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Åström, Karl Johan

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TRIP TO BOSTON FOR PARTICIPATION IN CACSD'83

KARL JOHAN ÅSTRÖM

DEPARTMENT OF AUTOMATIC CONTROL
LUND INSTITUTE OF TECHNOLOGY
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LUND INSTITUTE OF TECHNOLOGY
DEPARTMENT OF AUTOMATIC CONTROL
Box 725
S 220 07 Lund 7 Sweden

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Author(s)
Karl Johan Åström

Supervisor

Sponsoring organization
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Title and subtitle

TRIP TO BOSTON FOR PARTICIPATION IN CACSD '83

Abstract

This report summarizes experiences and conclusions from participation in the second IEEE Computer Aided Control System Design Symposium. The travel was supported by STU under contract No 83-5184.

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TRIP TO BOSTON FOR PARTICIPATION IN CACSD '83

Karl Johan Åström

This report summarizes experiences and conclusions from participation in the second IEEE Computer Aided Control System Design Symposium. The travel was supported by STU under contract No 83-5184.

CONTENTS

1. INTRODUCTION

There is a growing interest in computer aided design tools for control system engineering. This symposium was the 2nd symposium in this field arranged by the IEEE. Although we have done extensive research in this area we did not have possibilities to participate in the first symposium due to luck of funds. This time STU has generously provided travel support. The motivation for this is the planned program (ramprogram) in the field. The background for the symposium is summarized in Appendix A. The program for the symposium is listed in Appendix B. There were extremely good facilities for demonstration in the Kresge auditorium at MIT, where General Electric had supplied equipment for projection of colour video pictures on a big screen. There were about 300 participants. It was clear that the area now attracts substantial industrial interests. The participants, which are listed in Appendix C, were evenly distributed among industry and university. A list of participants is given in Appendix C. It is interesting to see from the program that there was an attempt to bringing in people from neighbouring fields, for example computer science and computer graphics. There were also presentations of the major projects.

2. PRESENTATIONS

The Department of Automatic Control at Lund Institute of Technology gave two presentations:

K.J. Åström:
"Computer aided control systems engineering - a tool for more realistic teaching"

H. Elmqvist:
"A graphical system for modeling and implementation of control systems"

The first lecture presented experiences from using Simnon in teaching. Live Simnon presentation was also given. The demonstrations went very well. The second demonstration dealt with results from the project LICS, which is supported by STU under project number 83-3647. This presentation went very well too in spite of the fact that the software was moved to an Apollo computer in a very short time and that special hardware was also brought

over for the demonstration. The list of the viewgraphs for my presentation is given in Appendix D.

3. VISIT TO SSI

There were several companies who expressed an interest in commercial exploitation of our software. A preliminary screening indicated that Scientific Systems Inc. in Cambridge Mass was the most suitable partner. We visited them on two occasions to discuss possibilities for them to market the software in USA. We agreed that SSI should send us a business plan with a proposal to be evaluated by STU. This has been followed up and we have succeeded to team up SSI with Processdata AB in Nynäshamn to secure that Swedish industry will be involved. Discussion of contract proposals are now under way.

4. OTHER ACTIVITIES

In connection with the trip I was also invited to present a lecture at MIT on "Automatic tuning of simple regulators". I also had the possibility to attend a lecture series by professor Jacob Schwartz at Harvard University. A presentation of this is included in Appendix F.

5. CONCLUSIONS

The visit was very worthwhile. It was encouraging to see that there is still a considerable interest in our software developed under STU-contracts 73-3553, 75-2776 and 77-3548. We were delighted to see that these results were still in the forefront of the field, in spite of the fact that this research results are now quite old. It was also very encouraging to see the reception of the graphics facilities developed by Hilding Elmqvist. This is way ahead of any other graphics in the control systems field. The meeting with SSI may also open up the possibilities for seriously marketing our software.

6. REFERENCE

K J Åström and J Wieslander: Computer aided design of control systems. Report, Dept of Automatic Control, Lund Institute of Technology, CODEN: LUTFD2/(TFRT-3160)/1-23/(1981).

APPENDIX A - BACKGROUND

THE SYMPOSIUM

Computer-Aided Control System Design (CACSD) has begun to emerge as an indispensable tool for the control system engineer. A CACSD capability, not only frees the engineer from routine and mundane tasks but also provides a vehicle whereby complex algorithms or control methodologies are made available to and usable by those unfamiliar with the myriad of details that make the CACSD software efficient. A good CACSD system draws on expertise from many disciplines including aspects of computer science, computer engineering, applied mathematics (for example, numerical analysis and optimization), as well as control system engineering. The need for such breadth is partially responsible for the paucity of high quality CACSD software today.

One way of fostering a more mature CACSD discipline is to hold a number of workshops or symposiums which are focused on some of the more pertinent topics such as numerically stable algorithms, programming languages, graphic displays, new design procedures, man-machine interfaces, data-base management, control software engineering, and architectures for CACSD packages.

In May 1981, H.A. Spang III organized the first CACSD workshop in Schnectady and Troy, New York under the sponsorship of General Electric and Rensselaer Polytechnic Institute. As a result of this highly successful workshop, the Administration Committee of the IEEE Control Systems Society approved the formation of a Technical Committee on CACSD and appointed H.A. Spang III as the Chairman in June 1981. The Technical Committee was partitioned into two subcommittees: a subcommittee on "algorithms" with A.J. Laub as Chairman and a subcommittee on "design" with C.J. Herget as Chairman.

A Program Committee consisting of C.J. Herget (Chairman), A.J. Laub, E. Polak and D.Q. Mayne then organized the Berkeley Workshop which was held at the University of California, Berkeley in April 1982. The Berkeley Workshop was sponsored by the IEEE Control Systems Society which highlighted various aspects of that meeting in the December 1982 special issue of the Control Systems Magazine. As part of the Berkeley workshop, a strong computer science flavor was injected into some of the sessions. This was enhanced by live presentations of design packages and computer graphics. Some of the demonstrations were run on computers at Berkeley, while most were linked to a computer at the speaker's home institution via telephone lines and modems. The audience was able to watch the presentations by using a television projection system to project the terminal's video output onto the auditorium screen.

A motion was subsequently passed at the June 1982 Administration Committee meeting which established a Steering Committee consisting of C.J. Herget, A.J. Laub, and H.A. Spang III to administer and direct further "Symposia on CACSD" on a continuing basis under the auspices of the IEEE Control Systems Society.

This symposium responds to the rapidly growing interest within the IEEE Control Systems Society to develop new control technology through CACSD for the 1980s and beyond. The symposium will encompass two mutually complementary themes:

- Live demonstrations of CACSD packages using a large screen projection television set.
- Papers contributed on recent developments of relevance to CACSD.

The main objectives of the symposium are:

- To provide a forum for control system engineers to exchange ideas and discuss recent developments on control system design packages, algorithms, languages, data-base management, graphics, and computer system hardware.
- To explore the application of interactive computation and graphics.
- To identify future needs and trends in CACSD.

ORGANIZING COMMITTEE

Mr. Robert R. Strunce, Jr. (Chairman)
The Charles Stark Draper Laboratory, Inc.

Professor Michael Athans
Massachusetts Institute of Technology

Dr. Charles J. Herget
Lawrence Livermore National Laboratory

Professor Alan J. Laub
University of Southern California

Dr. H. Austin Spang, III
General Electric Research & Development Center

APPENDIX B - SYMPOSIUM PROGRAM

WEDNESDAY, SEPTEMBER 28

8:30	Registration in the Lobby of Kresge Auditorium
9:00	INTRODUCTION Chair: R. Strunce The C.S. Draper Laboratory, Inc. WELCOME C.S. Draper The C.S. Draper Laboratory, Inc. Improving The Quality and Productivity of the Control System Design Process M. Athans Massachusetts Institute of Technology
10:00	Break
	MODELING, IDENTIFICATION AND CONTROL Chair: A.J. Laub University of Southern California
10:30	• KEDDC—A Computer-Aided Analysis and Design Package for Control Systems Chr. Schmid Ruhr-Universitat Bochum Federal Republic of Germany
11:30	Interactive Design and Evaluation of Advanced Spacecraft (IDEAS) Computer-Aided Design System L.B. Garrett NASA Langley Research Center
12:00	Lunch
	INTERFACE CONCEPTS Chair: P. Houpt Massachusetts Institute of Technology
1:30	User Interfaces for CACSD H.A. Spang III General Electric Company
2:00	Functional System Architecture for Advanced Interactive CAD/Control Design and Analysis L.J. Marggraff ROLM
2:30	Concepts and Requirements for Multivariable Control Design Analysis Package S. Pratt Honeywell, Inc.
3:00	Break
	ADA LANGUAGE AND MICROPROCESSOR UTILIZATION Chair: A. Levis Massachusetts Institute of Technology
3:30	ADA Integrated Environment Overview M. Ryer Intermetrics
4:00	Distributed Software for Embedded Computer Systems —An Experience with ADA S. Fujita Tokyo Institute of Technology, Japan
4:30–5:00	Concurrent Computing With Microprocessors E. Ducot and V. Klema Massachusetts Institute of Technology
5:30–7:00	Reception

• Demonstration

THURSDAY, SEPTEMBER 29

	INTERACTIVE CONTROL DESIGN Chair: R. Walker Integrated Systems, Inc.
8:30	"LSD" A Conversational Program for Linear System Design B. Friedland The Singer Company, Kearfott Division
9:00	• Two Interactive Programming Packages for Control Systems M. Jamshidi University of New Mexico
9:30	On the Development of Electrical Engineering Analysis and Design Software for an Engineering Workstation G.K.F. Lee Colorado State University H. Elliott University of Massachusetts
10:00	Break
	DELIGHT MIMO Project Chair: D. Frederick Renssalaer Polytechnic Institute
10:30	• An Interactive Multivariable Control System Design Package E. Polack and the University of California, Berkeley team D.Q. Mayne and the Imperial College London team C.J. Herget and the Lawrence Livermore National Laboratory team
12:00	Lunch
	CACSD WORKSTATION DEMONSTRATION Chair: C.J. Herget Lawrence Livermore National Laboratory
1:30	• A Control Design Workstation S.C. Shah, R.A. Walker and D.B. Varvell Integrated Systems, Inc.
2:15	• CTRL-C: A Workbench for the Computer-Aided Design of Multivariable Control Systems A. Emami-Naeini, J. Little, S. Bangert Systems Control Technology, Inc.
3:00	Break
	ALGORITHMS Chair: T. Johnson Bolt Beranek and Newman Inc.
3:30	RICPACK: Algorithms and Software for Matrix Riccati Equation W.F. Arnold and A.J. Laub University of Southern California
4:00	An Algorithm for Eigenvalue Assignment in Multi-Input Systems R.V. Patel Concordia University, Canada
4:30	Inner-Outer Factorization of Rational Matrices B-C Chang and J.B. Pearson Rice University

FRIDAY, SEPTEMBER 30

	GRAPHICS Chair: S. Bly Lawrence Livermore National Laboratory
8:30	Graphical Interfaces to Data C. Herot Computer Corporation of America
9:00	Use of Interactive Graphics for Controlling Complex Processes B. Roberts Bolt Beranek and Newman Inc.
9:30	Speech, Gesture, and Graphical Context R. Bolt Massachusetts Institute of Technology
10:00	Break
	COMPUTER-AIDED CONTROL SYSTEM ENGINEERING DEMONSTRATIONS Chair: M. Athans Massachusetts Institute of Technology
10:30	• Computer-Aided Control Systems Engineering—A Tool for More Realistic Teaching K.J. Åström and B. Wittenmark Lund Institute of Technology, Sweden
11:30	• A Graphical System for Modeling and Implementation of Control Systems H. Elmqvist Lund Institute of Technology, Sweden
12:00	Lunch
	FUTURE DIRECTIONS IN CASCD Chair: H.A. Spang III General Electric Company
1:30	Second-Generation Software Plan for Computer-Aided Control System Design J.H. Taylor General Electric Company A.G.J. McFarlane Cambridge University, England D.K. Frederick Renssalaer Polytechnic Institute
2:00	Flight Dynamics Laboratory Perspectives on CACSD S. Larimar AFWAL Flight Dynamics Laboratory
2:30	Future Directions and Needs in CACSD: A View From the Chemical Industry R. Pearson E.I. duPont de Nemours & Company
3:00	The DOE/EES/ORNL CACSD Development Effort: An Overview J.D. Birdwell The University of Tennessee S. Bly Lawrence Livermore National Laboratory A.J. Laub University of Southern California
3:30	Break
4:00–5:00	WRAP-UP AND INFORMAL DISCUSSIONS Chair: R. Strunce The C.S. Draper Laboratory

APPENDIX C - LIST OF PARTICIPANTS

Computer-Aided Control Systems Design Symposium

28 - 30 September 1983

LIST OF PARTICIPANTS

ARNOLD, WILLIAM
Naval Weapons Center
China Lake, CA 93555

ASTROM, K.J.
Lund Institute of Technology
Department of Automatic Control
P. O. Box 725
S-220, 07 Lund 7, Sweden

ATHANS, MICHAEL
Department of Electrical Engineering
and Computer Science
Massachusetts Institute of Technology
Room 35-406
Cambridge, MA 02139

AUBRUN, JEAN-NOEL
Lockheed Missiles & Space Company
Research & Development
3251 Hanover Street
0/52, B/205
Palo Alto, CA 94304

AZEVEDO, STEVE
Lawrence Livermore National Lab
P. O. Box 808, L-156
Livermore, CA 94550

BANGERT, S.
Systems Control Technology, Inc.
1801 Page Mill Road
Palo Alto, CA 94304

BATTSTONE, PATRICK
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

BELANGER, P.R.
McGill University
Department of Electrical Engineering
3480 University Avenue
Montreal, Quebec H3Z 1J4
Canada

BENNETT, JACK
Systolic Systems, Inc.
1550 La Pradera Drive
Campbell, CA 95008

BERNSTEIN, DENNIS S.
Lincoln Laboratory
P. O. Box 73
Lexington, MA 02173

BIRDWELL, J. DOUGLAS
University of Tennessee
Knoxville, TN 37996-2100

BLY, S.
Lawrence Livermore National Laboratory
P. O. Box 5504, L-156
Livermore, CA 94550

BOLT, RICHARD
Department of Architecture
Massachusetts Institute of Technology
Room 9-526
Cambridge, MA 02139

BOUSTANY, NADER
General Motors Research Labs
Technology Center
Warren, MI 48090-9055

BRENNAN, TERRY J.
The Aerospace Corporation
M4/971 P. O. Box 92957
Los Angeles, CA 90009

BUKOW, GEORGE J.
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

BUSSEY, HAROLD
C. S. Draper Laboratory
555 Technology Square, M/S 29
Cambridge, MA 02139

CASSIDY, JOHN F., JR.
Control Systems Society
General Electric Company
P. O. Box 43
Schenectady, NY 12345

CAUTIS, DAN
Priam Corporation
20 West Montague Expressway
San Jose, CA 95134

CHANG, B-C
Rice University
Department of Electrical Engineering
Houston, TX 77251

COCKETT, ROBIN
University of Tennessee
Knoxville, TN 37996-2100

CORLEY, RALPH
General Electric Aircraft Engine
390 Oliver Road
Cincinnati, OH 45215

DOWLING, EDWARD F.
Babcock & Wilcox Company
P. O. Box 1260
Lynchburg, VA 24505

DUCOT, E.
Laboratory for Information and Decision Systems
Massachusetts Institute of Technology
Room 35-410A
Cambridge, MA 02139

DRAPER, CHARLES S.
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

EDMUNDS, J. M.
U.M.I.S.T.
Control Systems Centre
Sackville Street
Manchester M60 1QD, England

ELLIOT, H.
University of Massachusetts
Department of Electrical and Computer Engineering
Amherst, MA 01003

ELMQVIST, HILDING
Lund Institute of Technology
Department of Automatic Control
P. O. Box 725
S-220 07 Lund 7, Sweden

EMAMI-NAEINI, ABBAS
Systems Control Technology, Inc.
1801 Page Mill Road
Box 10180
Palo Alto, CA 94303

FOLKERTS, CHARLES H.
General Motors Research Labs
Warren, MI 48090-9055

FREDERICK, DEAN K.
Department of Electrical, Computer, and Systems Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

FRIEDLAND, B.
The Singer Company
Kearfott Division
1150 McBride Avenue
Little Falls, NJ 07424

FUJITA, SHOHEI
Department of Computer Science
Tokyo Institute of Technology
Meguro-ku, Tokyo 152, Japan

GARRETT, L.B.
NASA Langley Research Center
M/S 364
Hampton, VA 23665

DE GASTON, RAYMOND R.E.
University of Southern California
Aerospace Corporation
Torrance, CA 90505

GAVEL, DON
Lawrence Livermore National Laboratory
University of California
Box 808
Livermore, CA 94550

GINTER, STEVEN D.
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

GRANT, REGINALD T.
Grumman Aerospace Corporation
M/S B21-35
Bethpage, NY 11714

HAWK, JOHN F.
Hughes Aircraft Company
Space and Communications Group
Building S12/V362
P. O. Box 92919 - Airport Station
Los Angeles, CA 90009

HAWLEY, PATRICIA A.
JHU Applied Physics Laboratory
Johns Hopkins Road
Laurel, MD 20707

HEATH, MICHAEL T.
Oak Ridge National Laboratory
Oak Ridge, TN 37830

HELLER, ROBERT
University of Tennessee
Knoxville, TN 37996-2100

HERGET, CHARLES
Lawrence Livermore National Lab
Box 808, L-156
Livermore, CA 94550

HEROT, CHRISTOPHER
Computer Corporation of America
Four Cambridge Center
Cambridge, MA 02142

HEWER, GARY A.
Naval Weapons Center
China Lake, CA 93555

HOUPT, PAUL K.
Department of Mechanical Engineering
Massachusetts Institute of Technology
Room 35-318
Cambridge, MA 02139

HOWERTER, EDWARD D.
Emhart Corporation, CTI
181 Elliott Street
Beverly, MA 01915

HYLAND, WAYNE W.
Control Systems Society
2691 Elane Drive
Lower Burrell, PA 15068

JAMSHIDI, M.
University of New Mexico
Department of Electrical and Computer Engineering
Albuquerque, NM 87131

JOHNSON, T.
Bolt Beranek and Newman Inc.
10 Moulton Street
Cambridge, MA 02238

KASTEN, ROBERT E.
Deere and Company
Technical Center
Moline, IL 61265

KLABUNDE, RICHARD
Naval Weapons Center
China Lake, CA 93555

KLEIN, LAWRENCE E.
Applied Physics Laboratory
Johns Hopkins Road
Laurel, MO 21044

KLEMA, VIRGINIA
Statistics Center
Massachusetts Institute of Technology
Room E40-131
Cambridge, MA 02139

LARIMAR, S.
AFWAL Flight Dynamics Laboratory
Wright - Patterson AFB, OH 45433

LATIMER, DAVID
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

LAUB, A.J.
University of Southern California
Department of Electrical Engineering Systems
Room 422 - Powell Hall
Los Angeles, CA 90007

LAW, STEPHEN
Garett Manufacturing Ltd.
255 Attwell Drive
Rexdale, Ontario M9W 5B8, Canada

LEE, GORDON, K.F.
Department of Electrical Engineering
Colorado State University
Fort Collins, CO 80523

LESIEUTRE, GEORGE
HR Textron Inc.
2485 McCabe Way
Irvine, CA 92714

LEVESQUE, A.
United Technologies
109 Paradise Harbor Boulevard
North Palm Beach, FL 33408

LEVIS, A.
Laboratory for Information and Decision Systems
Massachusetts Institute of Technology
Room 35-410B
Cambridge, MA 02139

LITTLE, JOHN
Systems Control Technology, Inc.
Palo Alto, CA 94303

LORELL, KENNETH R.
Lockheed Missiles & Space Company
Research and Development
3251 Hanover Street, 0/52-57, B/205
Palo Alto, CA 94304

LUSE, ALAN J.
Director of Research
Computer Controls Corporation
845 Woburn Street
Wilmington, MA 01887

MARGGRAFF, JAMES
ROLM Corporation
4900 Old Ironsides Drive
Santa Clara, CA 95050

MAYHEW, DAVID R.
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

MAYNE, D.Q.
Imperial College of Science and Technology
Department of Computing and Control
London SW7 2BZ, England

MCFARLANE, A.G.J.
Control and Management Systems Division
Cambridge University Engineering Department
Mill Lane
Cambridge CB2 1RX, England

MICHAEL, REX E.
General Electric Company
P. O. Box 5000
Room 687
Binghamton, NY 13902

MITCHELL, EDWARD E.L.
Mitchell & Gauthier Associates, Inc.
801 Main Street, P. O. Box 685
Concord, MA 01742

MORRIS, ROBERT L.
Ford Motor Company
P. O. Box 2053
Scientific Research Laboratory
Room S2097
Dearborn, MI 48121

MUNRO, N.
U.M.I.S.T.
Control Systems Centre
Sackville Street
Manchester M60 1QD, England

MUSOFF, HOWARD
C. S. Draper Laboratory
555 Technology Square
M/s 63
Cambridge, MA 02139

ORBACH, ABRAHAM
John Deere and Company
1905 Caras Road
Waterloo, IA 50701

PATEL, R.V.
Concordia University
Montreal, Quebec H3G 1M8, Canada

PEARSON, J. B.
Rice University
Department of Electrical Engineering
Houston, TX 77251

PEARSON, R.
E. I. duPont de Nemours & Company
Experimental Station
Building 357
Wilmington, DE 19898

POLACK, E.
University of California
Department of Electrical Engineering and Computer Science
Berkeley, CA 94720

PRATT, S.
Honeywell, Inc.
2600 Ridgeway Parkway
MN17-2375
Minneapolis, MN 55413

RALPH, JON
United Technologies
8350 Waterway Drive
West Palm Beach, FL 33406

RIMER, MELOYA
Grumman Aerospace Corporation
B21-35
Bethpage, MY 11714

ROBERT, B.
Bolt Beranek and Newman Inc.
10 Moulton Street
Cambridge, MA 02238

ROCHELLE, ROBERT
University of Tennessee
Knoxville, TN 37996-2100

ROSSI, MICHAEL J.
Grumman Aerospace Corporation
Bethpage, NY 11714

RYER, MICHAEL J.
Intermetrics, Inc.
733 Concord Avenue
Cambridge, MA 02138

SALAM, FATHI M.A.
Drexel University
32nd and Chestnut Streets
Philadelphia, PA 19104

SCHMID, CHARLES
Ruhr-Universitat Bochum
Lehrstuhl fur Elektrische
Steuerung and Regelung
Postfach 102148, 4630 Bochum 1
Federal Republic of Germany

SHAH, KUMAR N.
EG & G Torque Systems
26 Arlington Street
Watertown, MA 02172

SHAH, S.C.
Integrated Systems, Inc.
151 University Avenue
Palo Alto, CA 94301

SHALOM, ISH
IMB Corporation
Room 36009
Thomas J. Watson Research Center
Yorktown Heights, NY 10598

SMITH, CLIFFORD C.
Inland Steel Company
3001 East Columbus Drive
East Chicago, IN 46312

SPANG, H.A.
General Electric Company
Research & Development Center
Schenectady, NY 12345

SRIDHAR, BANAVAR
Lockheed Missiles & Space Company
Research & Development
3251 Hanover Street, 0/52-57/B/205
Palo Alto, CA 94304

STEFANOU, FRED F.
Control Systems Society
P. O. Box 306 Succ St. Lambert
St. Lambert, Quebec J4P 3P8
Canada

STERN, HENRY E.
U. S. Army Missile Command
Code DRSMI-RGN
Redstone Arsenal, AL 35898

STRUNCE, ROBERT
C. S. Draper Laboratory
555 Technology Square
Cambridge, MA 02139

STUVA, RICKIE
Emerson Electric
8100 West Florissant
St. Louis, MO 63136

TABAK, DANIEL
Boston University
ESLE Department
110 Cummington
Boston, MA 02215

TAYLOR, J.H.
General Electric Company
Building 5-233
Schenectady, NY 12345

THOMPSON, A. GEORGE
Department of Mechanical Engineering
Massachusetts Institute of Technology
Room 1-104
Cambridge, MA 02139

THOMPSON, PETER M.
California Institute of Technology
1201 East California Street
Pasadena, CA 91125

TILLY, DIANE
Lawrence Livermore National Laboratory
Box 808, L-156
Livermore, CA 94550

TRAVASSOS, RICHARD H.
Systolic Systems, Inc.
1550 La Pradera Drive
Campbell, CA 95008

TROXEL, LARRY
General Motors Research Labs
General Motors Technical Center
Warren, MI 48090

VACCARO, RICHARD J.
University of Rhode Island
Department of Electrical Engineering
Kingston, RI 02881

VARVELL, D.B.
Integrated Systems, Inc.
151 University Avenue
Palo Alto, CA 94301

VOELZ, LAWRENCE D.
Ford Aerospace and Communications
Corporation
Newport Beach, CA 92660

WALKER, R.
Integrated Systems, Inc.
151 University Avenue
Palo Alto, CA 94301

WEST, PHILLIP J.
University of Illinois
1101 West Springfield
Urbana, IL 61801

WITTENMARK, B.
Lund Institute of Technology
Department of Automatic Control
P. O. Box 725, S-220 07 Lund 7
Sweden

YOUNG, GARY E.
Oklahoma State University
School of Mechanical and Aeronautical
Engineering
Stillwater, OK 74078

APPENDIX D - VIEWGRAPHS FOR PRESENTATION

TOOLS FOR MORE REALISTIC TEACHING

K J ÅSTRÖM

DEPARTMENT OF AUTOMATIC CONTROL
LUND INSTITUTE OF TECHNOLOGY

1. INTRODUCTION
2. REVIEW OF TOOLS
3. SIMNON
4. EXAMPLES
5. FUTURE DIRECTIONS
6. CONCLUSIONS

WHAT CAN CAE OFFER?

- MORE REALISTIC EXAMPLES
  - Nonlinearities
  - High frequency dynamics
- LOOK AT PROBLEMS NOT EASILY AMENABLE TO ANALYSIS
  - Effects of sampling rates
  - Intersample behaviour
- MODEL LIBRARIES
  - High fidelity models
  - Design on simple models
  - validation on realistic models
  - Reproducability
- CONSEQUENCES FOR TEACHING

EXPERIENCES

AT OUR OWN DEPARTMENT

- ELEMENTARY COURSES
- ADVANCES COURSES
- PROJECTS
- RESEARCH
- BOOK WRITING 1)
- MODEL LIBRARY

AT OTHER DEPARTMENTS

- CONTROL DEPARTMENTS
- MATHEMATICS DEPARTMENTS
- STATISTICS DEPARTMENTS

IN INDUSTRY

- PORTABILITY
- HARDWARE REQUIREMENTS
- EDUCATIONAL REQUIREMENTS
- SPECIAL FEATURES

1) Åström - Wittenmark
Computer-Controlled Systems
Theory & Design.
Prentice Hall 1984

INTRAC

ONE MODULE FOR INTERACTION COMMON TO ALL PACKAGES

COMMAND ORIENTED

INITIATIVE STAYS WITH USER BUT MAY BE TRANSFERED TO COMPUTER WHEN NEEDED

FEATURES

ARGUMENTS

LOCAL AND GLOBAL VARIABLES

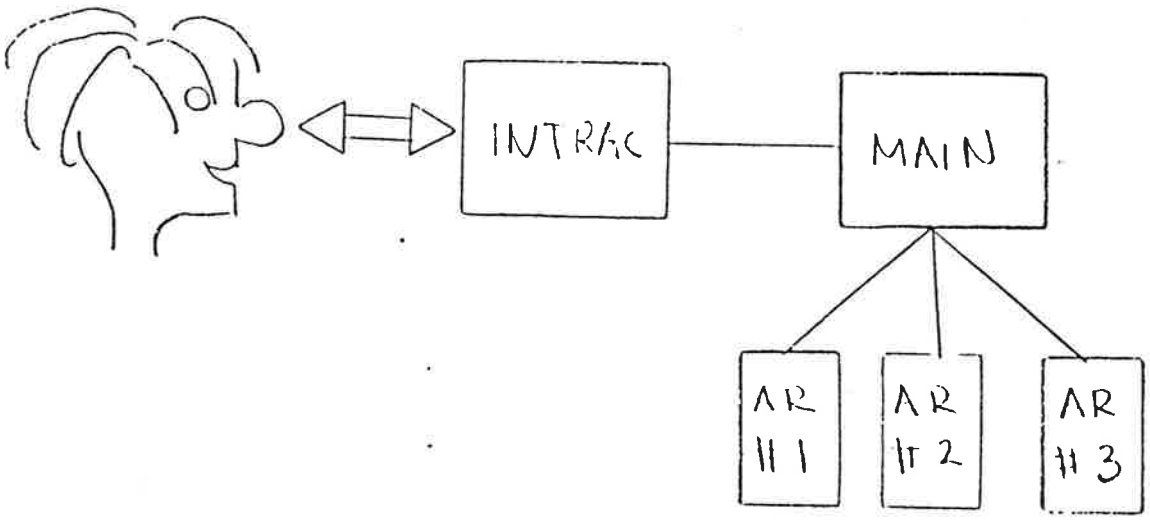
INPUT-OUTPUT, NUMBERS AND GRAPHS

CONTROL OF PROGRAM FLOW

SIMPLIFIED DIALOG

MACRO FACILITY

STRUCTURE



TOOLS FOR MORE REALISTIC TEACHING

1. INTRODUCTION
2. REVIEW OF TOOLS
3. SIMNON
4. EXAMPLES
5. FUTURE DIRECTIONS
6. CONCLUSIONS

EXAMPLES OF PACKAGES

SIMNON

INTERACTIVE SIMULATION LANGUAGE FOR NONLINEAR CONTINUOUS AND DISCRETE TIME SYSTEMS WITH FACILITIES FOR OPTIMIZATION AND USE OF EXPERIMENTAL DATA

IDPAC

INTERACTIVE LANGUAGE FOR IDENTIFICATION OF LINEAR SYSTEMS USING PARAMETRIC AND NON PARAMETRIC (COVARIANCES SPECTRA) METHODS

SYNPAC

STATE SPACE ORIENTED DESIGN PACKAGE FOR LINEAR SYSTEMS WHICH INCLUDES LQG, POLEPLACEMENT AND ROBUST DESIGNS FOR DISCRETE AND CONTINUOUS SYSTEMS

MODPAC

ANALYSIS AND TRANSFORMATIONS OF MODELS

POLPAC

POLYNOMIAL ORIENTED ANALYSIS AND DESIGN PACKAGE

LISPID

DYMOLA

TOOLS FOR MORE REALISTIC TEACHING

1. INTRODUCTION
2. REVIEW OF TOOLS
3. SIMNON
4. EXAMPLES
5. FUTURE DIRECTIONS
6. CONCLUSIONS

HIGH LEVEL PROBLEM SOLVING LANGUAGES

- VOCABULARY
  WORDS, DATA OBJECTS
- COMPOSITION RULES
  OPERATORS, GRAMMAR, SYNTAX
- MEANING
  SEMANTICS

THE LANGUAGE SHOULD BE:

- RICH TO SOLVE MANY PROBLEMS
- SIMPLE EASY TO LEARN
- EXTENDABLE

A CAD SYSTEM IS SIMPLY A LANGUAGE INTERPRETER

SIMULATION OF MIXED CONTINUOUS & DISCRETE TIME SYSTEMS

- CONTINUOUS SYSTEM

$$\frac{dx}{dt} = f(x, u, t)$$

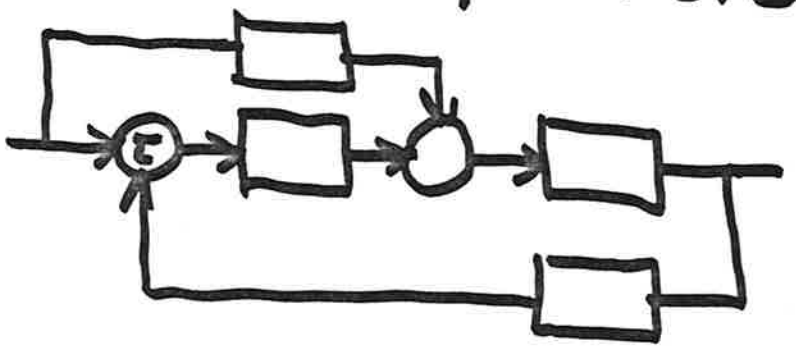
$$y = g(x, u, t)$$

- DISCRETE SYSTEM

$$x(t_{k+1}) = f(x(t_k), u(t_k), t_k)$$

$$y(t_k) = g(x(t_k), u(t_k), t_k)$$

- CONNECTING SYSTEM



DATA STRUCTURES

- CONTINUOUS SYSTEM
- DISCRETE SYSTEM
- CONNECTING SYSTEM

CONTINUOUS SYSTEM <ID>

[INPUT <simple variable>*]

[OUTPUT <simple variable>*]

[STATE <simple variable>*]

[DER <simple variable>*]

[TIME <simple variable>]

[INITIAL]

{Computation of initial values of state}

{Compute output variables}

{Compute derivatives}

{Parameter assignment}

{Initial value assignment}

END

```
DISCRETE SYSTEM <name>
[INPUT <simple variable>*]
[OUTPUT <simple variable>*]
[STATE <simple variable>*]
[NEW <simple variable>*]
[TIME <simple variable>]
TSAMP <simple variable>
{Compute initial values for state output tsamp}
{Compute auxiliary variables}
{Compute output}
{Compute new values of state variables}
Update TSAMP
{Modify states in continuous systems}
{Assign parameters & initial values}
END
```

CONNECTING SYSTEM <name>

[TIME <simple variable>]

[Compute auxiliar variables]

[Compute input variables]

[Parameter assignments]

END

SIMNON commands

1. UTILITIES
   - ✓ EDIT
   - GET
   - LIST
   - PRINT
   - SAVE
   - STOP
2. GRAPHIC OUTPUT
   - ✓ AREA
   - ASHOW
   - ✓ AXES
   - ✓ HCOPY
   - ✓ SHOW
   - ✓ SPLIT
   - TEXT
3. SIMULATION COMMANDS
   - ALGOR
   - ✓ DISP
   - ERROR
   - ✓ INIT
   - ✓ PAR
   - ✓ PLOT
   - ✓ SIMU
   - ✓ STORE
   - ✓ SYST

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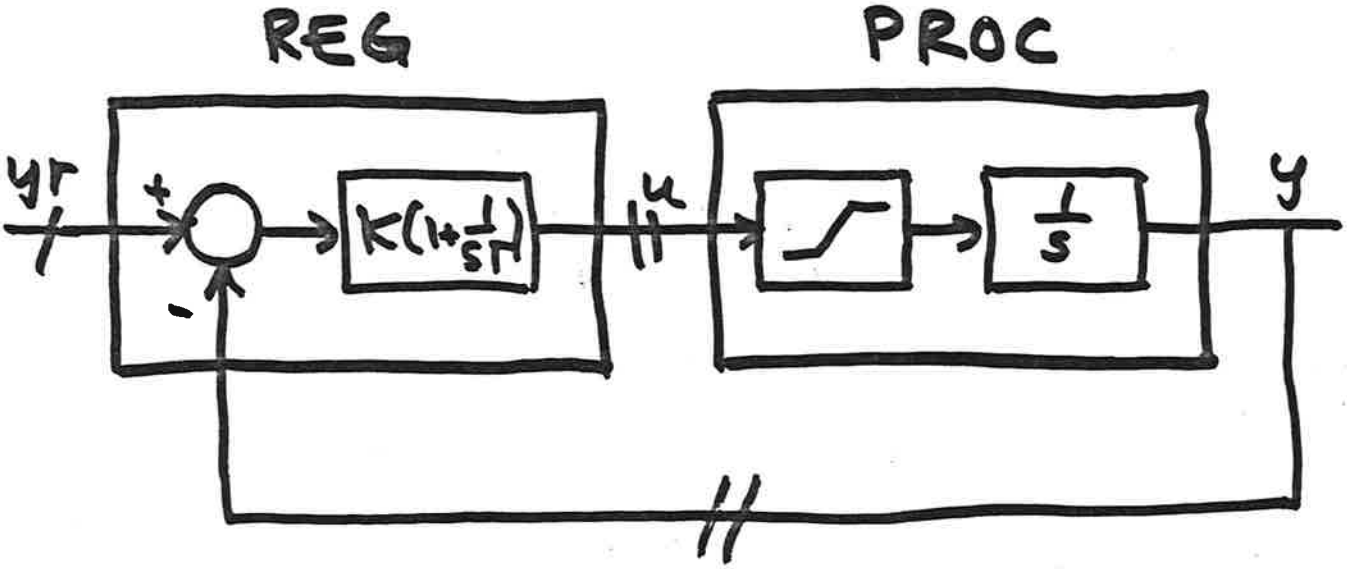
EXAMPLE 1
PI CONTROL WITH ANTIWINDUP



CONNECTING SYSTEM CON

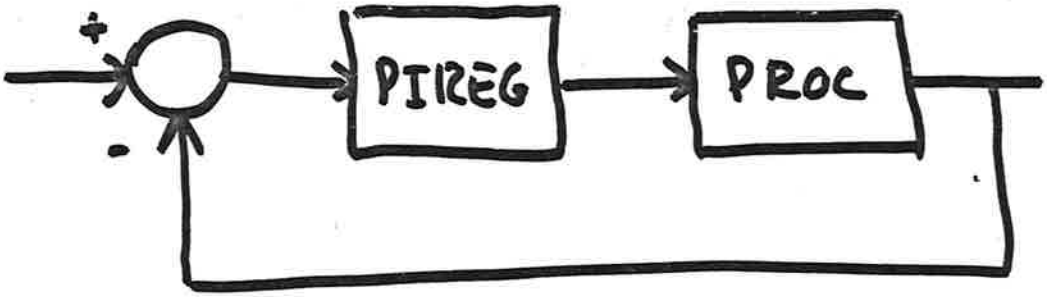
Time t

yr [REG] = 1

y [REG] = y [PROC]

u [PROC] = u [REG]

END



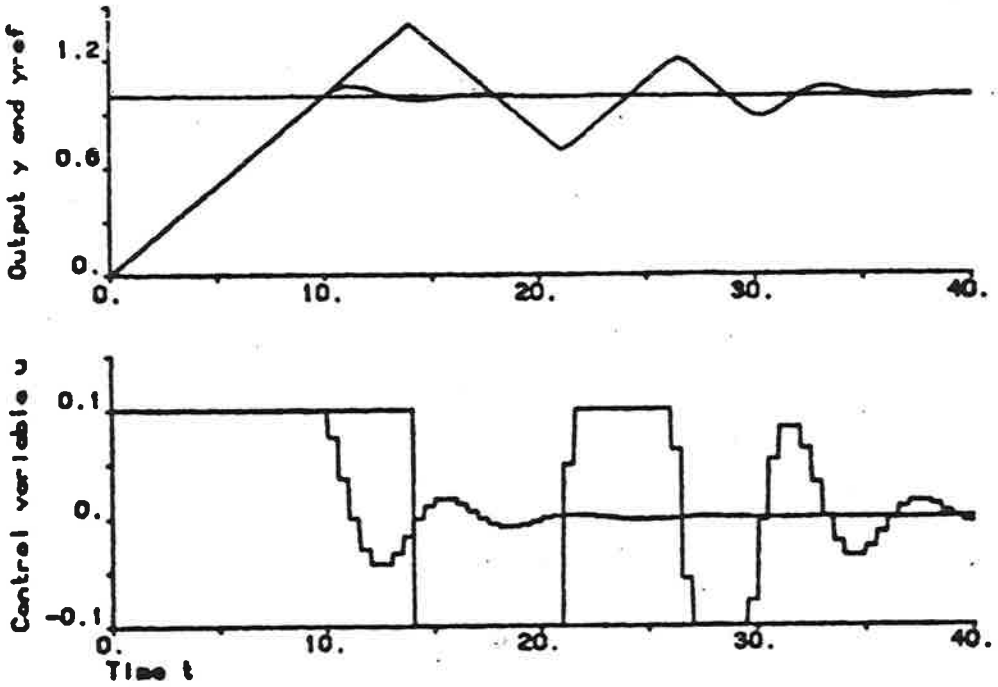

```
CONTINUOUS SYSTEM PROC
Input u
Output y
State
Der
:
END

DISCRETE SYSTEM PIREG
Input yr y
Output u
State i
New ni
Time t
Tsamp ts
:
END

CONNECTING SYSTEM
yr [PIREG] = 1
y [PIREG] = y[PROC]
u [PROC] = u[PIREG]
END
```

DISCRETE PI REGULATOR

```
DISCRETE SYSTEM REG
Input  yr  y
Output u
State  i
New    ni
Time   t
Tsamp  ts
e = yr - y
v = k*e + i
u = if v < ulow then ulow
    elseif v < uhigh then v
    else uhigh
ni = i + k*e*h/ti + h/to*(u-v)
ts = t+h
h: 0.2
ti: 1
to: 1
ulow: -1
uhigh: -1
END
```

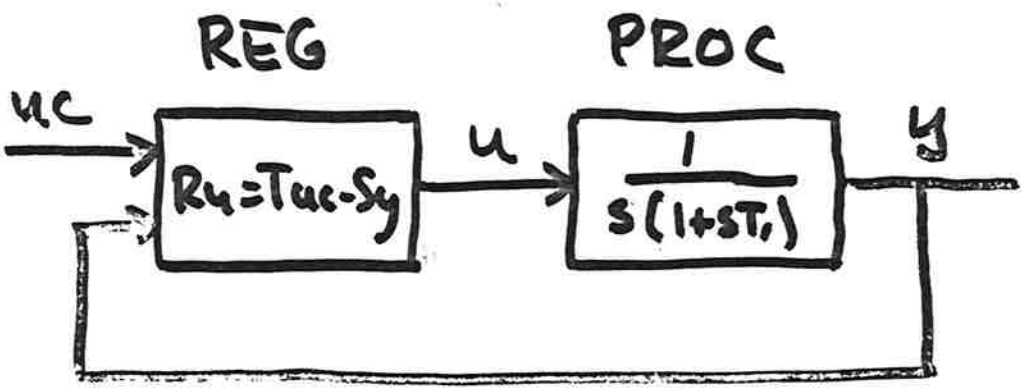
DECLARATIONS

PARAMETER ASSIGNMENTS




```
MACRO FIG9
"Generates Fig 9
syst integr pireg con
store yr y[proc] upr
simu 0 40/wup
par ulow: -0.1
par uhigh: 0.1
simu/nowup
split 2 1
ashow y/wup
show y/nowup
ashow upr/wup
show upr/nowup
```

INFLUENCE OF SAMPLING RATE IN POLE PLACEMENT CONTROL



CONNECTING SYSTEM CON
Time t
uc[reg] = 1
u[proc] = u[reg]
y[reg] = u[proc]
END

IT IS VERY HARD TO FIND OUT HOW THE RESPONSE IS INFLUENCED BY h BY ANALYSIS!

DISCRETE SYSTEM POLP

```
Input yc y
:
Tsamp ts
"Compute desired discrete char pol
p1 = -2*cos(w*h*sqrt(1-z↑2))
p2 = exp(-2*z*w*h)
"Sampling continuous model 1/s(s+1)
a2 = exp(-h/t1)
a1 = -(1+a2)
b1 = h-t1*(1-a2)
b2 = t1-a2*(t1+h)
"Solution of Diophantine eq AR+BS=PT

"Output
u = to*uc - s0*y - s1*yold - r1*uold
"Dynamics
myold = y
muold = u
ts = t+h
"Parameter assignments
:
END
```

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THE FUTURE

	SCENE OF 1970	SCENE OF 1980
NUMERICS	WILKINSON & REINSCH (1971)	EISPAC, LINPAC
HARDWARE	64 KBYTE FAST MEMORY 1 MBYTE DISC MEMORY TELETYPE STORAGE OSCILLOSCOPE	1 MBYTE FAST MEMORY 300 MBYTE DISC MEMORY HIGH RESOLUTION COLOR GRAPHICS
INTERACTION MODELS	ANALOG COMPUTER APL & BASIC LISP	LOGO SMALLTALK VISICALC
SOFTWARE	FORTRAN BASIC	PASCAL ADA
EXPERIENCES	NONE	DOZENS

WORK IN PROGRESS

- SIMPLIFIED DIALOG
  - GENTLE EXPERT GUIDANCE
  - DOCUMENTATION
- DESIGN OF HL PROBLEM SOLVING LANGUAGES
  - VOCABULARY
  - SYNTAX
  - SEMANTICS
- GRAPHICS
  - SYSTEM DESCRIPTIONS
  - COLOR
  - ANIMATION
- IMPLEMENTATION LANGUAGES
- SMALL EXPERIMENTAL SYSTEMS

INTERACTION PRINCIPLES

COMMANDS SHOULD BE

NATURAL

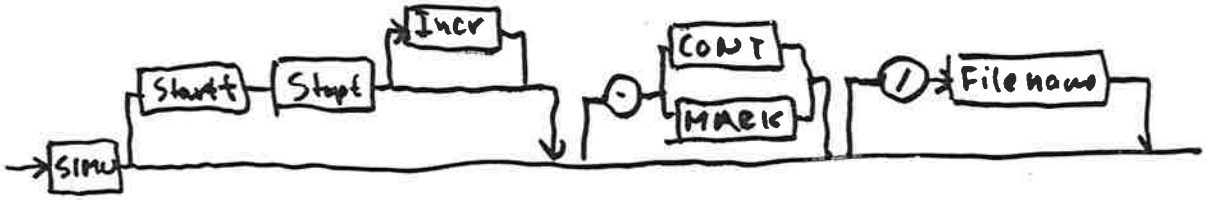
SELF-EXPLANATORY

SHORT

FLEXIBLE

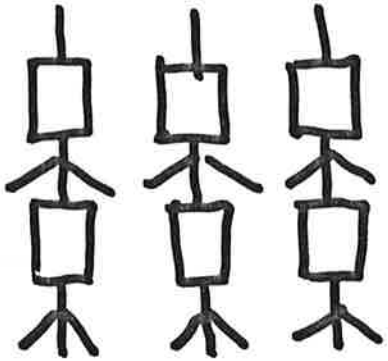
SHORT FORMS

DEFAULT PARAMETERS



THREE PHASES OF CAE

MENU DRIVEN DIALOG

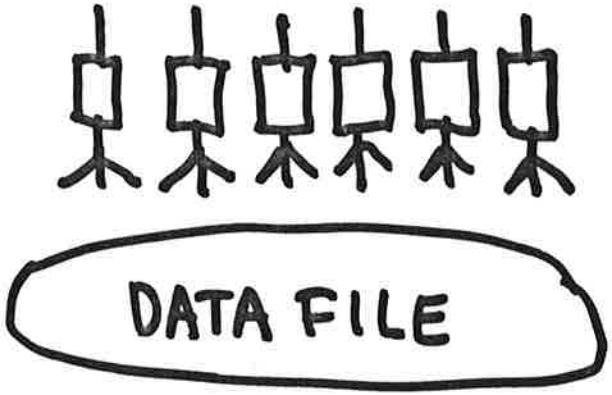


OPERATORS + FIXED LOGIC

EASY TO USE FOR THE PROBLEMS IT WAS DESIGNED FOR

STRAIGHT JACKET FOR OTHER

COMMAND DIALOG

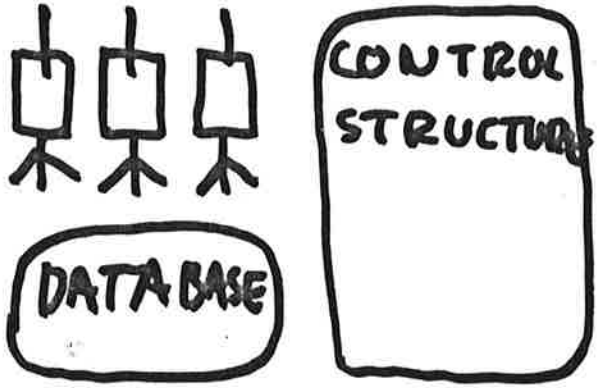


OPERATORS

HELD COMMAND PROC.

FLEXIBLE BUT MORE DIFFICULT TO USE

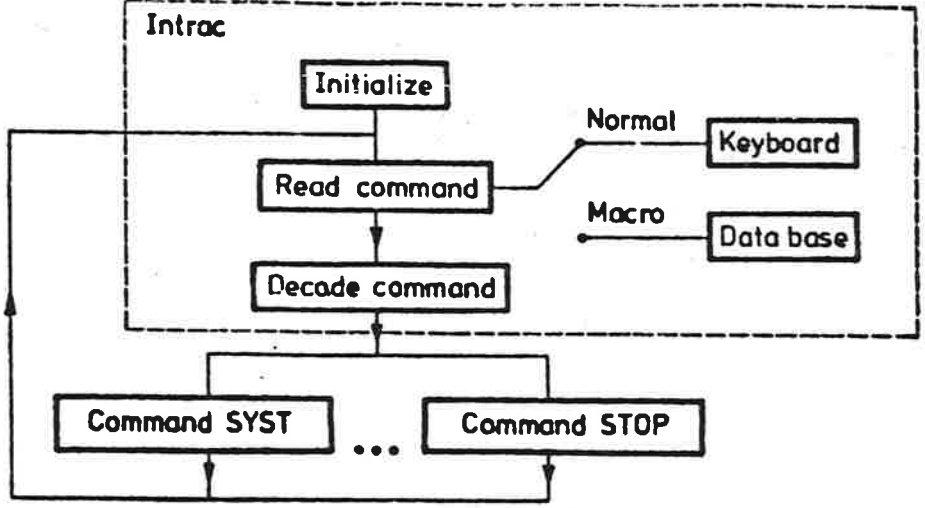
EXPERT GUIDED DIALOG



OPERATORS + FLEXIBLE DATA DRIVEN LOGIC

FLEXIBLE AND EASY TO USE

LEARNING FACILITY



TYPICAL COMMAND LANGUAGE INTERPRETER

NOTICE

MACROS

HIGH LEVEL PROBLEM SOLVING LANGUAGE

CONTROL STRUCTURES

AN INCREMENTAL COMPILER CAN BE BUILT IN A SIMILAR WAY.

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CONCLUSIONS

- COME CLOSER TO REALITY WITH MODEST EFFORT
- MODEL LIBRARY
- REPRODUCABLE RESULTS
  - EASY TO DOCUMENT
  - EASY TO REPEAT
  - EASY TO MODIFY
- WE HAVE BARELY SCRATCHED THE SURFACE

APPENDIX E - LECTURES BY PROFESSOR JACOB SCHWARTZ

HARVARD UNIVERSITY

Vinton Hayes Lectures
1983–84

Professor JACOB T. SCHWARTZ

New York University

Theoretical Issues in Robotics

I. The Motion Planning Problem

Monday, October 3 at 4 P.M.

II. Some Mathematics of Motion Planning

III. Computational Complexity of Motion Planning

Tuesday, October 4 at 3:00 and 4:30 P.M.

IV. Frictional Effects in Close-Tolerance Robot Assembly

V. Geometry, Control, and Software Approaches for Dextrous Manipulation

Thursday, October 6 at 3:00 and 4:30 P.M.

Lectures will be in

Pierce Hall 209

Division of Applied Sciences