# Computing and Systems Technology Division Communications

Volume 10, Number 2, September 1987

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## About This Issue

*Peter R. Rony and Joseph D. Wright*

"Hypercube macines reach the market on the promise of executing billions of operations a second to solve difficult simulation problems" is the lead to the article, "A Parallel Architecture Comes of Age at Last," written by Paul Wiley (Intel Scientific Computers) for IEEE Spectrum (June 1987, pp. 46-50). More than one year ago, we tried to get such an article from Intel Scientific Computers for publication in the Fall 1986 CAST Communications special issue on multiprocessors.

Your editor called Paul Wiley several months ago and reaffirmed the newsletter's interest in the iPSC. The result of our conversation was a substantial package of information—along with permission to publish both it and the IEEE Spectrum article. As these comments are being written, your editor has a pile of information, including,

- Parallel Processing on Intel Hypercube Systems: A Technical Seminar, Intel Corporation, 1986.
- The First Concurrent Supercomputer for Production Applications: The iPSC/2 , Intel Corporation, July 20, 1987 (held for release until August 31, 1987).
- The Intel iPSC/2 System: Product Information, Intel Corporation, July 1987 (held for release until August 31, 1987).
- Paul Wiley, "A Parallel Architecture Comes of Age at Last," IEEE Spectrum 24 (6), 46-50 (June 1987).
- Intel Scientific Corporation Application Briefs. For example, "LINPACK and EISPACK on the Intel iPSC," by R. Goliver, Bill Hughey, and Cleve Moler, Intel Scientific Computers.
- Elliott I. Organick, "Algorithms, Concurrent Processors, and Computer Science Education: or, Think Concurrent or Capitulate?", ACMSIGSE Bulletin 17 (1) (March 1985).
- A product brief for the SugarCube Concurrent Computing Workstation.
- A brochure from Hypercube Inc.: "Bringing Molecular Modeling to Parallel Computers."

plus the knowledge that CAST Communications has come up in the world a bit: we have been privy to pre-release information from Intel. We have decided to reprint excerpts from the IEEE Spectrum article. The hypercube geometry and concurrent programming are timely subjects for CAST Communications. Your editor believes that the hypercube geometry will be one method whereby a "personal supercomputer" will land on your desktop by the mid-1990s. Wafer scale integration, ASICs, and other technology all will combine to reduce the size of the iPSC in the same manner that the mainframes of the 1950s, 1960s, and 1970s were reduced in size by yesterday's semiconductor technology.

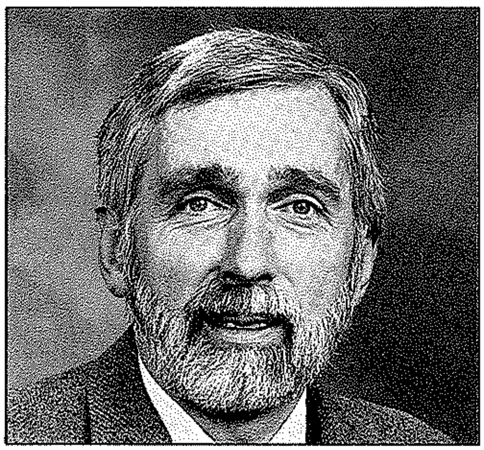
How can one resist such trademarks as SugarCube, Hypercube, and the 386 Cube Server? Your editor tried them on a colleague. He thought a Cube Server was something electronic for serving designer sugar cubes, trademarked SugarCubes. Further, he thought that the product was manufactured by those friendly folks who brought you Mr. Coffee, the electric toothbrush, and the electric back scratcher. Designer sugar cubes? A Christmas gift for the colleague who has everything.

Paul Wiley is a 1967 alumnus of Virginia Tech. In the early days of the microprocessor revolution, he coded an Intel 8080 to perform a real-time Walsh algorithm. We thank him for his kindness in providing so much information for publication in our Division newsletter.

On other matters, Chairman Jeff Siirola's message, plus a comment at the bottom of the Programming Board Chairman's introduction to the Call for Papers, "Prospective participants should note that the above session plans have not yet been confirmed by the Meeting Program Chairman. The possibility exists because of proposed plans for an increased number of plenary and special lectures that the number of sessions may have to be reduced." Give your Editors, in the fine tradition of newspaper reporting, the opportunity to solicit a letter to the editor about plans for the Washington D.C. Annual AIChE meeting on November 27, 1988 to December 2, 1988. In this issue, we introduce Professor Henry A. McGee, Jr., the 1988 Washington D.C. Meeting Program Chairman, who kindly consented to provide his contribution just before this newsletter went to press. The Conference on Emerging Technologies in Materials at the Minneapolis, Minnesota meeting (August 18-20, 1987) was an innovation in program scheduling, as were the changes in meeting format described by Jeff Siirola in the April 1987 CAST Communications Chairman's Message. Henry's plans, if implemented, continue this trend of experimentation.

The Editors thank Yaman Arkun for providing on a diskette almost a complete listing of the New Orleans meeting Area 10 papers and authors (it is helpful to have the Meeting Program Chairman down the hall). Thanks also go to our Chairman for his updated DOS file that listed papers and authors at the New York meeting.

On June 10, 1987, William Spencer, Vice President of the Corporate Research Group at Xerox Corporation, announced that Joseph D. Wright had been appointed Vice President and Manager of Xerox Research Centre of Canada, effective August 15. Joe replaces Robert H. Marchessault, who directed the Centre since 1978. Joe received his B.S. from the University of Alberta, and his Ph.D. in Control-Chemical Engineering from Cambridge University. He joined XRCC in 1977, and previously was Manager, Technology and Engineering Systems. "Joe has established an outstanding record as a scientist and technical leader. I expect him to bring an important balance to the relationships between XRCC's science and engineering activities, to the university research community, and our customers, as well," Spencer said. The CAST officers, directors, and publications board extend their congratulations to Joe.



The Editor acknowledges the assistance of his son, Paul, whose personally written, 8088 assembly-language coded program, SCTR.EXE, permitted him to recover two lengthy CAST newsletter files (MEETING.DOC and CALLS.DOC) from an IBM PC DOS diskette damaged when a university mainframe communications program unexpectedly wrote over the diskette directory. From experience with my sons (both engineering students), who have used their personal computers in a variety of ways, I do not question the value of placing PCs in the hands of undergraduate engineering students. In my opinion, the sooner, the better.

## Chairman's Message: AIChE Programming and Meetings Task Force

*Jeffrey J. Siirola, Eastman Kodak Company*

For some it may not seem possible, but in a few months CAST will be ten years old! I think our first decade has been quite remarkable in a number of ways, many characterized by growth: growth in the features, content, and size of this newsletter, for example; growth in our recognition of excellence in the field of chemical engineering computing through the establishment of our third divisional Computing Practice Award; growth in the number of areas of programming specialty through the creation of Area 10D for Applied Mathematics and Numerical Analysis; growth in our programming at national and annual meetings, now at thirty sessions a year; growth in special-format topical conferences through the successful 1987 FOCAPO meeting, which added to the tradition of our pioneering CPC and FOCAPD events; and finally, and just possibly because of the above, growth in CAST membership, now rapidly approaching the 2000 mark.

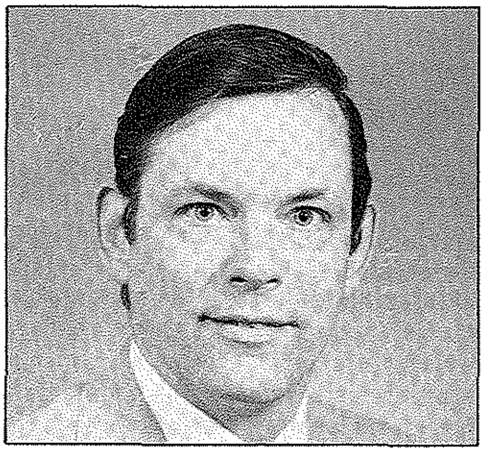
Many people feel that programming is the most essential Institute activity at the Division level. I do not know if our division's growth, with the resulting broadening of perspective and larger pool of talent, led to our increased programming activity, or vice versa.

I do know, though, that despite a tripling in AIChE membership over the past 25 years, the attendance at national and annual meetings has nevertheless remained nearly constant. There is suspicion that programming might have something to do with this situation. For this reason, Council has appointed a special task force to study all aspects of AIChE programming and meetings structure. This task force is chaired by Professor Bill Flood of the University of Lowell, is considering all current methods of meetings operation, and is trying to develop alternatives.

The task force recognizes that there are many constituencies within the Institute and that the purpose of meetings is to facilitate communication within and among these groups. It is trying to identify the various needs that the membership has for getting together, for example to teach, learn, evaluate, share, develop, plan, sell, recruit, and so forth. It is also trying to identify the factors that make a communication effort worthwhile and successful: timing, location, critical mass of people and ideas, and format. The task force is re-examining the policies and constraints that have led to our present meetings structure, as well as some of the practices of other professional societies.

In addition, the task force is taking a particularly hard look at format, including such factors as length of meeting; number of simultaneous sessions; length of sessions; types of sessions; block programming; regional, topical or divisional specialty conferences; joint sponsorships; international meetings; continuing education; expositions; business meetings; and the like. CAST has some experience with a few of these formats. We have practiced block programming for the last five years (in case you've wondered why we no longer have sessions at the summer meeting!), and we also sponsor regular, week-long specialty conferences in design, control, and operations. There is CAST representation on the task force.

The task force would like to hear from you. If you have not been attending AIChE meetings—or feel that in some way meetings have not met your needs or expectations—and have some ideas on more effective programming for the Institute in general or for CAST in particular, please drop a line to Professor Flood, Professor Warren Seider at the University of Pennsylvania, or me. We would very much appreciate your input.



## Editorial

*Peter R. Rony*

Jeff Siirola, in his Chairman's Message in this issue, describes what may prove to be a very important task force, one that will study all aspects of AIChE programming and meetings structure. If Henry McGee is successful with his efforts for the Washington D.C. Annual Meeting, experimentation with meeting structure will already be well underway in 1988.

A long time ago (early 1970s), your editor walked casually into a Sunday meeting of the AIChE Catalysis Subcommittee only to emerge two hours later, somewhat dazed, as its chairman. As his first official duty the next day, he attended a breakfast meeting of the AIChE Research Committee. When asked what he might do, he proposed that "quality speaking opportunities" at AIChE meetings be opened up to that segment of the catalysis community that was outside chemical engineering, for example, outstanding chemists of the 1960s and early 1970s such as James Collman, Tom Bruice, Myron Bender, and Jack Halpern, whose work in homogeneous catalysis and bio-organic chemistry was exciting and might stimulate chemical engineers to incorporate more chemistry in their work. Alas, the idea was of quality speaking opportunities for guests of the Institute was resoundingly trounced by the time breakfast was over.

Some observations: (1) We tend to talk to ourselves too much at our annual AIChE meetings, and (2) We Balkanize†† the available time slots for paper presentations to such a high degree that a "guest of the Institute" (for example, a chemist, biochemist, geneticist, physicist, or electrical engineer) is not likely to be well received (in terms of attendance) and thus should not waste his time presenting a talk to us. Because of the Balkanization of time slots, hospitality to those outside our profession seems to be almost impossible.

What to do? We enjoy the more leisurely meeting formats characteristic of Gordon Conferences, Engineering Foundation conferences, and the recent ASEE Summer School for Chemical Engineering Faculty. We present talks and publish manuscripts at the meetings and in the journals, respectively, of other societies. Why not reciprocate the courtesy?

Why not provide quality speaking opportunities to invited speakers who can deliver outstanding talks about exciting ideas and work that might just have impact upon the careers of some of us in the Institute. As one example, many new and exciting materials–high-temperature superconductors, organic conductors that rival copper on a weight (and maybe volume) basis, high-strength polymers, optoelectronic materials, and so forth–are being developed by physicists, chemists, and materials engineers. Should we not listen, in the comfort of our own meeting, to what they have to tell us? We have started to do this, for example, last August in Minneapolis.

Professor James Wei (M.I.T) has spoken about the need for a new paradigm in chemical engineering. With chemical engineers going off in every conceivable direction, it is difficult to see what form this paradigm will take. Whatever it may be, it is clear that in the future we will interact extensively with colleagues from other disciplines. We should extend the hospitality of our meetings and our publications to such colleagues. We need to do this to expand–as a profession and not simply as individuals–our conception of our future in chemical and biochemical science and engineering.

In my opinion, the time has finally come for experimentation with many important aspects of the AIChE. I personally welcome the challenge. This experimentation has started with the AIChE Journal, with CEP, and with the AIChE meetings structure. The recent resignation of Dr. J. Charles Forman as Executive Director, in retrospect, may prove to be the end of an era. These are interesting times for our Institute.

†† *Balkanize*: To break up into small hostile states, like the Balkan States, esp. in the period of the Balkan wars (1912-13). [Webster's New Collegiate Dictionary, 1958].

## Awards

### Robert Cavett is the First Winner of the New CAST Division Computing Practice Award

The Computing Practice Award is intended to honor an outstanding effort that resulted in a specific embodiment, or possibly an industrial or commercial application, of computing and systems technology. The new award consists of $1000 and a plaque. It will be presented at the CAST Division Award Dinner, November 18, 1987, New York AIChE Meeting.

The first recipient of this award is Robert H. Cavett, a Senior Mathematician, and also Supervisory System and Development Engineer, at the Monsanto Company from 1964 through 1976. Bob is the "originator and major developer of FLOWTRAN." The citation reads as follows:

*More than any other individual, Robert H. Cavett is responsible for the successful development and implementation of sequential modular process simulation. He developed the concept of the basic building-block structure of FLOWTRAN, in which blocks representing the unit operations are tied together by a FORTRAN main program. Overall parameter and retention vectors communicate process information, and physical properties and phase equilibria are provided to the blocks as requested. His pioneering work in 1963 and 1964 on the convergence of multiple recycle loops provided the benchmark against which subsequent efforts have been measured. As early as 1962, Bob included a physical property package of data and correlations within the simulation environment. His proprietary correlations for vapor pressure, liquid density, and liquid enthalpy used in FLOWTRAN and adopted by ASPEN have stood the test of time, unchanged from their original form.*

*As technical leader for the development of FLOWTRAN, Cavett provided the combination of computing insight, programming expertise, and persuasiveness that convinced a highly skilled development of the value of his ideas. With the passage of time, the outstanding merit of his contributions has become increasingly apparent.*

*Unfortunately, Bob was disabled in 1976, but his work continues to influence the chemical engineering literature to this day. Bob's impact in process simulation and physical property correlation has not been so much by the quantity of his published and proprietary work as by its far reaching nature. Each of his papers reported pioneering accomplishments, not just refinements of the work of others. He was truly ahead of his time.*

Bob can be reached at his current address, Arizona State University, Tempe, Arizona, (602) 965-4353.

## James M. Douglas is the Recipient of the 1986 CAST Computing in Chemical Engineering Award

The Computing in Chemical Engineering Award is given in recognition of an outstanding contribution in the application of computing and systems technology to chemical engineering. The award, supported by Intergraph and Simulation Sciences, Inc., consists of $1500 and a plaque.

The winner for 1987 is Professor James M. Douglas (Professor of Chemical Engineering at the University of Massachusetts) for "his contributions to teaching engineers how to think, and for his original contribution to the development of rational strategies for chemical process design and control." Professor Douglas will deliver his award address at the CAST Division Award Dinner on November 18, 1987, at the New York National AIChE Meeting.

The supporting statement for the award reads as follows:

*James Douglas is being nominated for his contributions to systems engineering. Author of a two-volume text on controls, and numerous articles on design and controls, Jim has always stressed that the role of the engineer is to THINK.*

*In earlier work, Jim was one of the pioneers in applying optimal control theory to the understanding of periodic processes. To illustrate his willingness to approach problems differently, he published work on using positive feedback to control a nonlinear reactor model, and showed that it could actually improve the optimal performance of such a system by keeping it in constant periodic motion.*

*His manuscript for an as yet unpublished senior-level textbook on design demonstrates that the art of design can be taught. The approach taken is almost unique among academics, giving rise to his obvious and, at the same time, profound guideline that designers should at all times strive to prove that their design will not work, and that they should attempt to do such a proof with minimum work expended. This approach permeates his latest publications in the area, and he has also presented it to industrial designers. The feedback Jim continually receives permits him to capture and formalize the design methodology as industrial designers perceive it should be done (and is done intuitively by the better designers in industry).*

*Jim has also contributed professionally to the CAST Division, being chairman of Area 15a from 1979 to 1981; running three symposia and contributing nine papers in the last five years. His dynamic presence is always felt in any activity in which he participates.*

Comments in support of his nomination include:

"The most exciting development by Jim Douglas has been his recent work on a hierarchical procedure for process synthesis, which has introduced a new and intriguing approach in this area (AICHE J., **31**, 353, 1985). The importance of this work is that it provides an effective and practical way for screening many alternative flowsheet structures."

"We regard Jim's work in the field of systematic methods for chemical process design as of major importance to engineering education and to industrial application. . . . What Jim has done is to demonstrate that process design is an activity amenable to analysis, and so can be carried out systematically and taught to students. The work therefore represents a breakthrough both in terms of engineering research and in engineering education."

"Jim's two books on Process Dynamics and Control, which appeared more than twelve years ago, are still unsurpassed in many aspects, in particular, their coverage of modeling. Jim's most recent effort in the area of process design has attracted worldwide attention. He has been invited to present short courses on process design in a number of large companies, both in the United States and overseas, and his course notes are being used, even before official publication, by about a dozen universities."

"We have followed Professor Douglas' research for a number of years in the areas of process design and synthesis as well as in control and reaction engineering. In each of these areas he has distinguished himself by his emphasis on understanding principles coupled with quick, order-of-magnitude estimates and tests. In this way, he has taught his students and colleagues to approach systems problems intelligently with a continuing concern for reasonableness."

## Thomas L. Wayburn Receives the CAST 1986 Ted Person Student Paper Award

The Ted Peterson Student Paper Award is given to recognize an outstanding published work, performed by a student, in the application of computing and systems technology to chemical engineering. This award, supported by ChemShare and IBM, consists of $500 and a plaque. The Award will be presented on November 18, 1987 at the CAST Division Award Dinner, New York.

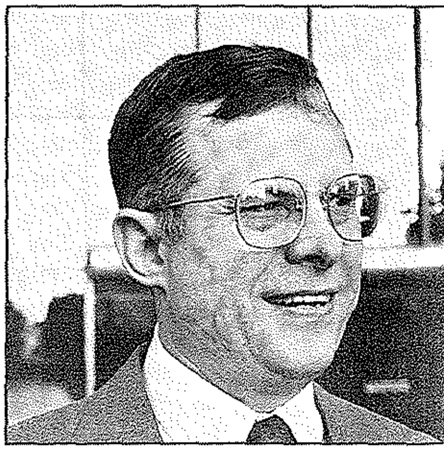
The 1987 winner is Dr. Thomas L. Wayburn, who currently is involved in program development and research with the ChemShare Corporation in Houston, Texas. Tom received his B.S.ChE at the University of Michigan in 1956; his M.S.Math at New York University in 1968, and his Ph.D. in chemical engineering at the University of Utah in 1983. His Ph.D. advisor was Professor J. D. Seader.

The award was given to Dr. Wayburn "for developing a flexible, robust procedure, based upon differential homotopy continuation and sparse matrix methods, for solving separation problems that were previously difficult to solve, and for discovering and explaining the reasons for multiple solutions, which were found for interlinked systems for the first time."

The award nomination statement of qualifications reads as follows:

*Whereas previous methods in the literature are based on Newton or quasi-Newton methods that are only locally convergent—such that they may fail if good starting guesses are not provided—Wayburn's procedure is globally convergent from any starting guess. The development of the new technique based on the use of differential arc-length homotopy continuation was made possible by two factors. One was the extensive mathematical background of Wayburn (M.S. in Mathematics from New York University). Second was his ability tc communicate with mathematics professors from Utah, Colorado State and Germany, who have beer developing the theoretical basis for th methods that Wayburn applied.*

*The method developed by Wayburn should be of great interest to industr because their existing programs ar known to fail for cases involving non ideal solutions and strongly interlinke cases. Wayburn's work was presente to eighty-five chemical engineers fror industry and seventy-six chemica engineers from universities at th International Conference o Foundations of Computer-Aide Design (FOCAPD-83), jointly sponsore by AIChE-CAST Division, NSF, an CACHE, held at Snowmass, Colorado o June 19-24, 1983. In competition wit twenty-one other papers prepare mainly by non-students, To Wayburn's paper was judged by th attendees of the conference to be tied f first place.*



*In the course of developing t homotopy-continuation procedu Tom found an unexpected result, tha multiple solutions. For the separat of a three-component mixture by energy-efficient, interlinked, t column system, four different soluti* *to the problem were discovered. These solutions could not be found by Newton-type local methods. Thus, it is believed that homotopy continuation will have a profound impact in the near future on the development of design methods for processes involving the solution of simultaneous nonlinear equations.*

## 1988 CAST Awards Solicitation of Nomination

Please use the form on the two pages at the end of this issue to submit your nomination for the 1988 Computing in Chemical Engineering Award, 1988 Computing Practice Award, and 1988 Ted Peterson Student Paper Award. Eight copies of the nominations for the Computing in Chemical Engineering and Computing Practice Awards, and four copies of the nomination for the Ted Peterson Award, should be sent by April 3, 1988 to Bruce A. Finlayson, Department of Chemical Engineering, University of Washington, Seattle, Washington 98195, (615) 336-4493.

## Excerpts from "A Parallel Architecture Comes of Age at Last," © 1987 IEEE. Reprinted, with permission, from IEEE Spectrum, Vol. 24, No. 6, June 1987.

*by Paul Wiley, Intel Scientific Computers*

. . . supercomputers built around a single processing unit–the Cray-1, the NEC-SX-2, or the Fujitsu VP200–may already be within an order of magnitude of their technological limit. This theoretical upper boundary, some 3 gigaflops (billions of floating-point operations per second), is established by the length of time it takes electrical signals to propagate, traveling through the wires at about half the speed of light.

Future scientific and engineering problems, however, in such fields as fluid dynamics, computation chemistry, geophysical modeling, and aerodynamics, are expected to require processing rates far in excess of that 3-gigaflops limit. But by dividing applications among many processors working in parallel, rates in the teraflops range–trillions of floating-point operations per second–are in theory possible.

The most popular architecture for large-scale parallel computers–intended for the kinds of applications normally handled by supercomputers–is the hypercube topology. This architecture has been the subject of at least two research and five commercial ventures since it was first demonstrated at Caltech just four years ago (see Table 1).

Hypercubes run multiple programs that operate on multiple sets of data. Within the machine, the individual processing units, called nodes, are independent and communicate with each other while executing programs. Each node has its own memory, floating-point hardware, communications processor, and copy of the operating system and applications program.

The computers are called hypercubes because their architecture can be thought of as a cube of any dimension, with a node at each "corner." The higher the dimensions, the more nodes there are. For example, a two-dimensional hypercube takes the form of four nodes connected by communications lines to form a square. In a three-dimensional architecture, eight nodes are connected into a cube. The number of processors is always a power of 2, the exponent representing the hypercube's dimension.

That dimension also denotes the number of other nodes to which each node is directly connected. For example, a six-dimensional hypercube has 64 nodes, each connected by dedicated communications channels to the six closest nodes, which are called its nearest neighbors. A node can communicate with other nodes that are not nearest neighbors only by passing messages through intermediary nodes.

The hypercube's communications system and each node's individual memory are key characteristics that allow engineers to expand these computers far beyond most parallel architectures. In many parallel computers, processing units share buses and memory, which generally accommodate no more than about 20 processors. Hypercubes, on the other hand, have already been built with 1024 32-bit processors, and machines with 16,384 nodes and more are planned for within five years.

### Computing in Parallel

There are a number of ways to classify parallel applications; the common ones use such programming features as communication characteristics, data-distribution methods, and mathematical techniques. Among the problems classified by communication characteristics are those requiring no communication between nodes, and those requiring communication only between nearest neighbors; the former are sometimes called *perfectly parallel*, the latter, *explicitly parallel* problems.

Explicitly-parallel applications include simulations of physical phenomena, such as the heat flow on a two-dimensional metal plate. A hypercube represents the plate as a collection of temperatures in individual regions. With a 1024-processor computer a programmer divides the plate into a grid 32 segments by 32. Each processor simulates the temperature distribution within a segment and, as

| Machine | Developer | Year | Topology | Maximum Number of Nodes | Maximum Memory per Node (KBYTES) | Node CPU | Estimated Node Performance (MEGAFLOPS) | Estimated Node Instruction Rate (MIPS) |
|---|---|---|---|---|---|---|---|---|
| Waterloop/64 | University of Waterloo, Ontario, Canada | 1983 | LOOP | 64 | 128 | 8086/7 | 0.025 | 0.7 |
| Cosmic Cube | Caltech, Pasadena, California | 1983 | Hypercube | 64 | 128 | 8086/7 | 0.025 | 0.7 |
| Mark II | Jet Propulsion Laboratory/ Caltech, Pasadena, California | 1985 | Hypercube | 64 | 256 | 80286/287 | 0.035 | 1.0 |
| iPSC | Intel Scientific Computers, Beaverton, Oregon | 1985 | Hypercube | 128 | 512 | 80286/287 | 0.035 | 1.0 |
| System 14 | Anetek Inc., Arcadia, California | 1985 | Hypercube | 256 | 256 | 80286/287 | 0.035 | 1.0 |
| NCube/ten | NCube, Beaverton, Oregon | 1986 | Hypercube | 1024 | 128 | Special | 0.3 to 0.5 | 2.0 |
| Computing Surface | Meiko, Kanagawa, Japan | 1986 | 2-Dimensional Mesh | 84 | 128 | Transputer | --- | 7.0 |
| iPSC-VX | Intel Scientific Computers, Beaverton, Oregon | 1986 | Hypercube | 64 | 1500 | Vector | 6 to 20 | 1.0 |
| T-Series | Floating Point Systems, Beaverton, Oregon | 1986 | Modified Hypercube | 16384 | 1000 | Vector | 16 to 20 | 7.0 |
| Connection Machine | Thinking Machines Corp., Cambridge, Massachusetts | 1986 | Hypercube | 65536 | 500 | Special | --- | 0.015 |
| Butterfly | Bolt, Beranek, and Newman, Cambridge, Massachusetts | 1986 | Banyon Switch | 256 | 1000 | 68020/81 | 0.1 | 1.0 |
| Mark III | Jet Propulsion Laboratory/ Caltech, Pasadena, California | 1986 | Hypercube | 1024 | 4000 | Vector | 20 | 1.0 |

Table 1: Distributed Message-Passing Machines at a Glance

the system converges on a solution, periodically communicates its results to processors simulating adjacent segments. This ensures consistent values along the boundaries. Other applications lending themselves to this type of solution include calculating diffusion of dopant molecules in a semiconductor, and modeling stresses within a solid.

Many such explicitly-parallel applications can be divided among processors in a physical representation of the original data. In a hypercube simulating the meteorology and atmospheric chemistry behind the formation of acid rain in the atmosphere, each node simulates conditions within a subsection of the region of the atmosphere under scrutiny. Neighboring nodes represent neighboring subsections of the atmosphere. Such an application is explicitly-parallel because simulation of events in one region depends on the status of nearby regions—for example, whether acid-forming pollutants are being emitted, which way the wind is blowing, and so on. Such information is exchanged between nodes for each time interval in the simulation.

In a perfectly-parallel application, each node is regarded as an independent computational unit. On a conventional computer with a sing processing unit, such applications ru sequentially, one segment aft another. On a parallel machine, ea processor solves its part of the proble independently. Overall execution tir falls by a factor proportional to t number of processors.

Virtually any computation involvin mathematical series is perfect parallel, because each process handles a different interval within t series, independently of the oth processors. But even the applications are not complete perfectly parallel, of course, becau after the computations are perforr

## Hypercube Topologies

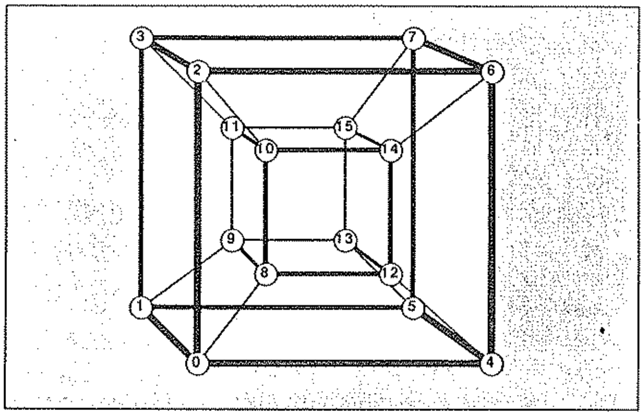


Figure 1:

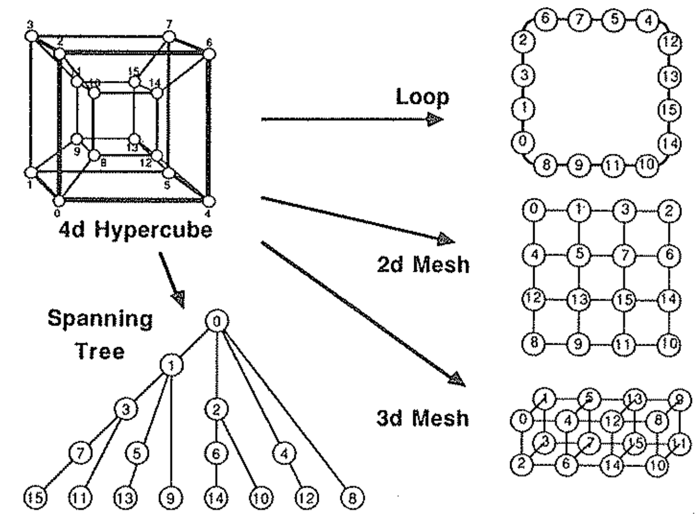



Figure 2:

the processors do need to communicate with each other briefly, to combine the results into the final answer.

**Solving Problems with Rings and Trees**

Another benefit of the hypercube architecture is the flexibility of its interconnect scheme. In hypercubes of four or more dimensions, programmers can choose from among several different standard network topologies to match the problem at hand. A programmer can view a four-dimensional network, for example, as a mesh, a tree, or a ring, and direct its internode connections accordingly (see Figures 1 and 2). Each topology is a useful abstraction for writing software for certain types of application.

For example, two-dimensional mesh topologies work well for simulating two-dimensional phenomena, such as the heat flow on a metal plate. Similarly, three-dimensional meshes are good for simulating spatial phenomena, like the dispersion of air pollutants or the diffusion of dopant molecules in a semiconductor. Tree structures are used for global broadcast or combination functions, and for the search algorithms common in artificial-intelligence software.

Rings are useful in situations where one or more data elements must be evaluated against all the others. One such situation is presented by a common astrophysical problem called the $n$-body simulation of the universe. In this simulation, the gravitational forces on each one of $n$ celestial bodies must be computed with respect to all the others, for a total of $n$ squared calculations. Mathematical representations of each body are distributed evenly through the ensemble of processors, which are linked so as to resemble a pearl necklace—the pearls in this analogy being the processors. With one or more bodies allotted to each processor, the forces are computed by passing each body's vital statistics through the ring and around the ensemble. In each processor, gravitational computations are carried out with respect to the bodies allotted to that node. Once a body has made the complete circuit and returned to its original node, all forces imposed on it by the other bodies will have been determined. Another iteration in the simulation can begin when all bodies have passed around the loop.

**To Probe Further**

The construction in 1983 of the first hypercube computer, at California Institute of Technology, Pasadena, was described by Charles L. Seitz in "The Cosmic Cube," **Communications of the ACM**, January 1985. The article has become a standard reference on hypercube architecture. At the annual International Conference on Parallel Processing, experts exchange ideas on hypercubes and other parallel architectures. For copies of the proceedings of past conferences, contact the IEEE Computer Society, P. O. Box 80542, Worldway Postal Center, Los Angeles, CA 90080. Other material on hypercubes includes "Minis and Mainframes," by Paul Wallich and Glenn Zorpette (commentary by C. Gordon Bell), **IEEE Spectrum**, January 1986, p. 36. Also consult the full article that has been excerpted here in CAST Communications: *A Parallel Architecture Comes of Age at Last*, by Paul Wiley, **IEEE Spectrum**, Vol. 24, No. 6, June 1987.

**About the Author**

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## Interfaces Between Process Control and On-Line Statistical Process Control

*by John F. MacGregor, Department of Chemical Engineering, McMaster University*

### 1. Introduction

The term statistical process control (SPC) has evolved to mean, in general terms, the use of statistical methods to improve process productivity and product quality. Included under the umbrella of SPC are all the statistical techniques involved with the design of experiments, the analysis of data, and on-line quality control methods, as well as the managerial aspects involved in effectively carrying out these improvement programs (Ishikawa, 1985).

A great number of statistical design and analysis methods that are extremely useful in the chemical process industries have become available over the past fifty years. Examples include, factorial and fractional factorial designs (Box, Hunter and Hunter, 1978), optimal designs (Himmelblau, 1968), response surface methods (Davies, 1963; Hill and Hunter, 1966), evolutionary operation (EVOP) (Box and Draper, 1969), nonlinear and multiresponse estimation and design methods (Himmelblau, 1968), multivariate analysis (Anderson, 1958), and time series analysis (Box and Jenkins, 1970). An excellent application of multivariate statistical analysis methods to help in understanding and improving the product quality in a high density polyethylene process was presented by Moteki and Arai (1986). The use of many of these techniques in the process industries can be attributed in many cases to the influence of Professor George E.P. Box of the University of Wisconsin. These statistical methods will continue to play a major role in helping us to improve the understanding of our processes through experimentation and data analysis.

In recent years, Dr. Genichi Taguchi (1985) has also been a major influence, particularly, in the automotive and electronics industries. His emphasis on the use of orthogonal experimental designs, at the developmental state of new processes, to study factors influencing variability has been enthusiastically accepted by these industries. For many years he has espoused the idea of searching for designs which are least sensitive to sources of process variability. Another very interesting contribution of Dr. Taguchi is his definition of quality and his use of cost functions to quantify it. He defines quality as the cost to the customer once the product has been shipped. With the attitudes that follow from such a definition, it is not surprising that the quality of Japanese goods have improved so dramatically over the past four decades.

The area of SPC, on which I am going to dwell at some length in the following sections, is that of on-line quality control. This field owes its origins largely to the early work of Shewhart (1931) which still provides the basis for much of the quality monitoring and control currently being practiced in our modern industries.

Finally, one must mention Dr. Edward Deming (1967, 1972, 1975, 1982, 1986), who has been the major force, first in Japan, and more recently in North America, in convincing management that product qualit should be the top priority, and that th failure of a company to produce qualit products is primarily a failure ( management. It is mainly due to h efforts that there has been a majo shift in management attitudes towarc quality, and that numerous qualit improvement programs are now i force in North American industr These programs have bee enthusiastically received by th statistical community. In fact, or might say that this quality revolutio coming in response to the flood of hig quality products from Japan, has do for the statistical community wh Sputnik did for the aerospac community.

But where does the process contr engineer fit in? Even as recently last year, polls conducted within son industrial process control grou placed product quality low on the li of reasons for implementing contr schemes (Schnelle and Richard 1986). Why are the ideas of proce control engineers so at odds with t present stress on quality? I feel that least some of the explanations for th attitude lie in the heavy emphasis o chemical engineering programs ha placed on petrochemical operatio where quality is somewhat less of concern than it is in special chemicals, electronics, biomateria etc. Another explanation might that, in the managerial structure many North American compani process control groups have become isolated from the final customer, a rarely are able to relate the qual problems that these customers a experiencing back to the operation a control of the process. Finally, might also be claimed that chemi engineers, with their inadequ backgrounds in statistics, are i equipped to handle the noi infrequent product quality data t typically is generated off-line quality control laboratories.

Given the tremendous commitment of North American management to producing quality products, and the success of the Japanese in achieving such high levels of quality using statistical process control methods, it is not surprising that the quality control programs in most companies are now being channelled through their statistical groups. In many ways the applied statistician is better equipped to handle this task. He has an excellent training in the analysis and interpretation of multivariate discrete data, in the design and analysis of experiments, and in methods for empirically modelling and analyzing process data. Chemical engineers, on the other hand, generally have a very poor background in statistical methods and in the analysis of data. Some universities still don't even have a required statistics course in their curriculum, and many of those that do have inadequate courses that offer nothing on the design of experiments, and little practical guidance for data analysis.

However, there is one very important area of overlap between the SPC groups and the process control groups. This is the area of on-line quality control. In many companies these two groups are both trying to solve this same basic problem, but they are using different techniques, and neither group fully understands the techniques of the other. Many of these quality control problems involve the use of discrete data obtained from infrequent samples analyzed off-line in a quality control laboratory. Although the statistician is comfortable with such discrete data, he has almost no background in process dynamics, nor any familiarity with classical continuous time control. Process control engineers, on the other hand, have a good understanding of process fundamentals, process dynamics, and classical continuous time control theory using tools such as Laplace Transforms and stability analysis.

In short, the groups appear to be nearly incompatible with one another, having almost no common base of knowledge on which they can build a relationship. It is the purpose of this paper to try to explore the interface between these areas of knowledge, and to hopefully present a common base. Not unexpectedly, stochastic control theory provides a means of achieving this.

There have been few published papers that discuss the interface between these two areas. One of these (Box et al., 1974) has been largely ignored, and so I shall borrow heavily from it in the discussion which follows.

## 2. Some Examples

The best way of introducing the on-line quality control problem is by way of a few examples. Consider the solution polybutadiene process described in Kelly et al. (1987). The process consists of a train of CSTR's in which the butadiene monomer, a solvent, a chain transfer agent, and the components of the Ziegler-Natta catalyst system (a transition metal catalyst and a catalyst promoter) are fed to the first reactor in the train. The rubber is coagulated, and the solvent and unreacted monomer are recovered and recycled. The major disturbances in the process are due to impurity variations (ppm) in the feeds and buildup of impurities in the recycle. The process temperatures and flows are all controlled by conventional PID controllers, and the feedrates of the various inlet and recycle streams are controlled via a computer based material balance algorithm employing an on-line GC. However, the most important control problem in the process is that of controlling the final properties of the rubber (e.g., Mooney viscosity, etc.). These quality variables cannot be measured on-line but rather samples of the "cement" leaving the final reactor are taken approximately every two hours and analyzed in the quality control (QC) laboratory. These properties can be controlled by manipulating the feedrates of the catalyst components and the chain transfer agent. However, the property data are contaminated with substantial analytical error, and since the measurements are available only every two hours, it is not possible to filter out this measurement noise in a conventional manner.

Similar situations are common in the manufacture of synthetic fibres. The important quality characteristics of the fibers (denier, dye depth, etc.) are nearly all measured infrequently and off-line in the QC lab. Other process industries (e.g., food processing and packaging) exhibit similar problems.

In all of these examples the objective is to maintain the quality variables as close as possible to their target values or setpoints. There is no interest in moving these setpoints to "better" values. Consistency of quality is the important thing. If a new set of target properties is eventually deemed to give a superior product in some way, then it is usually designated as a new product, and once under production, consistency is again the most important consideration.

Many different approaches have been taken to address these discrete data quality control problems. In the past many companies have simply left this quality control to the plant operators, who with years of experience develop a set of rules for interpreting and responding to quality variations. Statistical quality control charts have also been used extensively to monitor these quality variables, and to respond to "out-of-control" situations. DuPont, for example, has more than 10,000 CUSUM charts being actively used (Marquardt, 1984). More recently, process control approaches based on discrete stochastic control theory have been used in a number of these situations (MacGregor and Tidwell, 1979; Kelly et al., 1987). In the following sections we provide an overview of these latter two approaches, show where they overlap, and provide recommendations on their use.

## 3. Quality Control Charts

### 3.1 Shewhart Chart

Most of the basic philosophy behind the use of quality control charts to monitor and control manufacturing processes were laid out by Shewhart (1931). The idea of simply plotting the data in some manner as soon as it became available, and observing trends and changes is very basic, and yet it is so often ignored. In order to help in assessing whether or not changes have occurred, Shewhart suggested plotting the data sequentially in time on a chart containing the target value and upper and lower action limits. This Shewhart chart (Figure 1) is probably still the most commonly used control chart. In the manufacturing industries samples of $n$ units are usually taken periodically and both sample mean and the range of sample are plotted. The idea behind the test is that when the process is "in-control" the means should be independently and normally distributed about the target, and the variance should be constant.

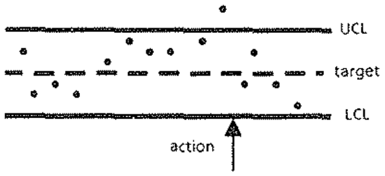


Figure 1: Shewhart Chart

If the action limits are placed at plus and minus three standard deviations about the target, there is only a very small probability that they would be exceeded on chance alone if the process were "in-control." Therefore, if the action limits are exceeded a change is called for to bring the process back to target (setpoint). This essentially constitutes a hypothesis test that the process mean is equal to the target against the alternative that it is not. Since this Shewhart procedure is not very sensitive to small deviations from target, it is common to augment it with runs tests, etc. (e.g., Ott, 1975).

The purpose behind Shewhart's procedures is not simply to provide a decision mechanism for when to take feedback control action. Rather, by indicating when an "out-of-control" situation has occurred, it enables one to examine carefully the process data around that period of time in order to find an assignable cause. It is chiefly by this latter route that continual process improvements can be made (Ott, 1975; Ishikawa, 1976).

### 3.2 CUSUM Chart

The cumulative sum (CUSUM) procedure was developed by Page (1954, 1961) and Barnard (1959) as a sequential Likelihood Ratio test for testing the hypothesis that the process mean is equal to the target value against the alternative hypothesis that it is not. Again it is assumed that the data are independently and normally distributed about a mean value $\mu$ with a constant variance ($\sigma^2$). In this procedure one plots the cummulative sum of the deviations from target since the last correction, i.e.,

$$\sum_{i=1}^{t} (Y_i - Target) \tag{1}$$

Any change in the mean of the output ($Y$) from target will show up as a change in the slope of the CUSUM plot. When the process is on target a horizontal trend will be obtained.

To assess the statistical significance o any change a V-mask (Figure 2) i often employed (Barnard, 1959; Va Dobben De Bruyn, 1968). When eithe leg of the V-mask crosses the plotte CUSUM values a statisticall significant change in mean ha occurred. With computer base systems, the graphical V-mas procedure has now largely bee replaced by the following equivalen two-sided procedure (Lucas, 1976 Woodall, 1986). Two cumulative sum are computed as

$$S_i = Max[0, S_{i-1} + Y_i - (Target + k)] \tag{2}$$

and

$$T_i = Min[0, T_{i-1} + Y_i - (Target - k)] \tag{3}$$

where $Y_i$ is the $i^{th}$ measurement or th average of a number of measurement $k$ is the allowable slack in the proces or one half the smallest shift in th mean that is considered importar enough to detect quickly. This CUSU procedure signals an out of contr situation at the first stage $N$ whe $S_N \geq h$ or $T_N \leq -h$. The decisio interval $h$ is chosen to provide a acceptable average run length (ARL) f both the in-control and out-of-contr situations. Tables are available for i selection (e.g., Lucas, 1976). Once a out-of-control signal has been give and an adjustment made, the CUSUM restarted.

In general, the CUSUM procedure able to detect smaller changes in t mean more rapidly than the Shewha procedure. As with the Shewha chart, many enhancements to t CUSUM procedure have been propos to increase its power in specif situations (e.g., Lucas and Crozie 1982).

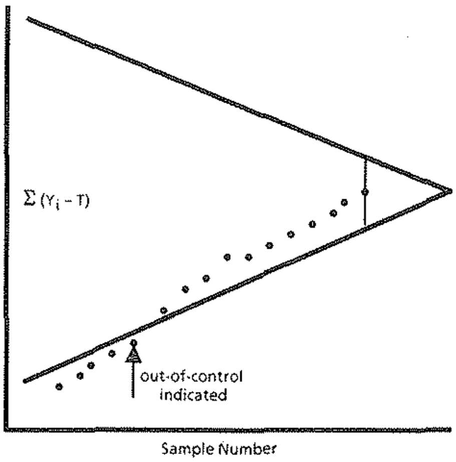


Figure 2: CUSUM Plot with V-mask

3.3 EWMA Chart

The exponentially weighted moving average (EWMA) control chart was proposed by Roberts (1959). A more recent discussion of this procedure is given by Hunter (1986). In this procedure the EWMA ($\overline{Y}_t$) of the observations is plotted, where

$$\overline{Y}_t = (1 - \theta) [Y_t + \theta Y_{t-1} + \theta^2 Y_{t-2} + \ldots] \quad (4)$$

$$= \theta \overline{Y}_{t-1} + (1 - \theta) Y_t \quad (5)$$

$\theta$ is the EWMA parameter ($0<\theta<1$) which determines how fast one discounts past data. Whenever the EWMA exceeds some upper or lower control limit an adjustment is called for.

Note that as $\theta$ tends to zero only the current point is weighted and the EWMA chart will be equivalent to a Shewhart chart, and as $\theta$ tends to unity the EWMA approaches a cumulative sum. Although in practice the value of $\theta$ is often selected from experience ($\theta = 0.8$ being a common choice) its optimal value can be estimated from the data themselves.

The original justification of Roberts for the EWMA chart was rather intuitive. It was later theoretically justified by Box et al. (1963, 1974) under the assumption of a commonly occurring disturbance process. This is discussed more in the following sections.

3.4 Justifications

Underlying these methods is the assumption that the observations ($Y_i$) are independently normally distributed about some mean ($\mu$) with constant variance ($\sigma^2$). The test procedures have then been developed as tests of the hypothesis that $\mu$ = target against the alternative that $\mu \neq$ target. Such a basis appears to be reasonable in the parts manufacturing industries where these SPC charting methods have indeed met with much success. If the data are not independent, but serially correlated, the charting procedures do not appear to be totally invalidated (Box et al., 1974), but their expected average run lengths (ARL) might be seriously in error and the control limits (e.g., $k$, $h$ of the CUSUM procedure) would have to be adjusted.

However, a more serious assumption behind this control chart philosophy is the idea that a hypothesis testing procedure is appropriate. This assumption implies that an adjustment to the process should be made only if a "significant deviation" is observed. To justify such a test-like procedure we would normally require that there be some cost associated with making an adjustment (Box and Jenkins, 1963; Barnard, 1959; Bather, 1963). Although this is usually true in most parts manufacturing industries, it is rarely true in the process industries where many cost-free adjustments are usually available. In this latter situation we shouldn't have to be convinced of the "reality" of a change in the process before control action is taken. Rather, actions should be taken simply on the basis that they will minimize the variations in quality or maximize profits.

Ultimately, any on-line control logic should also be based on knowledge about the nature of the disturbances and the nature of the process. Process knowledge in the form of gains and process dynamics is necessary in order to decide how to respond to observed upsets. Knowledge about the nature of the disturbances and noise in the outputs is necessary in order to efficiently detect out-of-control situations, and to efficiently estimate the true level of the output deviation from target.

Consider the simple single-input-single-output situation illustrated in Figure 3. The observed output ($Y$) is the sum of the effect of any input manipulations ($u$) made earlier plus the effect of the process disturbance ($D$). The disturbance ($D$) is the sum effect, on the output ($Y$), of all disturbances occurring anywhere within the process, including disturbances in any load variables, measurement errors, etc. This disturbance is illustrated in Figure 3 as entering at the process output because this is the only point at which one can observe and model it.

In the next two sections discrete time models for process disturbances and for process dynamics are briefly reviewed. These models will be used for developing stochastic control algorithms and for showing their relationship to SPC control charting methods.

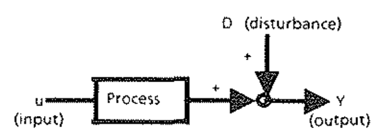


Figure 3: Simple Process

## 4. Discrete Process Models

Linear difference equation and discrete (pulse) transfer function models are well known to process control engineers, and so we shall only review them briefly here. Furthermore, in the subsequent sections we are only going to be concerned with the simplest forms of these models.

4.1 A Pure Gain (or Steady-State) Process

Consider the simple discrete-time model

$$Y_t = g\, u_{t-1} \tag{6}$$

where $Y_t$ and $u_t$ are deviations from steady-state conditions, and $t = 0, 1, 2, \ldots$ denotes the discrete time interval at which the observations ($Y_t$) and the input changes ($u_t$) are made. This model implies that for any input change made at time $t-1$, the output will have attained a new steady-state value by the next sampling interval ($t$). As simple as this model is, it is the dominant model for SPC applications in the parts manufacturing industries where a typical action is to adjust the setting of a machine. Such an action will generally have an immediate effect on the next part produced. In the process industries if the sampling interval is long enough, in particular, if it is longer than the setting time of the process, then this model will also be valid. Such a situation is not uncommon when infrequent laboratory analyses are involved.

4.2 Dynamic Models

When the sampling interval is short enough that dynamic or transient effects are important, the process can usually be modelled in some operating region by discrete linear dynamic models. A first order process sampled at discrete intervals ($T$) may be represented by the first order difference equation

$$Y_t = \delta Y_{t-1} + \omega u_{t-b} \tag{7}$$

or in operator notation by the first order transfer function

$$Y_t = \frac{\omega z^{-b}}{1 - \delta z^{-1}}\, u_t \tag{8}$$

where $z^{-1}$ is the backwards shift operator ($z^{-b}u_t = u_{t-b}$), and $b$ is the number of whole periods of process dead-time.

In general, one may use higher order transfer function models of the form

$$Y_t = \frac{\omega(z^{-1})\, z^{-b}}{\delta(z^{-1})}\, u_t \tag{9}$$

where $\omega(z^{-1})$ and $\delta(z^{-1})$ are polynomials in the backward shift operator $z^{-1}$.

## 5. Disturbance Models

Process disturbances are generally of two types. Stochastic disturbances arise from random variations occurring continuously in many processes. Examples include disturbances in polymer quality resulting from small impurity variations that are always present in the feed and recycle streams, or disturbances in pulp and paper quality resulting from raw material variations. Measurement and sampling errors are also stochastic. Deterministic disturbances are those which occur due to sudden step or ramp changes in a load variable at any particular instant of time. These load disturbances often occur randomly and infrequently in time, but their nature is well defined (deterministic).

5.1 Stationary Stochastic Disturbances

The most basic stochastic process is the discrete white noise sequence $\{a_t;\ t = 1, 2, \ldots\}$, where the $a_t$'s are independent, identically distributed, random variables with variance $\sigma_a^2$. Recall that the basic assumption behind most SPC charts is that the output ($Y$) follows such a process during "in-control" periods.

However, in the process industries such an independent behaviour from time to time is not typical of most process disturbances. Disturbances entering the process are often persistent in nature, such as variations in raw materials. The properties of these materials tend to drift high or low for many time periods. Furthermore, most processes are continuous in nature, and disturbances entering at various points will pass through part of the dynamics of the process, and continue to affect the output for several time periods. Therefore, the disturbance as it appears in the output measurement ($D_t$ in Figure 3) will, in general, not be just random white noise, but will exhibit a dependence upon past values, that is, it will be autocorrelated. Discrete time series models capable of representing such autocorrelated behaviour were first introduced by Yule (1927) and more recently treated thoroughly by Box and Jenkins (1970). The basic idea is that by starting with a white noise sequence and passing it through a digital shaping filter a highly autocorrelated disturbance process can result at the output.

Consider, for example, the first order autoregressive process

$$D_t = \phi D_{t-1} + a_t \tag{10}$$

or

$$D_t = \frac{1}{(1 - \phi z^{-1})}\, a_t \tag{11}$$

where $z^{-1}$ is the backward shift operator ($z^{-k} D_t = D_{t-k}$). This process results from passing white noise through a first order filter or transfer function. The behaviour of such a process for the parameter $\phi = 0.8$ is illustrated in Figure 4. For stationarity (stability) the parameter

$\phi$ must have magnitude less than unity.

More general stationary stochastic disturbance processes can be represented by autoregressive moving average (ARMA) models of the form (Box and Jenkins, 1970):

$$D_t - \phi_1 D_{t-1} - \ldots - \phi_p D_{t-p}$$

$$= a_t - \theta_1 a_{t-1} - \ldots - \theta_q a_{t-q} \quad (12)$$

or in shift operator notation as

$$\phi(z^{-1}) D_t = \theta(z^{-1}) a_t \quad (13)$$

5.2 Nonstationary Stochastic Models

In process control we are usually faced with disturbances that are drifting or nonstationary in nature. Box and Jenkins (1970) showed that such disturbances can usually be made stationary by taking differences between successive values (differencing), and that the differenced data ($\nabla D_t = D_t - D_{t-1}$) can be modelled by stationary ARMA model. This is equivalent to placing a pole of the disturbance model at unity. The simplest such nonstationary disturbance model is the random walk process

$$\nabla D_t = a_t \quad (14)$$

a realization of which is shown in Figure 5. For those readers who are investors, stock prices of major companies and stock markets indices tend to follow random walk behaviour.

A still simple but very important nonstationary process is the first order integrated moving-average process

$$\nabla D_t = (1 - \theta z^{-1}) a_t \quad (15)$$

This process is extremely common in SPC environments. It can arise from an underlying random walk process (14) that is observed with white noise measurement error, that is

$$D_t = X_t + e_t \quad (16)$$

$$\nabla X_t = a_t$$

where $X_t$ is the random walk process and $a_t$ and $e_t$ are independent white nose processes with variances $\sigma_a^2$ and $\sigma_e^2$ respectively. The moving-average parameter ($\theta$) in (15) is a function of $\sigma_e^2/\sigma_a^2$ (Box and Jenkins, 1970), tending to zero as the measurement error $\sigma_e^2$ gets small, and tending to unity as $\sigma_e^2$ gets large. A realization of (15) for $\theta = 0.6$ using the same random number sequence as in previous figures is shown in Figure 6.

When considering the design of stochastic controllers or SPC charts in the following sections it is going to be very important to examine optimal predictors for these disturbance processes. Consider the integrated moving average process (15). The minimum variance predictor for $D_{t+1}$ can be obtained by taking conditional expectations given the information available at time $t$ (Box and Jenkins, 1970), that is

$$\hat{D}_{t+1/t} = E[D_{t+1}/D_t, D_{t-1} \ldots]$$

$$= D_t - \theta a_t$$

$$= \theta \hat{D}_{t/t-1} + (1-\theta) D_t \quad (16)$$

$$= \frac{(1-\theta)}{1 - \theta z^{-1}} D_t \quad (17)$$

where in (16) use has been made of the fact that $a_t = D_t - D_{t/t-1}$ is the one-step ahead prediction error. As seen in equation (17) this predictor is obtained by filtering the actual disturbance at time $t$ (i.e., $D_t$) with a first order filter. By long division in (17) or by successive substitution for $D_{t/t-1}$ in (16), the predictor can also be expressed as an exponentially weighted moving-average (EWMA) of past disturbances, i.e.,

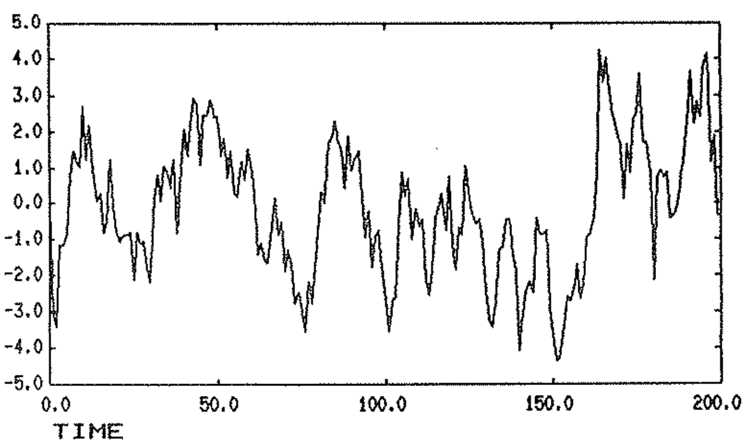


Figure 4: Stationary Autoregressive Disturbance ($\phi = 0.8$)

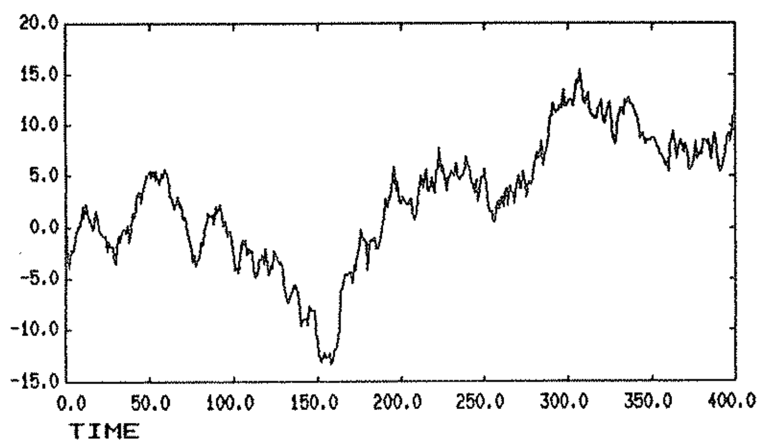


Figure 5: Random Walk Disturbance

$$D_{t+1/t} = (1-\theta)[D_t + \theta D_{t-1} + \theta^2 D_{t-2} + \theta^3 D_{t-3} + \ldots] \quad (18)$$

A general class of stochastic disturbance model is given by the integrated ARMA model

$$\phi_p(z^{-1})\nabla^d D_t = (\theta_q(z^{-1})\, a_t \quad (19)$$

The polynomial orders $(p,d,q)$ and the parameters of a model from this class which characterizes the disturbance in any given process can usually be identified directly from data collected from that process (Box and Jenkins, 1970). This area of identification is a mature field in both the statistics and the control literature.

For nonstationary disturbances the degree of differencing $(d)$ is usually not greater than one. An important result for nonstationary ARIMA processes in this class $(d = 1)$ is that, as one samples them less and less frequently (i.e., the sampling interval $T$ gets large), they all tend to the limiting first order integrated moving-average process in equation (15) (MacGregor, 1976). Since most SPC situations involve the use of infrequently measured laboratory data, it is not surprising that this disturbance process occurs so frequently in practice, and that EWMA control charts and predictions have proved so successful.

### 5.3 Randomly Occurring Deterministic Disturbances

This same class of ARIMA models (19) can also be used to model deterministic disturbances which occur randomly but infrequently in time such as steps, ramps, or exponential changes (MacGregor, et al., 1984). The difference in the models lies in the probability distribution of the random process $\{a_t;\ t = 1, 2, \ldots\}$. For deterministic disturbances these $a_t$'s are zero most of the time, except at the occurrence of a change. Since the minimum mean squared error predictors for these disturbances are independent of the nature of the probability distribution of the $a_t$'s (only requiring that it be symmetric) then the prediction equations are identical for the same model structure. The implication is that there is no difference between the design of optimal controllers for stochastic or deterministic disturbances.

The model for randomly occurring step changes is given by

$$\nabla D_t = a_t \quad (20)$$

the same structure as that for a random walk. If white measurement noise is present at each interval, then the process is again well approximated by a first order moving average (cf. equations (16)).

## 6. Minimum Variance Control

Given that a combined process dynamic and disturbance model of the system has been identified, that is

$$Y_t = \frac{\omega(z^{-1})z^{-b}}{\delta(z^{-1})}u_t + \frac{\theta(z^{-1})}{\phi(z^{-1})\nabla^d}a_t \quad (21)$$

one can easily design a control algorithm to satisfy a desired objective. In the case of product quality control a very reasonable objective is to try to minimize the variance of the output deviations from the target or setpoint. Therefore, in the following sections we examine the structure of minimum variance controllers in several special situations that arise commonly in SPC problems.

### 6.1 No Process Dynamics

Consider the situation where the process attains a steady-state in the interval between sampling instances, that is

$$Y_{t+1} = g u_t + D_{t+1} \quad (22)$$

As mentioned previously, this steady-state or pure gain model is the rule in most parts manufacturing applications, and may be reasonable in

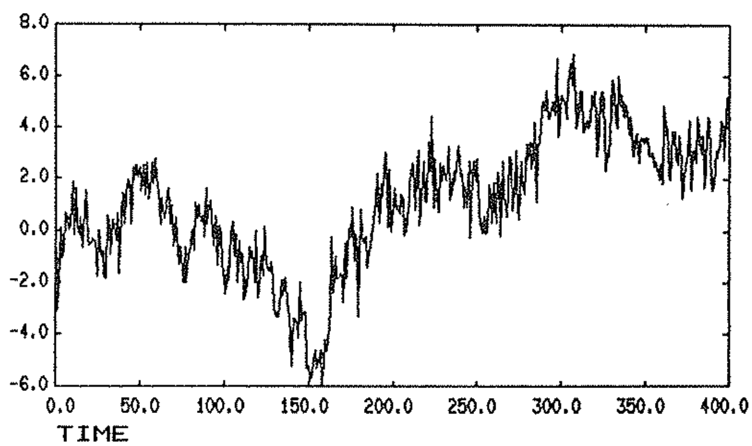

Figure 6: Integrated Moving-Average Distrubance

the process industries when the sampling interval is long relative to the process time constants.

For perfect regulatory control, in the face of disturbances ($D_t$), we should choose $u_t$ to set the deviation from setpoint, $Y_{t+1}$, equal to zero, that is, we should set

$$u_t = -\frac{1}{g} D_{t+1} \quad (23)$$

However, this control action is not realizable because it involves a future unknown value of the disturbance. Therefore, the best we can do is to minimize the variance of the output deviations from setpoint. It is readily shown (Box and Jenkins, 1970) that this is achieved by replacing $D_{t+1}$ by its minimum variance prediction ($\hat{D}_{t+1/t}$) i.e.,

$$u_t = -\frac{1}{g} \hat{D}_{t+1/t} \quad (24)$$

It is obvious that the control action depends largely upon the nature of the disturbance $D_t$.

Although we could consider many disturbance models at this point, we shall concentrate on the first order integrated moving-average model (15) since it arises so frequently in SPC situations. Recall that the minimum variance predictor for this disturbance model is the exponentially weighted moving-average (EWMA) predictor given in equations (16,17,18). Hence the minimum variance (MV) controller is given by

$$u_t = \frac{(1-\theta)}{g} [D_t + \theta D_{t-1} + \theta^2 D_{t-2} + \ldots] \quad (25)$$

$$= -\frac{1}{g} \cdot \frac{(1-\theta)}{(1-\theta z^{-1})} D_t \quad (26)$$

To implement this control, let us consider two distinct situations: (i) one often occurring in the parts manufacturing industries where there is a distinct non-zero cost associated with taking a control action (e.g., stopping a machine and readjusting it), and (ii) another more often occurring in the process industries where there is no direct cost associated with taking a control action (e.g., resetting the setpoint of a PID controller).

#### 6.1.1 *Non-Zero Costs:*

In this situation the optimal control policy (on the basis of maximizing profit) will not be to implement the MV control action (26) at every sampling interval. For small changes, the cost of stopping the production to make the changes will usually exceed the increased profit resulting from tighter control. The decision on whether or not to take action must obviously depend upon the relative cost associated with being off-target versus that associated with making a change. If control action is taken only infrequently, then between actions the process is running open-loop and thus

$$Y_t = D_t \quad (27)$$

At some point, where the predicted variation from target becomes sufficiently large a control action (26) must be taken. The resulting optimal control strategy therefore will be equivalent to an EWMA chart in which the EWMA predictions of the output deviations from target ($\hat{Y}_{t+1/t} \equiv \hat{D}_{t+1/t}$) are plotted. When the EWMA exceeds some control limit an action is taken, and the EWMA is restarted. Note that when the parameter $\theta$ of the disturbance model is equal to zero then $\hat{Y}_{t+1/t} = Y_t$, and the optimal control strategy is equivalent to that using a simple Shewhart control chart.

Although the optimal "non-zero cost" control strategy has been justified above on an intuitive basis, it has in fact been rigorously developed by Box et al. (1963, 1974) using dynamic programming methods. By considering that the loss associated with being off-target ($Y_t \neq 0$) is equal to $cY_t^2$, and the non-zero cost of making an adjustment is $C$, Box et al. also derived expressions for the placement of the upper and lower control limits. The placement of these limits depends upon relative costs ($c$,$C$) and the disturbance characteristics ($\theta$).

In summary, it has been shown that in the situation where there are both no process dynamics and non-zero control costs some of the traditional control chart methods indeed are optimal policies.

#### 6.1.2 *Zero Costs:*

Now consider a second situation, more common to the process industries, in which there is no cost associated with taking a control action. In this situation, there is no justification in waiting for a sufficiently large deviation from target before taking control action. Rather, to minimize the variance of the output deviations, the action (26) should be taken at every sampling interval. However, in this situation, the disturbance $D_t$, will no longer be simply equal to the measured output as in equation (27). Rather, the output will be a function of both the past control action and the disturbance, and hence the disturbance must be inferred by subtracting off the effect of past control actions, i.e.,

$$D_t = Y_t - g u_{t-1} \quad (28)$$

Substituting this into equation (26) gives the final MV controller. The structure of this controller is conveniently represented in the Internal Model Control (IMC) structure shown in Figure 7. The prediction of the process model output is subtracted from the measured output to reconstruct the disturbance. The disturbance is then passed through a first order prediction filter, and finally the control action is computed by multiplying this by the process model inverse.

In the IMC form (Figure 7) the calculated control action does not have to be implemented at every interval. However, if it is, then we can use operator algebra to express $D_t$ in terms of past outputs. Substituting the model for $D_t$ (equation 15) into the MV control equation (26) gives

$$u_t = -\frac{(1-\theta)}{g} \cdot \frac{1}{\nabla} a_t \qquad (29)$$

If this control action is implemented at each interval, then it is readily shown that the output deviation from setpoint ($Y_t$) is simply equal to the one-step ahead prediction error ($a_t$). Therefore substituting $Y_t$ for $a_t$ in (30) and expanding $\nabla^{-1}$ by long division as $(1+z^{-1}+z^{-2}+\ldots)$ we get the MV controller to be

$$u_t = -\frac{(1-\theta)}{g} \sum_{j=-\infty}^{t} Y_j \qquad (30)$$

This is a discrete "integral controller." Such pure integral controllers have found extensive applications in the process industries under similar conditions where fast dynamics and noisy, drifting disturbances are present. The most common example is that of flow controllers.

Note that the MV integral controller (30) resembles that of a CUSUM procedure (1), but the two are not equivalent. The MV integral controller relies upon control action being taken at every time interval, while the CUSUM procedure relies upon the fact that no control action is being taken as the CUSUM is being calculated. As shown in the above case of non-zero costs, the SPC equivalent of this integral control procedure is the EWMA chart.

## 6.2 With Process Dynamics

Consider now the case where process dynamics are important. This is the usual situation in the process industries unless the sampling interval ($T$) is very long. With the advent of on-line sensors and on-line actuators in the parts manufacturing industries, dynamics may also become important in those industries as the sampling interval is reduced.

Consider the process described by

$$Y_{t+b} = \frac{\omega(z^{-1})}{\delta(z^{-1})} u_t + D_{t+b} \qquad (31)$$

Again, the minimum variance controller is that which will cancel out the predicted effect of the disturbance on the output, that is

$$\frac{\delta(z^{-1})}{\omega(z^{-1})} u_t = -\hat{D}_{t+b/t} \qquad (3$$

The MV prediction will be given by

$$\hat{D}_{t+b/t} = F(z^{-1}) D_t \qquad (3$$

where $F(z^{-1})$ is the MV predicti filter. For the case of the first ord IMA disturbance $F(z^{-1})$ is the fir order filter (17). This MV controller illustrated in IMC form in Figure where again the disturbance reconstructed from the differen between the measurement and t process model output, and then pass through filter and process mod inverse blocks.

### 6.2.1 *Non-Zero Costs*

In the IMC form (Figure 8) the contr action does not have to implemented at every time period. an SPC environment where there a costs associated with taking contr action, the computed control action c be applied only when the predict output deviations exceed thresho limits. The limits again would depe upon the relative loss in being o target versus the cost of taking acti and upon the nature of t disturbance. In this way a band discrete MV controller in the IMC fo represents a generalization of S

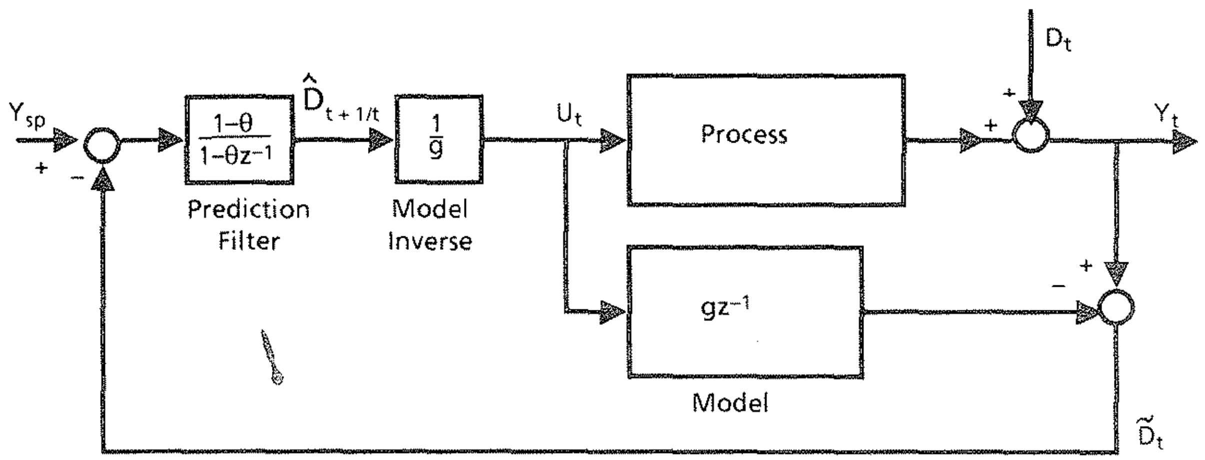


Figure 7: Minimum Variance Controller in IMC Form

control chart methods to systems with dynamics.

As an example, consider the first order process

$$Y_t = \frac{\omega_0}{1-\delta z^{-1}} u_{t-1} + \frac{1-\theta z^{-1}}{\nabla} a_t \qquad (34)$$

The MV controller is given by

$$\frac{\omega_0}{1-\delta z^{-1}} u_t = -\hat{D}_{t+1/t} \qquad (35)$$

where $\hat{D}_{t+1/t}$ is the EWMA predictor (18) of the reconstructed disturbance, $D_t$. Whenever the magnitude of $\hat{D}_{t+1/t}$ exceeded some threshold the control action (35) would be applied. However, since action is not being applied at every instant the rational polynomial on the LHS of (35) cannot be manipulated in the usual algebraic manner. Rather it should be expressed in impulse response form $v(z^{-1}) = \omega_0/(1-\delta z^{-1}) = (v_0 + v_1 z^{-1} + v_2 z^{-2} + \ldots)$ and implemented as

$$v_o u_t = (-v_1 u_{t-1} - v_2 u_{t-2} - v_3 u_{t-3} \ldots) - \hat{D}_{t+1/t} \qquad (36)$$

6.2.2 *Zero Costs*

If the calculated control action in (35) is applied at every sampling interval then again one can show that $Y_t = a_t$, and the usual algebraic manipulations of the operators can be used to express the controller in the form

$$u_t = \frac{(1-\theta)}{\omega_0} \cdot \frac{(1-\delta z^{-1})}{\nabla} Y_t \qquad (37)$$

$$= -\frac{(1-\theta)\delta}{\omega_0}[Y_t + \frac{(1-\delta)}{\delta}\sum_{j=-\infty}^{t} Y_j]$$

which is simply a discrete proportional plus integral controller–the mainstay of the process industries.

## 7. Further Considerations

In the previous section we considered only simple Minimum Variance stochastic control schemes. They were used to illustrate the parallels between SPC control chart methods and process control approaches. In particular, it was shown that for pure gain or steady-state processes in which there are non-zero costs associated with taking control actions, SPC charting methods can be optimal controllers. However, if there are no costs associated with taking control action, or if there exist process dynamics, then standard SPC charting methods can be far from optimal. In these latter situations, discrete stochastic control theory provides a more general and more powerful approach to quality control. Minimum variance, and Linear-Quadratic-Gaussian (LQG) control schemes (Astrom and Wittenmark, 1984; Harris and MacGregor, 1987) or variations of them such as Dynamic-Matrix Control (DMC; Cuttler and Ramaker, 1976) provide much more flexibility in handling process dynamics, dead-time and different disturbance structures, and they can be adapted to handle banded or non-zero cost control problems. However, the greatest benefit of these latter approaches comes from their ability to handle multivariable problems. In almost every quality control situation, many quality variables are measured. The previously mentioned processes for the production of synthetic butadiene rubber and for the production of synthetic fibres provide excellent examples. In these cases, product specifications are expressed in terms of not just one, but many quality variables that are measured off-line in the QC lab. The processes are also highly interactive in that

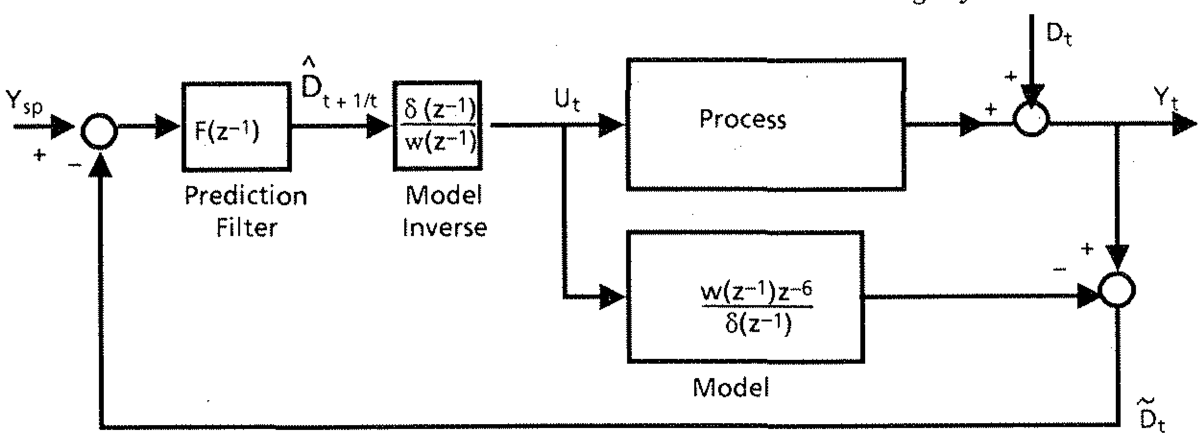


Figure 8: General Minimum Variance Controller in IMC Form

manipulating any one of the input variables (e.g., modifier flow rate, catalyst flow rate, or promoter flow rate) will affect almost all of the product quality variables. Hence the discrete control strategy should be multivariable in nature, and independent consideration of single variable SPC charts will usually be inefficient.

Hopefully, process control engineers will be pleased to see that the use of process control methods, with which they have some familiarity, are being advocated for tackling these discrete on-line quality control problems. However, before they feel too pleased about this, or before they say that all of this was obvious from the start, it should be noted that very few of them have ever used their process control methods to solve these problems. It has largely been the applied statiticians starting with Shewhart through to Deming who have addressed these problems. Furthermore, we need look no further than Japan to see how successful the intelligent use of such simple SPC methods have been in improving quality and productivity. Hence, it is not surprising that the quality control efforts being pushed by management are being channelled down through the companies' statistical organizations.

This poses a challenge to process control engineers to work with the statisticians and to demonstrate to them that process control theory often offers a better alternative to SPC charts for on-line control. However, there is also a lot that the process control engineer can learn from the statistician and from SPC methods. Aside from providing a procedure to decide on when to apply control actions to a process, SPC charts are invaluable as diagnostic tools. They highlight the periods where process upsets have occurred, and by analysing the process data in these periods one can often pinpoint the cause of the disturbances and perhaps eliminate or minimize such disturbances in the future. Of course, this is where real process improvement is made. Very efficient process control schemes often serve as bandaids that hide things that should be improved at the process level. To correct this control charts and other SPC methods could be used more frequently for analyzing control system performance, and as diagnostic tools.

## 8. Conclusions

In the introduction to this paper, it was stressed that there are many aspects to SPC. I have concentrated on only one of these in this paper; namely on the use of SPC charts for on-line control of product quality. Since statisticians and control engineers appear to have very little overlap in their knowledge base, this paper has used simple stochastic control theory to try to help bridge this gap.

It has been shown that control chart schemes are indeed optimal control schemes in many SPC situations, particularly in the parts manufacturing industries. However, to blindly extrapolate these methods to the process industries where process dynamics and control costs are very different, may not be efficient. On the other hand, there is much that the process control engineer can learn from the SPC movement. At the very least, he should capitalize on management's current commitment to improving product quality and productivity.

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## Review of Mathwriter, an Equation Writing Software Package for the MacIntosh

*by Bruce A. Finlayson*

There are very few computer programs that revolutionize how I work, but this is one of them. I have used the program for about nine months and have found it easy to use; it was designed with a technical writer in mind. The equations appear on the screen as they will in the document; this makes for easy editing. The program can, of course, do all the standard symbols: integrals, summations, fractions, and matrices. As an illustration of the excellent design, when an integral is chosen the computer immediately moves to the location for the lower limit of integration and automatically changes the font size to a smaller size. Superscripts and subscripts can be chosen with a mouse, and the font size is automatically reduced from what it was, as you would like. Greek letters are displayed at the bottom, and can be chosen with a mouse. This is easier than changing the font back and forth between Greek and Roman letters. There are many options available. For example, pallets containing all sorts of mathematical symbols can be added to the bottom as well. Equations, once formed, can be edited, copied, and otherwise changed. They can also be pasted into MacWrite and Word.

The program is especially useful for someone who uses lots of indices. You can create macros, like $c_{(i+1)}{}^{(n+1)}$. Then everytime that a symbol is needed it can be recovered with one keystroke. I found this feature especially useful when constructing finite difference formulations for transient problems. The ability to edit equations makes it almost faster to do the equations yourself rather than have a secretary do them; the time savings comes when an equation is modified for use in different parts of the document. I am able to do the modifications directly on the screen and avoid ever writing down the revisions on paper. The clear copy obtainable with the Laserwriter makes for a very satisfying result. The program creates the PostScript file needed by the Laserwriter. A version is also available to create a TEK file.

There is only one drawback. Once an equation is pasted into MacWrite, you cannot edit it. This means that you save a Mathwriter file, with all the equations, and also paste them into your document. If you need to revise a equation, you start with the Mathwriter file. This is because the Mathwriter format includes many more options than are needed to print the result, and only the needed ones are saved in the transfer to MacWrite. The equation documents are very large, but the MacWrite documents are not so large. When there are lots of super- and subscripts, the transfer to MacWrite is slow on a MacIntosh 512K machine, but fast enough on a Mac Plus. Once I learned to operate in this way, there were no particular problems. The program works with MacWrite and Word (and probably other software), but I have only used it with MacWrite.

What is exciting about this software is that it has affected the way I work. I can create equations on the computer; my hand-written notes are brief, since they include only enough information as needed to recognize the equation. Algebraic rearrangement can be done easily; the result is text that is more clear, with simpler steps, and is easier to follow. I have used the program extensively while writing a book, and the program is a virtual necessity now.

The software is available for $49.95 from Cooke Publications, P. O. Box 4448, Ithaca, New York 14852.

## Mrs. Elizabeth Hughes to Receive the Memorial Issue of Computers and Chemical Engineering in Honor of Prof. Richard R. Hughes at the CAST Division Dinner, November 18, 1987

The Memorial Issue, edited by Prof. Warren D. Seider, will be presented to Betty Hughes at the CAST Dinner in the New York Hilton on November 18. It contains articles by many close associates of Dick Hughes and is summarized below:

In Memory of Richard R. Hughes
W.D. Seider

Last Family Supper with Prof. Hughes
R. Malik

"A Robust Technique for Process Flowsheet Optimization Using Simplified Model Approximations"
N. Ganesh, L.T. Biegler

"Sequential Modular and Simultaneous Modular Strategies for Process Flowsheet Optimization"
T.P. Kisala, R.A. Trevino-Lozano, J.F. Boston, H.I. Britt, L.B. Evans

"Rapid Phase Determination in Multiple-Phase Flash Calculations"
P.A. Nelson

"Heterogenous Azeotropic Distillation-Homotopy-continuation Methods"
J.W. Kovach, III, W.D. Seider

"The Dominant Time Constant for Distillation Columns"
S. Skogestad, M. Morari

"An Algorithmic Procedure for the Synthesis of Distillation Sequences with Bypass"
R. Wehe, A.W. Westerberg

"Optimal Reflux Rate Policy Determination for Multicomponent Batch Distillation Columns"
U.M. Diwekar, R.K. Malik, K.P. Madhavan

"Synthesis and Sizing of Batch/Semicontinuos Processes: Single Product Plants"
N.C.C. Yeh, G.V. Reklaitis

"DESIGN-KIT: An Objective-oriented Environment for Process Engineering"
G. Stephanopoulos, J. Johnston, T. Kriticos, R. Lakshamann, M. Mavrovouniotis, C. Siletti

"Active Constrint Strategy for Flexibility Analysis in Chemical Processes"
I.E. Grossmann, C.A. Floudas

"Strategies for Formulating and Solving Two-stage Problems for Process Design under Uncertainty"
C.-C.D. Pai, R.R. Hughes

"Sensitivity to Modelling Errors in Steady-state Process Simulation"
I.H. Rinard

"Structural Design for Systems Fault Diagnosis"
S.W. Park, D.M. Himmelblau

"A Review of Spreadsheet Usage in Chemical Engineering Calculations"
E.M. Rosen, R.N. Adams

"Solution of Dynamic Distributed Parameter Model of Nonadiabatic, Fixed-Bed Reactor"
J.C. Pirkle, Jr., S.C. Reyes, P.S. Hagan, H. Kheshgi, W.E. Schiesser

"Use of 2D-Adaptive Mesh in Simulation of Combustion Front Phenomena"
J. Degreve, P. Dimitriou, J. Puszynski, V. Hlavacek, S. Valone, R. Behrens

"Contribution of Multiple Scattering to Light Transmission by a Collimated Beam"
S.S. Ou, J.D. Seader

"Inversion of Sparse Matrices by a Method based on Graph Theory"
G. Samuel, M. Pollatschek, E. Kehat

Copies are available from Pergamon Press for $25.00 per copy.

## The Intel iPSC/2: The First Concurrent Supercomputer for Production Applications

On August 31, 1987, Intel announced what it considers to be the next generation of concurrent computers, the iPSC/2. The Intel iPSC/2 offers full 32-bit node architecture, up to a gigabyte of memory, concurrent development tools (Concurrent Workbench (TM)), and new communications between nodes (Direct-Connect Routing). A standard system consists of 32 to 128 nodes. At each node, there is a Direct-Connect (TM) Routing Module; 1, 4, 8, or 16 megabytes of modular memory; an 80386 processor; an 80387 floating-point processor; and a UNIX-based development environment. An extended memory iPSC/2 MX system has 16 megabytes of memory per node, expandable to 64 nodes.

A vector iPSC/2 VX system consists of 16 to 64 nodes; a vector coprocessor paired with each node; and the VAST vectorizer. The peak performance of a single node is 20 million floating-point operations per second (MFLOPS) for single-precision calculations.

The cost of the iPSC/2 family of concurrent supercomputers ranges

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from $200,000 to $2,000,000. For further information, contact Chris Wain, Intel Corporation, 15201 N.W. Greenbrier Parkway, Beaverton, OR 97006, (503) 629-7631.

## Forum

In the April issue of CAST Communications we asked for readers comments on machine architecture, software systems and user interfaces. The following response from Gary D. Cera at DuPont was particularly interesting and we have enclosed it for your interest.

The Editors

## To the Editor

by Gary D. Cera

In the April 1987 issue of the AIChE Computing And Systems Technology (CAST) Division Communications newsletter the editors solicited responses concerning the ideal workstation and its attributes. I am eager to write this reply because I feel that although there are many readers of this newsletter who are working at the forefront of Chemical Engineering science, many of these researchers have not kept pace with the advances in state-of-the-art computing hardware and software that is capable of making them more productive in their profession. I suspect that the items on many engineers' "wish lists" can, for the most part, be filled by existing products but most researchers are unaware of the availability of the hardware or software for any one of a number of reasons. One such reason is that computer technology is changing much more rapidly than our fundamental engineering knowledge. Unless one is actively engaged in scientific computing (which I take to mean learning new computer languages, being aware of and evaluating new hardware, and keeping abreast of new software developments in one's field) it would be difficult to keep pace with advances in such a rapidly changing field. I would therefore like to share my impressions of the computer equipment that I have selected to use and would welcome views from those using other workstations.

I currently have three "desktop" machines in my office. The machines are: (1) a SUN 3/50 workstation, (2) a MacIntosh Plus computer, and (3) a Symbolics 3620 LISP machine. I will elaborate on each of their characteristics and uses in order of usage from the machine I use the most in my daily work to machines used less frequently.

A SUN 3/50 workstation is my primary workhorse. It is a diskless client node connected via an Ethernet local area network to a SUN 3/260 file server. The 3/50 is an impressive 1.5 MIPS machine in its own right and is networked to an even faster 4 MIPS file server cpu which can provide several users with the equivalent processing power of a DEC VAX 11/780. The 3/50 is configured with 4 megabytes of memory, a Motorola 68020 cpu running at 15 megahertz and a Motorola 68881 floating point coprocessor chip. It has a large 19 inch 1152 x 900 pixel monochrome screen and has an optical mouse. Two serial ports are provided which are often used for printer and modem peripherals.

Our SUN 3/260 file server is configured with 16 megabytes of memory, a Motorola 68020 cpu running at 25 megahertz and a Motorola 68881 floating point coprocessor chip. It has a large 19 inch 1600 x 1280 pixel high-resolution monochrome screen and has an optical mouse. Two serial ports are also provided on this unit. The 3/260 acts as a file server having 560 megabytes of disk storage which it shares among many "diskless" client nodes connected to it on one of our local area networks. Programming languages that we have installed which are used to solve chemical engineering problems are FORTRAN, C, C++, and LISP.

SUN workstations run the UNIX operating system. UNIX tends to be the "programmers" operating system of choice due to its rich set of commands and tools. UNIX is a multitasking operating system and SUN's development software toolkit provides for multiple windows on the screen. The multiwindow environment provides a tremendous increase in productivity since one can essentially work on several tasks simultaneously. I typically have three to four windows of various sizes opened simultaneously on my screen such as a text editor window, a window to the 3/260 which allows me to compile and link code on the faster 3/260 cpu, a graphics window for execution of my application programs, and a console window which informs me instantly of the arrival of electronic mail or diagnostic messages. A typical scenario for using the multiwindow system is to edit source code in one window, compile and link on another machine in another window, while simultaneously running and debugging previously compiled changes in yet another window. Typical applications I work on include graphical mouse/icon interactive process design and simulation programs, process simulation programs on a BBN Butterfly multiprocessor computer, and artificial intelligence applications in Process Engineering.

My secondary machine is a MacIntosh Plus. I composed this letter on the "Mac" and eventually performed a text file transfer to a SUN 3/110 gatewayed to BITNET in order to deliver this letter to the editors. All my correspondence (with the exception of electronic mail) including internal memoranda and papers for outside publication are composed on the Mac since there is an abundance of third-party software which makes it easy to merge publication-quality text and graphics. I create design drawings and document laboratory setups by sketching on the Mac because the computer-aided drawing programs available for this machine are simple and expedient to use due to the synergy of the MacIntosh's man/machine interface.

My third machine is a Symbolics 3620 artificial intelligence workstation with 4 megabytes of memory. This machine, like the SUN workstation, is also connected to our local area network and communicates via CHAOSNET with Symbolics, LMI, and Texas Instruments LISP machines. It shares files via TCP/IP with our UNIX machines and also supports DECNET for communication with our DEC machines. The 3620 is used to develop artificial intelligence applications for chemical process engineering.

The three machines I just described although very different in design philosophy have several important factors in common. The one shining feature shared by all three machines is the man/machine interface. Rote memorization of keyboard commands has been reduced due to substantial integration of "point-and-click" mouse selection with both the operating system and application software. In addition, all of these machines "feel" fast. There is nothing more frustrating than having to wait (and wait ... and wait ...) for a login to complete or for a menu or graph to pop up on the screen. I prefer the 32-bit cpu architectures because they noticeably outperform their 16-bit architecture counterparts in speed. A large high-resolution screen is best for ease of readability in a multiple window system since in that environment one often tries to fit much more information on a screen than a normal personal computer screen can handle. The MacIntosh Plus has a 9 inch screen which is uncomfortably small, but the newer MacIntosh II model has a larger 12 inch screen which is easier on one's eyes. Languages (i.e., FORTRAN, C, LISP) as well as operating systems (i.e., UNIX, VMS) are mostly a matter of user preference. I personally prefer the C programming language on a UNIX operating system since I know that the code I write will easily port to numerous vendor's machines both now and in the future.

At the present time, these three machines together satisfy all of my conventional computing requirements. I suspect that within the next five years that I will have only one machine in my office which will undoubtedly exhibit the best features of all three machines at a price under $10,000.

Gary D. Cera, E. I. DuPont de Nemours & Co., Experimental Station E328162B, Wilmington, DE 19898, (302) 695-1423. UUCP: {dgis, psuvax1}!eplrx7!cera, BITNET: CERA@DUPONTCR,

## To the Editor

by Henry A. McGee, Jr.

Chemical engineering is in a period of change. The Washington Annual Meeting and 80th Commemorative Celebration in 1988 will seek to highlight the state of the art as well as point toward the new, the different, and the most potential-laden areas of scientific opportunity and professional service. We also hope to capitalize on our presence in Washington D.C. immediately following the presidential elections to emphasize the political and social relevance of our enterprise.

We would like for the Washington Annual Meeting to be the most stimulating, the most provactive, and the most memorable AIChE meeting in anyone's recollection. I choose to experiment with a modified meeting format, with as many as twelve featured sessions to present the latest thinking from each programming area. On each morning, Monday through Thursday, there would be three such parallel sessions (there would be no featured sessions on Friday morning). We want each of these sessions to be "blockbusters." Only one such session has been confirmed, and it will deal with new developments in high-temperature superconductivity.

At other times throughout the week, including the evenings, we also will feature as many as nine special lectures where I hope well-known and stimulating people such as President Reagan, Lee Iacocca, Tom Peters, Eric Bloch, Secretary Bennett (Education), speakers from outside the United States, and others will appear.

Clearly, these innovations will be successful *only* if the National Program Committee makes it so. CAST then has at least three major challenges: (1) If you have one thousand or more of the Annual AIChE Meeting attendees at your morning session, what will you say and who will say it? (2) Who are the best possible special lecturers for the nine unopposed slots? Neither plenary speakers nor participants in plenary sessions need be chemical engineers. (3) Of the Area 10a, 10b, 10c, and 10d sessions that you are contemplating for the Washington D.C. meeting which are the most important and essential to your Division members as well as other attendees at the meeting?

Some key words for the meeting are impact, discovery, competitiveness, renaissance, management, international, political, and business. A unifying theme must still be selected, but it will involve these sorts of words.

We expect a total attendance of 4000 to 5000 in Washington. Space for nearly 200 sessions has already been requested, and more requests are arriving each day. None will be confirmed until the special "blockbuster" sessions are set. **Please call or write to me with your ideas–even fragmentary ideas–before November 1, 1987.** My address is Department of Chemical Engineering, Virginia Tech, Blacksburg, Virginia 24061; (703) 961-5258. Your immediate input is essential and sincerely appreciated.

The Technical Program Committee for the 1988 Washington D.C. Annual Meeting consists of Henry A. McGee (Virginia Tech, Chairman of Technical Program Committee), Tom Sciance (DuPont, Co-Chairman of Conference on Emerging Technologies in Materials, Minneapolis, August 1987), Attilio Bisio (CEP editor), Elmer Gaden (University of Virginia), Marshall Lih (NSF), and two colleagues from my own department, Y. A. Liu and Peter R. Rony (CAST Communications editor).

Henry A. McGee, Jr.
Department of Chemical Engineering
Virginia Tech
Blacksburg, Virginia 24061

## Meetings and Conferences

The following items summarize information in the hands of the Editor by August 15, 1987. Please send CAST Division session information, meeting, and short course announcements to me by January 1, 1987 (because of fact that the New Orleans meeting is at the beginning of March 1987) for inclusion in the spring 1988 issue of CAST Communications.

Peter R. Rony,
Editor, CAST Communications

## New York City AIChE Meeting (November 15-20, 1987)

**Area 10a Sessions**

1-2. **Design and Analysis I and II.** Richard S. H. Mah (Co-Chairman),Department of Chemical Engineering, Northwestern University, Evanston, IL 60201, (312) 491-5357 and Iftekhar Karimi (Co-Chairman), Department of Chemical Engineering, Northwestern University, Evanston, IL 60201, (312) 491-3558.

Session I:

"Systematic Procedures to Improve Process Flexibility in Retrofit Design," by Pistikopoulos and Grossmann

"Optimal Design Under Risk and Uncertainty," by Sunol

"Design and Analysis of Solids Processes," by Ng and Douglas

"SPARO: A System for Process Analysis of Refining Operations," by Kesler, Graham, and Weissbrod

"Reactor Selection and Optimization Using SIMUSOLV," by Blau and Dixit

"Developing Targets for the Performance Index of a Chemical Reactor Network," by Achenie and Biegler

Session II:

"Heuristic Synthesis of Sloppy Multicomponent Separation Sequences," by Cheng and Liu

"Synthesis and Optimal Design of Alternative Sequences for Separating Heterogeneous Azeotropic Mixtures," by Ryan and Doherty

"Recent Advances in the Analysis of Heat Recovery Problems," by Jones and Rippin

"Synthesis of Utility Systems Integrated with Chemical Processes," by Colmenares and Seider

"Process Integration Subject to Match Constraints," by O'Young and Linnhoff

"Design and Analysis of Heat Integrated Distillation Sequences for Multiperiod Operation," by Paules and Floudas

3. **Computer Aided Design of Batch Processes.** Kris R. Kaushik (Chairman), Shell Oil Company, P. O. Box 2099, Houston, TX 77252-2099, (713) 241-2098 and Malcolm L. Preston (Vice Chairman), Imperial Chemical Industries PLC, P. O. Box 7, Winnington, Northwich, Cheshire CW8 4DJ, England.

"Process Integration of Batch Processes," by Linnhoff and Jenkins

"Design of Multiproduct Batch Plants under Uncertainty with Staged Expansion," by Wellons and Reklaitis

"Design of Batch Distillation by Interactive Simulation on a Microcomputer," by Kolber and Anderson

"Design of Multiproduct Noncontinuous Processes with Intermediate Storage," by Modi and Karimi

"Incorporating Scheduling in the Optimal Design of Multiproduct Batch Plants," by Birewar and Grossmann

"Design of Flexible Multiproduct Plants–A New Procedure for Optimal Equipment Sizing under Uncertainty," by Reinhart and Rippin

"Efficient and Simplified Solution to the Predesign Problem of Multiproduct Plants," by Espuna, Lazaro, Martinez, and Puigjaner

4. **Artificial Intelligence in Process Engineering.** H. Dennis Spriggs (Chairman), Linnhoff March, P. O. Box 2306, Leesburg, VA 22075, (703) 777-1118 and V. Venkatasubramanian (Vice Chairman), Department of Chemical Engineering, Columbia University, New York, NY 10027, (212) 280-4453.

"Heat Exchanger Network Synthesis: A Knowledge Engineering Approach," by Fan

"An Expert System for Designing Distillation Plates," by Davis, Myers, and Herman

"STES: A Separation Process Expert System," by Netterfield and Sunol

"RIP: A Prototype Expert System for Retrofitting Chemical Plants," by Nelson and Douglas

"Design of Polymer Composites: A Blackboard Approach," by Venkatasubramian, Lee, and Gryte

"POPS: The Prototype Operating Procedure Synthesis Program," by Fusillo

### Joint Areas 10a and 10b Session

1. **Integration of Process Design and Control.** Bradley R. Holt, Department of Chemical Engineering, BF-10, University of Washington, Seattle, WA 98195, (206) 543-0554 and W. David Smith (Vice Chairman), Polymer Products Division, E. I. DuPont de Nemours and Co., Wilmington, DE 19898, (302) 772-1476.

"Robustness Measures Based on Refined Eigenvalue Inclusion Regions (REIR): Implications for Process Design and Control," by Kjambanonda and Palazoglu

"Simultaneous Process Synthesis and Control of Chemical Processes," by Floudas

"Optimum Size and Location of Surge Capacity on Continuous Chemical Processes," by Hiester, Melsheimer, and Vogel

"Control System Synthesis and Intermediate Storage Design for Interconnected Chemical Plants," by Co and Ydstie

"Process Monitoring and Control Strategies for Anaerobic Wastewater Treatment," by Ricker, Slater, Merigh, Furguson, and Benjamin

"A Target for the Flexibility Index for Heat Exchanger Networks," by Colberg and Morari

For further details concerning Area 10a sessions and scheduling, please contact Jeffrey J. Siirola (Chairman, Area 10a), ECD Research Laboratories, Eastman Kodak Co., Kingsport, TN 37662, (615) 229-3069.

### Area 10b Sessions

1. **Control of Batch Process** . Mark Juba (Chairman), Eastman Kodak Co., Bldg., 337, Kodak Park, Rochester, NY 14650, (716) 558-3637 and Christos Georgakis, Process Model and Control Research Center, 443 Whitaker Bldg., Lehigh University, Bethlehem, PA 18015, (215) 758-4781.

"Simultaneous Optimization and Solution Methods for Batch Reactor Control Profiles," by Cuthrell and Biegler

"Using Process Information to Control a Multipurpose Batch Chemical Reactor," by Davidson

"Experimental Studies of State and Parameter Estimation for the Control of Batch Reactors," by deValliere and Bonvin

"Adaptive Strategies for Automatic Start-up and Control of a Batch Process," by Merkle and Lee

"Optimization of Semibatch Copolymerization Reaction," by Cawthon and Knaebel

"Nonlinear Composition Control in Batch Copolymerization Reactors," by Kravaris and Wesson

"On Batch Process Control," by Manousiouthakis

"Batch Reactor Modeling, Optimization and Control by Use of Tendency Models," by Georgakis, Filippi, Bordet, and Villermaux

2. **Expert Systems Applied to Process Control**. Richard Weber (Chairman), Exxon Chemicals, P. O. Box 100, Baytown, TX 77520, (713) 428-6385 and George Stephanopoulos, Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, (617) 253-3904.

"Heuristic Manipulation of Process Identification and Adaptive Control Algorithms," by Cooper

"POPS: The Prototype Operating Procedure Synthesis Program," by Fusillo

"Expert Multivariable Control," by Georgakis, Tzouras, and Ungar

"An Operator Advisor for Controlling Corrosion in a Crude Fractionator," by Chen, Dasgupta, Loushin, Morley, and Pollack

"COMA: A Configurable Operator Monitor and Advisor Integrated into a Real-Time Control System," by J Adams

"Knowledge-Based, Real-Time Sensor Interpretation for Process Plants, by Touchton

"Operation Instruction System," by Ikuta, and Hamanaha

"Qualitative Modeling of Dynamic Systems," by Dalle Molle and Edgar

3. **Adaptive Control.** Won Kyoo Lee (Chairman), Department of Chemical Engineering, Ohio State University, Columbus, Ohio 43210, (614) 292-7907 and Dale Seborg, Department of Chemical and Nuclear Engineering, University of California, Santa Barbara, CA 93106.

"A Review of RLS Estimation Schemes for Adaptive Control," by Shah and Cluett

"Generation of Binary Multifrequency Signals for Use in Adaptive Control Algorithms," by Harris and Czekai

"Parameter Estimation and Adaptive Control with Multi-Rate Sampled-Data Models," by Young and Mellichamp

"Multivariable Adaptive Control with the Generalized Analytical Predictor," by Pavlechko and Edgar

"A Multivariable Cautious Self-Tuning Controller," by Papadoulis and Svoronos

"Bifurcation and Complex Dynamics in Adaptive Control Systems," by Golden and Ydstie

4-5. **Recent Developments in Process Control I and II** Evanghelos Zafiriou (Chairman of Session I), Department of Chemical Engineering, University of Maryland, College Park, MD 20742, (301) 45[illegible] 2431; Amhet Palazoglu (Chairman of Session II), Department of Chemical Engineering, University of California, Davis, CA 95616, (916) 752-8774; and Jim Rawlings (Vice Chairman of both sessions), Department of Chemical Engineering, University of Texas, Austin, TX 78712-1062, (512) 47[illegible] 3080.

Session I:

"Controller Tuning of Interacting Loops: A Model-Independent Approach," by Hwang and Chang

"A Control-Relevant Identification Methodology," by Rivera, Webb and Morari

"Model Predictive Control of Unstable Systems," by Cheng and Brosilow

"Control of A Multivariable Open-loop Unstable Processes," by Georgiou, Luyben and Georgakis

"Control of Linear Multivariable Systems Having Delays and RHP Zeros," by Jerome, and Ray

"On the Role of the Time-delay Matrix in Multivariable Control," by Shah, Mohtadi, and Clarke

"Discrete and Continuous Time Interactors for Multivariable Process Control," by Tsiligiannis and Svoronos

Session II:

"Detecting and Avoiding Unstable Operation of Autothermal Reactors, by Gusciora and and Foss

"Robustness Analysis of High Purity Distillation Control Using Highly Structured Correlated Model Uncertainty Descriptions," by McDonald and Palazoglu

"Feedforward and Feedback Linearization of Nonlinear Systems with Disturbances and its Implementation Using IMC: Theory and Applications," by Calvet and Arkun

"Robust Stability of Nonlinear State Feedback Controllers," by Kantor, Keenan, and Limqueco

"Robust Nonlinear Control of "Minimum Phase" Nonlinear Systems," by Kravaris, Palanki and Wright

"A Strategy for Constrained Nonlinear Control Problems," by Li and Biegler

"Nonlinear Adaptive Control Using Static Gains," by Golden and Ydstie

For further details concerning Area 10b sessions and scheduling, please contact Yaman Arkun (Chairman, Area 10b), Department of Chemical Engineering, Georgia Tech, Atlanta, Georgia 30332, (404) 894-2871.

## Area 10c Sessions

1-2. **Advances in Optimization I and II.** Ignacio Grossman (Chairman), School of Chemical Engineering, Olin Hall, Cornell University, Ithaca, NY 14853, (607) 255-7204 and Lorenz T. Biegler (Vice Chairman), Department of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2232.

Session I:

"Successive Quadratic Programming Methods for Chemical Process Optimization," by Hoza and Stadtherr

"Large-Scale Decomposition for Sequential Quadratic Programming," by Vasantharajan and Biegler

"Computational Representation of Thermodynamic Surfaces for Use in Optimization," by Swaney and Bell

"Global Methods for Chemical Process Optimization," by Lucia

"Optimization of Sulfuric Acid Process Using the Chemshare Flowsheeting System," by Richards and Pike

"Optimization with SPARO-System for Process Analysis in Refining Operations," by Kesler, Graham, and Weissbrod

Session II:

"On-Line Optimization of Complex Process Units: A Comparison of Centralized versus Distributed Approaches," by Darby and White

"Global Optimization of Nonconvex MINLP Problems in Process Synthesis," by Kocis and Grossman

"Simultaneous Heat Integration and Optimization of Distillation Sequences," by Lin and Prokopakis

"An MINLP Formulation for the Synthesis of Continuous Pressure Heat Integrated Distillation Sequences," by Floudas and Paules

"Process Optimization Through Symbolic Computation," by Sunol

"Adaptive Polynomial Approximations for Optimal Catalyst Profiles," by Heydweiller and Akgiray

3-4. **Scheduling and Planning of Operations. I. Continuous Processes, II. Batch Processes.** Moe Sood (Chairman), Mobil R and D Corporation, P. O. Box 1026, Princeton, NJ 08546, (609) 737-4960, and G. V. Reklaitis (Vice Chairman), School of Chemical Engineering, Purdue University, West Lafayette, IN 47907, (317) 494-4089.

Session I:

"Approximate Methods for the Scheduling of Single-Stage Batch Processes withParallel Units," by Musier and Evans

"An Improved Algorithm for Scheduling of Serial Multiproduct Batch Processeswith Mixed Storage," by Ku and Karimi

"Scheduling Network Flowshops so as to Minimize Makespan," by Kuriyan and Reklaitis

"Multiple Routings and Reaction Paths in Project Scheduling," by Rich and Prokopakis

"Optimal Schedule Generation for a Single Product Production Line," by Wellons and Reklaitis

"Minimizing the Effects of Batch Process Variability using On-Line Schedule Modification," by Cott and Macchietto

Session II:

"Optimization Model for Long Range Planning In the Chemical Industry," by Grossmann, Fornari, and Chatrathi

"Refinery Planning, Scheduling, Monitoring, and Control: Quantitative Capability for Management Requirements," by Dorweiler and Bryant

"Productivity Analysis of a Large Multiproduct Batch Processing Facility," by White

"Planning and Scheduling of Batch Operations," by Thomas and Shobrys

"Refinery Performance and Refining Methods," by Dorweiler and Bryant

"Approximate Method for Scheduling Multiproduct Multiline Operations," by Ford

5. **On-Line Fault Administration.** Mark Kramer (Chairman), Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, (617) 253-6508 and J. F. Davis (Vice Chairman), Department of Chemical Engineering, Ohio State University, 140 West 19th Avenue, Columbus, Ohio 43210.

"Operator-Assisted Learning in Expert Systems for Process Fault Diagnosis," by Venkatasubramanian

"A Connectionist Expert System Approach to Fault Diagnosis in the Presence of Noise and Redundancy," by Gallant

"Expert System in a Wastewater Treatment Process Diagnosis," by Marcos

"An Operator Aid for Analysis of Disturbances in Distillation Columns," by Andow

"MOLDOCTOR: An Expert Systems for Fault Diagnosis and Remedies in Injection Molding of Plastics," by Shenoy

"A Method of Fault Diagnosis: Presentation of a Deep-Knowledge System," by Modarres

"Real-Time Hazard Aversion and Fault Detection: Multiple Loop Control Example," by Ulerich

For further details concerning Area 10c sessions and scheduling, please contact Ignacio Grossman, School of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2228.

### Area 10d Sessions

1. **What Has Applied Mathematics Done for Chemical Engineers? What Next?** D. Ramkrishna (Chairman), School of Chemical Engineering, Purdue University, West Lafayette, IN 47907, (317) 494-4066 and Christos G. Takoudis (Vice Chairman), School of Chemical Engineering, Purdue University, (317) 494-2257; and Neal R. Amundson (Honorary Chairman), Department of Chemical Engineering, University of Houston, Houston, TX 77004.

"Models: Good and Bad," by Aris

"Chemical Reaction Engineering in Practice," by Krambeck

"Computer-Aided Mathematical Analysis," by Scriven

"Modern Analysis of Steady-State Multiplicity," by Luss

"The Role of Applied Mathematics in Polymerization Engineering," by Ray

"The Impact of Applied Mathematics in Computer-Aided Design," by Reklaitis

"Some Peculiarities in the Relationship between Mathematics and Chemical Reaction Engineering," by Feinberg

"Reflections," by Amundson

### Joint Areas 10d and 1h Sessions

1-2. **Instabilities and Nonlinear Phenomena in Chemical Engineering Systems I and II,** Runga Narayana (Co-Chairman), Department of Chemical Engineering, University of Florida, Gainesville, FL 32611, (904) 392-9103 and Gerasimos Lyberatos (Co-Chairman), Department of Chemical Engineering, University of Florida, (904) 392-0898.

"The John-Szekely Law of Additive Times," by Stakgold

"A New and Very Simple Method for the Solution of Stiff Differential Equations," by Hanna

"The Bifurcation of Feedback-Controlled Chemical Reactors," by Adomaitis and Cinar

"Weak Perturbation Theory for Periodic Systems," by Sterman and Ydstie

"Bifurcation of Quasiperiodic and Nonstationary Planforms under External Forcing," by Pismen

"The Dynamic Behavior of the Solution Polymerization of Vinyl Acetate in a CSTR," by Teymour and Ray

"Instabilities and Feedback Identification of Dynamic Reaction Systems with Multiple Delays," by Galatheos and Tsiligiannis

"Controller Induced Bifurcations in Time-Delay Systems," by Boe and Chang

"On the Analysis and Control of Basins of Attraction in Multi-stable Lumped Systems," by Keurekidis

"Spatial Wavelength Dependence of Directional Solidification Cells With Finite Depth," by Ramprasad, Brown, and Leal

"Bifurcation Phenomena in Mixed Convection Flows," by Jensen

The above sessions were developed by Area 10a but have now been transferred to the newly formed Area 10d. For further details concerning Area 10d sessions and scheduling, please contact Doraiswami Ramkrishna, Purdue University, School of Chemical Engineering, West Lafayette, IN 47907, (317) 494-4066.

## New Orleans AIChE Meeting
### (March 6-10, 1988)

### Area 10a Sessions

1. **Recent Advances in Computer-Aided Process Design.** Henry H. Chien (Chairman), Monsanto Company–CS7N, 800 N. Lindbergh Blvd., St. Louis, MO 63167, (314) 694-8274 and Jude T. Sommerfeld (Vice Chairman), School of Chemical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, (404) 894-2873.

2. **Simulation and Optimization of Unusual Systems.** Edward M. Rosen (Chairman), Monsanto Company-CS7S, 800 N. Lindbergh Blvd., St. Louis, MO 63167, (314) 694-6412 and Heinz A. Preisig (Vice Chairman), Department of Chemical Engineering, Texas AM University, College Station, TX 77843-3122, (409) 845-0386.

3. **Practical Application of Statistical Methods in the Processing Industries.** Gary E. Blau (Chairman), Dow Chemical Company, 1776 Building, Midland, MI 48674, (517) 636-5170 and David M. Himmelblau (Vice Chairman), Department of Chemical Engineering, University of Texas, Austin, TX 78712, (512) 471-7445.

4. **Applications of Personal Computers.** Peter R. Rony (Chairman), Department of Chemical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, (703) 961-7658 and Babu Joseph (Vice Chairman), Department of Chemical Engineering, Washington University, St. Louis, MO 63130, (314) 889-6076.

**Joint Areas 10a and 10b Session**

1. **Retrofitting for Improved Process Control.** Eli Neisenfeld (Chairman), Applied Synaptics, P.O. Box 634, Ridewood, MD 21139, (301) 821-5178 and James M. Douglas (Vice Chairman), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-2252

**Joint Areas 10a and 10c Sessions**

1-2. **Industrial Applications of Expert Systems I and II.** Krishna R. Kaushik (Co-Chairman), Shell Oil Company, P.O. Box 2099, Houston, TX 77252-2099, (713) 241-2098 and Mohinder K. Sood (Co-Chairman), Mobil R and D Corporation, P.O. Box 1026, Princeton, NJ 08540, (609) 737-4960.

For further details concerning Area 10a sessions and scheduling, please contact Michael F. Doherty (Area 10a Chairman-Elect), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-2359.

**Area 10b Sessions**

1. **Industrial Applications of Multivariable Control.** Heinz A. Preisig (Chairman), Department of Chemical Engineering, Texas A and M University, College Station, TX 77843-3122, (409) 845-0386 and Simon Tuffs (Co-Chairman), Process Control and Computer Technology, Division Alcoa Laboratories, Alcoa, PA 15069, (412) 337-2946.

2. **Experiences with On-Line Optimization.** Dr. Babu Joseph (Chairman), Department of Chemical Engineering, Campus Box 1198, Washington University at St. Louis, St. Louis, MO 63130, (314) 889-6076 and Lynn a Richard (Co-Chairman), Department Manager, Setpoint Inc., 950 Threadneedle, Houston, TX 77079, (713) 496-3220.

3. **Retrofitting for Improved Process Control.** James M. Douglas (Chairman), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-2252 and Eli Neisenfeld (Co-Chairman), Applied Synaptics, P. O. Box 634, Ridewood, MD 21139, (301) 821-5178.

For further details concerning Area 10b sessions and scheduling, please contact Yaman Arkun (Chairman, Area 10b), Department of Chemical Engineering, Georgia Tech, Atlanta, Georgia 30332, (404) 894-2871.

**Area 10c Sessions**

1-2. **The Role of Computers in Safety and Reliability I and II.** Richard S. H. Mah (Chairman), Department of Chemical Engineering, Northwestern University, Evanston, IL 60201, (312) 491-5357 and Ernest Henley (Vice Chairman), Department of Chemical Engineering, University of Houston, Houston, TX 77004, (713) 749-4947.

3-4. **Computer-Aided Engineering I and II.** Rajeev Gautam (Chairman), Union Carbide Corporation, P. O. Box 8361, South Charleston, WV 25303, (304) 747-3710 and Pete Parker (Vice Chairman), Shell Oil Company, P.O. Box 10, Norco, LA, (713) 241-6214.

For further details concerning Area 10c sessions and scheduling, please contact Ignacio Grossman, Department of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2228.

## Understanding Process Integration II, University of Manchester, England
**(March 22-23, 1988)**

**Call for Papers.** The full papers should have been submitted for refereeing by August 1, 1987. The final camera-ready version will be required by December 1, 1987.

The conference will be concerned with the design of integrated processes, both chemical and biochemical, and will concentrate on the following areas:

Reaction paths: techniques leading to novel reaction routes for new or existing products.

Separation systems: The synthesis of total separation systems involving distillation or other separation techniques, such as crystallization and membranes.

Heat recovery, heat power, and utility systems: The design of heat recovery and combined heat and power systems

Process operability and uncertainty in design: The design of integrated systems against a background of variable feedstocks and production requirements, etc.; or uncertainty in design parameters (technical or economic).

Batch processes: Systematic approaches to the design of integrated batch processes.

Steady-state and dynamic simulation: Recent research or applications experience in using simulators to evaluate integrated systems

Case studies in process integration: Case studies from continuous or batch processing in the oil, chemical, petrochemical, pharmaceutical, food, cement, steel, and paper industries showing the application of integration techniques.

Further information can be obtained from:

Mr. D. V. Greenwood (Conference Secretary), 45 Hadrian Way, Sandiway, Northwich, Cheshire CW8 2JT, United Kingdom. Tel: 0606 888238.

Dr. R. Smith, Chemical Engineering Department, UMIST, P.O. Box 88, Manchester M60 1QD, United Kingdom. Tel: 061 236-2174.

Mr. P. R. Crump, Design Systems Group ICI Engineering Dept., Brunner House, Winnington, P.O. Box 7, Northwich, Cheshire CW8 4DJ, United Kingdom. Tel: 0606 70-4887.

## Model-Based Process Control (International Workshop), Atlanta

**(June 13-14, 1988)**

**Call for Papers.** This Workshop will be concerned with the state of the art of model-based process control, including but not limited to model predictive, internal model, and dynamic matrix control. The Workshop will provide a forum for the presentation and discussion of papers that describe new model-based process control techniques and applications. The first day will consist of invited tutorials and industrial case studies. The second day will consist of contributed papers. The Workshop will precede the three-day 1988 American Control Conference.

The abstracts should describe in 800-1000 words the basic problem statement, the methods used, and the key results associated with the submitted full papers. Four copies of the abstract, in English, should be sent to Professor Thomas McAvoy, Department of Chemical Engineering, University of Maryland, College Park, MD 20742. The authors should clearly indicate the merits of their contribution, its relevance to the theme of the Workshop, and the covered topic areas. State name and lecturer, please.

The deadlines are:

Submission of abstracts
November 1, 1987

Notification of preliminary acceptance
January 1, 1987

Submission of full papers
March 15, 1987

Final Acceptance
April 15, 1987

All accepted papers will be photocopied and distributed to the participants at the Workshop. The Registration Fee is foreseen to be equivalent to 375 Swiss Francs (Students–150 Swiss Francs).

All inquires concerning the practical arrangements should be directed to the Workshop Address: Professor Yaman Arkun, Department of Chemical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332. Phone (404) 894-2871. Telex 542 507 GTRC OAC ATL. Please contact Professor Arkun for a copy of the official Workshop brochure.

## 1988 American Control Conference, Atlanta

**(June 15-17, 1988)**

The American Automatic Control Council will hold the seventh American Control Conference (ACC) on June 15-17, 1988 at the Atlanta Hilton and Towers, Atlanta, Georgia. The conference will bring together people working in the fields of control, automation, and related areas from the American Institute of Aeronautics and Astronautics (AIAA), American Institute of Chemical Engineers (AIChE), American Society of Mechanical Engineers (ASME), Association of Iron and Steel Engineers (AISE), Institute of Electrical and Electronic Engineers (IEEE), Instrument Society of America (ISA), and the Society of Computer Simulation (SCS).

Both contributed and invited papers are included in the program. The ACC will cover a range of topics relevant to theory and practical implementation of control and industrial automation and to university education in controls. Topics of interest include but are not limited to linear and nonlinear systems, identification and estimation, signal processing, multivariable systems, large scale systems, robotics and manufacturing systems, guidance and control, sensors, simulation, adaptive control, optimal control, expert systems, and control applications.

The schedule summary is:

September 15, 1987
Deadline for contributed papers
Deadline for requests on invited sessions.

November 1, 1987
Deadline for final submission of completed invited session forms.

February 1, 1988
Announcement of final selection of contributed papers and invited sessions.

March 15, 1988
Deadline for typed mats for Proceedings.

The organizing committee intends to arrange workshops to be held in conjunction with the 1988 ACC. Suggestions are solicited for appropriate subjects. Potential organizers should contact the Special Events Chairman, M. K. Masten, (214) 343-7695, or the General Chairman.

For further information, please contact:

Professor Duncan Mellichamp (AIChE Society Review Chairman), Department of Chemical Engineering, University of California, Santa Barbara, CA 93106, (805) 961-2821; Professor Jeffrey Kantor (Program Vice Chairman for Invited Sessions), Department of Chemical Engineering, University of Notre Dame, Notre Dame, IN 46556, (219) 239-5797; Professor Marija Ilic'-Spong (Program Vice Chairman for Contributed Sessions), Department of Electrical and Computer Engineering, University of Illinois, 1406 W. Green Street, Champaign-Urbana, IL 61801, (217) 333-4463; Professor Wayne J. Book (General Chairman), The George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, (404) 894-3247; or Professor Hassan Khalil (Program Chairman), Department of Electrical Engineering and Systems Science, Michigan State University, East Lansing, MI 48824, (517) 355-6689.

## Third International Symposium of Process Systems Engineering (PSE '88), Sydney, Australia

**(August 28-September 2, 1988)**

First Announcement and Call for Papers. This Conference is being sponsored by the Institution of Chemical Engineers in Australia and the Chemical Engineering College of the Institution of Engineers, Australia, on behalf of the Asian Pacific Federation of Chemical Engineering, the European Federation of Chemical Engineering, and the Inter American Federation of Chemical Engineering. It is the third in a triennial series entitled PSE, and follows highly successful events held in Kyoto, Japan in 1982 and in Cambridge, England in 1985.

In 1988 Australia celebrates its Bicentenary, and there will be a rich calendar of events throughout the country. PSE '88 is being held in affiliation with CHEMECA 88, Australia's Bicentennial conference on Chemical and Process Engineering, sharing the opening session in the Sydney Opera House and two other plenary sessions at the Sydney Hilton Hotel, where topics of importance to the chemical engineering community will be addressed by speakers of international standing. Delegates will be able to move between the Conferences, gaining a wider appreciation of the Australasian Industry scene, as well as focusing on their particular technical interests.

Following the tradition of the PSE series, the emphasis in 1988 will be on the presentation of new information on either technology or its application. Papers describing applications will be especially welcomed, particularly where they contain detailed information related to the value of a study.

Six technical sessions are planned, each conducted by a Chairman-Rapporteur, containing presentations of five to six papers of 30 minutes duration, including discussion. Following the successful poster session at PSE '85, a similar session is planned this time. The Conference proceedings will be published. An exhibition relevant to the themes of the Conference will run concurrently.

The main conference themes are:

Process Control and Optimization
- Benefits Assessment
- Operator/Process Interface
- Plant-wide Systems

Artificial Intelligence
- On-Line Expert Systems
- Design/Synthesis Applications

Batch Process Design and Operation
- Including Operability Considerations
- Scheduling Applications
- Batch Process Control

Industrial Applications
- Case Studies with Benefits Through Applications of PSE

Failure Analysis in Design
- Reliability/Availability Theory for Process Systems
- Applications to Process Design
- Hazard Identification Techniques

Design of Flowsheets
- Retrofitting
- Synthesis
- Operability
- Minerals, Solids and Other Non-Petrochemical Processes

Modelling
- New Models and Algorithms
- Process Identification

Education in PSE
- Undergraduate/Postgraduate
- Continuing Education

The timetable for authors is:

August 31, 1987 – Abstract to address overleaf

December 31, 1987 – Full paper for refereeing

April 30, 1988 – Final manuscript

The organizing committee is:

Dr. M. L. Brisk, ICI Australia Pty Ltd, Joint Chairman

Professor J. D. Perkins, University of Sydney, Joint Chairman

Mr. J. E. Atkins, CSR Ltd.

Dr. G. W. Barton, University of Sydney

Dr. I. Cameron, University of Queensland

Dr. R. D. Johnston, University of New South Wales

Mr. G. D. Kelly, BHP Steel International Group

Dr. D. Sutherland, CSIRO Division of Mineral Engineering

Professor D. Depeyre, France

Dr. W. B. Earl, New Zealand

Professor G. V. Reklaitis, United States of America

Professor R. W. H. Sargent, United Kingdom

Professor T. Takamatsu, Japan

Dr. J. D. Wright, Canada

Thinking of Attending?

If you are considering attending PSE '88, whether or not you plan to submit a paper, please return the **Registration of Interest** slip (duplicated below) now to ensure that you receive a copy of the Second Announcement and detailed Program.

## PSE '88 Registration of Interest

Please make a Xerox copy and complete the details of the following. Send it to the address shown.

Name:
Title:
Affiliation:
Postal Address:

I would like to submit a paper (abstract attached) Yes No

(Acceptance of papers is conditional upon at least one author attending the Conference to present it.)

I am considering attending PSE '88 and would like to receive the Second Announcement. Yes

I may be interested in post-conference tours in Australia to:

| | |
|---|---|
| The Great Barrier Reef | Yes |
| Queensland's Gold Coast | Yes |
| Central Australia | Yes |

Please mail to:

PSE '88 Conference
The Institution of Engineers, Australia
11 National Circuit
Barton, ACT 2600
Australia

## Washington, D.C., AIChE Meeting
### (November 27-December 2, 1988)

**Area 10a Sessions**

1-2. **Process Synthesis I and II.** James M. Douglas (Chairman), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-2252.

3-4. **Design and Analysis I and II.** G. V. Reklaitis (Chairman), School of Chemical Engineering, Purdue University, West Lafayette, IN 47907, (317) 494-4089 and Professor Ross E. Swaney (Vice Chairman), Department of Chemical Engineering, University of Madison, Madison, WI 53706, (608) 262-3641.

5. **Design of Integrated Biotechnology Process Systems.** George Stephanopoulos (Chairman), Department of Chemical Engineering 66-562, Massachusetts Institute of Technology, Cambridge, MA 02139, (617) 253-3004.

6. **Design of Polymer Process Systems.** Michael F. Malone (Chairman), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-4869 and Kendree J. Sampson (Vice Chairman), Department of Chemical Engineering, Ohio University, Athens, OH 45701, (614) 593-1503.

For further details concerning Area 10a sessions and scheduling, please contact Michael F. Doherty (Area 10a Chairman-Elect), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-2359.

**Area 10b Sessions**

1-2. **New Developments in Process Control I and II.** John W. Hamer (Co-Chairman), Research Laboratories, Eastman Kodak Company, B82 1st Flood, Rochester, NY 14650, (716) 477-3740 and Professor W. Harmon Ray (Co-Chairman), Department of Chemical Engineering, University of Wisconsin, 1415 Johnson Drive, Madison, WI 53706, (608) 263-4732.

3. **Robustness and Modeling Issues in Process Control.** Professor Ahmet N. Palazoglu (Co-Chairman), Department of Chemical Engineering, University of California, Davis, CA 95616, (916) 752-8774 and Professor Jeffrey C. Kantor (Co-Chairman), Department of Chemical Engineering, University of Notre Dame, Notre Dame, IN 46556, (219) 239-5797.

4. **Unsolved Problems in Process Modeling, Optimization, Control and Operations.** Professor Christos Georgakis (Chairman), Chemical Process Modeling and Control Research Center, Lehigh University, Bethlehem, PA 18015, (215) 758-4781 and Dr. Jorge Mandler (Co-Chairman), Air Products and Chemicals, P.O. Box 538, Allentown, PA 18015, (215) 481-3413.

5. **Adaptive Control.** Professor B. E. Ydstie (Chairman), Department of Chemical Engineering, University of Massachusetts, Amherst, MA 01003, (413) 545-2388 and Professor C. Brosilow (Co-Chairman), Department of Chemical Engineering, Case Western Reserve University, Cleveland, OH 44106, (216) 368-4180.

6. **Expert Systems in Process Control.** Professor Bradley R. Holt (Chairman), Department of Chemical Engineering BF-10, University of Washington, Seattle, WA 98195, (206) 543-0554 and Dr. Carlos Garcia (Co-Chairman), Shell Development Company, Westhollow Research Center, Houston, TX 77001, (713) 493-8873.

**Joint Session Between Areas 10b and 15c**

7. **Control of Biochemical Systems.** Professor Karen McDonald (Chairman), Department of Chemical Engineering, University of California, Davis, CA 95616, (916) 752-0400 and Prof. Anil Menawat (Co-Chairman), Department of Chemical Engineering, Tulane University, New Orleans, LA 70118, (504) 865-5772.

For further details concerning Area 10b sessions and scheduling, please contact Yaman Arkun (Chairman, Area 10b), Department of Chemical Engineering, Georgia Tech, Atlanta, Georgia 30332, (404) 894-2871.

**Area 10c Sessions**

1. **The Use of Advanced Computer Architectures in Chemical Engineering Computing.** Professor Mark A. Stadtherr (Co-Chairman), Chemical Engineering Department, University of Illinois, 1209 W. California Street, Urbana, IL 61801, (217) 333-0275 and Dr. Gary D. Cera (Co-Chairman), E.I. DuPont de Nemours and Company, Experimental Station E328/162B, Wilmington, DE 19898, (302) 695-1423.

2. **Computer Integrated Manufacturing in the Process Industries.** Dr. Norman E. Rawson (Chairman), IBM Corporation, DEM-1 5078, 6901 Ruckledge Drive, Bethesda, MD 20817, (301) 564-5959 and Dr. Verle N. Schrodt (Co-Chairman), Chemical Engineering, Science Division/M5773-00, National Bureau of Standards, 325 Broadway, Boulder, CO 80303, (303) 497-6944.

3. **Advances in Optimization.** Professor Ignacio E. Grossmann (Chairman), Department of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2228 and Professor Christodoulos A. Floudas (Co-Chairman), Department of Chemical Engineering, Princeton University, Princeton, NJ 08544, (609) 452-4595.

For further details concerning Area 10c sessions and scheduling, please contact Ignacio Grossman, Department of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2228.

**Area 10d Sessions**

1-2. **Nonlinear Analysis of Chemical Engineering Systems I and II.** Prof. Robert A. Brown (Chairman), Dept. of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, (617) 253-4571

3. **Applications of Population Balance.** Professor Doraswami Ramkrishna (Chairman), School of Chemical Engineering, Purdue University, West Lafayette, IN 47907, (317) 494-4066 and Professor Robert Ziff (Co-Chairman), Department of Chemical Engineering, University of Michigan, Ann Arbor, Michigan 48109-2136, (313) 764-5498.

For further details concerning Area 10d sessions and scheduling, please contact Doraiswami Ramkrishna, Purdue University, School of Chemical Engineering, West Lafayette, IN 47907, (317) 494-4066.

## Houston AIChE Meeting
**(Spring 1989)**

**Area 10c Sessions**

**Tentative Sessions: Innovative Uses of Computer Software and Plant Operations and Maintenance**

For further details concerning Area 10c sessions and scheduling, please contact Ignacio Grossman, Department of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2228.

## Foundations of Computer-Aided Process (FOCAPD-89)
**(Summer 1989)**

Jeffrey J. Siirola (Chairman), Eastman Kodak Company, PO Box 1972, Kingsport, TN 37662, (615) 229-3069; Ignacio E. Grossmann (Co-Vice Chairman), Department of Chemical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, (412) 268-2228; and George Stephanopoulos (Co-Vice Chairman), Department of Chemical Engineering, Massachusetts Institute of

Technology, Cambridge, MA 02139, (617) 253-3904.

Conference themes include: Design Theory and Methodology, ArtificialIntelligence, New Design Environments, Process Synthesis, Applied Mathematics, Process Simulation and Analysis, Applications of Supercomputing, Chemical Product Design, and Future Outlook.

# CALL FOR PAPERS

## CAST Sessions at AIChE Annual Meeting, Washington D.C.
(November 27-December 2, 1988)

The CAST Division is planning the following sessions at the Washington D.C. meeting:

**Area 10a: Computers in Process Design**

- Process Synthesis I and II
- Design and Analysis I and II
- Integrated Biotechnology Process Systems
- Polymer Process Design

**Area 10b: Computers in Process Control**

- New Developments in Process Control I and II
- Robustness and Modeling Issues in Process Control
- Control of Biochemical Systems (joint with Area 15c)
- Unsolved Problems in Process Modeling, Optimization, Control, and Operations
- Adaptive Control
- Expert Systems in Process Control

**Area 10c: Computers in Operations and Information Processing**

- The Use of Advanced Computer Architectures in Chemical Engineering I and II
- Computer Integrated Manufacturing in the Process Industries
- Advances in Optimization

**Area 10d: Applied Mathematics**

- Applications of Population Balance
- Nonlinear Analysis of Chemical Engineering Systems I and II

The names, addresses, and telephone numbers of the session chairpersons are given on the next several pages, as are brief statements of the topics to receive special emphasis in soliciting manuscripts for these sessions. Prospective session participants are encouraged to observe the following deadlines:

**April 15, 1988**: Submit an extended abstract of no less than 500 words in length to each of the session chairs.

**June 1, 1988**: Authors are informed of selection, and session content finalized.

**October 15, 1988**: Two copies of the final manuscript submitted to the session chairs.

Prospective participants should note that the above sessions have not yet been confirmed by the Meeting Program Chairman. The possibility exists, because of proposed plans for an increased number of plenary and special lectures, that the number of sessions may have to be reduced. Because of the importance of these proposed plans to CAST Division scheduling, the editor of CAST Communications invited the Washington D.C. Meeting Program Chairman, Dr. Henry A. McGee, to communicate his ideas to the Division membership. They are contained elsewhere in this newsletter.

**Process Synthesis I and II**

Papers are solicited in all areas of chemical process synthesis including design theory, new approaches and techniques, and applications in heat integration, separation trains, reactor networks, and overall flowsheets in both grassroots and retrofit situations, and the like.

*Chairman*

Prof. James Douglas
Department of Chemical Engineering
University of Massachusetts
Amherst, MA 01003 (413) 545-2252

**Design and Analysis I and II**

This session seeks contributions in all areas of application of computing and systems technology to process design and analysis. Topics of special interest include: design under uncertainty, design of batch operations, reliability and availability analysis, design for operability, retrofit design, applications of reduced order models in design, as well as quantitative methods for selecting the layout of process equipment.

*Chairman*

Professor G.V. Reklaitis
School of Chemical Engineering
Purdue University
West Lafayette, IN 47907
(317) 494-4089

*Co-Chairman*

Professor Ross E. Swaney
Department of Chemical Engineering
University of Madison
Madison, WI 53706
(608) 262-3641

**Integrated Biotechnology Process Systems**

Papers are solicited in the general area of development, design, operations and/or control of integrated biotechnological systems. The term 'integrated' is used to indicate that the focus of this session is not on the analysis or design of individual units, but that its emphasis is on the unique aspects arising from the integration of several units into a cohesive biotechnological process. Typical examples include:

(a) Interaction between bioreactors and downstream processing systems. (b) Analysis, design, operation and control of the downstream processing system, usually composed of several units. (c) Integrated batch plants carrying out a number of different bioproduction lines.

*Chairman*

Professor George Stephanopoulos
Department of Chemical Engineering
Massachusetts Institute of Technology
Room 66-562
Cambridge, MA 02139
(617) 253-3904

**Polymer Process Design**

Studies which focus on processes for polymer production or for the processing of polymeric materials are of interest. The topics may include but need not be limited to: equipment design, the interactions between design and control, physical property measurement and prediction for design, and especially systems interactions in polymer processes.

*Chairman*

Professor M.F. Malone
Dept. of Chemical Engineering
University of Massachusetts
Amherst, MA 01003
(413) 545-4869

*Co-Chairman*

Professor K. Sampson
Dept. of Chemical Engineering
Ohio University
Athens, OH 45701
(614) 593-1503

**New Developments in Process Control I II**

Papers are invited which demonstrate advances in process control, including advances in the areas of:

- multivariable control
- nonlinear control
- self-tuning and adaptive control
- control of nonsquare systems
- control of heat-integrated processes
- on-line optimizing control

Papers demonstrating advances in the application of process control are also invited.

*Co-Chairman*

John W. Hamer
Research Laboratories
Eastman Kodak Co.
B82 1st Flood
Rochester, NY 14650
(716) 477-3740

*Co-Chairman*

Professor W. Harmon Ray
Dept. of Chemical Engineering
University of Wisconsin
1415 Johnson Drive
Madison, WI 53706
(608) 263-4732

**Robustness and Modeling Issues in Process Control**

This session is intended to address issues of process modeling in control design and analysis. Relevant topics include

- Model identification and reduction
- Characterization of modeling errors in the time and frequency domains,
- Robust control synthesis
- Control analysis of linear and nonlinear process models,
- Incorporation of process models into controller implementations.

Theoretical studies, practical applications and relevant case studies are solicited.

*Co-Chairman*

Professor Ahmet N. Palazoglu
Dept. of Chemical Engineering
University of California
Davis, CA 95616
(916) 752-8774

*Co-Chairman*

Professor Jeffrey C. Kantor
Dept. of Chemical Engineering
University of Notre Dame
Notre Dame, IN 46556
(219) 239-5797

**Control of Biochemicals Systems**
(Joint Session Between Areas 10B and 15C)

The scope of this session includes experimental and theoretical studies involving new on-line monitoring techniques, dynamic process modelling and novel control strategies for bioreactors or downstream processing units. Topics may include applications of new biosensors for bioprocess control, state and parameter estimation techniques, dynamic model development for microbial or cell culture bioreactors and advanced control applications such as multivariable, nonlinear or adaptive control algorithms.

*Chairman*

Professor Karen McDonald
Dept. of Chemical Engineering
University of California
Davis, CA 95616
(916-752-0400

*Co-Chairman*

Prof. Anil Menawat
Dept. of Chemical Engineering
Tulane University
New Orleans, LA 70118
(504) 865-5772

**Unsolved Problems in Process Modeling, Optimization, Control and Operations**

This session aims to solicit presentations by academic and more importantly industrial researchers on what are the most important unsolved research problems in the following research areas:

- Process Modeling
- Process Optimization
- Process Control and
- Process Operations, including:
  - Statistical Process Control,
  - Safety,
  - Scheduling

Presentations will be brief and should not address a problem that has been only partially solved by the authors.

*Chairman*

Professor Christos Georgakis
Chemical Process Modeling
Control Research Center
Lehigh University
Bethlehem, PA 18015
(215) 758-4781

*Co-Chairman*

Dr. Jorge Mandler
Air Products & Chemicals
P.O. Box 538
Allentown, PA 18015
(215) 481-3413

**Adaptive Control**

This session will deal with new theories and applications of adaptive control to chemical processes.

*Chairman*

Professor B.E. Ydstie
Dept. of Chemical Engineering
University of Massachusetts
Amherst, MA 01003
(413) 545-2388

*Co-Chairman*

Prof. C. Brosilow
Dept. of Chem Eng
Case Western Reserve University
Cleveland, OH 44106
(216) 368-4180

**Expert Systems in Process Control**

This is a call for papers demonstrating the use of expert systems in process control. We are particularly interested in theoretical insights or actual applications of expert systems and other artificial intelligence techniques to real time control problems. Papers dealing with the use of expert systems for configuring and designing control systems as well as other applications related to process control will also be considered.

*Chairman*

Professor Bradley R. Holt
Dept. of Chemical Eng,
University of Washington
Seattle, WA 98195
(206) 543-0554

*Co-Chairman*

Dr. Carlos Garcia
BF-10 Shell Development Co.
Westhollow Research Center
Houston, TX 77001
(713) 493-8873

**Nonlinear Analysis of Chemical Engineering Systems (I, II)**

Papers are sought on application of the methods of nonlinear analysis to chemical engineering problems. Applications may cover any area of interest to chemical engineers (such as chemical reaction engineering, fluid mechanics, transport processes, process control, etc.) and may deal with one or more aspects of nonlinear analysis; for example bifurcation methods, singularity theory, elucidation of complex dynamics, etc.

*Chairman*

Prof. Robert A. Brown
Dept. of Chemical Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
(617) 253-4571

**The Use of Advanced Computer Architectures in Chemical Engineering Computing**

Advanced computer architectures involving the use of vector processing, multiprocessing (parallel processing), and vector multiprocessing provide the potential to greatly increase the speed of scientific and engineering computing. Topics of interest for this session include the application of advanced computer architectures to solve chemical engineering problems, the development of new algorithms or codes for exploiting advanced computer architectures, and descriptions or reviews of recent technological developments related to advanced computer architectures. Of particular interest are papers involving multiprocessing or vector multiprocessing architectures.

*Co-Chairman*

Professor Mark A. Stadtherr
Chemical Engineering Dept.
University of Illinois
1209 W. California Street
Urbana, IL 61801
(217) 333-0275

*Co-Chairman*

Dr. Gary D. Cera
E.I. DuPont de Nemours Co.
Experimental Station
E328/162B
Wilmington, DE 19898
(302) 695-1423

**Computer Integrated Manufacturing in the Process Industries**

Papers are being sought that address systems that are being planned and implemented for Computer Integrated Manufacturing in the process industries. They should address computing techniques used for the development and integration of business systems and manufacturing operations. The vision is one that will add to the definition and solution from the business planning, through the process plant to the sale of product.

*Chairman*

Dr. Norman E. Rawson
IBM Corporation
DEM-1, 5078
6901 Ruckledge Drive
Bethesda, MD 20817
(301) 564-5959

*Co-Chairman*

Dr. Verle N. Schrodt
Chemical Engineering
Science Division/M5773-00
National Bureau of
Standards
325 Broadway
Boulder, CO 80303
(303) 497-6944

**Advances in Optimization**

Topics of interest include computational methods for large-scale linear, nonlinear and mixed-integer optimization; applications to plant-wide and on-line optimization, planning and scheduling, retrofit design; interfaces with process simulators and modeling systems.

*Chairman*

Professor Ignacio E. Grossmann
Dept. of Chemical Engineering
Carnegie-Mellon University
Pittsburgh, PA 15213
(412) 268-2228

*Co-Chairman*

Professor Christodoulos
A. Floudas
Dept. of Chemical
Engineering
Princeton University
Princeton, NJ 08544
(609) 452-4595

**Applications of Population Balance**

We solicit papers on the application of population balance concepts to dispersed phase systems in chemical engineering. Applications to biological populations will also be of interest to this session.

*Chairman*

Prof. Doraswami Ramkrishna
School of Chemical Engineering
Purdue University
West Lafayette, IN 47907
(317) 494-4066

*Co-Chairman*

Prof. Robert Ziff
Dept. of Chemical
Engineering
University of Michigan
Ann Arbor, Michigan
48109-2136
(313) 764-5498

# AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
# 1988 AWARD NOMINATION FORM*

## A. BACKGROUND DATA

1. Name of the Award ______________________ Today's Date ____________

2. Name of Nominee ______________________ Date of Birth ____________

3. Present Position (exact title)

______________________________________________

4. Education:

| Institution | Degree Received | Year Received | Field |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

5. Positions Held:

| Company or Institution | Position or Title | Dates |
|---|---|---|
| | | |
| | | |
| | | |

6. Academic and Professional Honours (include awards, memberships in honorary societies and fraternities, prizes) and date the honor was received.

7. Technical and Professional Society Memberships and Offices

8. Sponsor's Name and Address

______________________________________________

______________________________________________

______________________________________________

______________________________________________ Sponsor's Signature

* A person may be nominated for only one award in a given year.

## B. CITATION

1. A brief statement, not to exceed 250 words, of why the candidate should receive this award. (Use separate sheet of paper.)

2. Proposed citation (not more than 25 carefully edited words that reflect specific accomplishments).

## C. QUALIFICATIONS

Each award has a different set of qualifications. These are described in the awards brochure. After reading them, please fill in the following information on the nominee where appropriate. Use a separate sheet for each item if necessary.

1. Selected bibliography (include books, patents, and major papers published.)

2. Specific identification and evaluation of the accomplishments on which the nomination is based.

3. If the nominee has previously received any award from AIChE or one of its Divisions, an explicit statement of new accomplishments or work over and above those cited for the earlier awards(s) must be included.

4. Other pertinent information.

## D. SUPPORTING LETTERS AND DOCUMENTS

List of no more than five individuals whose letters are attached.

| | Name | Affiliation |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |
| 5. | | |

Please send the completed form and supplemental sheets by April 3, 1988 to the CAST Division 2nd Vice Chairman, Bruce A. Finlayson, Department of Chemical Engineering, University of Washington, Seattle, Washington 98195, (615) 336-4493.