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REPORT OF THE JOINT WORKSHOP ON PATTERN RECOGNITION AND ARTIFIC--ETC(U)
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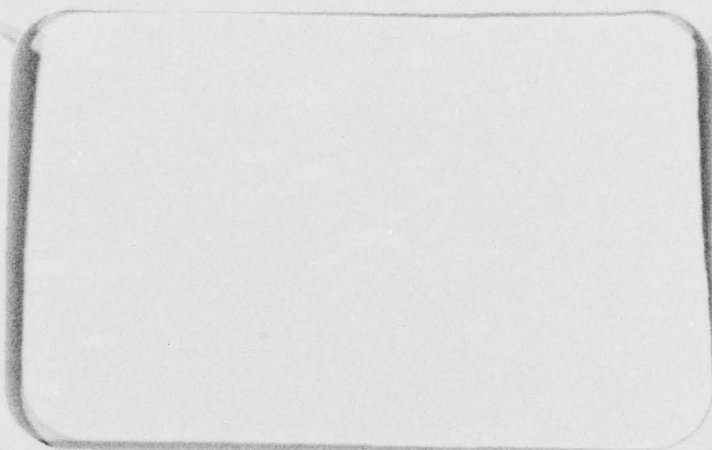
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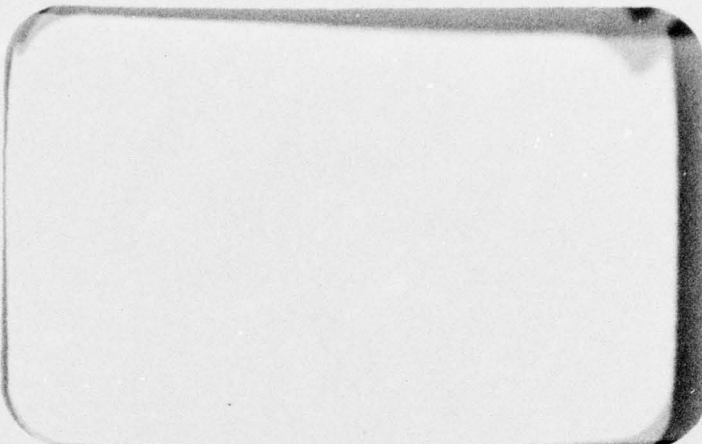


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18 19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFOSR - TR - 77 - 0124	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 REPORT OF THE 1976 JOINT WORKSHOP ON PATTERN RECOGNITION AND ARTIFICIAL INTELLIGENCE (1976).	5. TYPE OF REPORT & PERIOD COVERED 9 Interim rept.	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(S) 10 C. H. Chen	8. CONTRACT OR GRANT NUMBER(S) 14 EE-76-7 15 ✓ AF- AFOSR 76-2951-76 ✓	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Electrical Engineering Department Southeastern Massachusetts University North Dartmouth, Massachusetts 02747	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 61102F 17 A2 2304 A2	
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Office of Scientific Research/NM Bolling AFB DC 20332	12. REPORT DATE 11 21 Dec 76	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 19p.	13. NUMBER OF PAGES 16	15. SECURITY CLASS. (of this report) UNCLASSIFIED
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is the final report of the technical program of the workshop held June 1-3, 1976, at Hyannis, Mass. Papers presented at the meeting are carefully reviewed by topics: scene analysis and image processing, syntactic and statistical pattern recognition, relational data structure and data base management, language understanding and speech recognition, biomedicine, production systems and knowledge-based systems, computer graphics, game-playing programs and distortion modeling. Panel discussions sessions are examined. Recommendation and		

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SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Grant AFOSR 76-2951
Technical Report
TR No. EE-76-7
December 21, 1976

~~SECRET~~ REPORT OF THE
1976 JOINT WORKSHOP ON
PATTERN RECOGNITION AND
ARTIFICIAL INTELLIGENCE

by

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Abstract

This is the final report of the technical program of the workshop held June 1-3, 1976 at Hyannis, Mass. Papers presented at the meeting are carefully reviewed by topics: scene analysis and image processing, syntactic and statistical pattern recognition, relational data structure and data base management, language understanding and speech recognition, biomedicine, production systems and knowledge-based systems, computer graphics, game-playing programs and distortion modeling. Panel discussions sessions are examined. Recommendation and assessment for future developments in both pattern recognition and artificial intelligence are also presented.

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I. Introduction

The Joint Workshop on Pattern Recognition and Artificial Intelligence was held June 1-3, 1976 at Hyannis, Massachusetts, U.S.A. There were 48 papers actually presented and two panel discussion sessions. The estimated number of participants was 120. The workshop was organized on selected topics in pattern recognition and artificial intelligence with the objectives of assessing the state-of-art in both fields, examine the interrelationship between the two fields, and defining the future directions and approaches in both fields. There are two publications as a result of this meeting. One is the Conference Record published by the IEEE Computer Society in July 1976 with IEEE Catalog Number 76CH1169-2C. This record contains the abstracts of most papers and short versions of 12 papers presented at the workshop, and a detailed report of the two panel sessions. The second publication is the Proceedings of the Workshop which has been published by Academic Press in December 1976 with book catalog number ISBN: 0-12-180950-7 (636 pp., \$28.50). It is entitled, "Pattern Recognition and Artificial Intelligence" and contains 28 full-length papers presented at the meeting which describe many recent and unpublished results in both fields.

This final report of the workshop provides a critical review of the technical program of the meeting. Papers are carefully reviewed by topics. Panel sessions are examined so that specific recommendations for future development in both fields can be made. Since both fields are very broad and no conference can cover them all, suggestions for future meeting of this nature are also given. Although it does not provide mathematical and experimental details as the two publications stated above, this report gives a more complete overview of the two fields.

II. Scene Analysis and Image Processing

An important subject in advanced automation is the computer vision, i.e. the ability for the computer to analyze and recognize a scene. Applications are numerous. For example, by analyzing and understanding a scene, a computer can direct a manipulator or other devices such as a mechanical arm to pick up certain

objects. Image processing is needed to enhance the scene or picture so that it is easier for human to see or for computer to do further processing like recognition.

The paper, "Finding structure in outdoor scenes" by B.L. Bullock deals with the extraction of local and global structural features such as edge, line, vertex and curve in complex outdoor scenes with natural backgrounds and man-made objects. Experimental results along with the configuration of a "stripped down" scene analysis system are given. In many applications, however, just to find structure is not enough and a more complete analysis of a scene is needed. The paper "IGS: A paradigm for integrating image segmentation and interpretation" by J.M. Tenenbaum and H.G. Barrow describes interactive procedures for interpretation guided segmentation which make use of diverse sources of knowledge such as relations between adjacent regions. The procedures are, however, computationally inefficient and require a lot of priori knowledge. The paper, "Relaxation labelling local ambiguity, and low-level vision" by S.W. Zucker describes the use of knowledge in the form of constraint or compatibility expressions by relaxation labelling processes to reduce or remove ambiguities in local descriptions of a picture. Relaxation labelling processes are techniques for deciding among alternative symbolic interpretations for local variables. This is a good example of the application of image understanding to image processing.

The paper, "Region extraction using boundary following" by S.A. Dudani deals with the region extraction of binary pictures by boundary following algorithm which employs search and follow strategies and by silhouette generation which uses a region crossing function with combinational logic representation. Although the techniques are useful for noise removal, extraction of single and multiple objects in an image, etc., their applications are limited to well-defined images excluding for example the complex outside scenes. Getting back to the blocks world, the paper "Structural isomorphism of picture graphs" by E.C. Freuder describes a truly unique idea of structural isomorphism which preserves structural descriptions and captures our intuitive idea of structural similarity of picture graphs.

In the image processing area, the paper "Interactive screening of reconnaissance imagery" by G.C. Stockman and L.N. Kanal describes the hardware and algorithms of an interactive system where the human user is responsible for the complex task and relieved of the trivial. Such interactive system is more feasible than a fully automatic system for reconnaissance imagery screening at least in the near future. The paper, "Detection of global linear features in remote sensing data" by R.W. Ehrich considers the detection algorithms including directional filtering and global search for lineaments which frequently appear in most large area satellite imagery. For edge detection, the paper, "Aspects of transform method for curve detection" by S.D. Shapiro and the paper, "Edge detection in noisy images using recursive digital filtering" by J.W. Modestino and R.W. Fries represent two distinct approaches which are both feasible for practical implementation. Other related papers are "An analysis of false color information content in Landsat MSS imagery" by E. Baron, and "A minicomputer based real time eye tracking system for pattern recognition applications" by N. Corby and L.A. Gerhardt. The eye motion analysis and tracking system described in the latter paper represents a fully operational system for human vision study.

Additional papers in the image science area are: "Low ^{and} intermediate level processing for an image understanding system", by M.D. Levine; "Pattern recognition in continuous-tone photographs by preconstruction of straight-line-segment images and subsequent concatenation", by E. Kahn, and "Aerial perspective-monocular depth cue for landscape scenes" by R. Bajcsy, N. Friedman, and K.R. Sloan.

III. Syntactic and Statistical Pattern Recognition

The syntactic and the statistical approaches are now the two major approaches to pattern recognition. Although the required mathematical backgrounds are different, the two approaches complement each other well. The paper, "Tree languages and syntactic pattern recognition" by K.S. Fu describes a generalization

of one-dimensional strings to trees which are more suitable for high-dimensional representation. The paper examines a simple tree grammar inference procedure and the applications to the classification of bubble chamber events, fingerprint recognition and landsat data interpretation. A related paper, "Some multidimensional grammar inference methods", by J.M. Brayer and K.S. Fu describes the tree grammar inference, inference by application of known forms as proposed by Evans, and the inference by selected example. This paper along with "The derivation diagram of a web grammar and its application to scene analysis" also by Brayer and Fu illustrates a link between pattern recognition and artificial intelligence through pictorial description. An example of an arch analyzed in Winston's system uses the proposed k-tail method for the grammar inference. The paper "Syntactic pattern recognition on the basis of functional approximation" by T. Pavlidis describes a syntactic shape description and recognition procedure in which noise removal is performed by nongrammatical means. The polygonal approximation to contours is much needed for computer vision of fairly well-defined objects. The research interest in classical data analysis and statistical pattern recognition remains strong as evidenced by the papers "Typological selection of parameters", by E. Diday; "On the recognition of highly variable line drawings through use of maximum likelihood functions" by D.B. Cooper; "Design of optimal feature extractors by mathematical programming techniques" by R.J.P. deFigueiredo; "An evaluation of some feature selection techniques" by E.E. Gose and F.B.H. Wu; "Recognition experiments with handprinted numerals" by S.K. Kwon and D.C. Lai; "Hadamard and Haar transforms and their power spectra in character recognition" by S. Wendling and G. Stamon; "Complex adaptive array filter using stochastic approximation" by F. Everly; and "Reny's entropy-its properties and use in pattern recognition" by M. Ben-Bassat.

To derive the maximum advantage from both statistical and syntactic (structural) approaches, the mixture of two approaches is discussed in "On statistical and

structural feature extraction" by C.H. Chen. Although the paper emphasizes on the feature extraction aspect, the combined use of statistical and structural informations should be considered in all stages of a pattern recognition process. This is particularly important when the pattern is noisy and when neither statistical nor structural approach alone can provide satisfactory solution. Implementation of the mixed model, however, is problem (pattern) dependent.

Another important problem is the complexity of parser in syntactic pattern recognition. The paper, "Time/space tradeoff from the viewpoint of grammatical similarity" by E.L. Bertsch deals with this subject by considering time and/or space minimization of grammatical procedures, relationships between time, space, and descriptive power, and a practical compiler-oriented technique which meets the space requirement and error-detection facilities of simple parsers.

IV. Relational Data Structure and Data Base Management

"The development and utilization of large integrated data bases promises to be one of the most important data processing activities of the next decade. By an integrated data base, we mean one which contains all the data used by an enterprise in a variety of applications. There are many reasons for the incorporation of heretofore separate but related data bases with a high degree of duplication into a single integrated one. The reduction of storage and updating costs, and the elimination of inconsistencies that may be caused by different copies of the data in different stages of updating, are among the more important ones." The paper "Acquisition and utilization of access patterns in relational data base implementation" by M. Hammer and A. Chan considers an implementation of data base management system which support such integrated data base. A relational data base consists of a collection of relations. A relation is a named two-dimensional table, which has a fixed number of (named) columns and an arbitrary number of (unnamed) rows (called tuples). Relational data base languages

provide users the ability to selectively retrieve or modify individual tuples, as well as insert and delete tuples. There is also a query language processor which translate the specification of desired information into searches on the data base that utilize the precise storage structures and auxiliary access mechanisms used to store the data. The authors have been developing a self-adaptive data base management system which monitors the access patterns and the data characteristics of a data base, and uses this information to adjust its physical organization. The paper presents many interesting ideas on data base organization and discusses the use of exponential smoothing techniques in the deviation of parameters needed by a cost model, as well as the need for heuristics in solving the index selection problem. A closely related paper, "DEDUCE - A deductive query language for relational data bases" by C.L. Chang concerns more specifically with the language for inferences in a relational data base, because some information may not be explicitly stored. Illustrated by examples, the language DEDUCE allows one to state "queries, axioms, preferences, and heuristics."

A different data structure problem is discussed in "A data structure which can learn simple programs from examples of input-output", by R.B. Banerji. The structure of the language based purely on algebraic or structural-linguistic models is inadequate for handling descriptions which depend on complex relations in the objects being classified. The power of at least parts of ω -order predicate calculus is needed using n -ary relations with arbitrarily high n . Of the three algorithms described in the paper, recognition and construction are very efficient being based on the concept of a search-tree rather than that of graph matching. The learning algorithm developed use sequential question-answer technique, and can learn from example or counter-example conjunction descriptions.

A third aspect of data structures is on picture data structure and picture data base management, which consists of two papers, "An iconic/symbolic data structuring scheme" by S.L. Tanimoto and "DABI - A data base for image analysis

with nondeterministic inference capability" by Y. Yakimovsky and R. Cunningham. These efforts are important for the automatic data base design in pictorial information processing.

V. Language Understanding and Speech Recognition

Although there are only three papers directly involved in the speech area, they are representing the most up-to-date development in this important area. The BBN Speech Understanding System is discussed in "Knowledge, hypotheses, and control in the HWIM speech understanding system" by J.J. Wolf. The paper illustrates very nicely the use of both pattern recognition and artificial intelligence techniques in a complex (speech) pattern understanding system. Pattern recognition techniques are usually employed at the interfaces to the speech signal, while AI techniques are used to organize the understanding process. In the HWIM system, the knowledge sources at the levels of acoustic-phonetics, phonology, vocabulary, syntax, semantics, factual knowledge, and discourse are realized in the nine functional components of the system. The paper also discusses the control strategy for generating, evaluating, and extending hypotheses into a complete understanding of the spoken utterance.

The papers, "Statistical modeling and automatic parameter estimation in speech recognition" by L.R. Bahl, et.al. and the paper, "Distance measures for speech recognition - psychological and instrumental" by P. Mermelstein are concerned with the statistical models and signal processing approach to speech recognition. A more complete report of related work is in the book "Speech Recognition" edited by D.R. Reddy and published by Academic Press, Inc. 1975.

VI. Biomedicine

The paper, "Pictorial medical pattern recognition" by H.K. Huang and R.S. Ledley describes six different applications of pictorial medical pattern recognition. It provides the most comprehensive treatment on the broad subject of

biomedicine. One of the six areas is discussed in much greater detail by S.J. Dwyer, R.W. McLaren and C.A. Harlow in "Computer-aided diagnosis of breast cancer from thermography." Biomedicine is certainly an area which derives considerable benefit from the development of pattern recognition and artificial intelligence techniques. We hope papers on AI in medicine are available in future meetings. The remaining two papers: "An adaptive method for EEG analysis" by B. Vachon and B. Dubuisson, and "On the Bayesian approach and Myopic policies in sequential classification with special emphasis on computer-aided diagnosis of endocrinologic disorders", by M. Ben-Bassat, are both concerned with the use of statistical methods in biomedicine.

VII. Production Systems and Knowledge-Based Systems

The paper, "Serial pattern acquisition: a production system approach" by D.A. Waterman describes a learning technique for finding regularities in sequential patterns. Learning proceeds by first assuming that only one element in a particular pattern context is relevant and then, as this is proven false, falling back to the less general assumption that other elements in that pattern context are also relevant. When the learning phase is complete, the system has learned which pattern elements are relevant given any particular pattern context. The production system learning technique presented may more closely model human sequence prediction than sequence extrapolation. The paper thus not only demonstrates an artificial intelligence implementation of sequence extrapolation, but also provides a model of human problem solving.

Speaking more in engineering terms, the papers, "Patterns of induction and associated knowledge acquisition algorithms", and "Knowledge representation, organization, and control in large-scale pattern based understanding systems" by F. Hayes-Roth provide an excellent philosophical discussion of "knowledge engineering." He points out that the major obstacles to the implementation of

complex understanding systems are: (1) representing and organizing the numerous patterns and inferential rules pertinent to the task; (2) determining what behaviors to compute and how to represent their results; and (3) organizing and controlling the computation as efficiently as possible. These problems are considered by the author. The author also examines three types of general learning problems related to pattern classification, rule induction, and syntax learning. Each of these is approached within the theoretical framework of a related pattern of induction or learning paradigm. A pattern of induction is an analytical framework which relates and organizes the various components of learning problem and its solution. Four components of the induction pattern are: (1) a model of a knowledge-based system which defines a body of knowledge or information and a behavior generating function which operates on the knowledge to produce observable behaviors, (2) a collection of observed behaviors which constitute the training data for the induction algorithm, (3) a learning algorithm which operates on the training data to infer the knowledge which produces or "causes" the observed behavior, and (4) an induction theory which relates a learning algorithm to a presumed behavior generator.

Both papers by F. Hayes-Roth emphasize on the interfaces between, and the common need of, artificial intelligence and pattern recognition. Some of the problems facing the two fields are clearly stated. "Thus, to a large extent, the immediate need for general learning procedures in AI is to automate much of the work of knowledge programming. The field of PR, on the other hand, needs general learning procedures because the conventional methods of pattern description and learning do not perform well in most complex environments. The inadequacy of the well known dimensional, parametric, and syntactic techniques of representation and classification is made apparent by their inability to contribute significantly to modern AI understanding systems. In short, the field of PR has reached a point

where its principal tools no longer seem sufficiently suited to the recognition problems being encountered. The development of general learning procedures which can generate symbolic pattern representations and facilitate improved classification in such domains is a goal of great importance for the PR field."

VIII. Computer Graphics

A major problem in three-dimensional computer graphics is that of making available to the computer descriptions of complex objects in a form suitable for various graphics manipulations. The paper "Molding computer clay--steps toward a computer graphics sculptors' studio" by B. Chandrasekaran and R.E. Parent discuss some of the issues involved in the design of an interactive minicomputer-based 3-D data generation system. It also describes the creation of a sculptor's studio-like environment, in which the "sculptors" can create complex 3-D objects in the computer, as if moulding a piece of clay in the machine. Almost all sculpting operations call the basic intersection algorithm described in the paper. The paper also discusses a fast, efficient hidden-line processing routine. The authors are concerned with the computational and implementation limitations which are important considerations in the computer graphics. Development of pattern recognition and artificial intelligence requires much man-machine interactions. Computer graphics definitely plays a significant role in both fields. Along the direction of man-machine interaction, the paper, "Displaying high-dimensional data for interactive pattern analysis" by Y.T. Chien deals with the interactive pattern recognition which becomes increasingly important in many practical applications.

IX. Game-Playing Programs

For games like chess, it is necessary not only to find the evaluation function scoring the moves or the board positions but also to control the growth of the tree. The strength of the chess grandmaster is not that he generates larger trees, but that he chooses very well the moves that he considers at every level in the tree.

Chess playing programs are very inefficient in that way: they cannot accurately judge the value of the moves, so they consider too many moves. Although computers are faster than the human brain, they cannot go as deep as a grandmaster in the tree. It would be interesting to have a program learning to choose the moves which have to be considered in the tree. The paper "A program for learning to play chess" by J. Pitrat describes a program which understands a combination, performs simplification and generalization of trees, generates procedures and can learn with or without a teacher.

Computer game-playing has always provided fun and better understanding about machine intelligence. Continued interest, which now exists, on computer game-playing will be helpful to the progress in artificial intelligence.

X. Distortion Modeling

In addition to statistical and syntactic theories in pattern recognition, distortion modeling may be considered as another, but closely related, theory in pattern recognition. The paper, "Pattern recognition using degenerate reference data" by J.R. Ullmann is one of several articles by the author which discuss this subject. This paper is concerned with distortions that map a two-dimensional space into a two-dimensional space. The distortion modeling appears to be most suitable for handprinted character recognition which is used for illustrative purpose. When the two-dimensional pattern space is distorted, the distortion takes each black point to exactly one black point in the distorted space, and the same is true for white points. Furthermore the distortion takes each point that lies on a black/white edge to a point that lies on a black/white edge. Under these assumptions, the author considers degenerate nearest neighbor method which requires one single complicated computation per class instead of one computation per reference sample, an iterative nearest neighbor method using degenerate reference data, and the experimental substitution/reject relations for Bledose and Browning's method and the proposed method. The ideas of distortion modeling given in the paper,

while remaining to be tested with different patterns, appear to be useful, after suitable modifications, for many pattern recognition and scene analysis problems.

XI. Panel Discussion Session I

The complete report of Panel Discussion on Artificial Intelligence and Pattern Recognition is given as Report A, pp. 127-176 of the workshop record. Readers are urged to consult the Record for full details. The general views among the panelists are quite different. Some feel that the two fields are essentially the same field or one problem area. E.M. Riseman describes a contrast of pattern recognition and artificial intelligence approaches to problems by examining a specific application of each to a problem of pattern inference. In pattern recognition, information about the problem is usually limited by the primitive features which define the pattern space. In AI the state-space representation is augmented by semantic knowledge of the problem domain which provides a global view of the meaning of the patterns.

Several panel members reported more specific results. A.R. Hanson and E.M. Riseman reported a general computer vision system designed to segment and interpret natural scenes. They described the data structures required for representing a visual model, and some considerations in the control structures required for interfacing processes utilizing diverse forms of knowledge. D. Kozakos described a Bayes linear feature extraction technique for a wide class of statistics. R.B. Ives considered the important problem of feature and decision function selection with the short period seismograms for the detection of nuclear detonations from seismic signatures. The seismic data base he established has been very helpful to seismic studies in the pattern recognition community. A.D.C. Holden reported two AI research areas: (1) the problem of finding, and tracking objects in cine-films or television signals with very poor quality, noisy images, and (2) the design of spoken computer language.

E.E. Gose remarked that an artificial "superintelligence" which would be able to solve a large number of problems in the broad area of pattern recognition is not available in the foreseeable future. On the other hand, "superintelligence" has already been achieved in limited areas, as the computers have already surpassed certain human abilities. J. Sklansky summarized the major characteristics and current trends of the PR-AI field in six categories: (1) model-building, (2) search strategies, (3) languages, (4) hardware, (5) knowledge-based systems, and (6) training and learning.

The strong interest in the development of PR & AI as expressed by panelists and audience has been most encouraging. Indeed, "the future is very bright" in both fields (or PR-AI field), by using the words of Dr. M.M. Andrew. Although it has appeared to be the trend in both fields that more is promised than accomplished, the hope that more can be accomplished is most significant. If one looks back into what has been accomplished in the past two decades, he will be convinced that much more can be done now and in the near future. A continuing effort that is much needed is to prove whatever technique developed to be practically feasible in certain application(s).

XII. Panel Discussion Session II

The second panel session organized and chaired by M. Weinstein is on scene analysis which is of mutual interest to both PR and AI groups. Panel members include R. Bajcsy, E.M. Riseman, J.M. Tenenbaum, and S.W. Zucker. A sketchy report of the session is on Report B of workshop Records. However, much more was discussed than was printed. The discussion was focused on different viewpoints of computer vision and implementation techniques with illustrative examples. R. Bajcsy described the analysis and description of landscape scenes with colored images. E.M. Riseman provided an overview of VISION which is a scene analysis system. J.M. Tenenbaum described a working scene interpretation program, called MSYS, in which knowledge sources compete and cooperate until a consistent explanation of

the scene emerges by consensus. S.W. Zucker reiterated the relaxation labelling process and the reduction of local ambiguity.

Scene analysis is now a rapidly growing area. Its commercial applications should be available in the near future. The development of standard data sets and portable software would be of great value in the evolution of this area.

XIII. Recommendation and Assessment for Future Development

As the pattern recognition and artificial intelligence fields become increasingly more diversified in theory and practice, great care must be taken to examine the limitations and feasibilities of all techniques. The two fields could be in trouble if useful products in software and hardware cannot be made available for many practical needs. Thus the practical applications should play a much more important role than the explosive growth of journal papers of the two fields in the next two decades. The two fields should have more interaction each other and with other fields like the new electronics technology, digital signal processing, programming languages, etc.

Further improvement of the existing techniques should have higher priority than trying new ones. This is particularly important in pattern recognition in which practical constraints make many existing techniques useless. In artificial intelligence, however, more ideas and techniques need be developed. Successful applications to many real life problems remain to be seen.

XIV. Suggestions for Future Meeting

- (1) AI in biomedicine;
- (2) Description and recognition of three-dimensional objects; 3-D object reconstruction;
- (3) New development in software and hardware;
- (4) Relation with psychology - better understanding of human recognition process and manipulation of intelligence.
- (5) Automatic theorem proving.

More AI papers are strongly recommended for future meetings.

Grant AFOSR-76-2951

List of Technical Reports (January to December 1976)

1. C. H. Chen, "On statistical and structural feature extraction", TR No. EE-76-1, May 19, 1976.
2. Patrick Ci-Chung Chen, "Seismological and reconnaissance imagery pattern recognition", TR No. EE-76-2, June 10, 1976.
3. C. H. Chen, "Comparison of feature extraction techniques in seismic pattern recognition", TR No. EE-76-3, August 16, 1976.
4. C. H. Chen, "A new software package for seismic and imagery recognition", TR No. EE-76-4, September 7, 1976.
5. C. H. Chen, "A modified gradient technique for image analysis", TR No. EE-76-5, September 15, 1976.
6. C. H. Chen, "Performance bounds of a class of sample-based classification procedures", TR No. EE-76-6, September 21, 1976.
7. C. H. Chen, "Final report of the 1976 Joint Workshop on Pattern Recognition and Artificial Intelligence", TR No. EE-76-7, December 21, 1976.