INFORMATION SYSTEMS SUMMARIES

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Preface to Third Edition

INFORMATION SYSTEMS SUMMARIES

The Information Systems Branch of the Office of Naval Research has as its fundamental concern the enhancement of the Navy's (and the nation's) capabilities in national defense, to be accomplished through the specific medium of advancing the state-of-the-art in information systems. In keeping with the nature and mission of the Office of Naval Research, this effort is channeled primarily into the uncovering and dissemination of new knowledge. Although such knowledge hopefully will be useful subsequently for developing, improving, or supporting defense systems, responsibility for effecting such specific use of the knowledge is normally retained by other agencies of the Navy or the Department of Defense.

A program of basic and applied research in the information sciences, carried out under contract at universities, research institutes, and industrial laboratories, serves as the mechanism for uncovering knowledge. This program is planned, administered, and guided entirely by Information Systems Branch personnel, but extensive efforts are made continually to ensure that the program is responsive to the needs of the Navy and coordinated with related programs carried out by other groups.

The task of estimating the Navy's future requirements for mechanized information handling is a difficult one, since the Navy's activities span most forms of warfare, all known environments, and nearly all human occupations. Furthermore, the cost of doing such business is high, time is a perishable commodity, and the penalties for being technologically outflanked are catastrophic. However, two major critical problem areas may be isolated; these are computer augmentation of human reasoning (e.g., in command control, intelligence processing, scientific research) and reduction of tremendous quantitites of information (e.g., in inventories, photointerpretation, other scientific work). These major problem areas can be interpreted in terms of machine requirements: the Navy must have much higher computation speeds, much closer man-machine "coupling," and the ability to handle mechanically a much wider variety of tasks; further, the machines which provide these capabilities must be more thoroughly reliable, more reasonably sized, and better priced than is possible at present.

As a mechanism to aid rational management of research across this broad collection of requirements, the Information Systems Branch has tried several classification schemes for the information sciences as they relate to machines. Each has offered certain advantages but none succeeded either in eliminating or, conversely, in demonstrating the numerous interactions which exist between various segments of the overall subject area. The taxonomy used in this report—the same one tried in the second edition of this annual series—appears to work in practice at least as well as any others. Three broad divisions are involved: they concern respectively general information science, man-machine symbiosis, and information processing machinery *per se*.

General information sciences, the first division, involves primarily the theoretical work required for extending the understanding of information and of the systems which manipulate it. Classical information theory is of course included, as are other appropriate areas of applied mathematics such as logic, numerical analysis, and automata theory. This division tends also to serve as a catch-all for subjects which will not fit reasonably into the other major divisions.

Machine interaction with humans, the second division, is central to our interests and, in a very real sense, serves as the raison d'etre of the Information Systems Branch. It includes research leading toward such important applications as information retrieval, language analysis, automated teaching, command-control, and intelligence. Interwoven inextricably with these, of course, are more specific subjects such as computer programming, display techniques, time-sharing, heuristic processes, and pattern recognition.

However, progress toward machine aid to humans is dependent also upon many advances in machines themselves, without regard to their social environment, and thus the third major division concerns improved information processing machines. Self-organization—taken here to include learning machines, implicit programming, bionics, anastomotics, and other forms of self-adaptation—is a primary subject of concern. So is the investigation of various physical phenomena which hold promise for improved computer capabilities, such as optical and pneumatic techniques and magnetic and solid-state effects. Somewhat more

specialized subjects are also of interest, such as hybrid analog/digital techniques and multi-processing methods. Automatic control can be studied without consideration of human interaction, and thus pertains here. Finally, the construction of large experimental machines to test new principles is of considerable interest but, unfortunately, generally costs too much for austere research budgets.

Dissemination of the results, and their implications, stemming from the research program in these areas takes many forms in order to serve a vareity of purposes. Three distinct classes of recipients exist, each having its own requirements: development and engineering personnel need new ideas and techniques to solve their technical problems or to suggest new approaches; members of the scientific community need detailed knowledge of both new research findings and also new research tools and techniques; and research and development management personnel need current and projected status information on the state of technology and the cost in time, dollars, and manpower of pushing it forward. To satisfy these users the Information Systems Branch utilizes several media. Technical reports and report summaries from contractors are distributed wide'. A series of Data Processing Seminars is conducted approximately monthly, and major symposia are sponsored from time to time in newly developing technological areas. A Digital Computer Newsletter is published quarterly. This report itself represents an effort to acquaint interested personnel with the Information Systems Branch program and with a sampling of current significant research in the information sciences.

Additional details of specific research tasks summarized in this report would best be obtained from the appropriate principal investigators, since they are, after all, the specialists in their respective subjects. However, information concerning general areas of research in the information sciences, or the Navy's contract research program therein will be supplied gladly by any member of the technical staff of the Information Systems Branch. At present this staff consists of Richard H. Wilcox (Head), Gordon D. Goldstein, Donald K. Pollock, Margo A. Sass, and LTJG S. Jack Mathis. This report is the result primarily of the efforts of Mr. Mathis, with valuable assistance from Mrs. Yvonne Kilgore and Miss Elaine Strohl. Much appreciation is due also to the individual research investigators, who prepared drafts of their own task summaries.

One final note: just as with the two preceding editors of Information Systems Summaries, preparation and publication times remain as major difficulties; the information contained in this edition is in general accurate as of November 1964. Some modifications (hopefully, improvements) have been incorporated, but additional suggestions will be welcomed and given careful consideration. Feedback still appears to be the best technique for reducing errors and achieving desired objectives.

Washington, D.C.   Richard H. Wilcox
July 1965   Information Systems Branch
                                                             Office of Naval Research

A. GENERAL INFORMATION SCIENCES

MULTIDIMENSIONAL INFORMATION THEORY

S. GOLDMAN
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TASK NO. NR 049-117   CONTRACT Nonr 669(10)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task is a theoretical study of multidimensional information. An attempt is being made to generalize the concepts of classical one-dimensional information theory to several dimensions. Studies of the natural biological world are sometimes used to suggest optimum methods of information translation.

SUMMARY OF RECENT ACCOMPLISHMENTS

A study of the waveshape and coherence properties of light based upon the principles of quantum mechanics was continued. This was combined with a program of using the tools of communication theory in dealing with quantum mechanical problems and in using the points-of-view of communication theory in attempting to assess the significance of different aspects of quantum mechanics.

We have used results recently found by others concerning waveshape and coherence properties of thermal and of coherent radiation and extended them to superpositions of thermal and coherent radiation, and we have shown some of the relations of these results to communication theory. We have also shown how the techniques which we have developed can be used to simplify earlier work of others.

In the second part of this work, which is still continuing, we are studying the properties of photons, particularly as they are related to the waveshape and coherence properties of light in time and space, to photon correlation experiments, and to emission and absorption. Most of the results we have so far obtained in this part of the work are not new, but they are seen from a different point-of-view.

The third part of the work dealing with the application of communication theory to quantum mechanics is in its early stages.

A study of the significance of noise and of the failures of noise reduction in aging processes is also underway.

RECENT REPORTS OR PUBLICATIONS

"Carriers in Communication and in Physiology" by Stanford Goldman. *PERSPECTIVES in Biology and Medicine*, Vol. VII, No. 2, Winter, 1964, pages 159-168, University of Chicago Press, Chicago, Illinois.

"On the Quantum Mechanical Aspects of the Waveshape of Electromagnetic Radiation," by Gerard Lachs. Report No. EE-494-649 T-7 of the Syracuse University Research Institute, Syracuse, New York 13210.

RESEARCH IN INFORMATION THEORY

A. THOMASIAN
University of California
Berkeley, California

PRINCIPAL ASSOCIATES: D. BLACKWELL, L. BREIMAN, A. GILL

TASK DESCRIPTION

This task is a cooperative effort, by both statisticians and electrical engineers, to investigate various formal problems of information processing. Specifically, classical information theory techniques are examined to determine their applicability and bounds of validity, and extension of the techniques are sought.

SUMMARY OF RECENT ACCOMPLISHMENTS

Extensive research has been carried out in a wide variety of problem areas including: new information transmission situations, relations between information theory and general probability theory, pattern recognition, deterministic sequential machines, probabilistic sequential machines, dynamic programming, traffic flow, and quality control.

RECENT REPORTS OR PUBLICATIONS

D. Blackwell, L. Breiman, and A. J. Thomasian, "Proof of Shannon's Transmission Theorem for Finite-State Indecomposable Channels," *Ann. Math. Stat.*, Vol. 29, No. 4, December 1958 (Issue No. 226, January 20, 1959).

A. Gill, "Minimum-Scan Pattern Recognition," *IRE Trans. on Information Theory*, Vol. IT-5, No. 2, June 1959 (Issue No. 233, March 23, 1959).

D. Blackwell, L. Breiman, and A. J. Thomasian, "The Capacity of a Class of Channels," *Ann. Math. Stat.*, Vol. 30, No. 4, December 1959 (Issue No. 282, May 23, 1960).

D. Blackwell, "Infinite Codes for Memoryless Channels," *Ann. Math. Stat.*, Vol. 30, No. 4, December 1959 (Issue No. 281, May 23, 1960).

M. Freeman, "Monte Carlo Estimates of Excursion Probabilities of a Gaussian Process," (Issue No. 272, March 30, 1960).

A. Gill, "Optimal Organization of Serial Memory Transfers," *IRE Trans. on Electronic Computers*, Vol. EC-9, No. 1, March 1960 (Issue No. 311, August 29, 1960).

A. Gill, "Minimization of Contact Networks Subject to Reliability Specifications," *IRE Trans. on Electronic Computers*, Vol. EC-9, No. 1, March 1960 (Issue No. 308, August 22, 1960).

A. Gill, "On a Class of Transportation Problems," *J. Math. Phys.*, Vol. 39, No. 1, April 1960 (Issue No. 302, July 28, 1960).

A. J. Thomasian, "Error Bounds for Continuous Channels," *Proc. of the Fourth London Symposium on Information Theory*, Ed. by C. Cherry, Butterworth, London, 1961 (Issue No. 278, April 28, 1960).

A. J. Thomasian, "An Elementary Proof of the AEP of Information Theory," *Ann. Math. Stat.*, Vol. 31, No. 2, June 1960 (Issue No. 318, September 19, 1960).

M. M. Katz and A. J. Thomasian, "An Exponential Bound for Functions of a Markov Chain," *Ann. Math. Stat.*, Vol. 31, No. 2. June 1960 (Issue No. 319, September 19, 1960).

L. Breiman, "On Achieving Channel Capacity in Finite Memory Channels," *Illinois J. Math.*, June 1960 (Issue No. 288, June 27, 1960).

A. Gill, "A Comparison of Finite-State Models," *IRE Trans. on Circuit Theory*, Vol. CT-7, No. 2, June 1960 (Issue No. 323, October 26, 1960).

D. Blackwell, L. Breiman, and A. J. Thomasian, "The Capacities of Certain Channel Classes Under Random Coding," *Ann. Math. Stat.*, Vol. 31, September 1960 (Issue No. 437, February 20, 1962).

D. Blackwell, "Exponential Error Bounds for Finite-State Channels," *Proc. of the Fourth Berk. Symp. on Math. Stat. and Prob.*, Vol. 1, Univ. of Calif. Press, Berkeley and Los Angeles, 1961 (Issue No. 466, August 13, 1962).

L. Breiman, "Optimal Gambling Systems for Favorable Games," *Proc. of the Fourth Berk. Symp. on Math. Stat. and Prob.*, Vol. 1, Univ. of Calif. Press, Berkeley and Los Angeles, 1961 (Issue No. 467, August 13, 1962).

M. Katz and A. J. Thomasian, "A Bound for the Law of Large Numbers for Discrete Markov Processes," *Ann. Math. Stat.*, Vol. 32, No. 1, March 1961 (Issue No. 291, July 1, 1960).

L. Breiman, "Another Approach to Information Theory," (Issue No. 304, August 15, 1960).

A. J. Thomasian, "The Metric Structure of Codes for the Binary Symmetric Channel," *Proc. of the Fourth Berk. Symp. on Math. Stat. and Prob.*, Vol. 1, Univ. of Calif. Press, Berkeley 1961 (Issue No. 305, August 15, 1960).

A. Gill, "Analysis of Nets by Numerical Methods," (Issue No. 320, September 23, 1960).

C. B. Bell, D. Blackwell, L. Breiman, "On the Completeness of Order Statistics," *Ann. Math. Stat.*, Vol. 31, No. 3, September 1960.

A. Gill, "Characterizing Experiments for Finite-Memory Binary Automata," *IRE Trans. on Electronic Computers*, Vol. EC-9, No. 4, December 1960 (Issue No. 345, February 14, 1961).

A. Gill, "State-identification Experiments in Finite Automata," *Inf. and Control*, Vol. 4, No. 2, September 1961 (Issue No. 413, November 13, 1961).

D. Blackwell, "On the Functional Equation of Dynamic Programming," *J. of Math. Analysis and Applications*, Vol. 2, 1961 (Issue No. 380, July 5, 1961).

D. Blackwell, "Minimax and Irreducible Matrices," *J. of Math. Analysis and Applications*, Vol. 3, No. 1, August 1961.

A. Gill, "A Note on the Minimal Representation of Triggering Matrices," *Quart. Appl. Math.*, Vol. 19, No. 1, April 1961 (Issue No. 357, May 17, 1961).

R. N. Miller, "A Modification of Hamming Codes for Use in Error-Detection," (Issue No. 419, November 21, 1961).

J. W. Carlyle, "Equivalent Stochastic Sequential Machines," (Issue No. 415, November 14, 1961).

A. Gill, "Cascaded Finite-State Machines," *IRE Trans. on Electronic Computers*, Vol. EC-10, No. 3, September 1961 (Issue No. 412, October 27, 1961).

J. J. Birch, "Approximations for the Entropy for Functions of Markov Chains," *Ann. Math. Stat.*, Vol. 33, No. 3, September 1962.

D. Blackwell, "Discrete Dynamic Programming," *Ann. Math Stat.*, Vol. 33, No. 2, June 1962 (Issue No. 468, August 13, 1962).

L. Breiman, "The Poisson Tendency in Traffic Distribution," (Issue No. 473, August 22, 1962).

A. J. Thomasian, "A Finite Criterion for Indecomposable Channels," *Ann. Math. Stat.*, Vol. 34, No. 1, March 1963.

L. Breiman, L. LeCam, and L. Schwartz, "Consistent Estimates and Zero-one Sets," August 1962.

L. Breiman, "A Model for Quality Control," October 1962.

G. K. Machol, "Randomized Policies for Stochastic Sequential Systems," (Issue No. 488, December 10, 1962).

T. J. Wagner, "Generalized Coding and Uniform Finite-Memory Codes," (Issue No. 492 December 26, 1962).

A. J. Thomasian, "Foundations of Information Theory," to appear in *IEEE Trans. on Information Theory*.

APPLICATIONS OF INFORMATION THEORY

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New York, New York

TASK DESCRIPTION

This task is concerned with relatively unconventional aspects and applications of information theory. This includes such topics as the derivation of uncertainty principles from information restrictions on scientific observation, and also the informational aspects of biochemistry.

SUMMARY OF RECENT ACCOMPLISHMENTS

A paper on the basic assumptions in science was published by the big Italian review "Civiltà delle Machine" (Civilization of Machines).

A paper on the "Arrow of Time" was read at the "1964 International Congress for Logic, Methodology and Philosophy of Science, held in Jerusalem last August and September." This paper was very well received and met with general approval. It is to be printed in the official reports of the Congress. We presently prepare a presentation of this paper as one of our technical reports.

A discussion of the basic concepts of Relativity leading to a revision of some of its basic assumptions was presented (in French) to the "Académie des Sciences" in Paris. A first draft is being printed by the "Journal de Physique" and the whole problem will be written for a paper to the National Academy of Sciences in Washington. Many scientists are already working on new applications of the author's ideas, that lead to many revisions of relativistic mechanics.

RECENT REPORTS OR PUBLICATIONS

Tensors in Mechanics and Elasticity, a translation from the French book published by Masson, Paris, translated by Robert O. Brennan, S. J., altogether 478 pages. Academic Press.

Scientific Uncertainty, and Information, 164 pages, a thought-provoking book, presenting a complete reappraisal of the philosophical foundations of science, and emphasizing the fact that modern physics had to renounce to strict determinism, which is replaced everywhere by loose causality, with probability laws in all elementary processus. Academic Press.

LOGICAL DESIGN OF COMPUTER NETS

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TASK NO. NR 049-114   CONTRACT Nonr 1224(21)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task is devoted to the study of automata theory and the logical design of computer nets. Four basic problems in logical design are being investigated; behavior specification, analysis, synthesis, and minimality.

SUMMARY OF RECENT ACCOMPLISHMENTS

Two principal areas are under investigation. The first of these has to do with algebraic formulations of automata theory (where the automata under consideration need not necessarily be finite). Many algebraic formulations of finite automata theory have been proposed and employed. Each of these formulations appears to have value; according to the particular problems considered and solutions sought, one or another of these various formulations appear to have natural advantages. The presence of many alternative formulations leads one to consider the possibility of a more abstract algebraic theory, embracing all the present formulations, and hopefully, throwing light on deeper, more essential properties of automata and on the interrelationshps between the various formulations. The framework presently being considered for this more abstract theory is that of category theory. Several results such as the completeness of the representation and its relevance to the problems suggested have already been obtained.

The second area of research is that of growing cellular automata as formulated by John von Neumann. A detailed description of the construction of a universal machine in the von Neumann cellular system has been completed, and various improvements to particular submachines of the universal machine have been described.

The research in both of the above mentioned areas is continuing. The research in the first area should lead to a deeper, clearer understanding of both finite and infinite machines; the research in the second area should lead to a deeper understanding of the construction and programming of machines which grow, adapt, and duplicate.

RECENT REPORTS OR PUBLICATIONS

"Variants of Thatcher's Algorithm for Constructing Pulsers," S. Hedetniemi, Technical Report, August 1964.

"Outline for an Algebraic Study of Event Automata," Y. Give'on, Technical Report, June 1964.

"The Theory of Algebraic Automata I: Morphisms and Regular Systems," Y. Give'on, Technical Report, January 1964.

"Notes on Mathematical Automata Theory," J. W. Thatcher, Technical Note, December 1963.

"Transition Graphs and the Star-Height of Regular Events," L. C. Eggan, *Michigan Mathematical Journal,* Vol. 10 (1963), pp. 385-397.

"Universality in the von Neumann Cellular System," J. W. Thatcher, Technical Report, October 1964.

BIAX PERCEPTRON

J. HAWKINS
Aeronutronic Division, Philco Corp.
Newport Beach, California

TASK NO. NR 048-146   CONTRACT Nonr 2913(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with research on self-organizing computer networks, analogous to neural perception networks, capable of adjusting internal variables in the presence of inputs and error signals so as to perform sophisticated recognition of significant features present in the input.

SUMMARY OF RECENT ACCOMPLISHMENTS

During previous work several general features of successful learning networks had emerged: (1) minimizing the number of elements a ered; (2) selecting elements for undergoing weight change whose sums are nearest zero; (3) allowing the network to participate in determining the effectiveness of tent tive changes to see if they should be made permanent; (4) allowing each element to make, as nearly as possible, an autonomous decision as to whether to alter its weights; and (5) providing a number of weights and elements in the network somewhat in excess of the minimum needed to generate the required outputs. These requirements arose as a result of various empirical data including computer simulations of networks.

During the present reporting period these principles were incorporated in a new computer simulation of a learning network model using an IBM 7090. The specific model chosen involved restricting interconnecting weights (those attached to inputs of elements whose sources are other elements) to be positive, and using a common shifting bias term in each element's sum to perturb that element's state during a corrective process.

A total of about 2000 learning network trials were run using this simulation program. The results showed a considerable improvement over the cruder model used previously. In particular, the previous difficulty of endlessly repeating cycles was not encountered with the improved model. However, comparative series of various trials revealed that the interconnecting, positive weights appeared to contribute very little to the learning process.

To correct this difficulty a revision has been made to this computer program which allows negative as well as positive interconnecting weights, and which replaces the simpler common bias perturbation with a more complex one. A thorough testing of this model, and comparisons with the positive weight model, are in preparation now.

The above trials involved small numbers of inputs. A number of further simulations were made using a 32 by 32 array of binary inputs representing small photographs. Learning trials which were required to select certain features out of a series of 100 photographs resulted in very rapid learning. This continued to be the case when rotated versions of these images were added. It is planned to alter the program to allow for magnetic tape storage of the images so that a much larger number can be used in learning experiments.

RECENT REPORTS OR PUBLICATIONS

Roger A. Stafford, "Multi-Layer Learning Networks," Aug. 25, 1964, WESCON Paper #3.3 (set to official distribution list).

Roger A. Stafford, "A Learning Network Model," Oct. 13, 1964, Paper delivered at ONR Los Angeles Invitational on Biophysics.

ULTRA-RELIABLE COMPUTER TECHNIQUES

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Systems Research Group
Mineola, New York

PRINCIPAL ASSOCIATE: J. Enterline

TASK NO. NR 048-173   CONTRACT Nonr 3702(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

The purpose of this task is to develop experimental devices and test techniques which will be useful in the design and evaluation of ultra-reliable computer systems and sub-systems. Typical techniques to be investigated are simple and adaptive voting systems, self-diagnosis of errors, and anastomotic methods. Quantitative methods for analysis, test, and evaluation of such techniques will also be investigated.

SUMMARY OF RECENT ACCOMPLISHMENTS

The basic logic block for the ULTREC I computer has been completely redesigned. Although the cores used and the redundant techniques are still the same, the number of turns on each core has been changed and two transistor flip flops and a transistorized driver have been added to the core module. With these two major changes it has been proved that each core module can now handle the required loads. A five bit shift register was breadboarded and debugged. The operation proved to be very satisfactory.

Various other tests were conducted utilizing ring counters and shift registers with majority logic. The second of the previous mentioned major changes is the number of turns on each core. The "F" and "M" shift windings have reduced by a factor of 60 to 1. The primary reason for this change was to eliminate the problems encountered in driving a long string of core modules. Several test cores were wound and breadboarded with the new core module circuitry. In using this approach costs are minimized by utilizing some of the old shift registers.

Another major area accomplished during phase I of this project is the design of the Input/ Output unit. The I/O consists of a Flexowriter and the associated relay transistor circuitry. These circuits are used as an interface between the I O buffer and Flexowriter.

RECENT REPORTS OR PUBLICATIONS

None.

REDUNDANT SYSTEMS RESEARCH

W. MANN
Westinghouse Electric Corporation
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TASK NO. NR 049-179   CONTRACT Nonr 3842(00)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

The purpose of this task is to devise and investigate several forms of redundancy in logical systems and to develop associated techniques for evaluation and optimization of systems synthesized using these techniques.

SUMMARY OF RECENT ACCOMPLISHMENTS

The susceptibility of nonredundant electronic networks to error limits their effectiveness for the performance of complex tasks in environments in which repair is impracticable and failure is unacceptable. To overcome the limitation, a number of investigators have proposed the use of redundancy — the incorporation of extra parts such that some parts may fail without disturbing the function performed by the network.

This study is currently concerned with "multiple-line" redundancy, a particular form of a concept introduced by von Neumann. Replicas of the original circuits of the non-redundant network are operated in parallel such that at any point a number of lines carry nominally identical signals. Functions called restorers are incorporated into the redundant network to correct errors that appear on the lines. Previous investigations have shown that multiple-line redundancy is an effective means for increasing reliability.

During the past year research has concentrated on the development of a synthesis procedure for design of multiple-line redundant networks of arbitrary topology. The procedure optimizes the placement of sets of voting circuits in the network under a cost minimization criterion which includes linear penalties for weight, power, and probability of mission failure. A computer program which implements the procedure for order −3 majority voted networks has been developed. The program uses a reliability analysis technique previously developed under this contract for such systems. The program has not been fully evaluated, but with minor modifications it was used successfully on a design study of a digital spacecraft timing system for Jet Propulsion Laboratories.

RECENT REPORTS OR PUBLICATIONS

"The Synthesis of Redundant Multiple-Line Networks," — Second Annual Report, May 1, 1964. This report is self-contained and does not require reading of previous reports.

INFORMATION SYSTEMS REQUIREMENTS

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HRB-Singer, Inc.
State College, Pennsylvania

TASK NO. NR 348-001   CONTRACT Nonr 3818(00)

PROJ. NO. RR 003-10-02

TASK DESCRIPTION

The efforts of this task have been broken into four distinct, but interfacing studies. These include: (1) research directed toward the testing and continued evolution of the Operational Network Evaluation methodology for the evaluation of information collection and interpretation systems; (2) the investigation of profiling techniques leading to the compilation of data from which knowledge can be derived for particular information sources; (3) the structural analysis of selected naval intelligence networks within the fleets in terms of input-output requirements; and (4) a feasibility study concerned with the creation of an intelligence engineering discipline.

SUMMARY OF RECENT ACCOMPLISHMENTS

The Operational Network Evaluation has progressed in its development to the level where the first test of the methodologies involved was recently conducted. The Integrated Operational Intelligence System (IOIS) was selcted as the test vehicle and was carefully studied and broken into a well defined network structure. The evaluation demonstrated both the potential of the O.N.E. to perform its intended mission and the need for naval participation in the assignment of weighting factors to basic terms within the evaluation structure.

State-of-the-art studies were concluded in the various areas pertinent to information systems. The four areas studied included: (1) enemy weapon systems; (2) naval sensors; (3) naval communications systems; and (4) information handling and processing systems. A small effort is still being expended to continuously update these studies of the state-of-the-art.

RECENT REPORTS OR PUBLICATIONS

L. A. Doggett, *Bibliography of Project HOIST Data Files*, 352-R-6, 25 September 1963.

E. S. Carter, *On the Need for a Military Intelligence Discipline*, 352-R-8, November 1963.

D. W. McKinney, W. D Files, *Evaluated Trends in the Projected Enemy Environment*, 352-R-9, 20 April 1964.

D. R. Hild, *Evaluated Trends in Naval Communications State-of-the-Art*, 352-R-10, April 1964.

J. L. Oneill, *Trends in the Information Sciences Relative to Naval Intelligence Needs*, 352-R-11, July 1964.

W. D. Files, *Evaluated Trends in Sensor State-of-the-Art Relative to Naval Intelligence Needs*, 352-R-12 November 1964.

E. S. Carter, *Experimental Heuristic as an Approach in Problem Solving*, scientific paper presented at the Symposium on Computer Augmentation of Human Reasoning, July 1964. (Limited Distribution.)

D. J. Panzl, *A Navy Information System*, scientific paper presented at The Northeastern States Navy Research and Development Clinic, November 1964. (Limited Distribution.)

SELF-ORGANIZING MACHINES

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PRINCIPAL ASSOCIATES: A. NOVIKOFF, N. J. NILSSON, R. O. DUDA, J. W. MACHANIK

TASK NO. NR 049-169   CONTRACT Nonr 3438(00)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task involves theoretical research on various aspects of self-organizing machines. Of particular interest is "function modeling," an effort to derive from the final internal organization of a self-organizing machine an analytical or logical description of a process which it has previously "learned."

SUMMARY OF RECENT ACCOMPLISHMENTS

(1) *Function Modeling*

Previous studies had demonstrated that networks of adaptive threshold elements can be used to approximate or model functions with many independent variables. An experimental study in which these techniques have been successfully applied to certain statistical prediction problems has been completed. Effort is now being directed at obtaining information from the converged values of the weights, with particular emphasis on using the weight values to rank the input variables in order of their importance.

(2) *Training Methods for Inconsistent Data*

The presence of inconsistent samples in a body of training data can greatly degrade the performance of an adaptive network, particularly if atypical samples are among the last used for training. An idealized version of this problem has been investigated, *viz*, the training of a single threshold logic unit on linearly separable but randomly mislabeled patterns. For this case the standard error-correction rules give rise to a Markov process, the weight vectors obtained being associated with the states of the process. Conditions have been found under which the time-average of the weight vectors converges (with probability one) to a solution vector. In those cases for which the limiting average weight vector is not a solution vector, experimental results have shown that its performance is usually much better than that of weight vectors obtained by error-correction rules.

RECENT REPORTS OR PUBLICATIONS

Duda, R. O., J. W. Machanik, and R. C. Singleton. "Function Modeling Experiments." SRI Technical Report prepared for the Office of Naval Research, Washington 25, D.C., under contract Nonr 3438(00), December 1963.

Duda, R. O., and R. C. Singleton. "Training a Threshold Logic Unit with Imperfectly Calssified Patterns," presented at the 1964 Western Electronic Show and Convention, Los Angeles, August 1964.

AUTOMATA THEORY AND INFORMATION RETRIEVAL

Y. BAR-HILLEL
Hebrew University
Jerusalem, Israel

TASK DESCRIPTION

This task is devoted to study or analysis of automata theory, general information retrieval, and mechanical translation. The objective is to develop general principles which lead to practical solutions of these problems and may serve to guide future equipment research.

SUMMARY OF RECENT ACCOMPLISHMENTS

Rabin continued work on problems of Automata Theory, in particular determined relative strengths of one-tape *versus* two-tape real-time computation procedures, also applied Theory of Automata to solve word problem of commutative semi-groups. He further continued work on certain "sequential calculi" which are formal languages suitable for description of finite automata and sequential circuits. He obtained several positive and negative results concerning existence of effective solutions for various decision problems concerning this calculus.

Machover and Levy continued work on book on recursive functions of ordinal numbers, extending the notion of computability to transfinite numbers.

Gaifman worked on generalizations of the notion of computability, developing a notion of algorithm applicable not just to natural numbers but also to more general domains.

Machover worked on Lésniewski's logical calculi which have the property, shared with natural languages, that the meaning of a symbol depends on its context. He devised an effective procedure assigning correct syntactical categories to all phrases in a given context.

RECENT REPORTS OR PUBLICATIONS

Y. Bar-Hillel, *Language and Information: Selected Essays on Their Theory and Application*, Addison-Wesley, 1964.

M. Machover, *Contextual Determinacy in Lésniewski's Grammar*, Technical Report No. 16, May 1964.

M. Rabin and H. Wang, *Words in the History of a Turing Machine with Fixed Input*, Jour. of the Assoc. of Computing Machinery, October 1964.

M. Rabin, *Real-time Computation*, Israel Jour. of Mathematics, January 1964.

THE ALGEBRAIC THEORY OF MACHINES

K. KROHN
6001 Dunham Springs Road
Nashville, Tennessee

TASK DESCRIPTION

The principal objectives of this contract are to further develop the theoretical basis of the "Algebraic Theory of Machines" and to explore the possible applications of this theory to information theory, probabilistic machines, and actual computing hardware.

SUMMARY OF RECENT ACCOMPLISHMENTS

The central problem for finite semigroups and finite state machines on which we have been working is outlined in the introduction to *Complexity of Finite Semigroups*. Succinctly stated, the problem is to find all minimal decompositions of a given arbitrary finite state machine.

The major progress made during this contract are the results on the complexity of finite state machines. We determine the complexity of a large class of machines and results verify the importance of this concept and show that the precise mathematical definition of complexity and the intuitive notion of complexity agree in a satisfactory manner.

Computational methods were developed (suitable for programming on a digital computer) for the solutions of the minimal decompositions of group machines. Further, a general program was developed to embrace a very wide class of algebraic problems that arise in the algebraic study of machines and switching circuits. These methods were in the main developed by Dr. Douglas Maurer.

We also began preliminary investigations on the possibility that the minimal decompositions of a finite state machine could be stated in terms of a cohomology theory of the associated semigroup.

RECENT REPORTS OR PUBLICATIONS

Kenneth Krohn and John Rhodes, *Results on Finite Semigroups Derived from the Algebraic Theory of Machines*.

Kenneth Krohn and John Rhodes, *Algebraic Theory of Machines I, Prime Decomposition Theorem for Finite Semigroups and Machines*.

Kenneth K. hn, W. D. Maurer, and John Rhodes, *Algebraic Theory of Machines II, Prime Decomposition of Group Machines*.

Kenneth Krohn and John Rhodes, *Complexity of Finite Semigroups*.

W. D. Maurer and John Rhodes, *On a Property of Finite Simple Non-Abelian Groups*.

John Rhodes (seminar notes), University of California, *Algebraic Theory of Semigroups and Finite State Machines*.

B. MACHINE INTERACTION WITH HUMANS

ON-LINE COMPUTATION FOR COMMAND
AND CONTROL PROBLEMS

W. WILKINSON
Bunker-Ramo, Inc.
Canoga Park, California

TASK NO. NR 049-176   CONTRACT Nonr 4182(00)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

The purpose of this task is to investigate the feasibility of the application of on-line man-machine computational techniques to the solution of decision problems of the command staff; as an adjunct, the characteristics of an appropriate interface and software system are being defined.

SUMMARY OF RECENT ACCOMPLISHMENTS

The application of on-line techniques is one of several new areas of research directed toward improving the methodology of computer usage in the solution of unstructured problems such as those encountered in a command information system. In most conventional systems, the military user is hampered by the lack of convenient means for communicating with the computer system and by the inflexibility of the system to respond to a rapid change, either in the type of problem to be solved or in the method of solving a standard problem.

The major objective of on-line techniques is to put the user directly in the problem-solving system loop in such a manner that the experience and intuition of the user becomes closely coupled with the powerful computational capabilities of the computer so that there is a balanced interaction between the capabilities of each.

The difficult features to provide are those of allowing the user to communicate in his own terminology, allowing the user to structure the problem-solving process conveniently, and allowing the user to control or restructure this process, if desired, on a continuous basis.

The key concept has been to employ a functional approach, using the basic elements of the problem-solving process itself. In this approach the basic functional elements, or building blocks, for the problem solution are identified so that they can be structured by the user in his vocabulary or user language. The user or problem-solver himself is provided convenient access to these basic elements and allowed to assimilate them in any way that he desires. He then has the capability of building higher-level instructions and queries and, in a sense, doing his own programming.

RECENT REPORTS OR PUBLICATIONS

None.

PROJECT MAC

R. FANO
Massachusetts Institute of Technology
Cambridge, Massachusetts

TASK DESCRIPTION

Project MAC has two basic objectives. The first is the evolutionary development of a large computer system that will be easily and independently accessible to a large number of people and truly responsive to their individual needs. The second is the investigation of new ways in which computers can aid people in their creative work, whether it be research, engineering, design, management or education.

SUMMARY OF RECENT ACCOMPLISHMENTS

The MAC computer system has been in regular operation for approximately one year. The number of simultaneous on-line users that the system can satisfactorily serve has grown from 10 to 24 and very recently to 30. The system is operated daily for approximately 20 hours; the actual computer time devoted to on-line use has been averaging in recent months approximately 10 hours per day (exclusive of time devoted to background batch processing).

The system includes by now more than 100 teletypewriter terminals at various locations on the MIT campus and in the Greater Boston area. It is also connected to the Telex (Western Union) and TWX (Bell System) teletypewriter networks through which successful demonstrations were held from England and Norway as well as from many locations in the United States. The three-dimensional rotation matrix of the display console has been completed; surfaces and other spacial entities are currently being generated, modified and rotated on-line. A second display tube has also been added which can be operated independently by time multiplexing the same display generation equipment.

The number of system commands has grown to over eighty, and many of the new ones were developed by system users in conjunction with their own research; new language facilities include COGO, STRESS, SNOBOL, COMIT, GPSS, AED, OPL, DYNAMO, and LISP.

The planning of a new, more advanced MAC system began in earnest during the Spring. It will employ G.E. 635 equipment, with additions and modifications to permit efficient program segmentation. The details of such additions and modifications are currently being specified.

RECENT REPORTS OR PUBLICATIONS

Bobrow, Daniel G., "Natural Language Input for a Computer Problem Solving Language." AD-604 730.

Raphael, Bertram, "SIR: A Computer Program for Semantic Information Retrieval. AD-608-499.

Corbato, F. J., "System Requirements for Time-Sharing Computers. AD-608-501.

Ross, Douglas T. and Feldmann, C. G., "Verbal and Graphical Language for the AED System: A Progress Report." AD-604-678.

Biggs, John, and Logcher, Robert D., "STRESS: A Problem-Oriented Language for Structural Engineering." AD-604-679.

Weizenbaum, J., "OPL-1: An Open Ended Programming System within CTSS." AD-604-680.

Greenberger, Martin, "The OPS-1 Manual." AD-604-681.

Dennis, Jack, "Program Structure in a Multi-Access Computer." AD-608-500.

Fano, R. M., "The MAC System: A Progress Report." AD-609-296.

Greenberger, Martin, "A New Methodology for Computer Simulation." AD-609-288.

Bers, A., and Briggs, R. J., "Criteria for Determining Absolute Instabilities and Distinguishing Between Amplifying and Evanescent Waves." *Bull. Amer. Phys. Soc.*, Series 11, Vol. 9, No. 3. March 1964.

Bers, A., and Mills, J. D., "Computer Analysis and Display of Wave Instabilities." *M.I.T., R.L.E. Quart. Prog. Report* No. 73. April 1964.

Bers, A., Puri, S., and Mills, J. D., "Interaction of an Electron Beam with Ions in a Warm Plasma of Finite Transverse Dimensions." *M.I.T., R.L.E. Quart. Prog. Report* No. 74. July 1964.

Bobrow, Daniel G., and Raphael, Bertram, "A Comparison of List-Processing Computer Languages: Including a Detailed Comparison of COMIT, IPL-V, LISP 1.5, and SLIP." *Commun. of ACM*, Vol. 7, No. 4. April 1964.

Bobrow, Daniel G., and Weizenbaum, J., "List Processing and Extension of Language Facility by Embedding." *IEEE Transactions on Electronic Computers.* August 1964.

Bobrow, Daniel G., "A Question-Answering System for High School Algebra Word Problems." *Proc. Fall Joint Computer Conference.* 1964.

Brach, John, and Chamby, J. A., "The Use of Linear Programming in Architectural Design: The Space Allocation Problem," M.I.T. Civil Eng. Systems Division. May 1964.

Dailey, James E., "A Digital Computer Simulation of Unsteady Flow in Rectangular Non-Prismatic Channels," M.I.T., Dept. of Civil Eng. B.S. and M.S. Thesis.

Dennis, Jack, "Group Report, Computer Research," M.I.T., R.L.E. Quart. Prog. Report No. 76. January 1965.

Dennis, Jack, "A Multi-User Computation Facility for Education and Research," *Commun. of ACM*, Vol. 7, No. 9, September 1964.

Dennis, Jack, "Use of Computers in Speech Research. Computers in Medicine and Biology," Ann. New York Acad. Science (1964).

Electronic Systems Laboratory of M.I.T. Annual Report from July 1, 1963 to June 30, 1964.

Everest, Gordon, and Selwyn, Lee L., "Considerations for an Interactive Algebraic Compiler," M.I.T., Sloan School of Management. June 1964.

Fano, R. M., "The MAC System, the Computer Utility Approach," *IEEE Spectrum*, January 1965.

Fenves, S. J., Logcher, R. D., and Reinschmidt, D. F., "Preliminary Version STRESS: A Problem Oriented Language for Structural Engineering," M.I.T., Dept. of Civil Eng. Technical Report T63-8, October 1963.

Fenves, S. J., Logcher, R. D., Mauch, S. P., and Reinschmidt, D. F., "STRESS: A User's Manual, a Problem Oriented Language for Structural Engineers," M.I.T. Press (1964).

Gladdings, Dale G., "Automatic Selection of Horizontal Alignments in Highway Location," M.I.T., Dept. of Civil Eng. M.S. Thesis. May 1964.

Glaser, E. L., and Corbato, F. J., "Introduction to Time-Sharing," *Datamation*, Vol. 10, No. 11, November 1964.

Graham, Robert M., "Bounded Context Translation," Proc. Spring Joint Computer Conf. (1964).

Hadley, Roger A., "Investigation of Automated Direct Design of Steel Rigid Planar Frames," M.I.T., Dept. of Civil Eng. Thesis, February 1965.

Haines, E. C., Jr., "The TREET List Processing Language," M.I.T., Dept. of Elect. Eng. Thesis, September 1964.

Hamilton, M. L., and Weiss, A. D., "An Approach to Computer-Aided Preliminary Design," M.I.T., Depts. of Mech. Eng. and Naval Arch. M.S. Thesis, August 1964.

Hershdorfer, A. M., and Frazier, J. C., "User's Manual for the M.I.T. Time-Sharing Linear Programming System, M4tS," M.I.T., Dept. of Civil Eng. Publication, July 1964.

Hoag, J. K., "Instabilities in Transverse Waves Along B for a Beam Type Distribution," M.I.T., Dept. of Elect. Eng. Thesis, October 1964.

Johnson, William F., "The Use of Traffic Volume Data in the Evaluation of Highway User Costs," M.I.T., Dept. of Civil Eng. Publication, July 1964.

Kawaguchi, Stanley K., "Preliminary Computation and Data Reduction for STRESS," M.I.T., Dept. of Civil Eng. Thesis, August 1964.

Keller, Joseph, "The Critical Path Method, Its Implementation and Effective Utilization in Construction," M.I.T., Dept. of Civil Eng. M.S. Thesis, June 1964.

Kessler, A. R., "Structural Synthesis and Analysis, and Simulation of Interpersonal Power Systems," M.I.T., Dept. of Economics and Social Science B.S. Thesis, June 1964.

Kessler, M. M., "The M.I.T. Technical Information Project, Part I, System Description," November 1964. AD-608-502.

Krakauer, Lawrence J., "Syntax and Display of Printed Format Mathematical Formulae," M.I.T., Dept. of Elect. Eng. M.S. Thesis, June 1964.

Llewellyn-Jones, D. T., "Use of Interferometric Spectroscopy for Far Infrared Plasma Diagnostics," M.I.T., R.L.E. Quart. Prog. Report No. 74, July 1964.

Linderman, James L., "The Role of Memory in Information Storage and Retrieval," M.I.T., Dept. of Math. B.S. Thesis, June 1964.

Manheim, Marvin L., "Highway Route Location as a Hierarchically Structured Sequential Decision Process: An Experiment in the Use of Bayesian Decision Theory for Guiding an Engineering Process," M.I.T., Dept. of Civil Eng. Ph.D. Thesis, May 1964. Civil Eng. Research Report R64-15.

Mills, J. D., "Computer Display System for Analyzing Instabilities," M.I.T., R.L.E. Quart. Report No. 75, October 1964.

Minsky, M. L., and Cocke, J., "A Universality of Tag Systems with P=2," *J. ACM*, Vol. 11, No. 1, January 1964.

Papert, S., "Stereoscopic Synthesis as a Technique for Localizing Visual Mechanisms," M.I.T., R.L.E. Quart. Prog. Report No. 73, April 1964.

Papert, S., "Regularities in the Time Courses of Some Visual Processes," M.I.T., R.L.E. Quart. Prog. Report No. 73, April 1964.

Puri, Satish, "Electron Beam Interaction With Ions in a Warm Electron Plasma," M.I.T., Dept. of Elect. Eng. M.S. Thesis, April 1964.

Raphael, Bertram, "A Computer Which Understands," Fall Joint Computer Conf. (1964).

Roos, Daniel, and Miller, C. L., "COGO-90: Engineering User's Manual," M.I.T., Dept. of Civil Eng. Res. Report R64-12, April 1964.

Roos, Daniel, and Miller, C. L., "The Internal Structure of COGO-90," M.I.T., Dept. of Civil Eng. Res. Report R64-5, February 1964.

Roos, Daniel, and Miller, C. L., "COGO-90 Time-Sharing Version," M.I.T., Dept. of Civil Eng. Res. Report R64-18, May 1964.

Ross, D. T., "AED Jr: An Experimental Language Processor," M.I.T., E.S.L. ESL-TM-211, September 1964.

Ross, D. T., "Implication of Computer-Aided Design for Numerically Controlled Production," M.I.T., E.S.L. ESL-TM-212, September 1964.

Ross, D. T., Coons, S. A., and Ward, J. E., "Investigations in Computer-Aided Design for Numerically Controlled Production," M.I.T., E.S.L. Interim Eng. Prog. Report No. 1, ESL-IR-221, December 1964.

Selwyn, Lee L., "A Computer Controlled Tele-Communication System," M.I.T., Dept. of Industrial Management Thesis (1964).

Sklar, Jay R., "Sequential Measurement of Multi-Dimensional Transducers," M.I.T., Dept. of Elect. Eng. Ph.D. Thesis, September 1964.

Smith, A. A., Slosberg, D., and Van Horn, E. C., Jr.. "The Scientific Translating System," M.I.T., R.L.E. Quart. Prog. Report No. 73, April 1964.

Teager, Herbert, "Mass Memory Requirements for On-Line Real-Time Systems," Spring Joint Computer Conf., April 1964.

Teager, Herbert, "Workshop on Problem Solving Through the Use of Automatic Displays," Fall Joint Computer Conf. (1964).

Teitelman, Warren, "Real Time Recognition of Hand-Drawn Characters," Proc. Fall Joint Computer Conf. (1964).

Wallace, R. N., "An Investigation of Complex Waves in Electron Beam-Plasma Systems," M.I.T., Dept. of Elect. Eng. Thesis, September 1964.

Yntema, D. B., "The Software Problem," M.I.T., Lincoln Lab. Group Report, 1964-51, September 1964.

Greenberger, Martin, "The Computers of Tomorrow," *Atlantic Monthly*, May 1964.

Hamilton, M. L., Mackenzie, L., and Weiss, A. D., "An Approach to Computer-Aided Ship Design," ESL-TM-228, January 1965.

APPLICATIONS OF PROJECT MAC

L. CLAPP
Bolt, Berenek, and Newman, Inc.
Cambridge, Massachusetts

TASK NO. NR 049-191   CONTRACT Nonr 4367(00)

PROJ. NO. RR 003-08-01

(This task is administered jointly with the NRL Research Computation Center.)

TASK DESCRIPTION

The purpose of this task is to investigate the potential of various aspects of Project MAC (concentrating on time-sharing techniques) for possible applications in Navy Laboratories.

SUMMARY OF RECENT ACCOMPLISHMENTS

During the past year a study was conducted on the application of time-sharing in the environment of a general Naval Research Laboratory. In particular, arrangements were made with the staff of the Naval Research Laboratory to investigate the possible application of multi-access computing in various laboratory problem areas, and to determine if there is a legitimate need for time-sharing and to specify where this need is. A report summarizing our conclusions and recommendations is now in preparation.

RECENT REPORTS OR PUBLICATIONS

None.

LEARNING BY ADAPTIVE TECHNIQUES

A. HORMANN
System Development Corporation
Santa Monica, California

TASK DESCRIPTION

In this task techniques are to be investigated which could enable a machine to learn decision processes for solving problems of particular classes. These problem-solving and learning techniques or processes are similar to, but not necessarily a deliberate imitation of, those used by humans.

SUMMARY OF RECENT ACCOMPLISHMENTS

(This is a new task)

RECENT REPORTS OR PUBLICATIONS

None.

RESEARCH ON HEURISTIC PROBLEM SOLVING MACHINES

W. MANN
Westinghouse Electric Corporation
Baltimore, Maryland

TASK NO. NR 348-008   CONTRACT Nonr 4483(00)

PROJ. NO. RR 003-10-02

TASK DESCRIPTION

This task is an investigation of means to cause machines to carry out poorly defined processes which are capable of being carried out by people. Of particular interest are symbol-manipulating processes requiring multiple decisions for completion. The approach being taken provides for extensive man-aid in the machine construction of a process representation. The primary subject matter for man-machine communication is the examples of his own problem solving process provided by the man.

SUMMARY OF RECENT ACCOMPLISHMENTS

An approach has been formulated for dealing with symbol-manipulating tasks represented by a limited class of playing-card solitaire games. A method for characterization of solitaire plays and representing a history of distinct operations performed has been formulated and a basic computer program written in IPL-V. This program is expected to act as a skeleton for later programs in which additional freedom for generalization and induction is given to the man.

RECENT REPORTS OR PUBLICATIONS

None.

MULTI-LIST INFORMATION PROCESSING

N. PRYWES
University of Pennsylvania
Philadelphia, Pennsylvania

TASK DESCRIPTION

This task is an investigation of a list processing approach for storing retrieval and indexing of information as well as for communication with the computer storing the file. The system involves storing with each item of data several descriptors which serve to associate the item with others related to it. Searchers are then conducted along lines of association.

SUMMARY OF RECENT ACCOMPLISHMENTS

The purpose of this study is the development of techniques for mechanization of man-machine storage and retrieval systems for management or technical libraries.

The study consists of several tasks. Initially, tree structures and list techniques were developed to simulate an associative memory on an addressable memory, and the design of a processor was completed.

The techniques were tested in an IBM 1410 and two IBM 1301 disks system to handle U.S. Navy Supply Files at the Aviation Supply Office in Philadelphia. An executive routine was prepared for interrogation of the file from remote stations. A remote console facility using CRT display is being implemented as a research tool for faculty and students at the Moore School, University of Pennsylvania, together with the MULTILANG executive language.

Automatic classification algorithms for libraries have been developed and applied to the mathematics ASTIA thesaurus. Similar techniques are being applied to retrieval of Navy Supply information using English descriptors. These techniques are intended to solve two problems: efficient selective retrieval of document in response to providing a subset of the descriptors, and that of man-machine communication by which a user may make his query more or less selective.

Storage and retrieval of information in image form is being investigated and a compendium on image handling techniques is nearly completed.

The overall effort points to use of a computer as a problem solving facility with back and forth communication with the user.

RECENT REPORTS OR PUBLICATIONS

N. S. Prywes and H. J. Gray, "The Organization of a Multi-List Type Associative Memory," Proceedings of the Session on Gigacycle Computing Systems, AIEE Publication S-136, January 1962, pp. 87-101. Also, Communications and Electronics, September 1963, pp. 488-492.

P. Leifer, "A Statistical Optimization of Search Time in an Information Retrieval System," Moore School Technical Report No. 64-17, December 1963.

N. S. Prywes and D. Miller, "An Executive Program for Multiple Consoles." Interim Technical Report No. 64-12, March 1964.

P. Hubbell, "A Search for Improved Coding Methods for a Large-Scale Information Retrieval System," Moore School Technical Report No. 64-19, May 1964.

D. S. Sharp and J. E. McNulty, "On a Study of Information Storage and Retrieval," Interim Technical Report No. 65-01, May 1964.

B. Zimmerman, "Automatic Classification for the ASTIA Mathematics Collection," Moore School Technical Report No. 64-22, May 1964.

D. Sharp, "The Use of Real-Time Computers for Inventory Control," Moore School Technical Report No. 64-21, June 1964.

N. Prywes, "Browsing in an Automated Library Through Remote Consoles," Proceedings of the Symposium on Computer Augmentation of Human Reasoning, June 1964.

A. van Dam and D. Evans, "Shirtdif — A System for the Storage, Handling and Retrieval of Technical Data in Image Format," Proceedings of the American Documentation Institute, September 1964, pp. 323-329.

INFORMATION RETRIEVAL

J. O'Connor
Institute for Scientific Information
Philadelphia, Pennsylvania

TASK DESCRIPTION

This task is devoted to information retrieval, with primary emphasis on empirical study of whether high quality subject indexing by computer is possible. There is also some theoretical study of the general "logic" of subject indexing, with a view to possible implications for computer indexing and other possible implications for information retrieval.

SUMMARY OF RECENT ACCOMPLISHMENTS

The mechanized indexing study of a pharmaceutical retrieval system is almost completed. It provides illustrations and some evidence that proposed mechanized indexing procedures, more broadly proposals for subject searching of natural language text, may often be unsatisfactory.

1. A thesaurus to identify "near synonyms" of index terms will be insensitive to non-recurring, complex expressions in text, which readily convey meaning to a human reader. For example, "xanthoma resulting from cortisone therapy" is clearly about drug toxicity. Eight of a random sixty-two drug toxicity papers would be missed by a thesaurus for this reason.

2. Most of the non-thesauric toxicity expressions in these papers contained a substance-word, a disorder-word, and a connective in a particular order and closeness (few intervening words). If satisfactory lists of these kinds of words could be provided to a computer, it could identify such toxicity expressions, but with additional false identification in about five percent of all papers searched.

3. This method would miss other toxicity expressions, for example, "animals which received cortisone developed tuberculosis." Their diversity might make their recognition by computer difficult or impossible. No toxicity paper in the sample contained only such expressions, but some in the literature might.

4. Methods which identified all toxicity papers in the sample falsely selected about as many non-toxicity papers as well. Syntactic considerations helped reduce this selection only slightly. Sentence-paragraph position did not help at all.

5. Passages were found on subjects other than toxicity which also might not be identifiable by computer.

6. These and other results will soon be written for journal publication.

RECENT REPORTS OR PUBLICATIONS

O'Connor, John, "Mechanized Indexing Studies of MSD *Toxicity*, Part I," December 1963.
O'Connor, John, "Mechanized Indexing Studies of MSD *Toxicity*, Part II," March 1964.

O'Connor, John, "Correlation of Indexing Headings and Title Words in Three Medical Indexing Systems," *American Documentation*, Vol. 15, No. 2, April 1964, pp. 96-104. Reprints sent to the distribution list.

O'Connor, John, "Mechanized Indexing Methods and Their Testing," *Journal of the Association for Computing Machinery*, Vol. 11, No. 4, October 1964. Reprints and precis to be sent to the distribution list.

AUTOMATIC ABSTRACTING AND CLASSIFICATION

J. WILLIAMS
International Business Machines
Rockville, Maryland

TASK NO. 348-007   CONTRACT Ncnr 4456(00)

PROJ. NO. 003-10-02

TASK DESCRIPTION

The purpose of this task is to investigate the frequency distribution of the number of distinct words which occur a specific number of times in any particular document. The need for this investigation is related to the automatic abstracting and classification of documents.

SUMMARY OF RECENT ACCOMPLISHMENTS

The investigation has proceeded along two lines. First, the small sample (as small as abstract or query size) behavior of certain available asymptotic estimates is considered, where essentially nothing has been assumed about the underlying vocabulary. On the other hand, consideration is also given to fitting observed frequency distributions to various theoretical distributions.

Computer programs for generating random samples (documents) of any length have been developed. These programs permit a great deal of control over the vocabulary. Computer programs have also been developed for obtaining observed frequency distributions for each generated document. In addition, information related to the estimates mentioned above are obtained. Because we are sampling from a known vocabulary, a comparison of the estimates with the actual values is possible, hence the small sample behavior can be investigated. Finally, computer programs have been developed for fitting each observed frequency distribution to the following theoretical curves:

(a) Hyper-Poisson (a two-parameter family)
(b) Confluent Hypergeometric (a three-parameter family)
(c) Discrete form of the Pearson curves (a four-parameter family)
(d) I. J. Good's modification of Zipf's curve.

In these programs, comparison of each observed and theoretical curve is made on the basis of various goodness-of-fit tests.

RECENT REPORTS OR PUBLICATIONS

"Results of Classifying Documents with Multiple Discriminant Functions," J. H. Williams, to be published in the Proceedings of the Symposium on Statistical Associations Methods for Mechanized Documentation. Symposium held in Washington, D.C. on March 19, 1964.

INFORMATION ABSTRACTING AND EXTRACTING

B. RUDIN
Lockheed Missiles and Space Co.
Palo Alto, California

TASK DESCRIPTION

This task is a mechanical linguistics research program in automatic information abstracting and extracting involving analysis of sentences extracted from text by following the general procedure for automatic indexing based on syntax and phrase dictionaries. The approach is to study conceptual and syntactic relationships of information encountered in text.

SUMMARY OF RECENT ACCOMPLISHMENTS

An algorithm for determining the parts of speech of English words has been constructed and programmed for a digital computer. This program will be used as the main processing device in an experiment to determine the feasibility of syntactic indexing, abstracting and extracting; the objective being to measure to what extent the part-of-speech function carries the necessary information for these operations. To obtain this it was first necessary to provide an operational definition of English affixes. It was also necessary to derive a means for finding the number of syllables from the written form of the word. Closely connected to all three of these problems is the problem of determining the inflectional forms of English verbs—particularly the occasions when the final consonant must be doubled. Working solutions to all of these problems have been obtained.

Throughout these studies all proposed solutions have been tested against standard dictionaries. This effort was facilitated by the preparation of various magnetic tape dictionaries with part-of-speech and syllabification information. The more important orderings of these lists are being printed for distribution to interested workers in the field.

In a related area, an algorithm for translating written English into the phonetic forms given in the Shorter Oxford has been obtained for the one syllable words with gratifying accuracy. It was further found that the phonetic forms of the Shorter Oxford could be converted to those given by various American dictionaries by simple rules based on a carefully selected sample of 120 words.

RECENT REPORTS OR PUBLICATIONS

H. L. Resnikoff and J. L. Dolby, "The Nature of Affixing in Written English," presented at the Bloomington meeting of the Association for Machine Translation and Computational Linguistics, July 1964. (Submitted in revised form to *MT* in October 1964.)

B. V. Bhimani and J. L. Dolby, "Acoustic Phonetic Transcriptions of Written English," presented at the Austin meeting of the Acoustical Society of America, October 1964.

The English Word Speculum, Vol. 1, The Random Word List, Compiled by J. L. Dolby and H. L. Resnikoff, Lockheed Missiles and Space Company, October 1964. (Volumes 2, 3, and 4 are in process.)

J. L. Dolby and H. L. Resnikoff, "Counting Syllables—An Exercise in Written English," submitted to *Science,* October 1964.

H. L. Resnikoff and J. L. Dolby, "On the Inflection of English Words," submitted to *Science,* November 1964.

H. L. Resnikoff and J. L. Dolby, "Standards for Publishing Systems, I—The role of hyphenation in the composition of printed text," Lockheed Report, 28 July 1964.

J. L. Dolby, H. L. Resnikoff, and Lois Earl, "An Improved Part of Speech Algorithm," submitted to the Communications of the ACM, November 1964.

AUTOMATIC MECHANICAL TRANSLATION

H. JOSSELSON
Wayne State University
Detroit, Michigan

TASK NO. NR 049-128   CONTRACT Nonr 2562(00)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task is a joint endeavor by linguists, mathematicians, programmers, computer engineers, and systems engineers to do research on the mechanical translation of languages by the use of high-speed digital computers. The aim is to translate from Russian to English with a finished product which is as good as human translation.

SUMMARY OF RECENT ACCOMPLISHMENTS

During the current year the main efforts of the machine translation group, being supported by the Information Systems Branch of the U.S. Office of Naval Research, have been directed toward several important aspects of machine translation in the following areas: (1) correcting and up-dating the Russian-English mathematical glossary and text tapes; (2) developing new syntactic analysis routines and refining the old ones; (3) developing new language data processing routines for the IBM 7070 and IBM 1401; (4) investigating the problem of a more comprehensive verbal government code for recognition of syntactic structures and selection of the correct semantic implication of each lexical item in the structure; and (5) continuing active cooperation with domestic and foreign MT research groups.

The glossary tape has been up-dated by removing incorrect entries and adding new entries found in the mathematical text which has been processed. The grammar coding has also been modified somewhat in order to make it suit better the needs of further syntactic processing. During the current year, the syntactic analysis studies have been directed towards assigning the basic components of a Russian sentence, which have been previously identified by appropriate computer routines, their function in the Russian sentence. Computer programs are being developed to carry out this task.

New programs to facilitate dictionary and text tape up-dating have also been written, as well as programs which complete the automation of the processing of raw text through syntactic analysis. A start has also been made in investigating the problems of syntactic semantics in general, and the problem of verbal government in particular, by appropriately coding all the verbs found in the mathematical corpus.

Dr. Harry H. Josselson, principal investigator, was a member of the American team which visited Japan, April 20-28, 1964, for the purpose of participating in the U.S.-Japan Seminar on Mechanical Translation. This meeting was sponsored jointly by the National Science Foundation and the Japanese Society for the Promotion of Science. At this meeting Dr. Josselson gave the following paper: "Linguistic Basis of Mechanical Translation: Contributions to Standard Linguistic Theory." In addition, Dr. Josselson is continuing to serve as secretary-treasurer of the Association for Machine Translation and Computational Linguistics, the second annual meeting of which was held in Bloomington, Indiana, July 29-30, 1964.

RECENT REPORTS OR PUBLICATIONS

"Linguistic Basis of Mechanical Translation: Contributions to Standard Linguistic Theory," paper presented at the U.S.-Japan Seminar on Mechanical Translation, Tokyo, Japan, April 20-28, 1964.

Sixth Annual Report on Research in Machine Translation. Russian to English, August 31, 1964. Principal investigator, Harry H. Josselson.

SEMANTIC RESEARCH FOR MACHINE TRANSLATION

M. MASTERMAN
Cambridge Language Research Unit
Cambridge, England

TASK NO. NR 049-162   CONTRACT N 62558-1811

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

The Cambridge Language Research Unit has explored the potentialities of a semantic model of language obtained by coding, as a finite lattice, a structured set of work context of the Rogets' Thesaurus type. The model explored was static, and since language is dynamic, they are now investigating a theoretical method which could formalize the dynamic model.

SUMMARY OF RECENT ACCOMPLISHMENTS

(a) English speech, which underlies a great deal of written English, tends to fall into a succession of "phrases" (in the musical sense) of roughly similar duration — regardless of the number of words, since many light syllables are uttered in the time taken by a smaller number of heavy syllables. "Lightness" and "Heaviness" are partly a quality of particular sounds, partly a semantic quality.

(b) Each "phrase" tends to be formed round two stress points drawing attention to the principal semantic content. Of these two stress points, one will usually be the main semantic indicator and is the nuclear stress. The meaning is reinforced by the implication of contrast which it is one of the attributes of stress to suggest.

(c) This structure gives each "phrase" an *ictus* corresponding to that found in plain-chant, which (in the absence of marked melodic vareity) is what gives chanting its form. Speech is nearer to chanting than to song, chanting being indeed a way or ritualising speech.

(d) Each "phrase" thus has a binary structure (this can of course be expanded, about walking rhythm, heart-beats, etc.), which is completed, in the absence of one of the usual two stresses, by the existence of *pause* as a rhythmic factor, i.e., a slight beat. The verbal forms associated with the different stress patterns (e.g. two main stresses, one main stress plus one secondary stress, one main stress plus pause) are now being analyzed, and their semantic indications condified. The phrasing with its stress, or stress-pause, structure will be demonstrated with several hundred examples.

RECENT REPORTS OR PUBLICATIONS

Not available.

SPEECH ANALYSIS AND SYNTHESIS

G. PETERSON
University of Michigan
Ann Arbor, Michigan

TASK NO. NR 049-122   CONTRACT Nonr 1224(22)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task encompasses basic investigations in the general field of language automation. Specific studies include the analysis, automatic recognition, and artificial synthesis of human speech. Concurrently, research is being directed toward instrumentation problems in automatic speech recognition, and problems in the instrumental analysis of speech for individual voice identification.

SUMMARY OF RECENT ACCOMPLISHMENTS

Work is being done on the derivation of the various information-bearing parameters of the speech wave. The combined use of analog and digital techniques has been investigated for extracting the fundamental voice frequency. A method for the accurate measurement of the resonance frequencies in the speech wave has also been developed. Speech is first processed through a special filter bank and the resonance frequencies are then determined by a series of operations in a digital computer. The possibility of an auditory analog for speech wave analysis has also been studied. An electrical analog of the cochlea has been implemented and a small set of model neurons has been constructed for connecting to the analog.

An electro-acoustical speech synthesizer is being developed which can be controlled by means of a digital computer. Data for the various speech parameters are supplied to the computer, and the computer then prepares a digital tape which provides the control functions for the synthesizer. The optimal configuration for the various components of the synthesizer has been investigated.

The recording and reproducing of electrical signals with ferroelectric tapes has been investigated. Work has also been continued on a high quality sound spectrograph for speech analysis. An instrument which draws calibrating scales directly in the output display is now near completion.

RECENT REPORTS OR PUBLICATIONS

None.

ANALYSIS OF MANDARIN CHINESE SPEECH

W. S-Y WANG

Ohio State University

Columbus, Ohio

TASK NO. NR 049-181   CONTRACT Nonr 495(27)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task concerns an effort to develop a phonological description of Mandarin Chinese which could be used eventually for purposes of automatic speech recognition and machine translation.

SUMMARY OF RECENT ACCOMPLISHMENTS

In Mandarin, each word has a characteristic pitch pattern which is called its tone. Several experiments have been conducted on the automatic recognition of these tones by sampling at various time intervals. In addition, a computer program has been constructed and tested for the recognition of stressed monosyllables. Parallel to the acoustic work, linguistic analysis continues on the methods of coding the segments in terms of phonological features, and on the distribution of stresses over polysyllabic utterances.

RECENT REPORTS OR PUBLICATIONS

Brotzman, R., "Recognition of Lexical Tone in Mandarin Chinese by Sampling of Fundamental Frequency," presented to the *Acoustical Society of America,* New York City, May 9, 1964.

Hashimoto, M., "Phonological Rules in Mandarin," presented to the *Linguistic Society of America,* Bloomington, July 1964.

Li, K. P., "Automatic Recognition of Mandarin Monosyllables," presented to the *Acoustical Society of America,* New York City, May 9, 1964.

ANALYSIS OF KOREAN SPEECH

M. HAN

University of California
Los Angeles, California

TASK NO. NR 049-183   CCNTRACT Nonr 233(80)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task concerns an effort to develop a phonological description of standard Korean which could be used eventually for purposes of automatic speech recognition and machine translation.

SUMMARY OF RECENT ACCOMPLISHMENTS

Spectrographic analysis has been done in the following areas: (1) Korean vowels, (2) vowel duration of Korean, and (3) stop consonants of Korean.

1. *Vowel quality*: Distinctive features and recognition cues such as formant measurements, relative intensity of formants and inherent duration were studied. Allophones and cases of neutralization were described.

2. *Vowel duration*: Inherent duration of different vowels, phonotactic effects on vowel duration, phonemic contrast in short and long vowels were studied with spectrographic technique. The duration of monosyllabic word of the form CVC in different syntactic positions and that of the contained vowel were studied.

3. *Stop consonants*: Work continues on distinctive features and recognition cues of the three sets of three voiceless stops [p] [pʰ] [P], [t] [tʰ] [T], and [k] [kʰ] [K].

RECENT REPORTS OR PUBLICATIONS

Han, Mieko S.: *Acoustic Phonetics of Korean*, Technical Report No. 1, December 1963.

Han, Mieko S.: *Studies in the Phonology of Asian Languages II: Duration of Korean Vowels*, Technical Report No. 2, July 1964.

STYLISTIC ANALYSIS

S. SEDELOW
System Development Corp.
Santa Monica, California

TASK NO. NR 348-005 CONTRACT Nonr 4427(00)

PROJ. NO. RR 003-10-02

TASK DESCRIPTION

This project is directed toward finding stylistic discriminants that will make two distinctions—between writing by different authors and among different forms of writing. Style is, in a very real sense, the author's signature. If individual style can be detected, we open the way to perception of (1) specific individual hands within a collection (presumably the case in Sokolovsky's *Soviet Military Strategy*), (2) interpolations or rewriting suggestive of policy shifts or sensitivities, and perhaps, (3) shifts in psychological state of a writer, possibly indicating a distortion or lie

SUMMARY OF RECENT ACCOMPLISHMENTS

The project's first phase, the Verbally-Indexed Association program, explores man-machine examination of thematic relationships within a given text. During program operation, the machine collects information and "learns," sharply reducing the required human input. ViA's output is a cross-referenced thesaurus providing a conceptual outline or verbal map of the text. No lists or categories are made in advance of the text search; the thesaurus is based only upon words appearing in the work being examined.

Since contract began, in March, we have been writing the VIA program. Because FORTRAN is widely available, we are adapting it to this "list-processing" use. For instance, we "canonize" a text (group words by root) by matching the letters of one word with those of another, from the initial letters of each to the divergence point. Based on the putative suffixes, we then search three relatively short, linked lists of suffixes and "exceptions."

The entire VIA system should be ready to operate by December, 1964.

RECENT REPORTS OR PUBLICATIONS

"Stylistic Analysis," a paper presented to the American Bibliographical Center Board, Santa Barbara, California, April 1964.

"Computational Stylistics," a paper presented at the 1964 Annual Meeting of the Association for Machine Translation and Computational Linguistics, Indiana University, July 29-30, 1964.

"Some Parameters for Computational Stylistics: Computer Aids to the Use of Traditional Categories in Stylistic Analysis," an invited paper presented at IBM's Literary Data Processing Conference, Yorktown Heights, September 9-11. Proceedings will be published, reprints will be sent to official distribution list.

"Stylistic Analysis as an Information Science," a paper presented at the annual meeting of the American Documentation Institute, Philadelphia, October 4-8.

RESEARCH IN ADAPTIVE PATTERN RECOGNITION

D. BRICK
Information Research Associates, Inc.
Lexington, Mass.

TASK NO. NR 348-010   CONTRACT Nonr 4752(00)

PROJ. NO. RR 003-10-02

TASK DESCRIPTION

The purpose of this task is to derive a useful and realizable self-adaptive pattern recognition machine procedure based on a recently formulated mathematical theory of pattern recognition and self-organization. This theory uses sequential decision techniques for classifying items or concepts according to membership in classes or categories. The classes themselves may be well defined or might have to be derived by teleological means.

SUMMARY OF RECENT ACCOMPLISHMENTS

(This is a new task.)

RECENT REPORTS OR PUBLICATIONS

None.

C. IMPROVED MACHINES

DIGITAL COMPUTER COMPONENT RESEARCH

W. POPPELBAUM
University of Illinois
Urbana, Illinois

TASK NO. NR 048-102   CONTRACT Nonr 1834(15)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

The object of this task is to develop computer components and circuitry of very high speed and high reliability. Research is directed toward, but not limited to: magnetic core memories, arithmetic and control, transistor circuitry, magnetic switching circuits, and input-output devices.

SUMMARY OF RECENT ACCOMPLISHMENTS

The work of the group fell into four areas: Electro-Optics, Coupled Active Transmission Lines, Microplasma Breakdown and Tunneling Theory.

The Electro-Optical investigations led to the design of a GaAs-emitter diode — Riez receiving diode — current amp'. ˜er chain with delay and rise times of the order of 10 nsec. The coupling was performed by op. al fibers and the light used was noncoherent. A so-called "Interface Modulator" was developed in which a narrow beam of coherent light is reflected up to 60 times at the interface between glass and nitrobenzene. The angle of incidence is such that the electrical modulation of the index of the liquid will lead to total reflection. Very good sensitivity was observed. Another series of investigations led to a beam deflection device using inhomogenous fields in nitrobenzene: 5 mm deflection at 100 cm with applied voltages of 2 kv were observed.

The work on an amplifier consisting of two coupled strip lines of different characteristic impedance (using a negative resistance device in one of them) was led to conclusion. Experiments showed that systems using such amplifiers as buffers and Hot Electron Diodes as Logical Elements are feasible for pulses with subnanosecond rise times.

The experimental and theoretical study of microplasmas in reverse-biased junctions led to the admission that the delay between the application of the bias and the breakdown was impossible to predict or control. Nevertheless some preliminary results were obtained for a "Noise Computer" using pulse trains coming out of a microplasma junction.

The work on tunneling theory resulted in a generalization of the Esaki Integral to the case where tunneling includes more than two bands, nonperpendicular tunneling and indirect tunneling.

RECENT REPORTS OR PUBLICATIONS

"Transistor Current — Voltage Relationships," by L. Van Biljon, August 6, 1963, DCL Report No. 149.

"Tunnel Diode Circuits Coupled into Transmission Lines," by Tohru Moto-Oka, August 16, 1963, DCL Report No. 155.

"Characteristic Impedances of Generalized Strip-Transmission Lines," by H. Guckel, December 11, 1963, DCL Report No. 157.

"Tunnel Diode Circuits Based on Lumped Constant Circuitry," by Tohru Moto-Oka, August 9, 1963, DCL Report No. 158.

"High Electrical Field Effects in P-N Junctions — Fast Breakdowns," by L. Van Biljon, January 20, 1964, DCL Report No. 159.

DIGITAL TECHNOLOGY RESEARCH

G. ESTRIN
University of California
Los Angeles, California

TASK NO. NR 048-129   CONTRACT Nonr 233(52)

PROJ. NO. RR 003-09-01

(This task is supported jointly with the AEC.)

TASK DESCRIPTION

The primary purpose of this task is research in the physics and engineering of basic digital components, digital computer and control systems optimization and digital systems applications.

SUMMARY OF RECENT ACCOMPLISHMENTS

Studies of multiprocessor systems with particular attention given to automatic programming, automatic *a priori* and dynamic allocation of resources, and automatic generation of resources in the general case of a restructurable computer system. Studies of models of the computation of probabilities associated with vertices in a graph representation. Methods for measuring expected path lengths in the graph are now being more critically evaluated as a basis for specifying a computer system which may efficiently assign jobs to itself.

As part of studies of computer design automation a program to systematically and automatically lay out networks of printed circuit connections on a two-sided sheet has been developed.

In the study of dynamic allocation of computer resources, one model develops queues of data within the flow paths. A mathematical queueing model was developed for a diffusion problem. A SIMSCRIPT simulator written for this problem provides a valuable tool for the analyses of a large class of similarly structured problems.

Work in cooperation with the Campus Computing Facility's IBM 7094 and SWAC has led to the development of a modified Culler-Freed console system consisting of a storage tube, light pen, keyboard and associated software permitting intimate complex operation of th computer.

Research continued in the general areas of optimal control of computers and control systems, and, in particular, of adaptive control systems. Special emphasis has been placed on applying decision theory of certain adaptive control problems. In particular, the Bayesian approach has been used effectively.

RECENT REPORTS OR PUBLICATIONS

"Automatic Assignment of Computational Tasks in a Variable Structure Computer," Edward C. Russell, Department of Engineering Report No. 63-45, August 1963.

"Analysis of Computing Load Assignment in a Multi-Processor Computer System," M. Aoki, R. Mandell, and G. Estrin, Fall Joint Computer Conference, Las Vegas, Nevada.

"Successive Generation of Chebychev Approximation Solution," M. Aoki, to appear in J. Basic Engineering ASME, presented at ASME 1963 Winter Annual Meeting, November 1963, Philadelphia, Pennsylvania.

"On Performance Losses in Some Adaptive Control Systems," M. Aoki, Proceedings 1964 Joint Automatic Control Conference, Stanford University, Stanford, California, also to appear in J. Basic Engineering, ASME.

"On Optimal Control of Partially Observable Markov Processes," M. Aoki, Technical Report No. 64-16, Department of Engineering, UCLA.

"On Control System Equivalents of Some Decision Theoretic Theorems," M. Aoki and D. Sworder, presented at the 1964 Joint AIAA-SIAM-IMS Symposium on Optimization, Monterey, California, January 1964.

"A Queueing Model of Data Flow in a Restructurable Computer System," B. Bussell and E. C. Russell, presented at Western Section ORSA Meeting, September 1964, Honolulu, Hawaii.

"Annual Summary Report of Investigations in Digital Technology Research," The Staff, October 1963.

"Quarterly Progress Report for the Period Ending December 15, 1963-January 1964, Department of Engineering Report No. 64-2.

"On Bayesian Control of Certain Time-Continuous Adaptive Control Systems," Masanao Aoki, March 1964, Department of Engineering Report No. 64-13.

"Optimal Control of Partially Observable Markovian Control Systems," March 1964, M. Aoki, Department of Engineering Report No. 64-16.

"Quarterly Progress Report for the Period Ending March 15, 1964, Engineering Research," March 1964, Department of Engineering Report No. 64-19.

"Quarterly Progress Report for the Period Ending June 15, 1964," The Staff, Department of Engineering Report No. 64-32.

"Some Applications for Content-Addressable Memories," G. Estrin, R. H. Fuller, Proceedings-Fall Joint Computer Conference, 1963.

"Parallel Processing in a Restructurable Computer System," G. Estrin, B. Bussell, R. Turn, J. Bibb, IEEE Transactions on Electronic Computers, December 1963.

"Algorithms for Content-Addressable Memories," G. Estrin and R. Fuller, Proceedings of the 1963 Pacific Computer Conference, IEEE, 1963.

"Automatic Assignment of Computations in a Variable Structure Computer System," G. Estrin and R. Turn, IEEE Transactions on Electronic Computers, Vol. EC-12 No. 15, December 1963.

"An Evaluation of the Effectiveness of Parallel Processing," G. Estrin, B. Bussell, Proceedings of the 1963 Pacific Computer Conference, IEEE.

LOGICAL REALIZATION OF BILLION-GATE COMPUTERS

R. LEDLEY
National Biomedical Research Foundation
Silver Spring, Maryland

TASK NO. NR 049-160   CONTRACT Nonr 3265(00)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

The purpose of this task is to investigate theoretical aspects involved in the eventual construction of data processing equipment of immense size and complexity.

SUMMARY OF RECENT ACCOMPLISHMENTS

A feasibility study has been made to demonstrate that by utilizing current programming techniques and current logical design methods, a billion gate computer can be designed and programmed to significant advantage, provided of course that the hardware is realizable. The feasibility study included the organization of a multiple simultaneous access memory, a large systems processor, and a multiple unit simultaneous processor. Applications were studied in the field of artificial intelligence.

As basic mathematical advances in switching circuit theory the inverse and similarity transformations of Boolean matrices was studied and computational algorithms developed.

Studies have been made which indicate clearly that interval modulation information coding can have great advantages as a new mode for information processing methods. A series of experiments have been performed the results of which have indicated that circuits can be built in this mode that will operate over a wide range of input intensities. A comparative study with a digital differential analyzer has indicated more rapid convergence of computed functions to the real value by interval modulation methods.

RECENT REPORTS OR PUBLICATIONS

"The Inverse of a Boolean Matrix," by R. S. Ledley, NBR Report No. 64051.1 3265, May 1964.

"Similarity Transformations on Boolean Matrices," by R. S. Ledley, NBR Report No. 64501.2 3265, May 1964.

"Interim Report on Theory of Interval Modulation Information Coding (TIMIC)," by George C. Cheng, NBR Report No. 64051.3 3265, May 1964.

"Thousand Gate Computer Simulation of a Billion Gate Computer," by R. S. Ledley, NBR Report No. 64051.4 3265, May 1964.

"Majority Logic and Matrix Method of Its Probabilistic Behavior," by S. Aida, NBR Report No. 64061 3265, June 1964.

"Adaptive Design Methods for Cryogenic Circuits," by S. Aida, NBR Report No. 64062 3265, June 1964.

R. S. Ledley, Panelist at Solid State Conference held in Philadelphia, Pennsylvania, January 1964.

COMBINED ANALOG-DIGITAL METHODS

J. REINTJES
Massachusetts Institute of Technology
Cambridge, Massachusetts

PRINCIPAL ASSOCIATE: M. E. CONNELLY

TASK NO. NR 049-177   CONTRACT Nonr 1841(85)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

The purpose of this task is to combine the most appropriate characteristics of both analog and digital computers to achieve rapid, accurate, convenient solutions for mathematical problems involving partial differential equations.

SUMMARY OF RECENT ACCOMPLISHMENTS

The M.I.T. analog-digital computation facility has been completed and successfully employed in a complex, real-time simulation demonstration. The hybrid system consists of the PDP-1 digital computer, analog-digital conversion channels, discrete inputs and outputs, a 75-amplifier analog computer of M.I.T. design, a smaller, high-speed analog sub-system with sample and sample-and-hold gates operating under digital program control, and various display and recording options. In addition, authorization has recently been received to develop a magnetic drum memory for the rapid storage and retrieval of continuous analog signals.

Preparations are under way to utilize this hybrid facility for experimental verification of several mathematical procedures previously investigated by the project for the solution of partial differential equations. This backlog of techniques, some of which have been tried out on ad hoc analog or digital equipment, includes procedures for dealing with the diffusion equation, the Laplace equation, the Helmholtz equation, the Orr-Sommerfeld equation of hydrodynamics, and complex distributed process control systems. A recent project study has produced a technique by which linear boundary valve problems with a known fundamental solution can be reduced to two stable initial valve problems for analog computation.

RECENT REPORTS OR PUBLICATIONS

Richard Morones — *Solution of Hyperbolic Boundary Valve Problems on a Hybrid Computer* — D.S.R. 9128, Memorandum No. 6, October 11, 1963.

Shu-Kwan Chan — *Preliminary Investigation of an Analog Solution to the Orr-Sommerfeld Equation* — D.S.R. 9128, Memorandum No. 7, January 15, 1964.

Hans Witsenhausen — *Hybrid Solution of Initial Valve Problems for Partial Differential Equations* — D.S.R. 9128, Memorandum No. 8, August 1964 (Journal paper in preparation).

Shu-Kwan Chan and Edward F. Kurtz, Jr. — *On Using an Analog Computer to Study Hydrodynamic Stability* — D.S.R. 9128, Memorandum No. 9, August 1964. (Accepted for publication in *IEEE Transactions on Electronic Computers*; reprints will be sent to official distribution list.)

Richard Moroney — *Solution of Laplace's Equation in Two Dimensions on a Hybrid Computer*, 9128-WP-14, December 25, 1963.

Richard Moroney — *Hybrid Computer Solution of Parabolic Partial Differential Equations via the Continuous Space-Discrete Time Method*, 9128-WP-16, January 8, 1964.

Piermarco Romagnoli — *Distillation Column Dynamics: Hybrid and Digital Computer Simulation* — M. S. Thesis, M.I.T. Dept. of Electrical Engineering, October 1964.

VARIABLE STRUCTURE COMPUTER SYSTEM

G. ESTRIN
University of California
Los Angeles, California

TASK NO. NR 048-178 AEC CONTRACT

PROJ. NO. RR 003-09-01

(This task is administered and jointly supported by the AEC.)

TASK DESCRIPTION

This task will involve construction and evaluation of a new computer system organization, the Fixed-Plus-Variable Structure, which shows promise of being able to solve problems which cannot be solved on existing or proposed machines or of being able to solve problems faster and more economically, and which could provide a mechanism that will permit powerful contributions to methods of problem solving and digital technology.

SUMMARY OF RECENT ACCOMPLISHMENTS

An initial system has been constructed using basic variable logic modules and motherboards containing a 6 × 6 of array of modules. The signal interconnections between modules are made on a two sided etched "signal harness" which is removable by a dip tank process. The interconnections between motherboards in a frame are accomplished by bench prepared vertical cable runs and horizontal cable drawers. A frame contains up to 33 motherboards holding up a 1188 modules which in turn contain up to 4752 transistors and 23,760 diodes.

The initial system links to a general purpose computer, an IBM 7094, mechanizing five types of operations: transfer of 72 bit words from specified addresses in F (the 7094 to V (Variable Structure System); transfer of 72 bit words from V to specified addresses in F; interruption of a program in F upon observation by the system of special F-instructions; arbitrary interruption of a program in F; decoding a small set of operations in V.

Work is now proceeding with the enlargement of the V inventory; the implementation of modular arithmetic units permitting conventional and signed digit arithmetic; automation of the design and fabrication of special purpose configurations; reduction of the time for manual change in the system; introduction of card-programmed and stored programmed change of system functions; introduction of integrated circuit modules; and specification of an active intermotherboard transmission system.

Study of models of computation and models of systems are continuing with the goal of determining feasibility of a system which can be efficient at the process of reallocating its own resources dynamically.

RECENT REPORTS OR PUBLICATIONS

"Automatic Assignment of Computational Tasks in a Variable Structure Computer," Edward C. Russell, Department of Engineering Report No. 63-45, August 1963.

"Analysis of Computing Load Assignment in a Multi-Processor Computer System," M. Aoki, R. Mandell and G. Estrin, Fall Joint Computer Conference, Las Vegas, Nevada.

"Some Applications for Content-Addressable Memories," G. Estrin, R. H. Fuller, Proceedings-Fall Joint Computer Conference, 1963.

"Parallel Processing in a Restructurable Computer System," G. Estrin, B. Bussell, R. Turn, J. Bibb, IEEE Transactions on Electronic Computers, December 1963.

"Algorithms for Content-Addressable Memories," G. Estrin and R. Fuller, Proceedings of the 1963 Pacific Computer Conference, IEEE, 1963.

"Automatic Assignment of Computations in a Variable Structure Computer System," G. Estrin and R. Turn, IEEE Transactions on Electronic Computers, Vol. EC-12, No. 15, December 1963.

"An Evaluation of the Effectiveness of Parallel Processing," G. Estrin, B. Bussell, Proceedings of the 1963 Pacific Computer Conference, IEEE.

COGNITIVE SYSTEMS RESEARCH PROGRAM

F. ROSENBLATT
Cornell University
Ithaca, New York

TASK NO. NR 049-147   CONTRACT Nonr 401(40)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task is a basic investigation of "intelligent" systems. The program includes study of the mathematics, physics, physiology, and engineering of cognitive systems, both in living organisms and in artificial brain analogs, with the intent of providing a fundamental understanding of the principles involved in complex electronic systems which are capable of partially emulating the behavior of sensory organs, nerve nets, and the brain.

SUMMARY OF RECENT ACCOMPLISHMENTS

During the last year, the audio perceptron, Tobermory, has been brought close to completion, and experiments have already begun with the part of the system which is now operational. Plans for further expansion of this system have been elaborated, particularly with regard to the inclusion of a speech synthesizer within the next year. At the same time, digital simulation studies and theoretical studies of long-term experiential memory mechanisms have continued, and the neurophysiological program which is being conducted in conjunction with the theoretical program has obtained a number of significant results.

RECENT REPORTS OR PUBLICATIONS

None.

PATTERN-PERCEIVING AND LEARNING NETWORKS

P. GREENE
University of Chicago
Chicago, Illinois

TASK DESCRIPTION

This task is devoted to the investigation of networks which can exhibit pattern perception. The objective is not to recognize the entire pattern but rather to isolate certain constancies, or "Gestalten." The general approach concerns ways in which properties of objects are mapped into patterns of nervous system activity.

SUMMARY OF RECENT ACCOMPLISHMENTS

Work has proceeded in three directions, described by the following three headings.

1. *Theory of adaptive systems.* Studies of self-optimizing systems are widespread. Research under this contract has assumed that such devices work perfectly, and asked what could be done with them. A paper currently in print illustrates new mathematical problems involved in adaptive control.

2. *Computer program for perception and adaptive behavior.* Investigators everywhere try to transform sensory inputs into useful forms and to make them control desirable motor outputs. Work this year has explored a complementary approach making no essential distinction between sensory and motor systems, the perceptual structures themselves being built out of motor patterns. Unlike learning schemes in which connections are established between arbitrary computer symbols representing behavioral structures that *we* think about, this study has, where possible, kept the structures within the computer. An ultimate goal is to build a "compiler" for skilled actions, *i.e.*, a system which automatically organizes its basic patterns into a scheme to achieve a given purpose, much as we use those combinations of muscles which suffice to perform given motor tasks. A digital computer program is now running which is patterned after ways an infant achieves mastery of spatial relations. Its problems help guide work described in paragraph 1.

3. *Networks for producing patterned outputs.* Previous work under this contract showed how to utilize resonant responses of networks in order to cause the same set of output elements to perform any of a set of different patterns. A digital computer was used this year to learn whether a network could adjust itself, *e.g.*, by threshold modifications based on learning mechanisms, so as to achieve desired patterns. Results showed that it was easy to design a desired network by computing its parameters, but impractical (so far) to get the system to design itself by the learning mechanisms tried.

RECENT REPORTS OR PUBLICATIONS

None.

SELF-ORGANIZING NETWORKS

S. CAMERON
Illinois Institute of Technology Research Institute
Chicago, Illinois

TASK NO. NR 048-165   CONTRACT Nonr 3392(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with two aspects of self-organizing networks. On the one hand, research is being pursued on an optical implementation of the perceptron class of machines. At the same time, effort is being devoted to logical considerations involved in the design and utilization of such nets.

SUMMARY OF RECENT ACCOMPLISHMENTS

During approximately the last year of this program interest has focused on an approach to the general problem in which the concept of a single automation adjusting itself as a result of environmental experience is replaced with the notion of a population of automata, exchanging "genetic" information in a process which enables the "species" to adapt itself to the environment rather than individual members of the population. The primary objective of this work is to attempt to discover "efficient" search procedures based on evolutionary processes.

RECENT REPORTS OR PUBLICATIONS

None.

THEORIES OF SELF-ORGANIZING SYSTEMS

H. BREMERMANN
University of California
Berkeley, California

TASK DESCRIPTION

This task involves studies to gain better understandings of complex self-organizing systems. This will include such phases as principles of organization, detection of substructures, the organization of the brain for specific tasks, and the simulation of such functions by computers.

SUMMARY OF RECENT ACCOMPLISHMENTS

During the past year considerable progress has been made in overcoming difficulties that had been encountered in solving linear programming problems through evolution. Many methods that were previously tried tended to stagnate at points other than the optimum.

The successful evolution program has a remarkable feature which it shares with some microorganisms: It evolves asexually over long stretches of time, then goes through a sexual cycle, returns to asexual evolution, etc. until no further progress is made. Alternation between asexual and sexual evolution is determined by the progress of the evolution process itself. If asexual evolution stagnates, the program goes into a sexual cycle, then returns to asexual evolution, which is less time consuming but which easily "hangs up" on a stagnation point.

RECENT REPORTS OR PUBLICATIONS

Bremermann, H. J., and Salaff, S., Experiments with Patterns of Evolution, ONR Technical Report, Contract 222(85), November 1963.

Bremermann, H. J., and Rogson, M., An Evolution-Type Search Method for Convex Sets, ONR Technical Report, Contract 222(85), May 1964.

Rogson, M., A Search Method in Convex Programming, ONR Technical Report, Contract 222(85), to appear approximately December 1964.

Bremermann, H. J., Rogson, M., and Salaff, S., Search by evolution. To appear in the Proceedings of the 2nd Cybernetics Sciences Symposium. (Los Angeles Invitational on Biophysics held October 13, 1964, at University of Southern California.)

LEARNING SYSTEM THEORY

M. UFFELMAN
SCOPE Incorporated
Falls Church, Virginia

TASK NO. NR 048-195   CONTRACT Nonr 4467(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with the development of an information theoretic model of Learning Systems and the general theory of self organization.

SUMMARY OF RECENT ACCOMPLISHMENTS

This project is a new undertaking and is still in the formative stages. The primary effort up to this time has been expended in definition and model formulation. Learning systems have been broken into three levels. The lowest level is termed a trainable system and is a system which becomes able to perform a desired function through some training process. The memory of this system is fixed after training, and it is similar in operation to a fixed logic device. The second level is termed an adaptive system; it, unlike the trainable system, retains the capability of having its internal structure changed in operation. The highest level is the self-organizing system. It is an adaptive system coupled with a goal and evaluation system.

A tentative information theoretic model which describes all levels of learning systems has been proposed and is being analyzed.

A second aspect of the project is the inclusion of adaptive control systems under learning system theory. A self-organizing control system has been conceived and analyzed. Simulation experiments with the system are planned in the near future and a paper describing the work is in preparation.

RECENT REPORTS OR PUBLICATIONS

None.

RESEARCH ON EVOLUTIONARY PREDICTION

L. FOGEL

General Dynamics/Astronautics
San Diego, California

TASK NO. NR 048-196 . CONTRACT Nonr 4539(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

The purpose of this task is to explore the domain of applicability of evolutionary programming in which finite-state machines are permitted to evolve as sub-programs with the intent of predicting both stationary and non-stationary time series.

SUMMARY OF RECENT ACCOMPLISHMENTS

Intelligent behavior requires an ability to predict the environment with reasonable accuracy coupled with a suitable response algorithm with respect to a given goal. Such behavior is exhibited by an automaton which carries out a fast-time replication of some aspects of natural evolution using the finite-state machine as the evolving "organism." "Offspring" are produced through random mutation and individually scored in their ability to achieve the goal within the sequence of available experience. A selection is made of the best few machines to serve as "parents." Continual improvement is ensured through the retention of each parent-machine until an equally-good or superior offspring is found. Such fast-time mutation and selection is continued with real-time decisions being based on the logic specified by the surviving machine.

Experiments were conducted on the IBM 7094 to examine the domain of applicability of the evolutionary prediction technique. As expected cyclic signals in various degrees of noise were soon characterized by the predictor-machines. The transition probabilities without the sequence of predictions of low-order Markov processes were in close correspondence with those of the environment. The evolutionary program was also required to predict the (4-symbol) output sequence of an arbitrary machine which was driven by random binary notes. After 160 predictions the percent correct reached 51.5. When the evolutionary program was also given the input binary variable this score reached 80%, showing a rapid approach toward the 100% asymptote. In contrast, providing an uncorrelated binary variable degrades the performance to 40.5% by requiring an attempt to extract non-existent information. A formal technique was devised which translates each predictor-machine into a set of hypotheses concerning the logic of the environment.

RECENT REPORTS OR PUBLICATIONS

"On the Evolution of Artificial Intelligence" by Drs. L. J. Fogel, A. J. Owens, and Mr. J. Walsh. Proceedings of the Fifth National Symposium on Human Factors in Electronics, IEEE, San Diego, May 5-6, pp. 63-76.

"On Evolutionary Prediction Technique" by Drs. L. J. Fogel, A. J. Owens, and Mr. J. Walsh. Presented before International Conference on Microwaves, Circuit Theory, and Information

Theory, IEEE, Tokyo, Japan, September 7-11, 1964. Summary published in Part 3 of the Proceedings, pp. 173-174.

"Artificial Intelligence through the Simulation of Evolution" by Drs. L. J. Fogel, A. J. Owens, and Mr. J. Walsh. Proceedings of the Second Cybernetic Sciences Symposium, ONR, Los Angeles, October 13, 1964.

ADAPTIVE AND SELF-OPTIMIZING SYSTEMS

R. OLDENBURGER
Purdue University
Lafayette, Indiana

TASK NO. NR 049-167   CONTRACT Nonr 1100(20)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task involves research leading to new methods for analysis and synthesis of adaptive and self-optimizing control systems. Typical subjects of investigation are (a) on-line determination of the characteristics of operating systems, (b) analytical comparisons of alternative methods of self-optimization, and (c) minimal switching functions for optimal nonlinear control.

SUMMARY OF RECENT ACCOMPLISHMENTS

One of the problems of adaptive control is that of optimal response. What optimality is must be determined for each system and disturbance to which the system is subjected. Most of the past year was devoted to the writing and development of the theory of the investigator's new book on optimal control. This volume concerns optimal control from the viewpoint of control rather than guidance. The theory is carried out for systems to as high an order as appears to be justified for practical applications. It is assumed that the time rate of change of the input is bounded, as is normally true in practice, at least for fast control systems. It is proved that switching functions involving time derivatives no higher than the second will yield optimal response to the step disturbances normally encountered in the control of wide classes of linear systems. The effect of damping, noise, leads, lags, dead zones, pure delays and other factors on optimal response is studied.

A paper on the improvement in optimal response to step and pulse disturbances that can be obtained when these disturbances are known in advance was presented at the 1964 Joint Automatic Control Conference. It is shown that an improvement of 8:1 in the maximum error is possible in some applications. During 1964 the principle investigator published a survey of the literature on optimal control with an exposition of the history of the field and a look into the future. The problem of identifying pure delays in unknown systems from input-output data was solved for open and closed loop systems composed only of these delays and lumped elements with rational transfer functions. Sinusoidal inputs were treated.

RECENT REPORTS OR PUBLICATIONS

"Optimum Control," by Rufus Oldenburger, Applied Mechanics Reviews, Vol. 17, No. 4, April 1964, pp. 267-274.

"Optimum Nonlinear Control for Step and Pulse Disturbances," by Rufus Oldenburger and R. C. C. Chang, Proceedings of the Joint Automatic Control Conference, Palo Alto, California, June 1964, pp. 441-450.

"Optimal Control," by Rufus Oldenburger; book to be published by Holt, Rinehart and Winston.

"Identification of Linear Systems With Pure Delays," Purdue University thesis by Prakash, August 1964.

"Optimum Control," by Rufus Oldenburger, Technical Report No. 3 for ONR, August 1964. Sent to distribution list.

DIGITAL ADAPTIVE CONTROL SYSTEMS

J. T. Tou
Computer Sciences Laboratory
Northwestern University
Evanston, Illinois

TASK NO. NR 049-172   CONTRACT Nonr 1228(23)

PROJ. NO. RR 003-08-01

TASK DESCRIPTION

This task is concerned with the research leading to new techniques for analysis and design of digital adaptive and learning systems. The study aims at the development of fundamental principles for the design of intelligent machines for control and optimization.

SUMMARY OF RECENT ACCOMPLISHMENTS

During the past contractual year this program has continued to be concerned with the development of modern techniques for the optimum synthesis of digital control systems, the terminal control of systems with distributed energy constraints, general stability theory, system optimization via learning and adaptation, study of associative memory system for control.

Extending the method of coordinate transformation, we have developed an alternative solution to the time-optimal control problem. A control algorithm is developed for the determination of the optimum control law on the basis of the principle of optimality and the geometric structure of certain regions of the state space. The control law is expressed in the form of an algorithm which may be readily realized as an on-line digital controller.

Some efforts have been devoted to terminal control of systems with distributed energy constraints. We consider a linear n^{th} order time-varying system subject to r control signals. The control interval is subdivided into a sequence of k control subintervals with duration τ. We have determined control vectors $\{u_j\}$ for the jth subinterval to minimize the Euclidean norm of the terminal error vector subject to certain constraints on the control vectors, which are expressed in terms of vectors in the n-dimensional Euclidean space. Making use of nonlinear programming, we have developed a computational algorithm for determining the control vectors. We have developed some general stability theory for control systems.

Study on system optimization via learning and adaptation has been continued. We have derived algorithms for the determination of optimal control. Based upon the observed information pattern of the system, the learning controller determines the a posteriori probability and updates the data required in the optimization process.

RECENT REPORTS OR PUBLICATIONS

"Optimum Control of Discrete Systems Subject to Saturation," J. T. Tou, *Proc. IEEE*, January 1964.

"Synthesis of Discrete Systems Subject to Control-Signal Saturation," J. T. Tou, *Journal of the Franklin Institute*, May 1964.

"Determination of the Inverse Vandermonde Matrix," J. T. Tou, *IEEE Trans. on Automatic Control*, July 1964.

"On the Design of a Learning System for Control," V. Ivanenko and J. T. Tou, in *Computer and Information Sciences*, Spartan Book Co., Washington, D.C. (1964).

"On Some Problems in Cybernetic Medicine," J. T. Tou, *Proc. of the Third International Society of Cybernetic Medicine* (1964).

"Systematic Design of Cryotron Logic Circuits," C. C. Yang and J. T. Tou, *Proc., Fall Joint Computer Conference* (1964).

"System Optimization via Learning and Adaptation," J. T. Tou, presented at the International Conference on Microwaves, Circuit Theory, and Information Theory, Tokyo, Japan, September 1964.

"Time-Optimal Control of Discrete Systems Subject to Input Saturation," J. T. Tou and W. J. Hankley, Technical Report No. 105, Computer Sciences Laboratory, Northwestern University (1964).

"Learning, Adaptation and Control in Information Systems, Pt. I," J. T. Tou, H. C. Hsieh, G. P. Szegö, T. T. Lin, and P. P. Nuspl, Technical Report No. 106, Computer Sciences Laboratory, Northwestern University (1964).

"Dynamic Programming and Modern Control Theory," J. T. Tou, a chapter in *Progress in Control Engineering*, Vol. III, Academic Press, Inc., London, England (1964).

"Modern Synthesis of Discrete Control Systems," J. T. Tou, a lecture delivered at NAA Symposium on Theory and Applications of Modern Control (1964).

"Information Science and Neuro-cybernetics," J. T. Tou, a lecture delivered at the University of Missouri (1964).

"Optimal Control Theory," H. C. Hsieh, a lecture delivered at the University of California, Los Angeles (1964).

"Modern Control Theory" (book), J. T. Tou, McGraw-Hill Book Co., New York (1964).

"Computer and Information Sciences" (book), J. T. Tou and R. H. Wilcox (Eds.), Spartan Book Co., Washington, D.C. (1964).

FERROELECTRICITY AND FERROELECTRIC MATERIALS

H. Wieder
U.S. Naval Ordnance Laboratory
Corona, California

TASK NO. NR 048-119   CONTRACT Nonr PO-1-008

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with formulating and testing general theories concerning ferroelectricity and ferroelectric materials in order to facilitate use of the phenomena in computer devices. The programs are concerned primarily with certain crystalline solid materials which have a net polar moment and a reversible bistable, spontaneous polarization.

SUMMARY OF RECENT ACCOMPLISHMENTS

The growth and synthesis of large, (5 cm² or larger) tabular ferroelectric crystals of triglycine sulfate (TGS) was completed. Such crystals with a preferential orientation of the ferroelectric axis in the plane of the crystal are desired in order to obtain large single-domain regions suitable for the fabrication of information storage cells. Monovalent ions introduced into the solution in which the TGS crystal is grown, were found to produce such a preferential growth. The ferroelectric and dielectric properties of such crystals were related to the spatial dispersion of the spontaneous polarization and internal biasing fields. The investigation of the pyroelectric response in the μ-wave region of hydrogen-bonded ferroelectric crystals continues with emphasis on pyroelectric modulation of triglycine sulfate.

RECENT REPORTS OR PUBLICATIONS

"External Habit Modification and Ferroelectric Properties of TGS," H. H. Wieder and C. R. Parkerson, Journal of Physics and Chemistry of Solids, **25**, 241-245 (1964), sent to distribution list.

"Pyroelectric Sensitivity of Triglycine Sulfate Detectors," David J. White, NOLC Report 601, July 1, 1964. Sent to distribution list.

"Pyroelectric Response of Triglycine Sulfate to Amplitude Modulated X-band Signals," David J. White (to be published in the Journal of Applied Physics, December 1964).

SEMICONDUCTOR DEVICE RESEARCH

J. LINVILL
Stanford University
Palo Alto, California

PRINCIPAL ASSOCIATE: J. F. GIBBONS

TASK NO. NR 048-122   CONTRACT Nonr 225(31)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with studies of semiconductor phenomena and devices which have some potential for utilization in future Navy electronic equipment. These studies include the surface properties of semiconductors, high-frequency voltage-variable capacitors, and efficient means of controlling both the lifetime and electrical properties of semiconductors.

SUMMARY OF RECENT ACCOMPLISHMENTS

For the present year attention has been directed to the study of electro-optical phenomena and in particular to the use of such phenomena in electro-optical computers. The requirement in an electro-optical computer of a power gain element is basic. The need is apparent in logic circuits where a logic output must drive a number of input ports. In the event that the input is optical and the outputs are optical, one must have power gain between the ports, possibly involving an opto-electronic and electro-optical transducers in tandem. This combination consists of electronic detectors of light and luminescent devices driven electrically.

The gain and speed properties of several basic structures have been studied. These have included:

(a) A reverse-biased semiconductor diode as a detector in series with a number of injection luminescent diodes (ILD's) as output elements.

(b) A reverse-biased diode driving a transistor base with a series of ILD's in the collector circuit.

(c) Similar arrangement to (b), but with a field-effect transistor employed.

Evaluation of the gain to delay ratios for presently feasible devices of the classes indicated above reveal that they are several orders of magnitude poorer than corresponding all-electronic elements in the semiconductor family. A basic need at this point in the optical computer area is the invention of a significantly better gain element.

RECENT REPORTS AND PUBLICATIONS

"Circuit with Logarithmic Transfer Response," J. F. Gibbons and H. S. Horn, IEEE Trans. on Circuit Theory, CT-11, No. 3, September 1964, pp. 378-384.

"Measurement of the Temperature Dependance of Minority Carrier Mobility in a Transistor Base Region," Tsu-Lann Shao, Stanford Electronic Laboratories Tech. Report 4818-1, December 1963.

ELECTRON SPIN ECHO STORAGE

W. MAIN

Lockheed Missiles and Space Company
Palo Alto, California

TASK NO. NR 048-125   CONTRACT Nonr 2541(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with research leading toward a serial type computer memory utilizing electron spin echoes. With the method of electron magnetic resonance, radio frequency energy in the form of pulses can be stored serially and recalled at an arbitrary later time within the relaxation time of the spin sample.

SUMMARY OF RECENT ACCOMPLISHMENTS

A broadband microwave spin echo memory element has been developed as an outgrowth of our original zero field spin echo measurements. This memory element operates without dispersion over a bandwidth in excess of 3.2 kMc (7.6-10.8 kMc) in microwave X-band in the absence of an external magnetic field. A non-resonant helical slow wave structure is used to contain the active paramagnetic material, praseodymium doped calcium fluoride. Because of the coupling efficiency of the slow wave structure driving power requirements are low,—less than one watt for command pulses. Storage times of 20 microseconds in the first-in last-out type storage mode, and over 100 microseconds for the first-in first-out type storage mode have been obtained. Operation is currently at liquid helium temperatures.

Work is now underway to determine the total zero field bandwidth of this material, which is expected to be substantially greater than 3.2 kMc, and to further improve the efficiency of this memory element. Measurements to determine the storage times at higher temperatures are also being conducted.

Preliminary studies of possible applications of microwave spin echo phenomena as delay lines for radar and ECM systems have indicated several possible applications in these areas. It is anticipated that related developmental work will be undertaken.

RECENT REPORTS OR PUBLICATIONS

Anomalous Zero Field Spectra of (Ca,Ce)F$_2$ by Spin Echo Techniques, D. E. Kaplan, Meeting-in-Minature, American Chemical Society, Berkeley, 17 December 1963 (Invited Oral Presentation).
Application of Electron Spin Echo Resonance Phenomena, M. M. Siera, Technical Report No. 4, June 1964, Contract NOnr 2541(00), Lockheed Missiles and Space Co.

CRYOTRON RESEARCH

J. ROGERS
Space Technology Laboratories
Redondo Beach, California

TASK NO. NR 048-126   CONTRACT Nonr 2542(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with research on cryotrons and cryotron circuitry to determine their efficiency for logic and memory operations. Emphasis is on logical design of cryotron switching networks, fabrication techniques for large arrays and measurement of switching parameters of those arrays.

SUMMARY OF RECENT ACCOMPLISHMENTS

In the past year the major emphasis has been on the fabrication of test matrices of 900 cryotrons. The cryotrons use 0.001 inch wide lead controls and 0.010 inch wide tin gates. The insulating films are formed by electron bombardment of a thin film of silicone oil. The recent difficulties associated with successful fabrication have usually been of a random nature and involve such things as dust particles blocking control slits, maintenance of mask alignment, and control of vapor source parameters.

The superconducting properties of a number of matrices have been measured. It has been shown that the properties of the cryotrons are not affected by repeated cycling between room temperature and liquid helium temperature. Preliminary tests of the uniformity of the cryotrons on a given substrate indicate that a uniformity of $\pm 10\%$ can be realized by using a pair of control masks and choosing the best of the 900 control slits from the pair.

Concurrently, research has continued on the logical design of associative memory circuits. A design has been chosen which utilizes the same 900 cryotrons which comprise the matrix and which incorporates the experience gained from the matrix analysis. The memory will consist of 15 words/plane of 10 bits each. Layout of the circuits and design of the interconnection mask has been completed.

RECENT REPORTS OR PUBLICATIONS

Technical Report, "Low Temperature Computing Elements," TRW Space Technology Laboratories, 8971-6009-RU-000; March 1964.

H. T. Mann, "Electrical Properties of Thin Polymer Films. Part I. Thickness 500-2500 Å," *J. Appl. Phys.*, Vol. 35, pp. 2173-2179; July 1964.

A. J. Learn and R. S. Spriggs, "Superconductivity of High Agglomerated Indium Films," *J. Appl. Phys.*, to be published.

MICROMINIATURIZED ELECTRONIC CIRCUITS

C. ROSEN
Stanford Research Institute
Menlo Park, California

PRINCIPAL ASSOCIATE: K. SHOULDERS

TASK NO. NR 048-145   CONTRACT Nonr 2887(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is concerned with development of new means of fabricating complex circuits and high-density high-speed electronic data storage through the use of electron beam microminiaturization techniques. This unique approach employs a beam of electrons controlled through an electron microscope to etch out circuits on a resistive material. It is contemplated that the entire process can be programmed and directed by a suitable computer. Hopefully this program will lead to a document storage system with a capacity of 10^{10} to 10^{12} bits per square inch and with data recording and retrieval rates between 10^7 and 10^{10} bits per second.

SUMMARY OF RECENT ACCOMPLISHMENTS

Research is continuing on electron-beam-activated resist formation and molecular beam etching processes for machining films of refractory metals and dielectrics, to produce multilayer active and passive electronic structures in the sub-micron size range. Two new resist-forming materials were investigated and found to have a resolution of better than 100 angstrom units, as well as other desirable properties. An experimental search for efficient molecular beam etchants for aluminum oxide and molybdenum is under way. When fully developed, this micromachining technology can be applied to the formation of a surface having 10^8 micron-size field-emission tubes per square inch. A complete electronic system of 10^{11} components occupying a one-inch cube is envisioned. The active surfaces will be produced completely within a fully-instrumented, ultra-high-vacuum chamber, with versatile external mechanical manipulators, rapid accessibility, and 900°C bakeout capability for both chamber and instrumentation constituting its notable features. Most of the high temperature accessories, which include a high-resolution electron-optical system, a quadrupole mass spectrometer, electron multipliers, source materials evaporators, and evaporation rate monitors, have been developed. Concurrent research on optical intercoupling between micron-size devices yielded thin-film photon generators with adequate gain-bandwidth products. A search for suitable photon receptors was started. Research is being conducted on new machine-organization concepts, namely: (1) performing logic by parallel information transfer between two micromachined storage surfaces, using electron-optical techniques; (2) identifying and using memory, logic, and transfer functions in orbiting and interacting electrons within spatially-periodic fields.

RECENT REPORTS OR PUBLICATIONS

A paper entitled "Toward Complex Systems," by K. R. Shoulders, was presented at the Microelectronics and Large Systems Symposium in Washington, D.C., on 18 November 1964.

A short article entitled "Cathodoluminescence of Thin Films Containing Rare-Earth Oxides," by W. W. Hansen and R. E. Myers, has been submitted to *Applied Physics Letters*.

NEURISTOR DEVICES

M. GREEN
Stanford Research Institute
Menlo Park, California

TASK NO. NR 048-158   CONTRACT Nonr 3212(00)

PROJ. NO. RR 003-09-01

TASK DESCRIPTION

This task is intended (1) to study the theoretical system properties that are possible with neuristor devices, and (2) to study both analytically and experimentally the potential realization possibilities of neuristor devices.

SUMMARY OF RECENT ACCOMPLISHMENTS

During the past year project effort has been divided about equally between experimental and theoretical studies. Our experimental work has been directed toward the realization of distributed-parameter neuristors based on superconductive effects. In these devices a "pulse" comprises a thermally induced region of normal conductivity that propagates along a super-conductive path of small cross-sectional area. A typical circuit configuration consists of a long narrow fiber of a superconductor, such as tin, vapor deposited on a conductive substrate (*e.g.*, a thin layer of copper on glass). When biased with a current near the critical value, interfaces between normal and superconductive regions of the fiber are observed to propagate at velocities that can be as high as 100,000 cm/sec. The division of current between the normal fiber and the conductive substrate provides a mechanism that is theoretically adequate to induce recovery to the superconductive state after passage of a thermal pulse. In practice, however, it is difficult to achieve a reliable recovery process in completely distributed versions of the device. Although feasibility has been demonstrated the construction of practical neuristors based on this concept appears to require improvements both in superconductor materials properties and in fabrication techniques.

Theoretical work has continued the attempt to characterize neuristor pulse propagation as a property of distributed active processes. Most of the important features of neuristor behavior can be illustrated and analyzed with reference to a diffusion-type (R-C) transmission line containing shunt elements whose conductance is sometimes negative depending on local values of line excitation (current, voltage, and the time derivatives of these quantities). We have studied such lines from a formal mathematical standpoint and also carried out many digital-computer simulations of lines based on this model. An adequate treatment of pulse stability conditions has been worked out leading to means for synthesizing lines with different types of pulse interaction behavior. These neuristor models have some direct and interesting interpretations with respect to axon processes.

RECENT REPORTS OR PUBLICATIONS

Interim Report 8, "Preliminary Feasibility Study of Superconductive Neuristor Devices," D. R. Chambers, (August 1964).

Final Technical Report, "Modes of Neuristor Propagation: A Study in Distributed Active Processes," M. W. Green and H. D. Crane, (September 1964).

MICROMINIATURIZED DATA STORAGE

C. Rosen
Stanford Research Institute
Menlo Park, California

TASK DESCRIPTION

This task is concerned with development of new means of fabricating complex circuits and high-density high-speed electronic data storage through the use of electron beam microminiaturization techniques. This unique approach employs a beam of electrons controlled through an electron microscope to etch out circuits on a resistive material. It is contemplated that the entire process can be programmed and directed by a suitable computer. Hopefully this program will lead to a document storage system with a capacity of 10^{10} to 10^{12} bits per square inch and with data recording and retrieval rates between 10^7 and 10^{10} bits per second.

SUMMARY OF RECENT ACCOMPLISHMENTS

Techniques are being investigated for micromachining thin films of refractory materials on suitable substrates, for applications to high-density information storage. The basic approach involves the use of an electron beam to activate a chemical resist material in predetermined patterns on the film to be machined, followed by etching of the unprotected areas. The patterns produced would represent permanently stored information per se, or can be structured in multilayers to form mosaics containing large numbers of identical storage elements on which information can be written, retrieved, and erased. An electron-optical system that maintains microinch dimensional and alignment stability after 900°C bakeout, for use in micromachining and information processing, is almost ready for initial tests. Storage surfaces will be produced and investigated in a versatile ultra-high-vacuum chamber having 900°C bakeout capability for both chamber and instrumentation. Most instruments required have been developed, including a mass spectrometer, mating electron multiplier, manipulators, materials evaporators and controllers. A radial electron multiplier, for use with electron-optical systems, is still required. A resolution of 250 angstroms will permit the formation and use of 10^8 bit fields by electronic scanning alone; suitable substrate manipulators will yield surfaces with 10^{12} bits per square inch. With proposed binary deflection systems, random access to elements within any 10^8 bit field is believed possible in 10^{-6} seconds. Current work also includes investigation of microelement configurations and exploration of novel ideas for performing storage and logic by parallel information transfer between two micromachined surfaces, using electron-optical techniques.

RECENT REPORTS OR PUBLICATIONS

A paper entitled "A Bakeable, Distributed-Dynode Multiplier," by C. A. Spindt and K. R. Shoulders, was presented at the Seventh National Conference on Tube Techniques in New York City on 28 September 1964. It was also submitted to the *Review of Scientific Instruments* for publication.

OPTICAL TECHNOLOGY

N. KAPANY
Optics Technology
Belmont, California

TASK DESCRIPTION

This contract involves investigation of various techniques for optical information processing.

SUMMARY OF RECENT ACCOMPLISHMENTS

Theoretical and experimental studies have been initiated into those characteristics of active (laser) and passive fiber optics elements which may offer potential application to logical gates in computers. Various types of neodymium-doped glasses have been drawn into fibers. These fibers have been fabricated in several sizes, with and without a glass coating, and tested with respect to lasing threshold and signal characteristics in different pumping geometries. Such fibers, pumped below threshold, have been used to amplify the signal from a lasing fiber. "Hair trigger mode" operation has also been achieved by end-pumping a fiber which is side-pumped below threshold. Finally, a method of calculating the "beat length" between parallel fibers has been formulated and the associated resonant coupling between adjacent fibers has been demonstrated experimentally.

RECENT REPORTS OR PUBLICATIONS

N. S. Kapany, "Fiber Optics and the Laser," presented at the New York Academy of Sciences Conference on the Laser, New York, New York, May 4-5, 1964. To be published in the Proceedings.

PHOTOCHROMIC MATERIALS FOR
DATA STORAGE AND DISPLAY

R. ANDES

UNIVAC, Division of Sperry Rand Corporation
St. Paul, Minnesota

TASK DESCRIPTION

The purpose of this task is to conduct research on photochromic materials and on methods of utilizing such materials for data storage and display.

SUMMARY OF RECENT ACCOMPLISHMENTS

Initially, this program has been concerned with investigations of selected photochromic compounds, in order to obtain a better understanding of their capabilities and of the mechanisms of photochromic processes. Compounds being investigated are anils, especially those prepared from salicylaldehyde or substituted salicylaldehyde and an aromatic amine.

Many anils are polymorphic; these polymorphs behave differently when irradiated. Disalicylidene m-phenylenediamine, when crystallized below 50°C is fluorescent and thermochromic but not photochromic. When crystallized above 60°C, the form obtained is photochromic but not fluorescent or thermochromic. Salicylidene aniline crystallizes in at least three forms: one is fluorescent but not photochromic; two are photochromic but not fluorescent or thermochromic. The photochromic forms are changed from yellow to red by near ultraviolet, and from red to yellow by visible light. One photochromic form has unusually good retention of the red state in the dark. The two photochromic forms show slight differences in infrared absorption spectra, indicating a difference in molecular configuration. No significant differences, other than color, were found between the yellow and red photochromic states of a given material.

A few photochromic anils, such as salicylidene β-naphthylamine and salicylidene 3, 4-xylidene, are switched from yellow to red by visible light, but are little affected by ultraviolet radiation. The latter compound is unusual also in that one crystalline form shows fluorescence, thermochromism, and photochromism.

Since polymeric materials have desirable properties for producing films or coatings, three polymeric anils were prepared. These were fluorescent and thermochromic but not photochromic.

RECENT REPORTS OR PUBLICATIONS

None.

TANTALUM CLAD COMPOSITES FOR ELECTROLYTIC CAPACITOR MATERIALS

H. OGDEN
Battelle Memorial Institute
Columbus, Ohio

TASK DESCRIPTION

The objectives of the research program are to investigate techniques for producing metallographically bonded tantalum clad foil composites and to evaluate the electrical characteristics capacitance, dc leakage, dissipation factor of anodized material. Satisfactory electrical and mechanical stability of such composite structures (versus solid tantalum) could lead to significant reductions in the amount of high purity materials presently used in electrolytic capacitors. The metals being evaluated as potential low cost core materials include (1) commerical purity tantalum, (2) columbium, (3) titanium, and (4) aluminum. Thin layers of high purity tantalum are being joined to each core metal utilizing (1) gas pressure bonding, (2) hot roll cladding, and/or (3) cold roll cladding.

SUMMARY OF RECENT ACCOMPLISHMENTS

Preliminary studies have demonstrated the feasibility of producing high quality Ta-Ta, Ta-Cb, and Ta-Ti foil composites using both the hot and cold roll cladding techniques. Optimum rolling and annealing schedules to minimize interdiffusion and/or interstitial contamination during hot processing have not yet been established. Hot rolling temperatures of 1450°F (Ta-Ti) and 2000°F (Ta-Ta, Ta-Cb) to effect bonding have given good results. Cold reductions of 50-65 percent in one pass followed by a vacuum heat treatment have been used to fabricate each of these composites by cold roll cladding. The Ta-Al composite has not yet been successfully prepared by cold roll cladding.

Electrical studies have been initiated on 10-mil-thick composites of Ta-Ta, Ta-Cb, and Ta-Ti produced by hot roll cladding and a Ta-Cb composite produced by cold roll cladding. Control studies are being conducted on solid tantalum foil at several impurity levels and on material fabricated by hot and cold processing.

RECENT REPORTS OR PUBLICATIONS

None.

CRYOGENIC ASSOCIATIVE MEMORY RESEARCH

J. ROGERS
Space Technology Laboratories
Redondo Beach, California

TASK NO. NR 348-002   CONTRACT Nonr 3899(00)

PROJ. NO. RR 003-10-02

TASK DESCRIPTION

This task involves research leading to associative memories of advanced capability, including the performance of simple computations in parallel throughout the memory itself. In particular, techniques which lend themselves to cryogenic implementation are considered.

SUMMARY OF RECENT ACCOMPLISHMENTS

The form of associative memory with the greatest promise of versatility for computation and information retrieval incorporates a number of tag bits in each word which may be written into independently as a result of an interrogation. Several design variations have been considered in which different interrogation results initiate tag writing, and the effect of the choice on the efficiency of a number of operations has been studied.

One method of resolving multiple responses to an interrogation is an ordered readout on a field which uniquely identifies each record. An economical address bit has been designed for this purpose which requires only one cryotron per work for each two address digits. A tag bit circuit has been designed which allows a tag field in each word to function as a parallel counter. Operation of the normal tag bit as a counter requires sequential operation on the digits of the count field for each count increase.

Consideration has been given to the use of an associative memory for statistical problems such as the determination of the median or other binary subdivision of a set of data. An advantage is realized in that no ordering of data is required but the efficiency of the method is limited by the amount of record counting which must be done serially.

RECENT REPORTS OR PUBLICATIONS

J. L. Rogers and A. Wolinsky, "Associative Memory Algorithms and Their Cryogenic Implementation," TRW Space Technology Laboratories, 8670-6007-RU-000; December 1963.

Final Summary Report, "Research on Cryogenic Associative Memories," TRW Space Technology Laboratories, 8670-6008-RU-000; May 1964.

COORDINATED SCIENCE LABORATORY

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TASK NO. NR 341-015   CONTRACT DA 36-039-SC-56695

PROJ. NO. RR 011-02-02

TASK DESCRIPTION

The purpose of this task is to provide tri-service support of a large university laboratory. Research is centered upon subjects of direct application to military problems.

SUMMARY OF RECENT ACCOMPLISHMENTS

(Note: this summary is limited to items of interest in the information sciences and does not cover all research at the Coordinated Science Laboratory.)

In studies relating to computer analysis of systems, the problem of the generation of network trees without duplication has been solved. Necessary and sufficient conditions for the realizability of a completely specified synchronous machine as a quasilinear sequential machine have been found. The relationship between terminal capacities for a lossy communication net have been determined. Work on an automatic teaching system (PLATO) is progressing toward a 20 station teaching system for dialogues between machine and student. A compiler to allow teachers to prepare teaching logics for the PLATO system is complete. In the area of automatic control, a new comparison sensitivity has been introduced and applied to problems in feedback system synthesis. New results relating to system stability, system optimization, and rendezvous strategies have been reported. Conditions for the realizability of a given matrix as the A (state) matrix of an RLC half-degenerate network have been found. A general procedure for the design of network to accomplish the broadband matching of an arbitrary load to a source has been given. In studies of nonlinear equations, periodic solutions to the generalized Lienard equation have been investigated, and the parametric approach has been used to give new techniques for the analysis of nonlinear networks. The plasma delay line is a new component for information systems; signals carried by electrons or ions in a crossed field variable delay line have been delayed as much as 50 microseconds over a distance of 3 inches.

RECENT REPORTS OR PUBLICATIONS

(List limited to publications of interest in the information sciences.)

R. B. Ash, "Further Discussion of a Time-Continuous Gaussian Channel," *Information and Control*, Vol. 7, pp. 78-83, March 1964.

P. G. Braunfeld and L. D. Fosdick, "The Use of an Automatic Computer System in Teaching," *IRE Transactions on Education*, Vol. E-5, September-December 1963.

R. M. Brown, R. D. Jenks, J. E. Stifle, and R. L. Trogdon, "The CSX-1 Computer," *IEEE Trans. on Electronic Computers*, Vol. EC-13, June 1964.

D. H. Cooper, "Compensation for Tracing and Tracking Error," *J. Audio Eng. Soc.*, Vol. 11, pp. 318-322, October 1963.

D. H. Cooper, "Integrated Treatment of Tracing and Tracking Error," *J. Audio Eng. Soc.*, Vol. 12, pp. 2-7, January 1964.

D. H. Cooper, "Binary Quantization of Signal Amplitudes: Effect for Radar Angular Accuracy," *IEEE Trans. on Aerospace and Navigational Electronics*, Vol. ANE-11, pp. 65-72, March 1964.

J. B. Cruz, Jr., and W. R. Perkins, "A New Approach to the Sensitivity Problem in Multivariable Feedback System Design," *IEEE Trans. on Automatic Control*, Vol. AC-9, pp. 216-223, July 1964.

J. B. Cruz, Jr., and W. R. Perkins, "The Role of Sensitivity in the Design of Multivariable Linear Systems," *Proc. NEC*, Vol. 20, pp. 742-745, October 1964.

J. B. Cruz, Jr., "Progress in Time-Varying and Active Circuit Theory," *IEEE Trans. on Circuit Theory*, Vol. CT-11, pp. 6-10, March 1964.

A. Dervisoglu, "Bashkow's A Matrix for Active RLC Networks," *IEEE Trans. on Circuit Theory*, Vol. CT-11, pp. 404-406, September 1964.

D. Gieseking, "An Optimum Bistable Controller for Increased Missile Autopilot Performance," *IEEE Trans. on Automatic Control*, Vol. AC-8, pp. 306-11, October 1963.

B. L. Hicks, "Estimation of the Spectrum Function for Small Wind Waves," in *Ocean Wave Spectra* (Proceedings of a Conference arranged by the National Academy of Sciences), pp. 95-99, Prentice-Hall (1963).

D. S. Humphreys, "Equiripple Network Approximation Using Iteration Techniques," *Proc. NEC*, Vol. 20, pp. 753-758, October 1964.

H. W. Knoebel, "The Electric Vacuum Gyro: Pinpoint for Polaris Launching," *Control Engineering*, Vol. 11, pp. 93-98, February 1964.

W. R. Perkins and J. B. Cruz, Jr., "The Parameter Variation Problem in State Feedback Control Systems," *Proc. Joint Automatic Control Conference*, pp. 170-174 (June 1964; to appear in *Trans. ASME* (1964)).

R. A. Rohrer and M. Sobral, Jr., "Sensitivity Considerations in Optimal System Design," *Proc. NEC*, Vol. 20, pp. 746-747, October 1964.

R. A. Rohrer, "Transformation Techniques for the Application of Liapunov's Direct Method," *IEEE Trans. on Circuit Theory*. Vol. CT-11, pp. 171-173, March 1964.

R. A. Rohrer, "Minimum Sensitivity RC-NIC Driving-Point Synthesis," *IEEE Trans. on Circuit Theory*, Vol. CT-10, pp. 442-443, September 1963.

M. E. Van Valkenburg, "Progress in Passive Circuit Theory," *IEEE Trans. on Circuit Theory*, Vol. CT-11, pp. 3-6, March 1964.

S. D. Agashe, "Role of the Generalized Lipschitz Condition in Finite-Time Stability and in the Derivation of the Maximum Principle," June 1964.

J. K. Aggarwal, "A Study of Nonlinear Second Order Systems," July 1964.

R. A. Avner, "Detection of Rate Changes in Periodic Phenomena."

H. Barnard, "Synthesis of Probabilistic Communication Nets," May 1964.

Kenneth E. Batcher, "Speed Independent Nor Realizations," May 1964.

Maryann Bitzer, "Self-Directed Inquiry in Clinical Nursing Instruction by Means of the PLATO Simulated Laboratory," December 1963.

H. Y. Chang, "On Quasi-Linear Sequential Machines," July 1964.

W. K. Chen, "Some Applications of Linear Graphs," May 1964.

L. O. Chua and R. A. Rohrer, "Nonlinear Network Analysis – The Parametric Approach," July 1964.

J. B. Cruz, Jr., and W. R. Perkins, "A New Approach to the Sensitivity Problem in Multivariable Feedback System Design," August 1963.

J. B. Cruz, Jr., and W. R. Perkins, "The Sensitivity of General Multivariable Feedback Systems," August 1964.

A. Dervisoglu, "Bashkow's A Matrix for Active RLC Networks," July 1963.

A. Dervisoglu, "Realization of the A-Matrix of Half-Degenerate RLC Networks," July 1964.

D. M. Diamond, "Minimization of Atmospheric Turbulence Effects on High-Resolution Synthetic Aperture Systems," September 1963.

George G. Dodd, "Principles and Applications of Unistor Graphs," July 1964.

J. A. Easley, Jr., H. M. Gelder, and W. M. Golden, "A PLATO Program for Instruction and Data Collection in Mathematical Problem Solving," January 1964.

Bruce D. Elliott, "An Extension of Dasher Synthesis," August 1964.

J. C. Elsey, "An Algorithm for the Synthesis at Large Sequential Switching Circuits," May 1963.

D. Gieseking, "Control of Co-operative Systems: The Rendezvous Problem," July 1964.

S. J. Kahne, "On Direct Fixed Time Optimization of Invertible Systems," June 1963.

J. Kruus, "Upper Bounds for the Mean Life of Self-Repairing Systems," July 1963.

E. Manning, "A Performance Measure for Game-Playing Programs," May 1964.

W. Mayeda and S. Seshu, "Generations of Trees Without Duplications," July 1964.

W. Mayeda and M. E. Van Valkenburg, "Properties of Lossy Communication Nets," April 1, 1964.

W. Mayeda, "Application of Linear Graphs to Electrical Networks, Switching Networks and Communication Nets," April 1964.

W. Mayeda, "Properties of Classes of Paths," May 1964.

W. Mayeda, "Pseudo Cuts and Their Applications," July 1964.

W. R. Perkins and J. B. Cruz, Jr., "The Parameter Variation Problem in State Feedback Control Systems," October 1963.

Peter Ponzo and Nelson Wax, "On Certain Relaxation Oscillations: Confining Regions," July 1964.

Peter Ponzo and Nelson Wax, "On Certain Relaxation Oscillations: Asymptotic Solutions," July 1964.

M. Raether and D. L. Bitzer, "Design and Performance of the Polarity Coincidence Detector," August 1963.

J. Resh, "On Networks and Bi-Complete Graphs," July 1963.

R. A. Rohrer and J. P. Herner, "Optimal Matching of Nonlinear n-Port Networks," July 1964.

R. A. Rohrer and M. Sobral, Jr., "The Euler-Poisson Equation and Optimal Linear Control," July 1963.

R. A. Rohrer and M. Sobral, Jr., "Optimal Linear Switching for Singular Linear Systems," March 1964.

R. A. Rohrer and M. Sobral, Jr., "Optimal Singular Solution for Linear, Multi-Input Systems," April 1964.

R. A. Rohrer, J. Resh, and R. Hoyt, "Distributed Networks Synthesis and Approximation in the Time Domain," July 1964.

R. A. Rohrer and M. Sobral, Jr., "Sensitivity Considerations in Optimal System Design," June 1964.

R. Rohrer, "The Scattering Matrix: Normalized to Complex n-Port Load Networks," May 1964.

S. Seshu, "On an Improved Diagnosis Program," May 1964.

S. Seshu, "The Logic Organizer and Diagnosis Programs," July 1964.

Soe M. Win, "Time Optimal Control of Non-Linear Sampled-Data Systems," May 1964.

AUTHOR INDEX

Principal Investigators and Associates

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