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The CACE Project - Steering Committee Meeting, 1988-11-23

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Abstract

This report contains documentation handed out to the participants of the steering committee meeting of the STU Computer Aided Control Engineering Programme (CACE) on November 23, 1988. The minutes of the meeting are also included.

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Preface

This report contains documentation handed out to the participants of the steering committee meeting of the STU Computer Aided Control Engineering Programme (CACE) on November 23, 1988. The minutes of the meeting are also included.

CACE-projektet
Styrgruppssammanträde 1988-11-23

Dagordning

10.00 **Formalia**

10.15 **Projektläge**

12.00 **Lunch**

13.30 **Framtida planer – efter CACE**

Nästa sammanträde, övrigt

Demonstrationer

Project status

Contents

Published papers

1. Dag Brück
   "Modeling of Control Systems with C++ and PHIGS"
   USENIX C++ Technical Conference, Denver, Colorado, Oct 17–20, 1988.
2. Elmqvist, H. and S.E. Mattsson
   "A Simulator for Dynamical Systems Using Graphics and Equations for Modelling"
   Control Systems Magazine
3. Larsson, J.E. and P. Persson
   "An Intelligent Help System for Idpac"
   ECAI-88, European Conference on AI
   Munich, August 1–5, 1988
4. Larsson, J.E. and P. Persson
   "The Knowledge Database Used in an Expert System Interface for Idpac"
   IFAC Workshop on Artificial Intelligence in Real-Time Control
   Swansea, Sep 21–23, 1988

Published papers – cont.

5. Mattsson, S.E.
   "On Model Structuring Concepts"
   4th IFAC CADCS
   P.R. China, August 23–25, 1988
6. Mattsson, S.E.
   "On Modelling and DAE Systems"
   Simulation

Finished Master Projects

1. Michael Johansson
   "Interactive plotting of measurement data in several dimensions"
   for STFI
2. Ulf Jeppsson
   "An Evaluation of a PHIGS Implementation for Full Graphics Control Systems"
   in cooperation with ABB
3. Anders Nilsson
   "Object-oriented Graphics for the Future Instrument Panel"
   in cooperation with ABB
4. Per Anders Vallinder
   "Some Methods for Tearing of Differential/Algebraic Systems"

CADCS'88

4th IFAC Symposium on Computer-Aided Design in Control Systems, August 23–25, 1988, Beijing, P.R. China.

130 participants (30 Chineese)

Subjects:

1. Good surveys
2. CADCS packages
3. Design methods
4. CADCS expert systems
5. Applications

No new great ideas

Good opportunity to meet colleagues.

IFAC Working Group for CACSD Software

1. Command Interfaces
   - Draft standard for a command language for linear systems
     will be submitted to Automatica
   - Nonlinear systems: too early
     Investigate the status of IMACS and SCS
2. Data representation
   - Awaiting an ISO standard (Nov 88)
3. Algorithms
   - WGS in Benelux
     SLICE standard
     SLICOT (NAG)

UK: SERC

ECSTACY

1. An environment for control system theory, analysis and synthesis
   1. Man-machine interface
   2. File organizer
   3. Matrix manipulation tools
   4. System manipulation tools
   5. Archiving and report preparation
   6. Simulation tool
2. Beta-release of an embryo ECSTACY
   ProMatlab and ACSL
   We are promised to get a copy

Workshop "Future Research Needs in CACSD"
Cambridge 14 and 15 Dec 1988

S.E. Mattsson is invited to give a talk "Future modelling and simulation environments"

ESPRIT Project ITSIE

Intelligent Training Systems in Industrial Environments

1. Contractors
   Marconi Simulation, UK
   CRI, Denmark
   CISE, Italy
   Heriot-Watt University, UK
   Iberduero (electric utility) Spain
   Laboratories de Marcoussis, France
2. Aims
   - develop an architecture for ITSIE
   - industrialize qualitative modelling
   - two demonstrators
     operation of fossil fuel plant
     maint. and rep. of electr. dev.
3. Start in Jan 1989; 3.5 years
4. Budget 7 MECUs (50 man years)

Participation from Lund in ITSIE?

Had discussed common workshops with Roy Leitch.

Oct 1988: Active participation?
Minimum 2 people for 2 years

Had to respond in a few days.

The answer was no:

1. Shortage of manpower
2. Other commitments
3. The project was already set up
4. Development project
5. DUP?
   The results will be published
   Power system applications

Tools for model development and simulation

1. Compilation of model types
2. Symbolic manipulation of DAEs
3. Parser and interpreter for arithmetic expressions including vectors and matrices
4. Omola
5. Discrete events
6. Modeling of chemical processes

On the Evaluation of the CACE Project "Tools for Model Development and Simulation"

Sven Erik Mattsson

Introduction

At the steering committee meeting on June 1, 1988, strategies for evaluation of the results from the project "Tools for Model Development and Simulation" were discussed. Questions like "Are the concepts general?" and "Is it the best possible design?" were raised. No general answers can be given to such questions for several obvious reasons. For example, the needs, requirements and personal preferences vary from user to user. The objective of this paper is to try to sort out some obscurities.

Background

We are not trying to make the ultimate CACE package. First, new methods for analysis and design are developed. Second, different users may have conflicting demands.

Our aim is to introduce some new ideas and concepts that we think are useful. We are especially focusing on system representation. It is an important and critical part of a CACE system, since it should be made common to all tools. Our experiences from extensive use of CACE tools in a wide range of applications indicate that ways of representing models in current CACE packages are inadequate. They are adapted to the computer and different for each task. Concepts to represent the structure of a model are generally missing. This makes it difficult to reuse a model or parts of a model for various tasks in different applications.

Our belief is that CACE tools can support model development, but it will as we can understand always demand time and clever people to develop models from scratch. A more radical approach is to avoid model development work as far as possible and reuse already existing models. In computing science much work has been focussed on the possibilities to reuse software in different models. Unfortunately, it seems as if developers of tools for model development and simulation have neglected this possibility.

The results of the project

The basic result is a number of concepts to support model development and reuse of models:

1. Models on equation or symbolic forms and automatic generation of
   - efficient code for simulation
   - code for calculation of steady state
   - linear models etc.
   - descriptions accepted by other packages
   - control code

2. Model structuring concepts:
   - Hierarchical submodel decomposition
   - Model types
   - Multiple realizations
   - Model categorization
   - Multiple presentations
3. Parameterization of models

The design of these concepts is decomposed as follows:

1. Semantical properties
2. Textual and graphical representations
3. Internal representation and implementation

We believe that all users can agree on the basic semantics of these concepts, but that it is useful to allow the concepts to have different textual and graphical representations. For example as a graphical presentation of the model structure, we propose hierarchical block diagrams with information zooming. Our design includes also an internal representation to support these concepts. A prototype implementation is done using KEE.

The rationale for our design and the discussion of alternative approaches will be included in our reports and is an important outcome of the project.

Alternative approaches?

It is in this paper out of the scope to discuss alternative approaches as well as the pros and cons of our design. We will here only point out a few major important assumptions and design decisions.

Model decomposition. The concept for model decomposition is important since modularization is an important tool to handle complexity as well as make it possible to reuse parts of models.

We have proposed a hierarchical model decomposition concept. However, this is not the most general concept for decomposition. A model can be decomposed according to several principles. Two common ways are decomposition according to physical component structure and to function. Unfortunately, these two decomposition principles will in general result in different model structures, since a physical component may have several functions in a plant or a function may be implemented using several physical components. The simple hierarchical structure is lost and it is non-trivial to support a combined physical and functional decomposition. Morten Lind at DTH in Denmark has proposed a Multilevel Flow Modelling (MFM) language which aims at a functional description of complex processes with diagnosis as one application. We think that his approach is interesting, but its practical usefulness, however, has to be proven. In this conflict between generality and simplicity we have chosen the simpler solution, since it seems to us that the more general solution is too complex. There are no good methods to visualize such complex relations.

We would like to stress that the concepts which we propose are general and allow model decomposition according to different principles, but do not explicitly support simultaneous decomposition according to component structure and function. Our proposal that a model decomposition should be done according to the component structure is not imperative, but a proposal that we think could help the model developers and facilitate the reuse of models in various contexts. The physical structure of a system is more concrete and less ambiguous than the functional structure, which is more a function of the viewer's interests and background. Functional decompositions are often advocated in monitoring and diagnosis applications.

The proposed concepts to model interaction between submodels allow a developer of a library model to supply redundant information, which are used to check consistency.

Mathematical frameworks. We distinguish between primitive models and composite models. A composite model is decomposed into submodels and its behavior is described by the submodels and their interactions. A primitive model is not decomposed into submodels, but the behaviour is described in some mathematical or logical framework.

The model structuring concepts as well as the concepts to describe interactions between submodels are designed so general that they can be used for any kinds of frameworks to describe the behaviour of primitive models. However, it is one thing to allow and to accept any kinds of descriptions and another thing to provide tools that can analyse and deduce facts from the model. Our aim is to support differential-algebraic equation (DAE) systems, which we think are a natural mathematical framework for modelling of physical components. Unfortunately, it is too hard to provide a general framework for PDEs. We plan to support difference equations since it is a natural framework to describe digital controllers. Unfortunately, it is beyond the scope of the CACE project to penetrate the area of discrete event simulation. However, we will have some looks on how some uses of discrete events can be supported in what is basically a continuous-system model.

Symbolic descriptions. Symbolic descriptions and models on equation forms allow the model developer to enter his model on a for him natural form and support reuse of models for different tasks. A model developer should of course be allowed to define expressions in the form of (Fortran) functions, if he finds that more convenient or if he wants to reuse old code.

The risk of supporting models on equation forms is that the users will think that the tools which we can provide today are too poor. The tools may be considered to be too slow, unreliable etc. For example today's numerical DAE solvers are less efficient and less robust than the best numerical ODE solver. However, we think that this is the right way to go. The computers become more efficient and cheaper, while the costs for manpower increase. Reuse of models is a must.

User interface. User interfaces are difficult to design and evaluate. There are no theories for how to do it. Today it is more of art than science to design a user interface.

Another problem is the lack of graphics and window standards. Today it is almost impossible to make a portable graphical user interface.

Application project

We selected modelling of chemical processes as our application project, because

1. It is an important class of processes.
2. The modelling of chemical processes is sufficiently rich to allow us to illustrate our ideas.
3. We have expertise in this area.

It serves several purposes: source of inspiration, test case for ideas and concepts, test case for implementation, demonstration model to illustrate our ideas. Note that Bernt Nilsson, who is running the application project, has not been directly involved in the design of the concepts. His role is the users.

If he has any complaints or proposals they are carefully analysed to check if they are of general interests. The goal of the whole project is not to develop very sophisticated and specialized tools with expert system facilities for a specific application domain like chemical processes, power systems or robotics, but to support model development and simulation in general.

It is of course desirable to evaluate the tools in several applications. However, when considering the resources at hand, we think it is better to concentrate on one application and make it in detail, than to spread the efforts on several sketchy applications. We need a test case and a demonstration case that is worked out in the details.

Evaluation

It is very difficult to evaluate new concepts. First, a slow and unrobust prototype implementation may kill the best designs. Furthermore, it is not just to take an old team and an old problem, since then there is a potential risk that they just make a simple conversion and do not reconsider the problem and explore the new features available. They will then say "Well, it worked, but so what? We have been able to do this before". The experiences from marketing Simnon indicate that the best way to make a person creative and enthusiastic is to sit down at the terminal together with him and solve a problem his currently is working on.

The experiences from Simnon and language design is that it is a long process to get a polished product. The paradox of language design is that the concepts should be so natural for the users that they cannot understand that it has taken 20 years of hard work to design the concepts.

Seminars and Visits

June – November 1988

Sven Erik Mattsson

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This is a list of seminars and external contacts the Department of Automatic Control, Lund Institute of Technology has had during the period June – November 1988, which are of interest for the CACE project. The list includes visits to the department and visits of the staff to companies and other universities, as well as participation in conferences, symposia, workshops, courses etc.

Our visitors are normally given a presentation of our department and our research, as well as live demonstrations of our packages for CACE, so this is not explicitly mentioned in the list below.

1988

May 3 – June 30	Professor Douglas Birdwell from Electrical and Computer Engineering, University of Tennessee, Knoxville visited the department as a guest researcher in the CACE project.
June 1	Björn Tyréus and Ed Longwell, Du Pont, Newark, Delaware, USA visited the department to discuss modeling of chemical processes.
June 2	Professor Thomas McAvoy, Systems Research Center, University of Maryland visited the department. He gave a seminar titled "DICODE - a distillation column expert".
June 2	Dr D. J. Collins, Naval Research, London visited the department. He gave a seminar titled "Application of Eigenstructure Assignment of Self reconfiguring Aircraft MIMO Controllers".
June 16	Mikael Schmidt presented his MSc project "File Management on external memories for a small process computer system".
June 17	Douglas Birdwell gave a seminar titled "Teaching with the CASCADE Design Environment".
June 21	Douglas Birdwell gave a seminar titled "Stochastic Decision Theory".
Aug 1 – 5	Jan Eric Larsson and Per Persson attended the European Conference on Artificial Intelligence, ECAI, Munich, August 1–5, 1988. They gave a demonstration of their intelligent help system for Idpac.
Aug 18	Jan Eric Larsson and Per Persson gave a seminar titled "Impressions from the European Conference on Artificial Intelligence, ECAI in Munich, August 1–5, 1988".
Aug 23 – 25	Sven Erik Mattsson participated in the 4th IFAC Symposium on Computer-Aided Design in Control Systems, CADCS'88, August 23 – 25, 1988, Beijing, P.R. China. He presented his paper "On Model Structuring Concepts". He also got many opportunities to discuss common interests with colleagues from all around the world. He participated in the meeting of the working group Guidelines for CACSD-software. The working group has agreed on a draft standard for a command language when dealing with linear systems. The standard for representation on files will be based on the ISO standard for data representation. The draft standard will be submitted to Automatica for publication. It was agreed that it is to early to make a standard for non-linear systems. There are too many open questions. It was also agreed that the group shall investigate the status of the corresponding working groups of the International Association for Mathematics and Computers in Simulation (IMACS) and the Society for Computer Simulation (SCS). These groups are said to be inactive today. SCS issued in 1967 the CSSL standard, which are followed by most of today's commercial program for continuous time simulation.
Aug 24	Ulf Johansson presented his MSc project "A Scheduler for MICOS".

Sep 5 – 30	Andre Tits, Systems Research Center at the University of Maryland visited the department September 5 – 30 as a guest researcher in the CACE project. Tits main interest is optimization. He and Fan have designed a tool, CONSOLE, for optimization-based design of a large class of dynamical systems. CONSOLE has an interface to Simnon, in which you define your dynamical system. You define in a separate file the criterion, the constraints and the parameters to optimize. When the problem is set up, CONSOLE uses Simnon to evaluate the criterion and the constraints during the optimization procedure. We got access to CONSOLE. There is an interesting possibility to use CONSOLE as a tool for tuning models using measured data.
Sep 13	Andre Tits gave a seminar titled "Aspects of optimization-based CADCS".
Sep 15	Andre Tits gave a demonstration of CONSOLE.
Sep 20	Andre Tits gave a seminar titled "Generalized stability of parametric families of matrices".
Sept 20 – 23	Karl-Erik Årzén, Jan Eric Larsson and Per Persson attended the IFAC Workshop on Artificial Intelligence in Real-Time Control, Swansea, Wales, 21-23 September 1988. Karl-Erik Årzén presented his paper "An Architecture for expert system based feedback control". Jan Eric Larsson and Per Persson presented their paper "The Knowledge Database Used in an Expert System Interface for Idpac".
Sep 22	Sven Erik Mattsson participated in a one day working seminar on the use of simulators in the process industry. The seminar was arranged by the DUP program, which is financed by STU. Sven Erik Mattson gave a talk on "Methods and languages for development of simulation models".
Sep 23	Andre Tits gave a seminar titled "Robust stability and performance in the presence of parametric uncertainty and unmodeled dynamics".
Oct 8	The Lund Institute of Technology had open house. The department participated. Björn Wittenmark gave an popular introduction to adaptive control and Rolf Johansson spoke on how humans keep the balance. The following demonstrations were given: 1. Computer graphics and animation (Dag Brück) 2. The inverted pendulum (Kjell Gustavsson) 3. Image analysis (Toni Eriksson) 4. Model identification (Michael Lundh) 5. Robotics (Henrik Ruijter) 6. Smart controllers (Karl-Erik Årzén)
Oct 13	Anders Nilsson presented his master project "Object-oriented Graphics for the Future Instrument Panel" done for ABB, Lund.
Oct 17 – 21	Dag Brück attended the workshop the USENIX C++ Technical Conference, Denver, Colorado, October 17 – 20, 1988 and workshop October 21, 1988. He presented his paper "Modeling of

Control Systems with C++ and PHIGS".

Oct 19 — Karl Johan Åström, Karl-Erik Årzén, Jan Eric Larsson and Per Persson participated in a one day seminar on Expert Systems held at Sydkraft, Malmö for people from the power utilities. They gave the following talks:

1. An Introduction to Expert Systems (Jan Eric Larsson)
2. Real-time Expert Systems (Karl-Erik Årzén)
3. The Usage of Expert Systems in Man-Machine Interface (Per Persson)
4. Expert Systems for Regulator Tuning (Karl Johan Åström)

Oct 19 — Per Anders Vallinder presented his MSc project "Some methods for tearing of differential/algebraic systems".

Oct 26 — Karl-Erik Årzén, Jan Eric Larsson and Per Persson gave a seminar on the IFAC Workshop on Artificial Intelligence in Real-Time Control, Swansea, Wales, 21-23 September 1988.

Oct 28 — Lars Jonsson presented his MSc project "A prototype robot simulator".

Oct 31 — Olof Wickström presented his MSc project "An expert system for planning of hydro power generation on a week basis".

Nov 2 — Karl Johan Åström and Sven Erik Mattsson participated in a one day seminar on Simulation and Advanced Control of Power Plants at Sydkraft Malmö for people from the power utilities. They gave the following talks:

1. Drum water modeling (Karl Johan Åström)
2. Future modeling and simulation environments (Sven Erik Mattsson)

Nov 3 — David Stewart, the Mathematics Dept, University of Queensland, St. Lucia, Australia (visiting graduate student at the Department of Mathematics, CTH, Gothenburg) visited the department. He gave a talk titled "On the numerical solutions of discontinuous ODEs".

Nov 9 — Dag Brück gave an overview of C++ and gave a report from the USENIX C++ Technical Conference, Denver, Colorado, October 17 – 20, 1988.

Nov 9 — Bertil Strandman and Peder Edman, Sydsvenska Värmekraft, Barsebäck, visited the department to get a demonstration of Michael Johansson's master project "Interactive plotting of measurement data in several dimensions".

Nov 10 — Ola Larsson, STFI and five of his colleagues visited the department to get a demonstration of Michael Johansson's MSc project "Interactive plotting of measurement data in several dimensions".

Nov 10 — The DUP chemistry reference group visited the department.

Nov 11 — Dag Brück visited Ericsson Radar Systems, Mölndal, Sweden. He gave a report from the USENIX C++ Conference and discussed object oriented design in C++.

Nov 16 — Michael Johansson presented his MSc project "Interactive plotting of measurement data in several dimensions". The project was proposed by STFI.

Nov 17	Ulf Jeppsson presented his MSc project "An Evaluation of a PHIGS Implementation for Full Graphics Control Systems". The project was done at ABB, Lund.
Nov 18	Thomas Garvey, Artificial Intelligence Center, Stanford Research International visited the department. He gave two seminars including video demonstrations: "The SRI image understanding program" and "Practical aspects of evidential reasoning program".

The CACE Project 1988-11-18
Department of Automatic Control
Lund Institute of Technology, Lund, Sweden

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Compilation of model types

When using a library model type M,
M should not cause compilation errors:

1. Syntax errors
2. Inconsistencies

Straightforward to check the syntax.

More complex to check consistency.

Check of consistency

A model may have unspecified parts to be deduced from the context;

1. different ways of deducing must lead to consistent results
2. there must not be islands of undefined parts.

The consistency condition is
a conjunction of equivalence relations.

A deduced value could represent an unspecified attribute.

The user interface

Store the deduced attributes of M with M

1. allows a user to get the most specific definition
2. allows interactive checks when connecting terminals
3. makes model type compilation to a local operation
4. simplifies compilation and instantiation.

The steps at model type compilation

Compilation of a model type M:

1. check the syntax and basic semantics
2. infer the attributes of M's terminals and the values of M's parameters
3. check that the unspecified parts of M's submodels can be inferred or bound to M
4. check the consistency of M.

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What has to be inferred?

Parameter values and the terminal attributes

1. types of components
2. number of components
3. across or through
4. name of quantity
5. unit of measure
6. values of time invariant terminals

need not be explicitly specified, but has to be deduced context.

Constraints to be used when inferring unspecified parts

Parameters:

1. Setting of a parameter value
   p_1 := <*constant value*>
2. Making a parameter to a constant
   p_1 := constant <*constant value*>
3. Binding of a parameter to other parameters
   p_1 := <*parameter expr*>

Terminals:

1. quantity T_1 = quantity T_2 (ISO 31)
   quantity T_1 = derquantity T_2
2. unit T_1 = <*unit expr*> $*$ unit T_2
   ...
3. Same component structure
   struc T_1 = struc T_2
4. Same type; same component structure and compatible quantities and units
   type T_1 = type T_2
5. Connection between T_1 and T_2.
   Same type and the connection equations
   T_1 connected_to T_2

Multiple behaviour descriptions

To avoid combinatoric problems when a model M has multiple behaviour descriptions B_i:

1. The implications of all B_i on M's terminals and parameters must be consistent
2. The union of all implications are attributes of M
3. The difference between the number of equations and variables must be equal and is stored.

Symbolic manipulation of DAEs

In theory it is easy to use a numerical DAE solver to solve $g(t, \dot{x}, x, v) = 0$

- t time
- x unknown dynamic variables
- v unknown algebraic variables

Need only a routine to calculate the residual

$$\Delta = g(t, \dot{x}, x, v)$$

when the arguments are known.

To solve $\dot{y} = f(t, y)$ using an ODE solver a routine to calculate $f(t, y)$ is needed.

However, it is useful to do some symbolic manipulation first.

BLT partitioning

Make a Block Lower Triangular Partition of

$$g(t, \dot{x}, x, v) = 0$$

assuming $\dot{x}$ and v to be unknown and t and x to be known.

If the blocks are scalar and the assigned variables appear linear, it possible to solve for $\dot{x}$ and use an ODE solver.

This is the case for a Simnon or ACSL model.

With access to symbolic manipulation routines, it is possible to solve more complicated cases.

Do not introduce divisions by zero.

Advantages of this BLT partitioning:

1. There are efficient procedures for BLT-partitioning with minimal diagonal blocks.
2. No numeric operations
   just permutations of equs and vars
   cannot introduce singularities
3. If this BLT-partition is singular
   the problem may be well-defined,
   but it is then at least of index 2.
   Must differentiate equations to put it as $\dot{y} = f(t, y)$
   There are constraints on $x(t_0)$.
   Difficult problem for a DAE solver.

What can be done, if we cannot put the problem on state space form?

Consider the problem of solving $h(v) = 0$ using a numerical solver.

Need a routine for $\Delta = h(v)$

Consider the structural matrix for a h:

	a	b	c	d	e	f
1	x				x	x
2	x	x		x	x	x
3		x	x	x	x	x
4			x	x	x	x
5					x	x
6					x	x

Let us permute equations and variables:

	e	f	a	b	c	d
5	x	x				
6	x	x				
1	x	x	x			
2	x	x	x	x		x
3	x	x		x	x	x
4	x	x			x	x

Block diagonal form with 3 blocks;
3 smaller sequential tasks:

	Equs	Vars
1.	5, 6	e, f
2.	1	a
3.	2, 3, 4	b, c, d

How can we use the BLT-partitioning?

	e	f	a	b	c	d
5	x	x				
6	x	x				
1	x	x	x			
2	x	x	x	x		x
3	x	x		x	x	x
4	x	x			x	x

Assume that a appears linearly. $\Rightarrow$
Simple to solve a when e and f are known.

$\Rightarrow$

The numerical solver need only handle the problem:
Equations: 2–6
Unknowns: b–f

The residual routine can solve a from Equ 1.

Do not make any symbolic substitutions.

How can we explore the blanks in block 3?

	e	f	a	b	c	d
5	x	x				
6	x	x				
1	x	x	x			
2	x	x	x	x		x
3	x	x		x	x	x
4	x	x			x	x

The block is minimal.

If d is known and
b appears linearly in Eq 2
it is easy to solve b from Eq 2.

To the numerical solver:
Equations: 3–6
Unknowns: c–f

Residual routine calculates:
1. a from Eq 1
2. b from Eq 2.

Tearing

Divide unknowns and variables into 2 sets so that it easy to solve the first set when the variables of the other set is known.

An iterative procedure then just has to iterate over the second set.

Tearing was invented by Kron.

We will consider linear systems of order 1 or 2 as simple problems.

Methods for tearing

Two classes of heuristic methods:

1. Steward (1967, 1965, 1967)
   - (BLT partition)
   - Search for a long loop and cut it
   - BLT partition
   - Repeat the procedure on the blocks
2. the P^3 and P^5 algorithms
   - (BLT partition)
   - Makes a Bordered BLT
   - Block size vs border width

- They are simple to implement.
- Combinatorical difficulties.
- Numerical stability – pivoting.

The assignment problem

Not enough to make the system triangular.

The assigned variable must be analytically solvable.

For us, it must appear linearly.

P^3 and P^5 cannot take this into account; designed to treat linear problems.

Steward assumes that the assignment is done.

A method of eliminating algebraic variables before using a DAE solver

Consider $g(t, \dot{x}, x, v) = 0$

Assume we can only solve linear systems of order 1 or 2 analytically $\Rightarrow$

1. Could assume $\dot{x}$ and x known
2. If a component v_i do not appear linearly in any equation $g_i = 0$, assume it is known

Procedure

1. Let
   a. $\widehat{v}$ contain v_i which appears linear in any equation $g_i = 0$
   b. $\widehat{g}$ contain g_i which has an linear appearance of a v_i
2. Make an assignment for $\widehat{g}(\widehat{v}) = 0$
   a. Explore v_i =<*expr indep of* v_i>
   b. or other heuristic methods
   c. or the assignment procedure of BLT
   - $\widehat{v}$ and $\widehat{g}$ may be of diff length
3. Remove all redundant equations in $\widehat{g} = 0$
4. Assume that all unassigned $\widehat{v}_i$ are known
5. Use BLT partition and Steward to find $\widehat{v}_i$ that can be handled in the residual routine.

Partitioning to facilitate numerical solution?

Make the Jacobian simple?
Useful to know where there are zeros.

DAE solvers use often implicit multi step approximation of the derivatives.

Consider the Euler backward approximation

$$\dot{x}(t_n) \approx (x(t_n) - x(t_{n-1}))/h$$

It gives

$$g(t_n, (x_n - x_{n-1})/h, x_n, v_n) = 0$$

Has the same structural matrix as $g(t, z, z, v) = 0$ which in most cases is not that sparse.
BLT partition will give large blocks.

Conclusions

Use BLT partition to investigate if it is simple to put the problem on state space form so that ODE solvers can be used.

If a DAE solver has to be used, then use BLT partition and tearing as described above to eliminate algebraic variables.

OMOLA

- An Object-Oriented Modelling Language
- A textual way of describing model structure

Why?

- Complement to SEE
- A way to store models
- Good for documenting SEE
- Good for documenting models

OMOLA is a general object-oriented language for describing object structures.

- Inheritance: (specialization/generalization)

```
PowerGenerator IS AN ElectricMachine
     |                 |
  subclass          superclass
```

- Components: (terminals, parameters, etc.)

```
Tank IS A Model WITH
 terminals:
  Inflow  IS A Terminal;
  Outflow IS A Terminal;
 parameter:
  Area IS A Parameter;
END;
```

An OMOLA Example

```
Regulator IS A Model WITH
 terminals:
  mv IS A SimpleTerminal;
  sp IS A SimpleTerminal;
  cv IS A SimpleTerminal;
END;


RSTregulator IS A Regulator WITH
 realization:
  r1 IS A TransferFunction WITH
   R*cv = T*sp - S*mv;
   R = {1 2 2};
   S = {1 1};
   T = {1 1};
  END;
END;
```

```
PIregulator IS A Regulator WITH
 parameters:
  K, Ti IS A Parameter;
 realization:
  r1 IS A SetOfDAE WITH
   e = sp - mv;
   der(i) = e/Ti;
   cv = k*(e+i);
  END;
END;
```

Hybrid Models

A combination of:

- Continuous time models
- Sampled models
- Discrete event models

We need:

- A syntax describing events
- A way to simulate hybrid models

Cause of events:

- Casual events (depends on states)
- Scheduled events (e.g. sampling)

Effect of events:

- Discontinuous state change
- Make a sample
- Change of model realization

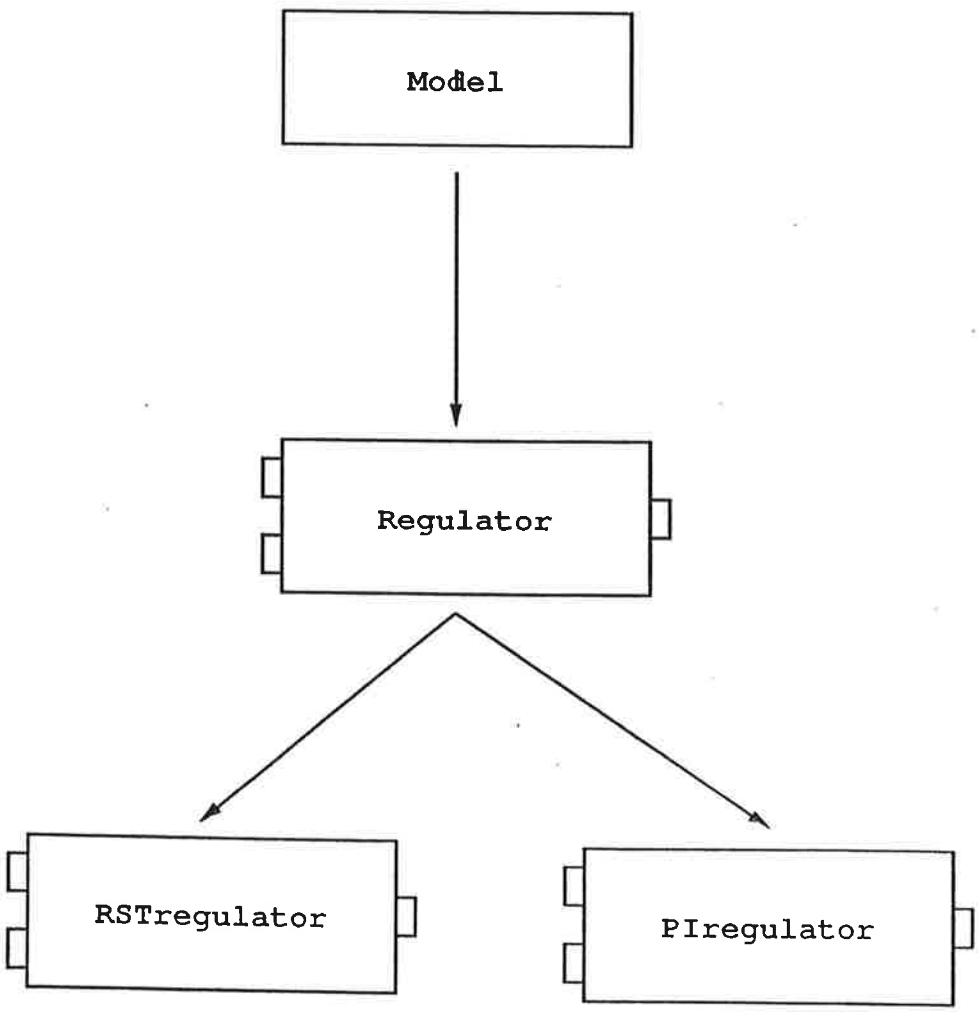
A new type of model componet: Event Handler

WHEN *condition effect*

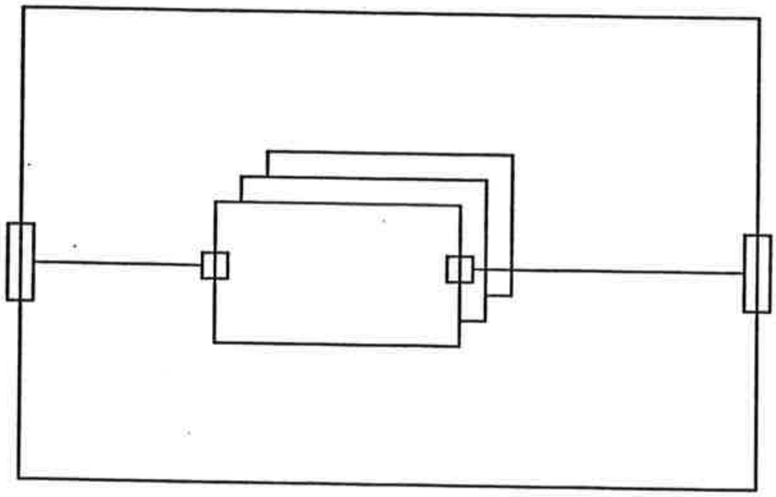
Example:

```
WHEN t > 10 DO x:=0 END;
WHEN temp > limit CAUSE alarm;
```

Model Type Inheritance



Multiple Realizations



Event selection:

```
WHEN temp > high-limit SELECT high-temp-model
WHEN temp < low-limit SELECT low-temp-model

.
.
.
```

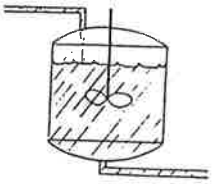
User selection:

```
SELECT complex-model
SELECT simple-model
.
.
.
```

Strukturer
vid
Modellutveckling

Bernt Nilsson

Beskrivning av Delmodeller



$$\frac{d(\rho V)}{dt} = \rho_{in} q_{in} - \rho_{ut} q_{ut}$$

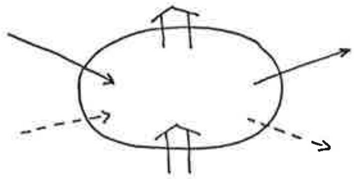
$$\frac{d(Vc_A)}{dt} = c_{A,in} q_{in} - c_A q_{ut} - V k_0 e^{-\frac{E_a}{RT}} c_A$$

$$\frac{d(VT)}{dt} = T_{in} q_{in} - T q_{ut} + \frac{\Delta H_{reak}}{\rho C_p} V k_o e^{-\frac{E_a}{RT}} c_A$$

Struktur ???

Svar: JA !

Modelleringsteknik

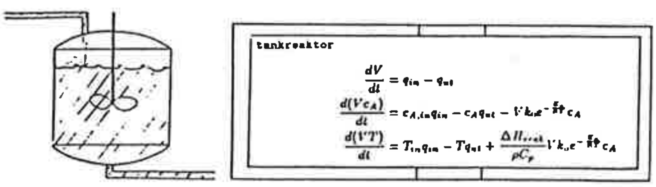


Tillstånd:
- massa, energi och impuls

Tillståndsekvationer:
- Massbalans
- Energibalans
- Impulsbalans

Termer i tillståndsekvationerna:
- Transportfenomen
- Kemisk kinetik
- Jämvikt
- Tillståndsrelationer

Modellutvecklingsstöd



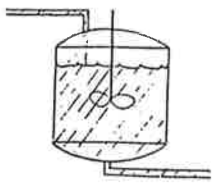
Identitet
- namn: *tankreaktor*
- sort: *processenhet*
- design: *Bernt Nilsson*

Terminaler
- inflöde: *massflödesterminal*
- utflöde: *massflödesterminal*

Beteende

Homogen Makroskopisk Blandningsmodell
- massbalans: *dynamisk*
- komponentbalans: *dynamisk*, *kemisk reaktion*
- energibalans: *dynamisk*

Modellutvecklingsstöd

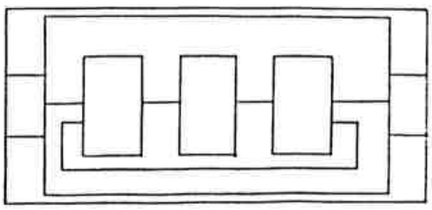


Identitet
- namn: *icke-ideal tankreaktor*
- sort: *tankreaktor*
- design: *Bernt Nilsson*

Terminaler
- inflöde: *massflödesterminal*
- utflöde: *massflödesterminal*

Beteende

Hetrogen Makroskopisk Blandningsmodell
Strukturerad Modell



Modellutvecklingsstöd

Identitet
- namn: *tubreaktor*
- sort: *processenhet*
- design: *Bernt Nilsson*

Terminaler
- inflöde: *massflödesterminal*
- utflöde: *massflödesterminal*

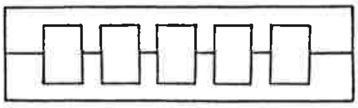
Beteende

Homogen Differentiell Blandningsmodell

reguljär struktur: *5 delmodeller i serie*

- massbalans: *dynamisk*
- komponentbalans: *dynamisk*, *kemisk reaktion*
- energibalans: *dynamisk*

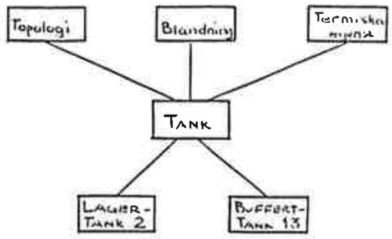
$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho v)}{\partial z} = 0$$
$$\frac{\partial c_A}{\partial t} + \frac{\partial(c_A v)}{\partial z} - k_0 e^{-\frac{E}{RT}} c_A = 0$$
$$\frac{\partial T}{\partial t} + \frac{\partial(T v)}{\partial z} + \Delta H_{reak} k_0 e^{-\frac{E}{RT}} c_A = 0$$



Modellutvecklingsstöd

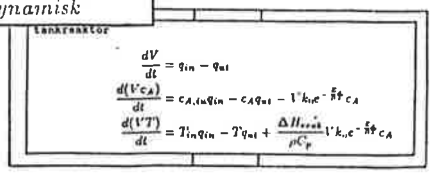
implementering

Multipel Ärvning

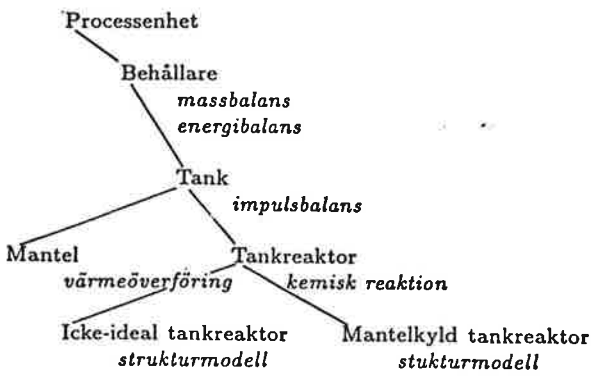


Intelligent Editor

massbalans	*dynamisk*
komponentbalans	*dynamisk*
	kemisk reaktion
energibalans	*dynamisk*



Modellåtervinning



Verktyg för Modellutveckling

- Automatisk generering av modellekvationer.
- Användarspecialisering av allmänna modellbibliotek.
- Återanvändning av modeller och delar av modeller.
- Generella modelleringshjälpmedel. Kan användas för helt andra syften.

After CACE

Alternatives related to CACE

- Implementation project
- Concepts and tools
- Application projects

Implementation project

- Why – why not
  - \+ Many requests
  - \+ Create something concrete
  - \+ Responsibility for spreading results just writing papers is not enough
  - – Academic merits
  - ? Resources needed
  - ? Continuation and maintenance
- Ambition

  Make a useful base version
  which shows the basic ideas
  and can grow in various directions.

Alternatives

1. Implementation in KEE and CommonLisp
2. Implementation in CommonLisp – CLOS
3. Implementation in a compiled language

Comments

- Alt 1
  - \+ least implementation work for us
  - – the users must have a big workstation with CommonLisp and KEE
  - – efficiency?
- Alt 2
  - \+ more potential users than alt 1?
  - – more implementation work than alt 1
  - – efficiency ($\approx$ alt 1)
- Alt 3
  - \+ more potential users than alt 1 and 2
  - \+ could be run on a normal workstation
  - – more implementation work than alt 2?

The Simnon Experience

30 kbyte source code

Level 0	Master project	3 man month
Level 1	ITM project	24 man month
Level 2	Polishing	
Level 3	The PC project Porting to PC Manual	24 man month

Concepts and tools

1. Basic tools for discrete event simulation
2. Different views to present a plant
   Structuring of control systems
3. Application specific tools

Application projects

1. DUP
   SSA, Arlöv
2. Power systems
   ENEL, Italy
   Sydkraft
   Vattenfall

Base version

The aim is to support

- model development
- simulation

of modularized, structured models described by

- differential-algebraic equation systems
- difference equations

Modeling language

1. Mathematical frameworks
   - Differential-algebraic equation systems
   - Difference equations
2. Structuring concepts
   - Hierarchical model decomposition
   - Model types
   - Multiple descriptions of behaviour (static selection)
   - Model categorization (flat)
   - Multiple presentations

Tools

- Creation and editing of models
- Problem setup
- Simulation
- Presentation of simulation results

Creation and editing of models

1. Internal routines to create, delete and modify submodels, terminals, parameters, realizations
2. Interactive tools

   Block diagram editor

   Text editor
3. External storage (model libraries)
4. Compilation of model types

Compilation of model types

The aims are:

1. to check the syntax and semantics so that the use of a model type does not cause compilation errors due to internal inherent errors.
2. to deduce all constraints on terminals and parameters so that a user easily can find out what are fixed or free.

Problem setup

- Selection of realization variants
- Parameter values
- Initial values
- Binding of external data files
- What are to be stored?
- What are to be plotted and how?

Simulation

1. Compilation of models
2. Symbolic manipulation
3. Numeric solution

Compilation of models

- Instantiation
- Syntax and semantics of primitive models
- Generate equations from connections
- Conversion to internal format

Symbolic manipulation

The aim is to facilitate the numerical solution.

What is done may depend on the numerical solver to be used:

- Selection of equations (realizations)
- BLT partition
- Tearing
- Dynamic variable storage allocation
- Code generation

Numeric solution

- Scheduler
- Interpreter
- Numerical ODE and DAE solvers
- Error handlers to numerical routines

Presentation of simulation results

Can be any thing from simple plotting to fancy animation.

1. Start with simple diagram plotting
2. Definition of simple expressions
3. An interface to TEX and PostScript
4. An interface to SattGraph 1000

User interface

General issues

- It should be possible to have individual user interfaces
- It will probably be based on Xwindows

More specific issues

- Block diagram editor
- A browsing facility for model libraries
- Hard copies in TEXand PostScrip format
- An interface to Sattgraph 1000

Extension: Discrete events

1. Detection of events
2. Extended scheduler
3. Dynamic changes of realizations

Extension: Low level descriptions

- Vectors and matrices
- Second and higher order derivatives
- Transfer function descriptions
- Interface to data files
- Interface to C and Fortran functions
- Describing function descriptions

Extension: Tools

- Access to other programs
- Bookkeeping facilities
- Analysis of simulated data
- Calculation of steady state
- Calculation of linear models
- Real-time simulation
- Tools for linear analysis and design

STYRELSEN FÖR TEKNISK UTVECKLING 1989-01-17
SWEDISH NATIONAL BOARD FOR TECHNICAL DEVELOPMENT
Arne Otteblad/ksb

PROTOKOLL

Från möte med STUs styrgrupp för ramprogram CACE den 23/11 1988, kl 10.00 - 17.00 vid Institutionen för reglerteknik, Lunds tekniska högskola.

Närvarande: Styrgruppsmedlemmar:

Sven Gunnar Edlund
Claes Källström
Gustaf Söderlind
Karl Johan Åström
Arne Otteblad

Projektengagerade:

Sven Erik Mattsson
Dag Brück
Mats Andersson
Bernt Nilsson
Thomas Schönthal

§ 1 Följande formaliteter avklarades inledningsvis:

Ordförande för mötet: Sven Gunnar Edlund
Sekreterare: Arne Otteblad
Justeringsman: Sven Erik Mattsson

Den föreslagna dagordningen godkändes.

Protokoll från sammanträde den 1/6 1988 godkändes.

§ 2 På samma utmärkta sätt som vanligt presenterade Sven Erik Mattsson och övriga projektmedarbetare den pågående projektverksamheten.

Presentationerna avslutades med en diskussion av vilka arbetsuppgifter som borde prioriteras under den resterande delen av ramprogrammet (formellt slut den 30 juni 1989). Slutsatsen blev att arbetet under våren borde koncentreras på implementeringen. Övriga uppgifter får hänskjutas till den framtida verksamheten vid Institutionen (se § 4).

§ 3 Styrgruppen konstaterade att bilagda dokument rörande verifiering och uttestning av CACE-verktygen hade sänts ut till gruppen. Gruppen tackade Sven Erik Mattsson för hans sammanställning.

§ 4 Diskussionen av CACE-verksamhetens fortsättning kom att handla mycket om spridningen av resultaten och hur man skulle lägga grunden för en bred användning av verktygen. En möjlighet ansågs vara att påbörja spridning genom applikationsstudier inom kemi- samt massa-pappers-branscherna.

STU STYRELSEN FÖR TEKNISK UTVECKLING
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Olika finansieringar av den fortsatta verksamheten diskuterades. Lösningar med projekt inom Nordisk Industrifond liksom "fria projekt" inom STUs planerade programområde "Informationsteknologins tillämpningar" nämndes. Under budgetåret 89/90 bör det finnas möjligheter att finansiera en del av verksamheten inom STUs program för "Mät- och reglerteknisk forskning".

Arbetsinsatsen för att åstadkomma en basprototyp, som någon sedan kan utveckla vidare till en kommersiell produkt bedömdes vara 4 á 5 manår.

§ 5 Institutionen för reglerteknik demonstrerade för styrgruppen ett antal intressanta projektresultat, t ex "Interaktiv plottning av mätdata i flera dimensioner".

§ 6 För diskussion av den planerade konferensen hösten 1989 bestämde styrgruppen tider för

telefonmöten den 26 januari 1989 kl 9 00 och

6 april 1989 kl 9 00

Ett vanligt sammanträde med styrgruppen bestämdes till den 14 juni 1989 i Lund.

Vid protokollet

Arne Otteblad

Justeras

Sven Erik Mattsson