: W. Brauer D. Gries J. Stoer



A. Prieto (Ed.)

# Artificial Neural Networks

International Workshop IWANN '91

Granada, Spain, September 17–19, 1991

Proceedings

**Springer-Verlag**

Berlin Heidelberg New York

London Paris Tokyo

Hong Kong Barcelona

Budapest

## Series Editors

Gerhard Goos  
GMD Forschungsstelle  
Universität Karlsruhe  
Vincenz-Priessnitz-Straße 1  
W-7500 Karlsruhe, FRG

Juris Hartmanis  
Department of Computer Science  
Cornell University  
Upson Hall  
Ithaca, NY 14853, USA

## Volume Editor

Alberto Prieto  
Departamento de Electrónica y Tecnología de Computadores  
Facultad de Ciencias, Universidad de Granada, 18071 Granada, Spain

CR Subject Classification (1991): B.3.2, B.7.1, C.1.3, C.3, C.5, F.1.1-2, F.2.2, H.3.m, I.2.6-10, I.4-5, J.2, J.7

ISBN 3-540-54537-9 Springer-Verlag Berlin Heidelberg New York  
ISBN 0-387-54537-9 Springer-Verlag New York Berlin Heidelberg

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in other ways, and storage in data banks. Duplication of this publication or parts thereof is only permitted under the provisions of the German Copyright Law of September 9, 1965, in its current version, and a copyright fee must always be paid. Violations fall under the prosecution act of the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1991  
Printed in Germany

Typesetting: Camera ready by author  
Printing and binding: Druckhaus Beltz, Hemsbach/Bergstr.  
2145/3140-543210 - Printed on acid-free paper

# Contents

## 1. Neural Network Theories, Neural Models

Cooperative Computing and Neural Networks P.A. Ligomenides . . . . .	1
Neural Net's Theory - The Specifications of a Computational Model of Memory and Information Processing in Decision-Making J. Mira, R. Moreno-Diaz, J. Simões da Fonseca . . . . .	11
Chaotic Neural Networks and Associative Memory T. Ikeguchi, M. Adachi, K. Aihara . . . . .	17
Nonequilibrium Model of Neural Networks P.L. Garrido, J. Marro . . . . .	25
A Modified Algorithm for Self-Organizing Maps Based on the Schrödinger Equation V. Tryba, K. Goser . . . . .	33
Neural Network Modelling by Means of Networks of Finite Automata C. Kemke . . . . .	48
Adaptive Optimization of Neural Algorithms C. Jutten, A. Guerin, H.L. Nguyen Thi . . . . .	54
Neural Networks with Hysteresis Type of Nonlinearity Exhibit Global Optimization Property J. Levendovszky, W. Mommaerts, E.C. van der Meulen . . . . .	62
Stability Measurement Criterion for Neural Networks of Competitive Learning A. Sacristán, E. Valderrama, C. Pérez-Vicente . . . . .	69
On the Power of Networks of Majority Functions E. Mayoraz . . . . .	78
Using Quadratic Perceptrons to Reduce Interconnection Density in Multilayer Neural Networks D. Röckmann, C. Moraga . . . . .	86

## 2. Biological Perspectives

Always Trying to Write an Equation for the Brain J. Mira, A.E. Delgado . . . . .	93
Transformation of Control Signals for Saccadic Eye Movements B. Breznen . . . . .	101

# Preface

**Artificial Neural Networks (ANNs)** are massively parallel interconnected networks of simple (usually adaptive) elements which are intended to interact with the objects of the real world in the same way as biological nervous systems do.<sup>1</sup>

The interest in these networks is due to the general opinion that they are able to perform some complicated and creative tasks, such as image and speech recognition, similarly to the way they are performed by human brains. The implementations of these tasks by traditional computing methods have only reached relatively low performances in some limited aspects or environments. Nevertheless, as neural systems show some properties, like association, generalization, parallel searching, and adaptation to changes in the environment, which are analogous to human brain properties, they promise improved results.

One of the most relevant properties of ANNs is the possibility of learning. By learning, a neural network can discover some regular patterns and the relations across them, and organize itself for making those associations. This feature has two very important consequences: the ability to solve problems with algorithms which are very difficult to specify (hard-to-write algorithms), and the capacity to extract statistical models and knowledge-based rules from large data sets. ANNs therefore constitute a clear complement to conventional computers for implementing some non-algorithmic tasks and for interfacing with the statistical nature of the environment. Thus, the emulation of biological functions of behaviour (sensory and motor functions) should be emphasized, without forgetting the implementation of the kind of internal processing loosely called thinking.

Another property that ANNs are expected to improve is processing speed, mainly supported by the massively parallel functioning of all the elements in the network. Although in this context the concept of "instruction" used in computer science has no sense, a neural network could be considered as a MIMD (Multiple Instruction stream–Multiple Data stream) system, because multiple processing elements simultaneously operate with the data which, in parallel, feed the network inputs. The goal is to emulate (in a very simple way) the behaviour of the brain, as P. Treleaven<sup>2</sup> has pointed out:

To stress the complexity of emulating the brain, it could be considered as a massively parallel computer with as many as 10–100 billion processing elements (neurons), and each neuron is connected with up to 10 000 others. Like the artificial neurons, the biological neurons make very simple computations. The brain is able to solve difficult vision or speech problems in approximately half a second. This is a very surprising thing as the time for a neuron, without considering the transitions across neurons, is in the rank of milliseconds. These circumstances imply that such complicated tasks as speech and vision can be carried out in only 100 processing steps, while a conventional computer would need billions of them.

Moreover, in many cases the study of ANNs has led to theories improving our knowledge of biological nervous system functioning.

---

<sup>1</sup> Kohonen, T.: An introduction to neural computing. *Neural Networks* 1, 3–16 (1988)

<sup>2</sup> Treleaven, P.: Neurocomputers. *Int. J. Neurocomputing* 1, 1–31 (1989)

The different levels under which the approach to ANNs may be made are the following:<sup>3,4</sup>

- 1) **Basic neuron level.** The goals at this level are to determine the basic operation of the nervous system from the behaviour of single neurons and their interconnections, and to obtain models of their operation.
- 2) **Network level.** This level considers homogeneous sets of neurons or interconnected processing elements, in which the collective properties that realize useful tasks with the input vectors are researched.
- 3) **Neuronal system level.** This level operates over the network subsets considered at the network level in order to implement relatively complex functions or to point out some abstract topics in sensory perception, such as automatic classification, motor control, concept creation, etc.
- 4) **Brain operation level.** This level deals with the description of operations, procedures, algorithms and policies usually called "human information processing". These models are intended to describe the basic actions related with cognition, thinking, problem-solving, etc.

Thus, it may be shown that the ANN field is multidisciplinary, involving such disciplines as neurobiology, psychology, physics, mathematics, electronics, and computer science and engineering. As an example of this situation, it should be remembered that two of the best known neural network models (Hopfield networks and Boltzmann machines) have emerged from physics.

Despite the large number of actual (commercial) neural network applications, there are some gaps in our knowledge, and it is necessary to improve the study of some topics related with them, such as:

- 1) The knowledge of biological nervous systems and the elaboration of new models or the improvement of existing ones.
- 2) Many networks and learning methods have been developed in an empirical way. It is necessary to strengthen the theoretical study of such networks in order to determine the optimal number of layers and processing elements in each layer, to improve convergence and learning speed, to develop procedures for building the learning pattern sequences, etc.
- 3) Implementations, either the ones made with software simulators or the ones made using (general-purpose or special-purpose) neurocomputers, need to be improved. The importance should be pointed out of making efficient and modular neuro-chips, in order to reach systems closer to the biological models with real-time parallel processing comparable to natural networks.
- 4) Development of new applications and improvement of the present ones.

There is no doubt that the research collected in this book represents a clear contribution to the development of these goals.

This book includes invited lectures and the full contributions to the **International Workshop on Artificial Neural Networks (IWANN '91)**, held in Granada, Spain, September 17–19, 1991. This workshop has been sponsored by the Spanish Chapter of the IEEE Computer Society, the "Asociación Española de Informática y Automática (AEIA)" (Spanish Association for Computing and Automation) and the Department of Electronics and Computer Technology of the University of Granada, with no restrictions on the participants. I would like to thank the International Program Committee for its labour in the selection of the contributions here presented. The authors of these papers came from 12 countries.

<sup>3</sup> Greenwood, D.: An overview of neural networks. *Behavioral Science* 36:1, 1–33 (1991)

<sup>4</sup> Kohonen, T.: State of the art in neural computing. *Proc. Int. Conf. Neural Networks* 1, 79–90 (1987)

The book is organized into six sections, covering:

- Neural network theories, neural models
- Biological perspectives
- Neural network architectures and algorithms
- Software developments and tools
- Hardware implementations
- Applications

We consider that this book represents a clear contribution to the development of neural network topics, and it gives a good idea of the present trends and the research done in this field. It is a suitable text for engineers and scientists working on Artificial Neural Networks.

Grenoble, July 1991

Alberto Prieto

## **PROGRAM AND ORGANIZATION COMMITTEE**

**Organization Chairman:** Alberto Prieto (Unv. Granada. Spain)

**Programme Chairman:** José Mira (UNED. Madrid. Spain)

Senén Barro	Unv. de Santiago (E)
François Blayo	Ecole Polytechnique Fédérale de Lausanne (S)
Joan Cabestany	Unv. Pltca. de Cataluña (E)
Marie Cottrell	Unv. Paris I (F)
Jose Antonio Corrales	Unv. Oviedo. (E)
Gerard Dreyfus	ESPCI Paris (F)
Gregorio Fernández	Unv. Pltca. de Madrid (E)
J. Simoes da Fonseca	Unv. de Lisboa (P)
Karl Goser	Unv. Dortmund (G)
Jeanny Herault	INPG Grenoble (F)
José Luis Huertas	CNM- Universidad de Sevilla (E)
Simon Jones	Unv. Nottingham (UK)
Chistian Jutten	INPG Grenoble (F)
Antonio Lloris	Unv. Granada (E)
Panos A. Ligomenides	Unv. of Maryland (USA)
Javier López Aligué	Unv. de Extremadura. (E)
Federico Morán	Unv. Complutense. Madrid (E)
Roberto Moreno	Unv. Las Palmas Gran Canaria (E)
Franz Pichler	Johannes Kepler Univ. (Aus)
Peter A. Rounce	Unv. College of London (U.K.)
Ulrich Rueckert	Unv. Dortmund (G)
Francisco Sandoval	Unv. de Malaga (E)
Carmen Torras	Instituto de Cibernética. CSIC. Barcelona (E)
V. Tryba	Unv. Dortmund (G)
Elena Valderrama	CNM- Unv. Autónoma de Barcelona (E)
Michel Verleysen	Unv. Catholique de Louvain (B)
Michel Weinfeld	Ecole Polytechnique Paris (F)

## **LOCAL ORGANIZING COMMITTEE (Granada University)**

Juan Julián Merelo  
Julio Ortega  
Francisco J. Pelayo  
Begoña del Pino



<b>On the Semantics of Morphogenesis in Photoreceptors</b> K.N. Leibovic, R. Moreno-Díaz Jr. . . . .	109
<b>Implementing a "Psychophysical" Pattern Classifier in a Decrementing Network</b> J.M. Salinas, V.G. Dobson . . . . .	116
<b>Contributions of Neural Net's Theory to the Understanding of Psychopathological Productions in Schizophrenia</b> J. Simões da Fonseca, J. Maltez, I. Barahona da Fonseca . . . . .	124
 <b>3. Neural Network Architectures and Algorithms</b>	
<b>Backpropagation Growing Networks: Towards Local Minima Elimination</b> I. Bellido, G. Fernández . . . . .	130
<b>Methods for Encoding in Multilayer Feed-Forward Neural Networks</b> E. Elizalde, S. Gómez, A. Romeo . . . . .	136
<b>Learning Algorithm for Feed-Forward Neural Networks with Discrete Synapses</b> C.J. Pérez Vicente, J. Carrabina, F. Garrido, E. Valderrama . . . . .	144
<b>Synthesis of Adaptive Memories with Neural Networks</b> F.J. López Aligué, M.I. Acevedo Sotoca, M.A. Jaramillo Moran . . . . .	153
<b>Minimally Disturbance Learning</b> V. Ruiz de Angulo, C. Torras . . . . .	162
<b>Fuzzy-Neunet: A Non Standard Neural Network</b> P. Andlinger, E.R. Reichl . . . . .	173
<b>Decrementing Hamming and Bayesian Neural Networks: Analog Implementations and Relative Performance</b> V.G. Dobson, J.M. Salinas . . . . .	181
<b>Dynamic Thresholds and Attractor Neural Networks</b> C. Campbell . . . . .	189
<b>Use of Genetic Algorithms in Neural Networks Definition</b> F.J. Vico, F. Sandoval . . . . .	196
<b>Simulated Evolution of Modular Networks</b> J. Fernández Falcón . . . . .	204
<b>Computational Experiments with Boltzmann Machines</b> A. d' Anjou, M. Graña, M.C. Hernandez, F.J. Torrealdea . . . . .	212

An Adaptive Resonance Theory Architecture for the Automatic Recognition of on-line Handwritten Symbols of a Mathematical Editor Y.A. Dimitriadis, J. López Coronado, J.L. Contreras Vidal . . . . .	216
--	-----

#### 4. Software Developments and Tools

An Experimental Design Advisor and Neural Network Analysis Package A.J. Owens, M.T. Mocella . . . . .	227
Extending an Object Oriented Concurrent Logic Language for Neural Network Simulations J.M. Troya, J.F. Aldana . . . . .	235

#### 5. Hardware Implementations

Application and Implementation of Neural Networks in Microelectronics K. Goser, U. Hilleringmann, U. Rückert . . . . .	243
CMOS Implementation of a Cellular Neural Network with Dynamically Alterable Cloning Templates M. Anguita, A. Prieto, F.J. Pelayo, J. Ortega, A. Diaz . . . . .	260
Systolic Implementation of Hopfield Networks of Arbitrary Size S. Barro, A. Bugarín, A. Yáñez . . . . .	268
VLSI Fully Connected Neural Networks for the Implementation of other Topologies J. Carrabina, F. Lisa, N. Avellana, C.J. Pérez-Vicente, E. Valderrama . . . . .	277
Backpropagation Multilayer Perceptron: A Modular Implementation A. Yáñez, S. Barro, A. Bugarín . . . . .	285
Toroidal Neural Network Processor: Multiple Learning Algorithm Support S. Jones . . . . .	296
CMOS Implementation of Synapse Matrices with Programmable Analog Weights F.J. Pelayo, B. Pino, A. Prieto, J. Ortega, F.J. Fernandez . . . . .	307
Analog VLSI Synapse Matrix with Enhanced Stochastic Computations M. Verleysen, P. Jespers . . . . .	315
CMOS Continuous BAM with On Chip Learning B. Linares-Barranco, S. Sánchez-Sinencio, A. Rodríguez-Vázquez, J.L. Huertas . . . . .	322
An Integrated Circuit for Artificial Neural Networks F. Castillo, J. Cabestany, J.M. Moreno . . . . .	328

## 6. Applications

An Application of Neural Networks to Natural Scene Segmentation M. Vicens, J. Albert, V. Arnau . . . . .	333
An Approach to Isolated Word Recognition Using Multilayer Perceptrons A. Cañas, J. Ortega, F.J. Fernández, A. Prieto, F.J. Pelayo . . . . .	340
The Use of Multilayer Perceptrons in Isolated Word Recognition M.J. Castro, F. Casacuberta . . . . .	348
Continuous Speech Recognition with the Connectionist Viterbi Training Procedure: A Summary of Recent Work M. Franzini, A. Waibel, K.-F. Lee . . . . .	355
Recurrent Neural Networks for Speech Recognition J.E. Díaz Verdejo, A. Peinado Herreros, J.C. Segura Luna, M.C. Benítez Ortúzar, A. Rubio Ayuso . . . . .	361
A Speech Recognition System that Integrates Neural Nets and HMM E. Monte, J.B. Mariño . . . . .	370
Comparison of Neural Networks and Conventional Techniques for Automatic Recognition of a Multilingual Speech Database D. Maravall, J. Ríos, M. Pérez-Castellanos, A. Carpintero, J. Gómez-Calcerrada . . . . .	377
Optimization Problems on Concurrent Testing Solved by Neural Networks J. Ortega, A. Prieto, F.J. Pelayo, A. Lloris, P. Martin-Smith . . . . .	385
Application of High-Order Hopfield Neural Networks to the Solution of Diophantine Equations G. Joya, M.A. Atencia, F. Sandoval . . . . .	395
Self-Organizing Feature Maps and Their Application to Digital Coding of Information A. Cabrera Izquierdo, J. Cid Sueiro, J.A. Hernández Méndez . . . . .	401
Neural Networks as Error Correcting Systems in Digital Communications I. Ortuño, M. Ortuño, J.A. Delgado . . . . .	409
Application of Vector Quantization Algorithms to Protein Classification and Secondary Structure Computation J.J. Merelo, M.A. Andrade, C. Ureña, A. Prieto, F. Morán. . . . .	415
Application of the LVQ Neural Method to a Stellar Catalogue M. Hernandez-Pajares, E. Monte . . . . .	422
Neural Network Design for Mobile Robot Control Following a Contour F. Arroyo, A. Gonzalo, L.E. Moreno . . . . .	430

<b>A Supervisory Technique to Apply Neural Networks in Control</b>	
F. García-Padilla, F. Morant-Anglada . . . . .	437
<b>Autonomous Controller Tuning by Using a Neural Network</b>	
J. Fernández de Cañete, A. Ollero, M. Díaz-Fondón . . . . .	445
<b>Neural Networks for Water Demand Time Series Forecasting</b>	
R. Griño Cubero . . . . .	453
<b>Using Artificial Neural Networks to Aid Decision Making Processes</b>	
J.E. Cano, M. Delgado, I. Requena . . . . .	461
<b>Data Analysis: How to Compare Kohonen Neural Networks to Other Techniques</b>	
F. Blayo, P. Demartines . . . . .	469