LA-SUB--95-190

**Technical and Analytical Support to
the ARPA Artificial Neural Network Technology Program**

Final Report

Prepared by:

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September 16, 1995

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SUMMARY

Strategic Analysis (SA) has provided ongoing work for the Advanced Research Projects Agency (ARPA) Artificial Neural Network (ANN) technology program. This effort provides technical and analytical support to the ARPA ANN technology program in support of the following information areas of interest:

- Alternative approaches for application of ANN technology, hardware approaches that utilize the inherent massive parallelism of ANN technology, and novel ANN theory and modeling analyses.
- Promising military applications for ANN technology.
- Measures to use in judging success of ANN technology research and development.
- Alternative strategies for ARPA involvement in ANN technology R&D.

These objectives were accomplished through the development of novel information management tools, strong SA knowledge base, and effective communication with contractors, agents, and other program participants. These goals have been realized. Through enhanced tracking and coordination of research, the ANN program is healthy and recharged for future technological breakthroughs.

BACKGROUND

The ARPA Microelectronics Technology Office (MTO) has funded a program in which the use of Artificial Neural Networks (ANNs) is being assessed through high-impact applications and scale-up/demonstration hardware. This program, now in its sixth year has realized a number of successful solutions. This original program included three major program components: Comparative Performance, Theory and Modeling, and Hardware Technology. This has evolved into other areas such as manufacturing/process control and advanced vision systems. Future efforts will build on accomplishments as the focus shifts from feasibility demonstration and performance evaluation to development of testable applications.

DESCRIPTION OF ACTIVITIES

SA is expected to prepare technical assessments, develop automated computer tools, and provide other quick response tasks to the ANN Program. Technical assessments include the following tasks: data gathering, conduct open database searches, prepare summary papers, synthesize available reports, review progress of specific program components, and attend selected technical meetings and workshops. Track and organize data from ARPA contractors. Additionally, develop databases on ANN articles in the press, promising military applications, and key ANN issues in the literature.

ACCOMPLISHMENTS

Planned and hosted topical workshops and other meetings for the ARPA ANN program. Maintained communication with agents and contractors to stay abreast of contract status. Developed, updated, and maintained a comprehensive database on the progress of ANN contractors. Also developed computer tools for tracking the ANN program and maintained databases on ANN technology, promising military applications, and key ANN technology issues. Populated this database by routinely monitoring press articles related to Artificial Neural Networks. Assembled pertinent information from sources such as Defense Daily, Electronic Engineering Times, Defense Electronics, Defense News, Military and Aerospace Electronics, and Business Week. Conveyed knowledge of developments in the field through attendance at conferences and special topical meetings.

FACILITATION OF RESEARCH

Coordinated technical workshops to promote the exchange of ideas. Reviewed status reports. Acted as liaison between agents and contractors in order to match groups working on related efforts. Encourage collaborative research. Leverage past work to avoid redundancy.

MANAGEMENT INFORMATION SYSTEM

Many of the databases and decision tools were combined into a comprehensive management information systems. A considerable amount of effort was expended in the development of this system to accommodate the following functions:

- Coordinate all of the different types of data
- Organize this data along technical as well as fiscal guidelines
- Access to detailed contractual information
- Interface to ARPA host management systems (AO writer, DEIS, etc.).
- Streamline much of the reporting process

The end product was a menu-driven data organization and reporting tool. Full spectrum of information access- from broad summaries (cross-cuts) to detailed information about a specific contract. Technical data was correlated with budgetary information to provide a complete picture of activities. This management information system made many of the in-house drills much easier. For example, MRAOs (Memorandum request for ARPA Order), year-end summaries, and other procurement processes were simplified.

SAMPLE REPORTS FROM THE MANAGEMENT INFORMATION SYSTEM

What follows are a selection of actual reports that can be viewed and printed from the menu-driven Information Management System developed by SA under this contract.

ARPA Artificial Neural Network Program Database

ROLODEX

**ONE PAGE
SUMMARY**

**PROGRAM
PARTICIPANTS**

**CONTRACTOR
QUESTIONNAIRE**

**GREEN
SHEET
MODEL**

**GROUP/CLASS
GREEN
SHEET**

**HISTORICAL
DATA**

**MAILING
LABELS**

**WEEKLY
ACTIVITY
REPORTS**

Boston University

9/15/95

TITLE: *Self-Organizing Neural Network Architectures for Incremental Learning, Pattern Recognition, and Image Understanding.*

GROUP: Theory & Mod.

CLASS: Vision

START DATE: 6/1/92

END DATE: 5/31/95

Subcontractor:

PRINCIPAL INVESTIGATOR

Dr. Stephen Grossberg
Center for Adaptive Systems
Boston University
Boston MA 02215

Phone: (617) 353-7857 **Fax:** 353-7755

AGENT INFO

Agency: ONR
ARPA Number: 8775
Agent: Dr. Thomas McKenna 703-696-4503
Contract Number: N00014-92-J-4015

BUDGET DATA

Real Contract Cost: \$734,596

BA23Y31260	FY92	FY93	FY94	FY95	FY96
Programmed ==>	\$100,000	\$220,000	\$290,000	\$124,596	
Obligated ==>	\$100,000	\$220,000			

OBJECTIVE:

- * Develop neural architectures for multi-scale image processing and pattern recognition
- * Integrate image processing and pattern recognition modules into an image and standing architecture
- * Design temporal planning and pattern recognition systems
- * Model attentive visual search
- * Improve pattern recognition system to better compensate for noisy or incomplete data
- * Develop new learning laws for stable distributed pattern recognition.

ACCOMPLISHMENTS:

Fusion ARTMAP: Synthesis of Adaptive Resonance Theory (ART), Fuzzy Logic, and Data Fusion

- * fast incremental supervised learning
- * multiple levels of generalization
- * selective search of least confident data
- * preservation of confident data in multiple fused categories

New Systems for Automatic

- * IF-THEN rule extraction
- * 3-D vision and figure-ground separation
- * invariant image processing
- * vowel recognition and pitch detection
- * control of complex motor skills -- handwriting, locomotion, tool use
- * segmentation of synthetic aperture radar (SAR) images

Applications

Adaptive Filters

Defense Group Inc. Dr. Morgan Grover (310) 394-8599
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ATR

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8830 : NVEOC Ms. Elizabeth Jones N/A Fax: 765-1283

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SAIC Dr. Robert B. Davidson (703) 821-4418
: ONR Dr. Thomas McKenna rdavidson@cpva.saic.com Fax: 821-3071

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7662 : ONR Dr. Thomas McKenna alex.waibel@cs.cmu.edu Fax: 268-5106

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8787 : ONR Dr. Thomas McKenna Fax: 822-1381

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University of Maryland Dr. H.H. Chen (301)
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Weekly Activity Reports

Performer: Mass Institute of Technology

Principle Investigator: Dr. Tomaso Poggio

Contract Number: N00014-92-J-1879

Most Recent Weekly Activity Report:

Automatic Person Identification: a new approach has been developed to perform face recognition for arbitrary poses and illumination. The technique has also been demonstrated via preliminary simulations.

The system goes well beyond current experimental systems which typically work only for frontal or nearly frontal images of faces. Currently the system stores 15 modal views spanning two rotational degrees of freedom in pose -- up/down rotation and left/right rotation. To recognize an input face, the face is compared against all model views of each person. To compare the input image against a particular model view, the major facial features are first used to align an input face image and the model view. Currently, eye and nose features are used and an affine transform is applied to the input face to align major features. An automatic correspondence technique is used to compensate for any remaining small transformation between the input image and the model image. Templates from the model are then compared with the image using the normalized cross correlation coefficient. The current system has achieved a recognition rate of 97.5% on a data base of 40 people, with 10 test images per person.

The major direct impact of the system under development is for security systems (access control) and human-computer interface but the basic approach can be used for other recognition tasks involving 3D objects.

Previous Weekly Activity Report:

ARTIFICIAL NEURAL NETWORK BUDGET

Green Sheets Model Through 1996

9/15/95

CONTRACTOR	TITLE	LINE NUMBER	1992		1993		1994	1995	1996
			Programmed	Obligated	Programmed	Obligated	Programmed	Programmed	Programmed

ARPA NUMBER:

SAIC

Summary for: ARPA Number: Agency: ONR

ARPA NUMBER: 6831

SAIC Non-US Neural Net Research BA23Y00200 200,000 200,000 49,966

Summary for: ARPA Number: 6831 Agency: CIA \$200,000 \$200,000 \$49,966

ARPA NUMBER: 7006

Defense Group Inc. Neural Nets for DoD BA23D2014 385,995 385,995 349,906 349,906 127,992
Intrinsic Circuits Time and Scaling in BA23D1222 110,000 110,000 136,910 136,910
Mass Institute of Technology Learning Techniques for BA23D2017 100,000 100,000 270,000 270,000 226,909
Tracor Applied Sciences, Advanced Neural Network BA23Y12150 99,622 99,622 150,000 150,000 199,949 57,084
University of New Neural Networks with Local BA23D1219 81,988 81,988 153,539 153,539 186,325

Summary for: ARPA Number: 7006 Agency: ONR \$777,605 ? ? ?\$741,175 \$57,084

ARPA NUMBER: 7012

BBN Systems & Neural Network Technology BA23Y20540 220,000 220,000 188,398 188,398 689,895
SRI International Neural Networks Technology BA23Y20560 245,000 245,000 286,557 286,557 296,995

Summary for: ARPA Number: 7012 Agency: NSA \$465,000 ? \$474,955 \$474,955\$986,890

ARPA NUMBER: 7013

Bellcore Research in VLSI System BA23Y1230 169,210 169,210 152,444 152,444
David Samoff Research Neural Networks for Interactive BA23Y21220 198,300 198,300 185,000 185,000 324,000 136,614
Harvard University Theory and Applications of Neural BA23D2123 130,000 130,000 299,915 299,915 299,930
U. of California, San Diego Development of free-space BA23Y31200 102,966 102,966 248,329 248,329 251,422 128,133
U. of Southern California Photonic Technology BA23Y31210 100,000 100,000 300,000 300,000 300,000 200,000
University of Maryland Adaptive Neural Network Models BA23D2120 100,010 100,010 149,439 149,439 148,877

Summary for: ARPA Number: 7013 Agency: AFOSR \$800,486 ? ? ? ? \$464,747

ARPA NUMBER: 7017

Hughes Research Lab Optical Neural Networks Based BA23Y30150 100,000 100,000 160,000 160,000 210,000 148,191
Nestor, Inc. NI1000 Multichip Neural Network BA23Y30111 280,185 280,185 340,000 340,000 436,167
Vision Applications, Inc. Construction of a Space-Variant BA23Y30160 300,000 300,000 200,000 200,000 400,000 300,000

Summary for: ARPA Number: 7017 Agency: ONR \$680,185 ? \$700,000 \$700,000 ? \$448,191

Historical Contract Data

California Institute of Tech. <i>An Information Theoretic Approach to Distributed Inference and Learning</i>		Objective: The objective of this research is to develop real-time distributed neural network expert systems which can adapt to their environment, reason with incomplete and uncertain information in real-time, and represent domain knowledge in an explicit manner. Innovative learning algorithms will be developed which will both be able to incorporate prior knowledge into an initial network architecture and subsequently adapt the network in an automatic manner. The research will build on a novel information-theoretic and statistical neural network model for knowledge representation, learning and information processing. This research will adapt ideas from both the symbolic and connectionist approaches using underlying information theoretic models with particular emphasis on implementing a hybrid distributed architecture. This architecture will combine both statistical (e.g. clustering) and connectionist techniques for efficient learning, and perform inference in real-time subject to information theoretic criteria (e.g. maximum entropy), while allowing for direct explanation of cause and effect at the number of hidden units. The resulting links in the networks correspond directly to heuristic rules, specifically the best set of class-attribute rules in the data. A minimum description length criterion is used to determine the size of the network. Theoretical results were derived regarding the size of the network that can be bounded for a given data set. (2) Demonstrated that there exists a general family of objective functions that lead to consistent probability estimates, and that cross-entropy and squared error learning criteria are the simplest members of this family.																				
ARPA#: 8785	Accomplishments:	(1) Developed probabilistic models for rule-based network classifiers that can build a network model from data without any prior specification of layers and number of hidden units. The resulting links in the networks correspond directly to heuristic rules, specifically the best set of class-attribute rules in the data. A minimum description length criterion is used to determine the size of the network. Theoretical results were derived regarding the size of the network that can be bounded for a given data set. (2) Demonstrated that there exists a general family of objective functions that lead to consistent probability estimates, and that cross-entropy and squared error learning criteria are the simplest members of this family.																				
<table><tr><td>Line Number</td><td>1988</td><td>1989</td><td>1990</td><td>1991</td></tr><tr><td>BE23D12290</td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td>338,366</td><td></td><td></td></tr><tr><td>BE23D12290</td><td></td><td></td><td></td><td></td></tr></table>		Line Number	1988	1989	1990	1991	BE23D12290							338,366			BE23D12290					
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FA962088C0112 California Institute of Tech. <i>An Optoelectronic Realization of Neural Network Models</i>		Objective: CCD test have been completed, showing proof of concept. A second contract involving a system level integration of similar chips is being pursued. Due to a layout error, the current chips are not suitable for system integration, although they work well enough to show the basic soundness of the concept. The phototransistor network shows promise as it is inexpensive to fabricate (due to the availability of MOSIS) and interface well with standard laboratory test equipment.																				
ARPA#: 6485	Accomplishments:																					
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Line Number	1988	1989	1990	1991																		
BE23D01400																						
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N00014-91-J-1131 Carnegie Mellon University <i>Comparative Performance Measurements for Continuous Speech Recognition by Neural</i>		Objective: Demonstrator a high performance Continuous Speech Recognition (CSR) system using ANNs. Develop the following neural network systems for the recognition tasks: <ul style="list-style-type: none">• Link Predictive Neural Nets (LPNN) for continuous speech recognition• Systematically integrate and evaluate TDNN networks into a large phonemic architecture.																				
ARPA#: 7662	Accomplishments:	Developed, tested, and compared a TDNN extensions (MS-TDNN) to connected word recognition, a predictive neural net and an HMM-NN hybrid approach to continuous speech recognition. Finally a new NN work spotting system was developed and tested. All four systems were evaluated and tested against standard databases and perform comparable or better than existing published state of the art methods. An implementation on parallel hardware (iWarp) was completed successfully.																				
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Line Number	1988	1989	1990	1991																		
BE23D20200																						
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F4962090C0010 David Sarnoff Research Center <i>Multi-Disciplinary Studies of Integrated Neural Network Systems</i>		Objective: To model the sensory and motor systems of a biological system, the barn owl, in performance of complex tracking behaviors in response to visual, acoustic, and proprioceptive sensory information. <ol style="list-style-type: none">1) Develop self-supervised learning in systems of Map-Like Neural Networks by extending existing computational model for the "acoustic retina" of the barn owl through the addition of mechanisms for self-supervised learning. This task will explain the system's ability to adaptively register its visual and acoustic representations of target direction.2) Develop Adaptive Sensory Signal Processing by studying detailed processing functions of the mammalian retina to understand how it adaptively processes the tremendous dynamic range of its sensory environment and interfaces with higher cortical processing.																				
ARPA#: 7013	Accomplishments:	Developed spline-nets as generalized versions of multi-layer perceptrons with B-spline connection functions and demonstrated their capability for rapid learning and computational efficiency. Developed a model of image discrimination with an objective function based on perceived differences and applied it to quantify the visibility of CRT and liquid crystal displays. Implemented a neural network on a parallel computer and demonstrated its ability for random noise removal from satellite images.																				
<table><tr><td>Line Number</td><td>1988</td><td>1989</td><td>1990</td><td>1991</td></tr><tr><td>BE23D21220</td><td></td><td></td><td></td><td></td></tr><tr><td>BE23D21220</td><td></td><td></td><td></td><td></td></tr><tr><td>BE23Y21220</td><td></td><td>500,000</td><td></td><td></td></tr></table>		Line Number	1988	1989	1990	1991	BE23D21220					BE23D21220					BE23Y21220		500,000			
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