PROCEEDINGS OF THE
SYMPOSIUM ON

COMPUTERS AND AUTOMATA

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FOREWORD

WELCOMING ADDRESS

DR. BENJAMIN ADLER
Acting President, Polytechnic Institute of Brooklyn

It is a privilege and pleasure for me to welcome this group to this MRI Symposium. Those of you who have attended previous symposia certainly remember that I was introduced as Acting President of Polytechnic Institute of Brooklyn on those occasions. I am getting to be known as the perennial Acting President, and this is one of the areas I want to discuss with you this morning.

The papers seem very interesting and I want to get down to being a listener. But I do want to point out to you that some of the problems that we have had for the past two years, are related to not having a permanent president. When President Weber reached retirement age and left us, I happened to be available and agreed to pitch in for a few months, and here I still am, two years later. I was very surprised when Jerry Fox showed me the preliminary copy of the prepared papers and the speeches from the last symposium on *Submillimeter Waves*. I remember making some remarks, and when I opened the page and looked at some of the things I said, I'm very much afraid that I am going to repeat the same things that I said at that time—but I think I can give you some encouragement towards some progress along the lines of solving our problems.

At that time, we had two problems: We needed a President; and we were trying to work out an arrangement with the State University. Right now, we have two problems, and yes, you guessed what they are. But I must say that we are very, very close to working out an arrangement with both the State University and the City University of New York. This has not yet been announced simply because we don't have all the details worked out, but one of the little details in connection with that move has to do with the banner you see right in front of the rostrum.

We haven't used (and I don't know where they dug this old banner up) *BPI* as our identification for quite a number of years. Right now, it is *PIB*, Polytechnic Institute of Brooklyn. Well, Brooklyn Polytechnic Institute may again be resurrected as we join one of the public institutions in New York State. Our identification as a Brooklyn-based Institution appears to be developing as an important ingredient in completing an arrangement with CUNY. So I want to tell Jerry Fox and those who run this meeting, "Wherever you found that banner, try to find some more because I think we may need them again." In any case, I think that things are looking up and we are moving rapidly toward an arrangement that will assure us of continuity. We have a President Designate who has not yet been

announced simply because he will only come with us after we complete our arrangements with the State and the City, and I think we may have an announcement to make within a month.

Be that as it may, I just want to express my sincere thanks to those who are cooperating with us in making this symposium possible and mention in particular the value of the support that we continue to receive from the Joint Services. We call this our Base program which has been going on ever since Dr. Ernst Weber started MRI. It started with a different format in the beginning, but it's only through this continuous activity and support that the Polytechnic has been able to achieve its level of excellence in the areas covered by MRI: *electronics*, *electrophysics*, *electrical engineering*, and so forth.

Today our symposium is in the area of information science and you might ask, "Why information science with the Microwave Research Institute?" One good answer is that we happen to have the facilities, the backing, and the funding to put on a show like this and to attract the kind of speakers that we have with us today. The other is that information science is the kind of discipline that pervades all areas of activity and definitely involves communications. We're going to see a tremendous explosion in this area, which makes this symposium so important at this time. Again, let me thank you for coming. I want to wish you every success for a fine and beneficial meeting.

GREETINGS FROM THE COSPONSORING AGENCIES

MR. PETER R. MURRAY

Deputy Director of Laboratories for Technology, Air Force Systems Command

It gives me great pleasure to participate in this twenty-first annual symposium arranged by the Microwave Research Institute of the Polytechnic Institute of Brooklyn, and to represent the Departments of the Army, Navy, and Air Force in extending best wishes for a very successful meeting on computers and automata.

I must say that I think your forward planning committee did an excellent job of picking a proper subject—for it is timely, important, and the effects can be extremely far reaching. The occasion of this symposia is equally as important as the subject—since in this overall area we universally suffer from a very-large communications "gap."

If just one person in attendance goes away with something of importance that he or she didn't know before, and does something about it, then all your work, all the travel, everything will have been amply repaid over and over again, and the symposia will be a howling success. Yet how often can that success be so obscure that even the participants have difficulty on "hind-sighting" later on.

As you know, we in the DoD have been under some criticism as part of the MIC—the military industrial complex, that is. But welcome aboard my friends—because in the mind's eye of the public, that C in MIC can just as easily stand for COMPUTER! Ask the man who has been billed wrongly, or hasn't been paid on time, or didn't get his state car license forms, etc., etc., etc.!

Now the remarkable thing to me about all this computer business is how the word "large" has changed its meaning over the years. After all, I visited whirlwind in the basement of MIT when it was working out the fundamentals of sector air defense. How I remember the racks and racks of relays and hot cathodes—especially 6SN7 twin-triodes. They must have been made by the billions! And that was a large computer, but only physically by today's standards. Today with large-scale integrated microcircuits, computers with more capability can be misplaced!

To those of us involved in airborne applications this downward trend in size, weight, and power required is extremely important. It has added an element of information and signal processing on a scale we hadn't dreamed of twenty years ago! But with it has come a driving responsibility to do our homework in the information-handling "architecting"—so that software and hardware flow together easily, and swiftly, and efficiently in order to serve man—not deliver him to an early grave!

And automata to me seem to be a very logical extension and exploitation of our expanding capability to do both software and hardware for increasingly-complex situations. But I plead with you to occasionally take time to translate this potential into clear, ordinary English for those people who have to make pivotal decisions! Just remember that although very-logical processes carried on serially and in parallel at nearly the speed of light may remain totally logical to you, there are many to whom it remains "black magic"!

We badly need information processing "architects" and those who can describe such work clearly. Perhaps in the papers today, we shall have the very good fortune to spot some of each! Thank you!

MR. ROBERT H. TANNER

Vice President, The Institute of Electrical and Electronics Engineers

I am very pleased to bring you the greetings and good wishes of the Institute of Electrical and Electronics Engineers, one of the cosponsors of this annual symposium on Computers and Automata. This has been a long and happy association and I hope that it will last for many years, despite the changing pressures which beset our profession and industry. Over the past year, particularly in some segments, these pressures have largely been negative and have left in their path unpleasant vacuums in many job situations. Unfortunately, we have become so accustomed over many years to the full employment of engineers that the present unemployment has caught many of us unaware, and unprepared to deal with it, and much individual unhappiness has resulted.

Many people are asking, and rightly so, what IEEE is doing about the present situation, and though my time is short I would like to try and answer this question. Immediately the seriousness of the trend was recognized, the Executive Committee and Board of Directors began to study ways in which the Institute could help those of its members who had lost their jobs or were in danger of so doing. The results of these deliberations are now appearing in a series of

interconnected actions which have been announced month by month in the "Inside IEEE" column in *Spectrum*. The agreement with NSPE to provide certain useful services to IEEE members for much less than full membership in NSPE; the halving of membership dues for unemployed members; cooperation with AIAA (whose membership is drawn from the hardest-hit sector of the industry) in seminars on unemployment; and lastly a positive drive, spearheaded by various U.S.-government departments, but with IEEE taking a lead among the technical and professional organizations, to set up action committees in the nine main centres of technological unemployment; these are the beginnings of a program which IEEE is undertaking, within the limits of its constitution, to improve conditions, and set the industry back on the track to renewed prosperity and full employment.

Should we stay within the limits of our constitution, or should we reorient the Institute along the lines of the American Medical or Bar Associations, so that we could carry out direct lobbying to influence U.S. governments? This is a big question which cannot be dealt with in the two minutes I have left. But we should remember that IEEE is, as were its predecessors before it, a technical rather than a professional organization, composed of only a portion of the whole engineering profession, yet covering this portion on an international basis. In my opinion, a viable professional society should embrace the whole of its profession, but on a national basis since the influencing of legislation in clearly a national affair. It would no doubt be possible to restructure IEEE into such a format, but in so doing it would lose almost all of its present characteristics, and would become in fact another NSPE limited to electrical engineering, and thus with less power behind its pronouncements. At the Monday night seminar at the recent New York convention, one speaker claimed that 50,000 of our members wanted IEEE to become a union. Assuming for a moment he is right, two points spring to the mind: firstly there must then be 120,000 who *don't* want it to become a union; and secondly, the 50,000 could form a much better organization from scratch, rather than trying to convert the IEEE. In my opinion, the Institute would not make a very good union: I know for certain that I wouldn't make a good union leader!

Well, as they say in the magazines, look for exciting new developments in forthcoming issues of "Inside IEEE." Meanwhile, I wish you an interesting and profitable symposium.

DR. DONALD L. THOMSEN, JR.

Chairman of the Board of Trustees, Society for Industrial and Applied Mathematics

On behalf of the Society for Industrial and Applied Mathematics (SIAM) I am very happy to greet you this morning on the occasion of the twenty-first Polytechnic Institute of Brooklyn Symposium, and at the same time express SIAM's appreciation for the invitation to participate formally as a cooperating professional society. In particular, I bring you greetings from SIAM's president, Dr. B. H. Colvin, Head of Mathematics and Information Science, the Boeing Company, who should be here speaking to you instead of myself. Dr. Colvin told

me last evening that he deeply regretted he was unable to come East this week and attend these sessions; he commented specifically to me noting their high quality.

SIAM is particularly glad to cooperate in this symposium since the objectives as stated in your advance program parallel to a considerable degree those of SIAM. The idea of "bringing together workers in both the field of computers and of automata," if one extends in a perfectly-natural way the field of application and simultaneously places mathematics in juxtaposition with automata (which your advance program also shows), is in harmony with SIAM's stated objectives to "further the application of mathematics to industry and science and promote basic research in mathematics leading to new techniques useful to industry and science."

It was in an atmosphere of a widening gulf, especially between those in industry who had real problems requiring mathematical analysis and those who had become overly enamored with the beauties of mathematical abstractions, that SIAM came into existence in 1952. I hasten to add that the reappearance of such a gulf even within SIAM itself is an ever-present possibility, maybe I should even say threat. And I would like to tell in this connection a short one on ourselves.

Several years ago SIAM held a meeting whose principal theme was combinatorics. The comment reached me afterwards that it was an excellent meeting with regard to the papers presented but it might just as well have been sponsored by a pure-mathematics society! Particularly for a field of mathematics related to the development of digital computers, one would have thought SIAM would not have strayed in this manner from its fundamental objectives. Straying once in a while is, however, probably not all that bad—it can serve to reinforce one's fundamental objectives.

The most enduring mathematics seems to have its origin in man's attempts to understand some real-world phenomenon and also in some deep involvement as well in that same real-world phenomenon. The abstractions which come later on that base can also become useful in again solving real-world problems. In a similar way this symposium reflects the joining of "workers in both the field of computers and automata," which had its "origin in the computer field" and has subsequently "developed independently."

Such a symposium as this one should serve to bridge if not to narrow or even prevent the kind of gulf which might otherwise develop as in the referenced instance in mathematics. The potential is evidently there for this to happen for I have already heard a distinguished head of a computer-science department express concern over the tendency of some computer-science departments, including his own, to follow a history similar to that of many mathematics departments. In fact, it is this very attitude of unconcern toward the solution of real-world problems on the part of such a relatively-large number of mathematicians that has contributed to the ingrown atmosphere of these same departments and eventually, at least in part, to their economic plight today. And the same could happen to computer science. Symposia with an excellent-quality program such as this one provide a deterrent to such a course and also reflect a positive anticipation of the potential dangers to such a course in the future.

As you can see, we believe this symposium represents a major step in the right direction.

SIAM is very glad to have been invited once again (for the fourth time I believe) to cooperate in this outstanding annual event whose purpose and philosophy it enthusiastically applauds.

THE POTENTIAL OF THE COMPUTER IN EDUCATION

Dr. M. E. Van Valkenburg
Chairman, Department of Electrical Engineering, Princeton University

As you read the title, you must have sensed that the most important or significant word is *potential*. The use of the computer in education is generally accepted from the elementary to college levels, although there remain many problems of implementation. The word "potential" should imply something about the future, and to discuss the future, we should assess where we now stand.

In the long run, the kind of education we give must relate to the real world after graduation. We know that the time constant for this adjustment is sometimes long. My own view is that it won't be long until everyone working in technology or science will work with a computer terminal of one kind or another near at hand. The computer will permeate most of our human creative effort, as well as our accounting and record keeping. I do not believe that everyone who uses the computer will understand its workings anymore than I believe that all people using the automobile understand it. In other words, the computer will take its place as one of the fruits of technology that is accepted and utilized, but not worshipped. I am reminded of an article in a recent issue of *DAEDALUS* by H. J. Hanham. After describing the use of the computer by historians, he says: "For most working historians, the greatest innovation of recent times has been the *Xerox machine*, not the computer." I will resist the temptation to ask you whether, if you had to give up one or the other, the Xerox or the computer would go!

Returning to an assessment of the present of the use of the computer in education, let me describe my views in terms of various levels of instruction. I shall confine my comments to engineering and science, initially at least. My listing:

(1) A course in FORTRAN or equivalent. Such instruction is offered at all universities and many high schools. It is available in various forms of self instruction

(2) The use of simulation languages, such as, ECAP, SIMSCRIPT, STRESS and the like. This is widespread but not universal in engineering schools, and in other isolated disciplines

(3) The use of the minicomputer—for programming, hands-on experience or the control of experiments

(4) The foundations of computer science and engineering. Some canonical courses are developing at schools with computer-science programs

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Address presented at the banquet following the opening day of the Symposium on Computers and Automata, Polytechnic Institute of Brooklyn, April 13-15, 1971.

(5) Digital systems in engineering. The engineer works with systems—more and more of these systems include a digital computer, or, at least, digital signals and processors. The analysis of such systems as well as their design is an important area of engineering education that we are just beginning to explore
(6) Finally, digital-computer engineering—both hardware and software.

Now let me work *backwards* and comment on each of the levels I have described.

The levels I have described as (5) and (6) reside primarily with the experts whose daily work consists of solving real-world computer problems. These experts are largely self educated, or educated by "on-the-job" training. The information is not yet codified for presentation to students in the classroom. And progress toward a set of canonical textbooks is painfully slow.

The areas represented by Levels (4), (5), and (6) is that which has received primary emphasis by the COSINE Committee. COSINE is an acronym for Computers in Electrical Engineering; this COSINE Committee is associated with the Commission on Education of the National Academy of Engineering, and operates through support by the National Science Foundation.

May I digress long enough to tell you something of this Committee of which I have served as Chairman since 1968, having recently been replaced by C. L. Coates. COSINE was formed in 1965 to suggest direction and encourage action in incorporating the computer in the electrical engineering curriculum. This has been done through meetings of department chairmen, meetings with representatives of industry and government, summer institutes, and issuing reports by the committee or prepared by appointed task forces. The titles of reports by these task forces indicate the thrust of committee efforts:

(1) "Some Specifications for a Computer-Oriented First Course in Electrical Engineering"
(2) "An Undergraduate Electrical-Engineering Course on Computer Organization"
(3) "Some Specifications for an Undergraduate Course in Digital Subsystems"
(4) "An Undergraduate Computer-Engineering Option for Electrical Engineering"
(5) "Impact of Computers on Electrical Engineering Education—A View from Industry"
(6) "Digital Systems Laboratories—Courses and Laboratory Development"
(7) "Computer-Aided Design"
(8) "An Undergraduate Course on Operating-Systems Principles"
(9) "Minicomputers".

There has been a strong organizational trend to provide computer engineering as an option or program within electrical engineering. In a survey I completed in February 1971, in which 203 departments responded, 87 indicated that they now offer an undergraduate option or program in electrical engineering. An additional 35 without such options now indicated new plans were in progress for their implementation within the next year.

Returning now to my level classifications, Level (3) is the minicomputer. As

you all know, we are in the midst of a revolution in minicomputers. The cost is low and getting lower. The machine offers the advantages in education of hands-on kind of experience (which is certainly not practical in computer centers), and real-time control of experiments. It is possible to connect such machines to large computers such as are found in computer centers, as was recently done by a small group of undergraduates at Princeton. The potential of the minicomputer in engineering education is just beginning to be realized, and is certainly exciting for the future!

Level (2) was the use of a simulation language in instruction, such as ECAP, SIMSCRIPT, etc. One of the first experiences with the use of such a compiler in electrical engineering was by William H. Huggins and his associates at the Johns Hopkins University. Using a program known as JOBSHOP, students at the sophomore level designed electronic circuits and assessed the economic merit of their design. Conceptually, it was shown that the sophomores could do a respectable job of design of transistor circuits with little background and little instructions. The motivational factor was very large, of course, as others have shown since that time. The real barrier, one that comes up again and again, is the *cost* of instruction for a class. Now, we have been in an era when such costs were payed for using "funny money," funds allocated by the University for education, or the equivalent of money used to pay for time that the computer would otherwise not be operating. Alas, the days of funny money are also coming to an end. Faced with real money barriers, many universities have had to limit the educational use of the computer in spite of any advantages that may have been demonstrated. The real cost is likely $5 per hour of $65/student/subject, as computed by L. D. Smullin of M.I.T. It becomes clear that a limitation must be placed on the extent to which students use the computer, unless some breakthrough in financing is found.

It would be unfair not to mention that paralleling, or even ahead of the activities I have described and attributed to the influence of COSINE, have been the action of the C^3S group of the ACM (Curriculum Committee in Computer Science of the Association for Computing Machinery). Certainly their model curricula have had a profound influence on the development of computer science, especially within the liberal-arts environment.

Now we arrive at Level (1), the so-called FORTRAN course taken by all students who find the interest. With a few exceptions, these students are in engineering, science, and mathematics. Such courses are relatively easy to implement, there being no scarcity of textbooks, and relatively inexpensive in terms of computer time. There would be no problem here except for one fact: The course is taken primarily by students in engineering, science, and mathematics! What about the "Silent Majority"?

This fact has been recognized in many places. Courses have been organized with the informal title of "Computing for People Who Hate the Digital Computer." This is one of the problems that we face. This is not really Level (1), for reasons I will discuss. Perhaps we should call it Level (0).

The Level (0) course at Harvard is taught by Bossert and has an enrollment of about 600 students! A similar course is taught at Dartmouth by Kurtz and others with an enrollment as high as 400. At Princeton, we hope to enter this game next year, with a course offered by Hamming. In announcing his

appointment at Yale, it was indicated that Perlis will stress "the use of the computer by the nonscientist."

There are several problems of Level (0) people, and these problems spill over into Level (1), (2), and (3) people, too. Perhaps I may use my son, David, to illustrate one of these. David was introduced to the computer by a friend, a member of his peer group—not by an instructor or his father. When he grasped the basic idea, he became totally immersed, and spent hours at all times of the day and night at the computer center, trying new ideas, solving problems, and exploring his new discovery. I remember that he tried to write a program to produce all of the verb forms in Latin, since he was taking Latin at that time. After this initial burst of enthusiasm, his use of the computer has dropped off, so that he seldom goes there any more. He can use the machine when he needs to. The problem is that he seldom has that need. And he has tired of inventing problems just to show that he can do it. Lesson: What good is a digital computer if you can solve all of your problems with the slide rule or on the back of an envelope?

David's problem was *not* that you communicate with a computer in a very unnatural way, with the annoying thought that the language is subject to almost constant change. Even FORTRAN was too complicated for many. Was not the breakthrough at Dartmouth produced by the implementation of a simple language, BASIC? The use of a mathematically- (or logically-) oriented language that is complex and, for most people, unnatural is too much of a barrier for many people—especially for "people who hate the computer."

It is not obvious that a better language will be the answer. The real boon for many people will be the development of a system of computer graphics, with ease in communication, and also ease in interaction. We are dealing with a generation of students who are chronic television viewers. It seems likely that they will learn better by an input that is neither the spoken word, the written word, nor the typewritten word. We have a long way to go before this is possible within our financial resources!

Let me turn next to an even more basic problem: The mathematical preparation of students for engineering and science has not yet entered the computer age!

It is nothing new to you that the computer operates in terms of discrete mathematics, that we never approach the limit so that $\Delta t \longrightarrow dt$ has meaning. You understood this at the beginning of your formal course in calculus, for example; the remainder of the course was devoted to the limit case of the integral rather than the summation derivative over a differential increment.

Even numerical methods were introduced early in your mathematical training, but then likely forgotten as analytical methods became established. You, in the audience have returned to learn the discrete case, algorithm, numerical methods, and the rest. What would happen if we stressed this kind of mathematics in the beginning, treating the limit case as a special case—if at all? We have not tried it, except for a few small experiments, and so it is not possible to say.

The experiments that should be done are those involved with introducing courses to stress discrete mathematics, the algorithmic approach, meaningful numerical methods. We need less stress on theorem proving, on special tricks that may be used for the evaluation of certain classes of integrals. Indeed, we

might question whether a course in calculus which is not organized is needed at all. What we really need is to rethink the structure of the mathematical training of students of engineering, perhaps science, too. Everything should be questioned. This is no mean task, of course; nor is the task of preparing suitable textbook material after the basic decisions have been made. We are talking in terms of tens of man-years of effort.

What are the obstacles to progress? I have mentioned a real one previously: cost. Funds available are diminishing as we enter the period of the "Seven Lean Years." The budgets of computer centers are tightening, and funds from the traditional sources for educational experimentation are drying up. There is also the question of manpower, or better the product of energy and manpower. There is always the question of lethargy. The old methods have worked well, haven't they? After all, all those attending this symposium are largely products of the old methods! Yet in each of us there must be the suspicion that it could be done easier, that there must be a logical order more effective than the one used in the past.

Let me close by complimenting those at the symposium on your choice of a field in which to work. You might have chosen a field reaching maturity where only small refinements are needed. Instead you have chosen one where we know no answers for sure, and only some of the questions. We have unfortunate constraints. Most important, I think, we have opportunity, enough to last for a long time.

PROGRAM

TUESDAY—APRIL 13, 1971

OPENING SESSION—9:30 A.M.

Chairman: A. A. Oliner
Polytechnic Institute of Brooklyn

Welcome

Dr. Benjamin Adler, *Acting President, Polytechnic Institute of Brooklyn*

Opening Remarks

For the Sponsoring Agencies and the Cooperating Societies

Mr. Peter R. Murray, *Deputy Director of Laboratories for Technology, Air Force Systems Command*

Mr. Robert H. Tanner, *Vice President, Institute of Electrical and Electronics Engineers*

Dr. Donald L. Thomsen, Jr., *Chairman of The Board of Trustees, Society for Industrial and Applied Mathematics*

SESSION I—INTRODUCTION

Chairman: E. J. Smith
Polytechnic Institute of Brooklyn

Computation Speed of Fixed and Self-Modifying Programs

J. Hartmanis, *Cornell University, Ithaca, NY*

Toward a Mathematical Semantics for Computer Languages

D. Scott, *Princeton University, Princeton, NJ;* and C. Strachey, *University of Oxford, England*

On the Design and Specification of a Common Base Language

J. B. Dennis, *Massachusetts Institute of Technology, Cambridge, MA*

SESSION II—2:00 P.M.
PROGRAMMING LANGUAGES

Chairman: A. A. Grau
Northwestern University, Evanston, IL

An ALGOL Compiler, Designed Using Automata Theory

P. M. Lewis and D. J. Rosenkrantz, *G.E. Research and Development Center, Schenectady, NY*

NUCLEOL—A Minimal List Processor and Its Formal Definition

J. Nievergelt, *University of Illinois, Urbana, IL*

On the Definition of Higher Level Language Machines

D. Bjørner, *IBM Research Laboratory, San Jose, CA*

Computer Program Models
C. V. Ramamoorthy, *University of Texas, Austin, TX*
Fuzzy Programs—Theory and Applications
S. K. Chang, *Cornell University, Ithaca, NY*

WEDNESDAY—APRIL 14, 1971

SESSION III—9:00 A.M.
OPERATING SYSTEMS

Chairman: H. W. Lawson, Jr.
Polytechnic Institute of Brooklyn

Design Principles for a High Performance System
H. Schorr, *IBM Thomas J. Watson Research Center, Yorktown Heights, NY*
An Approach to Hardware/Software Architectural Trade-Off Decisions
J. E. Deans and C. V. Ramamoorthy, *University of Texas, Austin, TX*
The Dynamic Variation of Software, Firmware and Hardware
D. Pager, *University of Hawaii, Honolulu, HI*
A Formal Microprogram Model of Parallelism and Register-Sharing
E. G. Coffman, Jr., *Pennsylvania State University, University Park, PA*
Toward Optimal Paginations for Structured Programs
L. Yelowitz, *Johns Hopkins University, Baltimore, MD*
Minimizing Wasted Space in Partitioned Segmentation
S. E. Gelenbe, *University of Michigan, Ann Arbor, MI* and, J. L. W. Kessels and J. C. A. Boekhorst, *Philips Research Laboratories, Waalre, The Netherlands*
Probability Models for Computer Systems
T. Gergely, *Hungarian Academy of Science, Budapest, Hungary*
On Transferences and Priorities in Computer Systems and Networks
J. Santos and M. I. Otero, *Universidad Nacional del Sur, Bahia Blanca, Argentina*
A Simple Model for Multiple Resource Allocation in Operating Systems
D. L. Epley, *University of Iowa, Iowa City, IA* and D. L. Boyd, *University of Minnesota, Minneapolis, MN*
Scheduling of Real-Time Computer Systems (Title only)*
D. L. Epley, *University of Iowa, Iowa City, IA*

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*Papers designated (Title only) will be included in the published Proceedings but will not be read at the symposium.