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# COMPUTER AND INFORMATION SCIENCES-II

COINS II

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*Proceedings of the Second Symposium on Computer and Information Sciences held at Battelle Memorial Institute, August 22–24, 1966*

Edited by

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# Preface

Three years ago the first Symposium on Computer and Information Sciences (COINS I) was held at Northwestern University. Since that time computer and information sciences have seen a great intensification of research and education: millions of research dollars spent, new departments of Computer Science and/or Information Science established, plans made in dozens of universities for establishing more such academic departments. All of these efforts attest to the evergrowing importance of this field and its leading role in the science-engineering professions. They also justify the decision, made during COINS I, to hold a second meeting to review recent progress in this fascinating field and to discuss the directions toward which it is heading.

The conception of computer and information sciences arises basically from the use of modern computer and information processing technology to extend man's intellect. This field of scientific study is interdisciplinary in nature and encompasses a very broad spectrum. In organizing the Symposium we attempted to fit eighteen technical papers into three days, reporting new developments in various representative aspects of the field. The authors of these papers came from various parts of the United States and from France, Japan, Sweden, Switzerland, and the Soviet Union. As in COINS I we avoided the need for parallel sessions, in the belief that a meeting of this kind is more fruitful if audience and speakers are kept together continually, thus finding opportunity for talk and discussion.

This book contains the Proceedings of the Symposium. The full texts of all the presented papers are included, together with Licklider's stimulating keynote address on some important aspects of interactive information processing, and the closing remarks by R. H. Wilcox. The papers cover a great variety of topics, ranging from biological memory to feature extraction, from adaptive control to evolutionary systems, from stochastic automata to intelligent robot, from pattern recognition to natural language processing. In order to maintain coherence between the papers and to help the reader locate items of particular interest, the papers in this book are arranged in logical groups and an index is provided.

Credit for any success in this Symposium must be shared with many people who contributed significantly of their time and talents. In organizing the Symposium the co-chairmen, Professor Julius T. Tou and Miss Margo A. Sass, received considerable help from the planning committee including Richard H. Wilcox of the Office of Naval Research, Roger L. Merrill and Kenneth B. Hobbs of Battelle Memorial Institute, Marlin O. Thurston and John C.

Barton of The Ohio State University. Much credit is due to our invited reviewers of the Symposium papers. My very best thanks are also due to Robert O. Stith, Lester L. Hinshaw, John J. Rheinfrank, Miss Nancye Spicer, Miss M. Faye Vance, Mrs. Thecla K. Scanlan of Battelle-Columbus Laboratories, members of the Information Systems Branch of the Office of Naval Research, and several persons of the Technical Information Division of the Naval Research Laboratory for their valuable assistance in preparing announcements, programs and badges, in arranging and running the Symposium, and in some of the editorial work for this book.

It is the authors of the individual papers whose contributions made possible the Symposium and the subsequent proceedings. The participation of Vice President E. E. Slowter of Battelle and Governor James A. Rhodes of the State of Ohio enhanced the stature of the Symposium significantly. To all of them, the editor wishes to express his heartfelt appreciation.

JULIUS T. TOU

*May 1967*

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J. B. FRASER



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## $\iint dC_o dI_n$

# Interactive Information Processing

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## I. Introduction

At a conference of this kind, the keynote speech usually focuses upon the principal topics to be discussed in the conference. This keynote speech is unusual because it does not do so—or at least does not do so directly. Most of the papers in the conference deal with adaptive or self-organizing or learning information systems. This keynote talk, however, is about "interactive information processing." My first obligation, therefore, is to explain why I think it is appropriate to discuss interactive information processing as a way of leading into, and indeed a keynote of, this conference. To put it into a nutshell: I think that interactive information processing is the key to the understanding and synthesis of systems that adapt, organize themselves, learn, and do the other sophisticated things that we shall be discussing in this conference.

Our field—the field of computer and information sciences and technology—is an extremely reflexive, regenerative field. It is concerned in large part with development and understanding of tools and techniques for dealing with information. Thus it is in a sense the science and technology of processes fundamentally involved in the advancement of science and technology. Every accomplishment makes it easier to make further accomplishments—in other branches of science and technology as well, but particularly in the science and technology of computers and information.

Now, the problems with which this conference will be directly concerned are, in the main, extremely difficult problems. We have been attacking them mainly with conventional methods, tools, and techniques. Indeed, until very recently, we have been attacking them exclusively in conventional ways. We have made progress, as the papers of this conference will attest. However, the progress has been, by and large, the slow and hard-won progress that one is happy enough to make when he is working on a very difficult problem.

In the process, we have found out something about what it is that makes certain problems difficult, and we have formulated ideas about the nature of problem-solving techniques and facilities that would make such problems less difficult.

One of the things that makes a problem difficult, of course, is to have a large space of possible solutions. Another thing that makes a problem difficult is not to have a structure, known *a priori*, that relates partial solutions to complete solutions, that organizes hypotheses, or that suggests or limits or constrains approaches. Some problems that have the two properties just mentioned have also a third property that makes them extremely difficult. They are penetrated only a little way by any hypothesis, and—to make matters worse—much detailed and necessarily precise information processing is involved in testing any hypothesis. Such a problem one cannot "think his way through," because he cannot in a reasonable time, without the aid of a computer, carry out the precise, detailed calculations. Nor can one, working on such a problem, simply prepare a massive program and turn it over to a computer, because the result of the testing and information processing is usually only to indicate that the hypothesis has to be revised, and at best it is to produce a small increment in understanding and set the stage for a new formulation which will lead to further testing and further processing of information.

In what I referred to as the "conventional approach" to solving problems —the approach based on conventional methods, tools, and techniques—the formulation of hypotheses and the having of hunches, together with the evaluation of the results found by testing and calculating, are almost pure brainwork, aided little if at all by computers, and the execution of the algorithms involved in the precise, detailed information processing to which I referred is assigned largely either to clerks or to computers. It has been in large part the slowness and inefficiency of the shifting from the one kind of informational activity to the other that has held progress in the solution of problems in this class to its relatively slow pace.

During the last few years, there has been, as you know, a growing sense of excitement in several quarters of our field, an excitement kindled by the prospect of a significant advance in our way of dealing with such recalcitrant problems. It is exciting to "sense" the promise of a new approach and even more exciting to become convinced that one is participating in an intellectual revolution. I have a feeling that the excitement dulls the critical faculty, and that it is quite dangerous to "recognize" great advances while they are in incipient stages. I am aware that some such "great advances" turn out only to be fads. Nevertheless, I am willing to be honest and to admit that I believe that we are indeed participating in an intellectual revolution, that the approach to the solution of difficult, complex, recalcitrant problems offered by on-line man-computer interactive information processing will during the next decade or so revolutionize an important part of our collective intellectual process. At any rate, that is what I want to talk about, and I think that it is clear enough that, if its promise is borne out, interactive information processing will have been proved appropriate as a keynote to this conference.

## II. Three Stages in the Development of Interactive Information Processing

The first stage in the development of interactive information processing is the achievement of effective man-computer interaction. In that statement, both the "man" and the "computer" are singular. The purpose of the interaction is to couple closely together—to interleave or to blend or to meld—the man's heuristic capabilities and the computer's algorithmic capabilities. When these capabilities are brought into close interaction, the difficulty associated with the shifting back and forth between the two aspects of the intellectual process discussed earlier is in large part overcome. I shall not say that highly effective man-computer interaction has yet been achieved, but I think there have been instances in which the interaction has been sufficiently effective to prove itself—at least to those who have had the experience—and I shall mention some of those instances later. It is evident, however, that to provide facilities for effective man-computer interaction over a wide range of problems and decisions will require significant advances in hardware (e.g., displays and controls) and a very large and coherent effort in software (e.g., problem-oriented languages and libraries of generalized subprograms).

The second stage in the development of interactive information processing might be termed the achievement of "men-computer interaction." By that, I mean to imply more than multiple access to a computer, more than quasi-simultaneous interaction between a number of individual men and a large-scale time-sharing machine. As I see it, the value that emerged from the pioneering experiments with time-sharing computers—that emerged, for example, at the Massachusetts Institute of Technology and the Systems Development Corporation, without being fully expected—was the value of community cooperation in developing a sufficiently large and comprehensive software base to support man-computer interaction in a variety of fields. It appears that that value will emerge of its own accord when multiple-access interactive computing is introduced into a creative intellectual community. It is evident, however, that the techniques for facilitating cooperation and fostering a coherent community software effort have to be experimented with and deliberately developed if the evident potential value is to be realized in full in a fairly short time.

In the third stage of the development of interactive information processing, "computer" appears in the plural as well as "men." This is the stage of networks of geographically distributed computers, the stage of what are coming to be called "information networks." Although there are no general-purpose networks of geographically distributed computers to point to as examples, there is already a considerable amount of enthusiasm for information networks. I shall mention the EDUCOM Summer Study on information networks here and say a few sentences about it later. Let me merely introduce two basic points here: (1) The technologies of computation and communication are ripe for the kind of fusion that will make it possible for geographically separated computers to "talk" with one another in a sufficiently facile way to permit geographically separated users to communicate and cooperate with one another in joint interaction with stored information. (2) The effect of bringing geographically distributed users into network-mediated interaction seems likely to be greater than the effect that can be achieved through multiple-access interaction in any local community. The reasoning underlying the latter statement is that it is difficult to achieve a "critical mass" of intellect in a single organization or even in a single city. It is practicable to develop excellent facilities for fifty or a hundred of the best men working in a particular problem area, but usually not for five or ten. It is practicable to get five or ten of the best men to come together in a given geographical area, but usually not fifty or a hundred. A promising aspect of the information-network idea is that, through information networks, intellectual community may be achieved despite geographical distribution.

The keynote that I want to sound, then, is that achievement of interactive information processing at the most advanced of the three stages just described will markedly improve our effectiveness in working on the difficult problems with which this conference is concerned, and that advances toward the solution of those problems will in turn augment the effectiveness of the interactive information processing.

Eventually, if we are successful in actually solving the problems of adaptive, self-organizing, and learning automata, it may be that the amount of man-computer interaction required in problem solving and decision making will decrease, but I am not very sanguine about seeing that conclusion proved at any early date. I think that, for a long time, advances in adaptive, self-organizing, and learning systems will have mainly the effect of making computers better partners for men—and, of particular significance to this conference, better partners for men engaged in research in the computer and information sciences.

## III. Facilities for Interactive Information Processing

The facilities required for the first and second stages of man-computer interaction are widely known through the experiences in on-line interactive