Bit-Serial Neural Networks
Alan Murray, Anthony Smith, Zoe Butler
A bit - serial VLSI neural network is described from an initial archi tecture for a synapse array through to silicon layout and board design. The issues surrounding bit - serial computation, and analog/digital arithmetic are discussed and the parallel development of a hybrid analog/digital neural network is outlined. Learning and recall capabilities are repor ted for the bit - serial network along with a projected specification for a 64 - neuron, bit - serial board operating at 20 MHz. This tech(c id:173) nique is extended to a 256 (2562 synapses) network with an up date time of 3ms, using a "paging" technique to time - multiplex calcu lations through the synapse array.
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Connectivity Versus Entropy
Yaser Abu-Mostafa
How does the connectivity of a neural network (number of synapses per neuron) relate to the complexity of the problems it can handle (measure d by the entropy)? Switching theory would suggest no relation at all, since a ll Boolean functions can be implemented using a circuit with very low c onnectivity (e.g., using two-input NAND gates). However, for a network that learns a problem from examples using a local learning rule, we prove that the entropy of the problem becomes a lower bound for the c onnectivity of the network.
****
The Hopfield Model with Multi-Level Neurons
Michael Fleisher
The Hopfield neural network. model for associative memory is generalize d. The generalization
****
How Neural Nets Work
Alan Lapedes, Robert Farber
There is presently great interest in the abilities of neural networks to mimic "qualitative reasoning" by manipulating neural incodings of symbols. Less work

has been performed on using neural networks to process floating point numbers and it is sometimes stated that neural networks are somehow inherently inaccu(c id:173)
rate and therefore best suited for "fuzzy" qualitative reasoning. Nevert heless,
the potential speed of massively parallel operations make neural net "n umber
crunching" an interesting topic to explore. In this paper we discuss some of our
work in which we demonstrate that for certain applications neural networks can

achieve significantly higher numerical accuracy than more conventional t ech(cid:173)
niques. In particular, prediction of future values of a chaotic time se ries can
be performed with exceptionally high accuracy. We analyze how a neural net
is able to do this , and in the process show that a large class of fu nctions from
Rn. ~ Rffl may be accurately approximated by a backpropagation neural net
with just two "hidden" layers. The network uses this functional approximat ion
to perform either interpolation (signal processing applications) or extrapolati on
(symbol processing applicationsJ. Neural nets therefore use quite familiar meth

(cid:173)
ods to perform. their tasks. The geometrical viewpoint advocated here seems to be a useful approach to analyzing neural network operation and relates neural
networks to well studied topics in functional approximation.
****
Spatial Organization of Neural Networks: A Probabilistic Modeling Approach
Andreas Stafylopatis, Marios Dikaiakos, D. Kontoravdis
The aim of this paper is to explore the spatial organization of neural networks under Markovian assumptions, in what concerns the be(cid:173) haviour of individual cells and the interconnection mechanism. Space(cid:173) organizational properties of neural nets are very relevant in image modeling and pattern analysis, where spatial computations on stocha(cid:173) stic two-dimensional image fields are involved. As a first approach we develop a random neural network model, based upon simple probabi(cid:173) listic assumptions, whose organization is studied by means of dis(cid:173) crete-event simulation. We then investigate the possibility of ap(cid:173) proXimating the random network's behaviour by using an analytical ap(cid:173) proach originating from the theory of general product-form queueing networks. The neural network is described by an open network of no(cid:173) des, in which customers moving from node to node represent stimula(cid:173) tions and connections between nodes are expressed in terms of sui(cid:173) tably selected routing probabilities. We obtain the solution of the model under different disciplines affecting the time spent by a sti(cid:173) mulation at each node visited. Results concerning the distribution of excitation in the network as a function of network topology and external stimulation arrival pattern are compared with measures ob(cid:173) tained from the simulation and validate the approach followed.
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A Neural-Network Solution to the Concentrator Assignment Problem
Gene Tagliarini, Edward Page
Networks of simple analog processors having neuron-like properties have been employed to compute good solutions to a variety of optimization prob(cid:173) lems. This paper presents a neural-net solution to a resource allocation prob(cid:173) lem that arises in providing local access to the backbone of a wide-area com(cid:173) munication network. The problem is described in terms of an energy function that can be mapped onto an analog computational network. Simulation results characterizing the performance of the neural computation are also presented.
****
LEARNING BY STATE RECURRENCE DETECTION
Bruce Rosen, James Goodwin, Jacques Vidal
This research investigates a new technique for unsupervised learning of nonlinear control problems. The approach is applied both to Michie and Chambers BOXES algorithm and to Barto, Sutton and Anderson's extension, the ASE/ACE system, and has significantly improved the convergence rate of stochastically based learning automata.
****
Stability Results for Neural Networks
Anthony Michel, Jay Farrell, Wolfgang Porod
In the present paper we survey and utilize results from the qualitative theory of large scale interconnected dynamical systems in order to develop a qualitative theory for the Hopfield model of neural networks. In our approach we view such networks as an inter(cid:173) connection of many single neurons. Our results are phrased in terms of the qualitative properties of the individual neurons and in terms of the properties of the interconnecting structure of the neural networks. Aspects of neural networks which we address include asymptotic stability, exponential stability, and instability of an equilibrium; estimates of trajectory bounds; estimates of the domain of attraction of an asym

ptotically stable equilibrium; and stability of neural networks under structural perturbations.
****
Introduction to a System for Implementing Neural Net Connections on SIMD Architectures
Sherryl Tomboulian
Neural networks have attracted much interest recently, and using parallel
****
Optimization with Artificial Neural Network Systems: A Mapping Principle and a Comparison to Gradient Based Methods
Harrison Leong
General formulae for mapping optimization problems into systems of ordinary differential
****
Optimal Neural Spike Classification
James Bower, Amir Atiya
Being able to record the electrical activities of a number of neurons simultaneously is likely to be important in the study of the functional organization of networks of real neurons. Using one extracellular microelectrode to record from several neurons is one approach to studying the response properties of sets of adjacent and therefore likely related neurons. However, to do this, it is necessary to correctly classify the signals generated by these different neurons. This paper considers this problem of classifying the signals in such an extracellular recording, based upon their shapes, and specifically considers the classification of signals in the case when spikes overlap temporally.
****
REFLEXIVE ASSOCIATIVE MEMORIES
Hendricus G. Loos
In the synchronous discrete model, the average memory capacity of bidirectional associative memories (BAMs) is compared with that of Hopfield memories, by means of a calculat10n of the percentage of good recall for 100 random BAMs of dimension 64x64, for different numbers of stored vectors. The memory capac1ty Is found to be much smal1er than the Kosko upper bound, which Is the lesser of the two dimensions of the BAM. On the average, a 64x64 BAM has about 68 % of the capacity of the corresponding Hopfield memory with the same number of neurons. Ortho(cid:173) normal coding of the BAM Increases the effective storage capaCity by only 25 %. The memory capacity limitations are due to spurious stable states, which arise In BAMs In much the same way as in Hopfleld memories. Occurrence of spurious stable states can be avoided by replacing the thresholding in the backlayer of the BAM by another nonl1near process, here called "Dominant Label Selection" (DLS). The simplest DLS is the wlnner-take-all net, which gives a fault-sensitive memory. Fault tolerance can be improved by the use of an orthogonal or unitary transformation. An optical application of the latter is a Fourier transform, which is implemented simply by a lens.
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The Performance of Convex Set Projection Based Neural Networks
Robert Marks, Les Atlas, Seho Oh, James Ritcey
and
****
Speech Recognition Experiments with Perceptrons
David Burr
Artificial neural networks (ANNs) are capable of accurate recognition of simple speech vocabularies such as isolated digits [1]. This paper looks at two more difficult vocabularies, the alphabetic E-set and a set of polysyllabic words. The E-set is difficult because it contains weak discriminants and polysyllables are difficult because of timing variation. Polysyllabic word recognition is aided by a time pre-alignment technique based on dynamic pro(cid:173) gramming and E-set recognition is impr

oved by focusing attention. Recogni(cid:173) tion accuracies are better than 98% for both vocabularies when implemented with a single layer perc eptron.
****
On Properties of Networks of Neuron-Like Elements
Pierre Baldi, Santosh Venkatesh
The complexity and computational capacity of multi-layered, feedforward n eural networks is examined. Neural networks for special purpose (structured) f unctions are examined from the perspective of circuit complexity. Known r e(cid:173) sults in complexity theory are applied to the special instance of ne ural network circuits, and in particular, classes of functions that can be implemented in shallow circuits characterised. Some conclusions are als o drawn about learning complexity, and some open problems raised. The dual problem of determining the computational capacity of a class of multi-layered networks with dynamics regulated by an algebraic Hamiltonian is consid ered. Formal results are pre(cid:173) sented on the storage capacities of programmed higher-order structures, and a tradeoff between ease of prog ramming and capacity is shown. A precise de(cid:173) termination is made of the static fixed point structure of random higher-order constructs, and ph ase-transitions (0-1 laws) are shown.
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Ensemble' Boltzmann Units have Collective Computational Properties like those of Hopfield and Tank Neurons
Mark Derthick, Joe Tebelskis
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On Tropistic Processing and Its Applications
Manuel Fernández
The interaction of a set of tropisms is sufficient in many
****
Neuromorphic Networks Based on Sparse Optical Orthogonal Codes
Mario Vecchi, Jawad Salehi
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A 'Neural' Network that Learns to Play Backgammon
Gerald Tesauro, Terrence J. Sejnowski
We describe a class of connectionist networks that have learned to play back(cid :173)
****
Learning Representations by Recirculation
Geoffrey E. Hinton, James McClelland
We describe a new learning procedure for networks that contain groups of non(cid :173)
****
A Computer Simulation of Cerebral Neocortex: Computational Capabilities of Nonli near Neural Networks
Alexander Singer, John Donoghue
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PATTERN CLASS DEGENERACY IN AN UNRESTRICTED STORAGE DENSITY MEMORY
Christopher Scofield, Douglas L. Reilly, Charles Elbaum, Leon Cooper

in
****
Strategies for Teaching Layered Networks Classification Tasks
Ben Wittner, John Denker
There is a widespread misconception that the delta-rule is in some sense guara nteed to work on networks without hidden units. As previous authors have m entioned, there is no such guarantee for classification tasks. We will begi n by presenting explicit counter(cid:173) examples illustrating two different i nteresting ways in which the delta rule can fail. We go on to provide condit ions which do guarantee that gradient descent will successfully train ne tworks without hidden units to perform two-category classification tasks . We discuss the generalization of our ideas to networks with hidden units and to multi(cid:173) category classification tasks.
****
Invariant Object Recognition Using a Distributed Associative Memory
Harry Wechsler, George Zimmerman
This paper describes an approach to 2-dimensional object recognition. C omplex-log con(cid:173) formal mapping is combined with a distributed as sociative memory to create a system which recognizes objects regardless of changes in rotation or scale. Recalled information from the memor ized database is used to classify an object, reconstruct the memorized ver(cid:173) sion of the object, and estimate the magnitude of changes in scale or rotation. The system response is resistant to moderate amounts of noise and occlusion. Several experiments, us(cid:173) ing real, gray sca le images, are presented to show the feasibility of our approach.
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Cycles: A Simulation Tool for Studying Cyclic Neural Networks
Michael Gately
A computer program has been designed and implemented to allow a researcher
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Learning on a General Network
Amir Atiya
This paper generalizes the backpropagation method to a general network containi ng feed(cid:173)
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Neural Net and Traditional Classifiers
William Huang, Richard P. Lippmann
Abstract. Previous work on nets with continuous-valued inputs led to gene rative
procedures to construct convex decision regions with two-layer perceptrons (on e hidden
layer) and arbitrary decision regions with three-layer perceptrons (two hid den layers).
Here we demonstrate that two-layer perceptron classifiers trained with back prop agation
can form both convex and disjoint decision regions. Such classifiers a re robust, train
rapidly, and provide good performance with simple decision regions. Whe n complex
decision regions are required, however, convergence time can be excessi vely long and
performance is often no better than that of k-nearest neighbor classifiers. T hree neural
net classifiers are presented that provide more rapid training under s uch situations.
Two use fixed weights in the first one or two layers and are similar t o classifiers that
estimate probability density functions using histograms. A third "feature map c lassifier"
uses both unsupervised and supervised training. It provides good perform

ance with
little supervised training in situations such as speech recognition where much u nlabeled
training data is available. The architecture of this classifier can be used to implement
a neural net k-nearest neighbor classifier.
****
Scaling Properties of Coarse-Coded Symbol Memories
Ronald Rosenfeld, David Touretzky
Abstract: Coarse-coded symbol memories have appeared in several neural network symbol processing models. In order to determine how these models would scale, one
must first have some understanding of the mathematics of coarse-coded re presenta(cid:173)
tions. We define the general structure of coarse-coded symbol memories and derive
mathematical relationships among their essential parameters: memory 8ize, 8ym bol-8et
size and capacity. The computed capacity of one of the schemes agrees well with actual
measurements oC tbe coarse-coded working memory of DCPS, Touretzky and Hinton's

distributed connectionist production system.
****
Synchronization in Neural Nets
Jacques Vidal, John Haggerty
The paper presents an artificial neural network concept (the Synchroniz able Oscillator Networks) where the instants of individual firings in the f orm of point processes constitute the only form of information transmi tted between joining neurons. This type of communication contrasts with that which is assumed in most other models which typically are continuo us or discrete value-passing networks. Limiting the messages received by e ach processing unit to time markers that signal the firing of other units p resents significant implemen tation advantages.
****
A NEURAL NETWORK CLASSIFIER BASED ON CODING THEORY
Tzi-Dar Chiueh, Rodney Goodman
The new neural network classifier we propose transforms the classification prob lem into the coding theory problem of decoding a noisy codeword. An input vecto r in the feature space is transformed into an internal representation which is a codeword in the code space, and then error correction decoded in this space t o classify the input feature vector to its class. Two classes of codes which gi ve high performance are the Hadamard matrix code and the maximal length sequenc e code. We show that the number of classes stored in an N-neuron system is line ar in N and significantly more than that obtainable by using the Hopfield type memory as a classifier.
****
Microelectronic Implementations of Connectionist Neural Networks
Stuart Mackie, Hans Graf, Daniel Schwartz, John Denker
In this paper we discuss why special purpose chips are needed for us eful implementations of connectionist neural networks in such application s as pattern recognition and classification. Three chip designs are de scribed: a hybrid digital/analog programmable connection matrix, an analo g connection matrix with adjustable connection strengths, and a digital pipe lined best-match chip. The common feature of the designs is the distributio n of arithmetic processing power amongst the data storage to minimize data move ment.
****
Analysis of Distributed Representation of Constituent Structure in Connectionist Systems

Paul Smolensky
A general method, the tensor product representation, is described for the distributed representation of value/variable bindings. The method allows the fully distributed representation of symbolic structures: the roles in the structures, as well as the fillers for those roles, can be arbitrarily non-local. Fully and partially localized special cases reduce to existing cases of connectionist representations of structured data; the tensor product representation generalizes these and the few existing examples of fuUy distributed representations of structures. The representation saturates gracefully as larger structures are represented; it penn its recursive construction of complex representations from simpler ones; it respects the independence of the capacities to generate and maintain multiple bindings in parallel; it extends naturally to continuous structures and continuous representational patterns; it pennits values to also serve as variables; it enables analysis of the interference of symbolic structures stored in associative memories; and it leads to characterization of optimal distributed representations of roles and a recirculation algorithm for learning them.
****
Hierarchical Learning Control - An Approach with Neuron-Like Associative Memories
Enis Ersü, Henning Tolle
Advances
****
Presynaptic Neural Information Processing
L. Carley
The potential for presynaptic information processing within the arbor of a single axon will be discussed in this paper. Current knowledge about the activity dependence of the firing threshold, the conditions required for conduction failure, and the similarity of nodes along a single axon will be reviewed. An electronic circuit model for a site of low conduction safety in an axon will be presented. In response to single frequency stimulation the electronic circuit acts as a lowpass filter.
****
An Optimization Network for Matrix Inversion
Ju-Seog Jang, Soo-Young Lee, Sang-Yung Shin
Inverse matrix calculation can be considered as an optimization. We have demonstrated that this problem can be rapidly solved by highly interconnected simple neuron-like analog processors. A network for matrix inversion based on the concept of Hopfield's neural network was designed, and implemented with electronic hardware. With slight modifications, the network is readily applicable to solving a linear simultaneous equation efficiently. Notable features of this circuit are potential speed due to parallel processing, and robustness against variations of device parameters.
****
Basins of Attraction for Electronic Neural Networks
Charles Marcus, R. Westervelt
We have studied the basins of attraction for fixed point and oscillatory attractors in an electronic analog neural network. Basin measurement circuitry periodically opens the network feedback loop, loads raster-scanned initial conditions and examines the resulting attractor. Plotting the basins for fixed points (memories), we show that overloading an associative memory network leads to irregular basin shapes. The network also includes analog time delay circuitry, and we have shown that delay in symmetric networks can introduce basins for oscillatory attractors. Conditions leading to oscillation are related to the presence of frustration; reducing frustration by diluting the connections can stabilize a delay network.
****

Programmable Synaptic Chip for Electronic Neural Networks
Alexander Moopenn, H. Langenbacher, A. Thakoor, S. Khanna
A binary synaptic matrix chip has been developed for electronic neural networks. The matrix chip contains a programmable 32X32 array of "long channel" NMOSFET binary connection elements imple(cid:173) mented in a 3-um bulk CMOS process. Since the neurons are kept off(cid:173) chip, the synaptic chip serves as a "cascadable" building block for a multi-chip synaptic network as large as 512X512 in size. As an alternative the programmable NMOSFET (long channel) connection elements, tailored thin film resistors are deposited, in series with FET switches, on some CMOS test chips, to obtain the weak synaptic connections. Although deposition and patterning of the resistors require additional they promise substantial savings in silcon area. The performance of a synaptic chip in a 32- neuron breadboard system in an associative memory test application is discussed.
****
Learning a Color Algorithm from Examples
Tomaso A. Poggio, Anya Hurlbert
A lightness algorithm that separates surface reflectance from illumination in a Mondrian world is synthesized automatically from a set of examples, pairs of input (image irradiance) and desired output (surface reflectance). The algorithm, which re(cid:173) sembles a new lightness algorithm recently proposed by Land, is approximately equiva(cid:173) lent to filtering the image through a center-surround receptive field in individual chro(cid:173) matic channels. The synthesizing technique, optimal linear estimation, requires only one assumption, that the operator that transforms input into output is linear. This assumption is true for a certain class of early vision algorithms that may therefore be synthesized in a similar way from examples. Other methods of synthesizing algorithms from examples, or "learning", such as backpropagation, do not yield a significantly dif(cid:173) ferent or better lightness algorithm in the Mondrian world. The linear estimation and backpropagation techniques both produce simultaneous brightness contrast effects.
****
Generalization of Back propagation to Recurrent and Higher Order Neural Networks
Fernando Pineda
A general method for deriving backpropagation algorithms for networks
****
Neural Network Implementation Approaches for the Connection Machine
Nathan Brown
The SIMD parallelism of the Connection Machine (eM) allows the construction of neural network simulations by the use of simple data and control structures. Two approaches are described which allow parallel computation of a model's nonlinear functions, parallel modification of a model's weights, and parallel propagation of a model's activation and error. Each approach also allows a model's interconnect structure to be physically dynamic. A Hopfield model is implemented with each approach at six sizes over the same number of CM processors to provide a performance comparison.
****
On the Power of Neural Networks for Solving Hard Problems
Jehoshua Bruck, Joseph Goodman
This paper deals with a neural network model in which each neuron performs a threshold logic function. An important property of the model is that it always converges to a stable state when operating in a serial mode [2,5]. This property is the basis of the potential applications of the model such as associative memory devices and combinatorial optimization [3,6]. One of the motivations for use of the model for solving hard combinatorial problems is t

he fact that it can be implemented by optical devices and thus operate at a higher speed than conventional electronics. The main theme in this work is to investigate the power of the model for solving NP-hard problems [4,8], and to understand the relation between speed of operation and the size of a neural network. In particular, it will be shown that for any NP-hard problem the existence of a polynomial size network that solves it implies that NP=co-NP. Also, for Traveling Salesman Problem (TSP), even a polynomial size network that gets an €-approximate solution does not exist unless P=NP.

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HOW THE CATFISH TRACKS ITS PREY: AN INTERACTIVE "PIPELINED" PROCESSING SYSTEM MAY DIRECT FORAGING VIA RETICULOSPINAL NEURONS

Jagmeet S. Kanwal

of

****

Phasor Neural Networks

André Noest

A novel network type is introduced which uses unit-length 2-vectors

****

Computing Motion Using Resistive Networks

Christof Koch, Jin Luo, Carver Mead, James Hutchinson

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Experimental Demonstrations of Optical Neural Computers

Ken Hsu, David Brady, Demetri Psaltis

We describe two expriments in optical neural computing. In the first a closed optical feedback loop is used to implement auto-associative image recall. In the second a perceptron-Iike learning algorithm is implemented with photorefractive holography.

****

MURPHY: A Robot that Learns by Doing

Bartlett Mel

MURPHY consists of a camera looking at a robot arm, with a connectionist network architecture situated in between. By moving its arm through a small, representative sample of the 1 billion possible joint configurations, MURPHY learns the relationships, backwards and forwards, between the positions of its joints and the state of its visual field. MURPHY can use its internal model in the forward direction to "envision" sequences of actions for planning purposes, such as in grabbing a visually presented object, or in the reverse direction to "imitate", with its arm, autonomous activity in its visual field. Furthermore, by taking explicit advantage of continuity in the mappings between visual space and joint space, MURPHY is able to learn non-linear mappings with only a single layer of modifiable weights.

****

SPONTANEOUS AND INFORMATION-TRIGGERED SEGMENTS OF SERIES OF HUMAN BRAIN ELECTRIC FIELD MAPS

D. Lehmann, D. Brandeis, A. Horst, H. Ozaki, I. Pal

The brain works in a state-dependent manner: processin9

****

Simulations Suggest Information Processing Roles for the Diverse Currents in Hippocampal Neurons

Lyle Borg-Graham

A computer model of the hippocampal pyramidal cell (HPC) is described

****

An Artificial Neural Network for Spatio-Temporal Bipolar Patterns: Application to Phoneme Classification

Les Atlas, Toshiteru Homma, Robert Marks

An artificial neural network is developed to recognize spatio-temporal bipolar patterns associatively. The function of a formal neuron is generalized by replacing multiplication with convolution, weights with transfer functions, and thresholding with nonlinear transform following adaptation. The Hebbian learn(cid:173) ing rule and the delta learning rule are generalized accordingly, resulting in the learning of weights and delays. The neural network which was first developed for spatial patterns was thus generalized for spatio-temporal patterns. It was tested using a set of bipolar input patterns derived from speech signals, showing robust classification of 30 model phonemes.
****

Teaching Artificial Neural Systems to Drive: Manual Training Techniques for Autonomous Systems
J. F. Shepanski, S. A. Macy
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****

Correlational Strength and Computational Algebra of Synaptic Connections Between Neurons
Eberhard Fetz
Intracellular recordings in spinal cord motoneurons and cerebral cortex neurons have provided new evidence on the correlational strength of monosynaptic connections, and the relation between the shapes of postsynaptic potentials and the associated increased firing probability. In these cells, excitatory postsynaptic potentials (EPSPs) produce cross(cid:173) correlogram peaks which resemble in large part the derivative of the EPSP. Additional synaptic noise broadens the peak, but the peak area -- i.e., the number of above-chance firings triggered per EPSP -- remains proportional to the EPSP amplitude. A typical EPSP of 100 ~v triggers about .01 firings per EPSP. The consequences of these data for information processing by polysynaptic connections is discussed. The effects of sequential polysynaptic links can be calculated by convolving the effects of the underlying monosynaptic connections. The net effect of parallel pathways is the sum of the individual contributions.
****

Discovering Structure from Motion in Monkey, Man and Machine
Ralph Siegel
The ability to obtain three-dimensional structure from visual motion is
****

Static and Dynamic Error Propagation Networks with Application to Speech Coding
A. Robinson, F. Fallside
Error propagation nets have been shown to be able to learn a variety of tasks in which a static input pattern is mapped outo a static output pattern. This paper presents a generalisation of these nets to deal with time varying, or dynamic patterns, and three possible architectures are explored. As an example, dynamic nets are applied to tbe problem of speech coding, in which a time sequence of speech data are coded by one net and decoded by another. The use of dynamic nets gives a better signal to noise ratio than that achieved using static nets.
****

Schema for Motor Control Utilizing a Network Model of the Cerebellum
James Houk
This paper outlines a schema for movement control
****

Distributed Neural Information Processing in the Vestibulo-Ocular System
Clifford Lau, Vicente Honrubia
A new distributed neural information-processing
****

Time-Sequential Self-Organization of Hierarchical Neural Networks

Ronald Silverman, Andrew Noetzel
Self-organization of multi-layered networks can be realized time-sequential organization of successive neural layers. by Lateral inhibition operating in the surround of firing cells in each for unsupervised capture of excitation patterns presented by the previous layer. By presenting patterns of organization, higher implicit in the pattern set.
****
A Method for the Design of Stable Lateral Inhibition Networks that is Robust in the Presence of Circuit Parasitics
John Wyatt, D. Standley
In the analog VLSI implementation of neural systems, it is
****
Constrained Differential Optimization
John Platt, Alan Barr
Many optimization models of neural networks need constraints to restrict the space of outputs to a subspace which satisfies external criteria. Optimizations using energy methods yield "forces" which act upon the state of the neural network. The penalty method, in which quadratic energy constraints are added to an existing optimization energy, has become popular recently, but is not guaranteed to satisfy the constraint conditions when there are other forces on the neural model or when there are multiple constraints. In this paper, we present the basic differential multiplier method (BDMM), which satisfies constraints exactly; we create forces which gradually apply the constraints over time, using "neurons" that estimate Lagrange multipliers.
****
Encoding Geometric Invariances in Higher-Order Neural Networks
C. Giles, R. Griffin, T. Maxwell
We describe a method of constructing higher-order neural
****
A Novel Net that Learns Sequential Decision Process
Guo-Zheng Sun, Yee-Chun Lee, Hsing-Hen Chen
We propose a new scheme to construct neural networks to classify pat(cid:173)
****
Mathematical Analysis of Learning Behavior of Neuronal Models
John Cheung, Massoud Omidvar
In this paper, we wish to analyze the convergence behavior of a number of neuronal plasticity models. Recent neurophysiological research suggests that the neuronal behavior is adaptive. In particular, memory stored within a neuron is associated with the synaptic weights which are varied or adjusted to achieve learning. A number of adaptive neuronal models have been proposed in the literature. Three specific models will be analyzed in this paper, specifically the Hebb model, the Sutton-Barto model, and the most recent trace model. In this paper we will examine the conditions for convergence, the position of conver(cid:173) gence and the rate at convergence, of these models as they applied to classical conditioning. Simulation results are also presented to verify the analysis.
****
New Hardware for Massive Neural Networks
Darryl Coon, A. Perera
Transient phenomena associated with forward biased silicon p + - n - n + struc(cid:173) tures at 4.2K show remarkable similarities with biological neurons. The devices play a role similar to the two-terminal switching elements in Hodgkin-Huxley equivalent circuit diagrams. The devices provide simpler and more realistic neuron emulation than transistors or op-amps. They have such low power and current requirements that they could be used in massive neural networks. Some observed properties of simple circuits containing the devices include action potentials, refractory periods, threshold behavior, excitation, inhibition, summation over synaptic inputs, synaptic weights, temporal integration, memory, network connectivity modification

based on experience, pacemaker activity, firing thresholds, coupling to senso rs with graded sig(cid:173) nal outputs and the dependence of firing rate on input current. Transfer functions for simple artificial neurons with spik etrain inputs and spiketrain outputs have been measured and correlated with in put coupling.
****
An Adaptive and Heterodyne Filtering Procedure for the Imaging of Moving Objects
F. Schuling, H. Mastebroek, W. Zaagman
Recent experimental work on the stimulus velocity dependent time resolving powe r of the neural units, situated in the highest order optic ganglion of the blow fly, revealed the at first sight amazing phenomenon that at this high level of the fly visual system, the time constants of these units which are involved in t he processing of neural activity evoked by moving objects, are -roughly spoken(cid:173) inverse proportional to the velocity of those objects over an extremely wide range. In this paper we will discuss the implementation of a two dimensio nal heterodyne adaptive filter construction into a computer simulation model. T he features of this simulation model include the ability to account for the exp erimentally observed stimulus-tuned adaptive temporal behaviour of time constan ts in the fly visual system. The simulation results obtained, clearly show that the application of such an adaptive processing procedure delivers an improved imaging technique of moving patterns in the high velocity range.
****
Phase Transitions in Neural Networks
Joshua Chover
Various simulat.ions of cort.ical subnetworks have evidenced something l ike phase transitions with respect to key parameters. We demonstrate t hat. such transi t.ions must. indeed exist. in analogous infinite array models. For related finite array models classical phase transi t.ions (which describe steady-state behavior) may not. exist., but. there can be distinct. quali tative changes in ("metastable") transient behavior as key system parameters pass through crit.ical values .
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Using Neural Networks to Improve Cochlear Implant Speech Perception
Manoel Tenorio
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Self-Organization of Associative Database and Its Applications
Hisashi Suzuki, Suguru Arimoto
An efficient method of self-organizing associative databases is proposed together with applications to robot eyesight systems. The proposed dat abases can associate any input with some output. In the first half pa rt of discussion, an algorithm of self-organization is proposed. From an aspect of hardware, it produces a new style of neural network. In t he latter half part, an applicability to handwritten letter recognition and tha t to an autonomous mobile robot system are demonstrated.
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Temporal Patterns of Activity in Neural Networks
Paolo Gaudiano
Patterns of activity over real neural structures are known to exhibit time(cid:173)
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Network Generality, Training Required, and Precision Required
John Denker, Ben Wittner
We show how to estimate (1) the number of functions that can be implem ented by a particular network architecture, (2) how much analog precis ion is needed in the con(cid:173) nections in the network, and (3) the numb er of training examples the network must see before it can be expected to for m reliable generalizations.
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High Order Neural Networks for Efficient Associative Memory Design

Gérard Dreyfus, Isabelle Guyon, Jean-Pierre Nadal, Léon Personnaz
We propose learning rules for recurrent neural networks with high-order interactions between some or all neurons. The designed networks exhibit the desired associative memory function: perfect storage and retrieval of pieces of information and/or sequences of information of any complexity.
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The Capacity of the Kanerva Associative Memory is Exponential
Philip Chou
The capacity of an associative memory is defined as the maximum
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The Sigmoid Nonlinearity in Prepyriform Cortex
Frank Eeckman
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Probabilistic Characterization of Neural Model Computations
Richard Golden
Information retrieval in a neural network is viewed as a procedure in

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Learning in Networks of Nondeterministic Adaptive Logic Elements
Richard Windecker
from
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HIGH DENSITY ASSOCIATIVE MEMORIES
Amir Dembo, Ofer Zeitouni
from a description of desired properties
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A Mean Field Theory of Layer IV of Visual Cortex and Its Application to Artifici al Neural Networks
Christopher Scofield
A single cell theory for the development of selectivity and ocular do minance in visual cortex has been presented previously by Bienenstock, Cooper and Munrol. This has been extended to a network applicable to layer IV of visual cortex2 . In this paper we present a mean field approximation that captures in a fairly transparent manner the quanti tative, results of the network theory. Finally, we consider the applic ation of this theory to artificial neural networks and show that a s ignificant reduction in architectural complexity is possible.
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Neural Networks for Template Matching: Application to Real-Time Classification o f the Action Potentials of Real Neurons
James Bower, Yiu-Fai Wong, Jashojiban Banik
Much experimental study of real neural networks relies on the proper c lassification of
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Capacity for Patterns and Sequences in Kanerva's SDM as Compared to Other Associ ative Memory Models
James Keeler
The information capacity of Kanerva's Sparse, Distributed Memory (SDM) an d Hopfield-type neural networks is investigated. Under the approximations used here, it is shown that the to(cid:173) tal information stored in these systems is proportional to the number connections in the net(cid: 173) work. The proportionality constant is the same for the SDM and H opJreld-type models in(cid:173) dependent of the particular model, or th e order of the model. The approximations are checked numerically. This same analysis can be used to show that the SDM can store se(cid:17 3) quences of spatiotemporal patterns, and the addition of time-delayed co

nnections allows the retrieval of context dependent temporal patterns. A minor modification of the SDM can be used to store correlated patterns.
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The Connectivity Analysis of Simple Association

Dan Hammerstrom

The efficient realization, using current silicon technology, of Very Large Connection Networks (VLCN) with more than a billion connections requires that these networks exhibit a high degree of communication locality. Real neural networks exhibit significant locality, yet most connectionist/neural network models have little. In this paper, the connectivity requirements of a simple associative network are analyzed using communication theory. Several techniques based on communication theory are presented that improve the robust(cid:173) ness of the network in the face of sparse, local interconnect structures. Also discussed are some potential problems when information is distributed too widely.
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Performance Measures for Associative Memories that Learn and Forget

Anthony Kuh

Recently, many modifications to the McCulloch/Pitts model have been proposed where both learning and forgetting occur. Given that the network never saturates (ceases to function effectively due to an overload of information), the learning updates can con(cid:173) tinue indefinitely. For these networks, we need to introduce performance measmes in addi(cid:173) tion to the information capacity to evaluate the different networks. We mathematically define quantities such as the plasticity of a network, the efficacy of an information vector, and the probability of network saturation. From these quantities we analytically compare different networks.
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Centric Models of the Orientation Map in Primary Visual Cortex

William Baxter, Bruce Dow

In the visual cortex of the monkey the horizontal organization of the preferred orientations of orientation-selective cells follows two opposing rules: 1) neighbors tend to have similar orientation preferences, and 2) many different orientations are observed in a local region. Several orientation models which satisfy these constraints are found to differ in the spacing and the topological index of their singularities. Using the rate of orientation change as a measure, the models are compared to published experimental results.
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A Computer Simulation of Olfactory Cortex with Functional Implications for Storage and Retrieval of Olfactory Information

James Bower, Matthew Wilson

Based on anatomical and physiological data, we have developed a computer simulation of piri(cid:173) form (olfactory) cortex which is capable of reproducing spatial and temporal patterns of actual cortical activity under a variety of conditions. Using a simple Hebb-type learning rule in conjunc(cid:173) tion with the cortical dynamics which emerge from the anatomical and physiological organiza(cid:173) tion of the model, the simulations are capable of establishing cortical representations for differ(cid:173) ent input patterns. The basis of these representations lies in the interaction of sparsely distribut(cid:173) ed, highly divergent/convergent interconnections between modeled neurons. We have shown that different representations can be stored with minimal interference. and that following learning these representations are resistant to input degradation, allowing reconstruction of a representa(cid:173) tion following only a partial presentation of an original training stimulus. Further, we have demonstrated that the degree of overlap of cortical representations for different stimuli can also be modulated. For instance similar input patterns can be induced to generate distinct cortical representations (discrimination). while dissimilar inputs can be induced to

generate overlapping representations (accommodation). Both features are presumably important in classifying olfacto(cid:173) ry stimuli.
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Towards an Organizing Principle for a Layered Perceptual Network
Ralph Linsker
An information-theoretic optimization principle is proposed for the developmen t of each processing stage of a multilayered perceptual network. This principle of "maximum information preservation" states that the signal trans formation that is to be realized at each stage is one that maximizes the inform ation that the output signal values (from that stage) convey about the input si gnals values (to that stage), subject to certain constraints and in the presen ce of processing noise. The quantity being maximized is a Shannon information rate. I provide motivation for this principle and -- for some simple model ca ses -- derive some of its consequences, discuss an algorithmic implementation, and show how the principle may lead to biologically relevant neural a rchitectural features such as topographic maps, map distortions, orienta tion selectivity, and extraction of spatial and temporal signal correlations. A possible connection between this information-theoretic principle and a principle of minimum entropy production in nonequilibrium thermodynamics is suggested.
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A Trellis-Structured Neural Network
Thomas Petsche, Bradley Dickinson
We have developed a neural network which consists of cooperatively inter(cid:173)
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Supervised Learning of Probability Distributions by Neural Networks
Eric Baum, Frank Wilczek
We propose that the back propagation algorithm for super(cid:173)
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Stochastic Learning Networks and their Electronic Implementation
Joshua Alspector, Robert Allen, Victor Hu, Srinagesh Satyanarayana
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Connecting to the Past
Bruce MacDonald
Recently there has been renewed interest in neural-like processing syst ems, evidenced for ex(cid:173) ample in the two volumes Parallel Distribute d Processing edited by Rumelhart and McClelland, and discussed as parallel distributed systems, connectionist models, neural nets, value passing sy stems and multiple context systems. Dissatisfaction with symbolic manipu lation paradigms for artificial intelligence seems partly responsible for this attention, encouraged by the promise of massively parallel systems implemented in hardware. This paper relates simple neural-like systems based on multiple context to some other well-known formalisms-namely pr oduction systems, k-Iength sequence prediction, finite-state machines and Turi ng machines-and presents earlier sequence prediction results in a new lig ht.
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PARTITIONING OF SENSORY DATA BY A CORTICAL NETWORK
Richard Granger, Jose Ambros-Ingerson, Howard Henry, Gary Lynch
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A Dynamical Approach to Temporal Pattern Processing

W. Stornetta, Tad Hogg, Bernardo Huberman
Recognizing patterns with temporal context is important for such tasks as speech recognition, motion detection and signature verification. We propose an architecture in which time serves as its own representation, a nd temporal context is encoded in the state of the nodes. We contrast this with the approach of replicating portions of the architecture to represent time.
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Minkowski-r Back-Propagation: Learning in Connectionist Models with Non-Euclidia n Error Signals
Stephen Hanson, David Burr
Many connectionist learning models are implemented using a gradient descent in a least squares error function of the output and teacher signal. The present mo del Fneralizes. in particular. back-propagation [1] by using Minkowski-r power metrics. For small r's a "city-block" error metric is approximated an d for large r's the "maximum" or "supremum" metric is approached. while for r=2 the standard back(cid:173) propagation model results. An impleme ntation of Minkowski-r back-propagation is described. and several experime nts are done which show that different values of r may be desirable for various purposes. Different r values may be appropriate for the reduction of the effects of outliers (noise). modeling the input space with more co mpact clusters. or modeling the statistics of a particular domain more naturall y or in a way that may be more perceptually or psychologically meaningful (e.g. speech or vision).
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Analysis and Comparison of Different Learning Algorithms for Pattern Association Problems
J. Bernasconi
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