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ABSTRACT

This annual report contains a summary of the research which has been carried on in the department during the 1978-1979 academic year, and information about its organizational structure, objectives, instructional programs, computing facilities, interaction within the university, and interaction with the computer and information science community. Summaries of four completed research projects are included, and 12 ongoing research grants are described. Research was supported in part by grants from government agencies and industry, as well as by the Ohio State University. Appendices include listings of courses by number and title, computer and information science faculty, the computer and information science seminar series, related departmental activities, publications of the department staff, a technical report series, and recipients of the Doctor of Philosophy degree. (JEG)

ANNUAL REPORT

JULY 1978 - AUGUST 1979

DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

THE OHIO STATE UNIVERSITY

COLUMBUS, OHIO 43210

FOREWORD

This publication contains the annual report of the Department of Computer and Information Science and a summary of the research which has been carried on during the 1978-79 academic year. This research has been supported in part by grants from governmental agencies and industry, as well as by The Ohio State University.

The Department of Computer and Information Science is a separate academic unit located administratively in the College of Engineering, operating in part as an interdisciplinary program with the cooperation of many other departments and colleges throughout the University. Under the department is the Computer and Information Science Research Center which is the publishing outlet for a technical report series. Research of the faculty and graduate students in the Department of Computer and Information Science is reported periodically in this series. A bibliography of recent research reports published by the Center is included in this publication as Appendix G. Copies of some of these reports are still available on a complimentary basis from the Computer and Information Science Research Center, The Ohio State University, 2036 Neil Avenue Mall, Columbus, Ohio 43210. Titles with PB or AD numbers may be obtained from The National Technical Information Service, The U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, 22161, in paper copy, magnetic tape, or microfiche. Titles with ED numbers may be obtained from the ERIC Document Reproduction Service, P.O. Box 190, Arlington, Virginia, 22210. There is a nominal charge for their service.

Lee J. White, Chairman
Department of Computer
and Information Science
September 21, 1979

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I. THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

Computer and information science deals with the body of knowledge concerned with the quantitative relationships, concepts, theory and methods common to the processing and utilization of information, and with the theory and operation of the systems which process information. The study of both natural and artificial languages as modes of communication and of natural and artificial systems which process information is fundamental to computer and information science. Common properties of information are induced logically by the study of specific systems and specific areas of science and technology which have a concern with the handling of information. Information is defined as data of value in decision making.

ORGANIZATIONAL STRUCTURE

The Department of Computer and Information Science is a separate academic unit located administratively in the College of Engineering, operating in part as an interdisciplinary program with the cooperation of many other departments and colleges throughout the University. The department was organized in 1960 and achieved departmental status in 1968.

OBJECTIVES OF THE DEPARTMENT

The program at The Ohio State University emphasizes education, research, service and the professional practice and application of computer and information science. The educational program offers undergraduate and graduate degrees through the Ph.D. The research activities which are a central part of the program consist of a broad conceptual base supported by a number of contracts and grants as well as by the University. The broad core research program and these other research tasks interact to form an integrated framework.

HIGHLIGHTS OF DEPARTMENT ACTIVITIES, 1978-79

Lee J. White was appointed as Chairman of the Department of Computer and Information Science, effective July, 1979. He had served as Acting Chairman during the 1978-79 academic year.

Paul D. Amer, a CIS Graduate Teaching Associate, won a 1978-79 Graduate Associate Teaching Award, given by the Graduate School of Ohio State University. The recognition carries a $1000 cash award. Paul Amer was also awarded his Ph.D. from the Department in June, 1979.

An NSF Equipment Grant of $150,000 was made to the Department in May 1979 in order to establish a loop network facility. The nine node network configuration includes a host computer node consisting of a DEC 20-20, which will replace the DECsystem-10; each of the other eight nodes will consist of a DEC 11/03 microcomputer. This network facility constitutes a considerable addition to the research capability of the Department.

Computer Security, written by David K. Hsiao, Douglas S. Kerr, and Stuart E. Madnick, was published by Academic Press, Inc., June 1979.

Enrollment in all courses was 8,447 for the four quarters of the academic year.

Degrees awarded were 7 Ph.D. degrees, 59 Masters' degrees, 126 baccalaureate degrees.

Faculty appointments, promotions, leaves of absence, and resignations:

Bruce W. Ballard was appointed as an Assistant Professor, and was awarded his Ph.D. from Duke University in 1979; his areas of interest are programming languages, natural languages, and program synthesis.

K. V. S. Bhat was appointed as a Visiting Assistant Professor, and comes from Shiraz University, Shiraz, Iran. He received his Ph.D. from the University of Hawaii in 1975, and his areas of interest are data structures, computational graph theory, and assembler and programming languages.

David J. H. Brown was appointed as a Visiting Assistant Professor, and comes from Teesside Polytechnic, Middlesbrough, Cleveland, Great Britain. He received his Ph.D. from Witwatersrand, Johannesburg, South Africa, in 1976, and his areas of interest are artificial intelligence, information storage and retrieval, and file processing.

Frank C. Crow was appointed as an Assistant Professor, and comes from the University of Texas. He received his Ph.D. from the University of Utah in 1976, and his areas of interest are computer graphics, computer architecture and networks.

Subrata Dasgupta was appointed as an Assistant Professor, and comes from Simon Fraser University. He received his Ph.D. from the University of Alberta in 1976, and his areas of interest are microprogramming, computer architecture and minicomputer systems.

Thomas G. DeLutis resigned, effective September 1979 to form his own company, Information Architects, Inc., located in Washington D. C.

David K. Hsiao was granted a sabbatical and research leave of absence for the 1979-80 academic year to stimulate further development of the database computer concept. He will be spending time at M.I.T. and Sperry Univac for that purpose.

Timothy J. Long was appointed as a Visiting Assistant Professor, and comes from New Mexico State University. He received his Ph.D. from Purdue University in 1978, and his areas of interest are abstract complexity theory, data structures, and algorithm analysis.

Howell H. W. Mei was granted a leave of absence for the 1979-80 academic year to work with the Director of Quality Assurance, U.S. Army Computer Systems Command in Fort Belvoir, Virginia.

Jayashree Ramanathan was appointed as an Assistant Professor, and comes from the University of Houston. She received her Ph.D. from Rice University in 1977, and her areas of interest are programming languages, computer systems and software engineering.

Lawrence L. Rose was granted a leave of absence for the 1979-80 academic year to work with Battelle Labs (Columbus) as a Principal Research Scientist in Systems and Modeling.

Lee J. White was appointed Acting Chairman of the Department of Computer and Information Science for the 1978-79 academic year, and Chairman beginning in the 1979-80 academic year.

National Recognitions

S.A. Mamrak and P.D. Amer each received a United States Department of Commerce Certificate of Recognition and a $400 Cash Award for their co-authorship of a National Bureau of Standards Special Publication entitled "A Methodology for the Selection of Interactive Computer Services".

J. Rothstein received the "Most Original Paper Award" for his paper entitled "Toward an Arithmetic for Parallel Computation", and was presented with a walnut plaque at the 1978 International Conference on Parallel Processing in Bellaire, Michigan, August 22-25, 1978.

M.C. Yovits was elected to a four-year term as Member-at-Large of the Section on Information, Computing, and Communication of the American Association for the Advancement of Science, October 1978.

M.C. Yovits was elected to the Nominating committee of EDUCOM, the Interuniversity Communications Council, Inc.

M.C. Yovits has been re-elected to a second three-year term as East Central Regional Representative of the Association for Computing Machinery (ACM).

INSTRUCTIONAL PROGRAMS

The program of the Department of Computer and Information Science is broad and extensive. The number of students enrolled in all courses was 8447. A total of 126 students received baccalaureate degrees, 59 students received the M.S. degree, and 7 students received the Ph.D. degree. The number of applications for graduate study during this period was 479. Seventy two graduate students received support from the department. There was a total of 21 full time faculty and 13 parttime faculty. For additional statistics, see Appendix A.

Undergraduate Programs

Undergraduate degrees in computer and information science are available to students in the College of Engineering, the College of Mathematics and Physical Sciences of the College of Arts and Sciences, and the College of Administrative Sciences. The particular program chosen depends upon the student's interests and career objectives.

The undergraduate program in the College of Engineering leads to the degree of Bachelor of Science in Computer and Information Science. This program is designed for the student who wants to specialize in computer and information science from within an engineering environment. Hence, the program provides the student with a core of computer and information science, mathematics, and engineering science. Both depth and breadth in computer and information science are assured by specific required course sequences in several areas of engineering and science and yet sufficient flexibility exists so that a student can elect a portion of his technical work in order to develop his individual interests.

There are two undergraduate programs in the College of Mathematics and Physical Sciences. These programs lead either to the degree of Bachelor of Science or the degree of Bachelor of Arts with a major in computer and information science. The programs are cast in a liberal arts setting and are similar in content. The Bachelor of Science program provides a somewhat more technical and thorough education in computer and information science and mathematics while the Bachelor of Arts program is somewhat more flexible and provides an opportunity to relate computer and information science to some other discipline.

The undergraduate program in the College of Administrative Science leads to the degree of Bachelor of Science in Business Administration with a major in computer and information science. This program is designed for the student that is business oriented and desires an education in computer and information science and a general education in the administrative sciences. The program's objective is not to make a computer specialist out of a student, but rather to enable him to recognize the opportunities to use the computer in his managerial activities, to know what to expect from it, and to know how to communicate effectively with computer specialists so that computerized projects will be properly handled from a technical as well as a managerial point of view.

Graduate Programs

The Department of Computer and Information Science offers graduate programs leading to both the Master's and Ph.D. degrees. The graduate program leading to the Master's Degree is available in nine options.

Option I for the student desiring a theoretical foundation in computer and information science.

Option II for the student specializing in administrative systems.

Option III for the student specializing in computer systems.

Option IV for the student specializing in numerical analysis.

Option V for the student specializing in operations research.

Option VI for the student specializing in biomedical information processing.

Option VII for the student specializing in administrative science.

Option VIII for the student specializing in mathematics.

Options IX for the student specializing in hardware and software.

Each of these options provides a background in several aspects of computer and information science, as well as additional mathematical sophistication appropriate to the student's interest. Each of the options may lead to the Doctoral Program in computer and information science, and each may be taken with a thesis option or without a thesis option. (See Appendix B for a listing of courses by number and title.)

All courses of study at the Master's level require completion of a core program in computer and information science, together with the required courses specified for one of the options and additional courses as specified by the student's adviser. Beginning with the 1979-80 academic year, the core program will be contracted in order to allow the graduate student greater flexibility in arranging his course of study for the M.S. or Ph.D. degree. The new core program can be summarized as:

Subject	Course	Credits
Operating Systems	6940	3
Programming Languages	694P	3
Computer Architecture	675	5
Data Structures and Analysis of Algorithms	680	5
Mathematical Foundations of CIS	707	3
Seminar on Applications in CIS	889	2
Tutorial on Current Research Topics in CIS	694K	1
	TOTAL	22

The graduate program leading to the Doctoral Degree in Computer and Information Science is flexible in that it is tailored to the particular background and interests of the individual student. These interests may lie in any one of the research and instructional areas already listed as well as in many other cognate areas. A cognate field is defined as a field supporting or closely related to the fourteen Departmental fields and is ordinarily specified by an integrated program of study in other departments of the University.

Course Offerings

Currently there are about 84 courses (each one quarter in length) offered by the Department, 22 of which are largely undergraduate with the remainder being upper level undergraduate and graduate courses. In addition to these courses there are over two hundred courses offered by a variety of departments of the University which are of interest to our graduate students who are encouraged to take these courses.

Faculty

The Department of Computer and Information Science has a full time faculty of twenty-three members at the assistant professor level and above. They have a wide range of backgrounds and experience. The above faculty is supplemented by staff who have joint appointments with other departments; by staff from other departments or by visiting faculty who teach courses primarily for Computer and Information Science students; by adjunct staff people who are employed in off-campus organizations who teach in the Department of Computer and Information Science; (See Appendix C). There are currently a total of about 19 supplemental staff in this category.

COMPUTING FACILITIES

Computing facilities available to students are among the best in the country. The Instruction and Research Computer Center (IRCC) maintains an AMDAHL 470 V6 Model 2 with batch and timesharing terminals throughout the campus. In addition, the IRCC/CIS Computing Laboratory has a DECsystem-10 with batch and timesharing facilities, and a MICRODATA 1620 with a microprogrammable control store, which are used

mainly by the Department for teaching and research. The hardware connected with the DECsystem-10 includes several CRT character terminals, a graphics CRT terminal, and a CALCOMP plotter. In the 1979-80 academic year, the DECsystem-10 will be upgraded to a DEC 20-20 system, which will be the host computer for a loop network of nine nodes, with each of the smaller nodes consisting of a PDP 11/03 microcomputer. This system will be made available because of an NSF equipment grant made in 1979.

INTERACTION WITHIN THE UNIVERSITY

The Department of Computer and Information Science interacts with other departments and research programs within the University because of the multidisciplinary nature of the activities encompassed in this field. A number of the academic faculty have joint appointments in other departments. Staff members of the Department of Computer and Information Science have appointments in the following departments and organizations:

a. Accounting
b. Allied Medicine
c. Art
d. Electrical Engineering
e. Engineering
f. Instruction and Research Computer Center
g. Mathematics
h. Psychology
i. University Libraries
j. University Systems Computer Center

INTERACTION WITHIN THE COMPUTER AND INFORMATION SCIENCE COMMUNITY

Columbus, Ohio, is one of the major centers for information science and for the transfer of information in the United States. A number of organizations are involved with the activities of computer and information science. This affords an opportunity for students and faculty to interact with appropriate personnel in these organizations. Some of these are:

a. Chemical Abstracts Service
b. Battelle Memorial Institute
c. Bell Laboratories
d. City National Bank
e. Columbus and Southern Ohio Electric Company
f. Western Electric Corporation
g. Rockwell International Corp.
h. Industrial Nucleonics
i. State of Ohio Department of Finance; Department of Highways
j. Columbus Board of Education
k. Ohio College Library Center

There are a large number of scientists who come to Columbus in order to visit the Department and who usually present a seminar. (The lectures and seminars for the period of this report are listed in Appendix D). These persons cover virtually all phases of computer and information science.

In addition, our people interact at most of the major technical meetings in this country as participants giving papers, assisting on panels, as attendees, and as officials. Hardly a major technical meeting in the appropriate fields is held without a contribution from one or more of the personnel from the Department of Computer and Information Science (CIS). A list of these activities can be found in Appendix E.

Research efforts of the staff are disseminated to the professional community through several publication channels. A list of current publications of the Department staff is included as Appendix F. In addition, the Research Center issues a technical report series (see Appendix G for reports issued from 1977 to date).

DOCTOR OF PHILOSOPHY DEGREE

The Doctor of Philosophy degree was awarded to the following students during 1978-79. See Appendix H for a complete list of Ph.D. dissertations.

Name	Dissertation
Amer, Paul D.	Experimental Design for Computer Comparison and Selection
Banerjee, Jayanta	Performance Analysis and Design Methodology for Implementing Database Systems on New Database Machines
Brownsmith, Joseph D.	A Methodology for the Performance Evaluation of Data Base Systems
Dickey, Frederick J.	Translations Between Programming Languages
Lee, Mary Jane	An Analysis and Evaluation of Structured Design Systems
Natarajan, K.S.	A Graph-Theoretic Approach to Optimal File Allocation in Distributed Computer Networks
Wang, Jin-Tuu	Design of a Mixed Voice/Data Transmission System for Computer Communication

II. RESEARCH IN COMPUTER AND INFORMATION SCIENCE

Four areas of research in the Department of Computer and Information Science are briefly summarized in this chapter. These are:

Artificial Intelligence in Medical Diagnosis

Databases

Distributed Double-Loop Computer Network (DDLCN)

Important data Type with Full Logical Completeness

Following these four summaries is a listing of research and development awards received by the faculty.

RESEARCH SUMMARIES

Artificial Intelligence in Medical Diagnosis

Balakrishnan Chandrasekaran

AI in the Department

It is a truism that the impact of computers has been revolutionary in its social effects. There is a less noticed consequence of the advent of computers -- and computer science -- that is more intellectual in nature; this has to do with the effect of the computational metaphor in established, traditional disciplines such as philosophy and psychology. Artificial intelligence research is the vehicle by which the computational metaphor is traveling outside of computer science and slowly changing the nature of the questions in epistemology, cognitive psychology, perception etc. The combination of the social and intellectual aspects of this field makes artificial intelligence an area of vital importance to the future of computer science.

Artificial intelligence research in the Department is of recent origin, but it is a highly active component of the Department's research effort. Some of the projects that are currently operational are: conceptual programming by Gomez, a computational theory of temporal aspects of early vision by Flinchbaugh and Chandrasekaran, natural language graphics by Brown, and a new approach to medical diagnosis by Chandrasekaran, Gomez, Mittal, and Smith. We shall choose the last-mentioned area for further exposition in this note.

Conceptual Structures for Medical Knowledge Representation

Our main intellectual interest is in the problem of knowledge representation, especially in knowledge-rich domains. Clinical medicine turned out to be an excellent example of such a domain, not the least for its positive social benefit. The important constraint on representing large amounts of knowledge is that pieces of knowledge that are relevant to any particular stage in problem solving should be accessible without an inordinate amount of search.

The power of an experienced medical diagnostician seems to us to arise from a knowledge organization whose very structure helps keep the combinatorial growth of processing under control. This structure mirrors the deep conceptual structure of the field. We propose a knowledge representation scheme called conceptual structures, which organizes knowledge in the form of production rules or more complex procedures in such a way that they are accessed and used as needed. This structure is dominantly hierarchical, the successors of a conceptual node standing for subconcepts which refine that concept. Associated with each concept is a set of procedures (experts) which attempt to apply the relevant knowledge to the case at hand; this might include turning over control to selected subconcepts for more detailed analysis. Thus, abstractly, the conceptual structure organizes the invocation of procedures available to the diagnostician. The calling of a specialist by a physician is akin, we think, to control transfer to a subconcept in the cognitive structure of a diagnostician during problem solving; the difference is in the level of detail of the cognitive map.

The underlying metaphor is one of a society of experts among whom the knowledge of the domain and the procedures for acting out that knowledge are distributed. The organization of knowledge as experts raises many important questions, such as what knowledge should be organized into an expert and what other knowledge distributed between them; the nature of control transfer and communication between experts; the data-base organization and access; and the relation between redundancy of knowledge and data on one hand and the speed of processing on the other. While the idea of experts is not new, we believe that the epistemological principles needed as criteria for decomposing a body of knowledge into experts, in order that their interaction is controlled rather than chaotic, have been missing. Our discussion in the next few sections will attempt to highlight some of these principles.

A given field of knowledge has an underlying conceptual structure which enables effective use of that body of knowledge. This is the deep structure to which the knowledge representation in the field should strive, and this is what effective teachers communicate and effective learners build. This conceptual structure can be viewed as a way of organizing knowledge in such a way that purposeful, focused access to the relevant parts of the knowledge structure is achieved. Knowledge in the form of facts, heuristics, production rules or more complex procedures cannot be effectively used unless it is embedded in this underlying structure in such a way as to facilitate access as needed.

Principles of Knowledge Organization

What are the principles by which domains of knowledge are to be organized so that they can be used effectively? Our thesis is that the major criterion has to do with the efficiency of transfers of control or access to different parts of the knowledge structure. There are correct and incorrect analyses of the conceptual structure of a field. Incorrect analyses lead to a proliferation of control transfers; correct ones should generally lead to focused and controlled communication between different parts of the structure.

The organization of the medical community provides a concrete case study in the principles of knowledge structuring. A phenomenological account of medical decision making seems to us to be very revealing in this regard.

Our work can also be viewed as a concrete realization of the society of minds paradigm that has been put forward by Minsky and Papert [1]. In order for this paradigm to go beyond being a metaphor, we need to know how a society of minds, whether in an individual or as a collection of experts solving a common problem, should coordinate the activities of, and communication among, members to produce intelligent behavior. We feel that the organization of specialties in the medical community reflects the underlying conceptual structure, and, to a certain extent, the requirements of efficiency in control and communication structures as well. The same principles that lead to effective communication among real experts in a medical community are to be used in organizing and structuring knowledge within a specialty. A simplified rendering of these principles are:

P1) There is some sort of a hierarchical organization with respect to control transfer. That is, the GP who had original responsibility might, after deciding that it is a liver problem, transfer control to the liver specialist. The liver specialist might in some cases hand over control to a super specialist in a subarea, but it would be highly unusual for him to transfer the patient to a heart specialist. If such a thing is ever done, it'd be usually through return of control to the GP who would then accomplish such a transfer.

P2) The expert who is contemplating control transfer knows enough about the domain of knowledge of the subexperts who are likely to be called by him to decide, generally correctly, which subexpert is relevant, but not enough to solve the problem himself.

P3) Each expert knows enough about the domain of others in his level of the hierarchy to decide when he himself has been mistakenly called.

P4) There are some experts who do not belong in the main hierarchy, but who are outside of it, so to speak. They are not generally given control for the purpose of diagnosing the original complaint. They are used as resource experts to accomplish specific subtasks requiring their expertise. They communicate back to the expert who called them with the answer. An example of this type of expert is the radiologist.

P5) The communication between an expert and a subexpert is of several forms: answer specific questions dealing with the subspecialty, confirm or reject possibilities, or, in difficult cases, hand over total control. Further, in some instances a mere number standing for weight or probability is returned (see P7 below); in most cases, however, the communication is symbolic in nature, in a vocabulary which, in parts, is particular to the specialty subject matter.

P6) An expert often has enough knowledge of the subject matter of the subexperts to be able to solve easier cases. For example, most GP's know enough about liver diseases to solve "easy" liver cases, enough about heart diseases to solve easy heart cases, etc. Among the criteria that determine which knowledge should be abstracted at this level are: how common is this kind of malfunction, how conceptually complex is this, etc. This sort of organization keeps the combinatorics of control transfer to a minimum, since only in a relatively few cases will there be a large number of accesses to subexperts.

P7) While many significant decisions involve manipulating symbol structures associated with concepts, there are very definite situations which are best viewed as weighting several pieces of evidence to produce a numerical weight for a hypothesis. This piece of information is eventually incorporated in symbolic structures which are used for problem solving.

The form of the structure as a tree already exercises a strong constraint over communication. An expert cannot call other experts arbitrarily, but can only communicate via their super and subconcepts. While it is hard at this stage to advance this principle as an absolute requirement, we have found that violations indicate either that the analysis was incorrect or that the concept actually belongs outside the structure in some sense, with specific restricted modes of communication with the experts in the main structure. This is consistent with principle P4) above.

We note in passing that the principles governing the organization of conceptual structures are meant not only to make effective use of knowledge, but also to aid in the acquisition of it. The concepts get refined as a function of further learning, and the node at which the refinement takes place gets appropriate abstractions about the subconcepts. Another point to be noted is that often heuristics are formed which enable the system to go directly to a concept several levels below, sidestepping the methodical, level by level communication. But concentration on this second order optimization device obscures the clarity of the underlying structure. In fact, expertise often consists of an accumulation of such heuristics, and, for this reason, experts tend to be poor elucidators of the underlying structure.

MDX -- A Medical Diagnosis System

We have designed and implemented a system called MDX which is currently capable of diagnosing illnesses in a liver syndrome called Cholestasis.

It should be kept in mind that the task of knowledge analysis -- the discovery of conceptual organization -- is still a creative act, which can be aided but not automated by the above principles.

An interesting distinction between experts located at the tip nodes and those higher in the hierarchy can be noted. The tip node experts have a very limited scope, and they are mostly implemented by pattern-matching over a relatively small set of data features; e.g., the stone expert can judge the applicability of the stone concept in a simple pattern matching fashion, as long as the context has been established by the higher level nodes. The higher nodes are more symbolic in nature, and involve more complex and sophisticated cognitive functions. This is close in spirit to the computational theory of vision that Marr [2] is developing, in which the low level computations are basically simple edge and other masks, and the higher one moves in building visual abstractions, the more complex are the symbol structures.

MDX's problem solving is basically of the "establish-and-refine type". That is, each expert, when it gets control determines its appropriateness and passes control to selected lower level experts in an attempt to obtain further detail. This is akin to the liver expert determining that the patient is indeed a liver case, and probably cholestatic, but calling the Cholestasis super-specialist to determine the precise cause.

The system has been tested on a number of real cases, obtained both from the personal practice of a collaborating hepatologist and medical journals. The performance of the system has been very satisfactory, but only the actual details can be really convincing in this regard. For more information on the system and its performance, the reader is referred to [3], [4], [5].

References

[1] Minsky, M. "Plain Talk about Neurodevelopmental Epistemology", Proc. IJCAI-77, Cambridge, Mass., August 1977, pp. 1083-1092.

[2] Marr, D. "Early Processing of Visual Information", Phil. Trans. Roy. Soc. Lond. B 275, pp. 483-519, 1976.

[3] B. Chandrasekaran, F. Gomez, S. Mittal and J. Smith, M.D., "An Approach to Medical Diagnosis Based on Conceptual Structures", Proc. IJCAI-79, Tokyo, Japan, August 1979 (To appear).

[4] F. Gomez, B. Chandrasekaran, "Conceptual Structures for Knowledge Representation and Distribution", to appear in IEEE Trans. Systems, Man & Cybernetics, Special Issue on "Natural and Social Systems as Metaphors for Distributed Processing", 1980.

[5] S. Mittal, B. Chandrasekaran and J. Smith, M.D., "An Overview of MDX -- A Medical Diagnosis System", Proceedings, III Annual Symposium on Computer Applications in Medical Care, October 14-17, 1979, Washington D.C.

Databases

David K. Hsiao

Information is intrinsic to modern societies and the advancement of society depends crucially on the effective utilization of information. Databases are repositories of information and the computer is the only viable means of effectively utilizing the information contained in a large database consisting of perhaps 10 billion characters of data. In addition to the technical issues involved with the efficient management of data by computer systems, there are also ethical issues relating to the privacy of sensitive personal and proprietary information. The database research activities in the Department of Computer and Information Science at The Ohio State University focus on a number of these important issues and involve a number of graduate students and faculty members, and several major industrial and governmental organizations. This research has been very fruitful and in this brief report we will highlight some of the more important results that have been achieved. Some of the key publications of the past two years along with the principal investigators and students involved in this research will be mentioned. We will also describe an important joint study currently being carried out by this Department in cooperation with the Sperry-Univac Corporation and supported by the Office of Naval Research. Finally, we describe some of the work being carried out by our recent graduates indicating further the impact this Department is having on the field of database research and development as a whole.

The effective utilization of computerized databases should not be achieved by sacrificing the privacy of personal and proprietary data. To this end, one of our primary research interests has been the impact of privacy legislation on computerized databases and the development of security measures. Since computer systems involve people, surroundings, software, hardware, and databases, our research activities have focused on a wide variety of topics including operational security, physical security, software protection procedures, hardware protection mechanisms, secure database-to-database communications in distributed systems, and access control mechanisms for centralized shared databases.

Professors David K. Hsiao and Douglas S. Kerr are the principal investigators in this area. In cooperation with Dr. Stuart E. Madnick, Associate Professor of Management at MIT, and with the support of the Office of Naval Research, they recently published a comprehensive review and assessment of computer security research as an ACM Monograph [1].

In addition to reviewing and assessing current security measures, we are also conducting fundamental research into the nature of database security. Since databases hold information and information has inherent meaning, one may ask whether a database management system can simultaneously capture the meaning of the information, uphold protection requirements, and enforce security procedures. To capture the semantics of a database, representations of the inference structure of the database must be available. Intelligent security mechanisms which can detect the occurrence of a privacy violation must then be developed for the database management system. By relying on a graph-theoretic representation of the database and its pro-

tection requirements, we have made progress on these problems. In particular, we have obtained results [2] pertaining to the following questions:

(1) Given a database with a set of protection relations, is it possible to find a maximal subset of the database such that access to an item in the subset will not lead to an unauthorized access to another item?

(2) Given a database with a set of protection relations, is it possible to find a sequence of accesses such that the protection requirement is enforced without a violation?

Database security research has produced two Ph.D.'s who remain active in security research. Dr. Rex Hartson, now an Assistant Professor at the Virginia Polytechnic Institute and State University, is continuing to conduct research in database security with U.S. Army support [3]. Dr. Jay McCauley, a project manager with Ford Aerospace and Communication Corporation, has extended his research in database security into operating system security [4]. His group is working on producing the first truly secure operating system for the Department of Defense's Advanced Research Projects Agency (ARPA).

Research into the problem of efficient management of databases by computer systems quickly revealed that conventional von Neumann-type computers were not adequate for the management of very large databases with, say, 10 billion characters of data. The complexity and size of modern databases requires a database management system with a high level of throughput not achievable by contemporary software database management systems. Consequently, much effort in recent years has been devoted to seeking hardware solutions to these problems in the form of high-performance, low-cost special-purpose computers. Professors David K. Hsiao and Richard Underwood are the principal investigators on database computer architectures.

Research on database computer architectures is being conducted in three related areas with the support of the Office of Naval Research:

(1) Design and analysis of new architectures, which incorporate emerging technology such as magnetic bubble memories and modifications of existing storage technology such as moving-head disks, and which utilize microprocessor technology to obtain functionally specialized logic and high degrees of parallelism;

(2) Analysis and evaluation of proposed architectures in terms of their storage requirements and transaction execution times in support existing database management applications in comparison with conventional software systems running on general-purpose computers;

(3) Design and construction of a prototype for the purpose of conducting experimental studies of database computer architecture and for verifying and testing software in database management applications.

The research in area (1), the new architecture, is nearly completed, resulting in a number of publications of which two recent ones are listed herein [5, 6]. In this area we produced two Ph.D.'s: Dr. Richard Baum, who is with IBM's Poughkeepsie Lab and is continuing computer architectural design and evaluation work; and Dr. Krishnamurthi Kannan, who is with IBM's Thomas J. Watson Research Center and is investigating database computers for text handling.

The research in areas (2), evaluation of support for existing database management systems, is also nearly concluded, resulting in, again, a number of publications of which we shall cite only one [7]. These research results indicate that our proposed database computer can indeed outperform conventional hardware and software systems in current database management applications. Further, they indicate that new applications are possible because of the enhanced security and performance. We produced one Ph.D. in this area: Dr. Jayanta Banerjee, who devised and conducted the theoretical analysis and evaluation work. He is now with Univac's Advanced Systems research group.

The research in area (3), prototype development and experimentation, is a joint activity started in March 1978 between this Department and Sperry-Univac with the encouragement and support of the Office of Naval Research. Our aim is to design and construct a database computer prototype which reflects our proposed database computer architecture. This work is proceeding rapidly. By the Spring of 1980, the first prototype is expected to be operational at the Advanced Systems group of Sperry-Univac. Plans are being made to install an exact copy of the prototype in the Department by September 1980. Essentially, the prototype is configured with six Univac V77 superminicomputers, seven 256-kbyte MOS-type RAMs, five 150 megabyte disks and controllers, a specially made cross-bar switching network, and assorted consoles, terminals, printers and tape drives. The principal investigators in this joint study also include the following Sperry-Univac researchers: Drs. George Champine, Harvey Freeman, John Jordan and Jayanta Banerjee, and Mr. Olin Brady. Several graduate students in the Department will be utilizing the prototype as an experimental vehicle for dissertation research. Plans are also being made with the Naval Data Automation Command and the Naval Military Personnel Command to conduct experimental studies on large, complex real-world database applications. In general, as indicated in [8], there is a need for much more work to be carried out on prototype database computers.

In summary, the Department of Computer and Information Science at The Ohio State University recognizes that database systems is a fundamental discipline in computer and information science and engineering. The importance of database research was also identified by Arden's Computer Science and Engineering Research Study (COSERS) and Conway's Survey of Ph.D.-granting computer science and engineering departments in North America. We are happy that we have taken and will continue to take an active part in it.

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The Distributed Double-Loop Computer Network (DDLCN)

Ming-Tsan Liu

The fields of distributed processing and computer networking are growing at a very rapid rate within university, government, and industrial communities. Basically, a distributed processing system is the interconnection of a number of individual computers so as to share resources and to improve availability of the whole system.

Conceived as a means of investigating fundamental problems in distributed processing and local networking, the Distributed Double-Loop Computer Network (DDLCN) is designed as a fault-tolerant distributed processing system which interconnects midi, mini and micro computers using a double-loop structure in a local environment. The network is designed in such a manner that its users will see only a single, integrated computing facility with great power and many available resources without being aware of the system's actual organization and method of operation. It is the successor to our previous single-loop network, called DLCN (the Distributed Loop Computer Network). A nine-node prototype of DDLCN, interconnecting eight LSI-11 microcomputers and one DECsystem-20 computer system, is currently being im-

plemented under an NSF grant.

The research on both DLCN and DDLCN has been sponsored also by the NSF, and covered topics on interface design, communication protocols, distributed operating systems, distributed database systems, distributed programming systems, and performance studies. As of August 1979, research results have been published in 21 technical papers, one M.S. thesis, and four Ph.D. dissertations.

Research concerning DDLCN has concentrated on four areas of its system design: the double-loop and interface design, interprocess communication protocols, distributed synchronization models, and distributed system programming languages. Several new features and innovative ideas have been integrated into the hardware, communications, software and applications of DDLCN, so that it can realize its potential of becoming a powerful, unified distributed processing system.

The interface design is unique in that it incorporates tri-state control logic, thereby enabling the network to become fault-tolerant in instances of link failure by dynamically reconfiguring the logical direction of message flow. Three classes of N-process communication protocols, each providing a different degree of reliability, have been developed for exchanging multi-destination messages. Two synchronization mechanisms, event-counts and sequencers (low level) and control abstractions (high level), are provided for use in distributed process synchronization. A high-level distributed system programming language (DSPL) is developed for use in implementing distributed systems software. The language is object-oriented and uses the notion of "remote operations" to avoid low-level message exchange at the programming language level.

The DDLCN will be the heart of the CIS Distributed Computing Laboratory, which has been established recently by the CIS Department in order that research and instruction can be conducted in distributed processing, computer networking and other areas. The Laboratory will also provide both undergraduate and graduate students hands-on experience with microcomputers, computer networks, and distributed computing.

The primary node of the network is a medium-scale DECsystem-20 Model 20. The 2020 is a versatile system, supporting concurrent, interactive, on-line, and multi-stream batch computing capabilities. The system has 512K words (of 36 bits each) MOS memory, two disk drives (67 Mb each), one magnetic tape drive, and one line printer. The availability of 12 terminals will provide the faculty and graduate students working on various projects with easy access to the 2020 system as well as the other nodes of the network.

Four of the LSI-11 nodes each have 64Kb MOS memory, one 1 Mb dual floppy disk drive, and only one terminal. The remaining four nodes each have one LSI-11 processor with 65Kb MOS memory only, which will be used as processing elements for remote execution of tasks dispatched from the other nodes of the network. This gives the system enough flexibility to be used not only for file sharing and the other high-level communications, but will allow for parallel task execution and the investigation of distributed control.

problems as well.

The Loop Interface Unit (LIU) uses bit-sliced microprogrammable microprogrammable microprocessors AM2900. Actual circuit design for the LIU was carried out by graduate students working on the project, and implementation is underway.

An Important Data Type with Full Logical Completeness

Daniel J. Moore

Introduction

An algebraic approach has been used to study the formal properties of data abstractions, and to provide a theoretical framework for the process of data specification [3]. An abstraction viewed algebraically can be studied using the large body of results about algebras to yield important information, and to structure our way of thinking. For example, the object an abstraction describes is a certain initial algebra. An inconsistent abstrac-straction corresponds to a degenerate algebra. The very form in which a specification is written is influenced by algebraic notation.

Any one theoretical framework is usually not sufficient to answer all of the important questions that are raised, and the algebraic formulation of data typing is no exception [5]. In this paper we use formal logic and model theory [1] in place of algebra. A data abstraction is viewed as a many sorted first order theory. The models of that theory are the objects being specified. An implementation of one data type by another is an interpretation of one theory in another. An abstraction is consistent if it has a model. Thus the logical approach provides us with an alternative method of viewing these specifications which is quite as rich as the algebraic. In addition, the logical approach provides us with a tool called completeness which is not readily available otherwise, and the use of this tool is the subject of our paper.

An abstraction, or its first order theory, is complete if it is maximally consistent; that is, if everything is expressed which can be, without so much being expressed that an inconsistency results. A complete theory is generally more useful than an incomplete version. For example, all models of a complete theory, and therefore all implementations, have the same first order properties. In addition, all of the true first order statements about the data type described by a complete theory are available, which can be important to anyone proving the correctness of a program using the type, or to anyone showing that an implementation of one type by another is correct. For these reasons it is important to know whether an abstraction corresponds to a complete theory.

In this paper we show how one particular data type is described using a first order theory, how this description can be proven complete, and why this is useful information.

The Example Type

Linear list with head and tail, or stack with pop and top, is commonly used as an example type because it occurs very often in real programming, and because it appears to be s. ple. It can be described by a first order theory on two sorts of objects as follows.

The language in which our theory LLHT(n) is written contains the following symbols. There are several constant symbols:

nil, error1 of type list;

error$_a$, a1, a2, ..., an of type atom, for some fixed n.

There are several variable symbols:

b, b0, b1, ... of type atom;

x, x_0, x_1, ... of type list.

In the metalanguage, y ranges over variables of both sorts. There are three function symbols:

cons of type atom X list → list

head of type list → atom

tail of type list → list

Terms in the language are defined inductively for each sort:

0. Any variable of sort S or constant symbol of sort S is a term of sort S.

1. If t1 is a term of sort atom and t2 is a term of sort list, then

cons(t1,t2) is a term of sort list,

tail(t2) is a term of sort list,

head(t2) is a term of sort atom.

In a similar way, atomic formulas and well formed formulas (wffs) are defined. In this way we obtain a description of all the syntactically correct first order sentences dealing with linear lists. In order to distinguish a subset of these sentences, the true ones, we provide a list of basic truths, or axioms, and some processes, or rules of inference, for generating new truths from those already at hand.

Six single axioms are given. For example, "$\forall x\ \forall b$ [nil $\neq$ cons(b,x)]" is an assertion that there is no possibility of constructing a list equal to the nil list. Such an assertion would not appear in an algebraic data

abstraction because, in that setting, one does not assert that two strings are unequal. The only assertions there are of equalities, or rewrite rules. Another axiom is "head(nil) = errora". This would appear in an algebraic data abstraction.

An induction schema is also given. It stands for an infinite number of axioms of the indicated form. It is not possible to give an axiomatic description of linear list with only a finite number of axioms.

The standard rules of inference (modus ponens and generalization) can be used to generate new truths from those already given as axioms [1]. The set of all sentences generated in this way from the axioms is called a theory, in this case the theory LLHT(n).

The Abstraction is Complete

Three different ways are discussed for showing that LLHT(n) is complete. The descriptions are at a level of detail chosen to illustrate the methods, their similarities, and the utility of each for showing the completeness of other types.

The Los-Vaught test is based upon the semantic notion of model of a theory. If a theory has no models with a finite number of elements, and if, for some cardinal k, all models of size k are isomorphic, then the test is passed and the theory is complete. We show this for LLHT(n). This method is, in some ways, the easiest and the most difficult one. It is easiest in that an intuitive picture of examples of the type is discussed, and much detail work is avoided. It is most difficult in that great care must be taken so that all possible ways of constructing models of a given size must be considered, and one can easily fail to consider some arcane construction.

The elimination of quantifiers method is based upon syntactic notions. A theory admits elimination of quantifiers if any sentence in the language can be converted into a logically equivalent sentence that contains no quantifiers. A quantifier-free sentence can be written as a conjunction of atomic formulas or their negations. Since the truth value of an atomic formula can be easily computed, the truth value of the whole formula can be computed. Thus, any sentence in the language can be proven or refuted, and so the theory is complete. In order to prove that a theory admits elimination of quantifiers, a careful study must be made of all the possible forms that terms can take, and canonical representations of them which can be easily manipulated must be found. This can be a tedious process, as the full paper shows. However, it is very rewarding in that a deep understanding is obtained of the varieties of forms the type can contain. For LLHT(1) the proof is easy, whereas the proof for an arbitrary finite number of atoms ($1 < n < \infty$) is difficult, and the proof for a countable infinite number of atoms (which is the common situation in real programming languages, if the limit on length of identifiers is removed) seems impossible with this method. From this we can infer that lists with one, several, or an infinite number of atoms are quite different objects.

In order to prove that LLHT(ω) is complete, we use a third method which combines syntactic and model theoretic notions. We show that LLHT(ω) is submodel complete by examining the relationships between various sub-

models. This is used to show that LLHT(ω) admits elimination of quantifiers [4].

Completeness Is Important

All of the models of a complete first order theory have identical first order properties. Thus, if we have two implementations of a data type described by a complete abstraction, they will behave in exactly the same way relative to any property that can be described in the language used.

The best way to characterize the implementation of one data type using another (for example, implementing lists using arrays) is by using the notion of interpretations [1]. When showing that a theory A is properly interpreted in a theory B, assertions of the form $\exists x \forall y \exists z P(x,y,z)$ must be proven in the language of theory B. Thus it is important for theory B to be complete, at least for $\exists\forall\exists$ sentences, which is guaranteed by completeness.

In a correctness proof of a program facts about the data objects are often needed. If the associated data type corresponds to a complete theory, then all possible assertions about the type are provable or refutable.

Algebra Is Not Enough

The notion of sufficient completeness [3] of data abstractions has been studied in the algebraic setting. This corresponds to a notion of partial completeness in logic. No counterpart to full completeness is known in algebra.

Thus algebraic notions are not sufficiently powerful, at least in the study of completeness of specifications. Algebraic and logical approaches differ in the information they supply about other topics, like proof systems and consistency.

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RESEARCH AND DEVELOPMENT AWARDS

Most Original Paper Award

Title: Toward an Arithmetic for Parallel Processing

Author: Jerome Rothstein

Sponsor: IEEE Computer Society and Wayne State University

Date & Place: August 23-26, 1977, Bellaire, Michigan

Abstract: A new positional binary number system was devised in an attempt to avoid carrying in addition. It originated from the groupoid string formalism, previously shown to have the computation universality of Turing machines and the parallel capabilities of cellular and bus automata. It is uniquely defined by the natural conditions (a) a number is doubled by adding a copy, shifted one place left, to the original number, where digits are added mod 2, and (b) adding 1 to any number adds 1 mod 2 at precisely one place. Arithmetical, combinatorial, and parallel computational properties of the binary system are discussed and some properties of similar systems with higher radix briefly noted.

Equipment Grant

Title: Computer Science and Computer Engineering Research Equipment

Principal Investigator: Lee J. White

Co-Principal Investigator: Roy F. Reeves

Sponsor: National Science Foundation, Computer Science Section

Date: July 1, 1979

Amount: $150,348

Abstract: A distributed processing system is proposed with a sufficiently powerful host computer as the major node, and a number of microcomputer systems constituting the other nodes. The distributed system will be

a fault-tolerant, flexible double-loop network developed and designed at The Ohio State University. This network will be required to support research in the following areas:

(1) computer program testing

(2) natural language graphics programming

(3) computer vision

(4) distributed processing hardware and software

(5) automated medical diagnosis

(6) analysis and design of a synchronous parallel algorithm

(7) data base design for networks

Graduate Training Grant

Title: Graduate Training Program in Biomedical Computing and Information Processing

Program Directors: A. E. Petrarca, Associate Professor, Department of Computer and Information Science
Gregory L. Trzebiatowski, Associate Dean, College of Medicine

Sponsor: National Library of Medicine (NIH Grant LM 07023)

Duration: 7/1/79-6/30/80

Amount: $93,732

Abstract: In order to meet the needs for specialists in biomedical computing, an interdisciplinary Graduate Training Program in Biomedical Computing and Information Processing was established through a joint effort of the School of Allied Medical Professions of the College of Medicine and the Department of Computer and Information Science. Students who are interested in the study and application of computer and information science to health care, medical education, and biomedical research may pursue, through one of the participating departments, the graduate degrees of Master of Science (via Allied Medical Professions of Computer and Information Science) and Doctor of Philosophy (via Computer and Information Science or appropriate Ph.D. granting departments in the College of Medicine).

Research Grants

Title: Development of Information Measures and their Application to a General Theory of Information

Principal
Investigator: Marshall C. Yovits

Sponsor: National Science Foundation (IST- 7621949 A01)

Duration: 9/1/76-8/31/79

Amount: $66,300

Abstract: Research is performed in the area of theoretical information science. Decision-maker learning is modeled using learning rules to determine the importance of parameters such as learning rate and confidence factor. Information profiles are developed and applied to information storage and retrieval problems. This research thus provides an in-depth model of information flow by which quantitative measures can be applied to measure information content, decision-maker effectiveness, and learning. Application of the model to realistic situations demonstrates its utility and capability to illustrate information flow in a comprehensive informative manner that was not previously possible.

Title: The Distributed Loop Computer Network

Principal
Investigator: Ming T. Liu

Sponsor: National Science Foundation (MCS77-23496)

Duration: 6/1/78-5/31/80

Amount: $71,104

Abstract: The Distributed Loop Computer Network (DLCN) is envisioned as a powerful distributed computing system which interconnects mini-midi computers, terminals and other peripheral devices through careful integration of hardware, software and a loop communication network. The prime aim of the proposed research is to investigate the feasibility that DLCN can provide effitient, inexpensive, reliable and flexible service for a localized user community.

Title: Extension and Application of a Theory of Information Flow and Analysis; The Use of Information in a Decision-Making Environment

Principal
Investigator: M. C. Yovits

Sponsor: National Science Foundation, Div. of Information Science and Technology (DSI-76-21949)

Duration: 7/1/79-6/30/81

Amount: $121,489

Abstract: This research program builds on previous research which has been underway at Ohio State University for the last few years. We now plan to extend our research in three different but complimentary directions: 1) We are extending the basic theoretical work; 2) We are gathering additional data with the use of a flexible, sophisticated, simulation model in order to establish new relationships and important parameters; and 3) We are developing, designing and carrying out experiments involving human subjects in order to obtain real data about use of information by decision-makers.

Title: Evaluation of Programming Methodologies Using Software Science

Principal Investigator: Stuart H. Zweben

Sponsor: Dow Chemical USA

Duration: January 1978 - September 1979

Amount: $18,300

Abstract: The area of Software Science has developed relationships based on the structure of computer programs which appear to capture certain observed phenomena in the development and maintenance of these programs. This research seeks to ascertain the extent to which the relationships are consistent with, and can be used to support, principles of programming methodology. In particular, the research effort has centered on issues involving modularity and control flow. Strengths and weaknesses of the Software Science approach viz-a-viz other approaches to measuring these characteristics of program quality are being analyzed.

Title: Methodologies for Computer Program Testing

Principal Investigators: B. Chandrasekaran, L. J. White

Sponsor: U.S. Air Force Office of Scientific Research (77-3416)

Duration: 7/1/77-6/30/79

Amount: $120,490

Abstract: One major class of program errors concerns domain errors, i.e., those errors which result from incorrect predicates in branch statements. A new strategy is outlined to test for domain errors with almost complete reliability by using only a finite number of test points, for linear predicates and a class of nonlinear predicates. Further theoretical

research into reducing the complexity of this strategy will be undertaken to make it practical for moderately large input space dimensionality.

Title: Nuclear Accountability Analysis

Principal Investigator: L. J. White

Sponsor: Monsanto Chemical Mound Laboratory (Miamisburg, Ohio)

Duration: 10/1/78-9/30/79

Amount: $20,000

Abstract: The objective of this study is to develop a rigorous computational method with which to evaluate a plan for nuclear accountability. More specifically, a criterion has been given that no more than X kg of nuclear material should be diverted with a probability of detection of Y% which can be discovered within Z units of time after the X units are diverted. A computational method of discovering worst case scenarios has been developed for various situations, obtaining a maximum X, given parameters Y and Z. This analysis will be continued through the 1979-80 academic year.

Title: Properties of Axiomatic Data Specification

Principal Investigator: Daniel J. Moore

Sponsor: National Science Foundation (MCS78-02615)

Duration: 6/1/78-5/31/80

Amount: $75,563

Abstract: Properties of the process of axiomatic specification of abstract data types are to be studied. Primitive data types and the use of those primitive types in constructing user-defined data types will be investigated. The possibility of automatic completeness checking and implementation by compiler will be evaluated.

Title: Research in Data Security, Data Secure Systems, and Database Computers

Principal Investigator: David K. Hsiao

Investigators: Douglas S. Kerr and Richard R. Underwood

Sponsor: Office of Naval Research (N00014-67-A-0232; N00014-75-C-0573)

Duration: 3/1/73-2/29/80

Amount: $638,705

Abstract: The research focuses on three major database areas:

(1) Data security - A survey and assessment of computer security research with emphasis on data security was conducted. Fundamental problems in data security were identified. Attempts to lay a theoretical foundation of some of the data security problems are made.

(2) Data secure systems - The design and experimentation of database management systems with new security mechanisms were conducted. The notion of security atom, a technique of compartmentalization of a database for controlling accesses and enforcing protection requirements, was discovered. Subsequent experimentation of this notion with a real-world sample database was conducted.

(3) Database computers - Hardware solutions to high-performance and low-cost special-purpose computers for database management were pursued. A functionally specialized database computer architecture is proposed and analyzed. A joint study with Sperry-Univac on the construction of a prototype to reflect the proposed architecture is being pursued.

Title: A Study of Ohio Clinton Sands and Shale Gas Flow

Principal Investigator: L. J. White

Sponsor: Monsanto Chemical Mound Laboratory (Miamisburg, Ohio)

Duration: 10/1/78-9/30/79

Amount: $16,141

Abstract: A number of statistical analyses of shale gas well data have been conducted in order to be able to discover several predictive models for the gas flow in both Ohio Clinton Sands and shale gas wells. In one study, those well parameters which produce maximum gas flow are to be identified. In another study, an analysis of geochemical data has been made in order to find those predictors to indicate those wells with maximum gas potential, and at which depths such gas potential can be expected. These studies are expected to be continued through the 1979-80 academic year.

Title: Theoretical Foundations of Software Technology

Principal Investigators: H. W. Buttelmann, B. Chandrasekaran, L. J. White

Sponsor: U. S. Air Force Office of Scientific Research (F49620-79-C-0152)

Duration: 7/1/79-6/30/80

Amount: $140,401

Abstract: This research will develop basic theoretical models and results in the areas of software and programming language structure and design, with the purpose of producing knowledge that will enable development of more reliable and transportable software. The current focus is on three areas: semi-automatic program testing, where an interactive prototype system is being developed; automatic program synthesis from algorithms stated in English; and computability and complexity issues in formal syntax and semantics, language definition, translation, and translator generation.

Title: Theoretical Research on the Translation of Phrase-Structure Languages

Principal Investigator: H.W. Buttelmann

Sponsor: U.S. Air Force Office of Scientific Research (AFOSR-75-2811)

Duration: 5/1/75-6/30/79

Amount: $173,351

Abstract: The purpose of this research is to develop theoretical results relevant to the technology of language translation and the science of linguistics, for both the translation of technical natural language and high level programming languages. We will develop a formal theory of linguistic description which integrates syntax and semantics in such a way as to explicate their role in translation, and prove results about the general translation problem and about some specific problems intended to speed up translation. We will also develop a computer program system for translating arbitrary context-free languages, driven by the syntax-semantics descriptions of the source and target languages.

APPENDIX A

GROWTH OF DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

	SEPT '73	SEPT '74	SEPT '75	SEPT '76	SEPT '77	SEPT '78	SEPT '79
A. Staff							
1. Full Time	18	20	21	22	20	21	27
2. Part Time	16	12	12	12	13	12	14
B. Graduate Students	209	198	201	182	197	198	200 (est)
C. Undergraduate Students	510	475	450	470	470	470	470 (est)
D. Course Enrollment (Autumn Quarter)	1728	1925	2098	2290	2308	2568	2800

	'73-74	'74-75	'75-76	'76-77	'77-78	'78-79
Students Taught	6129	6876	7241	7615	7528	8447
Baccalaureate Degrees Awarded	139	109	103	118	125	126
M.S. Degrees Awarded	67	58	64	70	54	59
Ph.D. Degrees Awarded	4	7	13	5	8	7
Ph.D. Degrees Awarded- Total	16	23	36	41	49	56
Applications for Graduate Study	290	355	325	333	335	479
Number of Graduate Students Supported	78	81	77	81	92	72

APPENDIX B

COMPUTER AND INFORMATION SCIENCE COURSE LISTING BY NUMBER AND TITLE

100 Computers in Society

201 Elementary Digital Computer Programming

211 Computer Data Processing I

212 Computer Data Processing II

221 Programming and Algorithms I

222 Programming and Algorithms II

294 Group Studies

311 Introduction to File Design and Analysis (Withdrawn Spring 1979)

313 Introduction to File Design

321 Introduction to File Processing

380 File Design and Analysis

411 Design of On-Line Systems

505 Fundamental Concepts of Computer and Information Science

511 Computer Systems and Programming for Administrative Sciences

541 Survey of Numerical Methods

542 Introduction to Computing in the Humanities

543 Intermediate Digital Computer Programming

548 Computer Science for High School Teachers

550 Introduction to Information Storage and Retrieval (Withdrawn Summer 1979)

551 Database Systems (Effective Autumn 1979)

555 Survey of Programming Languages

557 Minicomputer Programming Systems (Effective Spring 1980)

607 Mathematical Foundations of Computer and Information Science I (Effective Autumn 1979)

610 Principles of Man-Machine Interactions

640 Numerical Analysis

641 Computer Systems Programming I

642 Numerical Linear Algebra

643 Linear Optimization Techniques in Information Processing

644 Systems Programming

675 Digital Computer Organization

676 Minicomputer and Microcomputer Systems

677 Computer Networks

680 Data Structures

693 Individual Studies

694 Group Studies

694J Data Models and Database Systems

694K Current Topics in Computer and Information Science

694L Biomedical Information Processing

694M Software Engineering

6940 Introduction to Operating Systems (Effective Autumn 1979)

694P Programming Languages (Effective Autumn 1979)

694S Introduction to Operating Systems: Laboratory (Effective Winter 1980)

705 Mathematical Foundations of Computer and Information Science (Withdrawn Summer 1979)

707 Mathematical Foundations of Computer and Information Science II (Effective Winter 1980)

712 Man-Machine Interface

720 Introduction to Linguistic Analysis

726 Theory of Finite Automata

727 Turing Machines and Computability

728 Topics in Theory of Computing

730 Basic Concepts in Artificial Intelligence

735 Statistical Methods in Pattern Recognition

740 Computer Systems Programming II

741 Comparative Operating Systems

745 Numerical Solution of Ordinary Differential Equations

746 Advanced Numerical Analysis

750 Modern Methods of Information Storage and Retrieval

751 Fundamentals of Document-Handling Information Systems

752 Techniques for Simulation of Information Systems

753 Theory of Indexing

754 Language Processing for Information Storage & Retrieval (Withdrawn Summer 1979)

755 Programming Languages

756 Compiler Design & Implementation

765 Management Information System

775 Advanced Computer Organization

780 File Structures

781 Aspects of Computer Graphics Systems

788 Intermediate Studies in Computer and Information Science

788.01 - Theory of Information

788.02 - Information Storage & Retrieval

788.03 - Theory of Automata

788.04 - Artificial Intelligence

788.05 - Pattern Recognition

788.06 - Computer Systems Programming

788.06A - Computer Center Organization and Management

788.07 - Programming Languages

788.08 - Computer Organization

788.09 - Numerical Analysis

788.10 - Man-Machine Interaction

788.10A - Advanced Topics in Computer Graphics

788.11 - Formal Languages

788.12 - Management Information Systems

788.12A - Seminar in Management Information Systems

788.13 - Biological Information Processing

788.14 - Socio-Psychological Aspects of Information Processing

793 Individual Studies

797 Interdepartmental Seminar

805 Information Theory in Physical Science

806 Cellular Automata & Models of Complex Systems

812 Computer & Information Science Research Methods

820 Computational Linguistics

835 Special Topics in Pattern Recognition

845 Numerical Solution of Partial Differential Equations

850 Theory of Information Retrieval I

852 Design and Analysis of Information Systems Simulations

855 Advanced Topics in Programming Languages

865 Seminar on Socio-Psychological Aspects of the Information Sciences (Withdrawn Summer 1979)

880 Advanced Theory of Computability

888 Advanced Studies in Computer & Information Science

888.01 - Theory of Information

888.02 - Information Storage & Retrieval

888.03 - Theory of Automata

888.04 - Artificial Intelligence

888.05 - Pattern Recognition

888.06 - Computer Systems Programming

888.07 - Programming Languages

888.08 - Computer Organization

888.09 - Numerical Analysis

888.10 - Man-Machine Interaction

888.11 - Formal Language

888.12 - Management Information Systems

888.13 - Biological Information Processing

888.14 - Socio-Psychological Aspects of Information Processing

889 Advanced Seminar in Computer & Information Science

894 Group Studies

899 Interdepartmental Seminar

999 Research

APPENDIX C

COMPUTER AND INFORMATION SCIENCE FACULTY

Lee J. White, Ph.D., (University of Michigan).
Professor and Chairman of the Department of Computer and Information Science and Professor of Electrical Engineering. Algorithm analysis and complexity, data structures, organization of information.

Ranko Bojanic, Ph.D., (Mathematical Institute of the Serbian Academy of Science). Professor of Computer and Information Science and Professor of Mathematics. Mathematical analysis, theory of approximation.

Kenneth Breeding, Ph.D., (University of Illinois).
Professor of Computer and Information Science and Professor of Electrical Engineering. Computer organization and switching theory.

Balakrishnan Chandrasekaran, Ph.D., (University of Pennsylvania).
Professor of Computer and Information Science. Pattern recognition, artificial intelligence, interactive graphics, finite memory decision theory.

Charles A. Csuri, M.A., (The Ohio State University).
Professor of Computer and Information Science and Professor of Art. Advancement of computer graphics technology in software and hardware (language algorithms, data generation or inputs), use of computer technology in telecommunications.

Richard I. Hang, M.A., (The Ohio State University).
Professor of Computer and Information Science and Professor of Engineering Graphics. Computer graphics, engineering application of computers.

David K. Hsiao, Ph.D., (University of Pennsylvania).
Professor of Computer and Information Science. Systems programming, computer architecture, database management systems, access control and privacy protection of data, database computers.

Clyde H. Kearns, M.S., (The Ohio State University).
Professor of Computer and Information Science and Professor of Engineering Graphics. Computer graphics, engineering application of computers.

Robert D. LaRue, P.E., M.S., (University of Idaho).
Professor of Computer and Information Science and Professor of Engineering Graphics. Computer graphics, engineering applications of computers.

Ming-Tsan Liu, Ph.D., (University of Pennsylvania).
Professor of Computer and Information Science. Computer architecture and organization, computer communications and networking, parallel and distributed processing, mini/micro computer systems.

Robert B. McGhee, Ph.D., (University of Southern California).
Professor of Computer and Information Science and Professor of Electrical Engineering. Robotics, switching theory, logical design.

Roy F. Reeves, Ph.D., (Iowa State University).
Professor of Computer and Information Science and Professor of Mathematics. Director, Instruction and Research Computer Center. Numerical analysis, programming, computer center management.

Jerome Rothstein, A.M., (Columbia University).
Professor of Computer and Information Science and Professor of Biophysics. Information and entropy, foundations of physics, methodology, biocybernetics, automata theory, formal languages, cellular automata, parallel processing.

Charles Saltzer, Ph.D., (Brown University).
Professor of Computer and Information Science and Professor of Mathematics. Coding theory, numerical analysis, automata theory.

Marshall C. Yovits, Ph.D. (Yale University).
Professor of Computer and Information Science and Professor of Electrical Engineering. Information systems, theory of information flow and analysis, self-organizing systems, management information systems.

H. William Buttelmann, Ph.D., (University of North Carolina).
Associate Professor of Computer and Information Science. Formal language theory, computational linguistics, language processing, programming languages.

Thomas G. Delutis, Ph.D., (Purdue University).
Associate Professor of Computer and Information Science. Methodologies for the design and evaluation of information processing systems, database management systems architecture, simulation studies.

Ronald L. Ernst, Ph.D., (University of Wisconsin).
Associate Professor of Computer and Information Science and Associate Professor of Psychology. Man-computer interaction, decision-systems, general theory of human performance.

Clinton R. Foulk, Ph.D., (University of Illinois).
Associate Professor of Computer and Information Science. Systems programming, computers in education.

Douglas S. Kerr, Ph.D., (Purdue University).
Associate Professor of Computer and Information Science. Programming, database systems, numerical analysis.

Anthony E. Petrarca, Ph.D., (University of New Hampshire).
Associate Professor of Computer and Information Science. Automatic indexing, chemical structural information processing, automated search systems, other aspects of information storage and retreival, biomedical information processing.

James B. Randels, Ph.D., (The Ohio State University).
Associate Professor of Computer and Information Science and Assistant Director, University Systems Computer Center. Computer operating systems and utilities, telecommunications applications, subroutine libraries, programming languages.

James E. Rush, Ph.D., (University of Missouri).
Adjunct Associate Professor of Computer and Information Science. Indexing theory, automated language processing, organization of information, parallel processing, structured programming, program testing and program management.

Celianna I. Taylor, B.S.L.S., (Graduate School of Library Science, Case-Western Reserve University). Senior Research Associate and Associate Professor of Library Administration. Database design (natural language data), information system (natural language) design, library systems.

Bruce W. Ballard, Ph.D., (Duke University). Appointment Autumn 1979.
Assistant Professor of Computer and Information Science. Programming languages, natural languages, and program synthesis.

Ramamoorthi Bhaskar, Ph.D., (Carnegie-Mellon University).
Assistant Professor of Computer and Information Science and Assistant Professor of Accounting.

Frank C. Crow, Ph.D. (University of Utah). Appointment Winter 1980.
Assistant Professor of Computer and Information Science. Computer graphics, computer architecture, and networks.

Subrata Dasgupta, Ph.D. (University of Alberta). Appointment Winter 1980.
Assistant Professor of Computer and Information Science. Microprogramming, computer architecture, and minicomputer systems.

Sandra Mamrak, Ph.D., (University of Illinois).
Assistant Professor of Computer and Information Science. Computer system performance evaluation, computer networks, systems programming.

Howell H. W. Mei, Ph.D., (Cornell University).
Assistant Professor of Computer and Information Science. Nonlinear optimization, nonlinear systems of equations, operating systems design, algorithm design.

Daniel J. Moore, Ph.D., (University of Kansas).
Assistant Professor of Computer and Information Science. Complexity theory, recursion theory, semantics of simulation systems, formal theory of data abstraction.

Richard E. Parent, Ph.D., (The Ohio State University).
Adjunct Assistant Professor of Computer and Information Science and Associate Director Computer Graphics Research Group.

Jayashree Ramanathan, Ph.D., (Rice University). Appointment Autumn 1979.
Assistant Professor of Computer and Information Science. Programming languages, computer systems, and software engineering.

Lawrence L. Rose, Ph.D., (Pennsylvania State University).
Assistant Professor of Computer and Information Science. Programming languages, information storage and retrieval, simulation, information theory.

Richard R. Underwood, Ph.D., (Stanford University)
Assistant Professor of Computer and Information Science. Numerical linear algebra, solution of large sparse systems of equations, eigenvalue analysis, linear least squares problems, numerical solution of differential equations.

Bruce W. Weide, Ph.D., (Carnegie-Mellon University).
Assistant Professor of Computer and Information Science. Analysis of algorithms, approximation algorithms, concrete computational complexity, computational geometry, parallel algorithms, probabilistic algorithms.

Stuart H. Zweben, Ph.D., (Purdue University).
Assistant Professor of Computer and Information Science. Programming languages, programming methodology, data structures, analysis of algorithms, systems programming.

K.V.S. Bhat, Ph.D., (University of Hawaii). Appointment Autumn 1979.
Visiting Assistant Professor of Computer and Information Science. Data structures, computational graph theory, and assembler and programming languages.

David J. H. Brown, Ph.D., (Witwatersrand, Johannesburg, South Africa).
Appointed Autumn 1979. Visiting Assistant Professor of Computer and Information Science. Artificial intelligence, information storage and retrieval, and file processing.

Timothy J. Long, Ph.D. (Purdue University). Appointment Autumn 1979.
Visiting Assistant Professor of Computer and Information Science. Abstract complexity theory, data structures, and algorithm analysis.

Neelamegam Soundararajan, Ph.D., (Bombay University).
Visiting Assistant Professor of Computer and Information Science. Theory of computation, semantics of programming languages, semantics of parallel processing.

Charles J. Shubra, Jr., M.S. (Pennsylvania State University).
Visiting Instructor of Computer and Information Science. Database management, management information systems, programming methodology.

Ernest Staveley, B.S., (U.S. Naval Postgraduate School).
Administrative Assistant and Assistant Director, C.I.S. Research Center.

APPENDIX D

COMPUTER AND INFORMATION SCIENCE SEMINAR SERIES

July 20, 1978 "The Design and Construction of Hierarchically Structured Software", R. W. Witty, Senior Scientific Officer, Atlas Computing Division, Rutherford Laboratory, England.

August 3, 1978 "A Methodology for the Performance Evaluation of Data-base Systems", Joseph D. Brownsmith, Ph.D. Candidate, Department of Computer and Information Science, The Ohio State University.

August 10, 1978 "Natural Language Graphics", David C. Brown and Stan C. Kwasny, Ph.D. Candidates, Department of Computer and Information Science, The Ohio State University.

August 17, 1978 "A Heuristic Approach to Optimal File Allocation in Computer Networks", K.S. Natarajan, Ph.D. Candidate, Department of Computer and Information Science, The Ohio State University.

October 5, 1978 "The OSU Advanced Design Methods Laboratory", Dr. George H. Sutherland, Mechanical Engineering, The Ohio State University.

October 12, 1978 "Real Time Algorithms from String Matching and Palindrome Recognition", Dr. Zvi Galil, Professor of Mathematical Sciences, Tel-Aviv University, Israel.

October 19, 1978 "Computer Science Education in Hungary", Istvan (Steve) Kaszap, Instructor, Visiting UN Fellow, Deputy Manager of System Analysis Training Department, International Computer Education and Information Centre (SZAMCK), Budapest, Hungary.

October 26, 1978 "Computer Based Education in Architecture", J. Brooks Breeden, Jr., Assistant Professor of Landscape Architecture, and John P. Marchion, Director of Educational Resources, School of Architecture, The Ohio State University.

November 16, 1978 "Reorganization Techniques for Matrix Multiplication in a Paging Environment", Dr. Patrick C. Fischer, Professor of Computer Science, Whitmore Laboratory, The Pennsylvania State University.

November 20, 1978 "Towards More Complicated Computer Imagery", Dr. Franklin C. Crow, Professor of Computer Science, University of Texas.

November 29, 1978 "Some Thoughts on Automatic Information Retrieval and the Library of the Future", Dr. Gerald Salton, Professor and Chairman of Computer Science, Cornell University.

January 11, 1979 "Toward an Arithmetic for Parallel Computation", Jerome Rothstein, Professor of Computer and Information Science, The Ohio State University.

January 18, 1979 "Computing at Mershon Center", William J. Dixon, Computer Consultant, Mershon Center, and Richard I. Haller, Senior Computer Specialist, Research Foundation, The Ohio State University.

February 8, 1979 "Semantic and Procedural Processing for a Natural Language Programming System", Bruce W. Ballard, Department of Computer Science, Duke University.

February 14, 1979 "Towards a Methodology for Software Engineering", Dr. John R. White, Associate Professor, Department of Electrical Engineering and Computer Science, The University of Connecticut.

March 1, 1979 "Proofs of Properties of Programs", N. Soundararajan, Department of Computer and Information Science, The Ohio State University.

March 7, 1979 "Computer Interconnection Networks", Hikyu Lee, Department of Electrical Engineering and Computer Science, Princeton University, New Jersey.

March 13, 1979 "Attributed Metaforms for Top-Down Design and Analysis of Algorithms", Jayashree Ramanathan, Department of Computer Science, University of Houston.

March 14, 1979 "Operational Analysis ... An Alternative to Stochastic Modeling?" Peter J. Denning, ACM Lecturer, Computer Sciences Department, Purdue University.

March 15, 1979 "Towards Automatic Program Synthesis", P. A. Subrahmanyam, Department of Computer Science, SUNY, Stony Brook.

March 29, 1979 "Knowledge-Based Systems for Medical Consultation: Expert and CASNET/Glaucoma Consultation Systems", Casimir A. Kulikowski, Department of Computer Science, Rutgers University.

April 9, 1979 "Computer Aided Design", Dale Bussman, Director of Research, Auto-Trol Corporation, Denver, Colorado.

April 11, 1979 "Automated Communications Protocol Validation", Colin H. West, IBM Research Laboratory, Zurich, Switzerland.

April 19, 1979 "Industrial Microprocessor Applications", George W. Kinder, Supervisor, Billing Terminal and Controller Group, Bell Laboratories, Columbus, Ohio.

May 10, 1979 "A Survey of Multidimensional Search Strategies", Jon L. Bentley, Department of Computer Science, Carnegie-Mellon University.

May 11, 1979 "Microprogramming: Some Issues in Language Design", Subrata Dasgupta, Computing Science Department, Simon Fraser University, Burnaby, B. C.

May 17, 1979 "Logical Properties of Data Abstraction", Daniel J. Moore, Assistant Professor, Computer and Information Science Department, The Ohio State University.

May 24, 1979 "Computer Chess", Monroe Newborn, School of Computer Science, McGill University, Montreal, Canada.

June 11, 1979 "Proving Consistency of Database Transactions", Georges Gardarin, Institut de Programmation, Universite of Paris VI, France.

June 14, 1979 "Architectural Considerations of Mass Storage Systems", Dr. Akira Sekino, Systems Development Department of the Computer Engineering Division, Nippon Electric Co., Ltd. (NEC), Tokyo, Japan.

APPENDIX E

RELATED ACTIVITIES OF THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

P.D. Amer presented a paper entitled "Computer System Selection" at COMPCON '78, Washington, D.C., September 7, 1978.

P.D. Amer presented a paper entitled "Experimental Design for Computer Comparison and Selection" (Co-author: S.A. Mamrak) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

A. L. Baker presented a paper entitled "Software Science and Programming Methodology (Co-author: S.H. Zweben) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

J. Banerjee gave a presentation on database machine performance at the 4th International Conference on Very Large Data Bases, Berlin, Germany, September 14, 1978.

J. Banerjee presented a paper entitled "A Methodology for Supporting Existing CODASYL Databases with New Database Machines" at the 1978 National Conference of the Association for Computing Machinery, Washington D.C., December 13, 1978.

D.C. Brown presented a paper entitled "Picture Production from Stored Descriptions", (Co-author: B. Chandrasekaran) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

W. Carlson presented a paper entitled "A 3-D Color Graphics System for Interactive Analysis in Computer-Aided Design" (Co-authors: Richard Parent and Charles Csuri) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

B. Chandrasekaran presented invited seminars on "An Approach to Medical Diagnosis Based on Conceptual Structures" at the following locations: Department of Computer Science, State University of New York at Buffalo, October 26, 1978; IEEE SM & C Annual Conference, Tokyo, November, 1978; and at the Department of Computer Science, Simon Fraser University, Burnaby, BC, Canada, December 7, 1978.

B. Chandrasekaran was Chairman of the session on "Testing Tools", member of the Program Committee, and panelist for the Workshop on Software Testing and Documentation, Ft. Lauderdale, Florida, Dec. 17-20, 1978.

B. Chandrasekaran presented an invited talk on "Artificial Intelligence and Cognitive Psychology for the Department of Psychology, The Ohio State University, Colloquium Series, April 13, 1979.

B. Flinchbaugh presented a paper "Early Spatio-Temporal Visual Information Processing" (Co-author: B. Chandrasekaran) at the following locations:

the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979; and at the Workshop on Computer Analysis of Time-Varying Imagery, Philadelphia, PA, April 5-6, 1979.

C.R. Foulk presented a paper entitled "Information Flow and Analysis" (Co-author: M.C. Yovits) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

A. Haley Presented a paper entitled "Independent Modules for a Domain Testing Strategy", (Co-authors: L.J. White, S.H. Zweben, and B. Chandrasekaran) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

D.K. Hsiao made five presentations during September 1978 on Computer Security and Database Machine research at the Universities of Stuttgart, Karlsruhe, and Darmstadt, at the IBM Scientific Center of Heidelberg, and at The IBM Programming Laboratory at Stuttgart.

D.K. Hsiao presented a paper entitled "Computer Security: Problems and Solutions" to the Local Chapter of IEEE Computer Society as part of their Distinguished Visitor Program, on January 24, 1979 in Bexley, Ohio.

D.K. Hsiao was elected to the Digital Systems Group (known as WG 10.3) of the International Federation of Information Processing Societies (IFIPS). He also presented his work on database machines to the WG 10.3 at the IFIPS meeting in Toulouse, France, February 12, 1979.

D.K. Hsiao presented a paper entitled "Database Computers" at the National Bureau of Standards, Gaithersburg, Maryland, on March 13, 1979, and at Data General, Marlborough, Massachusetts on March 27, 1979.

D.K. Hsiao presented a paper entitled "Privacy and Security" at the 24th Annual Ohio Pharmaceutical Seminar on "The Impact of Information Management on the Practice of Pharmacy", in Columbus, OH, on April 2, 1979. He also served as a panelist at another session.

D.K. Hsiao presented a tutorial on Database Computers and chaired a panel with Dr. George Champine of Sperry-Univac, on Future Directions of Database Computers at the 6th International Symposium on Computer Architecture, Philadelphia, Pennsylvania, April 23, 1979.

D.K. Hsiao and S.E. Madnick (of M.I.T.) presented a two-day seminar on Computer Security through OSU's Continuing Education Program at the Center for Tomorrow, May 10 and 11, 1979.

J. Kemeny presented a paper entitled "A Mechanism for a Real-Time Distributed Operating System" (Co-authors: C. Foulk and A. Petrarca), at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

D.S. Kerr presented a database security tutorial at the 4th International Conference on Very Large Data Bases in Berlin, Germany, on September 14, 1978.

D.S. Kerr served as General Chairperson of the 10th Technical Symposium on Computer Science Education held in Dayton, sponsored by the Special Interest Group on Computer Science Education of the Association for Computing Machinery on February 20-22, 1979.

K.I. Ko presented a paper entitled "Average-Case Analysis of Polynomial Time Approximation" at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

S. Kwasny presented a paper entitled "Techniques for the Treatment of Ungrammaticality in Natural Language Systems" at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

M.T. Liu and J.J. Wolf presented a paper entitled "A Distributed Double-Loop Computer Network (DDLCN)" at the Seventh Texas Conference on Computing Systems in Houston, Texas, October 30-November 1, 1978.

M.T. Liu and A.Y. Teng presented a paper entitled "A Formal Approach to the Design and Implementation of Network Communication Protocols" at the IEEE Second International Computer Software and Applications Conference, Chicago, Nov. 13-16, 1978.

M.T. Liu and A.Y. Teng presented a paper entitled "A Formal Model for Automatic Implementation and Logical Validation of Network Communication Protocols" at the NBS/IEEE Computer Networking Symposium, Gaithersburg, Maryland, December 13, 1978.

S.A. Mamrak and P.D. Amer presented a paper entitled "Tutorial: Computer System Selection" at the Computer Performance Evaluation Users Group Conference, Boston, Mass., October 23, 1978.

S.A. Mamrak and P.D. Amer each received a United States Department of Commerce Certificate of Recognition and a $400 Cash Award for their co-authorship of a National Bureau of Standards Special Publication entitled "A Methodology for the Selection of Interactive Computer Services".

S. Mittal presented a paper entitled "Representation of Patient Data for Medical Diagnosis" (Co-author: B. Chandrasekaran), at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

K.S. Natarajan presented a paper entitled "Multiple Facility Location in Sparse Networks" (Co-author: L.J. White) at a conference on Constructive Approaches to Mathematical Models, a Symposium in honor of R.J. Duffin, held at Carnegie-Mellon University, Pittsburgh, Pennsylvania, July 13, 1978.

A.E. Petrarca became Chairman of the Central Ohio Chapter of the American Society for Information Science at the annual business meeting of the chapter on December 4, 1978, having served the preceding year as Chairman-elect and Program Chairman.

R. Ringenberg presented a paper entitled "An Implementation of the Domain Testing Strategy for Computer Software" (Co-authors: L.J. White, B. Chandrasekaran, A. Haley, M. Mihalyi, F. Teng, and J. Hoyte) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

L.L. Rose chaired the Student Roundtable entitled "What Can ACM Do for Student Chapters and What Can Student Chapters Do for ACM?" at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979. He also served as Official Judge for the ACM National Programming Contest held on February 21, 1979.

J. Rothstein received the "Most Original Paper Award" for his paper entitled "Toward an Arithmetic for Parallel Computation", which was presented at the 1977 International Conference on Parallel Processing. He received a walnut plaque at the 1978 International Conference in Bellaire, Michigan, August 22-25, 1978 in recognition of the award. He also presented a paper entitled "Topological Pattern Recognition in Parallel and Neural Models on Bus Automata" at the Conference.

N. Soundararajan presented 3 papers entitled (1) "Remarks on Proof Techniques for Parallel Programs", (2) "Termination of Parallel Programs", and (3) "Axiomatic Proofs of Total Correctness of Programs" at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

A.Y. Teng presented a paper entitled "Protocol Constructions for Communication Networks" (Co-author: M.T. Liu) at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

L.J. White presented a paper entitled "A Domain Strategy for Computer Program Testing" (Co-author: E. Cohen) at the Workshop on Software Testing and Documentation, Ft. Lauderdale, Florida, December 17-20, 1979.

L.J. White chaired a session on Information Retrieval at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

J.J. Wolf presented a paper entitled "A Distributed Double-Loop Computer Network (DDLCN)" at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

M.C. Yovits addressed the Student Association for Computing Machinery Chapter at Western Kentucky University on Professionalism and the Computer Scientist, September 26, 1978.

M.C. Yovits presented an invited colloquium talk entitled "A Generalized Model for Information Flow and Analysis" to the Mathematics Department of Kent State University, October 6, 1978.

M.C. Yovits presented a talk on "Professionalism and the Computer Scientist" to the student chapter of the Association for Computing Machinery at Western Kentucky University, September 26, 1978.

M.C. Yovits addressed the OSU Student Chapter of the Association for Computing Machinery on the topic of Professionalism and Computer Science, November 7, 1978.

M.C. Yovits served on a review team for the Computer Science Department at San Jose State University, October 22-25, 1978.

M.C. Yovits was elected to a four-year term as Member-at-Large of the Section on Information, Computing, and Communication of the American Association for the Advancement of Science, October 1978.

M.C. Yovits was elected to the Nominating Committee of EDUCOM, The Interuniversity Communications Council, Inc.

M.C. Yovits chaired a session on Information Retrieval and served as a member of the CSC Planning Committee at the 1979 ACM Computer Science Conference in Dayton, Ohio, February 20-22, 1979.

M.C. Yovits has been re-elected to a second three-year term as East Central Regional Representative of the Association for Computing Machinery (ACM).

S.H. Zweben was a panelist on Chapter Continuity at the Association for Computing Machinery (ACM) North and East Central Regional Chapter Officers Workshop, Madison, Wisconsin, August 5, 1978.

S.H. Zweben was coordinator and workshop leader of the ACM Southeast Regional Chapters Workshop, Tampa, Florida, October 7, 1978.

S. H. Zweben presented a paper entitled "Chapter Management" at an Association for Computing Machinery Chapters Workshop held in conjunction with the ACM'78 Annual Conference, Washington, D.C., December 2, 1978.

S.H. Zweben has been appointed to the Committee on Chapters of the Association for Computing Machinery (ACM).

APPENDIX F

PUBLICATIONS OF THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE STAFF

BAKER, A. L.; ZWEBEN, S. H. The use of software science in evaluating modularity concepts. In: IEEE Transactions on Software Engineering, Vol. SE-5, No. 2, March 1979, pp. 110-120.

BANERJEE, J.; HSIAO, D.K.; KRISHNAMURTHI, K. DBC -- A Database computer for very large databases. In: IEEE Transactions on Computers, Vol. C-28, No. 6, June 1979, pp. 414-429.

CHANDRASEKARAN, B. Testing tools. Computer, March 1979, pp. 102-103.

LAKSHMANAN, K. B.; CHANDRASEKARAN, B. Compound hypothesis testing with finite memory. Information and Control, Vol. 40, No. 2, February 1979, pp. 223-233.

CHANDRASEKARAN, B.; REEKER, L. H. Artificial Intelligence: a critical analysis (in Russian). Znanie, series on Mathematical Cybernetics (Moscow, USSR), October 1978, pp. 14-37.

BROWN, D.C.; KWASNY, S.C.; CHANDRASEKARAN, B.; SONDHEIMER, N.K. An experimental graphics systems with natural language input. Computers & Graphics, Vol. 4, 1979, pp. 13-22.

DASARATHY, B.; WHITE, L. J. A characterization of nearest neighbor rule decision surfaces and a new approach to generate them. In: Pattern Recognition, Vol. 10, 1978, pp. 41-46.

FLINCHBAUGH, B. E.; CHANDRASEKARAN, B. Early visual processing of spatio-temporal information. Proceedings of the Workshop on Computer Analysis of Time-Varying Imagery, Philadelphia, PA, April 1979.

HSIAO, D.K.; KERR, D. S.; MADNICK, S.E. Privacy and security of data communications and data bases. In Proceedings of Fourth International Conference on Very Large Data Bases, Berlin, Germany, September 1978.

HSIAO, D. K.; BANERJEE, J. Performance study of a database machine in supporting relational databases. In: Proceedings of Fourth International Conference on Very Large Data Bases, Berlin, Germany, September 1978.

HSIAO, D. K.; KERR, D. S.; MADNICK, S. E. Operating system security - a tutorial of recent research. In: Proceedings of the 1978 IEEE Conference on Software and Applications, November 1978.

HSIAO, D. K.; BANERJEE, J. A methodology for supporting existing CODASYL databases with new database machines. In: Proceedings of ACM '78 Conference, December 1978.

HSIAO, D. K.; BAUM, R. I.; BANERJEE, J. Concepts and capabilities of a database computer. In: ACM Transactions on Database Systems, Vol. 3, No. 4, December 1978.

HSIAO, D. K. Database Machines are Coming, Database Machines are Coming! In: Computer Magazine, March 1979, pp. 7-9.

KAR, G.; WHITE, L. J. A distance measure for automatic document classification by sequential analysis. In: Information Processing & Management, Vol. 14, 1978, pp. 57-69.

KERR, D. S. Data base machines with large content-addressable blocks and structural information processors. In: Computer Magazine, Vol. 12, No. 3, March 1979, pp. 64-79.

LIU, M. T. Event driven protection for enhancing data sharing in data base systems. In: Proceedings of the International Conference on Data Bases, August 1978, pp. 411-431.

LIU, M.T.; COHEN D. Derivation protection in data base systems. In: Proceedings of the Third Jerusalem Conference on Information Technology, August 1978, pp. 165-169.

LIU, M. T.; PARDO, R.; BABIC, G. A. An N-Process communication protocol for distributed processing. In: Computer Network Protocols (A. Danthine, editor), 1978, pp. D7.1-D7.10.

LIU, M. T. Distributed loop computer networks. In: Advances in Computers, Volume 17, (M. C. Yovits, ed.). Academic Press, 1978, pp. 163-221.

MAMRAK, S. A. ; AMER, P. D. Estimation of run times using signature table analysis. In: Proceedings CPEUG 78 - Computer Performance Evaluation Users Group, October 1978, pp. 183-191.

MAMRAK, S. A. ; AMER, P. D. A methodology for the selection of interactive computer services. NBS Special Publication 500-44 (National Bureau of Standards). January 1979. 81 pp.

MAMRAK, S. A. ; AMER, P. D. Computer system selection. In: NBS Special Publication 500-41 (National Bureau of Standards). October 1978.

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MOORE, D. J. Simulation languages for archaeologists. In: Simulation Studies in Archaeology, Cambridge University Press, Cambridge, 1978, pp. 11-21.

NATARAJAN, K. S.; WHITE, L. J. Optimum domination in weighted trees. In: Information and Processing Letters, Vol. 7, Number 6, October 1978, pp. 261-265.

ROSE, L. L.; GOTTERER, M. H. Dynamic file movement in multilevel storage systems. In: Information Systems, Volume 3, pp. 117-21.

ROSE, L. L. Computer Systems/Database Simulation. AIRMICS final report. U. S. Army Research Office. October 15, 1978, 117 pp.

ROTHSTEIN, J. Optical Communication Theory, ed. by R. O. Harger. A book review in Applied Optics, Volume 17, No. 18, September 15, 1978, p. 2863.

ROTHSTEIN, J. Topological pattern recognition in parallel and neural models on bus automata. In: Proceedings of the 1978 International Conference on Parallel Processing, Bellaire, Michigan, IEEE Catalog No. 78CH1321-9C.

ROTHSTEIN, J. Generalized entropy, boundary conditions and biology. In: The Maximum Entropy Formalism, ed. by Raphael Levine and Myron Tribus, M.I.T. Press, Cambridge, MA 1979, pp. 423-68.

ROTHSTEIN, J. Generalized life. In: Cosmic Search, March 1979.

MOSHELL, J. M.; ROTHSTEIN, J. Bus automata and immediate languages. In: Information and Control, Volume 40, No. 1, January 1979, pp. 88-121.

ROTHSTEIN, J. Willis E. Lamb, Jr., a Festschrift on the Occasion of his 65th Birthday, ed. by D. Ter Haar and M. O. Scully. Book review in Applied Optics, Volume 18, No. 12, June 15, 1979, pp. 1889 and 1912.

WEIDE, B. W.; ANDREWS, L. T.; IANNONE, A. M. Real-time analysis of EEG using Walsh Transforms. In: Computers in Biology and Medicine, Volume 8, 1978, pp. 255-63.

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APPENDIX G

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APPENDIX H

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