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# AD-A277 375

## REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

...ated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources ... reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this ... burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson ... Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

...ORT DATE

3. REPORT TYPE AND DATES COVERED
FINAL/01 MAY 90 TO 30 SEP 93

4. TITLE AND SUBTITLE
NEURAL NETWORKS FOR MODEL-BASED RECOGNITION (U)

5. FUNDING NUMBERS
2305/B3
AFOSR-90-0224

6. AUTHOR(S)
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DTIC ELECTE MAR 23 1994 S F D

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
AEOSR-TR- 94 0048

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NM
110 DUNCAN AVE, SUITE B115
BOLLING AFB DC 20332-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFOSR-90-0224

11. SUPPLEMENTARY NOTES

94-09043

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

12b. UL

13. ABSTRACT *(Maximum 200 words)*

In this work during this grant period, the investigators explored issues involving the use of neural nets for object recognition. The PI, Gene Gindi moved from Yale to Stony Brook late in the grant period, and continued the brunt of the work at Stony Brook under a subcontractual arrangement with Yale. A colleague, Eric Mjolsness, became the titular PI during this period, and a postdoc involved in this work, Anand Rangarajan, stayed at Yale but had his salary partially paid during the SUNY subcontractual period. This final progress report is authored by Gene Gindi.

DTIC QUALITY INSPECTED 2

94 3 22 061

| 14. SUBJECT TERMS | 15. NUMBER OF PAGES |
|---|---|
| | 16. PRICE CODE |

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | SAR(SAME AS REPORT) |

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

8011

# Final Progress Report
# AFOSR Contract 90-0224
# Neural Networks for Model - Based Recognition

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November 1993

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## Introduction

In this work during this grant period, the investigators explored issues involving the use of neural nets for object recognition. The PI, Gene Gindi moved from Yale to Stony Brook late in the grant period, and continued the brunt of the work at Stony Brook under a subcontractual arrangemnt with Yale. A colleague, Eric Mjolsness, became the titular PI during this period, and a postdoc involved in this work, Anand Rangarajan, stayed at Yale but had his salary partially paid during the SUNY suncontractual period. This final progress report is authored by Gene Gindi. This grant was a continuation of a previous AFOSR funded grant ( F49620-88-C-0025) that ran from 12/88 to 3/90. The content of the final progress report for that grant is not duplicated here. All publications refer to the current grant only.

We summarize progress via publications that were created during the grant period. Below we give a brief summary of each. Reprints are attached. Following the discussion of each article, we offer a brief discussion placing the work in context.

## Publications Associated with Grant

1. J Utans and **G Gindi**: "Improving Convergence in Hierarchical Matching Networks for Object Recognition ", *Advances in Neural Information Processing Systems V*, pp. 401 - 408, C Giles, S Hanson and J Cowan, eds. Morgan Kaufman, San Mateo, 1993.

   A basic theme that we have pursued involves object recogition through a neural net that attempts to *match* model components to object components through a match network reminiscent of the Hopfield network for the TSP problem. To perform other than trivial matching, notions of abstraction and hierarchy need be incorporated into the network. (The basic theme is described in detail in publication 2 below.) One not unexpected problem is computational; like other complex network problems, this one has problems converging. The object recognition problem is difficult in that it involves coupled problems of grouping, segmentation and matching. This NIPS publication describes methods of initalizing the networks so as to improve convergence. A given class of problems reduces to a weighted match with parameter - dependent weights. Here we show that we can first solve for estimates of the parameters instead of solving for them simultaneously. The resulting networks converge more quickly.

2. **G Gindi**, E Mjolsness, P Anandan: "Neural Networks for Model-Based Recognition", in *Neural Networks: Concepts, Applications and Implementations, vol III*, P. Antognetti and V. Milutinovic', eds., pp. 144 - 173, Prentice - Hall, 1991.

   This is book chapter that summarizes work by us and collaborators over the years and give a detailed exposition of the model matching approach. It gives the basic approach of reformulating model matching as an optimization, and shows how to incorporate notions of hierarchy via pointer matrices and other data structures. The result is an elaborate objective function that is expressive enough to include features of the sort of AI frame-based recognition system not usually expressed as an optimization. A discussion of optimization techniques is given, where constraints may be expressed either as soft (additive) constraints or hard constraints. The dynamics of the networks follow Hopfield dynamics or can be modified to include hard constraints. Experiments in the recognition of simple stick figures, and in line grouping , are performed.

3. **G Gindi**, and J Utans : "A Neural Network Approach to Object Recognition and Image Partitioning Within a Resolution Hierarchy", Proc. SPIE Intelligent Information Systems, Orlando, April 1992.

   This was a poster presented at a conference that illustrated the problem of segmenting a complex multipart object by first classifying it into a broad catgory and using the resulting match to index into specific criteria for segmenting further parts.

4. **G Gindi**, and J Utans : "A Neural Network Performs Context-Guided Segmentation of Shapes", Proc. Snowbird Conference Neural Networks Computing, Salt Lake City UT, 1992.

   This was a Snowbird poster similar to the poster above.

5. J Utans: "Neural Networks for Object Recognitin within Compositional Hierarchies", Ph.D. thesis, Dept Electrical Engineering, Yale University, 1992.

   Mr. Utans, in his Ph.D. thesis (G. Gindi thesis advisor) explores several issues in hierchical optimizing nets for object recognition. Experiments in simple systems that perform segmentation, grouping, and matching in a coupled fashion are reported. Much of the work of other publications appears in somewhat more detailed form here.

6. G Shumaker: " Neural Networks for Object Recognition via Graph Matching", M.D Thesis, Yale University School of Medicine , 1991.

   In this masters level (actually MD) thesis. Mr. Shumaker performed detailed experiments on the recognition of articulated stick figures. He explored different ways to express constraints (hard vs. soft), showed, computationally, the advantage of an ISA specialization hierarchy. Of interest here is ani intil attempt to incorporate learning into the network. Our previous efforts were elaborate hardwired optimization nets. Here, he attempts, with some success, learning of recognition parameters through the use of modified backpropagation network.

7. **G Gindi**, A Rangarajan and G Zubal : "Atlas-Guided Segmentation of Brain Images via Optimizing Neural Networks", Proc. SPIE Biomedical Image Processing IV, San Jose, February 1993.

8. **G Gindi**, A Rangarajan and G Zubal : "Neural Network for Model Based Segmentation of MR Brain Images", pp. 90 – 93, Proc.12th Southern Biomedical Engineering Conference, New Orleans, April, 1993.

9. A Rangarajan and **G Gindi**: "Optimizing Networks Applied to Atlas – Guided Segmentation of Brain Images ", Proc. Snowbird Conference on Neural Networks for Computing, Salt Lake City UT, 1988.

   The above two articles and one Snowbird poster apply the model matching strategy to a medical domain in which a model consists of stored shapes reflecting normal brain anatomy, ie. an atlas. This is to be used to guide the segmentation of a Magnetic Resonance brain scan into anatomical regions. Of interest is that this domain has a shape regularity amenable to modelling, yet exhibits enough variation to be interesting and not trivial. (

Also, successful segmentation turns out to be quite useful in a variety of applications. ) Here, the model consists of bounding contour information as stored in an atlas. Contours on the test image are adjusted until they best match, according to an objective function, the model and are also consistent with the underlying 2-D greyscale image. In this setting, model matching becomes a sort of model - guided snake. (Here, snake is used in the sense of deformable contour popular in the computer vision community.) Match neorons appear still as variables that match elements of both contours.

10. **G Gindi**, C Darken, K O'Brien, M Stetz and L Deckelbaum: "Neural Network and Conventional Classifiers for Fluorescence Guided Laser Angioplasty " , pp. 453 - 463, IMIA Yearbook of Medical Informatics 1992, Advances in Interdisciplinary Science, Intl. Medical Informatics Society, J. van Bemmel, A. T. McCray, eds., Schatttauer Pub. Co., Geneva, 1992. (this article originally apeared in IEEE Trans Biomed Eng vol 38, pp. 246 - 252 1991. )

    A conventional neural net application for classification of optical spectra.

## Discussion:

The work conducted during the three-year duration of the grant has resulted in the exposition of an approach to general recognition problems. The approach attempts to unify the disparate problems of segmentation, grouping, and matching into a unified framework expressed as an optimization. Neural nets are good at optimization, so merely recasting the vision problem in this sense allows for the possiblity of fast analog nets to solve complex problems in vision. There is no magic in reducing the complexity of these problems; the complexity is merely pushed onto the objective function, and expressed as the conventional difficulties associated with optimizing complicated objectives. However, the uniform notation allows for progress. Complex vision problems that are still simpler than the most general vision problems may indeed be amenable to this sort of attack. In earlier work, problems in industrial part recognition was attacked. The incorporation of better optimization techniques and learning may also help.

We express our gratitude for the AFOSR support.