Trip to Boston for Participation in CACSD'83

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1984

Document Version:
Publisher's PDF, also known as Version of record

Link to publication

Citation for published version (APA):
Åström, K. J. (1984). *Trip to Boston for Participation in CACSD'83*. (Travel Reports TFRT-8040). Department of Automatic Control, Lund Institute of Technology (LTH).

Total number of authors:
1

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CODEN: LUTFD2/(TFRT-8040)/1-49/(1984)

TRIP TO BOSTON FOR PARTICIPATION IN CACSD'83

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MAY 1984

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Document name
Travel report

Date of issue
May 1984

Document number
CODEN: LUTFD2/(TFRT-8040)/1-49/(1984)

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Sponsoring organization
The Swedish Board of Technical Development (STU)

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.

Key words

Classification system and/or index terms (if any)

Supplementary bibliographical information

ISSN and key title	ISBN

Language	Number of pages	Recipient's notes
English	49	
Security classification		

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, database 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

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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

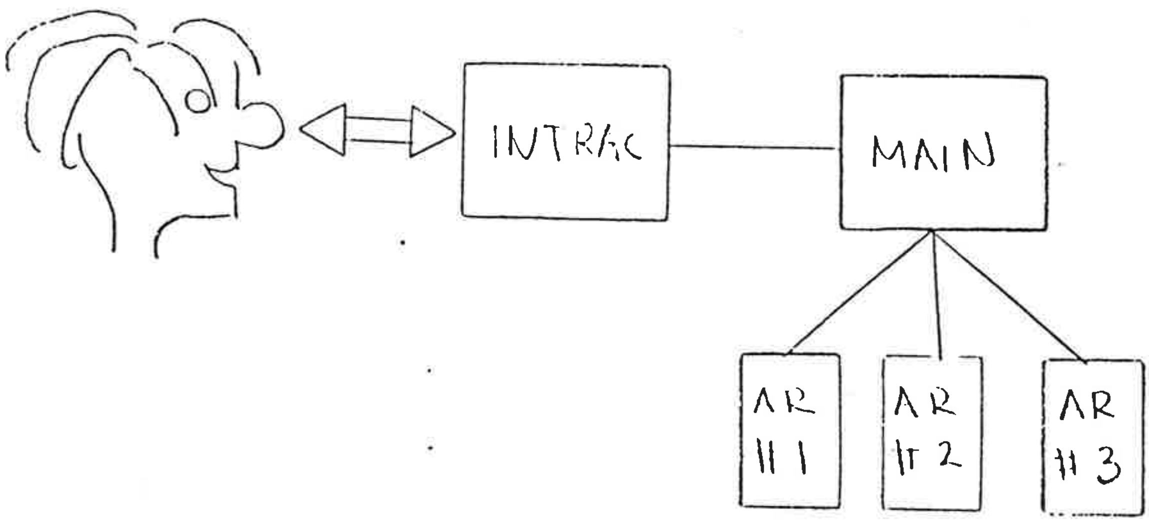
COMMAND ORIENTED

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

SIMNON

SIMULATION OF MIXED CONTINUOUS & DISCRETE TIME SYSTEMS

- CONTINUOUS SYSTEM

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

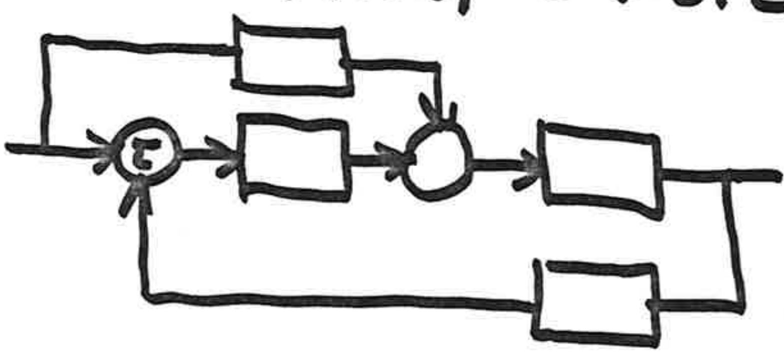
$$y = g(x, u, t)$$

- 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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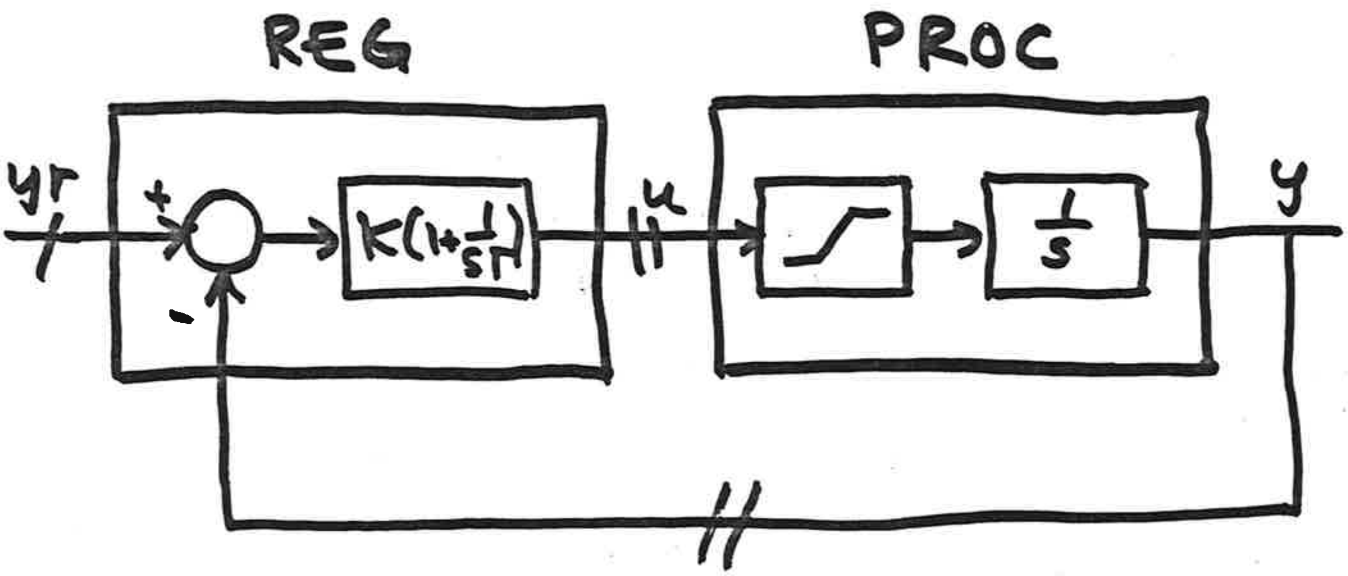
EXAMPLE 1
PI CONTROL WITH ANTIWINDUP



CONNECTING SYSTEM CON

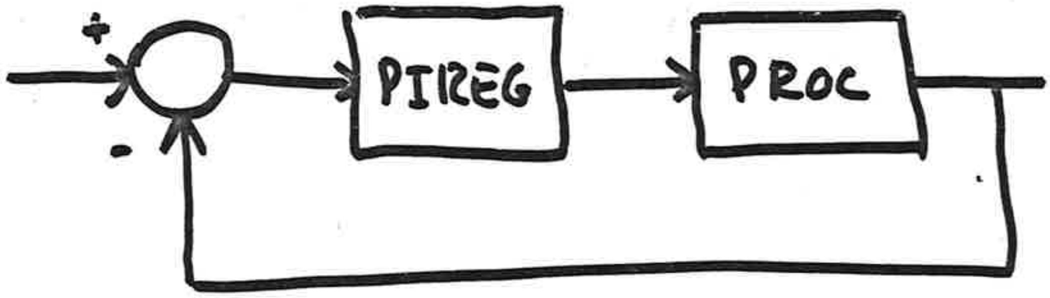
Time t

yr [REG] = 1

y [REG] = y [PROC]

u [PROC] = u [REG]

END



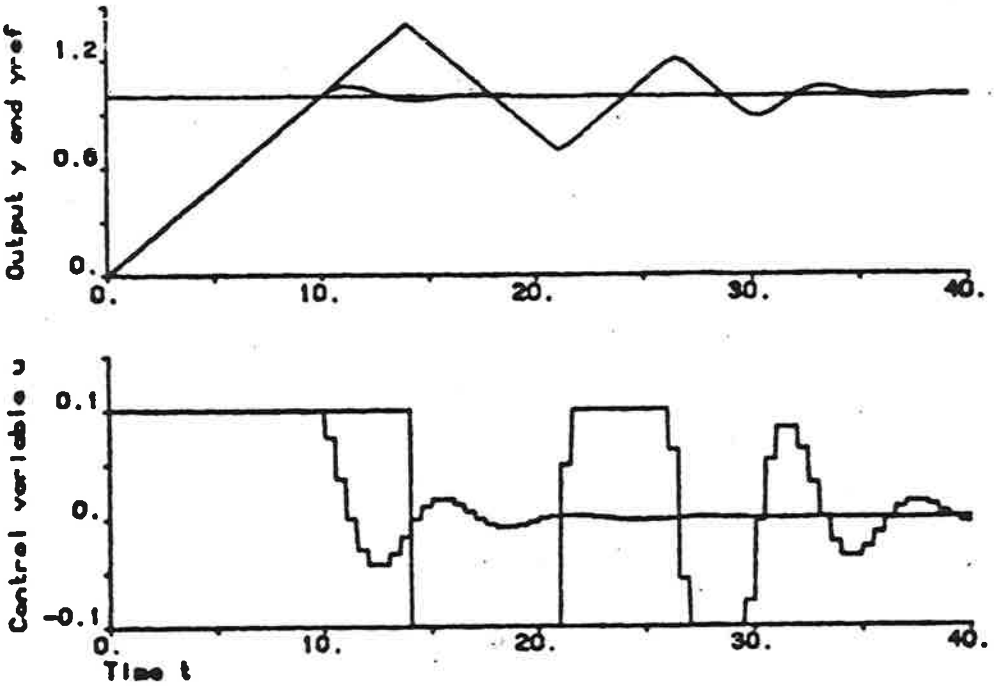

```
CONTINUOUS SYSTEM PROC
Input u
Output y
State
Der
:
END

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
```

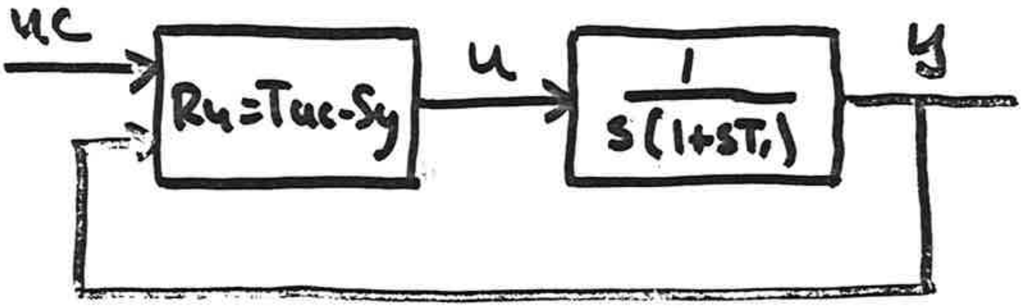
DISCRETE PI REGULATOR

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




```
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 uc 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=t0*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

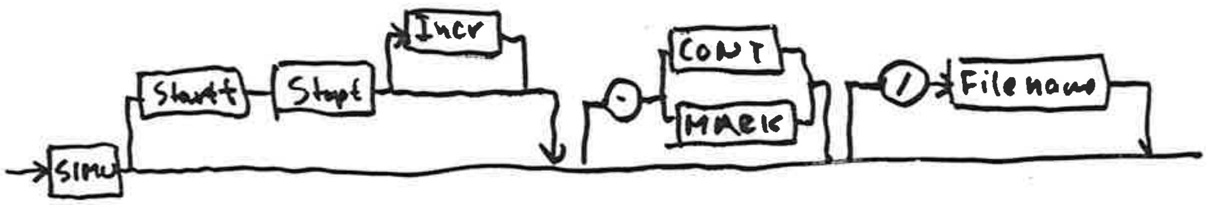
INTERACTION PRINCIPLES

COMMANDS SHOULD BE

- NATURAL
- SELF-EXPLANATORY
- SHORT
- FLEXIBLE

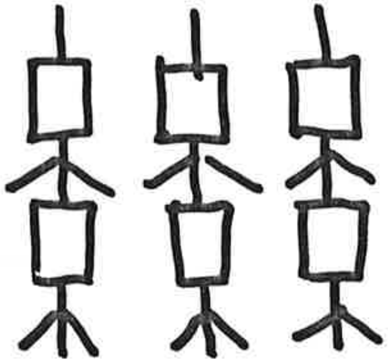
SHORT FORMS

DEFAULT PARAMETERS



THREE PHASES OF CAE

MENU DRIVEN DIALOG



OPERATORS + FIXED LOGIC

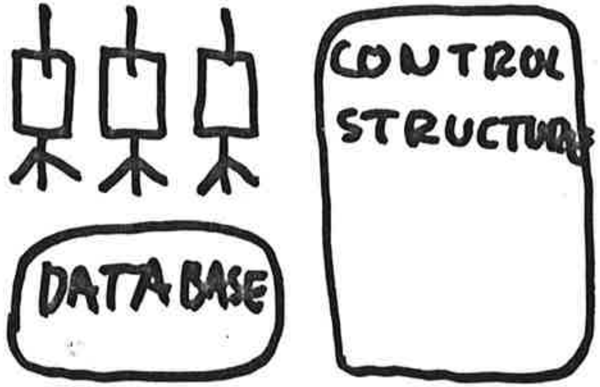
EASY TO USE FOR THE PROBLEMS IT WAS DESIGNED FOR
STRAIGHT JACKET FOR OTHER

COMMAND DIALOG

OPERATORS HELD COMMAND PROC.

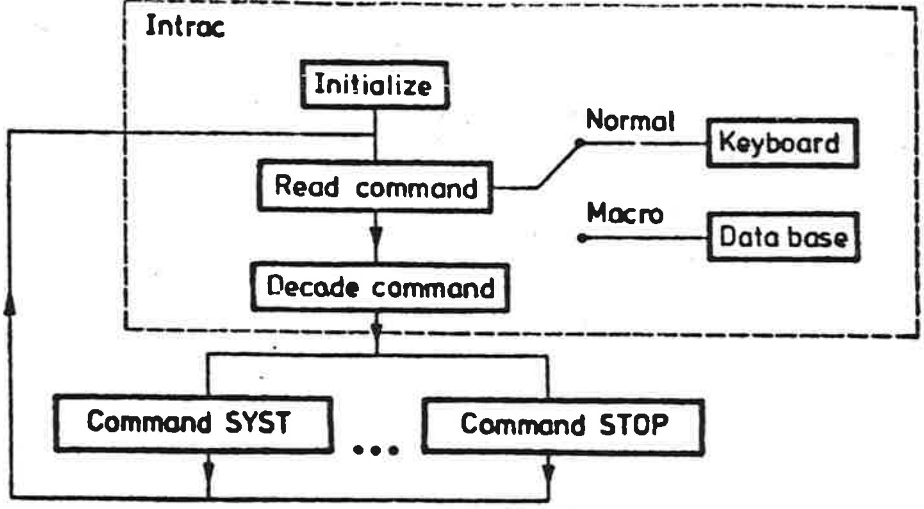
FLEXIBLE BUT MORE DIFFICULT TO USE

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