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AIR FORCE OFFICE of SCIENTIFIC RESEARCH

INFORMATION SCIENCES, 1965

ROWENA SWANSON
Directorate of Information Sciences

Co-Ce-1

OFFICE OF AEROSPACE RESEARCH
United States Air Force

Washington, D. C.

To people . . . .

To the creative people we have been privileged to sponsor;

To those who have given us inspiration and guidance;

To those who find the information sciences an exciting and challenging field,

And who are, have been, and will be devoting much of their time, intellect, and heart toward advancing knowledge and understanding of it.

Foreword

"Information" is a common word. Fewer people feel comfortable with the word "science." Put the two words together and there results a term that everyone knows something about and a sufficient number will expound on.

"Information science," in august halls, could be intoned as the major emerging discipline of our generation. But it's difficult to establish an image for something elusive, though ever present.

Man has turned his attention to "science" long enough to be able to say something about scientific method and results of taking a scientific approach to the study of phenomena. But ask a man to say something about what "information" is. He will bluster and, suddenly, toss himself headlong into intensively subjective explanations.

Shannon tried the objective approach. He neatly defined a measure of "information" capacity. But Shannon tells only about quantity of throughput. He says nothing about the meaning of the signals passing through the channel.

Subjectively, we know that "information" has to do with what the signals are about. We know that a signal can mean different things to different people. We know that meaning is a function of what a person is looking for. Why he is looking depends on his age, his mission, his curiosity, his goals--a host of variables that have yet to be defined. Whether a signal is meaningful is also related to the meaning of the signals he's already received and the meaning of the signals he expects subsequently to receive.

"Information science" is trying to apply the scientific method of inquiry to an understanding of all the factors that are embedded in the concept of information. This inquiry takes one down many paths. Perhaps the most obscure is the one man has spent the most time on--the one concerned with an understanding of himself, how he thinks, how he comes to understand, how he learns, what he wants his goals to be, and why. Perhaps the least obscure is the comparatively new route being paved by modern technology. Man has harnessed the computer and many other machines, complex concatenations of many components, to sense and process signals that he knows about but cannot see or hear or touch.

Information science may be this generation's contribution to science. It is invading this discipline and that, extracting an idea here and an equation there, and it is beginning to weave the pieces into a pattern. The picture is beginning to tell another part of the story about man and the environment he lives in. It is beginning to show features dealing with the acquisition and coding of information, the communication process, storage and recall of information, and how information is and can be used.

This volume is an account of some of today's studies of some of the problems that concern information science. Hopefully, these studies bear seeds that will flower into tomorrow's information systems and a deeper understanding of information and how this understanding can be exploited to serve man. Hopefully, this program will be able to serve the future information needs of the United States Air Force that supports it and the wellsprings of science that nourish it.

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The author wishes to acknowledge the foresight of Col. William O. Davis, Deputy Commander for Operations, AFOSR, who created a Directorate of Research Communication in 1956, forerunner of the present Directorate. Dr. Knox Millsaps established the Directorate of Information Sciences in January 1962. Active interest of Dr. William J. Price, the present Executive Director, AFOSR, in the program has been gratifying and is much appreciated.

Rowena Swanson
Acting Director
Directorate of Information Sciences

Air Force Office of Scientific Research
Office of Aerospace Research
United States Air Force

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Introduction

Essentially, this volume is an annual report, the third in a series, for calendar year 1965, of the program of the Directorate of Information Sciences, AFOSR. Since it is an annual report of a program representing the expenditure of about one million dollars, it cannot and does not purport to be a treatise on the entire field of information sciences research. One million dollars, even when spent in 25 to 35 thousand dollar chunks, doesn't go very far. However, given one million dollars for information sciences research, how does one spend it? This volume is one answer to the question.

The text consists primarily of summaries of projects that were current during calendar year 1965. The nature of funding patterns is such that some of the projects terminated during the year and some started near the year's end. Dates have not been given principally because it was not desired that termination suggest a value judgment on a project. (Information science teaches that value is not an absolute measure). The summaries, therefore, vary in content. Those for new projects consist of statements of objectives and initial directions of research. Those for projects that began early in the year or have continued from previous years include highlight results of research and a listing of publications that appeared or were written during the period. In most instances, the highlights were provided by the principal investigators for the project; the remainder of the prose is the author's.

The selection of areas and projects for funding is made within the Directorate. Selection is a product of many factors, not the least of which is total available budget. Guidance is obtained from experts, and has proved very helpful. Insofar as the Directorate staff is small, sponsorship of a few large-dollar projects to reduce paperwork is a constant attraction. However, large projects receive support under ARPA, Joint Services, and other auspices. The Directorate has elected a different route, keyed to what it believes are current needs in information sciences research. The Directorate has turned its attention to studies in depth of some of the fundamental principles that must be explored and understood to advance basic concepts of information representation and processing. At this stage in the evolution of the information sciences, these studies fortuitously are often efforts of one person or small teams. Though this is a familiar pattern in science, it must be remembered that this is but one pattern in science.

Emphasis in the late 1950's with a much smaller budget was on such library-oriented topics as indexing and classification and the applicability of machines to information-center operations. Gradual shift to the present program has resulted as much from an awareness of engineers, physiologists, physicists, psychologists, mathematicians, linguists, and philosophers that they were dealing with information science problems as it did from an awareness of the Directorate that problems in many disciplines are basically information problems. The tasks within the program are as follows:

1 - Information systems research
2 - Information identification and classification
3 - Transmission of information
4 - Adaptive and self-organizing systems
5 - Language and linguistics research
6 - Theoretical foundations of information sciences

These tasks do not encompass all of the information sciences, nor could they from the given budget. Several major areas that are excluded concern studies of materials, hardware components and assemblies, structure and behavior of biological systems, and large-scale man-machine and time-sharing interactions. Most of the excluded areas are included in other AFOSR and DoD programs. Inclusion and exclusion are, of course, value judgments, but value, as indicated above, is based on a variety of considerations. Amplifying comments on the tasks begin each of the next six sections. It can be seen that the tasks are not mutually exclusive.

A further remark may be appropriate with respect to inclusion and exclusion. Given one million dollars and a mission--for the Directorate, to help assure the timely impact of information science on the future operational Air Force--selections have been made which are identified with technological problems of Air Force interest. Additionally, we believe that we are sponsoring pioneering research on logical foundations and design structures for systems exhibiting intelligent activities. In the field of transmission of information, which receives its major support elsewhere, we sponsor connecting research to maintain involvement consonant with our mission.

The Directorate is headed by Dr. Harold Wooster, who has been detailed to the office of the Director of Technical Information, Director of Defense Research and Engineering, to act as Executive Secretary of the Panel on Information Sciences Technology, Committee on Scientific and Technical Information, Federal Council on Science and Technology, Office of Science and Technology, Executive Office of the President, for Fiscal Year 1966. Thomas K. Burgess, Captain, USAF, terminated his service in December. The author is therefore obliged to accept such comments as may be made on this volume.

Section 1. Information Systems Research

Information systems research looks at the structure and operation of entire systems or of units within a system viewed in the framework of the entire system. Efficiency and effectiveness of methods and tools for the input, throughput, dissemination, and use of information are principal topics for investigation.

Information systems abound. They are used for document control, data control, logistics, management and command, and intelligence within military and civilian contexts. Many existing systems are based on ad hoc planning and have suffered explosive, unanticipated growth. Frequently mechanization or other changes have been introduced to alleviate some information processing difficulties, but the effects are usually far from optimum.

Questions must be asked about systems in the abstract. What are possible information flow patterns? With what configurations of men and machines can each be achieved? What is the match between pattern and purpose of the system? What effect does the environment have on the system? Who feeds the system? Who uses it? Who could feed it or use it? What are the tradeoffs for a given system for a given purpose?

Questions must also be asked about existing systems. Existing structures and operations must be quantitatively and realistically analyzed. The effects of perturbations must be examined in the abstract and tested in simulations and in on-going operations. Live data under perturbations are invaluable but difficult to obtain, it has been found, because of inertial forces built into people and systems.

The construction of networks of information systems is frequently discussed as a short-range objective. Nothing in principle negates the possibility of ever increasing networks. However, large-capacity machines do not per se make a system. Machines operate on instruction, whether the instruction comes from a man or another machine. At some point, there was a designer, and if he did not anticipate correctly, the last machine in the chain will not disgorge anything useful, if indeed it will disgorge at all.

Systems research is slow-producing research. There are many variables, and they are difficult to isolate, control, and test. They pertain to the behavior of men as well as to machines. They must, however, be studied, which means that ways must be found for studying them. A few questions on systems of several types and sizes are being examined in the projects summarized on the following pages.

1-1. American Society of Mechanical Engineers, New York, N. Y.

Applied Mechanics Reviews

Dr. Stephen Juhasz

AF 49(638)-1549

Objectives ....

Toward development of new approaches to the acquisition, processing, and dissemination of scientific information in the journal medium.

Project summary ....

New approaches to mechanized indexing and announcement techniques are being tested empirically in the context of an ongoing information service. Applied Mechanics Reviews is a monthly periodical which provides abstracts, in English, of papers in the field of mechanics and related sciences which originally appear in twenty-five languages and over 900 journals. AMR also provides state-of-the-art reviews, book reviews, and some translations.

Research findings ....

The second edition of the computer-produced Word and Author Index (WADEX) was published and incorporates improvements in the program recognition of word groups for selection as index terms.

Evaluations are in progress on user satisfaction with WADEX and on time delays, reviewer productivity, and value of the critical reviews in the publication, Applied Mechanics Reviews.

Publications ....

E. A. Ripperger, Harold Wooster, Stephen Juhasz, and David Falconer. WADEX, Word and Author Index. (For entries in Applied Mechanics Reviews, vol. 16, 1963). Washington, D.C.: Government Printing Office, 1965. $3.50.

E. A. Ripperger, Harold Wooster, Stephen Juhasz, and David Falconer. "WADEX, Word and Author Index. Part I - Description, Part II - Program Documentation." June 1965.

Stephen Juhasz, Harold Wooster, E. A. Ripperger, and David Falconer. "Extended Word System: Tool for Browsing, Searching and Express Information with Adjustable Intellectual Preparation Effort." Proceedings, 1965 Congress, International Federation for Documentation (FID), Washington, D.C., 10-15 Oct. 1965.

Stephen Juhasz and O. Amringer. "Critical Abstracts." Paper, Seventh Annual Institute on Information Storage and Retrieval, American University, Washington, D.C., 2 Feb. 1965.

1-2. C.E.I.R., Inc., Applied Research and Management Sciences Div., Arlington, Va.

Development of a Standardized Language for Describing Documentation Systems

Mrs. Lea M. Bohnert

AF 49(638)-1636

Objective ....

Toward systematizing methods of analyzing and evaluating operations in documentation systems and methods of assessing mechanization possibilities.

Project summary ....

Fundamental operations (e.g., routing, summarizing, sorting, searching) common to all documentation systems are being analyzed for the purpose of standardizing the description of these operations as an aid to knowledgeable modification of existing systems and the design of new systems. Results of the analysis will be used to evaluate existing documentation systems, including the structures, operations, and costs of such systems. The applicability of computer-based display techniques to documentation operations will be examined toward developing procedures of integrating machines into systems for various user needs.

1-3. Herner and Company, Washington, D.C.

Study of Indexing Procedures and Mechanisms

Mr. Saul Herner

AF 49(638)-1424

Objective ....

Toward evaluation of methods and tools employed in information systems and assessment of relationships between systems and potential and actual users.

Research summary ....

An examination is being made of indexing methods and mechanisms, the role of tools such as thesauri in information storage and retrieval systems, and the effects of and needs for information systems. Concepts of accuracy vs. precision in indexing are being compared. Data from user studies are being assessed in relation to the following areas of information system design: subject fields of user interest; language employed in the subject description; types of query and non-query services required; and tools and resources for performing the required services. A generalized model is sought for conducting user studies.

Research findings ....

Analysis of word occurrences and word combinations in the text of psychiatric interviews suggests a method for the production of thesauri and the preparation of user profiles automatically.

1-4. Lehigh University, Center for the Information Sciences, Bethlehem, Pa.

Study of the Man-System Interface in Libraries

Mr. Robert S. Taylor

AF-AFOSR-724-66

Objective ....

Toward developing a "new look" for libraries and present and possible operations from the viewpoint of the library as an information system.

Project summary ....

Based on the postulate that the library is (or can be) an evolutionary information system, the various user-library interface points are being analyzed, with a view to merging results with results of library system studies and man-machine studies. Tests of new interface structures are planned as suggested from analysis of the merged results. Particular emphasis is being given to understanding the processes involved in "negotiating the question" of users in both test and real-system situations.

Research findings ....

See Lehigh University, AF-AFOSR-724-65.

1-5. University of Montreal, Institute of Experimental Medicine and Surgery, Montreal, Canada

Analysis of Information Storage, Search and Retrieval Processes

Dr. Hans Selye and Dr. Giulio Gabbiani

AF-AFOSR-930-65

Objective ....

Toward specification of factors affecting the use of information retrieval systems.

Project summary ....

A notation system for representing detailed scientific information content, called the Symbolic Shorthand System, is being examined for its amenability to subject expansion and its utility for information retrieval. A unique data base in the medical science literature is the test corpus. Experiments are being conducted to qualitatively evaluate the documentation service based on the notation system. The experiments have been designed within the environment of on-going service operations.

Research findings ....

Preliminary interaction with a potential user population for a specialized information service provides contradictory results; on the one hand, enlistment of users has progressed slowly, and on the other, response of the system to inquiries indicates capability of the system to retrieve at a depth and specificity not provided by other systems.

1-6. *University of Pennsylvania, Moore School of Electrical Engineering, Philadelphia, Pa.*

Information System Design for the Information Processing Field

Dr. Morris Rubinoff

AF 49(638)-1421

Objective ....

Toward design of information systems tailored to user need and the development of principles and implementation criteria for mechanized information storage and retrieval systems.

Project summary ....

Organization and mechanization possibilities for an information storage and retrieval system are being examined in advance of final system design on the assumption that research rather than an ad hoc approach will result in a better system. The Association for Computing Machinery Repository and the E. E. Dept. library are being used as the test corpus. A novel approach to classification and indexing has been developed which includes transformation tables for four echelons of terms developed which includes transformation tables for four echelons of terms through open-ended mapping relationships. Continued study is planned of such features as: remote-conaole retrieval by on-line search; search of such features as: remote-console retrieval by on-line search; search strategies which maximize user-machine interaction to the exclusion of human reference assistants; and an evaluation of user search strategies for system up-grading.

Research findings ....

A user-oriented information system has been designed and is being implemented which includes remote teletypewriter access on-line to an information file in 1301 disc store auxiliary to an IBM 7040/1401 system.

The system design includes use of an unrestricted search vocabulary, access through one or more of a large number of entry ports, and stochastic-type searching through related categories, sections, and classes of data established through thesauri and microthesauri.

Publications ....

Morris Rubinoff and John F. White, "Establishment of the ACM Repository and Principles of the IR System Applied to its Operation." Communications of the ACM, vol. 8, no. 10 (Oct. 65) 595-601.

"ACM Repository." (A selection of 100 entries from the 1300 document file.) Computing Reviews, vol. 6, no. 6 (Nov-Dec 65) 437-447.

1-7. Purdue University, Thermophysical Properties Research Center, West Lafayette, Ind.

Machine Processing Techniques for Reference Text Production

Dr. Yeram S. Touloukian

AF 49(638)-1371

Objective ....

Toward methods and techniques for computer generation of indexes and statistical records from raw reference text data.

Project summary ....

The feasibility is being explored of recording raw reference text data in machine interpretable form in a single manual operation so that the separate requirements of typographic composition, selective data extraction, and data retrieval are simultaneously satisfied. The test corpus is the input for several volumes of the series, Masters Theses in the Pure and Applied Sciences. Study is planned on the feasibility of extending the methodology to cumulations, to related collections of raw data, and to the value of the data for statistical analyses, including analyses of trends in graduate research.

Research findings ....

A modified IBM standard program was tested on Volume VI, Masters Theses, data and was found unsatisfactory both in operation and format.

A new set of criteria have been established for the Masters Theses data and a new program has been developed and tested which incorporates a statistical analysis of the effectiveness of the preparation of author indexes by a new method.

1-8. *Rutgers University, Graduate School of Library Service, New Brunswick, N.J.*

Scientific Bases for Information Processing

AF-AFOSR-531-64; AF-AFOSR-531-66

Dr. Ralph R. Shaw

Objective ....

Toward specification of efficient operations in information handling systems.

Project summary ....

Basic principles pertaining to storage, retrieval, and indexing operations and comparisons and evaluations of systems and indexing techniques are being made for the structuring of more efficient information systems. Previous studies have examined such problem areas as: automatic book indexing by computer; the scope and operating efficiencies of information centers; book vs. card catalog costs; and the comparative performance of three information retrieval systems. Present emphasis is on: (a) the scope of activities in information centers and the knowledge and skills required for performance, and (b) citation indexing as a reference-retrieval system.

Research findings ....

A framework for describing the index as a system has been established for the comparison of citation indexing and subject indexing in the field of genetics.

1-9. System Development Corp., Santa Monica, Calif.

Information Processing Potentials in Large-Scale Operations

Dr. Beatrice K. Rome and Dr. Sydney C. Rome

Part of AF 19(628)-5166

Objective . .

Toward specification of the information policies and command behavior in complex, large-scale systems in precisely observable and measurable terms.

Project summary ....

Hierarchies in the organization and management of large-scale systems are viewed as incorporating structures of intentional logic, including such concepts as relevance, valuation, condensation, filtering, and intentional reference. Formal quantitative system models are being simulated to study shifts and developments of interaction over time in a large information processing organization under rapidly increasing load. The models are poly-nets and incorporate authority trees, functional specialization, groupings of technical competence, feedback patterns, communication trees, and demand tables of crisis urgencies.

Research findings ....

Principles and techniques have been developed to structure, formalize, and computerize higher-order executive intentional transactions in large-scale information-processing operations. These include decision making, contingency planning, procedures and norm formation, and authority allocation.

Publications ....

B. K. Rome and S. C. Rome. "Leviathan, and Information Handling in Large Organizations." A. Kent and O. Taulbee, eds., Electronic Information Handling. Washington, D.C.: Spartan Books, Inc., 1965, 161-192.

B. K. Rome and S. C. Rome. "Leviathan." SDC Magazine, vol. 8, no. 4 (April 1965) 17-26.

B. K. Rome and S. C. Rome. "Automated Learning Process (ALP)." R. V. Bowers, ed., Studies on Behavior in Organizations: A Research Symposium. Athens, Ga.: University of Athens Press, in press, 312-347.

B. K. Rome and S. C. Rome, "Leviathan: An Experimental Study of Large Organizations with the Aid of Computers." Ibid., 257-311.

B. K. Rome and S. C. Rome, "Executive Decision Making in Large Organizations: The Next Generation Leviathan Research." Submitted to American Scientist.

B. K. Rome and S. C. Rome, "A Phenomenological Approach to Computer-Based Large-Group Experimentation." J. F. T. Bugental, ed., Humanistic Psychology Today, in press.

1-10. Western Reserve University, Center for Documentation and Communication Research, Cleveland, Ohio

Search Strategy in Information Retrieval

Dr. William Goffman

AF-AFOSR-403-65; AF-AFOSR- -66

Objective ....

Toward mathematical description and structuring of efficient communication techniques required for reliable information transmission systems.

Project summary ....

Strategies are being postulated and evaluated for querying, searching, and manipulating information stores. Attempts are being made to develop an abstract description and analysis of the search process, and to establish procedures for achieving retrieval that is responsive to user needs. Mathematical models are being formulated based on two concepts of epidemic theory as applied to the transmission of information. The first model uses intermediary hosts as carriers in an open population; the second uses a migrating population concept. Experiments are planned for comparing human and computer performance in searching tasks.

Research findings ....

Through application of Lyapunov's direct method and Pontryagin's maximum principle to the study of communication processes as epidemic processes, the state (i.e., stable or unstable) of a communication process has been determined as well as those admissible controls which will optimally produce the desired state.

Publications ....

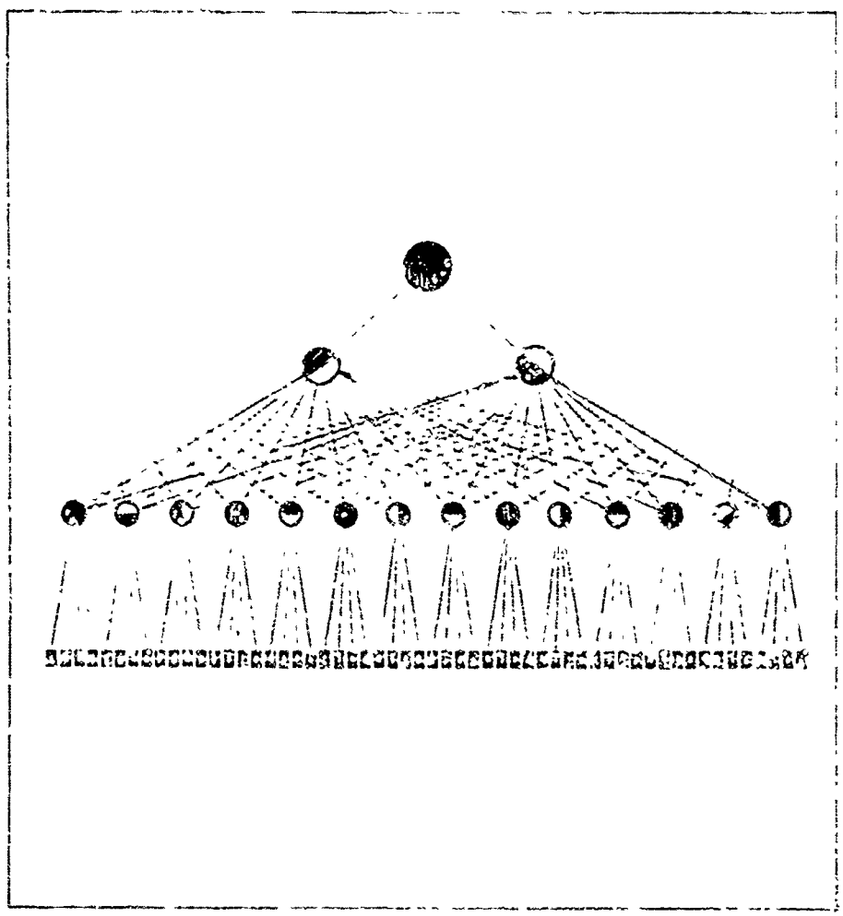
William Goffman. "An Epidemic Process in a Open Population." Nature, vol. 205, no. 4975 (20 Feb 65) 831-2.

William Goffman. "On the Logic of Information Retrieval." Information Storage and Retrieval, vol. 2 (1965) 217-20.

William Goffman and Vaun A. Newill. "Communication and Epidemic Processes." In preparation.

William Goffman. "A Mathematical Model for Describing the Compatibility of Infectious Diseases." In preparation.

William Goffman. "A Stability Theorem for an Epidemic Process with Migrating Populations." In preparation.



Adaptation from B. K. and S. C. Rome

"Programming the Bureaucratic Computer," 1964

Section 2. Information Identification and Classification

The problem of selecting appropriate descriptors of information and organizing them into a structure was originally thought of as a library-type problem. It is still a crucial problem of information service activities handling the technical document literature. Conventional library classification schemes are not readily amenable to frequent and major modifications of narrow subject areas which must be accessed in specificity and depth as research expands knowledge of them. Conventional library indexing practices can similarly not readily accommodate to current requirements for many terminological access points to the subject content of documents.

The problem of identification and classification has, however, been aggravated by a technology that has produced computers and sensors. Machines that can "read" printed and handwritten characters and can "look at" maps and photographs need instructions to tell them how to recognize a pattern and how to differentiate one pattern from another. This raises the question of how to describe a pattern. What are the information-bearing parameters in a line drawing, in a letter of the alphabet, in an aerial photograph? Are the bits that are significant to a human significant to a machine? Can rules or algorithms be developed that can give machines the intelligence to identify patterns they haven't seen before and to separate signals from noise?

Projects concerned with both categories of problems pertaining to classification are included in this task. It will probably be advisable to subdivide the task in the future. Descriptor structures for document systems are frequently related to other aspects of total system organization and operation. As methods are perfected for mechanizing useful indexing procedures, new approaches to input, search and retrieval can be explored and incorporated in systems. Work with natural language may also lead to abstractions pertaining to syntactic and semantic structures in language (see Section 5). Clarification of the pattern recognition process, on the other hand, is becoming a problem of artificial intelligence (see Sections 4 and 5). Rules that characterize the process must describe procedures by which machines can learn from experience and can adjust or adapt to new inputs. How patterns are coded also bears on information content and information loss in their transmission (see Section 3).

The possibility exists that models for characterizing patterns will also describe concepts represented by clusters of word descriptors. The data base for such determinations is sadly lacking.

2-1. *University of Arizona, Analog/Hybrid Computer Laboratory, Tucson, Arizona*

A Study of Performance, Design, and Organization of Hybrid Computer Systems

Dr. Granino A. Korn

AF-AFOSR-89-65

Objective ...

Toward design and construction of novel types of hybrid analog/digital computers.

Project summary ...

Research centers on the design of components for and computational procedures with the ASTRAC II (Arizona Statistical Repetitive Analog Computer), an all-solid-state iterative differential analyzer that employs ±10 v, transistor amplifiers with a unity-gain bandwidth beyond 20 mc and very low computing impedances. Emphasis is being given to studies on: parameter and functional optimization; Monte-Carlo studies of random processes; the computation of statistical data with coarse quantization; and operations beyond simple averaging. Applications of the ASTRAC II delay-line memory are being explored to such problems as the solution of integral equations, partial differential equations, correlation experiments, and programming for variable time delays.

Research findings ...

Studies of a hybrid-code differential analyzer system demonstrated possible tradeoffs between computer accuracy and speed and verified results predicted by Skramstad's original theory. It is anticipated, however, that the system will be overtaken by improved all-digital differential equation solvers.

A simple digital-display multiplexer was developed for the ASTRAC II which permits simultaneous display of four digital-logic outputs on a single oscilloscope without analog switching.

Publications ...

Emmett P. O'Grady, "A Hybrid-Code Differential Analyzer," ACL Memo No. 87, April 1965.

R. L. Maybach, "Generation of Inverse Functions by the Method of Steepest Descent," ACL Memo No. 120, June 1965.

Granino A. Korn and Robert H. Whigham, "Oscilloscope Display of Multiple Digital Signals," ACL Memo No. 116, Sept. 1965.

"Hybrid Computers and Monte-Carlo Techniques, 1964-1968," EES Series, Rept. No. 8, (4 papers).

All ACL memoranda partially sponsored by this grant are not listed here. See "List of ACL Publications," ACL Memo No. 105, rev. April 1965.

2-2. *Florida State University, Library School, Tallahassee, Fla.*

Analysis of Personal Index Structures and Uses

Dr. Gerald Jahoda

AF-AFOSR-895-65

Objective ...

Toward determination of patterns of information-gathering habits of scientists for the design of useful storage and retrieval systems.

Project summary ...

A case-history analysis is being made of the personal index practices of a selected group of scientists both to characterize these practices and attempt to determine operating patterns by which information centers could more usefully serve as information sources. Experiments are planned on examining the variables affecting the interface between the information specialist and the scientist. Effectiveness of the personal index will be analyzed. The personal index will also be evaluated as a means of determining index profiles and as a means of indicating significant areas of scientific research.

Research findings ...

Case histories of personal index use are being obtained on a regular basis, and subject searches are being examined to compare indexing approaches.

Publications ...

Gerald Jahoda, Ronald D. Hutchins, and Robert R. Galford. "Characteristics and Use of Personal Indexes Maintained by Scientists and Engineers in One University." Submitted to American Documentation.

2-3. *University of Hawaii, Graduate Dept. of Oceanography, Honolulu, Hawaii*

Linear Network Theory and Pattern Recognition

Mr. A. Timothy Ewald and Dr. Gordon Groves

AF-AFOSR-1041-66

Objectives ...

Toward methods for detecting meaningful patterns in noisy systems and for quantitatively measuring and categorizing them for automatic decision systems and learning networks.

Project summary ...

Linear separability techniques can fall short in dividing data sets into discrete classes that are meaningful, since the physical world is not linear. This effort employs primarily linear techniques, but is examining the identification process with respect to discovering differentiating descriptors and associations among descriptors that can provide analytic relationships for describing the phenomenological world. Point radar waveforms are being used as the principal source of data. Preliminary results suggest that a relaxation of convergence criteria will lead to quantitative classification procedures for identifying detectible pattern information, possibly through the use of secondary signal cues.

Research findings ...

See General Electric Co. (Temp), AF 49(638)-1520

2-4. *Herner and Company, Washington, D.C.*

Unification of Theory and Empiricism in Information Retrieval

Mr. Robert A. Fairthorne

AF 49(638)-1427; AF 49(638)-1617

Objective ...

Toward unification of empirical observations (i.e., documentary notions) and theoretical results (e.g., mathematical representations) for precision in designing and operating information systems.

Project summary ...

Studies are being made of: (a) combinatorial properties of retrieval systems, largely those resulting from the structure of their vocabulary; (b) fundamental working characteristics of retrieval systems; and (c) bases and rational aims of documentary activities. A theory of minimal (i.e., necessary but not sufficient) documentary activity is being developed based on observations that all linguistic situations involve triadic relations; that documentation on any level must involve message, channel, code, source, designation, and destination; and that the first problem of documentation is bringing together appropriate messages and appropriate destinations. A method is being developed for displaying the performance of systems that uses all-but-not-only and only-but-not-all duality considerations.

Research findings ...

Examinations have been made of the various distinct entities blanketed by the words "information" and "relevance;" there is no self-subsistent entity called "information" that is shared and conserved in common by all activities as ordinary forms of speech suggest.

The all-but-not-only and only-but-not-all duality discloses that, whatever the methods and procedures, rejection of more than a certain minimum of acceptable items and selection of more than a certain minimum of unacceptable items cannot be avoided in any retrieval system.

Publications ...

Robert A. Fairthorne. Rapporteur's report, Session on Collection Dynamics and Relevance. Proceedings, International Study Conference on Classification Research, Elsinore, Denmark, 14-18 Sept. 1964. Copenhagen: Munksgaard, 1965.

Robert A. Fairthorne. "'Use' and 'Mention' in the Information Sciencies." Proceedings, Symposium on Education for Information Science, Warrenton, Va., 7-10 Sept. 1965. Washington, D.C.: Spartan Books, Inc., 1965, 9-12.

Robert A. Fairthorne. "Notification Theory." Abstracts, 1965 Congress, International Federation for Documentation (FID), Washington, D.C., 10-15 Oct. 1965, 66.

2-5. *Institute for Scientific Information, Philadelphia, Pa.*

Citation Index Studies for Information Control

Dr. Eugene Garfield; Dr. Irving Sher

AF 49(638)-1547

Objective ...

Toward methods of tracing and predicting patterns in the genesis, development, and use of scientific theories and results.

Project summary ...

The citation index is being evaluated as an objective measuring tool for tracing the use of reports and communications by scientists. The test corpus is a machine-stored file of approximately two million citations from over 600 journals in the physical, mathematical and life sciences, primarily for 1960-1961 literature. Trends in the citation patterns will be critically examined.

Research findings ...

Comparison studies of Science Citation Index and Index Medicus showed earlier announcement in the quarterly and annual editions of SCI than in the monthly and annual IM's for a random group of journals having common coverage.

Studies of citation patterns in U.S. patents show that about half of the citing patents differ, even on the broadest generic component of the classification assigned to the patent, from the cited patent.

Publications ...

Eugene Garfield. "World Brain or Memex--Mechanical and Intellectual Requirements for Universal Bibliographic Control." Paper, Eighth Annual Summer Symposium on the Foundations of Access to Knowledge, Syracuse U., 30 July 1965.

2-6. *Institute for Scientific Information, Philadelphia, Pa.*

Computer Indexing For Information Retrieval

Dr. John O'Connor

AF 49(638)-1300

Objective ...

Toward determination of the feasibility of indexing natural language text by machine.

Project summary ...

Several problems associated with machine generation of indexes are being investigated: (a) exceptions arising in the application of thesaurus rules for the retrieval of documents; (b) identification of necessary and sufficient sections of text for indexing purposes; (c) definition of the concept of satisfactory retrieval within the context of indexing systems and retrieval goals; and (d) formalization of the bases that humans use in indexing.

Research findings ...

Computer rules for identifying papers concerned with "toxicity" were at least as successful as human-indexer methods, but machine indexing falsely identified as many papers as it correctly identified, whereas human indexers rarely overassign terms.

Automatic indexing of the concept "toxicity" was reduced to the above level only by the application of a number of rules, including relative frequency, syntactic centrality, first sentence-first paragraph, etc., and was not as "successful" with the concept "penicillin."

Publications ...

John O'Connor. "Automatic Subject Recognition in Scientific Papers: An Empirical Study." Journal of the Association for Computing Machinery, vol. 12, no. 4 (Oct. 65) 490-515.

2-7. Lehigh University, Dept. of Philosophy, Bethlehem, Pa.

A Formal Theory of Conceptual Affiliation for Document Reconstruction

Dr. Donald J. Hillman

AF-AFOSR-1028-66

Objective ...

Toward construction of a notationally and algorithmically simple grammar for machine processing of natural language text.

Project summary ...

Logical and epistemological considerations are being combined with linguistic studies to develop the fundamental concepts for a grammar for retrieval purposes. A theory of conceptual affiliation is being formulated to supply the logical foundation of a process by which characteristic terms may be organized into coherent document-forming sets. Logical refinement of the notions of term-term and document-term associations will be made toward the construction of a grammar for machine processing of text.

Research findings ...

See Lehigh University, AF-AFOSR-724-65

2-8. *University of Michigan, Sensory Intelligence Lab., Ann Arbor, Mich.*

Theoretical Frameworks for Pattern Recognition Problems

Dr. Wilson P. Tanner, Jr. and Mr. Richard F. Arnold

AF-AFOSR-367-65

Objective ...

Toward explication of the pattern recognition process, by operations it is implicitly assumed that man performs as a pattern recognizer.

Project summary ...

It is assumed that pattern recognition consists of the following operations: input weighting and storage; decomposition on a mixed distribution of stored input; estimation of the parameters of the distributions determined by the decomposer (the parameters defining the elementary codes from which patterns are constructed); statement of the pattern set and associated probabilities based on all (distant and recent) of the prior state of knowledge; and storage of experience. Research centers on the following parametric statistical problem: given a statistical sample from a population which is known to be a mixture of populations of a known parametric form, determine the composition of the mixture. Use is being made of the transform domain for multivariate cases based on the assumption of a random sample drawn according to an n-dimensional probability function f(X), where f(X) is the weighted sum of r summand functions, $f_i(X)$, where r may or may not be known, some or all of the v_i's may not be known, and the parametric forms of the $f_i(X)$ are the same and known but the parameter values are generally different and not known.

Research findings ...

A method has been devised for estimating the Fourier expansion of an arbitrary continuous probability function over an n-dimensional finite rectangular domain using only a finite sample drawn from the function. Relationships of the sample size to the estimates are being investigated. This forms the basis for the decomposition of weighted sums of n-dimensional normal probability functions using Medgyessy-type linear operators.

Publications ...

Richard F. Arnold and Donald L. Richards, "Monotone Congruence Algorithms," Technical Rept, No. ISL-65-2, April 1965.

Richard F. Arnold and Donald L. Richards, "Monotone Congruence Algorithms," Accepted for publication, Information and Control.

2-9. *New York University, Dept. of Electrical Engineering, Bronx, N.Y.*

Pattern Analysis of Planar Geometric Configurations

Dr. Herbert Freeman

AF-AFOSR-24-65; AF-AFOSR-24-66

Objective ...

Toward digital-computer analysis of complex geometric patterns.

Project summary ...

Problems concerned with the analysis, classification, and smoothing of graphical, line-drawing type data are being investigated. The studies concern: (a) intrinsic information-bearing features of line drawings and their use in developing classification hierarchies; (b) methods for "segment fitting," with emphasis on those that are orientation invariant; (c) smoothing of line-drawing data; and (d) the detection of specific features, in particular, sharp slope discontinuities (corners).

Optimum solutions are also being sought for the two-dimensional allocation problem, i.e., minimizing waste and cost in scheduling, making layouts, etc., for various shape restrictions.

Queuing problems are also being studied for a communication system in which two or more digital computers are linked with a significant delay; the computers can transmit or receive, but cannot do both simultaneously.

Research findings ...

A formal mathematical model for contour maps was developed which greatly facilitates the solution of contour map problems.

An algorithm was developed for the two-dimensional "hidden-line" problem.

A solution was found for the message interference problem in a two-way computer communication system with transmission delay.

Publications ...

S. P. Morse. "Computer Storage and Analysis of Contour Map Data," Feb. 1965. NYU Technical Rept. No. 400-106.

Jerome Feder and Herbert Freeman. "Segment Fitting of Curves in Pattern Analysis Using Chain Correlation." March 1965. NYU Technical Rept. No. 400-108.

S. P. Morse, "Analysis of a Contour Map on a Closed Surface," Sept. 1965. NYU Technical Rept. No. 400-123.

Philip Kaszerman, "A 'Region' Concept and Its Application to Threshold Logic," Information and Control, vol. 8, no. 5 (Oct. 1965) 531-551.

S. P. Morse, "A Mathematical Model for the Analysis of Contour Line Data," Oct. 1965. NYU Technical Rept. No. 400-124.

Jerome Feder and Herbert Freeman, "Digital Curve Matching Using a Contour Correlation Algorithm" Accepted for publication, IEEE International Convention Record, March 1966.

Herbert Freeman, "Pattern Analysis of Planar Geometric Configurations," In preparation.

2-10. Sperry Rand Corp., Univac Division, Blue Bell, Pa.

Optimization and Standardization of Information Retrieval Language and Systems

Dr. Gilbert Kaskey and Mr. Earl G. Fossum

AF 49(638)-1194

Objective ...

Toward specification of optimum file organizations for real-time, low-cost information storage and retrieval systems.

Project summary ...

Studies are in progress on (a) an analysis of parameters related to file partitioning for optimization of organization and search time; (b) development of an automatic indexing and search system having general applicability; and (c) definition of the functional specifications for a real-time, low-cost, efficient information processor through integration of the logic and computing capabilities of machines with the coding, storage and retrieval requirements of the information system.

Research findings ...

It has been found that index-term associations tend to be used without recognition of implicit relationships in the structure of the thesaurus for the vocabulary of an information storage and retrieval system, with the result that large-scale data storage and processing requirements are generated which may not be necessary.

Criteria have been developed for determining optimum file organization based on specified system parameters: document sequenced, inverted sequenced, and "chained" organization of the index term file.

Publications ...

Earl G. Fossum and Gilbert Kaskey. "Some Notes on the Use and Data Processing Aspects of Association Factors in Information Storage and Retrieval Systems." Rept. No. 5, March 1965.

2-11. *University of Toronto, Dept. of Industrial Engineering, Toronto, Canada*

Compendium of the Distributions of Mathematical Statistics and Applications

Dr. Samuel Kotz

AF-AFOSR-1009-66

Objective ...

Toward production of a bibliographic and reference tool for research in statistics and the information sciences.

Project summary ...

A compendium of statistical distributions is being compiled which will contain compact but detailed descriptions of the distributions, properties of the estimated parameters, and examples from major areas of their application. Source materials for the compendium include a substantial number of non-U.S. papers, including Russian materials, that are being analyzed in the original languages. Over forty distributions and their variations and generalizations are being considered.

2-12. *Westat Research Analysts, Inc., Denver, Colo.*

Theoretical Foundations for Associative Retrieval

Dr. Edward C. Bryant

AF 49(638)-1484; AF 49(638)-1671

Objective ...

Toward mathematical formulation of the association relationships among concepts represented in language descriptions in documents.

Project summary ...

Formulas are being developed for associating index keys with search keys when these keys are not identical for effective retrieval from information stores. The sets of keys are being related by a linear transformation. Conditions or restrictions that must be imposed on the transformation, and optimization of the transformation are being investigated.

Research findings ...

Formulas were derived which quantify the improvement in retrieval that can be expected through the use of associative methods for correcting underindexing in zero-one indexed files.

Publications ...

Edward C. Bryant, "A Status Report on Research in Information Retrieval," Paper presented at a program on Management Information Systems and the Information Specialist, Purdue U., 12-13 July 1965.

Edward C. Bryant, Donald T. Searls, and Robert H. Shumway, "Some Theoretical Aspects of the Improvement of Document Screening by Associative Transformations," AF 49(638)-1484, final rept., Nov. 1965.

Section 3. Transmission of Information

It is an understatement to say that many mechanisms exist by which information is transmitted. A simple organism can have a multiplicity of sensors for orientation in and adaptation to its environment. Man has mechanisms within mechanisms compounded by his higher animal abilities of perception, awareness, and thought. Physical systems display order, a balancing of cause and effect, and adaptation that suggest other mechanisms that may be disclosed as man probes space.

Living systems present a challenge to man's understanding of information processing. In packages smaller than he can fabricate, complex processes occur that he cannot yet model. What are the algorithms for seeing, for hearing, for remembering, r forgetting, for integrating one bit of information with another, for making quantum jumps in thought that lead to creative syntheses? How are impulses sensed, sorted, coded, transmitted, stored, recalled, evaluated? How are judgments made and decisions reached? How do organisms communicate with each other, and, in particular, how effectively does man communicate with man? Inquiry into information transmission mechanisms ranges from studies of interactions at the subcellular level to those among men and between men and machines.

This task principally sponsors connecting-type research (see Introduction). The NIH, psychology and physiology branches of other agencies, as well as the Directorate of Life Sciences, AFOSR, have major programs directed toward answers to some of the above questions. However, other sponsors are not necessarily concerned with information science objectives that seek isolation of information-bearing parameters, models of information-processing mechanisms, and techniques for improving communication processes. Since the range is broad and the budget is small, only a few projects can be supported. They highlight the difficulties that are inherent in attaining information science objectives and suggest rates of progress that could be achieved toward their attainment.

J-1. University of Birmingham, Neurocommunications Research Unit, Birmingham, England

Studies in Neurocommunications (The Role of Inhibition in Information Transfer)

Dr. Ian C. Whitfield

AF-EOAR-115-63

Objective ...

Toward understanding methods for filtering, coding, storing and transmitting patterns along pathways having apparently limited capacities.

Project summary ...

Studies are being made of changes in the coding pattern that occur when the pulse pattern in the auditory nerve is transformed by passage through the cochlear nucleus. The input/output transformation has been related to the interconnections of the units within the nucleus and the interplay of excitatory and inhabitory channels. A method has been devised using a micro-tap for releasing drugs into the "space" around the test cell to study the transformation model.

Research findings ...

Several pieces of evidence strongly suggest that acetylcholine is the synaptic transmitter for one of the centrifugal nervous pathways from the higher centers terminating in the cochlear nucleus. The channel appears to operate a "normally closed" gate for controlling sensory information passing through the nucleus, since blocking the pathway results in the response to an input being cut off, whereas its activation lowers the sound threshold.

Publications ...

S. D. Comis and I. C. Whitfield, "The Effect of Acetylcholine on Neurones of the Cochlear Nucleus." Accepted for publication in Journal of Physiology.

3-2. *General Dynamics Electronics, Research Division, Rochester, N.Y.*

Communication and Information Theory Aspects of the Nervous System

Dr. Eugene Agalides

AF 49(638)-1470

Objective ...

Toward determining the multicoding-unichannel and multicoding-multichannel phenomena in living systems for applicability to the synthesis of composite channels and complex networks.

Project summary ...

This study is quantitatively investigating the performance of various cutaneous sensory transducers and their relationships to higher nervous centers to determine network structures and coding patterns. Coding and information theory aspects of the signal responses of skin sensory receptors and nerve endings to sirgle, paired, and triple stimuli are being examined. Data on frequency-amplitude-excitation relationships are expected to clarify such phenomena as differences of response by anatomically similar but functionally different receptors, variances in threshold produced by habituation, and selective discrimination and extinction of signals. The data may provide a by-product by indicating tolerance levels for man to acoustic pressure and frequency in the performance of such information processing tasks as hearing, speaking, and thinking.

Research findings ...

The Pacinian corpuscle, a pressure sensory receptor of the skin of primates, was found to respond to a multitude of stimuli; the threshold to acoustic stimuli varied with frequency.

Lorenzini Ampullae, multiple sensory elements in the skins of fish, appear anatomically similar in different species but experiments on the Negaprion Brevirostris (lemon shark) and other species show physiologically selective functioning, for example to pressure, temperature, and electric stimuli.

Publications ...

Eugene Agalides. "Biophysical Communications, 1964 Research Report." Rept. No. GD-1465-12. July 1965.

3-3. *Indiana University, Hearing and Communication Lab., Bloomington, Ind.*

Auditory Signal Detection, Correlation and Transmission

Dr. James P. Egan

AF-AFOSR-548-65; AF-AFOSR-548-66

Objective ...

Toward specification of human performance and system efficiency in several common perception and decision-making situations.

Project summary ...

The theory of signal detectability is being applied to the fundamental detection problem in the context of auditory detection in the formulation of a theoretical model, called the method of free response, for analyzing listener response to auditory signals. (The theory of signal detectability, a normative theory which describes the performance of an ideal observer who uses all relevant information available to him to arrive at a "best" decision, has provided a framework for the reformulation of certain problems in the field of psychophysics). Research is principally concerned with phenomena associated with masking-level differences. Two models of the action of the binaural processing system are being studied: (a) an equalization/cancellation model which assumes that the inputs from both ears are equalized and then cancelled by a subtraction process, and (b) the Jeffress model which postulates that a phase difference results between the two waveforms, one at each ear, when the signal is added to the noise, and the phase difference is the stimulus cue for detection.

Research findings ...

The detection of a sinusoid against a background of continuous noise is markedly improved under appropriate conditions of binaural listening. The release from masking is diminished by about five decibels when the noise and the signal are turned on and off together, a result having implications for theories of binaural unmasking.

When the same noise is presented continuously to both ears, and when sinusoidal signals of different frequencies are also presented, one to each ear, a release from masking occurs. The filter characteristic of the binaural processing system was estimated by measuring the amount of release from masking as a function of the difference in frequency between the two sinusoids, one at each ear.

Publications ...

James P. Egan, William Lindner, and Dennis McFadden. "Masking-Level Differences and the Form of the Psychometric Function." Journal of the Acoustical Society of America, vol. 37 (1965) 1181(A).

James P. Egan. "Masking-Level Differences as a Function of Interaural Disparities in Intensity of Signal and of Noise." Journal of the Acoustical Society of America, vol. 38 (Dec. 1965).

James P. Egan and William Benson. "Lateralization of a Weak Signal Presented With Correlated and With Uncorrelated Noise." In manuscript.

3-4. *University of Michigan, Communication Sciences Lab., Ann Arbor, Mich.*

Problems in Speech Communication and Automatic Speech Recognition

Dr. Gordon E. Peterson and Dr. June E. Shoup

AF-AFOSR-595-65

Objective ...

Toward formulation of a general phonetic theory, a general phonemic theory, and a set of logical procedures for converting the information-bearing acoustic and linguistic parameters of speech to a discrete code.

Project summary ...

To achieve speech communication with a digital computer, the computer must be able to accept and interpret a speech input (automatic speech recognition) and to produce a speech output (automatic speech synthesis). In prior research in this project, a general phonetic theory and a phonemic theory have been formulated, and a programmable set of logical procedures have been developed for converting acoustic parameters to sets of phone types. The sets of phone types can be converted to phonemes by reference to an allophonic environmental statement for the various phonemes. Research is continuing on: (a) a theory of phonology, particularly prosodemic theory and the relation between phonology and grammar including lexicon and syntax; (b) logical procedures for interpreting the acoustic parameters of speech; and (c) a structural description of the phonology of midwestern American English for an understanding of linguistic requirements independent of lexical and grammatic information needed for the conversion of phone types to orthographic sequences. The theories are being reduced to algorithms for computer processing.

Research findings ...

A general phonetic theory based on the physiological parameters of speech production has been completed.

An investigation of the essential elements of an acoustic phonetic theory has been completed.

Publications ...

Gordon E. Peterson and June E. Shoup. "A Physiological Theory of Phonetics." Journal of Speech and Hearing Research, vol. 9, no. 1 (March 1966)

Gordon E. Peterson and June E. Shoup. "The Elements of an Acoustic Phonetic Theory." Journal of Speech and Hearing Research, vol. 9, no. 1 (March, 1966)

Gordon E. Peterson and June E. Shoup. "Glossary of Terms from the Physiological and Acoustic Phonetic Theories." Journal of Speech and Hearing Research, vol. 9, no. 1 (March, 1966)

3-5. *Montana State University, Dept. of Speech, Missoula, Mont.*

Model and Measures for the Human Communication Process

Dr. Forrest L. Brissey

AF-AFOSR-62-214; AF-AFOSR-878-65

Continuation under University of Oregon, AF-AFOSR-1055-66

Objective ...

Toward identification of potentially significant parameters of the human communication process and methods of measuring them.

Project summary ...

Procedures are being developed for measuring communication effectiveness in terms of the non-verbal decision behavior of both the source and receiver. A quantitative measure is sought for the degree to which displays are or may be efficiently and accurately coded in a specified symbol system. The relevance of concepts of uncertainty and redundancy derived from information theory and applied to a linear sequence of binary events is being examined toward the definition of a useful measure of encodability for a matrix of binary events. Factors such as confrontation, status, and decoding aptitude on message-mediated decisions will be examined empirically.

3-6. *University of Oregon, School of Education, Eugene, Ore.*

Model and Measures for the Human Communication Process

Dr. Forrest L. Brinsey

AF-AFOSR-1055-66

For Objectives and Project summary of current research, see Montana State University, AF-AFOSR-878-65

3-7. University College (London), Dept. of Psychology, England

Stochastic Models and Choice Behavior

Dr. Robert J. Audley

AF-EOAR-62-69

Objective ...

Toward determination of the factors which control behavior and affect decision making in choice situations.

Project summary ...

A model is being developed that accounts for factors involved in processes of choice. Various choice situations are being examined systematically. A family of probability models is being used as a guide in the selection of testable hypotheses and as a means of describing the data.

Research findings ...

In a study of the relation between the probability of choosing one of two alternatives and the statistical distribution of the time taken to make the choice, a new experimental technique was devised toward ensuring that the subject maintains the same level of effort after accuracy at all levels of response probability, and that his choices are relatively uninfluenced by response bias.

An hypothesis about the mechanism of choice is supported by the data.

Publications ...

Robert J. Audley and A. R. Pike. "Some alternative stochastic models of choice." British Journal of Mathematical Statistics in Psychology, vol. 18 (1965) 207-225.

Robert J. Audley. "Models of Choice: Some Problems of Evaluation." Proceedings, Conference on Mathematical Models in Psychology, Centre National de la Recherche Scientifique, Paris, in press.

3-8. *University of Utah, Dept. of Psychology, Salt Lake City, Utah*

Exploratory Research on Communication Abilities and Creative Abilities

Dr. Calvin W. Taylor

[ ] AFOSR-144-63

Objective ...

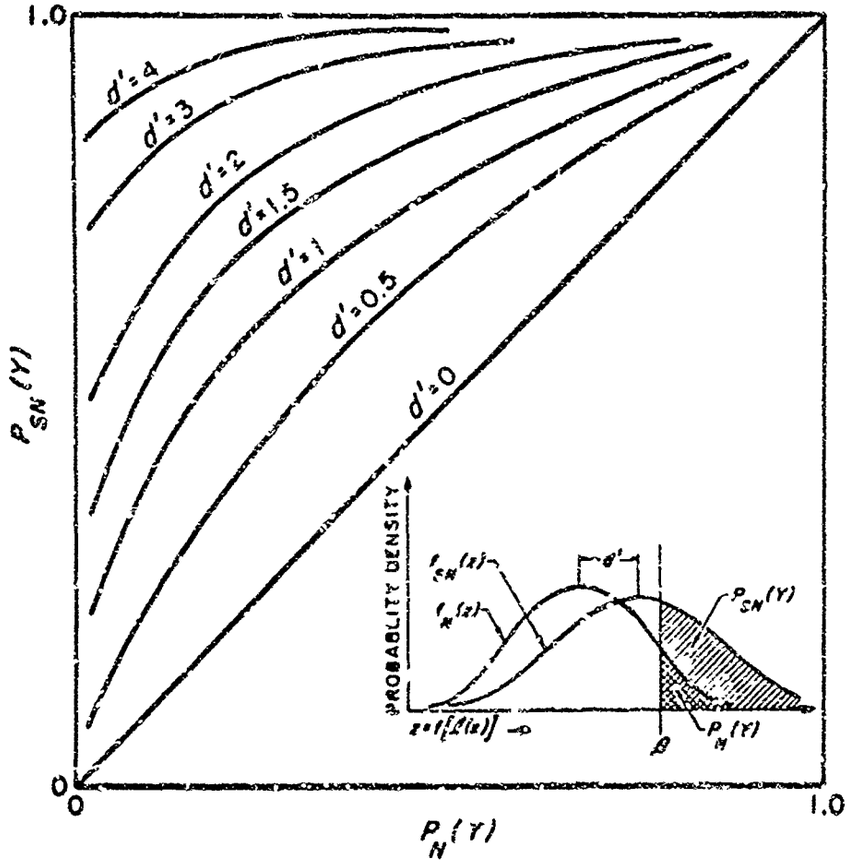
Toward isolating measurable criteria leading to optimization of the human component in communication systems.

Project summary ...

Understanding, identification, and measurement of the human abilities required for a good communication system are sought. These abilities appear measurable by several relatively distinct, central variables or dimensions which require clarification. Communication and creative abilities and their interrelationships are being examined through study of significant dimensions involved in reception and expression, the tasks eliciting these abilities, and the conditions under which each of these abilities will function. Relationships to education and training will be suggested.

Publications ...

Calvin W. Taylor. "Productive Thinking in Science Education." Science Education at the Junior High Level, a National Education Association publication, in press.



From J. A. Swets and D. M. Green

"Signal Detection by Human Observers," 1963

Section 4. Adaptive and Self-organizing Systems

Man, the information processor, intrigues man, the circuit designer, and man, the model builder. Man's nervous system is a fascinating structure, its operation a subject for conjecture. Some of man's sensory systems, his eye, his ear, are better understood and offer existence proofs to the engineer. Beyond what man can see are processes he calls perception, consciousness, and thought. Will he be able to find neural networks or molecules he can associate with these processes? Where and how is experience stored to provide for memory and recall? What is the sequence of events by which this unique animal called man evolved from lower forms?

Man and lower living systems embody principles of structure and performance which far surpass equations that he has been able to formulate and hardware that he has been able to build. Man has repeatedly built machines exceeding his own capabilities--construction equipment, infrared detectors, computers, spacecraft. He has also synthesized drugs and built pacemakers and prosthetic devices to extend his life and assist physical performance. But, except to minor degrees, he has not yet built devices he can work with as extensions of himself in the way that he can work with other men. He has not built machines he can send into hostile and adverse environments that can report back to him selectively and reliably the information he would want to know. He has built machines which record vast quantities of data about the physical universe, yet few machines can distinguish the significant bits from the rest.

In information science terms, research to understand and model the dynamic processes of living systems is variously termed artificial intelligence, the field of adaptive and self-organizing systems, and when the construction of hardware is involved, bionics. The term cybernetics is sometimes used, because these systems incorporate control and feedback mechanisms that adjust their performance toward specified goals.

Research on adaptive systems may produce spectacular results over the short range, but such results can only be a first and gross approximation to what the long range holds. The mechanical eye or hand, the computer that voices the words "Bravo!" or "Come again?", the tracker that finds a target embedded in noise go part of the way. Mechanical devices with more and higher level features of human intelligence and adaptation could teach and train man. Machines might not only help accelerate learning, but could also be used to stimulate and enhance man's inventiveness and creativity if more were known about his memory and thought processes. The equations by which man discriminates, makes decisions, integrates disjoint bits into a whole greater than the sum of its parts can be successively approximated. It would be short-sightedness, however, to consider first approximations as more than precisely that.

Engineers, mathematicians, and perhaps administrators, tend to get carried away with the potential prospects of the intelligent machine. It is error to ignore data bases. The neurophysiologist knows something about the nervous system, but he has a lot more to discover. The psychiatrist and psychologist know something about behavior, but only a little something. The molecular biologist knows compound composition and structure, but what is the explanation for memory? Optimum results over the long range can only come from close cooperation, actually cybernetic coupling, across the range of disciplines that contribute pieces to the puzzle. The generalist and the specialist are both needed in the various fields, and they must be able to exchange ideas. Science is becoming one again as it simultaneously increases in specialization.

I-1. Bell Aerosystems Company, Buffalo, N. Y.

Nonlinear Preprocessing of Inputs to Linear Neural Networks

Dr. Johannes G. Goerner

AF 33(638)-1627

Objective ....

Toward the development of discriminating multilayer nets for physically implementable learning and adaptive control systems.

Project summary ....

The combination of a linear neural net and nonlinear input preprocessing is being examined as one direction of extending the capabilities of neural nets. Preprocessing methods to be studied include: (a) quantizing analog inputs and weighting each quantization interval separately; (b) digitizing analog inputs; and (c) coding digital inputs to achieve desired input-output transformations. Methods for allowing the network to automatically establish proper quantization intervals will also be studied. The preprocessing schemes will be used in conjunction with error correcting training algorithms developed previously for linear neural nets. Understanding the behavior of one-layer nets with nonlinear preprocessing should enable extensions to cascade arrangements resulting in multilayer nets.

Research findings ....

Deterministic training algorithms for linear, single-layer learning nets have been analyzed and an algorithm based on the method of steepest descent has been developed for optimizing a system given in quadratic index of performance. Effects of component deficiencies have been determined.

A magnetic ferrite core arrangement has been developed as a trainable analog memory element for implementing the algorithms.

Publications ....

J. G. Goerner, L. A. Gerhardt, and F. D. Dowell, "The Application of Error Correcting Learning Machines to Linear Dynamic Systems," Proceedings, National Electronics Conference, vol. 21 (Oct 65) 541-6.

J. G. Goerner, L. A. Gerhardt, and F. D. Powell "A Unifying Mathematical Theory for Training Learning Nets." AF 49(638)-1449, final rept., Oct. 65. BAC Rept. No. 9500-920032.

L. A. Gerhardt. "Some Basic Applications of Self-Organizing Systems." April 1965. BAC Rept. No. 9500-920036.

F. D. Powell. "Frequency Domain Error Analysis of Systems Having a Time Varying Coefficient in an Open Loop." Submitted for publication.

4-2. Decision Science, Inc., San Diego, Calif.

Design of Evolutionary and Conscious Automata

Dr. Lawrence J. Fogel, Dr. Alvin J. Owens, and Dr. Michael J. Walsh

AF 49(638)-1651

Objective ....

Toward incorporating complex predictive and decision-making specifications into the data-processing programs for digital computers.

Project summary ....

This effort proposes to formalize intelligent decision making in terms of programs which develop a succession of logical models of the sensed environment through iterative mutation and selection of finite-state machines which are evaluated with respect to their experience and defined goals. Factors to be studied which affect the success of the program in producing appropriate models include: the nature of the goal and its invariance with time; the amount of orderliness in the sample of the sensed environment; the size of the sample; and the nature of the mutation noise distribution. A goal structure is anticipated, i.e., a series of levels of internal modelers, the highest level model providing a goal for the next lower level and thus, indirectly, for all lower levels. This is an approach to describing unknown transducers and evolving entities, i.e., conscious automata, whose descriptions include models of the logical properties of both the environment and the automaton, with the capability of demonstrating knowledge about either one through suitable response to queries for information from an external observer.

4-3. General Electric Co. (Tempo), Santa Barbara, Calif.

Multilevel Adaptive Threshold Logic for Pattern Recognition

A. Timothy Ewald

Contract AF 19(638)-1520

For Objectives and Project summary of current research, see University of Hawaii, AF-AFOSR-1041-66

Research findings ....

The applicability of adaptive threshold logic has been demonstrated as a tool for the pattern recognition of data classes whose sensor signal characteristics are complicated and not amenable to analytic solution.

In noisy radar systems, it appears that only the beginning and ending intervals of the radar scan provide useful information, prompting further study into the reasons why this occurs.

Publications ....

A. Timothy Ewald. "Adaptive Threshold Logic for Identification of Simulated Radar Targets," Final rept., Nov. 5, 65TMP-84.

4-4. *Grafix, Inc., Albuquerque, N. Mex.*

A General Adaptive Motor Learning Program for a Digital Computer

AF 49(638)-1476

Mr. Gene R. Bussey

Objective ....

Toward the specification of generalized procedures of learning and adaptation that can be described in the form of computer programs.

Project summary ....

Study is in progress on the generation of effective coded command sequences for the performance of accommodation-type tasks such as are involved in maintaining balance, adjusting vision, etc. General principles are sought from an examination of the interaction of two computer programs: Pupil (the learning program) and Tutor (the environment simulation which also computes evaluative data for analyzing performance). It is hypothesized that general programs can be extrapolated from specialized programs for the performance of a variety of non-homeostatic activities.

Research findings ....

An elementary hierarchic motor control system that includes system self-establishment of subgoals leading to self-development of goal-seeking behavior, was successfully incorporated into Pupil which was reprogrammed for the IBM 360.

Publications ....

Gene R. Bussey. A General Adaptive Motor Learning Program for a Digital Computer. Final rept., Pts. I and II, AF 49(638)-1203. Dec. 64. AD 611334.

Gene R. Bussey. A General Adaptive Motor Learning Program for a Digital Computer. Final rept., Pts. III and IV, AF 49(638)-1203. Dec. 64. AD 611335.

Gene R. Bussey. "Computer Experiments in Motor Learning." AFIPS Conference Proceedings, vol. 27, pt. 1, 1965 Fall Joint Computer Conference, 1965, pp. 753-774.

4-4. Grafix, Inc., Albuquerque, N. Mex.

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Gene R. Bussey. "Computer Experiments in Motor Learning." AFIPS Conference Proceedings, vol. 27, pt. 1, 1965 Fall Joint Computer Conference, 1965, pp. 753-774.

1-5. Hollander Associates, Fullerton, Calif.

Criteria for Adaptive Systems

Mr. Gerhard L. Hollander

AF 49(638)-1664

Objective ....

Toward the development of system-independent assessment and evaluation measures for comparing systems and relating them to operational requirements.

Project summary ....

This effort will examine the various approaches to adaptive-system design (approaches range from mathematical analysis to hardware design, and are designated by a variety of descriptive terms including "self-organizing" and "learning" systems and "artificial intelligence") to develop evaluation formulas relating system characteristics to potential applications. A functional approach will be applied in studying the external characteristics of the systems. Factors to be evaluated include: range of adapting ability; convergence speed; complexity of design; percentage of components required for learning ability; and flexibility.

4-6. University of Illinois, Biological Computer Lab., Urbana, Ill.

Theory and Application of Computational Principles in Complex Intelligent Systems

Dr. Heinz von Foerster

AF-AFOSR-7-64; AF-AFOSR-7-66

Objective ....

Toward discovery of the fundamental computational principles in complex intelligent systems governing information selection and transfer, for their application in the construction of automata.

Project summary ....

Through interdisciplinary research, epistemological, theoretical, and experimental penetrations are being made of the computational principles in biological systems affecting information selection, reduction, and transfer. The effort includes further development of the mathematical theory of control and communication in complex systems; the study of large random and structured networks exhibiting memory, cognition, self-organization, and anticipation; advancement of the concepts of multi-valued logical systems toward the description of perceptive and self-reflecting systems; and the development of an approach to the empirical examination of the semantic structures of natural language for data processing.

Research findings ....

Exhaustive analysis by computer simulation of the structure of behavior of all 256 different complex systems, each of which consists of exactly 100 randomly connected like elementary components which compute on their two inputs precisely one out of the 256 possible recursive logical functions, showed strong and, in many cases, unexpected relations between behavior on the elementary level (the particular logical function computed) and behavior on the systems level (transients, cycle length, multiple periodicities, etc.), while variations in the topology of connections contributed surprisingly little to changes in behavior.

In a first step toward developing algorithms for nonlinear composition rules, particularly superpositions for nonlinear operators, an extension of the classification of operators showed that a number of well-known nonlinear differential operators belong to these extended classes and are reducible to a canonical form.

In a study of linguistic invariants, when all tree structures obtained by the "noun-chain method" from English, French, and German dictionaries were taken together and the number of nodes they contained at each level relative to the root were determined and plotted as a distribution of the number of nodes vs. level, similarities were found to be greater than differences, e.g., the maximum number in each case occurred at the third level, the mean levels were within one-half unit of each other, and curves interpolated between points had the same shape for all three languages within observational error. So far, no tree has shown a depth greater than 8 levels.

Publications ....

Heinz von Foerster. "Memory Without Record." D. P. Kimbel, ed., The Anatomy of Memory. Palo Alto: Science and Behavior Books, 1965, 388-433.

Heinz von Foerster. "Bionics Principles." R. Willaume, ed., A Lecture Series in Bionics. Paris: AGARD, 1965, 1-11.

W. Ross Ashby. "Measuring the Internal Information Exchange in a System." Cybernetica, vol. 6 (1965) 5-22.

W. Ross Ashby. "Constraint Analysis of Many-Dimensional Relations." N. Wiener and J. P. Schade, eds., Progress in Biocybernetics, vol. 2. Amsterdam: Elsevier Publishing Co., 1965, 10-18.

Alex M. Andrew. "Self-Improvement Using a Disturbed Measure of Goal Achievement." Preprint, Technical Rept., 1965, for Proceedings, IFAC, London, 1966.

Alfred Inselberg. "On Classification and Superposition Principles for Nonlinear Operators." Technical Rept. No. 4, May 1965.

Crayton C. Walker. "A Study of a Family of Complex Systems." Technical Rept. No. 5, June 1965.

Alex M. Andrew. "Tables of the Stirling Numbers of the Second Kind." Technical Rept. No. 6, in press.

Alex M. Andrew. "Tables of the Modified Stirling Numbers of the Second Kind." Technical Rept. no. 7, in press.

Alex M. Andrew. "Automatic Adjustment in a Continuous Environment." Technical Rept. No. 8, Sept. 1965.

Alex M. Andrew. "Counting to 1,099,508,482,050 Without Carries." Accepted for publication, Electronic Engineer.

Alex M. Andrew. "A Beam-Blanking Circuit." Accepted for publication, Electronic Engineer.

W. Ross Ashby. "Basic Issues of Today." Accepted for publication, Journal of General Physics (special issue.)

M. David Freeman. "A Signal Analysis Technique with Application to the Analysis of Musical Instrument Tones." Accepted for publication, Proceedings, IEEE.

Heinz von Foerster. "From Stimulus to Symbol." G. Kepes, ed. Sing, Image, Symbol, vol. IV. Vision and Value. New York: G. Braziller, in press.

Heinz von Foerster. "Large Systems and Cybernetics." Proceedings, Symposium on the Social Impact of Cybernetics. Washington, D.C.: Georgetown University Press, in press.

4-7. *University of Illinois at Chicago Circle, Dept. of Information Engineering, Chicago, Ill.*

Evolutionary and Multilevel Information Processing Networks

AF-AFOSR-978-65; AF-AFOSR-978-66

Dr. Earl E. Gose

Objective ....

Toward describing the training of logical elements for adaptive networks and evolutionary structures.

Project summary ....

Procedures are being studied for training multilevel networks consisting of more than one layer of adjustable parameters. The procedures involve either the mutation or replacement of network elements. Criteria are being determined for evaluating the elements. Decision procedures are being formulated for effecting changes in the network structures. Preliminary results show that the evolutionary approach requires significantly fewer elements with an appreciable decrease of error over training procedures. An attempt is planned to design an adaptive evolutionary network descriptive of physical world situations in terms of nonlinear integro-differential equations.

Research findings ....

An algorithm for the training of nonlinear multi-threshold networks has been proven.

A comparison was made of the abilities of evolutionary and non-evolutionary networks to realize functions.

Publications ....

Earl E. Gose. "An Adaptive Network for Producing Real Functions of Binary Inputs." Information and Control, vol. 8, no. 2 (April 1965) 111-12.

Earl E. Gose. "A Synthesis Technique for Networks Consisting of Logical Functions Feeding a Linear Summation Element." IEEE Transactions on Electronic Computers, (April 1965).

Anthony N. Mucciardi and Earl E. Gose. "Pattern Recognition by Evolutionary Nonlinear Multi-Threshold Networks." Accepted for publication, IEEE Trans. on Electronic Computers.

A. Klopf. "Evolutionary Adaptive Networks." Sept. 1965.

4-8. Information Research Associates, Inc., Cambridge, Mass.

Application of Wiener Canonical Expansions to Bionic Systems

Dr. Donald B. Brick

AF 49(638)-1631

Objective ....

Toward the description of conditional probability computers over a broad class of stochastic inputs.

Project summary ....

Research on Wiener canonical expansions of Bayes' rules have suggested a powerful class of pattern recognizing automata applicable to a broad class of stochastic inputs. The automata, known as conditional probability computers, appear to avoid the major disadvantages of such computers, i.e., the tendency toward exponential growth as the number of learning samples increases. The usefulness and limits of this approach are being explored in the modeling of decision procedures. The value of this approach will be compared with other methods, for example, power series or Edgeworth series expansion procedures.

4-9. Michigan State University, Dept. of Electrical Engineering, East Lansing, Mich.

Logical and Circuit Investigation of a Command and Control Automaton

Dr. William L. Kilmer

AF-AFOSR-1023-66

Objective ....

Toward formulation of a theory of the circuit action of the reticular formation and a model for communication and command and control systems.

Project summary ....

The reticular formation functions as a command and control center par excellence. It receives relatively unrefined information from all sensory-motor systems and from all internal housekeeping systems. It processes crucial information across a broad front and arrives at a decision which commits the entire organism in a fraction of a second. Computer simulations are being made of a mechanical reticular calculus of relations approximating the output modal behavior of the reticular formation. Recent advances in hypothesis-making probabilistic automata and sequential decision theory will be incorporated as suggested by simulation results and reticular formation physiology. An attempt will be made to develop a model which will incorporate both the economy of logical design and the complexity of operation of the reticular formation toward the design of complex decision-making machines.

4-10. University of Southern California, Electronics Sciences Lab., Los Angeles, Calif.

Theory and Models of Asynchronous Automata

Dr. George A. Bekey

AF-AFOSR-1018-66

Objective ....

Toward modeling discrete adaptive-control systems incorporating sampling and other performance characteristics found in living systems.

Project summary ....

Analytic and computational tools are being developed for modeling information transfer and control processes which appear to occur in living systems, in terms of asynchronous automata theory. Gradient techniques will be examined and extended for identifying unknown sampling intervals for fixed (aperiodic) and variable (asynchronous) discrete systems. Various control strategies will be studied toward the definition of criteria for, and a description of, adaptive systems in which the sampling interval is dependent on system performance. Suitability of the approach will be tested for describing sampled data systems with continuous inputs and outputs and multi-axis control. Design requirements for the inclusion of stable and transient states will be tested on a model for quadruped locomotion which is being extended from a synchronous to an asynchronous automaton.

4-11. System Research, Ltd., Richmond, Surrey, England

Cybernetic Investigation of Learning and Perception

Dr. Gordon Pask

AF 61(052)-640

Objective ....

Toward models of learning behavior in terms of a hierarchy of processes, a hierarchy of mechanisms, and levels of metalanguage.

Project summary ....

A learning or perceptual system is conceived as a self-organizing system, the ordering relations being derived from interaction between the learning organism and its environment. The essential parts of a model for concept learning have been defined as a hierarchy of problem-solving processes, a hierarchy of mechanisms corresponding to the process hierarchy, and levels of metalanguage with reference to an object language. Least elaborate systems capable of learning are being demonstrated through interactions between pairs of subsystems; in special cases, one of the subsystems may be a machine. Algorithms for describing prototypes of the systems, particularly the interactions between levels in the hierarchies, are being explored.

Research findings ....

A steady-state experimental method has been developed in which changes due to learning in a subject (usually man) are compensated by adaptive variations in a machine that controls the experimental situation. The coupled man-machine system does not learn (even though the subject learns and the machine adapts), but enables certain of the "stationary valued" features of the learning process to be measured.

A cybernetic model for the learning process has been developed that resembles models used successfully in molecular biology. Computer simulations of some aspects of the model in steady-state experimental conditions disclose a distinction between "closed" and "open" learning.

Publications ....

Gordon Pask. "Comments on an Indeterminacy that Characterises a Self-Organising System." E. R. Caianiello, ed., Cybernetics of Neural Processes. Rome: Quaderini de la Ricerche Scientifico, 1965, 212-242.

Gordon Pask. "A Discussion of Self Organization and Artificial Intelligence." M. Rubinoff, ed., Advances in Computers, Vol. 5. New York: Academic Press, 1965, 108-227.

Gordon Pask. "Advertising as a Symbolic Game." Advertising Quarterly, no. 3 (1965) 55-61.

Gordon Pask. "Teaching as a Control-Engineering Process." Control and Automation Progress. A four-part series, part I in vol. 9, no. 79 (Jan. 1965) 6-11; parts II, III, IV in Feb., March, and April issues.

Gordon Pask. "Man/Machine Interaction in Adaptively Controlled Experimental Conditions." Accepted for publication, Bulletin of Mathematical Biophysics.

Gordon Pask and Richard J. Feldmann. "Test for a Simple Learning and Perceiving Artifact." Accepted for publication, Cybernetica.

Gordon Pask and George E. Mallen. "The Method of Adaptively Controlled Psychological Learning Experiments." Proceedings, IFAC (Teddington) Symposium 1965 on The Theory of Self-Adaptive Control Systems, 14-17 Sept. 1965.

Gordon Pask. "The Cybernetics of Ethical, Social, and Psychological Systems." Progress in Biocybernetics, vol. 3. Amsterdam: Elsevier Publishing Co., in press.

Gordon Pask. "Man as a System that Needs to Learn." S. Beer, F. George, eds., Advances in Cybernetics. New York: Academic Press, in press.

4-12. *University of Washington, Dept. of Electrical Engineering, Seattle, Wash.*

Machine Learning for General Problem Solving

Dr. David L. Johnson

AF-AFOSR-468-65; AF-AFOSR-939-65

Objective ....

Toward description of methods for simulating complex problem solving and decision making tasks.

Project summary ....

Problem-solving routines are being formulated, particularly in relation to theorem proving and game learning. Various patterns of learning are being studied, including heuristic, associational, and statistical approaches. The goal is to be able to (a) formulate optimum problem-solving routines that will incorporate aspects from the several approaches, and (b) gain an understanding of how man and machine can interface in the performance of these tasks.

Research findings ....

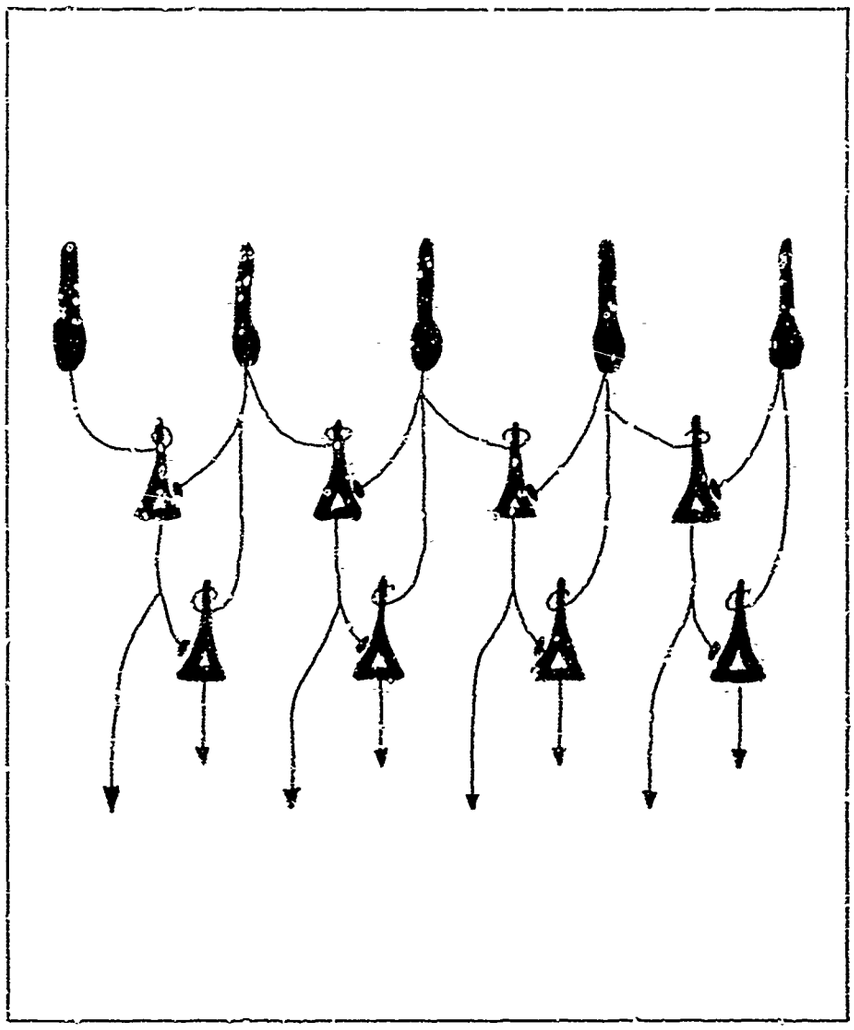
A theory has been formulated for certain classes of sequential, finite-state machines and developed for ternary application with allowance for extension fo n-ary systems; transition constraints in n-ary applications that have no counterpart in typical binary problems are shown to exist.

A model has been designed for simulating the development of mental processes in a child that enable it to interact with the environment based on heuristics and transformation procedures previously developed.

Publications ....

David L. Johnson and Kenneth O'Keefe. "The Application of Ternary Memory Elements to Secondary-State Assignment." Submitted for Bionics Symposium 1966, 3-5 May 1966.

Alistair D. C. Holden and David L. Johnson. "Simulation of the Growth of Scientific Reasoning in the Child." Submitted for Bionics Symposium 1966, 3-5 May 1966.



From H. von Foerster

"Structural Models of Functional Interactions," 1962

Section 5. Language and Linguistics Research

Language consists of groups of symbols arranged according to a set of rules. Viewed this way, "language" includes both the languages people speak and all synthetic symbol systems. So language is viewed in this task.

Language is a tool. It is a device for representation. Information science is concerned with its use for representing concepts, relationships among concepts, models for automata, and instructions for information processing devices.

Natural language has proved tractable with difficulty. Structure or syntax has been amenable to modeling, but the number of grammatically correct sentences that can be meaningless is, for practical purposes, infinite. Major emphasis is now on semantics, to elicit rules for recognizing meaning and generating meaningful sentences. Research on natural language was originally sponsored (not by AFOSR) to develop procedures for machine translation. It is believed that disenchantment with work to date is premature. The solution of hard problems merely takes more time. Machine production of translations, indexes, and abstracts, and other machine manipulations of natural language text are requirements if achievable, because man's capacity to assimilate bits of information is limited. As document volume increases, automatic methods that intelligently select the significant bits appear mandantory for efficient handling of information. Results are slow in coming because the data base is large (see Section 2), large-scale projects are expensive, and perhaps creative ideas are few. The results we have, however, do not suggest impossibility.

Work on synthetic or artificial languages can be roughly subdivided into work on machine and programming languages and work on languages for representing concepts and procedures simulating intelligent processes. The Directorate program has not included much programming language research. This research receives other sponsorship, an appreciable amount from hardware manufacturers, since software packages are important to computer sales. An area of Directorate interest is in translators and compilers which make machines accessible to non-programmer scientist and manager users.

Languages for game playing and theorem proving suggest approaches to the representation and association of concepts that may be approximations to characterizing thought processes (see Section 4). Considerable progress has been made, some under AFOSR sponsorship, on languages for problem-solving procedures. Enough may now be known about some languages for automata to permit generalizations on useful procedures that can be accomplished on computers (see Section 6).

5-1. *Bunker-Ramo Corp., Language Analysis and Translation Group, Canoga Park, Calif.*

Inductive Methods in Language Analysis

Dr. Paul L. Garvin

AF 49(638)-1516

Objective ...

Toward specification of a description of natural language in terms amenable to computer processing for indexing, abstracing, and translation.

Project summary ...

Linguistic analysis is viewed as essentially an inductive process. Attempts are being made to derive a listing of elements and a set of statements both from an examination of the responses of informants and from the study of text. Both sources of data are expected to show regularly recurrent elements of different types and orders of complexity. Through classification of the elements and statement of their conditions of distribution, i.e., patterns of co-occurrence, an inductive description of language is being formulated. The inductively ascertained units and relations are being verified by computer routines.

Research findings ...

A pilot study of an inductive methodology for semantic analysis, called predication typing, showed the feasibility of using the paraphrasing technique to classify semantic content in large natural language corpuses.

Publications ...

Paul L. Garvin. "Computer Processing and Cultural Data: Problems of Method," in Del Hymes, ed., The Use of Computers in Anthropology. The Hague: Mouton and Co., 1965, 119-139.

Paul L. Garvin, Jocelyn Brewer, and Madeleine Mathiot. "Predication Typing: A Pilot Study in Semantic Analysis." Accepted for publication, UCLA Language Monograph Series.

5-2. *University of California, Center for Research in Languages and Linguistics, Los Angeles, Calif.*

Studies in Mathematical and Computational Linguistics for Language Research

Dr. Harold P. Edmundson

AF-AFOSR-612-64; AF-AFOSR-612-65

Objective ...

Toward evaluation of mathematical and computational linguistics for machine processing of natural language data.

Project summary ...

An examination is being made of the fundamental concepts of mathematical and computational linguistics and the relationships of these concepts to the various needs of language data processing (i.e., language analysis, abstracting, indexing, and translation). Concepts in mathematical logic, algebra, geometry, and statistics are being considered. A study is planned of computer routines and programs, including general-purpose routines for search, sort, lookup, and frequency; special routines for parsing, segmentation, and idioms; and programs for dictionary, thesaurus, and concordance compilation. The relative roles of theoretical linguistic models and empirical language data will be examined.

5-3. *Case Institute of Technology, Systems Research Center, Cleveland, Ohio*

Formal Descriptions for Recognition, Learning, and Concept Formation

Dr. Ranan B. Banerji

AF-AFOSR-125-65

Objective ...

Toward description and efficient programming of such aspects of intelligent activity as recognition, learning, and concept formation.

Project summary ...

Formalisms are being developed for the generation of concepts, including concepts learned from a systematization of experience, i.e., internally generated. Refinements in a language based on the predicate calculus are being examined for expressing recognition, learning, and concept formation. A subclass of context-free languages (the finitely representable) is being extended to include simply unbounded languages whose derivations may, but need not, contain strings with an unbounded number of non-terminal symbols. A hierarchy of languages beyond the simply unbounded will be investigated. Determination of the efficiencies of several concept-formation program simulations is planned.

Research findings ...

A program was developed for playing a significantly strong Qubic (three dimensional Tic-Tac-Toe) game based on the concept of "forcing states" rather than the usual intermediate evaluation minimax technique.

A small description language was developed for describing forcing states in a large class of board games (Tic-Tac-Toe, Qubic, Go-Moku, Bridge-it, and Hex).

The elements of a formal model for translation between related context-free languages have been defined which enable the construction of efficient machine language programs from arithmetic expressions of Algol-like languages.

Publications ...

Ranan B. Banerji. "Toward a Formal Language for Describing Object Classes." Proceedings, Second Congress on the Information System Sciences, Hot Springs, Va., 22-25 Nov. 1964. Washington, D.C.: Spartan Books, Inc., 1965, 451-7.

Ronald L. Citrenbaum. "The Concept of Strategy and Its Application to Three Dimension Tic-Tac-Toe." Rept. No. SRC 72-A-65-26. 1965.

James M. Snediker. "A Generalized Program for Information Retrieval." Rept. No. SRC 77-A-65-29. 1965.

Robert Fiellman. "Computer Solution for Cryptograms and Ciphers." Rept. No. SRC 82-A-65-32. 1965.

James M. Snediker. "A Self-Organizing Program for Describing Concepts." Proceedings, ACM 65, 20th National Conference, Cleveland, Ohio, 24-26 Aug. 1965, p. 101.

Elmer C. Milliken, Jr. "A Language for Class Description and Its Processor." Proceedings, ACM 65 as above, p. 77.

Edward G. Altman and Ranan B. Banerji. "Problems of Finite Representability." Information and Control, vol. 8 (June 1965) 251.

5-4. *Connecticut College for Women, Dept. of Philosophy, New London, Conn.*

A Study of Certain Philosophical Intrusions into Current Linguistic Theory

AF-AFOSR-787-65; AF-AFOSR-787-66

Dr. Alice Koller

Objective ...

Toward exposing and discussing philosophical positions on philosophical issues being used by linguistic theorists.

Project summary ...

This is an analysis by a philosopher of the implicit use being made of philosophical positions in the current development of theories and hypotheses about language. It is anticipated that this examination will elucidate the concepts and interrelationships among concepts constituting basic problem areas in linguistic research, and will aid clarification of basic concepts in the evolution of a philosophy of language.

Research findings ...

An examination of topics (currently numbering 115) which make implicit use of certain philosophical positions on certain philosophical issues found in the writings of linguists and others interested in developing theories and hypotheses about language show branchings from a few central beliefs about: the kind of science linguistics is, the nature of its subject matter, and the nature of meaning.

5-5. *Istituto Documentazione Associazione Meccanica Italiana (IDAMI), Milan, Italy*

Automatic English Sentence Analysis

Mr. Ernst von Glasersfeld and Dr. -ing. Paolo Terzi

AF-EOAR-64-54; AF-EOAR-65-76

Objective ...

Toward specification of a procedure for analysis of the syntactic and semantic content of natural language for automatic processing of text.

Project summary ...

A language analysis procedure is being developed which incorporates examination of semantic as well as syntactic factors, for use in real-time operations. The approach identifies these factors by means of a correlation structure, a hierarchic system which accounts for both the meaning of individual words and the relations by which they are linked. Correlators, the linguistic expressions by which relations are specified, are being enumerated and classified as to use. The feasibility will be explored of an approach which depends on the isolation and classification of weights of semantic factors for machine analysis of sentences and translations. Geometric and mathematical representations of the correlation structure are also being formulated for reducing search operations to predictably possible relationship patterns. The applicability of nomographic theory to language analysis is being investigated.

Research findings ...

In the second phase of studying the relational analysis of prepositions, limiting the analysis by means of the criterion of constant determinate output in other languages has proved a valuable tool in practice and for semantic theory.

The Multistore procedure has been refined, particularly with respect to the combination rules that govern the formation of correlations and the reclassification rules and subroutines. The logical program for the procedure was completed and is being programmed for the GE-425.

Publications ...

Ernst von Glasersfeld, Pier Paolo Pisani, and Jehane Burns. "'Multistore' - A Procedure for Correlational Analysis." Rept. No. ILRS-T10, 650120, Jan. 1965.

Ernst von Glasersfeld. "Toward the Automatic Analysis of Language: Multistore - A Procedure for English Correlational Analysis." Automazione e Automatismi, vol. 9, no. 2 (March-April 1965) 5-28.

Ernst von Glasersfeld and Paolo Terzi. "Automatic English Sentence Analysis. Part I. Research of the Linguistics Group. Part II. Research of the Mathematics Group." AF-EOAR-64-54, Final Rept., No. ILRS-T11, 650630, June 1965.

Ernst von Glasersfeld. "An Approach to the Semantics of Prepositions." Paper presented at the Symposium on Computer-Related Semantic Analysis, Las Vegas, Nev., 3-5 Dec. 1965.

Jehane Burns. "English Prepositions in Machine Translation." Beitrage zur Sprachkunde und Informationsverarbeitung, vol. 2, no. 7 (Dec. 1965); also Rept. No. ILRS-T9, Jan. 1965.

Franco Rusconi and Paolo Terzi. "The Hierarchy of Mental Relations as Expressed in Language." Paper for presentation at a Conference of the Istituto Lombardo di Scienze e Lettere, Milan, Italy, Jan. 1966.

Paolo Terzi. "A Mathematical Representation of Language." Paper for presentation at the Conference cited above.

5-6. *Lehigh University, Center for the Information Sciences, Bethlehem, Pa.*

Computational, Phonological and Morphological Linguistics and Retrieval Studies

Mr. Robert S. Taylor; Dr. A. F. Brown; Dr. Donald J. Hillman

AF-AFOSR-724-65

For Objectives and Project summary of current research, see
Lehigh University (R. S. Taylor), AF-AFOSR-724-66
Lehigh University (D. J. Hillman), AF-AFOSR-1028-66

Research findings ...

A network of subject-heading relationships for metallurgy is nearing completion and will be combined with tables of contents and similar information for a programmed learning display system.

An initial study of the question-asking process has been made as the first step in an analysis of reference negotiations.

Publications ...

Donald J. Hillman. "Computational, Phonological and Morphological Linguistics and Retrieval Studies. Rept. No. 1. Grammars and Text Analysis." 23 Aug. 1965.

C. E. Rieber. "An Analysis of Questions and Answers in Libraries." In preparation.

5-7. *University of Michigan, Communication Sciences Lab., Ann Arbor, Mich.*

Grammatical Analysis of Spoken Language

Dr. June E. Shoup

AF-AFOSR-22-64

Objective ...

Toward development of a symbolic representation of grammatical structures in spoken language and a grammatical interpretation for the prosodies of speech.

Project summary ...

Three problems in the grammatical analysis of spoken language are being investigated: identification of the basic units of grammar leading toward an axiomatic system for grammatical structures; development of a symbolic description for the grammatical structures; and formulation of a grammatical interpretation of the prosodies of speech, particularly of American English.

Research findings ...

An experimental technique has been developed for investigating the prosodies of speech by which phonetic information may be eliminated from the speech signal while retaining the prosodic information. Fundamental voice frequency may be retained or excluded as desired.

A format is being developed for the detailed description of part of the phonology of a language, specifically French verbs.

Publications ...

Michael H. O'Malley and Gordon E. Peterson. "An Experimental Method for Prosodic Analysis." Submitted to Phonetica.

Andre-Pierre Benguerel. "Generation of Verbal Forms in French." Submitted to Language.

5-8. *University of Michigan, Dept. of Mathematics, Ann Arbor, Mich.*

Automatic Programming

Dr. Bernard A. Galler

AF-AFOSR-1017-66

Objective ...

Toward systematic analysis and description of programming languages.

Project summary ...

Automatic programming concepts and techniques are being analyzed for systematic presentation. The analysis will include examination of the application of symbolic logic to language structure. Consequences suggested by the analysis will be explored, e.g., the automatic generation of translators for artifical languages; ability to change the definition of the language being translated, even during the translation; and possibilities of redefining operations and modes of arithmetic in procedure-oriented computer languages.

5-9. New York Research Group, Inc., New York, N.Y.

Analysis of Structures of Human Communication Systems

Dr. Frederic T. Sommers, Mr. David Rothenberg, and Mr. David M. Massie

AF-AFOSR-881-65; AF 49 (638)-

Objective ...

Toward measures for the "information capacity" of a language and methods for the efficient encoding of information in communications.

Project summary ...

Models exhibiting similarities of structure are being developed for describing information transmission in two modes of communication, language and music. The model which describes the perception of music is concerned with such syntactic and semantic problems as perceived similarities of form, logical structure, "information content," and "meaning." New combinatorial techniques are being formulated to compute predictions pertaining to the perception of tones in their musical context. The predictions will be verified experimentally. A method of adapting a tree theory to computer analysis of semantic structure for a given set of predicates will be applied to an examination of the minimization of semantic structure in ordinary usage, a problem related to maximal efficiency in the use of language.

Research findings ...

New combinatorial techniques and a mathematical model have been developed for the perception of tones in context which provide predictions suitable for experimental validation.

Among results of study of the implications of the semantic structure of ordinary language described by the "tree theory" for certain formal systems, it has been shown that semantic distinctions can be introduced formally into formalized arithmetic, and a new interpretation of Gödel's incompleteness theorem (1931) results which is significantly different; it has been shown that formalized arithmetic may be considered both complete and consistent, but semantically incomplete.

Publications ...

David Rothenberg. "A Mathematical Model for Measurement and Classification of Context-Embedded Stimuli." In manuscript.

Frederic T. Sommers. "On a Fregean Dogma." Proceedings, International Colloquium on the Philosophy of Science, London, England, 11-16 July 1965.

5-10. RCA Labs., David Sarnoff Research Center, Princeton, N.J.

Automatic Theory Formation and Relative Complexity of Programs

Dr. Saul Amarel

AF 49(638)-1184

Objective ...

Toward development of a conceptual framework for ordering problem types and their corresponding problem-solving schemata.

Project summary ...

A general rationale for theory formation strategies is being developed through the mathematical representation and evaluation of general features of problem-solving procedures disclosed from analysis of a variety of problem-solving tasks. A theory formation system has been formulated which includes a language for expressing the structure of computer programs under formation, an evaluation procedure for candidate programs, and a strategy of formation. Results suggest a broad hierarchy of problem types; study of the relationships between different problem types in the hierarchy indicates that by increasing the power of representations, a given problem may be made to move down in the hierarchy. Study of theoretical approaches to the notion of relative complexity of computer programs that are input-output equivalent is exploring the space of formable programs and the feasibility of developing a general theory of program translation.

Research findings ...

In the automatic program formation problem, syntactic and semantic bases have been obtained for representations which provide a precise and fruitful notation of program space; formation strategies are now interpreted and problem-solving procedures that direct searches in this space.

Studies of problem-solving procedures of the reduction type within logical systems of natural inference for a wide range of problems (theorem proving, syntactic analysis, transportation scheduling, domino covering, question-answering over pictorial data) have shown that the relative power of a solution procedure strongly depends on the representation of solution space.

A more satisfactory definition of relative program complexity was developed, based on the existence of birudimentary isomorphisms between computation sets, which effects a strict distinction

between a machine and its simulation on a universal machine in several cases.

Publications ...

Saul Amarel. "Languages of Representation in Problem-Solving Procedures of the Formation Type." Paper presented at Symposium on Logic, Computability and Automata, Oriskany, N.Y., 25-27 Aug. 1965.

Saul Amarel. "An Approach to Heuristic Problem Solving and Theorem Proving in the Propcsitional Calculus." Proceedings, Conference on Computer Science and Systems, University of Western Ontario, Canada, 9-10 Sept. 1965.

Saul Amarel. "Problem Solving Procedures for Efficient Syntactic Analysis," Proceedings, ACM 65, 20th National Conference, Cleveland, Ohio, 24-26 Aug. 1965.

Francis P. Larkin. "Complexity in Program Translation." Paper presented at Symposium on Logic, Computability and Automata, Oriskany, N.Y., 25-27 Aug. 1965.

Robert O. Winder. "An Evaluation of Heuristics for Threshold Function Test-Synthesis." To be submitted, Journal of SIAM.

5-11. Stanford University, Inst. for Mathematical Studies in the Social Sciences, Stanford, Calif.

A Theory of Computer Languages

Dr. Andrzej Ehrenfeucht

AF-AFOSR-1004-66

Objective ...

Toward design and implementation of machine languages that can be readily read and interpreted by human users.

Project summary ...

An examination is being made of the structure and usefulness of languages ranging from those of Algol-like generality to those of machine-language specificity. An attempt is being made to develop a theory of languages for describing computational processes and the organization of computations that can be employed in the design and implementation of man-manipulable machine languages. Applications of the theory will be sought to the formulation of useful procedures in such areas as mechanical theorem proving.

5-12. Westinghouse Electric Corp., Baltimore, Md.

Syntax Oriented Translators for Language/User Interfaces

Contract AF 49(638)-1452

Mr. Peter Z. Ingerman*

Objective ...

Toward specification of a syntax-oriented translator to facilitate the writing of computer programs by inexperienced users.

Project summary ...

Language definition schemes are being explored for increasing both grammar and vocabulary flexibilities within the constraints of existing synthetic machine languages to make them adaptable to changes in problem definition and user requirements. The syntax-oriented translator will allow a language to specify changes to itself in its own language. (The capability of instructing the translator in the same language that it knows how to translate is characteristic of unstratified languages, exemplified by natural languages and by several assembly programs for extant machines).

Research findings ...

A syntax-oriented translator of sufficient generality has been specified for use in translating from most of the higher-level programming languages currently in use to an assembly-type intermediate language.

An assembly-type language was developed which can serve not only as the target for the syntax-oriented translator, but can also be used in its own right both as an assembly language and as one possible solution to the reprogramming problem.

Publications ...

Peter Z. Ingerman and M. L. Graham, "A Universal Assembly Mapping Language," in Proceedings of the 20th National Meeting of the Association for Computing Machinery, 1965, pp. 409-421.

Marvin L. Graham and Peter Z. Ingerman. "An Assembly Language for Reprogramming." Communications of the ACM, vol. 8, no. 12 (Dec. 65) 769-774.

Peter Z. Ingerman. A Syntax-Oriented Translator. To be published, Academic Press, 1966.

*Present address: Radio Corp. of America, Electronic Data Processing, Bldg. 204-2, Camden, N.J. 08101

Correlation indices of the word "HE":

N1		N2	M1		M2
203	218	421	203	218	421
204	219	473	204	219	473
205	220		205	220	
207	223		207		
208	225		208		
209	536		209		
213	603		213		
215	605		215		
216	609		216		
217	611		217		
	613				

E1		E2	F1	F2
003	045	014	---	---
007	049	031		
014	057	044		
019	059	077		
029	075			
031	079			
032	080			
036	084			
041	086			
044	092			
	098			

From reference 3, project 5-5.

Section 6. Theoretical Foundations of Information Sciences

Most of the studies in this task concern developments in symbolic logic. We were not thinking of the new mathematics called for by von Neumann to describe intelligent activities when we established the task. Our sponsored projects in multi-valued logics increasingly suggest this as a possible route. Since the McCulloch-Pitts logical calculus of 1943, procedures have been sought for expressing such "ideas immanent in nervous activity" as learning and recognition and the ability of automata to function reliably under duress, with unreliable components, and with incomplete information. Space flight and hostile environments now impose requirements on logical elements of adaptation and self-repair.

Automata theory is another route for building intelligent systems. The use of algebraic methods to describe the language and behavior of automata may lead to machines that are both fundamental and behavioristically simple. Combinatorial algebras may give useful models for information retrieval systems. Techniques for simplifying proof procedures offer possibilities of eliminating exhaustive enumerations that are time consuming and can exceed machine capacities. Questions concerning algorithmic unsolvability and other problems in recursive function theory (the theory of computability) are amplifying notions of constructibility, decidability, consistency, and completeness.

The logic models supply formal approaches that can be applied to problems in the structuring and processing of information and language. The precise descriptions of automata are models of realizable networks and define bounds on their performance. Automata are beginning to be assessed for the solution of natural language problems. However, it is expected that applications to information problems will await further examination of such questions as complexity, equivalence, and the behavior of automata with and without restrictions on time and space.

6-1. *Cambridge Language Research Unit, Cambridge, England*

A Sequential Logic for Information Structuring

Dr. Edward W. Bastin

AF-EOAR-65-78

Objective ....

Toward representation of hierarchic and dynamic features of physical information systems, and the control structure therein.

Project summary ....

A control system model is being studied in which flow and processing of information are described by a developing system of discrete transforms capable of representing a continuum. Validity of the model is being examined in applications to the behavior of physical systems and to the logical problem of defining a continuum of numerical values in the Brouwerian sense, i.e., a progressive determination of values that involves a gradual introduction of contingency into the set of physically interpretable values. Study is planned of the principle of symmetry and the principle of discreteness for hierarchic structures. A concept of structural information will be examined for representing characteristics of messages.

Research findings ....

The hierarchy algebra previously described has been formalized as a discrimination system in which a mathematical structure is deduced from the requirement that a set of elements be able to extend and thus generate itself through a process whereby one element discriminates among other elements already in existence.

A physical application of the discrimination has been described.

Publications ....

E. W. Bastin, "A Calculus for a Bootstrap Dynamics." Seminar paper, King's College, University of London. Jan. 1965.

J. C. Amson and A. F. Parker-Rhodes, "Essentially Finite Chains." Sept. 1965.

6-2. *City College, City University of New York, Dept. of Philosophy, N. Y.*

Automata Theory and Finite-State Machines

Dr. Richard C. Jeffrey

AF-AFOSR-523-65

Objective ....

Toward characterization of the information flow in, and behavior of finite-state machines as paradigms of, multi-input/multi-output switching nets.

Project summary ....

Study is extending a new theory of finite-state transformations which characterizes the terminal behavior of finite-state machines and provides a method for synthesizing simplest machines with a given terminal behavior. By viewing finite-state automata as linear arrays of identical combinatorial nets between which information flows in only one direction, results are being extended to nets of n-dimensionally infinite arrays of identical machines. Definition is sought for a generalization of the notion of index for each n. Study is planned for n > 1 with information flow in two directions.

Research findings ....

Results focused on inductive logic viewed as a critique of the belief function (subjective probability measure) and on ethics viewed as a critique of the desirability function (utility function) were basically philosophical.

One principal thesis was that the "principle of induction" is, in fact, either platitudinous or false in all of its existing formulations; preliminary results were obtained on interpersonal comparisons of utility.

Publications ....

Richard C. Jeffrey. The Logic of Decision. New York: McGraw-Hill Book Co., Inc., 1965.

Richard C. Jeffrey. "New Foundations for Bayesian Decision Theory." Proceedings, 1964 International Congress for Logic, Methodology and Philosophy of Science, Jerusalem, Israel, 26 Aug - 2 Sept. 1964. Amsterdam: North-Holland Publishing Co., 1965, 289-300.

Richard C. Jeffrey. "Remarks on Inductive Logic." Proceedings, International Colloquium on the Philosophy of Science, London, 11-16 July 1965.

6-3. General Precision, Inc., Librascope Group, Glendale, Calif.

Abstract Machines Based on Association Mechanisms

Mr. Richard F. Reiss

AF 49(638)-1236

Objective ....

Toward establishment of a fundamental framework and axiomatic scheme based on association mechanisms for analyzing whole-system structures.

Project summary ....

Study is directed to a formal postulational elaboration of abstract machines and analyses of their behavior in the light of all suggestive notions derivable from various association mechanisms. (The modern development of association theory incorporates laws proposing to explain the highest levels of conscious thought processes in terms of a few machinistic forces operating on discrete entities, and a set of secondary laws and processes which are believed to describe fundamental principles capable of being directly related to data processing functions). Three basic mechanistic aspects are being studied: (a) the sensory, concerning the interrelations of sensory tokens and their performance as a whole; (b) attention, relating to the admission, selection, and ejection of tokens at several levels; and (c) motor, relating to the ability to adjust to, manipulate, and act on the environment.

Research findings ....

An abstract formal system intended for constructing psychological theories, particularly association theories, has been described based on the notion of finite set functions and incorporating some of the concepts used in sequential machine theory.

Publications ....

Richard F. Reiss. "An Axiomatic Conceptual Framework for Association Theory." Final rept., Dec. 1965.

6-4. *Hughes Aircraft Co., Data Processing Products Div., Fullerton, Calif.*

Applications of Combinatoral Algebra and Recursive Function Theory to Information Sciences

Dr. Frank B. Cannonito

AF 49(638)-1643

Objective ....

Toward systematizing the assignment of descriptors in hierarchic structures, and developing adequate and efficient computer realizable algorithms for processing information.

Project summary ....

Some semigroups which are finite semilattices reflect some of the basic abstract structural features of a library. In particular, the information retrieval problem is related to the "word problem" in this mathematical model. Although the word problem for finite structures is trivially solvable, and realistic consideration is limited to only finite subsets of the set of words, questions remain on the efficiency of the general algorithm and the adequacy of the model. Study in combinatorial algebra will be extended toward the design and simulation of a model combinatorial information retrieval (CIR) system. A procedure for obtaining solutions for systems possessing some degree of freedom in the sense that all inquiries processed do not end at the same general terminus will be examined. Methods of implementing the CIRs will be explored. An alternative approach will also be studied to producing truly unpredictable sequences in the sense of recursive function theory (i.e., not Turing predictable).

6-5. *Illinois Institute of Technology Research Institute, Chicago, Ill.*

Theorem Proving by Computer

Mr. Bruce Kallick

AF 49(638)-1458

Objective ....

Toward the development of problem-solving techniques that machines can process efficiently.

Project summary ....

For machine recognition of the notion of proof, algorithmic procedures must provide a translation from natural language into a formal language, and formal rules defining what is meant by a proof. In predicate calculus proof procedures, exhaustive enumeration is a crucial weakness. This project has examined the approach of expressing the denial of the theorem to be proved as a prefix formula of predicate calculus and then generating an inconsistent set of instances of this formula.

Research findings ...

A hybrid procedure was developed to increase the efficiency of the refutation procedure which incorporates features of Friedman's algorithm with those of a refutation procedure based on J. A. Robinson's resolution principle.

Three procedures have been described which decide the same classes of formulas as Friedman's procedure, but more efficiently; a fourth procedure decides formulas in a certain subclass of the AEA prefix class.

Publications ....

Bruce Kallick. "Decision Procedures Based on the Resolution Method." Submitted to Journal of the ACM.

Bruce Kallick. "Theorem-Proving By Computer." Final Rept., AF 49(638)-1458, June 1965. Rept. No. IITRI-H6008-5. AD 611 815.

6-6. *University of Illinois, Biological Computer Lab., Urbana, Ill.*

Information. Communication, Many-Valued Logic, and Meaning

Dr. Gotthard Gunther

AF-AFOSR-480-64

Objective ....

Toward specification of a many-valued logic to describe systems having the capacities of intelligence, self-reflection, and evolution.

Project summary ....

Trans-classical (many-valued) logic is being explored as a distribution order in which two-valued systems can spread as logical units over an enlarged range of inference, based on morphogrammatic (value-sequence) configurations. A hologrammatic theory of logic is being developed which incorporates distinctions of protogrammatic (place occupancy) and heterogrammatic (different symbol) structure and "core" and "frame" distinctions within the morphograms. The logic can thus account for both the duality of the two classical values (positive and negative) and the duality of acceptance and rejection, and the existence of complex orders of two-valued systems so that a rejection value in one may simultaneously have the character of an acceptance value in another.

Research findings ....

A new concept of structure, introduced with the idea of the morphogram in 1962, has been extended and completed by showing that morphograms are parts of a more comprehensive "kenogrammatic" structure with three subdivisions.

A method has been found for reducing the large number of logical constants in many-valued systems which range upward from 10^{150} to manageable proportions for computer operations.

A theory of designation for m-valued systems ($m > 2$) has been developed.

Publications ....

Gotthard Gunther. "Nicht-Aristotelische Logik und das Problem der Mehrwertigkeit." To be published in Sprache im Technischen Zeitalter.

Gotthard Gunther. "Time, Timeless Logic and Self-Referential Systems." Proceedings, N.Y. Academy of Sciences Symposium on Interdisciplinary Perspectives of Time, 17-19 Jan. 1966.

Gotthard Gunther. "Cybernetics and the Transition from Classic to Trans-Classic Logic." Submitted for publication.

6-7. LFE Electronics, Boston, Mass.

Entropy Concepts in Complex Systems

Mr. Jerome Rothstein

AF 49(638)-1450

Objective ....

Toward analysis of the entropy concept in connection with descriptions of organization and information flow in physical systems.

Project summary ....

Similarity in mathematical form of the statistical entropy of physics to the quantitative measure of information derived from communication theory has led to use of this concept in descriptions of phenomena pertaining to organization and information flow in physical systems. This study is examining use of the entropy concept to explain the nonpredictability of the behavior of a "well-informed heat engine," i.e., an automaton whose specific behavior depends on input or information acquired from the environment in which it interacts. An operational definition is sought for the notion of a physical concept as a pattern in terms of information and organization functions and semantic content.

Research findings ....

A proof was found that noncomputable behavior can be realized by an automaton, and arguments have been devised to make intelligent behaviors a subclass of noncomputable behavior.

Publications ....

Jerome Rothstein. "Intelligence and Non-Computability." Paper presented at Symposium on Logic, Computability and Automata, Oriskany, N.Y., 25-27 Aug. 1965.

6-8. New York University, Dept. of Mathematics, New York, N. Y.

The Existence and Use of Algorithms

Dr. Martin D. Davis and Dr. Hilary Putnam

AF-AFOSR-995-66

For description, see Yeshiva University, AF-AFOSR-345-65

6-9. *University of Rochester, Dept. of Mathematics, Rochester, N. Y.*

Logic for Self-Adapting Automata and Universal Elements

Dr. John F. Randolph

AF-AFOSR-481-65; AF-AFOSR-481-66

Objective ....

Toward design of networks and devices capable of adaptation and self-repair and reliable performance for unmanned and hostile environments.

Project summary ....

This is a study of the design of logic elements capable of adaptation or reorganization. An algorithm is being developed for constructing an adaptive network which will yield the "simplest" net when many components are involved. Probabilistic logics of equivalence classes are being examined in an effort to identify maximal (probabilistically reliable) elements. The isolation of elements having the property of remaining in the same equivalence class irrespective of error offers an approach superior to indiscriminate multiplexing to increase reliability.

Research findings ....

In study of a learning model, a second-order approximation of the variance of expected learning time has been obtained and shown to be adequate for judging performance for learning nets of $N \leq 300$ components (the range in which exact results were previously computed and beyond which exact value would be extremely costly).

Simulations on the IBM 7074 show good agreement on samples with $N \leq 300$ and indicate that $N = 1000$ will be feasible.

Publications ....

John F. Randolph. "Cross-Examining Propositional Calculus and Set Operations." American Mathematical Monthly, vol. 72, no. 2 (Feb. 1965) 117-127.

6-10. Rockford Research Institute, Inc., Cambridge, Mass.

Theory of Methods for Implementing Inductive Inference

Mr. Raymond J. Solomonoff

AF-AFOSR-464-65

Objective ....

Toward mechanization of the inductive inference process of formulating predictive patterns from input data.

Project summary ....

Present methods of inductive inference are being examined toward developing more adequate theories and shorter, more efficient methods of implementation. Prior research provided a method of quantitatively assessing a set of processes for inductive inference. The approach is to operate on actual input data and develop a representation of the input through coding techniques by means of the shortest possible program capable of discovering the maximum number of significant predictive regularities in the data. The most general possible form of heuristic search is sought for all kinds of regularities within a corpus of data.

Research findings ....

A formalization of the general heuristic search problem was devised in the form of a network of tasks to be accomplished.

Some practical approximation methods were developed to solve task nets, and theoretical solutions have been obtained for some general forms of the problem.

G-11. *Stanford University, Institute for Mathematical Studies in the Social Sciences, Stanford, Calif.*

A Formal Theory and Algorithms for Intelligent Activities

Dr. E. Mark Gold

AF-AFOSR-256-65, AF-AFOSR-856-66

Objective ....

Toward development of a formal theory of language that can account for human-type intelligent activities.

Project summary ....

Recursive-theoretic methods are being examined to demonstrate that class of problems in artificial intelligence for which a solution procedure can eventually solve any problem of the class, and to characterize features which distinguish between this class of problems and the class for which there is no universal solution. It is planned to reduce results to practical algorithms, particularly for the second class of problems. A class of tree predicates has been introduced that appears large enough to include the question-answer predicate, the implication predicate in English, and the predicate "is proof" in the propositional calculus. The class of tree predicates appears to be a theoretical test for a proposed thinking algorithm. Simple, but formal, approximations to the definition of uses of language are being made toward the construction of a theory of language which can account for four aspects of language usage: analysis, synthesis, learning, and complexity.

Research findings ....

Two closely related, preliminary models are nearing completion which describe the relations that can occur in natural language that would be considered suitable for determining outputs from an organism as a function of its inputs.

Publications ....

E. Mark Gold. "Identification in the Limit." Informal summary paper, April 1965.

E. Mark Gold. "Syntax Extension." Informal rept., June 1965.

6-12. Wayne State University, Monteith College, Detroit, Mich.

A Brain Model Using Multi-Valued Logics

Mr. Alfred L. Stern

AF-AFOSR-530-65; AF-AFOSR-530-66

Objective ....

Toward specification of a model that operates with non-numeric information in the specially patterned ways called intelligent behavior.

Project summary ....

An attempt is being made to define a proper model for the information handling capability of the central nervous system with respect to its perceptual and storage capacity and its information handling techniques in terms of multivalued-logic representations. Ternary logic is being used in a first approximation. A simulated ternary environment and the generation of ternary objects in it have been programmed. Simulations are being programmed that describe ternary subsystems for sensory input, transmission, memory, and command and control. Results will be extrapolated to a quaternary logic. Based on results with ternary and quaternary logics, the order of complexity will be determined for a system using multivalued elements (with operations of the same logical order) which would be needed for a proper model of the central nervous system.

Research findings ....

A computer program has been written which simulates a ternary 40 x 40 matrix as the environment for a brain model and provides for the generation of ternary objects in the environment.

Publications ....

Alfred L. Stern. "A Brain Model Using Multi-Valued Logics." Interim progress report, Preliminary draft, Dec. 65.

6-13. Yeshiva University, New York, N. Y.

The Existence and Use of Algorithms

Dr. Martin D. Davis and Dr. Hilary Putnam

AF-AFOSR-345-63; AF-AFOSR-345-65

Continuation under New York University, AF-AFOSR-995-66

Objective ....

Toward extension of modern developments in mathematical logic as tools or prescriptions for the explicit representation of procedures generally labeled as intelligent activities.

Project summary ....

Studies are being made of proof procedures (a) on a problem in the elementary theory of groups; (b) on the problem of identity; (c) on problems in number theory from developments of finitely axiomatized systems and infinitely axionatized systems with a finite set of axioms and induction schema; and (d) on systems of notation for transfinite ordinal numbers. Study is planned of semi-computable (recursively enumerable) sets in an attempt to extend earlier results relevant to number theory and automata theory. Effort has begun on the development of new theorem-proving methods for an infinitely axiomatized system of first-order number theory.

Research findings ....

Prof. Davis - A new proof of Hilbert's second epsilon theorem based on Herbrand's fundamental theorem was obtained which may find applicability in connection with mechanical theorem proving.

Prof. Putnam - A hierarchy of degrees of unsolvability has been constructed that extends the Spector hierarchy to all sets of integers that are "constructable" in the sense of Gödel.

Publications ....

Hilary Putnam. "Trial and Error Predicates and the Solution to a Problem of Mostowski." Journal of Symbolic Logic, vol. 30, no. 1 (March 1965) 49-57.

Hilary Putnam and Gustav Hensel. "The Ramified Analytical Hierarchy." Submitted to Journal of Symbolic Logic.

Hilary Putnam. "Truth and Proof." Submitted to Journal of Philosophy.

6-14. Yeshiva University, Belfer Graduate School of Science, New York, N. Y.

Symbolic Logic and Recursive Function Theory

Dr. Raymond M. Smullyan

AF-AFOSR-433-64; AF-AFOSR-433-65

Objective ....

Toward simplification of mathematical statements of proofs amenable to digital computer processing.

Project summary ....

Applications of the theory of computable (recursive) functions are being investigated to requirements of computing machines and finite automata. Modifications of a unifying principle in quantification theory are being explored for intuitionist logic and recursive function theory. Unifying principles are also being sought in set theory.

Research findings ....

Some results of research on translation processes between different formal proof procedures for simplifying proofs are reported in the first two references below.

Study has started on "proof theory," toward the constructive demonstration of the consistence of various mathematical systems.

Publications ....

Raymond M. Smullyan. "Analytic Natural Deduction." Journal of Symbolic Logic, vol. 30, no. 2 (June 1965)

Raymond M. Smullyan. "Trees and Nest Structures." Accepted for publication, Journal of Symbolic Logic.

Raymond M. Smullyan. "On Transfinite Recursion." Accepted for publication, Transactions, New York Academy of Sciences.

Raymond M. Smullyan. "The Continuum Problem." Accepted for publication, Encyclopedia of Philosophy.

Section 7. Statistics

A total of 68 projects is reported on in this volume. Funds for a project range from $6,046 to $91,200, the majority being in the $25,000 to $35,000 range. The table below summarizes the fiscal years from which the projects reported were funded.

Fiscal Year	Contracts	Grants
66	16	21
65	9	14
64	1	3
63	1	2
62	-	1
Totals	27	41

Most of the projects are funded on an annual basis, though longevity is desirable, particularly for studies that require extended periods for fruitful results. Planned longevity is reflected in the above data. Unanticipated longevity is also reflected. This arises when computer programs don't perform as they should, or equipment delivery is delayed, or staff assistants leave who are difficult to replace, etc.

The FY 66 projects initiated include the 37 shown above and 7 which begin in 1966 (see Section 8).

This volume lists citations to 144 papers or publications. Certainly, publication is important in science. However, "publication" is more than that which is recorded in technical reports, journal articles, books. Perhaps the most useful publication for the researcher is the content of personal correspondence and discussion at meetings or informal "bull sessions." This tells him what is going on and gives him ideas, helps him to make syntheses that can give new direction to his work. One "half-baked" idea cannot be published and negative results too infrequently are, but these are as useful and as much the foundation for thought as neatly tabulated results. The publication is a record, valuable to those who come after and to those who will build the next story. It is a measure of accomplishment, but only one of many factors for determining worth of a research project or the productivity and creativity of a man.

Section 8. Projects Initiated During the Period but Starting in 1966

Association pour l'Étude et la Recherche en Traitement de l'Information, Paris, France
Algebraic Methods in Automata Theory
Dr. Marcel P. Schützenberger and Mr. Maurice P. Nivat
Task 6

Bunker-Ramo Corp., Canoga Park, Calif.
1966 Linguistic Institute Conference on Linguistic Method
Dr. Paul L. Garvin
AF 49(638)-1677
Task 5

University of California, Dept. of Psychology, Los Angeles, Calif.
Mathematical Design of an Automaton to Experience Simple Sense Data
Dr. James T. Culbertson and Dr. F. Nowell Jones
AF-AFOSR-1036-66
Task 2

University of Georgia, Dept. of Physics and Astronomy, Athens, Ga.
Integration of Theory and Experiment into a Unified Concept of Visual Perception
Dr. Heinz von Foerster and Dr. Humberto R. Maturana
Task 3

P.E.C. Research Associates, Inc., Boulder, Colo.
Logic and Rational Processing in Scientific Discovery
Dr. Norwood R. Hanson
AF 49(638)-1677
Task 6

Sperry Rand Corp., Univac-Defense Systems Div., St. Paul, Minn.
Studies in Logic on Information Capacity and Command Hierarchies
Dr. Marius Cohn and Dr. William H. Hanson
Task 6

Universidad Nacional de Trujillo, Facultad de Letras y Educación, Trujillo, Peru
Comparative Analysis of Four Languages in Relation to Yngve's Depth Hypothesis
Dr. Ernesto Zierer
Task 5

Section 9. Index to Institutions

Note: Project numbers rather than page numbers are given for location.

Section 10. Index to Principal Investigators

Note: Project numbers rather than page numbers are given for location.

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11 SUPPLEMENTARY NOTES (Citation)

12 SPONSORING MILITARY ACTIVITY
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13 ABSTRACT

This is the third in a series of annual reports of the basic research program of the Directorate of Information Sciences, Air Force Office of Scientific Research. Summaries of projects current during calendar year 1965 are given within six categories: (a) information systems research, (b) information identification and classification, (c) transmission of information, (d) adaptive and self-organizing systems, (e) language and linguistics research, and (f) theoretical foundations of information sciences. Brief comments are made about each category. Indexes to institutions and principal investigators are included.

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