Contents

Simulation for Analysis of Aircraft Elevator Feedback and Redundancy Control

Pieter J. Mosterman[1], Manuel A. Pereira Remelhe[2], Sebastian Engell[2], and Martin Otter[1]

[1] Institute of Robotics and Mechatronics, DLR Oberpfaffenhofen,
P.O.Box 1116, D-82230 Wessling, Germany
[2] Process Control Laboratory, Department of Chemical Engineering,
University of Dortmund, 44221 Dortmund, Germany

Abstract. Safety critical systems such as aircraft require functional and hardware redundancy to achieve prescribed safety levels. Discrete event control is applied to ensure that a safe system configuration is available at all times. Since, at present, formal verification techniques are restricted to models with few continuous states, in this paper, simulation is used to verify that the overall system operates according to the requirements when an actuator failure occurs. The feasibility study to modelling and simulation of complex controlled systems presented here is characterised by (i) a complex object-oriented model of aircraft dynamics, including gravity, aerodynamics, etc., (ii) the specification of the discrete event redundancy control by a domain specific formalism that includes statecharts, (iii) the usage of energy based hybrid bond graphs to model the dynamics of the hydraulic actuators, (iv) model integration on the model level as well as on the data level, (v) support of DAEs with dynamically changing index and (vi) illustrative simulation results.

1 Introduction

Redundancy is one of the most important techniques to achieve the desired level of safety in systems such as aircraft, nuclear plants, chemical plants, and other safety critical applications. Its basic premise is to include redundant functionality into a system that can be activated when failures of the normal operating components occur and to validate and select normal behaviour (e.g., voting procedures).

1.1 Aircraft Attitude Control

To illustrate the concept, consider the primary (attitude) control surfaces of an aircraft as shown in Fig. 1. The ailerons are used to control roll, the elevators control pitch, and the rudder controls yaw motion. This paper concentrates on the pitch control, performed by the elevators. Each of the elevators is positioned by one of two actuators, the other one operates as a passive load. Discrete-event control embedded on two primary flight control units (PFCU) selects the controlling actuator and ensures that the redundant actuator is loading. Each PFCU controls one actuator per elevator, so that both elevators can be controlled, even if one PFCU fails completely. The PFCUs also generate the position control signals for the four actuators.

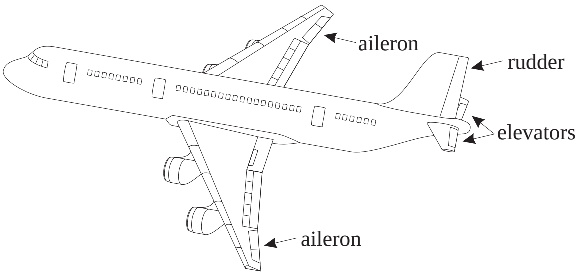


Fig. 1. Primary control surface of an airplane

Feedback control is used for normal operation whereas so-called direct link control is applied to single actuators in the case of certain failures. To ensure minimal transient disturbances caused by actuator switching, the loading actuator should be shadowing the control signals ready to switch to a mode where it actively controls the elevator. However, in some extreme cases the actuator may be disengaged, i.e., it is loading but not shadowing. Thus, each PFCU has to decide for two actuators whether an actuator is disengaged, shadowing, or controlling and whether a feedback or a direct link controller is used for shadowing or controlling. These decisions depend on the mode of the other actuator, the state of the other PFCU and the detected failures. The best possible consistent state configuration of both PFCUs for a given failure situation is achieved by a complex iterative interaction of both PFCUs.

The hydraulic actuator design and the controller parameters may influence the overall behaviour of the aircraft significantly. Therefore, all contributing parts and phenomena of the aircraft such as aerodynamics, gravity, engines, etc. have to be considered in order to assess the design of the elevator control system. Because of the immense complexity and the intricate redundancy management model-based validation is required.

Formal verification techniques are widely used for pure discrete-event systems and much research has been carried out recently on the verification of hybrid systems. However, at present, the complexity of systems amenable to hybrid systems verification techniques is restricted to a low order continuous dynamics (typically not more than three continuous state variables) (Benedetto and Sangiovanni-Vincentelli, 2001, Lynch and Krogh, 2000, Vaandrager and van Schuppen, 1999). Consequently, formal methods are applied to the discrete-event part only, e.g., a so-called Failure Mode Effect (FME) analysis is employed to verify certain safety and reliability properties of the redundancy management system. However, its interaction with the continuous parts as well as the design of the position controllers and the hydraulic actuators can not be evaluated with formal verification techniques. Therefore, the only practical model-based approach for this task is to perform extensive simulation studies.

1.2 Model Design

In this contribution, we concentrate on the modelling and simulation of the elevator control system and the aircraft. The model formulation is driven by the assumption that the simulation studies have the purpose to assess whether the design of the evaluator control system meets the requirements with respect to the overall behaviour of the aircraft (e.g., lateral and longitudinal aircraft velocity and flight path angle). In particular, different sets of parameters of the controllers and of the hydraulic actuators have to be tested in combination with certain failure scenarios.

As a consequence, the simulation model has to incorporate a realistic model of the aircraft dynamics, including all essential effects and components such as aerodynamics, gravity, engines, and hydraulic oil supply. In order to automatically generate the correct Boolean input signals of the feedback controllers and the actuators depending on the sequence of failure events it is convenient to include at least the input-output behaviour of the redundancy management components. Since the sampling times of the PFCUs are very fast in comparison to the bandwidth of the actuators, the hardware aspects of the PFCUs can be neglected, i.e., the redundancy management model reacts instantaneously on failures and the controllers are modelled as ideal continuous controllers. Another idealisation is introduced for the hydraulic actuators. There are many small physical effects such as oil elasticity, viscosity, and fluid inertia which do not influence the overall dynamics significantly, but considerably increase the modelling effort, so that these effects are not considered in the corresponding models.

These basic model design decisions cause several difficulties for the modelling and the simulation. With respect to modelling, the complexity of the systems and their heterogeneous nature mandates the use of dedicated formalisms. These formalisms differ greatly in their visual representation and require the interoperation of specific and powerful modelling environments.

Present day simulation technology, on the one hand, can handle large systems of differential and algebraic equations (DAE), possibly extended by some discontinuous equations (ABACUSS, 1995). On the other hand, discrete-event simulators apply an event driven approach to manage the huge number of state changes in discrete-event models (Group, 1999). The combination of discrete and continuous behaviour requires the integration of a numerical integrator with some sort of discrete-event simulation. Especially, the detection and location of discrete events during continuous integration has to be supported. Furthermore, at event times discontinuities in continuous state variables may occur. For the aircraft model, this phenomenon emerges because the abstractions in the hydraulic actuator models result in a DAE with dynamically changing index. This requires a special simulation engine that switches the active equations and automatically reinitialises the state variables according to physical conservation laws, when the index changes. This contribution presents techniques that cope with all these problems.

1.3 The Modelling and Simulation Approach

For the components of the physical system we use object-oriented modelling. In this context, the term object-oriented modelling means that every physical object is modelled independently without making assumptions about its environment and preserving the physical connection structure of the object. The connections of a model component have to correspond to physical interactions the computational causality of which is not fixed a priori, i.e., the variables involved in an interaction are not a priori defined as inputs or outputs. Furthermore, the behaviour of the component should be defined in a declarative way where a set of (possibly implicit) equations is regarded as a set of behavioural constraints rather than as a calculation formula. To illustrate this, let us consider a hydraulic line. The component model of the line would have two connections which each incorporate a pressure and a flow variable. These variables represent neither inputs nor outputs, since depending on the structure of the environment the pressure drop causes the flow or the flow causes the pressure drop. In some cases the causality can even change dynamically so that a quantity that would be regarded as an input in signal flow diagrams becomes an output and vice versa. This is why the equation-based behavioural description is inherent to object-oriented modelling. Using equations (which may be written in an implicit style) for the description of the behaviour does not impose a specific calculation scheme. From the modelling perspective the equations of all model components and all connections of the overall aircraft model simply form a global set of differential and algebraic equations (DAE) so that simulation is the task to find a solution to these equations, i.e., functions over time that satisfy the equations. To generate efficient simulation code, the model equations must be processed by a symbolic engine and compiled into executable code.

The existing DAE based modelling languages such as gPROMS (Barton, 1992), VHDL-AMS (Heinkel, 2000, Christen, 1997) , MODELICA (Modelica,), etc. differ in many aspects. This work utilises an aircraft library (Moormann et al., 1999, Moormann, 2001) developed using MODELICA which allows to build domain-specific graphical component libraries and supports many features known from object-oriented programming such as inheritance, packages, etc. For the modelling and the symbolic processing task DYMOLA (Dymola,) was used. It provides a graphical user interface for model composition. The symbolic engine of DYMOLA generates C-code from a MODELICA model. Then a standard C-compiler generates the executable simulation code.

This configuration is already powerful enough to model most parts of the aircraft and to simulate the resulting complex DAE system including certain discontinuities (a so-called ‘hybrid DAE’). However, for simulating DAEs with dynamically changing index, the current symbolic engine of DYMOLA (version 4.1d) is too limited. Therefore, a specially developed environment, HYBRSIM (Mosterman and Biswas, 1999), which is based on hybrid bond graphs (Mosterman and Biswas, 1995) was used to model the components with variable index, i.e., the hydraulic actuators. The C-code generated by the two environments, DYMOLA and HYBRSIM was then merged manually and simulated using a general purpose hybrid dynamic system simulator MASIM (Mosterman, 2001).

The purely discrete-event parts of the elevator control, i.e., the redundancy management, are modelled by a domain-specific formalism including statecharts. It will be shown that the syntax and the semantics of the object-oriented modelling paradigm is not well suited to represent the objects of such a formalism. Instead, a separate modelling environment has been implemented which supports this formalism and generates a monolithic MODELICA component that can be integrated into the MODELICA aircraft model .The behaviour of this component is defined by an algorithm that is interpreted by MODELICA as an additional model constraint, i.e., it is equivalent to one equation with multiple input and output variables. In contrast to the other parts of the model the causality of the interface variables and the calculation scheme of the resulting object are predetermined. While the actuator model is integrated on the data level, the redundancy management model is integrated on the model level.

Section 2 presents a system level view of the elevator redundancy control. Section 3 discusses the different parts in detail and presents the respective models. Simulation results are given in Sect. 4. Finally some conclusions are drawn in Sect. 5.

2 Aircraft Elevator Control System

The aircraft elevator control system includes several forms of redundancy (Seebeck, 1998). The system itself consists of two elevators, the control surfaces. Each of these are controlled by one of two hydraulic actuators while the other one is operating as a passive load. The four actuators take their power from three hydraulic subsystems as depicted in Fig. 2. Two primary flight control units are available to compute actuator control signals and modes.

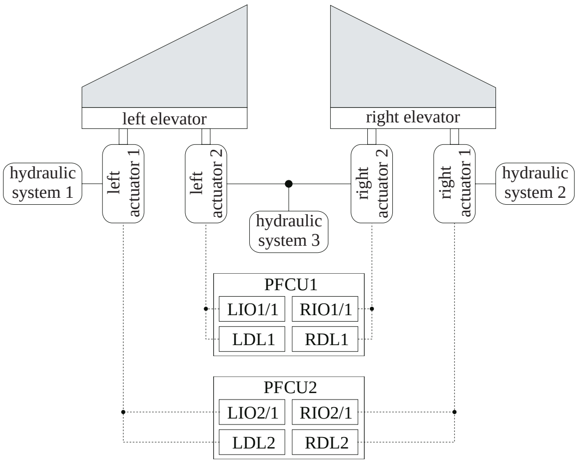


Fig. 2. Elevator system

The functionality of each actuator is specified in textual form in terms of a number of module actuator control modes (MACM) all with their specific behaviour characteristics. These are defined in Table 1. Note that the MACM definitions include behavioural information along with structural information about the particular mode of operation of the actuator components.

Table 1. Module actuator control modes

MACM	Description	Actuator Servo valve	Actuator Spool valve
active	The module controls the servo valve in closed loop mode. The corresponding actuator is active and controls the elevator movement.	controlled	open.
hot and standby	The module controls the servo valve in closed loop mode. The corresponding actuator is not active and operates as a load.	controlled	closed.
passive	The module is waiting and does not generate actuator control signals. *It can change its mode at any time to take on control of the corresponding actuator.*	not controlled	closed
off	The module is turned off temporarily because of an intermittent failure and does not generate actuator control signals. *As long as the failure has not been fixed, it cannot change to a mode where it controls the corresponding actuator.*	not controlled	closed
isolated	The module is turned off indefinitely. *A persistent fault in the control loop of the corresponding system isolates the module and it cannot change to a mode where it controls the corresponding actuator.*	not controlled	closed

The discrete outputs of the redundancy management system are transformed into physical behaviour by means of a spool valve and a servo valve in the hydraulic actuator. Power is supplied by one of the hydraulic systems and delivered to the actuator cylinder that positions the elevator. This flow of energy is modulated by the servo valve, the modulation is computed by a PID feedback control law. The control signals for the actuators are generated by two *primary flight control units* (PFCU) that can operate as *input-output* modules (IOM) or as *direct-link* modules (DLM) controlled by a switch in the control law. The IOMs calculate setpoint values for the actuators based on a PID control algorithm and monitor a number of critical system variables and change between the modes in response. The DLMs allow limited but direct control of the actuators in case the IOMs are not available. The control modules can be in different modes for each of the actuators separately. Moreover, they may control other aircraft actuators as well. In addition, the servo valve may not be controlled and its piston then is in a default position. Also, the spool valve can be turned on and off to switch between active control and passive loading. Continuous feedback control drives the elevator to its desired setpoint, while higher level redundancy management selects the active actuator and the control law to be used.

Interaction between the actuator and the aircraft model consist of forces and moments acting on the elevator that is stiffly connected to the actuator positioning cylinder as well as the pressure generated by the hydraulic systems. Three hydraulic systems supply the oil for the actuators shown in Fig. 1. When a failure occurs, the redundancy management switches between actuators and oil supply systems to achieve maximum control.

The behavioural redundancy requirements may be formalised by a set of rules for the redundancy management to switch between module actuator control modes as follows (Seebeck, 1998):

1. Mode changes only occur when
   - a system failure is detected, or
   - control of an uncontrolled elevator is requested, or
   - one module requests control of both elevators which are controlled by separate modules.
2. One module should be simultaneously in either *active*, *hot*, or *standby* for both elevators as long as possible.
3. If not overruled by the previous specification, the module priority is such that the switching sequence is IOM2/1 → IOM1/1 → DLM2 → DLM1.
4. There is always one and only one module that controls one elevator, i.e., that is *active*.
5. In case of a failure of the controlling module, control is assumed by a module that is *hot* or *standby*. If no module is in this mode, the one with highest priority that is *passive* assumes control.
6. A module switches to *hot* when the other module that controls the same elevator, and, therefore, is *active*, belongs to another PFCU and both elevators are controlled by IOMs.
7. A module switches to *standby* when the other module that controls the same elevator, and, therefore, is *active*, belongs to another PFCU and one of the elevators is controlled by a DLM.
8. In case of pressure failure, the 'low pressure' signal only serves for fault classification. It does not cause a direct mode change.
9. In case of 'low pressure' and if a sensor detects an elevator positioning system failure, the module switches *off*. The module switches back to *passive* only when no system failure is reported and the 'low pressure' condition does not hold anymore.
10. If 'low pressure' is not reported and the elevator positioning system is reported to fail then the module switches to *isolated*.

To prevent nondeterministic switching, priorities are assigned to the possible transitions. Because of the critical nature of switching to the *isolated* mode to prevent damage to the system, this transition has the highest priority. In addition this causes another module to immediately assume control. This is also desired when, e.g., a pressure loss is detected and the module switches *off*. Therefore, the corresponding transition has second highest priority. Another decision criterion is to allow modules to take over control as quickly as possible. As a result, modes that implement as much control as possible should have highest priority. So, when a module can be switched *active* this should be immediately executed rather than first switching to *standby* if this transition is also enabled. This yields the following priorities:

1. Transition to *isolated*
2. Transition to *off*
3. Transition to *active*
4. Transition to *hot*, *standby*, and *passive*.

Sensors in the elevator control system provide the PFCUs with information about the functioning of the system. In case of abnormal readings, the entire set of measurements is used to infer a particular failure mode. Details of this inference mechanism are beyond the scope of this paper. To test the redundancy management, failure mode effect (FME) analysis investigates the availability of the system for several test cases that embody a set of sensor readings:

- Pressure decrease in the hydraulic system (H1, H2, H3)
- Predefined set of failures (F)
  - IO module failure (1, 2)
  - DL module failure (1, 2)
  - Actuator failure (left inner/outer, right inner/outer).

These failures represent abstractions of actual physical phenomena underlying the failure detection. FME is still the most important step in verifying system safety and reliability of discrete-event control (Mai and Schröder, 1999, Osder, 1999).

The combined discrete redundancy management for two of the four actuators on each of the four modules results in eight redundancy modules. This adds up to a considerable discrete behavioural complexity. Each module consists of six possible local modes and there are eight such modules. Thus, the total number of modes of the redundancy management control is 48. There is always one and only one active state in each of the discrete-event models. But, because of the redundancy specification, each of the models needs to have information about the mode of each of the other ones. This interaction is based on the MACMs and causes logic connections between each of the actuator control modules. Finally, an additional discrete-event model is used to model possible fault scenarios by activating states that correspond to particular failure modes. This model has eleven states.

3 Modelling the Parts of the System

The elevator control system described in Section 2 contains a number of parts that are best captured by different modelling approaches: (i) the aircraft dynamics, (ii) the redundancy control, including control law switching, and (iii) the actuator switching behaviour.

3.1 Aircraft Dynamics

To investigate the effect of actuator switching on the overall flight characteristics such as nick rate (q) and angle of attack (α), an aircraft model is required. The more realistic this model, the higher is the probability that the analysis results also hold for the actual implementation on the aircraft.

Object-Oriented Modelling The design of a realistic aircraft model is a tremendous task that combines several domains within aircraft design such as (i) aerodynamics, (ii) gravity, atmospheric, and wind models, (iii) engine/thrust models, (iv) rigid body models including the effects of fuel consumption, and (v) systems models for primary (attitude) control.

Traditionally, such complex aircraft models are written in a computer processable format such as, e.g., FORTRAN, and they are completely integrated with facilities for behaviour generation, e.g., the numerical solver. This, however, renders the models unwieldy, error-prone, and rather costly to implement and update.

Recently, a more structured approach to aircraft modelling has been developed based on object-oriented modelling techniques and the use of libraries of the domain specific components mentioned before (Moormann et al., 1999, Moormann, 2001). Object-oriented modelling techniques rely on the notion of *encapsulation* to hide the details of physical component models and to increase maintainability. Furthermore, the models are organised hierarchically which allows successive refinement of behaviours at increasing levels of detail.

Graphical Syntax Figure 3 shows a top-level view of the aircraft model with the engine objects (left), the systems component (top) and the aerodynamics model (right), the rigid body model, and the gravity/atmosphere/wind models (bottom-right). These components can be decomposed hierarchically in similar object diagrams.

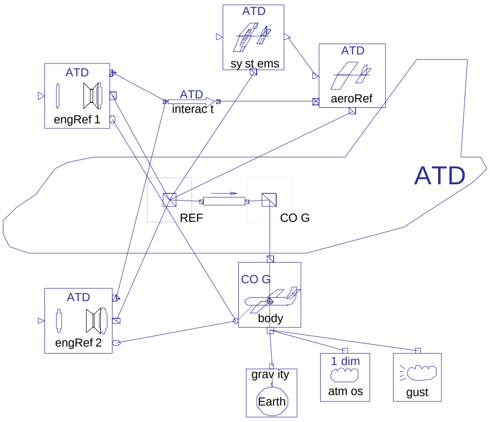


Fig. 3. Top level object diagram of the aircraft model

Communication between objects is realised through ports that also constitute the interface to the next level in the hierarchical decomposition. For a set of connected variables, v_i, these ports use two different connection semantics, (i) $\forall i(i \neq 0 | v_i = v_0)$, i.e., all connected variables are set equal, and (ii) $\Sigma_i v_i = 0$, i.e., the connected variables are summed to 0. This allows for a convenient implementation of energy flows across ports where the different semantics correspond to the across and through variables, respectively, the product of which constitutes power.

Execution Model The behaviour of each of the primitive model objects is described in terms of algebraic and differential equations. These are treated as noncausal, i.e., no computational direction of the variables is assigned (it is not determined which variable is to be computed from an equation), which is a convenient way of modelling physical systems in terms of declarative constraint specification. Furthermore, it enhances model reuse.

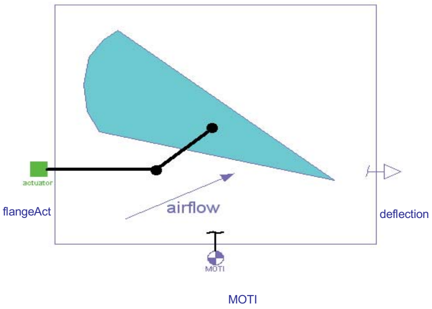


Fig. 4. Elevator control surface library component

To illustrate, consider the elevator control surface library component in Fig. 4. This surface consists of one or more movable parts to adjust the aerodynamic force acting on the aircraft. The library component is connected to the remainder of the aircraft model by three ports: (i) a mechanical port *flangeAct*, that contains the elevator deflection, δ, (ii) an aerodynamic port, *deflection*, that carries the forces because of the airflow around the elevator, and (iii) a mechanical port, *MOTI*, that contains the force acting on the aircraft. The elevator computes the force F_{act} from

$$0 = f(F_{act}, V_a^2, \delta, \rho, S_{cs}, \ldots, m_{cs}, g, \ldots), \tag{1}$$

the deflection δ from

$$\delta = k_{kin} x_{act}, \tag{2}$$

and, finally, its rate of change $\dot{\delta}$ from

$$\dot{\delta} = k_{kin} v_{act} \ . \tag{3}$$

Table 2. ControlSurface class interface variables

Interface Variables		
across	x_{act}	displacement of actuator flange
	v_{act}	displacement velocity of actuator flange
	V_a	airspeed velocity
	ρ	air density
	g	gravitational acceleration
through	F	force acting on actuator flange

Note that k_{kin} is a parameter internal to the object that represents the kinematics of the mechanism.

To enable the execution, the primitive object equations and the connection constraints for across and through variables are accumulated by a global model interpretation scheme. It sorts and solves the overall system of differential and algebraic (DAE) equations by assigning causality so that the unknowns can be computed from the equations and input and state variables. Algebraic manipulations are performed to reduce the system of equations, e.g., (Andersson, 1994).

To represent switching, equations may be conditionally active. When the conditions change their truth value, this causes *events*. When events occur, variables may undergo discontinuous changes. In addition to the differential and algebraic equations, a ‘pre’ operator is defined to allow access to the value of a variable immediately before a discontinuous change. Because this introduces discrete state behaviour, an iteration is required to converge to a consistent state before the continuous simulation is resumed. Though this mechanism can be used for implementing discrete-event behaviour, it is difficult to mimic state transition diagrams using object diagrams and even more so to describe the state transition behaviour by local equations of the primitive states and transitions. The graphical syntax of object diagrams does not allow annotation of component connections, thus it is not possible to write conditions, events, and actions alongside a transition. Furthermore, transitions are not objects in object diagrams. Therefore, the transition behaviour requires a specific transition object to be inserted. Execution has to be described in terms of local algebraic constraints that communicate between states and transitions to evaluate whether a state is active and a transition is enabled (Mosterman et al., 1998).

The result of collecting the local equations, adding the connection constraints, and sorting and solving these leads to a global system of equations of the form

$$\begin{aligned} \dot{x} &= f_\alpha(x,u,t) \\ 0 &= g_\alpha(x,u,t) \\ \alpha^+ &= \phi_\alpha(x,u,t) \end{aligned} \tag{4}$$

where f_α specifies the dynamics in mode α, g_α the event generation functions (‘zero crossings’), and ϕ_α the next mode function. Before continuous simulation can start or be resumed after an event occurred, a consistent mode α, i.e., $\alpha^+ = \alpha$, has to be found. Typically, this is performed by a fixed point iteration scheme.

3.2 Redundancy and Position Control

The main purpose of the two primary flight control units is the generation of appropriate continuous and discrete control signals for the four elevator actuators. Each PFCU contains a failure monitoring function, a specific discrete-event part for the redundancy management as well as one feedback and direct link controller per elevator. When a failure is detected, the redundancy management parts of both PFCUs interact tightly in order to achieve a consistent decision on the appropriate reaction, before switching the operating control laws. This is because each PFCU is responsible for different actuators and has to take the discrete state of the other PFCU into account in order to guarantee that each elevator is controlled by one actuator only. Therefore a simple failure may trigger a sequence of transitions in both PFCUs, where a discrete mode transition in one PFCU may lead to a state which forces another transition in the other PFCU and so on.

Graphics Since hardware aspects are beyond the scope of this paper, the redundancy management parts of both PFCUs are unified in one discrete-event model component neglecting the distributed architecture of the system. As a consequence, the aircraft model contains only one elevator control component. This is divided into three parts: (i) a failure injection module that replaces the failure monitoring functions so that specific failure scenarios can be studied, (ii) the combined redundancy management parts of both PFCUs that react on changes of the failure configuration and (iii) the switched position controllers of both PFCUs the transfer functions of which depend on the actual modes of the redundancy management component (Fig. 5).

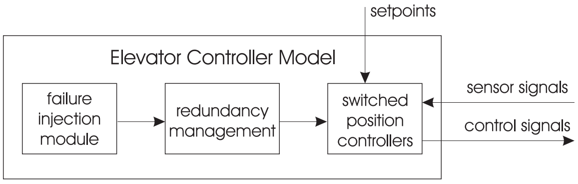


Fig. 5. The structure of the elevator controller model

The requirements for the redundancy management which were formulated informally in Section 2 state that each redundancy module contains 6 possible local modes. Since a redundancy module switches from one mode to another under certain conditions, the modules should be modelled by a kind of state transition diagram, where the modes are represented by discrete states and the transition arrows represent the possible mode switchings. In order to take the transition priorities into consideration, hierarchical states as known from the statechart formalism (Harel, 1987) are used. Additional states are introduced that do not correspond to a mode, but represent the priorities of the transitions: The higher a state in the hierarchy the higher is the priority of its outgoing transitions, e.g., the transition ToOff in Fig. 6 has a higher priority than ToAct and a lower priority than ToIso. The statechart model in Fig. 6 reflects the state transition aspects of a redundancy module declared in the informal description of the requirements.

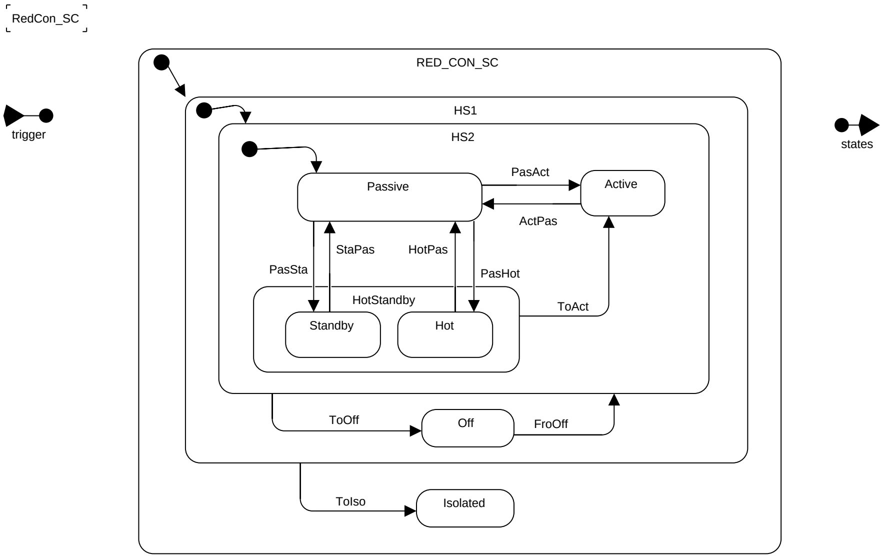


Fig. 6. The redundancy module statechart

The transition conditions can be derived from the switching rules of the requirements and differ for each statechart. In order to keep the statechart model generic and take architectural aspects into consideration, a specific hierarchical block diagram formalism is used (Fig. 7). Two blocks on the top level represent the two primary flight control units. The input port contains the failure values that originate from the failure injection module whereas the output ports transmit the actual module modes to the switched controllers. Each PFCU block contains four control modules (LIO, RIO, LDL and RDL) as subblocks. Their behaviour is defined by the statechart in Fig. 6. The transition conditions are calculated outside the statecharts in a special block (PFCU1_Logic and PFCU2_Logic) with no state behaviour.

Execution The intended behaviour of the elevator control model is as follows: The failure injection module generates Boolean signals that indicate the presence of specific failures. When a failure signal changes, the transition conditions of both PFCUs are evaluated and their values are transmitted to the statechart blocks that perform their transitions independently. After all statecharts have converged to a persistent discrete state, i.e. no further transitions happen, the transition conditions

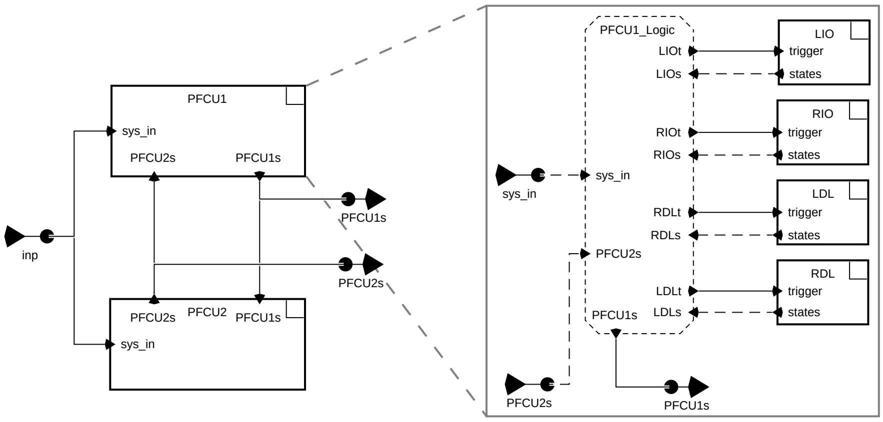


Fig. 7. Two block diagrams of the discrete-event part

are calculated again taking the new states into account and a new set of transitions may be performed in the modules again. When the overall discrete-event system reaches a stable state, this local event iteration is stopped, the output values are set, and the position controllers may change their mode.

In order to analyse the behaviour of the elevator control and the overall aircraft for different failure scenarios, the failure injection module generates predetermined sequences of failures. These scenarios can be modelled by equations containing logical expressions and inequalities over the independent variable time and parameters as shown in the following example where IO2failure is present from time t_1 to t_2:

$$\text{IO2failure} = (t > t_1) \wedge (t < t_2). \tag{5}$$

The output of the redundancy management part switches the position controllers that are easily described using equations. The following example shows the controller equations of PFCU1 for the left elevator:

$$e_{act,l1} = w_{act} - x_{act,l} \tag{6}$$

$$u_{act} = \begin{cases} 0 & \text{if PFCU1states.LIO is Off or Isolated} \\ w_{act} & \text{else if PFCU1states.LDL is Active,} \\ k_p e_{act,l1} + k_d v_{act,l} & \text{else} \end{cases} \tag{7}$$

$$u_{spool,l1} = \text{PFCU1states.LIO.Active} \tag{8}$$

3.3 Actuator Dynamics

The hydraulic actuators are the interface between the discrete-event domain of redundancy control and the continuous domain of the aircraft dynamics. The actuator here is not modelled with all details as this would lead to steep gradients in the behaviour that are difficult to handle and slow down simulation of the aircraft behaviour, even if efficient numerical solvers such as DASSL (Petzold, 1982) are used.

Higher Index DAE The decision to remove small physical effects such as fluid storage in lines and oil elasticity and viscosity leads to DAEs with a higher complexity because state variables are then directly coupled instead of interacting through additional states with small time constants. These DAEs can be transformed by differentiation before simulation run, but the switching effects of the actuators may also cause such algebraic constraints to emerge during simulation, requiring two phenomena to be handled: (i) the state variables that become algebraically coupled are constrained to a subspace of reduced dimension and the values before the constraint becomes active have to be projected into this subspace, and (ii) the future dynamic behaviour of these state variables must be in this reduced subspace.

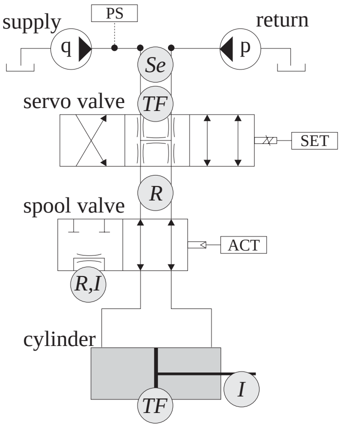
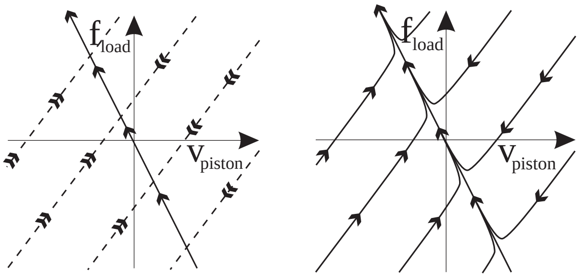


Fig. 8. Schematic of hydraulic actuator

To illustrate these effects, consider the actuator model in Fig. 8. When initially the actuator is *active*, the supply path is open, i.e., control signals generated by the servo valve are supplied to the positioning cylinder, causing the piston to accelerate. When, at a given point in time, the actuator is switched to be *off*, the loading path becomes active. Because of the inertial effects in the loading pathway, there is dependency between the piston and this fluid inertia and an algebraic constraint between these two variables ($v_{piston} = -A_p f_{load}$) restricts the state space in which the system evolves. This is illustrated in Fig. 9(a), where the double arrow heads on the dashed field lines indicate the direction of the discontinuous change. This algebraic dependency would be eliminated by introducing small parasitic storage effects for the piping and some oil elasticity and viscosity, but this adds very steep gradients to overall system behaviour as illustrated by Fig. 9(b) that complicate simulation and are not relevant for the overall behaviour of the aircraft.

The implicit jumps in the state variable values have to be computed during simulation. At present, commercially available simulation tools cannot handle such abrupt changes in DAE models. Therefore the experimental modelling and simulation environment HyBrSim (Mosterman and Biswas, 1999) was used which has been realised for the purpose of testing algorithms for the reinitialisation of switched



(a) Discontinuous changes

(b) Steep gradients

Fig. 9. Phase space for v_p and f_{load}

systems with index changes. HyBrSim is based on bond graph modelling of the physical system.

Bond Graph Model of the Actuators Figure 10 shows the hybrid bond graph model of the two left hydraulic actuators. The two *Se* elements[1] are sources (inputs) of a bond graph model which are connected to the hydraulic circuits in the aircraft model that provide the input pressure. The servo valve modulation is applied by the *TF* elements, where the *setL1* and *setL2* elements are connected to the setpoint generated by the aircraft control model. The *I* elements represent connections (equal flow points) and the attached *R* element captures dissipative effects. Note that these are modelled as linear phenomena. The *loadL1* (*loadL1*) connection also has some inertia associated with it, embodied by the *IloadL1* (*IloadL2*) element. The cylinder chamber is modelled by a 0 element, an equal pressure point. Both cylinders connect through a piston with area modelled by a *TF* element to one equal velocity point for the elevator control surface movement. This velocity, as well as the displacement and force are inputs to the aircraft model.

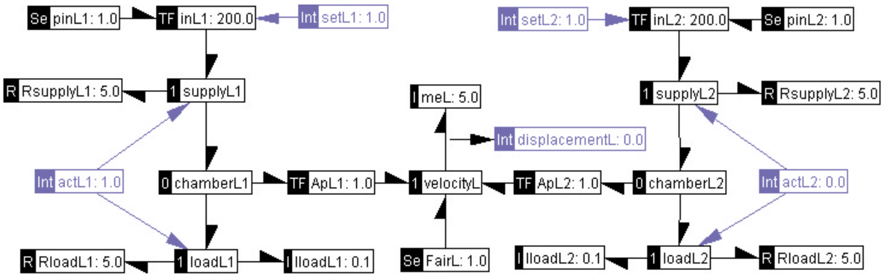
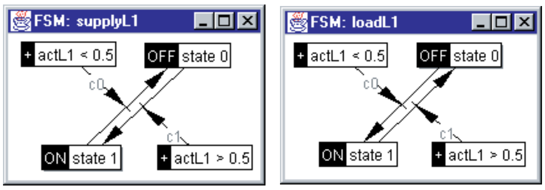


Fig. 10. Hybrid bond graph of the two left hydraulic actuators

---

[1] The element type is listed on the left of each element rectangle.

The switching behaviour is modelled by two *controlled junctions* (Mosterman and Biswas, 1995) in each actuator, in the left actuator these are *supplyL1* and *loadL1*. The local finite state machines that control their states are given in Fig. 11. The control event *actL1* is generated by the redundancy control in the enclosing part of the model. When the *supplyL1* junction is ON and *loadL1* is OFF, the actuator is active. When *supplyL1* is OFF and *loadL1* is ON, it is loading (either hot, standby, passive, or isolated). Note that the mutual switching constraints allow no other configurations.



(a) Supply path (b) Load path

Fig. 11. Finite state machines of actuator 1 in the hybrid bond graph

Equations The equations generated from the hybrid bond graph by HYBRSIM incorporate the switching effect as guarded equations. This prevents the need for pre-enumeration which would cause an exponential growth of the number of modes.[2] For example, for the loading pathway, *loadL1*, the equation generated is

$$0 = (-chamberL1.p + IloadL1.p + RloadL1.p)\alpha_i + (loadL1.f) * (1 - \alpha_i) \quad (9)$$

where α_i is the i^{th} entry in the mode vector α. This ensures that in a mode where this connection is active, $\alpha_i = 1$, the pressure drops of the connected elements are balanced. When the connector is not active, $\alpha_i = 0$, the fluid flow through *loadL1* becomes 0. This models ideal switching but may lead to higher index DAEs (e.g., because *IloadL1* and *mpL* become algebraically related). A numerical solver such as DASSL can handle systems up to index 1 directly and up to index 2 with some provisions, e.g., the step-size control of index 2 variables needs to be switched off (Bujakiewicz, 1994). Another prerequisite is that DASSL should be given a set of consistent initial conditions, i.e., those that are in the correct subspace of continuous behaviours. This is achieved by applying a projection mechanism which is consistent with physical conservation laws (Griepentrog and März, 1986, van der Schaft and Schumacher, 1996, Verghese et al., 1981).

---

[2] For the hybrid bond graph in Fig. 10 there are already $2^4 = 16$ possible modes, but only two occur during normal operation.

The discontinuous changes are computed by first linearising the system with a finite difference method. Then a pseudo Weierstrass normal form is derived (up till index 2)

$$0 = \begin{bmatrix} \bar{E}_{11} & 0 & 0 \\ 0 & 0 & \bar{E}_{22,12} \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{\bar{x}}_{1} \\ \dot{\bar{x}}_{2,1} \\ \dot{\bar{x}}_{2,2} \end{bmatrix} + \begin{bmatrix} \bar{A}_{11} & \bar{A}_{12,1} & \bar{A}_{12,2} \\ 0 & \bar{A}_{22,11} & \bar{A}_{22,12} \\ 0 & 0 & \bar{A}_{22,22} \end{bmatrix} \begin{bmatrix} \bar{x}_{1} \\ \bar{x}_{2,1} \\ \bar{x}_{2,2} \end{bmatrix} + \begin{bmatrix} \bar{B}_{1} \\ \bar{B}_{2,1} \\ \bar{B}_{2,2} \end{bmatrix} \begin{bmatrix} u \end{bmatrix}, \quad (10)$$

where $\bar{E}_{11,11}$, $\bar{A}_{22,11}$, and $\bar{A}_{22,22}$ are of full rank. This allows computation of the initial conditions as (Mosterman, 2000b)

$$\begin{aligned} \bar{x}_1 &= \bar{x}_1^0 + \bar{E}_{11}^{-1} \bar{A}_{12,1} \bar{A}_{22,11}^{-1} \bar{E}_{22,12} (\bar{x}_{2,2} - \bar{x}_{2,2}^0) \\ \bar{x}_{2,1} &= -\bar{A}_{22,11}^{-1} (\bar{B}_{2,1} u + \bar{E}_{22,12} \dot{\bar{x}}_{2,2} + \bar{A}_{22,12} \bar{x}_{2,2}) \\ \bar{x}_{2,2} &= -\bar{A}_{22,22}^{-1} \bar{B}_{2,2} u \,, \end{aligned} \quad (11)$$

where $\bar{x}_0$ are the user-provided initial values after the coordinate transformation to achieve the desired normal form, $\bar{x}_0 = Zx_0$. The values for $\bar{x}$ can then be transformed back to obtain initial values for x that are in the correct subspace of the dynamic behaviour, and in this manner the implicit jump is determined.

4 Simulation of the Overall System

The aircraft model, the redundancy control system, and the actuator feedback and discrete event control were modelled using different modelling formalisms and tools (DYMOLA, HYBRSIM, DOME). Each of these is best suited for the respective task. To enable a comprehensive analysis, however, the parts have to be integrated into a coherent model.

4.1 Integrating the Components

Since the descriptions of the failure injection module and the redundancy management system laws are based on equations, they can be incorporated easily into the object-oriented and equation-based aircraft model. This also holds for the hydraulic actuators, in principle, because the bond graph models correspond to a set of hybrid differential and algebraic equations. But due to present restrictions of the simulation software available for object-oriented modelling languages, specific simulation code is generated from the bond graphs of the actuators and merged with the C-code that results from the aircraft model.

For the redundancy management component, the modelling environment generates a simulation algorithm that defines the input-output behaviour of the discrete-event component. This automatically generated algorithm is designed in a way that is compatible to the MODELICA language so that it can be embedded directly into the aircraft model. In MODELICA such an algorithm is regarded simply as an additional model constraint that corresponds to an equation that contains a function with a fixed set of input and output variables.

To simulate the resulting hybrid model, MODELICA's hybrid DAE semantics is exploited. The temporal inequality expressions in the failure injection module are transformed into time events for the numerical integrator so that the continuous integration stops exactly when a switching time has elapsed. Then the whole set of equations is re-evaluated with the new values of the inequality expressions. Thereby, the algorithm of the redundancy management is also re-evaluated resulting possibly in a new state which may switch the feedback control laws.

4.2 Simulation Results

The phugoid in Fig. 12 is the result of two interacting phenomena: When the aircraft pitch angle increases, it gains altitude and at the same time loses airspeed. Because of this loss of airspeed, there is less upward thrust, which causes the aircraft to lose altitude in return. However, as it starts losing altitude, it picks up speed again and the airspeed rises. This results in a slightly damped oscillatory behaviour which is required to be stable in commercial aircrafts.

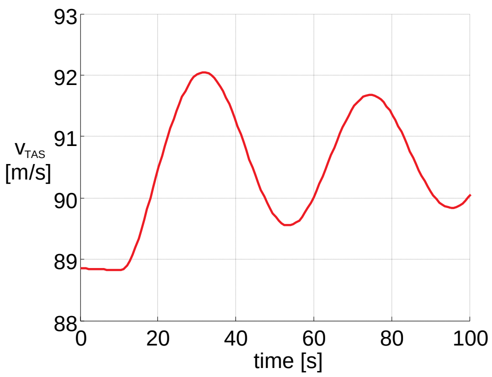


Fig. 12. Simulation shows a phugoid typical for aircraft

To investigate the effect of the redundancy control on the aircraft's behaviour, an actuator failure is introduced during a setpoint change. The setpoint change occurs at $t = 0.05\ [s]$ and the actuator failure at $t = 0.08\ [s]$. Figure 13 shows that the failure leads to an immediate change of the active actuators and the switching transients in the hydraulics cause a sharp drop in elevator velocity. Because small effects such as oil elasticity and viscosity are neglected in the simulation, this results in a discontinuous change that occurs because of the algebraic dependency between elevator inertia and fluid inertia of the new loading path.

During a short period of time, the PID control causes the elevator velocity to ramp up to the value which it would have assumed without the failure. Note the short delay that is possible because the actuator that switches to active was *hot* and *shadowing* the PID control.

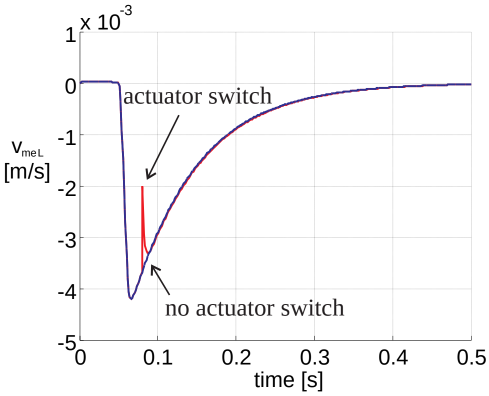
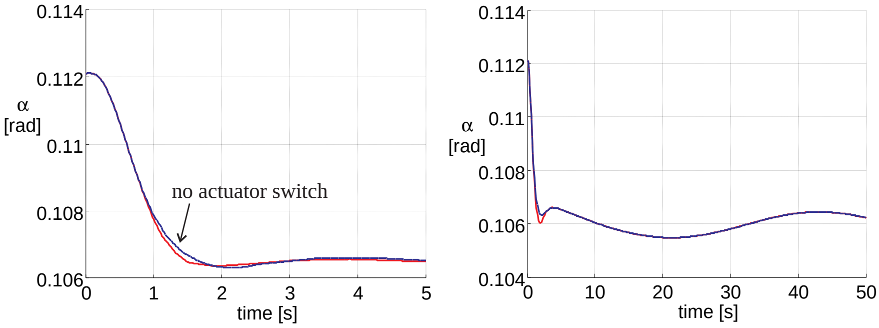


Fig. 13. Elevator velocity when a failure occurs at t = 0.08 shortly after a setpoint change at t = 0.05

The aircraft redundancy control is designed such that an actuator failure should not have a noticeable effect on the behaviour of the aircraft. Using the comprehensive model with switching logic and transients, and an extensive model of the aircraft dynamics, this effect can be studied as well. Figure 14(b) shows the effect of the actuator switch on the aircraft pitch angle, and Fig. 15(b) shows the effect on the pitch angle velocity. This verifies that the actuator switch has almost no effect on the overall aircraft behaviour which, because of the realistic aircraft model, provides much confidence for the real implementation. Note that the small effect of the actuator switching on the global behaviour manifests itself after a significant delay.

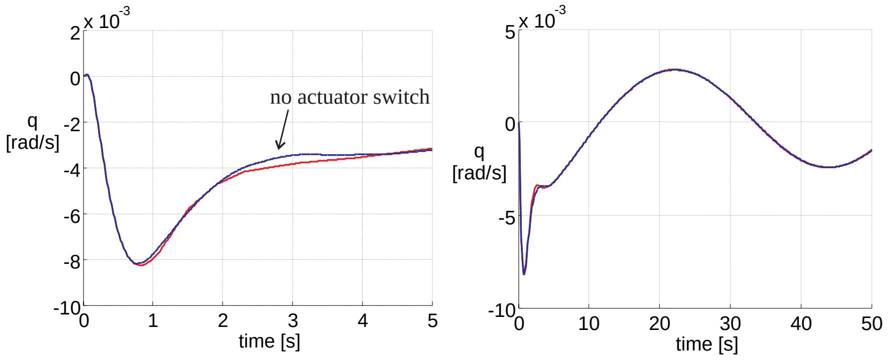


(a) Detailed view

(b) Overall behaviour

Fig. 14. Pitch angle for normal behaviour and for an actuator switch at 0.08 $[s]$

Table 3 illustrates how the redundancy management reacts, when the IO module failure occurs in PFCU2. In the first local transition the statecharts of LIO and RIO (Left / Right IO) of PFCU2 switch from *Active* to *Isolated*, since these modules should not be activated again (see rules 1 and 10 in Section 2). Then PFCU1 takes



(a) Detailed view (b) Overall behaviour

Fig. 15. Pitch angle velocity for normal behaviour and for an actuator switch at 0.08 [*s*]

over the actuators by activating its LIO and RIO modules (rules 1, 3, 5). In the last local transition, the LDL and RDL (Left / Right DL) statecharts of PFCU2 switch into the *Hot* mode preparing the system for a possible second failure (rule 6). Since state 2 would violate rule 4 and the transition from state 3 to state 4 would violate rule 1, the internal iterations have to be hidden from the outer system in order to prevent inconsistent outputs. This is why only the global transition from state 1 to state 4 is made observable to the outside.

Table 3. State transitions of the redundancy management system

components		local steps			
		1	2	3	4
PFCU2	IO	Active/Active	Isolated/Isolated	Isolated/Isolated	Isolated/Isolated
	DL	Passive/Passive	Passive/Passive	Passive/Passive	Hot/Hot
PFCU1	IO	Hot/Hot	Hot/Hot	Active/Active	Active/Active
	DL	Passive/Passive	Passive/Passive	Passive/Passive	Passive/Passive
actuator	outer	control/control	-/-	-/-	shadow/shadow
	inner	shadow/shadow	-/-	-/-	control/control
global visibility		yes	no	no	yes

5 Conclusions

The comprehensive model of the aircraft developed here incorporates the redundancy management system, the switched positioning controllers, the actuator models as well as a complex model of the general dynamics of the aircraft. Hence, it is possible to assess the design of the elevator control system with respect to the overall behaviour of the aircraft in the case of failures. Since the less important physical effects of the hydraulic actuators were neglected, the simulation is fast enough to be used also in the context of a multi-objective parameter optimisation (MOPS) (Joos, 1999). Such an optimisation may, e.g., reduce the elevator surface or the actuator power such that the switching transients still do not affect the level of aircraft handling.

The abstractions used in the actuator models, i.e. neglecting small physical effects such as oil elasticity and viscosity, result in a DAE that may change its index during simulation. A standard DAE solver, such as DASSL, can be applied for this model, if the re-initialisation at event times results in a consistent state. For a correct behavioural simulation, this re-initialisation has to satisfy the physical conservation laws. For the purpose of this feasibility study the actuators were modelled in HYBRSIM, a modelling environment based on hybrid bond graphs that supports the necessary re-initialisation procedure. The C-code generated by this environment was manually combined with the C-code generated by DYMOLA which includes the rest of the aircraft model. The hybrid system simulator MASIM was used to generate behaviors. MASIM has facilities to compute discontinuous changes of generalized state variables as algebraic constraints between them become active. The discrete-event parts of the aircraft are modelled using a visual specification language and are translated into a MODELICA algorithm that can be integrated into the aircraft model on the model level (Mosterman et al., 2002).

The presented modelling and simulation approach that combines an object-oriented modelling language such as MODELICA, domain-specific model libraries, discrete-event modelling formalisms and powerful simulation methods including correct state re-initialisation, was successfully applied to the aircraft elevator control system and seems to be promising for general complex technological systems.

References

[Dr0,] http://www.r-drath.de/VON/von_e.htm.

[Des,] Design/cpn version 4.0.1. http://www.daimi.au.dk/designCPN.

[IEE, 1998] (1998). volume 43.

[DED, 1998] (1998). Special issue on hybrid systems. *Discrete Event Dynamic Systems: Theory and Application*, 8:99–222.

[Aut, 1999] (1999). A special issue on hybrid systems. *Automatica*, 35:347–519.

[dom, 1999] (1999). DOME guide. http://www.htc.honeywell.com/dome/, Honeywell Technology Center, Honeywell. version 5.2.1.

[IEE, 2000] (2000). volume 88.

[61131-3, 1992] 61131-3, I. (1992). Programming language for programmable controllers. Technical report, Committee IEC 61131-3.

[ABACUSS, 1995] ABACUSS (1995). http://yoric.mit.edu/abacuss/abacuss.html. Massachussets Institute of Technology.

[Abadi and Cardelli, 1996] Abadi, M. and Cardelli, L. (1996). *A Theory of Objects*. Springer-Verlag, New York.

[Abel, 1990] Abel, D. (1990). *Petri-Netze für Ingenieure*. Springer, Berlin, Germany.

[Adjiman et al., 1998] Adjiman, C., Schweiger, C., and Floudas, C. (1998). Mixed-integer nonlinear optimization in process synthesis. In D.-Z., D. and P.M., P., editors, *Handbook of Combinatorial Optimization*, volume 1, pages 1–76. Kluwer Acadademic Publisher.

[Albro and Bobrow, 2001] Albro, J. and Bobrow, J. (2001). Optimal motion primitives for a 5 dof experimental hopper. In *Proceedings of the IEEE International Conference on Robotics and Automation (Seoul, Korea)*, pages 3630–3635.

[Allgor and Barton, 1997] Allgor, R. and Barton, P. (1997). Mixed integer dynamic optimization. *Computational Chemical Engineering*, 21:451–456.

[Alur et al., 1995] Alur, R., Courcoubetis, C., Halbwachs, N., Henzinger, T., Ho, P.-H., Nicollin, X., Olivero, A., Sifakis, J., and Yovine, S. (1995). The algorithmic analysis of hybrid systems. *Theoretical Computer Science*, 138:3–34.

[Alur et al., 1993] Alur, R., Courcoubetis, C., Henzinger, T., and Ho, P.-H. (1993). Hybrid automata: An algorithmic approach to the specification and verification of hybrid systems. In et al., R. G., editor, *Hybrid Systems*, pages 209–229. Springer.

[Alur and Dill, 1990] Alur, R. and Dill, D. (1990). A theory of timed automata. *Theoretical Computer Science*, 126:183–235.

[Alur et al., 2000a] Alur, R., Grosu, R., Hur, Y., Kumar, V., and Lee, I. (2000a). Modular specification of hybrid systems in Charon. In *Proc. HSCC'00*, Springer LNCS 1790.

[Alur et al., 2000b] Alur, R., Henzinger, T., Lafferiere, G., and Pappas, G. (2000b). Discrete abstractions of hybrid systems. *Proceedings of the IEEE*, 88(7):971–984.

[Alur and Henzinger, 1999] Alur, R. and Henzinger, T. A. (1999). Reactive modules. *Formal Methods in System Design: An International Journal*, 15(1):7–48.

[Alur et al., 1996a] Alur, R., Henzinger, T. A., and Ho, P.-H. (1996a). Automatic symbolic verification of embedded systems. *IEEE Transactions on Software Engineering*, 22:181–201.

[Alur et al., 1996b] Alur, R., Henzinger, T. A., and Sontag, E. D., editors (1996b). *Hybrid Systems III: Verification and Control*, volume 1066 of *Lecture Notes in Computer Science*. Springer.

[Anderson et al., 2000] Anderson, B. D. O., Brinsmead, T., Davoren, J. M., and Moor, T. (2000). Interim progress report: Development of design methodologies for robust, adaptive, autonomous, hierarchical systems. Technical report, RSISE, Australian National University, Acton ACT 0200, Australia.

[Anderson et al., 1999] Anderson, B. D. O., Bruyne, F. D., Dey, S., and Wong, K. (1999). Ensuring robustness in hybrid control systems. Technical report, RSISE, Australian National University, Acton ACT 0200, Australia.

[Andersson, 1994] Andersson, M. (1994). *Object-Oriented Modeling and Simulation of Hybrid Systems*. PhD dissertation, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden.

[Antsaklis, 2000] Antsaklis, P., editor (2000). *Special Issue on Hybrid Systems: Theory and Applications*, volume 88, no. 7 of *Proceedings of the IEEE*.

[Antsaklis et al., 1999] Antsaklis, P., Kohn, W., Lemmon, M., Nerode, A., and Sastry, S., editors (1999). *Hybrid Systems V*, volume 1567 of *Lecture Notes in Computer Science*. Springer.

[Antsaklis and Koutsoukos, 1998] Antsaklis, P. and Koutsoukos, X. D. (1998). On Hybrid Control of Complex Systems: A Survey. In *Proceedings Hybrid Dynamical Systems*, ADPM '98, pages 1–8, Reims, France.

[Antsaklis and Nerode, 1998] Antsaklis, P. and Nerode, A., editors (1998). *Special Issue on Hybrid Control Systems*, volume 43 of *IEEE Transactions on Automatic Control*.

[Antsaklis et al., 1995] Antsaklis, P., Nerode, A., Kohn, W., and Sastry, S., editors (1995). *Hybrid Systems II*, volume 999 of *Lecture Notes in Computer Science*. Springer.

[Antsaklis et al., 1997] Antsaklis, P., Nerode, A., Kohn, W., and Sastry, S., editors (1997). *Hybrid Systems IV*, volume 1273 of *Lecture Notes in Computer Science*. Springer.

[Apt et al., 1980] Apt, K. R., Francez, N., and de Roever, W.-P. (1980). A proof system for communicating sequential processes. *ACM Transactions on Programming Languages and Systems*, 2(3):359–385.

[Asarin et al., 2000a] Asarin, E., Bournez, O., Dang, T., and Maler, O. (2000a). Reachability analysis of piecewise-linear dynamical systems. In 3^{rd} *Int. Workshop of Hybrid Systems: Comp. and Control*, volume 1790 of *LNCS*, pages 20–31. Springer.

[Asarin et al., 2000b] Asarin, E., Bournez, O., Dang, T., Maler, O., and Pnueli, A. (2000b). Effective synthesis of switching controllers for linear systems. *Proceedings of the IEEE*, 88:1011–1025.

[Back et al., 1993] Back, A., Guckenheimer, J., and Myers, M. (1993). A dynamical simulation facility for hybrid systems. In Grossmann, R., Nerode, A., Ravn, A., and Rischel, H., editors, *Lecture Notes in Computer Science: Hybrid Systems*, volume 736, pages 255–267. Springer Verlag.

[Balas, 1985] Balas, E. (1985). Disjunctive programming and a hierarchy of relaxations for discrete optimization problems. *SIAM Journal Alg. Disc. Meth.*, 6(3):466–486.

[Barros, 1996] Barros, F. J. (1996). The dynamic structure discrete event system specification formalism. *Transactions of the SCS International*, 13(1):35–46.

[Barton, 1992] Barton, P. I. (1992). *The Modelling and Simulation of Combined Discrete/Continuous Processes*. PhD dissertation, University of London.

[Bastide, 1995] Bastide, R. (1995). Approaches in unifying Petri nets and the Object-Oriented Approach. In *Object-Oriented Programming and Models of Concurrence 16th International Conference on Application and Theory of Petri Nets*, Italy.

[Baumgarten, 1990] Baumgarten, B. (1990). *Petri-Netze: Grundlagen und Anwendungen*. BI-Wissenschaftsverlag, Mannheim, Wien, Zürich.

[Bellman, 1957] Bellman, R. (1957). *Dynamic Programming*. Princeton University Press.

[Bemporad and Morari, 1999a] Bemporad, A. and Morari, M. (1999a). Control of systems integrating logic, dynamics, and constraints. *automatica*, 35(3):407–427.

[Bemporad and Morari, 1999b] Bemporad, A. and Morari, M. (1999b). Verification of hybrid systems using mathematical programming. In Vaandrager, F. W. and van Schuppen, J. H., editors, *Hybrid Systems: Computation and Control, Proc. 2nd Int. Workshop,* *HSCC'99, Berg en Dal, The Netherlands, March 1999*, Lecture Notes in Computer Science 1569, pages 31–45. Springer.

[Bender and Kaiser, 1995] Bender, K. and Kaiser, O. (1995). Simultaneous Engineering durch Maschinenemulation. *CIM Management*, 11(4):14–18.

[Benedetto and Sangiovanni-Vincentelli, 2001] Benedetto, M. D. D. and Sangiovanni-Vincentelli, A. L., editors (2001). *Hybrid Systems: Computation and Control*, volume 2034 of *Lecture Notes in Computer Science*. Springer-Verlag.

[Betts, 1998] Betts, J. (1998). Survey of numerical methods for trajectory optimization. *AIAA Journal of Guidance, Control, and Dynamics*, 21(2):193–207.

[Bhat et al., 1995] Bhat, G., Cleaveland, R., and Grumberg, O. (1995). Efficient on-the-fly model checking for CTL*. In *LICS '95: 10th Annual IEEE Symposium on Logic in Computer Science, San Diego, California, USA, June 26–29, 1995*, pages 388–397. IEEE Computer Society Press.

[Blanke et al., 2000a] Blanke, M., Frei, C., Kraus, F., Patton, R., and Staroswiecki, M. (2000a). *Fault-tolerant Control Systems*, chapter 8, pages 165–189. Springer Verlag, London.

[Blanke et al., 2000b] Blanke, M., Frei, C. W., Kraus, F., Patton, R. J., and Staroswiecki, M. (2000b). What is fault-tolerant control? In *Proceeding of SAFEPROCESS 2000: 4th Symposium on Fault Detection*, page 40. IFAC.

[Bobbio et al., 1999] Bobbio, A., Garg, S., Gribaudo, M., Horváth, A., Sereno, M., and Telek, M. (1999). Modeling software systems with rejuvenation, restoration and checkpointing through fluid stochastic petri nets. In *Proc. Eighth International Workshop on Petri Nets and Performance Models - PNPM'99*, pages 82–91.

[Bolognesi and Brinksma, 1987] Bolognesi, T. and Brinksma, E. (1987). Introduction to the ISO specification language LOTOS. *Computer Networks*, 14:25–59.

[Bournez et al., 1999] Bournez, O., Maler, O., and Pnueli, A. (1999). Orthogonal polyhedra: representation and computation. In Vaandrager, F. and van Schuppen, J., editors, *Hybrid Systems: Computation and Control (HSCC'99)*, LNCS 1569, pages 46–60. Springer-Verlag.

[Boyd et al., 1994] Boyd, S., Ghaoui, L., Feron, E., and Balakrishnan, V. (1994). *Linear Matrix Inequalities in System and Control Theory*. SIAM Studies in Applied Mathematics. SIAM, Philadelphia.

[Brack, 1974] Brack, G. (1974). *Dynamik technischer Systeme*. VEB Deutscher Verlag für Grundstoffindustrie, Leipzip.

[Branicky, 1993] Branicky, M. (1993). Topology of hybrid systems. In *Proceedings of the 32nd IEEE Conference on Decision and Control (San Antonio, TX)*, pages 2309–2314.

[Branicky, 1994a] Branicky, M. (1994a). Analyzing continuous switching systems: Theory and examples. In *Proceedings of the American Control Conference (Baltimore, MD)*, pages 3110–3114.

[Branicky, 1994b] Branicky, M. (1994b). Stability of switched and hybrid systems. In *Proceedings of the 33rd IEEE Conference on Decision and Control (Lake Buena Vista, FL)*, pages 3498–3503.

[Branicky, 1994c] Branicky, M. (1994c). A unified framework for hybrid control. In *Proceedings of the 33rd IEEE Conference on Decision and Control (Lake Buena Vista, FL)*, pages 4228–4234.

[Branicky, 1995] Branicky, M. (1995). *Studies in Hybrid Systems: Modeling, Analysis and Control*. PhD thesis, Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science.

[Branicky, 1996] Branicky, M. (1996). General hybrid dynamical systems: Modeling, analysis, and control. In Alur, R., Henzinger, T., and Sontag, E., editors, *Lecture Notes in Computer Science: Hybrid Systems III*, volume 1066, pages 186–200. Springer Verlag.

[Branicky et al., 1998] Branicky, M., Borkar, V., and Mitter, S. (1998). A unified framework for hybrid control: Model and optimal control theory. *IEEE Transactions on Automatic Control*, 43:31–45.

[Branicky et al., 1999] Branicky, M., Hebbar, R., and Zhang, G. (1999). A fast marching algorithm for hybrid systems. In *Proceedings of the 38th IEEE Conference on Decision and Control (Phoenix, AZ)*, pages 4897–4902.

[Branicky, 1998] Branicky, M. S. (1998). Multiple Lyapunov Functions and Other Analysis Tools for Switched and Hybrid Systems. *IEEE Trans. Aut. Control*, 43(4):475–482.

[Brenan and Campbell, 1996] Brenan, K. E. and Campbell, S. L. (1996). *Numerical Solution of Initial-Value Problems in Differential-Algebraic Equations*. siam.

[Brockett, 1993] Brockett, R. (1993). Hybrid models for motion control systems. In Trentelmann, H. and Willems, J., editors, *Essays on Control: Perspectives in the Theory and its Applications*, pages 29–53. Boston: Birkhäuser.

[Broenink et al., 1998] Broenink, J., Hilderink, G., and Bakkers, A. (1998). Conceptual design for controller software of mechatronic systems. In Bradshaw, A. and Counsel, J., editors, *Computer aided Conceptual Design '98*.

[Bröhl and Dröschel, 1995] Bröhl, A. and Dröschel, W. (1995). *Das V-Modell*. Oldenburg-Verlag.

[Brooke et al., 1998] Brooke, A., Kendrick, D., Meeraus, A., and Raman, R. (1998). *GAMS/CPLEX – A User's Guide*. GAMS Development Corporation.

[Broucke et al., 2000] Broucke, M., Di Benedetto, M., Di Gennaro, S., and Sangiovanni-Vincentelli, A. (2000). Theory of optimal control using bisimulations. In *Proc.* 3^{rd} *Int. Workshop of Hybrid Systems: Comp. and Control*, volume 1790 of *LNCS*, pages 89–102. Springer.

[Brown and de Kleer, 1990] Brown, J. S. and de Kleer, J. (1990). A qualitative physics based on confluences. In *Qualitative Reasoning about Physical Systems*, pages 88–126. Morgan Kaufmann Publishers, San Mateo, CA.

[Broy, 2001] Broy, M. (2001). Refinement of time. *Theoretical Computer Science*, 253(1):3–26.

[Bryant, 1986] Bryant, R. E. (1986). Graph-based algorithms for Boolean function manipulation. *IEEE Transactions on Computers*, C-35(8):677–691.

[Bryant, 1992] Bryant, R. E. (1992). Symbolic Boolean manipulation with ordered binary-decision diagrams. *ACM Computing Surveys*, 24(3):293–318. Preprint version published as CMU Technical Report CMU-CS-92-160.

[Buchholz, 1999] Buchholz, J. J. (1999). Systemsimulation. Vorlesungsmanuskript.

[Bühler and Koditschek, 1993] Bühler, M. and Koditschek, D. (1993). From stable to chaotic juggling: Theory, simulation, and experiments. In Spong, M., Lewis, F., and Abdallah, C., editors, *Robot Control – Dynamics, Motion Planning, and Analysis*, pages 525–530. New York: IEEE Press.

[Bujakiewicz, 1994] Bujakiewicz, P. (1994). *Maximum weighted matching for high index differential algebraic equations*. PhD dissertation, TU Delft, Delft, Netherlands. ISBN 90-9007240-3.

[Buss, 2000] Buss, M. (2000). *Control Methods for Hybrid Dynamical Systems – Models, Control Loops, Optimal Control, Computation Tools, and Mechatronic Applications – (in German)*. PhD thesis, Institute of Automatic Control Engineering, Technische Universität München.

[Buss et al., 2002] Buss, M., Glocker, M., Hardt, M., von Stryk, O., Bulirsch, R., and Schmidt, G. (2002). Nonlinear hybrid dynamical systems: Modeling, optimal control, and applications. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Buss et al., 1997] Buss, M., Schlegl, T., and Schmidt, G. (1997). Development of Numerical Integration Methods for Hybrid (Discrete-Continuous) Dynamical Systems. In *Advanced Intelligent Mechatronic AIM97*, Tokyo, Japan.

[Buss et al., 2000] Buss, M., von Stryk, O., Bulirsch, R., and Schmidt, G. (2000). Towards hybrid optimal control. *at–Automatisierungstechnik*, 48:448–459.

[Caines and Wei, 1998] Caines, P. E. and Wei, Y. J. (1998). Hierarchical hybrid control systems: a lattice theoretic formulation. *IEEE Transactions on Automatic Control*, 43:4:501–508.

[Cavalier et al., 1990] Cavalier, T., Pardalos, P., and Soyster, A. (1990). Modeling and integer programming techniques applied to propositional calculus. *Comp. and Oper. Res.*, 17(6):561–570.

[Cellier et al., 1995] Cellier, F., Elmqvist, H., and Otter, M. (1995). Modeling from physical priciples. In Levine, W., editor, *The Control Handbook*, CRC Press, Boca Raton, FL.

[Cellier et al., 1996] Cellier, F., Elmqvist, H., and Otter, M. (1996). Modelling from physical principles. In Levine, W., editor, *The Control Handbook*, pages 99–107. CRC Press, Boca Raton, FL.

[Champagnat et al., 1996] Champagnat, R., Esteban, P., Pingaud, H., and Valette, R. (1996). Petri Net Based Modeling of Hybrid Systems. In *Proc. of ASI'96*, pages 53–60, Toulouse, France. Advanced Summer Institute.

[Champagnat et al., 1998] Champagnat, R., Esteban, P., Pingaud, H., and Valette, R. (1998). Modeling and Simulation of a Hybrid System Through PR/TR PN-DAE Model. In *Proc. of the 3rd Int. Conf. on Automation of Mixed Processes*, pages 131–137, Reims, France.

[Cheng, 1979] Cheng, V. H. L. (1979). A direct way to stabilize continuous-time and discrete-time linear time-varying systems. *IEEE Transactions on Automatic Control*, 24:641–643.

[Chouikha, 1999] Chouikha, M. (1999). *Entwurf disktret-kontinuierlicher Steuerungssysteme - Modellbildung, Analyse und Synthese mit hybriden Petrinetzen*. PhD thesis, TU Braunschweig.

[Chouikha et al., 2000a] Chouikha, M., Decknatel, G., Drath, R., Frey, G., Müller, C., Simon, C., Thieme, J., and Wolter, K. (2000a). Petri net-based descriptions for discrete-continuous systems. *at - Automatisierungstechnik*, 48(9):415–425.

[Chouikha et al., 2000b] Chouikha, M., Decknatel, G., and et al., R. D. (2000b). Petri net-based descriptions for discrete-continuous systems. *Automatisierungstechnik*, 48(9):415–425.

[Chouikha and Krebs, 1998] Chouikha, M. and Krebs, V. G. (1998). Beschreibungsmittel und Methoden für kontinuierlich-diskrete Systeme. In Abel, D. and Lemmer, K., editors, *Theorie ereignisdiskreter Systeme*, München, Wien. Oldenbourg Verlag GmbH.

[Chouikha et al., 2001] Chouikha, M., Ober, B., and Schnieder, E. (2001). Automatisierter Steuerungsentwurf für diskrete und kontinuierlich-diskrete Systeme. *at - Automatisierungstechnik*, 49(6):280–289.

[Chouikha and Schnieder, 1998a] Chouikha, M. and Schnieder, E. (1998a). Beschreibung kontinuierlich-diskreter systeme mit hybriden petrinetzen. In *GMA-Kongress '98 Mess- und Automatisierungtechnik*, pages 365–372, Ludwigsburg. Institut für Regelungs- und Automatisierungstechnik, TU Braunschweig, VDI-Verlag GmbH. VDI-Bericht 1397.

[Chouikha and Schnieder, 1998b] Chouikha, M. and Schnieder, E. (1998b). Modelling of continuous-discrete systems with hybrid petri nets. In *IEEE: Computational Engineering in Systems Applications*, pages 606–612.

[Chow, 1996] Chow, A.-H. (1996). Parallel DEVS: A parallel, hierarchical, modular modeling formalism and its distributed simulator. *Transaction of the SCS International*, 13(2):55–67.

[Christen, 1997] Christen, E. (1997). The vhdl 1076.1 language for mixed-signal design. http://www.analogy.com/support/wp/vhdl_ern.htm.

[Chutinan and Krogh, 1999a] Chutinan, A. and Krogh, B. (1999a). Computing approximating automata for a class of linear hybrid systems. In *Hybrid Systems V: Proc. Int. Workshop, Notre Dame, USA*, Lecture Notes in Computer Science 1567, pages 16–37. Springer.

[Chutinan and Krogh, 1998] Chutinan, A. and Krogh, B. H. (1998). Computing polyhedral approximations to flow pipes for dynamic systems. In *Proc. of the 37th International Conference on Decision and Control, CDC'98*. IEEE Press.

[Chutinan and Krogh, 1999b] Chutinan, A. and Krogh, B. H. (1999b). Verification of polyhedral-invariant hybrid automata using polygonal flow pipe approximation. In 2^{nd} *Int. Workshop on Hybrid Systems: Computation and Control*, volume 1569 of *LNCS*, pages 76–90. Springer.

[Ciardo et al., 1999] Ciardo, G., Nicol, D., and Trivedi, K. (1999). Discrete-event simulation of fluid stochastic petri nets. *IEEE Trans. Softw. Eng.*, 25(2):207–217.

[Clarke and Kurshan, 1996] Clarke, E. and Kurshan, R. (1996). Computer-aided verification. *IEEE Spectrum*, pages 61–67.

[Clarke and Emerson, 1982] Clarke, E. M. and Emerson, E. A. (1982). Design and synthesis of synchronization skeletons for branching time temporal logic. In Kozen, D., editor, *Logics of Programs Workshop, IBM Watson Research Center, Yorktown Heights, New York, May 1981*, volume 131 of *Lecture Notes in Computer Science*, pages 52–71. Springer-Verlag.

[Clarke et al., 1999] Clarke, E. M., Grumberg, O., and Peled, D. A. (1999). *Model Checking*. MIT Press.

[Collins, 1995] Collins, D. (1995). *Designing Object-Oriented User Interfaces*. Benjamin/Cummings Publishing Company, Inc., Redwood City, CA.

[Commission, 1993] Commission, I. E. (1993). International standard IEC 1131 programmable controllers, part 3, programming languages.

[Console et al., 1992] Console, L., de Kleer, J., and Hamscher, W., editors (1992). *Readings in Model-based Diagnosis*, San Mateo, CA. Morgan Kaufmann Publishers.

[Courcoubetis et al., 1992] Courcoubetis, C., Vardi, M. Y., Wolper, P., and Yannakakis, M. (1992). Memory-efficient algorithms for the verification of temporal properties. *Formal Methods in System Design*, 1(2/3):275–288.

[Cury et al., 1998] Cury, J. E. R., Krogh, B. A., and Niinomi, T. (1998). Synthesis of supervisory controllers for hybrid systems based on approximating automata. *IEEE Transactions on Automatic Control, Special issue on hybrid systems*, 43:564–568.

[Czogalla and Hoyer, 1997] Czogalla, O. and Hoyer, R. (1997). Simulation based design of control strategies for urban management and control. In *4th World Congress on Intelligent Transport Systems*, Berlin.

[Czogalla and Hoyer, 1999] Czogalla, O. and Hoyer, R. (1999). Model based approximation of traffic actuated signal control for mesoscopic traffic simulation. In *6th World Congress on Intelligent Transport Systems*, Toronto.

[Dang and Maler, 1998] Dang, T. and Maler, O. (1998). Reachability analysis via face lifting. In Henzinger, T. and Sastry, S., editors, *Hybrid Systems: Computation and Control, Proc. 1st Int. Workshop, HSCC'98, Berkeley, USA, March 1998*, Lecture Notes in Computer Science 1386, pages 96–109. Springer.

[David and Alla, 1987] David, R. and Alla, H. (1987). Continuous Petri Nets. In *8th European Workshop on Applications and Theory of Petri Nets*, pages 275–294, Spain.

[David and Alla, 1992] David, R. and Alla, H. (1992). *Petri nets and Grafcet - Tools for modelling discrete event systems*. Prentice Hall, New York, London.

[David and Alla, 1993] David, R. and Alla, H. (1993). Autonomous and timed continuous petri nets. *Lecture Notes in Computer Science*, 674:71–90.

[David and Alla, 1994] David, R. and Alla, H. (1994). Petri Nets for Modeling of Dynamic Systems - A Survey. *Automatica*, 30(2):175–202.

[David and Alla, 1998] David, R. and Alla, H. (1998). Continuous and hybrid Petri nets. *International Journal of Circuits and Systems*, 8(1):159–188.

[Davoren and Moor, 2000] Davoren, J. M. and Moor, T. (2000). Logic-based design and synthesis of controllers for hybrid systems. Technical report, RSISE, Australian National University. Submitted for publication.

[Davoren and Nerode, 2000] Davoren, J. M. and Nerode, A. (2000). Logics for hybrid systems. *Proceedings of the IEEE*, 88:985–1010.

[de Kleer and Weld, 1990] de Kleer, J. and Weld, D. S., editors (1990). *Readings in Qualitative Reasoning about Physical Systems*, San Mateo, CA. Morgan Kaufmann Publishers.

[de Roever, 1998] de Roever, W.-P. (1998). The need for compositional proof systems: A survey. In (de Roever et al., 1998), pages 1–22.

[de Roever et al., 2001] de Roever, W.-P., de Boer, F., Hannemann, U., Hooman, J., Lakhnech, Y., Poel, M., and Zwiers, J. (2001). *Concurrency Verification: Introduction to Compositional and Noncompositional Methods*. Number 54 in Cambridge Tracts in Theoretical Computer Science. Cambridge University Press.

[de Roever et al., 1998] de Roever, W.-P., Langmaack, H., and Pnueli, A., editors (1998). *Compositionality: The Significant Difference, Proceedings of the International Symposium COMPOS ’97, Malente, Germany, September 7–12, 1997*, volume 1536 of *Lecture Notes in Computer Science*. Springer-Verlag.

[Decknatel and Schnieder, 1998] Decknatel, G. and Schnieder, E. (1998). Hybrid petri nets as a new formalism for modelling railway systems. In *Computers in Railways VI*, pages 773–782. Computational Mechanics Publications/WIT Press.

[Decknatel and Schnieder, 2000] Decknatel, G. and Schnieder, E. (2000). A formal definition and discrete-event simulation of hybrid high-level petri nets. In *ADPM 2000*, pages 337–342, Dortmund.

[Decknatel et al., 2002] Decknatel, G., Slovák, R., and Schnieder, E. (2002). Definition of a type of continuous-discrete high-level petri nets and its application to the performance analysis of train protection system. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Denk, 1999] Denk, J. (1999). Online optimal control strategies for mechatronic systems under multiple contact configurations. Technical report, Institute of Automatic Control Engineering, Technische Universität München. Internal Report.

[Deparade et al., 2001] Deparade, A., Pereira Remelhe, M., and Engell, S. (2001). Eine modellierungs- und simulationsumgebung für hybride technische systeme mit ereignisdiskreten steuerungen. In *3. VDI/VDE-GMA Aussprachetag, Rechnergestützter Entwurf von Regelungssystemen, Dresden*, volume 36 of *GMA-Berichte*, Düsseldorf. GMA-Aussprachetag FA-6.23, VDI/VDA-GMA.

[Dijkstra, 1969a] Dijkstra, E. W. (1969a). On understanding programs (EWD 264). Published in an extended version as (Dijkstra, 1969b).

[Dijkstra, 1969b] Dijkstra, E. W. (1969b). Structured programming. In Buxton, J. and Randell, B., editors, *Software Engineering Techniques, Report on a conference sponsored by the NATO Science Committee*, pages 84–88. NATO Science Committee.

[Dimitriadis et al., 1996] Dimitriadis, V., Shah, N., and Pantelides, C. (1996). A case study in hybrid process safety verification. *Computers and Chem. Eng.*, 20, Suppl.:S503–S508.

[Dimitriadis et al., 1997] Dimitriadis, V., Shah, N., and Pantelides, C. (1997). Modelling and safety verification of dicrete/continuous processing systems. *AIChE Journal*, 43(4):1041–1059.

[Dixon et al., 2000] Dixon, W., Dawson, D. M., Zergeroglu, E., and Zhang, F. (2000). Robust tracking and regulation control for mobile robots. *International Journal of Robust and Nonlinear Control*, 10:199–216.

[Doğruel and Özgüner, 1995] Doğruel, M. and Özgüner, U. (1995). Modeling and stability issues in hybrid systems. In Antsaklis, P., Kohn, W., Nerode, A., and Sastry, S., editors, *Lecture Notes in Computer Science: Hybrid Systems II*, volume 999, pages 148–165. Springer Verlag.

[Doğruel et al., 1996] Doğruel, M., Özgüner, U., and Drakunov, S. (1996). Sliding-mode control in discrete-state and hybrid systems. *IEEE Transactions on Automatic Control*, 41:414–419.

[Drath, 1999] Drath, R. (1999). *Modellierung hybrider Systeme auf der Basis modifizierter Petri-Netze*. PhD thesis, TU-Ilmenau, Fachgebiet Automatisierungsanlagen und Prozeßleittechnik, Ilmenau. ISBN-Nr.: 3-932633-40-7.

[Drath et al., 1999] Drath, R., Engmann, U., and Schwuchow, S. (1999). Hybrid aspects of modelling manufacturing systems using modified petri nets. In *5th Workshop on Intelligent Manufacturing Systems*, Granado, Brasil.

[Drath and Schwuchow, 1997] Drath, R. and Schwuchow, S. (1997). Modellierung diskret-kontinuierlicher Systeme mit Petri-Netzen. In Schnieder, E., editor, *Entwurf komplexer Automatisierungsysteme 5. Fachtagung*, pages 265–283, Braunschweig.

[Dymola,] Dymola. Homepage: http://www.dynasim.se/.

[Egerstedt et al., 1998] Egerstedt, M., Hu, X., and Stotsky, A. (1998). Control of a car-like robot using a virtual vehicle approach. In *Proc. of the 37th International Conference on Decision and Control, CDC'98*, pages 1502–1507. IEEE Press.

[Einarsson, 2000] Einarsson, V. (2000). *Model Checking Methods for Mode Switching Methods*. PhD thesis, Department of Electrical Engineering, Linköping University, Sweden.

[Elmqvist et al., 1993] Elmqvist, H., Cellier, F. E., and Otter, M. (1993). Object-oriented modeling of hybrid systems. In *ESS'93, European Simulation Symposium*, Delft.

[Engell, 1997] Engell, S. (1997). Modellierung und analyse hybrider dynamischer systeme. *at–Automatisierungstechnik*, 45(4):152–162.

[Engell, 2000] Engell, S., editor (2000). *Special Issue on Discrete Event Models of Continuous Systems*, volume 6, no. 1 of *Mathematical and Computer Modelling of Dynamical Systems*.

[Engell et al., 2001] Engell, S., Herrmann, P., Huuck, R., Kowalewski, S., Krumm, H., Lakhnech, Y., Lukoschus, B., and Treseler, H. (2001). Approaches to the formal verification of hybrid systems. *at - Automatisierungstechnik*, 49(2):66–74.

[Engell et al., 1997] Engell, S., Hoffmann, I., and Sapronowa, L. (1997). Chaos in einfachen kontinuierlich-diskreten dynamischen systemen. *at–Automatisierungstechnik*, 45(9):399–406.

[Engell et al., 1996] Engell, S., Kowalewski, S., and Krogh, B. (1996). Discrete events and hybrid systems in process control. In Kantor, J., Garcia, C., and Carnahan, B., editors, *Chemical Process Control V: Assessment and New Directions for Research*, volume 316 of *AIChE Symposium Series*, pages 165–176.

[Engell et al., 2000a] Engell, S., Kowalewski, S., Schulz, C., and Stursberg, O. (2000a). Continuous-discrete interaction in chemical processing plants. *Proceedings of the IEEE*, 88(7):1050–1068.

[Engell et al., 2000b] Engell, S., Kowalewski, S., and Zaytoon, J., editors (2000b). *4th Int. Conf. on Automation of Mixed Processes: Hybrid Dynamic Systems (ADPM 2000), Dortmund, Germany*. Shaker Verlag, Aachen.

[Engstrom and Krueger, 2000] Engstrom, E. and Krueger, J. (2000). A meta-modeler's job is never done: Building and evolving domain-specific tools with DOME. In *Proceedings of the IEEE International Symposium on Computer Aided Control System Design*, pages 83–88, Anchorage, Alaska.

[Enste, 2001] Enste, U. (2001). *VDI Fortschritt-Berichte, Reihe 8, Nr. 884, Generische Entwurfsmuster in der Funktionsbausteintechnik und deren Anwendung in der operativen Prozessführung*. VDI-Verlag.

[Enste and Epple, 1998] Enste, U. and Epple, U. (1998). Standardisierte prozessfuehrungsbausteine - die basis fuer applikationsmodelle zur operativen fuehrung von verfahrenstechnischen produktionsanlagen. In *VDI Bericht 1397*. VDI-Verlag.

[Enste and Fedai, 1998] Enste, U. and Fedai, M. (1998). Flexible process control structures in multi-product and redundant-routing-plants. In *9th IFAC Symposium on Automation in Mining, Mineral and Metal Processing*, pages 211–214.

[Enste and Kneissl, 2000] Enste, U. and Kneissl, M. (2000). Modelling of software structures in process control systems - avoiding bugs by using graph grammars. In *IMACS Symposium on MATHEMATICAL MODELLING, ARGESIM Report No. 15: Proceedings Vol.1, Vienna*, pages 381–384.

[Enste and Uecker, 2000] Enste, U. and Uecker, F. (2000). Use of supervision information in process control. *IEE Computing & Control Engineering Journal*, pages 234–241.

[Enste and U.Epple, 2001] Enste, U. and U.Epple (2001). Technical application of hybrid modeling methods to specify function block systems. *Automatisierungstechnik - at*, 49(2):52–59.

[Epple, 1994] Epple, U. (1994). Operational control of process plants. In *Process Control Engineering*. VCH-Verlagsgesellschaft, Weinheim.

[Ernst et al., 1997] Ernst, T., Jähnichen, S., and Klose, M. (1997). Object-oriented physical systems modeling, Modelica, and the SmileM simulation environment. In Sydow, A., editor, *Proceedings of the 15th IMACS World Congress on Scientific Computation, Modelling and Applied Mathematics*, volume 6, pages 653–658.

[Ernst et al., 2000] Ernst, T., Klein-Robbenhaar, C., Nordwig, A., and Schrag, T. (2000). Modellierung und Simulation hybrider Systeme mit Smile. *Informatik Forschung und Entwicklung*, 5.

[et al., 1993] et al., J. S. (1993). An approach to the description and analysis of hybrid systems. In *Lecture Notes in Computer Science*. Springer Verlag.

[et al., 1996] et al., N. L. (1996). Hybrid i/o automata. In *Hybrid Systems III, LNCS*. Springer Verlag.

[et al., 1995] et al., R. A. (1995). Hybrid automata: An algorithm approach to the specification and verification of hybrid systems. In *Bd. 736 LNCS, Berlin, Heidelberg*. Springer Verlag.

[Fábián et al., 1998] Fábián, G., van Beek, D. A., and Rooda, J. E. (1998). Integration of the discrete and the continuous behaviour in the hybrid chi simulator. In *1998 European Simulation Multiconference, Manchester*, pages 207–257.

[Fahrland, 1970] Fahrland, D. (1970). Combined discrete event continuous systems simulation. *Simulation*, 14(2):71–72.

[Farzzoli et al., 1999] Farzzoli, E., Dahleh, M. A., and Feron, E. (1999). A hybrid control architecture for agressive meneuvering of autonomous helicopters. In *Proceedings of the 38th International Conference on Decision and Control, CDC'99*, pages 2471–2476. IEEE Press.

[Fellendorf, 1994] Fellendorf, M. (1994). VISSIM: A microscopic Simulation Tool to evaluate Actuated Signal Control including Bus priority. In *64th ITE Annual Meeting*, Dallas.

[Floyd, 1967] Floyd, R. W. (1967). Assigning meanings to programs. In Schwartz, J., editor, *Proceedings AMS Symposium Applied Mathematics*, volume 19, pages 19–31, Providence, RI. American Mathematical Society.

[Föllinger, 1994] Föllinger, O. (1994). *Regelungstechnik. Einführung in die Methoden und ihre Anwendung*. Hüthig.

[Forbus, 1990] Forbus, K. D. (1990). Qualitative reasoning. Draft chapter.

[Förstner et al., 2002] Förstner, D., Jung, M., and Lunze, J. (2002). A discrete-event model of asynchronous quantised systems. *Automatica, to appear*.

[Foundation, 1996] Foundation, F. (1996). Device description language specification. Technical report, Fieldbus Foundation, Austin Texas.

[Frank, 1998] Frank, P. M. (1998). Komplexe systeme - nichtlineare rückkopplungssysteme jenseits der stabilität. *at - Automatisierungstechnik*, 46(4):167–179.

[Frank, 2001] Frank, R. (2001). Entwicklung einer Internetanbindung für den Modellprozess Drei-Tank-System. Diplomarbeit, Institut für Automatisierungs- und Softwaretechnik (IAS), Universität Stuttgart.

[Franke et al., 2000] Franke, D., Moor, T., and Raisch, J. (2000). Discrete supervisory control of switched linear systems. *at-Automatisierungstechnik*, 48:9:461–467.

[Frehse et al., 2002] Frehse, G., Stursberg, O., Engell, S., Huuck, R., and Lukoschus, B. (2002). Modular analysis of discrete controllers for distributed hybrid systems. In *b '02: The XV. IFAC World Congress, Barcelona, Spain, July 21–26, 2002*. To appear.

[Frehse et al., 2001] Frehse, G. F., Stursberg, O., Engell, S., Huuck, R., and Lukoschus, B. (2001). Verification of hybrid controlled processing systems based on decomposition and deduction. In *ISIC 2001: 16th IEEE International Symposium on Intelligent Control, Mexico City, Mexico, September 5–7, 2001*, pages 150–155. IEEE Control Systems Society, IEEE Press.

[Friesen, 1995] Friesen, V. (1995). An exercise in hybrid system specification using an extension of Z. In Bouajjani, A. and Maler, O., editors, *Second European Workshop on Real-Time and Hybrid Systems*, pages 311–316.

[Friesen, 1997] Friesen, V. (1997). *Objektorientierte Spezifikation hybrider Systeme*. PhD thesis, Technical University of Berlin.

[Friesen, 1998] Friesen, V. (1998). A logic for the specification of continuous systems. In (Henzinger and Sastry, 1998a).

[Friesen et al., 1998a] Friesen, V., Nordwig, A., and Weber, M. (1998a). Object-oriented specification of hybrid systems using UML$^{\mathrm{h}}$ and ZimOO. In *Proc. 11th Int. Conf. on the Z Formal Method (ZUM)*, LNCS 1493. Springer.

[Friesen et al., 1998b] Friesen, V., Nordwig, A., and Weber, M. (1998b). Toward an object-oriented design methodology for hybrid systems. Proceedings of the Colloquium on Object Technology and System Re-Engineering, Oxford.

[Fröhlich, 1996] Fröhlich, P. (1996). *Überwachung verfahrenstechnischer Prozesse unter Verwendung eines qualitativen Modellierungsverfahrens*. Dissertation, Institut für Automatisierungs- und Softwaretechnik (IAS), Universität Stuttgart.

[Gamma et al., 1995] Gamma, E., Helm, R., Johnson, R., and Vlissides, J. (1995). *Design Patterns, Elements of Reusable Object-Oriented Software*. Addison-Wesley.

[Gao and Antsaklis, 1991] Gao, Z. and Antsaklis, P. J. (1991). Stability of the pseudo-inverse method for reconfigurable control systems. *International Journal of Control*, 53:717–729.

[Gazis et al., 1959] Gazis, D. C. et al. (1959). Car following theory of steady-state traffic flow. *Operns. Res.*, 7:499–505.

[Geisler et al., 1998] Geisler, R., Klar, M., and Pons, C. (1998). Dimensions and dichotomy in metamodeling. Technical Report 98-2, Technical University of Berlin.

[Genrich, 1978] Genrich, H. J. (1978). Ein kalkül des planes und handelns. In *Ansätze zur Organsiationstheorie rechnergestützter Informationssysteme*, GMD Bericht 111, pages 77–92. Oldenbourg Verlag.

[Genrich, 1987] Genrich, H. J. (1987). Predicate/transition nets. *Advances in Petri nets 1986, part I. Lecture Notes in Computer Science*, 254:207–247.

[Genrich and Lautenbach, 1981] Genrich, H. J. and Lautenbach, K. (1981). System modelling with high-level petri nets. *Theoretical Computer Science*, 13.

[Ghezzi et al., 1991] Ghezzi, C., Mandrioli, D., Morasca, S., and Pezzè, M. (1991). A unified high-level petri net formalism for time-critical systems. *IEEE Transactions On Software Engineering*, 17(2):160–172.

[Gill et al., 1997] Gill, P., Murray, W., and Saunders, M. (1997). *User's guide for SNOPT 5.3: a fortran package for large-scale nonlinear programming*. Department of Mathematics, Univ. of California San Diego.

[Gilles et al., 1986] Gilles, E. D., Holl, P., and Marquardt, W. (1986). Dynamische simulation komplexer chemischer prozesse. *Chem.-Ing.-Tech*, 58(4):268–278.

[Giua and Piccaluga,] Giua, A. and Piccaluga, A. Bibliography on hybrid petri nets. http://bode.diee.unica.it/~hpn/.

[Giua and Usai, 1996] Giua, A. and Usai, E. (1996). High-level hybrid petri nets: a definition. In *35th Conference on Decision and Control*, pages 148–150, Kobe, Japan.

[Giua and Usai, 1998] Giua, A. and Usai, E. (1998). Modeling hybrid systems by high-level petri nets. pages 316–323.

[Glover, 1975] Glover, F. (1975). Improved linear integer programming formulations of non-linear integer problems. *Managem. Science*, 22(4):455–460.

[Göhner and Lauber, 1999] Göhner, P. and Lauber, R. (1999). *Prozessautomatisierung 2*, volume 2. Springer-Verlag, Berlin Heidelberg, 1 edition.

[Gokbayrak and Cassandras, 2000] Gokbayrak, K. and Cassandras, C. G. (2000). Hybrid controllers for hierarchically decomposed systems. In *Proc.* 3^{rd} *Int. Workshop of Hybrid Systems: Computations and Control*, volume 1790 of *LNCS*, pages 117–129. Springer.

[Goldstein and von Neumann, 1947] Goldstein, H. H. and von Neumann, J. (1947). Planning and coding problems of an electronic computing instrument. In Taub, A., editor, *J. von Neumann—Collected Works*, pages 80–151. McMillan, New York.

[Goux et al., 2000] Goux, J.-P., Leyffer, S., and Nocedal, J. (2000). Mixed-integer non-linear programming solver for metacomputing platforms. Technical report. http://www-unix.mcs.anl.gov/metaneos/optsolvers/nlbranch.html.

[gPROMS,] gPROMS. Homepage: http://www.psenterprise.com/.

[Greenstreet and Mitchell, 1999] Greenstreet, M. and Mitchell, I. (1999). Reachability analysis using polygonal projections. In Vaandrager, F. W. and van Schuppen, J. H., editors, *Hybrid Systems: Computation and Control, Proc. 2nd Int. Workshop, HSCC'99, Berg en Dal, The Netherlands, March 1999*, Lecture Notes in Computer Science 1569, pages 103–116. Springer.

[Gribaudo et al., 1999] Gribaudo, M., Sereno, M., and Bobbio, A. (1999). Fluid stochastic petri nets: An extended formalism to include non-markovian models. In *Proc. Eighth In-*

ternational Workshop on Petri Nets and Performance Models - PNPM'99, pages 74–81, Zaragoza, Spain.

[Griepentrog and März, 1986] Griepentrog, E. and März, R. (1986). *Differential-Algebraic Equations and Their Numerical Treatment*. BSB Teubner, Leipzig. ISBN 3-322-00343-4.

[Grossman et al., 1993] Grossman, R. L., Nerode, A., Ravn, A. P., and Rischel, H., editors (1993). *Hybrid Systems*, volume 736 of *Lecture Notes in Computer Science*. Springer.

[Grosu et al., 2000] Grosu, R., Krüger, I., and Stauner, T. (2000). Hybrid Sequence Charts. In *Proc. of ISORC 2000*. IEEE.

[Grosu et al., 1998] Grosu, R., Stauner, T., and Broy, M. (1998). A modular visual model for hybrid systems. In *Proc. of FTRTFT'98*, LNCS 1486. Springer-Verlag.

[Group, 1999] Group, I. . W. (1999). IEEE standard 1076.1-1999. http://www.vhdl.org.

[Hanisch, 1992] Hanisch, H.-M. (1992). *Petri-Netze in der Verfahrenstechnik*. Oldenbourg Verlag, München, Wien.

[Hanisch et al., 1998a] Hanisch, H.-M., Lautenbach, K., Simon, C., and Thieme, J. (1998a). Timestamp nets in technical applications. In *IEEE International Workshop on Discrete Event Systems*, San Diego, CA, USA.

[Hanisch et al., 1998b] Hanisch, H.-M., Lautenbach, K., Simon, C., and Thieme, J. (1998b). Timestamp petri nets in technical applications. In Giua, A., Smedinga, R., and Spathopoulos, M. P., editors, *IEE International Workshop on Discrete Event Systems*, IEE Control, pages 321–326, Cagliari, Sardinia, Italy.

[Hanisch et al., 1998c] Hanisch, H.-M., Lautenbach, K., Simon, C., and Thieme, J. (1998c). Zeitstempelnetze in technischen anwendungen. Fachberichte Informatik 2–98, Universität Koblenz-Landau, Institut für Informatik, Rheinau 1, D-56075 Koblenz.

[Hardt et al., 2000] Hardt, M., Helton, J., and Kreutz-Delgado, K. (2000). Numerical solution of nonlinear $\mathscr{H}_2$ and $\mathscr{H}_\infty$ control problems with application to jet engine compressors. *IEEE Transactions on Control Systems Technology*, 8(1):98–111.

[Hardt and von Stryk, 2000] Hardt, M. and von Stryk, O. (2000). Towards optimal hybrid control solutions for gait patterns of a quadruped. In *CLAWAR 2000 – 3rd International Conference on Climbing and Walking Robots, Madrid, 2–4 October, Professional Engineering Publishing, UK*, pages 385–392.

[Harel, 1987] Harel, D. (1987). Statecharts: A Visual Formalism for Complex Systems. *Science of Computer Programming*, 8:231–274.

[Harel and Gery, 1996] Harel, D. and Gery, E. (1996). Executable object modeling with Statecharts. In *Proceedings of the 18th International Conference of Software Engineering*, IEEE Press.

[He and Lemmon, 1998] He, K. X. and Lemmon, M. D. (1998). Lyapunov Stability of Continous-Valued Systems Under the Supervision of Discrete-Event Transition Systems. In Henzinger, T. A. and Sastry, S., editors, *Hybrid Systems: Computation and Control*, LNCS 1386, pages 175–189, Berlin, Germany. Springer.

[Hedlund and Rantzer, 1999] Hedlund, S. and Rantzer, A. (1999). Optimal control of hybrid systems. In *Proceedings of the 38th IEEE Conference on Decision and Control (Phoenix, AZ)*, pages 3972–3977.

[Heiming and Lunze, 1999] Heiming, B. and Lunze, J. (1999). Definition of the three-tank benchmark problem for controller reconfiguration. In *European Control Conference*.

[Heinkel, 2000] Heinkel, U. (2000). *The VHDL reference*. Wiley, Chichester.

[Henzinger et al., 1995] Henzinger, A., Kopke, P., Puri, A., and Varaiya, P. (1995). What's decidable about hybrid automata. In *Proceedings of the 27th Annual ACM Symposium on Theory of Computing (STOC1995)*, pages 373–382.

[Henzinger et al., 1997] Henzinger, T., Ho, P., and Wong-Toi, H. (1997). Hytech: A model checker for hybrid systems. *Software Tools for Technology Transfer*, 1(1,2):110–122.

[Henzinger et al., 1998a] Henzinger, T., Kopke, P., Puri, A., and P.Varaiya (1998a). What's decidable about hybrid automata. *J. Comp. Syst. Science*, 57:94–124.

[Henzinger et al., 1998b] Henzinger, T., Qadeer, S., Rajamani, S., and Tasiran, S. (1998b). You assume, we guarantee: Methodology and case studies. In *Proc. 10th Int. Conf. on Computer-Aided Verification*, volume 1427 of *Lecture Notes in Computer Science*, pages 440–451. Springer-Verlag.

[Henzinger, 1996] Henzinger, T. A. (1996). The theory of hybrid automata. In *Proc. of 11th Annual IEEE Symposium on Logic in Computer Science (LICS'96)*, pages 278–292. IEEE Computer Society Press.

[Henzinger and Majumdar, 2000] Henzinger, T. A. and Majumdar, R. (2000). A classification of symbolic transition systems. In *Proc. of 17th International Symposium on Theoretical Aspects of Computer Science (STACS'00)*, LNCS. Springer-Verlag.

[Henzinger and Sastry, 1998a] Henzinger, T. A. and Sastry, S., editors (1998a). LNCS 1386, Berlin, Germany. Springer.

[Henzinger and Sastry, 1998b] Henzinger, T. A. and Sastry, S., editors (1998b). *Hybrid Systems – Computation and Control (HSCC'98)*, volume 1386 of *Lecture Notes in Computer Science*. Springer.

[Hinrichsen et al., 1989] Hinrichsen, D., Ilchmann, A., and Pritchard, A. (1989). Robustness of stability of time-varying linear systems. *Journal of Differential Equations*, 82:219–250.

[Hoare, 1969] Hoare, C. (1969). An axiomatic basis for computer programming. *Communications of the ACM*, 12(10):576–580, 583.

[Hoare, 1985] Hoare, C. (1985). *Communicating Sequential Processes*. Prentice-Hall International, Engelwood Cliffs.

[Horn and Ramadge, 1995] Horn, C. and Ramadge, P. J. (1995). Robustness issues for hybrid systems. In *Proceedings of the 34th International Conference on Decision and Control, CDC'95*, pages 1467–1472. IEEE Press.

[Horton et al., 1998] Horton, G., Kulkarni, V. G., Nicol, D. M., and Trivedi, K. S. (1998). Fluid stochastic petri nets: Theory, applications and solution. *European Journal of Operations Research*, 105(1):184–201.

[Huber et al., 1997] Huber, F., Schätz, B., and Einert, G. (1997). Consistent graphical specification of distributed systems. In *FME '97: 4th International Symposium of Formal Methods Europe, LNCS 1313*, pages 122 – 141.

[Hubert et al., 1991] Hubert, P., Jensen, K., and Shapiro, R. (1991). Hierarchies in couloured petri nets. *Lecture Notes in Computer Science*, 483.

[Huuck et al., 1997] Huuck, R., Engell, S., Kowalewski, S., Lakhnech, Y., Preußig, J., and Urbina, L. (1997). Comparing timed c/e systems with timed automata. In *International Workshop on Hybrid and Real-Time Systems (Hart '97)*, LNCS 1201, pages 81–86, Grenoble. Springer.

[Huuck et al., 2002] Huuck, R., Lukoschus, B., Frehse, G., and Engell, S. (2002). Compositional verification of continuous-discrete systems. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Ioannou, 1996] Ioannou, P. (1996). *Robust Adaptive Control*. Prentice-Hall Upper Saddle River NJ.

[Isermann, 1996a] Isermann, R. (1996a). Modellgestützte überwachung und fehlerdiagnose technischer systeme (teil 1). *atp*, 38(5):9–20.

[Isermann, 1996b] Isermann, R. (1996b). Modellgestützte überwachung und fehlerdiagnose technischer systeme (teil 2). *atp*, 38(6):48–57.

[ITU, 1999] ITU (1999). ITU-T Recommendation Z.120: Message Sequence Charts (MSC).

[Jaffar and Maher, 1994] Jaffar, J. and Maher, M. (1994). Constraint logic programming: A survey. *Journal of Logic Programming*, 19/20:503–581.

[Jähnichen and Klein-Robbenhaar, 2000] Jähnichen, S. and Klein-Robbenhaar, C. (2000). Generic modeling and simulation of hybrid systems with adaptive modeling depth. Technical report, Technical University of Berlin. (in German).

[Jensen, 1992] Jensen, K. (1992). *Coloured Petri Nets: Basic Concepts, Analysis Methods and Practical Use*, volume 1. Springer-Verlag.

[Jensen, 1997] Jensen, K. (1997). *Coloured Petri Nets: Basic Concepts, Analysis Methods and Practical Use*, volume 2. Springer.

[Jensen and Rozenberg, 1991] Jensen, K. and Rozenberg, G. (1991). High-level petri nets: theory and application. Springer-Verlag.

[Jiang and Nijmeijer, 1997] Jiang, Z.-P. and Nijmeijer, H. (1997). Tracking control of mobile robots: a case study in backstepping. *Automatica*, 33:1393–1399.

[Jirstrand, 1998] Jirstrand, M. (1998). *Constructive Methods for Inequality Constraints in Control*. PhD thesis, Department of Electrical Engineering, Linköping University, Linköping, Sweden.

[Johannson and Rantzer, 1998] Johannson, M. and Rantzer, A. (1998). Computation of Piecewise Quadratic Lyapunov Functions for Hybrid Systems. *IEEE Trans. Aut. Control*, 43(4):555–559.

[John, 2001] John, S. (2001). Transition selection algorithms for Statecharts. *Proceedings of the GI/OCG annual congress*, 1:pp. 622–627.

[Jones, 1981] Jones, C. B. (1981). *Development Methods for Computer Programs including a Notion of Interference*. PhD thesis, Oxford University Computing Laboratory. Printed as: Programming Research Group, Technical Monograph 25.

[Jones, 1983] Jones, C. B. (1983). Tentative steps toward a development method for interfering programs. *ACM Transactions on Programming Languages and Systems*, 5(4):596–619.

[Joos, 1999] Joos, H.-D. (1999). A methodology for multi-objective design assessment and flight control synthesis tuning. *Aerospace Science and Technology*, 3(3):161–176.

[Kailath, 1980] Kailath, T. (1980). *Linear Systems*. Prentice-Hall, NJ.

[Kaiser and Beaumariage, 1997] Kaiser, R. and Beaumariage, T. (1997). Conceptual design of an artificial intelligence architecture for decision making in manufacturing simulation. In Wallace, J. and Beaumariage, T., editors, *Object-Oriented Simulation Conf. OOS'97*, pages 11–15. SCS International, San Diego.

[Khalil, 1996] Khalil, H. (1996). *Nonlinear Systems*. Prentice-Hall. Second edition.

[Kienle, 2000] Kienle, A. (2000). Low-order models for ideal multicomponent distillation processes using nonlinear wave propagation theory. *Chemical Engineering Science*, 55:1817–1828.

[Klar and Mann, 1998] Klar, M. and Mann, S. (1998). A Metamodel for Object-Oriented Statecharts. *The Second Workshop on Rigorous Object Oriented Methods, ROOM 2*.

[Klein et al., 2000] Klein, E., Itigin, A., Raisch, J., and Kienle, A. (2000). Automatic generation of switching start-up schemes for chemical processes. *Proc. ESCAPE10 – 10th European Symposium on Computer Aided Process Engineering*, pages 619–624.

[Klein et al., 1998] Klein, E., Kienle, A., and Raisch, J. (1998). Synthesizing a supervisory control scheme for the start-up procedure of a distillation column - an approach based on approximating continuous dynamics by des models. *Proc. LSS'98 - 8th IFAC Colloquium on Large Scale Systems*, pages 716–721.

[Klein et al., 1999] Klein, E., Kienle, A., Raisch, J., and Wehlan, H. (1999). Synthese einer Anfahrregelung für eine Destillationskolonne auf der Grundlage einer ereignisdiskreten Approximation der kontinuierlichen Dynamik. *6. Fachtagung Entwicklung and Betrieb komplexer Automatisierungssysteme (EKA99)*, pages 447–464.

[Kloas et al., 1995] Kloas, M., Friesen, V., and Simons, M. (1995). Smile — A simulation environment for energy systems. In (Sydow, 1995), pages 503–506.

[Knobloch et al., 1993] Knobloch, H. W., Isidori, A., and Flockerzi, D. (1993). *Topics in Control Theory*. Birkhäuser-Verlag, Basel.

[Komarow and Skotschinski, 1956] Komarow, W. B. and Skotschinski, A. A. (1956). *Grubenbewetterung*. VEB Verlag Technik Berlin.

[Kondak and Hommel, 2001] Kondak, K. and Hommel, G. (2001). Computation of time optimal movements for autonomous parking of non-holonomic mobile platforms. In *Proceedings of the IEEE International Conference on Robotics and Automation (Seoul, Korea)*, pages 2698–2703.

[König and Quäck, 1988] König, R. and Quäck, L. (1988). *Petri-Netze in der Steuerungs- und Digitaltechnik*. Oldenbourg Verlag, München, Wien.

[Koo et al., 2001] Koo, T. J., Pappas, G. J., and Sastry, S. (2001). Mode switching synthesis for reachability specifications. In Benedetto, M. D. D. and Sangiovanni-Vincentelli, A., editors, *Hybrid Systems: Computation and Control (HSCC'01)*, volume 2034 of *LNCS*, pages 333–346. Springer-Verlag.

[Koutsoukos et al., 2000] Koutsoukos, X., Antsaklis, P. J., Stiver, J. A., and Lemmon, M. D. (2000). Supervisory control of hybrid systems. *Proceedings of the IEEE*, 88:1026–1049.

[Kowalewski, 1996] Kowalewski, S. (1996). *Modulare diskrete Modellierung verfahrenstechnischer Anlagen zum systematischen Steuerungsentwurf*. Dissertation, Fachbereich Chemietechnik, Dortmund.

[Kowalewski, 2002] Kowalewski, S. (2002). Introduction to the analysis and verification of hybrid systems. In *this volume*.

[Kowalewski et al., 1999] Kowalewski, S., Engell, S., Preussig, J., and Stursberg, O. (1999). Verification of logic controllers for continuous plants using timed condition/event system models. *Automatica*, 35(3):505–518.

[Kowalewski et al., 2001] Kowalewski, S., Herrmann, P., Engell, S., Huuck, R., Krumm, H., Lakhnech, Y., and Lukoschus, B. (2001). Approaches to the formal verification of hybrid systems. *at-Automatisierungstechnik*, 49(2):66–74.

[Kowalewski and Preußig, 1996] Kowalewski, S. and Preußig, J. (1996). Timed condition/event systems: A framework for modular models of chemical plants and verification of their real-time discrete control. In Margaria, T. and Steffen, B., editors, *Tools and Algorithms for the Construction and Analysis of Systems, Proc. 2nd International Workshop TACAS'96*, Lecture Notes in Computer Science 1055, pages 225–240, Passau. Springer.

[Kowalewski et al., 1998] Kowalewski, S., Stursberg, O., and Treseler, H. (1998). Diskrete modellierung verfahrenstechnischer prozesse zur steuerungsverifikation. *at - Automatisierungstechnik*, 4:180–187.

[Kramer, 1997] Kramer, D. (1997). *JDK 1.1.1 Documentation*. Sun Microsystems, Inc.

[Krebs and Editors), 2000] Krebs, V. G. and Editors), E. S. G. (2000). Hybrid Systems I: Modeling and Control. *Automatisierungstechnik*, 48.

[Kripke, 1963] Kripke, S. A. (1963). Semantical considerations on modal logic. *Acta Philosophica Fennica*, 16:83–94.

[Krogh, 1993] Krogh, B. (1993). Condition/event signal interfaces for block diagram modeling and analysis of hybrid systems. In *8th Int. Symp. on Intelligent Control Systems*, pages 180–185.

[Krogh and Chutinan, 1999] Krogh, B. A. and Chutinan, A. (1999). Hybrid systems: modeling and supervisory control. In Frank, P. M., editor, *Advances in Control, highlights of ECC'99*, pages 228–246. Springer-Verlag.

[Kuipers, 1986] Kuipers, B. (1986). Qualitative simulation. *Artificial Intelligence*, 29:289–338.

[Kuipers, 1994] Kuipers, B. (1994). *Qualitative Reasoning*. MIT Press.

[Kurz, 1990] Kurz, H. (1990). Realisierung gehobener methoden der regelungstechnik auf prozessleitsystemen - ein diskussionsbeitrag. *Automatisierungstechnische Praxis - atp*, 32(10):489–494.

[Kurzhanski and Varaiya, 2000] Kurzhanski, A. B. and Varaiya, P. (2000). Ellipsoidal techniques for reachability analysis. In Lynch, N. and Krogh, B., editors, *Hybrid Systems: Computation and Control (HSCC'00)*, LNCS 1790, pages 203–213. Springer-Verlag.

[Labinaz et al., 1996] Labinaz, G., Bayoumi, M. M., and Rudie, K. (1996). Modeling and Control of Hybrid Systems: A Survey. In *Proc. IFAC 13th Triennial World Congress*, pages 293–304, San Francisco, USA. IFAC.

[Lafferiere et al., 1999] Lafferiere, G., Pappas, G., and Yovine, S. (1999). A new class of decidable hybrid systems. In Vaandrager, F. W. and van Schuppen, J. H., editors, *Hybrid Systems: Computation and Control, Proc. 2nd Int. Workshop, HSCC'99, Berg en Dal, The Netherlands, March 1999*, volume 1569 of *Lecture Notes in Computer Science*, pages 137–151. Springer.

[Lafferriere et al., 2000] Lafferriere, G., Pappas, G., and Sastry, S. (2000). O-minimal hybrid systems. *Mathematics of Control, Signals, and Systems*, 13(3):1–21.

[Larsen et al., 1997] Larsen, K., Pettersson, P., and Yi, W. (1997). Uppaal in a nutshell. *Software Tools for Technology Transfer*, 1(1,2):134–152.

[Laudwein, 1999] Laudwein, A. (1999). Konzeption und entwicklung einer steuerungs- und regelungssoftware für den modellprozess “drei-tank-system”. Diplomarbeit, Institut für Automatisierungs- und Softwaretechnik (IAS), Universität Stuttgart.

[Laufenberg, 1997] Laufenberg, X. (1997). *Ein modellbasiertes qualitatives Verfahren für die Gefahrenanalyse*. Dissertation, Institut für Automatisierungs- und Softwaretechnik (IAS), Universität Stuttgart.

[Lautenbach and Simon, 1999] Lautenbach, K. and Simon, C. (1999). Erweiterte zeitstempelnetze. Fachberichte Informatik 03–99, Universität Koblenz-Landau, Institut für Informatik, Rheinau 1, D-56075 Koblenz.

[Lautenbach and Simon, 2000] Lautenbach, K. and Simon, C. (2000). Verification in a logic of actions. In *7. Workshop Algorithmen und Werkzeuge für Petrinetze*, Koblenz.

[Lautenbach and Simon, 2001] Lautenbach, K. and Simon, C. (2001). Modellierung der dynamik einer batch-anlage. In Schnieder, E., editor, *Engineering komplexer Automatisierungssysteme, EKA 2001*, Braunschweig.

[Le Bail et al., 1991] Le Bail, J., Alla, H., and David, R. (1991). Hybrid petri nets. In *European Control Conference*, pages 1472–1477.

[Lee, 2000] Lee, J.-D. e. a. (2000). Analysis of moving and fixed autoblock systems for korean high speed railway. In *Computers in Railways VII*, pages 843–851. Bologna.

[Lee and Grossmann, 2000] Lee, S. and Grossmann, I. (2000). New algorithms for nonlinear generalized disjunctive programming. *Comp. and Chemical. Eng.*, 4:2125–2141.

[Lemmon et al., 1999] Lemmon, M., He, K., and Markovsky, I. (1999). Supervisory hybrid systems. *IEEE Control Systems Magazine*, 19:42–55.

[Leue et al., 1998] Leue, S., Mehrmann, L., and Rezai, M. (1998). Synthesizing ROOM Models from MSC Specifications. Technical Report TR-98-06, University of Waterloo.

[Levin and Gries, 1981] Levin, G. M. and Gries, D. (1981). A proof technique for communicating sequential processes. *Acta Informatica*, 15(3):281–302.

[Li et al., 2000] Li, Z., Soh, C., and Xu, X. (2000). Lyapunov stability of a class of hybrid dynamic systems. *Automatica*, 36:297–302.

[Liberzon and Morse, 1999] Liberzon, D. and Morse, A. S. (1999). Basic problems in stability and design of switched systems. *IEEE Control Systems Magazine*, 19.

[Lichtenberg and Kamau, 2001] Lichtenberg, G. and Kamau, S. (2001). A classification of the input-output behaviour of hybrid systems. In *European Control Conference*.

[Lichtenberg et al., 1999a] Lichtenberg, G., Lunze, J., and Raisch, J. (1999a). Two approaches to modeling the qualitative behaviour of dynamic systems. *at-Automatisierungstechnik*, 47:187–198.

[Lichtenberg et al., 1999b] Lichtenberg, G., Lunze, J., and Raisch, J. (1999b). Zwei Wege zur Modellierung des qualitativen Verhaltens dynamischer Systeme. *at - Automatisierungstechnik*, 47(5):187–198.

[Lichtenberg et al., 1999c] Lichtenberg, G., Lunze, J., Scheuring, R., and Schröder, J. (1999c). Prozessdiagnose mittels qualitativer Modelle am Beispiel eines Wasserstoffverdichters. *at - Automatisierungstechnik*, 47(3):101–109.

[Liggesmeyer and Mäckel, 2000] Liggesmeyer, P. and Mäckel, P. (2000). Automtisierung erweiterter Fehlerbaumanalysen für komplexe technische Systeme. *at - Automatisierungstechnik*, 48(2):67–76.

[Lincoln and Rantzer, 2001] Lincoln, B. and Rantzer, A. (2001). Optimizing linear system switching. In *Proc.* 40^{th} *IEEE Conf. Decision and Control*, pages 2063–2068.

[Litz, 1989] Litz, L. (1989). Automatisierung verfahrenstechnischer prozesse - anforderungen und defizite. *Automatisierungstechnik - at*, 37(10):330–376.

[Lorch et al., 2000] Lorch, O., Denk, J., Seara, J., Buss, M., Freyberger, F., and Schmidt, G. (2000). Vigwam — an emulation environment for a vision guided virtual walking machine. In *Proceedings of the First IEEE-RAS International Conference on Humanoid Robots HUMANOIDS 2000 (Cambridge, MA, USA)*.

[Lötzbeyer and Pretschner, 2000] Lötzbeyer, H. and Pretschner, A. (2000). AutoFocus on Constraint Logic Programming. In *Proc. (Constraint) Logic Programming and Software Engineering*.

[Lunze, 1994] Lunze, J. (1994). Qualitative modelling of linear dynamical systems with quantized state measurements. *Automatica*, 30:417–431.

[Lunze, 1995] Lunze, J. (1995). Stabilisation of nonlinear systems by qualitative feedback controllers. *Intern. J. Control*, 62:109–128.

[Lunze, 1998] Lunze, J. (1998). Qualitative Modellierung dynamischer Systeme durch stochastische Automaten. *at - Automatisierungstechnik*, 46(6):271–283.

[Lunze, 1999] Lunze, J. (1999). A timed discrete-event abstraction of continuous-variable systems. *Intern. J. Control*, 72:1147–1164.

[Lunze, 2000a] Lunze, J. (2000a). Diagnosis of quantized systems based on a timed discrete-event model. *IEEE Trans. SMC*, 30:322–335.

[Lunze, 2000b] Lunze, J. (2000b). Process supervision by means of qualitative models. *Annual Reviews in Control*, 24:41–54.

[Lunze, 2002] Lunze, J. (2002). *Regelungstechnik, Band 2*. Springer Verlag.

[Lunze, 2001] Lunze, J. (submitted 2001). Control reconfiguration. In *Encyclopedia of Live Support Systems*. EOLSS Publishers.

[Lunze et al., 2000] Lunze, J., Heiming, B., and et. al., M. S. (2000). Three-tank control reconfiguration. In Aström, K., editor, *Control of Complex Systems*. Springer Verlag.

[Lunze and Nixdorf,] Lunze, J. and Nixdorf, B. Discrete reachability of hybrid systems. *Intern. J. Control, submitted*.

[Lunze and Nixdorf, 2002] Lunze, J. and Nixdorf, B. (2002). Representation of hybrid systems by means of stochastic automata. *Mathematical Modelling of Systems*, 7:383–422.

[Lunze et al., 1997] Lunze, J., Nixdorf, B., and Richter, H. (1997). Hybrid modelling of continuous-variable systems with application to supervisory control. In *Proceedings of the European Control Conference 1997*.

[Lunze et al., 1999] Lunze, J., Nixdorf, B., and Schr"oder, J. (1999). Deterministic discrete-event representations of linear continuous-variable systems. *Automatica*, 35:395–406.

[Lunze and Raisch, 2002] Lunze, J. and Raisch, J. (2002). Discrete models for hybrid systems. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Lunze and Schiller, 1997] Lunze, J. and Schiller, F. (1997). Qualitative Prozessdiagnose auf wahrscheinlichkeitstheoretischer Grundlage. *at - Automatisierungstechnik*, 45(8):351–359.

[Lunze and Schröder, 1999] Lunze, J. and Schröder, J. (1999). Process diagnosis based on a discrete-event description. *at – Automatisierungstechnik*, 47:358–365.

[Lunze and Steffen, 2000] Lunze, J. and Steffen, T. (2000). Reconfigurable control of a quantised system. In *Proceeding of SAFEPROCESS 2000: 4th Symposium on Fault Detection*, pages 822–827. IFAC.

[Lunze and Steffen, 2002] Lunze, J. and Steffen, T. (2002). Hybrid reconfigurable control. In *this volume*.

[Lüth, 1998] Lüth, T. (1998). *Technical Multiagent Systems*. Hanser Publisher. (in German).

[Lygeros et al., 1999] Lygeros, J., Tomlin, C., and Sastry, S. (1999). Controllers for reachability specifications for hybrid systems. *Automatica*, 35:349–370.

[Lynch and Krogh, 2000] Lynch, N. and Krogh, B. H., editors (2000). *Hybrid Systems – Computation and Control (HSCC 2000)*, volume 1790 of *Lecture Notes in Computer Science*. Springer.

[Lynch et al., 2001] Lynch, N., Segala, R., and Vaandrager, F. (2001). Hybrid I/O automata revisited. In Benedetto, M. D. D. and Sangiovanni-Vincentelli, A., editors, *Hybrid Systems: Computation and Control (HSCC'01)*, volume 2034 of *LNCS*, pages 403–417. Springer-Verlag.

[Lynch et al., 1996] Lynch, N., Segala, R., Vaandrager, F., and Weinberg, H. B. (1996). Hybrid I/O automata. In Alur, R., Henzinger, T. A., and Sontag, E. D., editors, *Hybrid Systems III*, LNCS 1066, pages 496–510. Springer-Verlag.

[Maciejowski, 2002] Maciejowski, J. (2002). *Predictive control with constraints*. Prentice Hall.

[Mai and Schröder, 1999] Mai, G. and Schröder, M. (1999). Simulation of a Flight Control Systems' Redundancy Management System using Statemate. 7. User group meeting STATEMATE.

[Maler, 1997] Maler, O., editor (1997). *Hybrid and Real-Time Systems (HART'97)*, volume 1201 of *Lecture Notes in Computer Science*. Springer.

[Maler, 2001] Maler, O., editor (2001). *Special Issue on Verification of Hybrid Systems*, volume 7, issue 4 of *European Journal of Control*.

[Maler and Dang, 1998] Maler, O. and Dang, T. (1998). Reachability analysis via face lifting. In Henzinger, T. A. and Sastry, S., editors, *Hybrid Systems: Computation and Control (HSCC'98)*, LNCS 1386, pages 96–109. Springer-Verlag.

[Manna and Pnueli, 1993] Manna, Z. and Pnueli, A. (1993). Models for reactivity. *Acta Informatica*, 30:609–678.

[Manz, 1999] Manz, S. (1999). Qualitative Modeling of a Three-Tank-System. In *Interkama-ISA Tech Conference*, Düsseldorf.

[Manz, 2000] Manz, S. (2000). On-line monitoring and diagnosis based on hybrid component models. In *13th International Conference on Software & Systems Engineering and Applications ICSSEA 2000*, Paris.

[Manz, 2001a] Manz, S. (2001a). Fuzzy based qualitative models in combination with dynamical models for online monitoring of technical systems. In *International Conference on Computational Intelligence for Modelling, Control and Aut. CIMCA 2001*, Las Vegas.

[Manz, 2001b] Manz, S. (2001b). Online fault detection and diagnosis of complex systems based on hybrid component models. In *14th International Congress on Condition Monitoring and Diagnostics Engineering Managem. COMADEM2001*, Manchester.

[Mareczek et al., 1998] Mareczek, J., Buss, M., and Schmidt, G. (1998). Robust Global Stabilization of the Underactuated 2-DOF Manipulator R2D1. In *Proceedings of the IEEE International Conference on Robotics and Automation (Leuven, Belgium)*, pages 2640–2645.

[Mareczek et al., 1999] Mareczek, J., Buss, M., and Schmidt, G. (1999). Robust Control of a Non-Holonomic Underactuated SCARA Robot. In Tzafestas, S. and Schmidt, G., editors, *Lecture Notes in Control and Information Sciences: Progress in System and Robot Analysis and Control Design*, volume 243, pages 381–396. Springer Verlag.

[Marsan et al., 1995] Marsan, M. A., Balbo, G., Chiola, G., Donatelli, S., and Franceschinis, G. (1995). *Modelling with Generalized Stochastic Petri Nets.* John Wiley & Sons.

[Martin and Bobrow, 1997] Martin, B. and Bobrow, J. (1997). Minimum effort motions for open chain manipulators with task-dependent end-effector constraints. In *Proceedings of the IEEE International Conference on Robotics and Automation (Albuquerque, New Mexiko)*, pages 2044–2049.

[Matlab,] Matlab. Homepage: http://www.mathworks.com.

[Matsuno and Doi, 2000] Matsuno, H. and Doi, A. (2000). Hybrid Petri Net Representation of Gene Regulatory Network. In *Pacific Symposium on BioComputing 2000*, pages 341–352, Hawaii.

[Matsuno et al., 2000] Matsuno, H., Doi, A., Drath, R., and Miyano, S. (2000). Genomic object net: Object representation of biological systems. *Genome Informatics*, 11.

[Matsuno et al., 2001] Matsuno, H., Doi, A., Drath, R., and Miyano, S. (2001). Genomic object net: Hybrid petri net for describing biological systems. In *Fifth Annual International Conference on Computational Molecular Biology*, Montreal, Canada.

[Matsuno and Miyano, 2000] Matsuno, H. and Miyano, S. (2000). A platform for virtual cells; simulation of gene regulatory control by hybrid object net. *bit*, 32:22–31. (in Japanese).

[McMillan, 1995] McMillan, K. L. (1995). A Technique of a State Space Search Based on Unfolding. In *Formal Methods in System Design 6 (1)*, pages 45–65.

[Merz and Litz, 2000] Merz, R. and Litz, L. (2000). Objektorientierte mathematische modellierung. *Informatik Spektrum*, pages 90–99.

[Merz, 2001] Merz, S. (2001). Model checking: A tutorial overview. In et al., F. C., editor, *Modeling and Verification of Parallel Processes*, volume 2067 of *Lecture Notes in Computer Science*, pages 3–38. Springer-Verlag.

[Meyer, 1992] Meyer, B. (1992). *Eiffel: The Language*. Object-Oriented Series. Prentice Hall, New York, NY.

[Meyer, 1997] Meyer, B. (1997). *Object-Oriented Software Construction, Second Edition*. The Object-Oriented Series. Prentice-Hall, Englewood Cliffs (NJ), USA.

[Michalewicz and Fogel, 2000] Michalewicz, Z. and Fogel, D. (2000). *How to solve it: Modern Heuristics*. Springer.

[Millington and Stapleton, 1995] Millington, D. and Stapleton, J. (1995). Special report: Developing a RAD Standard. In *IEEE Software*, volume 12(5).

[Milner, 1989] Milner, R. (1989). *Communication and Concurrency*. Prentice-Hall International, Engelwood Cliffs.

[Misra and Chandy, 1981] Misra, J. and Chandy, K. M. (1981). Proofs of networks of processes. *IEEE Transactions on Software Engineering*, 7(4):417–426.

[Modelica,] Modelica. Homepage: http://www.modelica.org/.

[Modelica Design Group, 2000] Modelica Design Group, T. (2000). Modelica – a unified object-oriented language for physical system modeling v1.4. `http://www.modelica.org`.

[Modeling and Office, 1996] Modeling, D. and Office, S. (1996). Hla time management design document.

[Moody and Antsaklis, 1998] Moody, J. O. and Antsaklis, P. J. (1998). *Supervisory Control of Discrete Event Systems Using Petri Nets*. Kluwer Academic Publishers.

[Moor, 2000] Moor, T. (2000). *Approximationsbasierter Entwurf diskreter Steuerungen für gemischtwertige Regelstrecken*, volume 2 of *Forschungsberichte aus dem Max-Planck-Institut für Dynamik komplexer technischer Systeme*. Shaker-Verlag, Aachen, Germany. Also PhD thesis, Fachbereich Elektrotechnik, Universität der Bundeswehr Hamburg.

[Moor and Davoren, 2001] Moor, T. and Davoren, J. M. (2001). Robust controller synthesis for hybrid systems using modal logic. In Benedetto, M. D. D. and Sangiovanni-Vincentelli, A., editors, *Hybrid Systems: Computation and Control (HSCC'01)*, volume 2034 of *LNCS*, pages 433–446. Springer-Verlag.

[Moor et al., 2001a] Moor, T., Davoren, J. M., and Raisch, J. (2001a). Modular supervisory control of a class of hybrid systems in a behavioural framework. In *Proceedings of the European Control Conference 2001*, pages 870–875.

[Moor and Raisch, 1999a] Moor, T. and Raisch, J. (1999a). Discrete control of switched linear systems. In *Proceedings of the European Control Conference 1999*.

[Moor and Raisch, 1999b] Moor, T. and Raisch, J. (1999b). Supervisory control of hybrid systems within a behavioural framework. *Systems and Control Letters*, 38:157–166.

[Moor and Raisch, 2000] Moor, T. and Raisch, J. (2000). Approximation of multiple switched flow systems for the purpose of control synthesis. In *Proc. of the 39th International Conference on Decision and Control, CDC'00*. IEEE Press.

[Moor and Raisch, 2002] Moor, T. and Raisch, J. (2002). Abstraction based supervisory controller synthesis for high order monotone continuous systems. In *this volume*.

[Moor et al., 2001b] Moor, T., Raisch, J., and Davoren, J. M. (2001b). Computational advantages of a two-level hybrid control architecture. In *Proc. of the 40th International Conference on Decision and Control, CDC'2001*, pages 358–362. IEEE Press.

[Moor et al., 2001c] Moor, T., Raisch, J., and Itigin, A. (2001c). Discrete approximation and control of high-order nonlinear continuous systems. Technical report, RSISE, Australian National University. Submitted.

[Moor et al., 2002] Moor, T., Raisch, J., and O'Young, S. D. (2002). Discrete supervisory control of hybrid systems based on l-complete approximations. *Journal of Discrete Event Dynamic Systems*, 12:83–107.

[Moormann, 2001] Moormann, D. (2001). *Automatisierte Modellbildung der Flugsystemdynamik*. PhD dissertation, Aachen Technical University (RWTH Aachen), Aachen, Germany. in German.

[Moormann et al., 1999] Moormann, D., Mosterman, P., and Looye, G.-J. (1999). Object-Oriented Computational Model Building of Aircraft Flight Dynamics and Systems. *Aerospace Science and Technology*, 3:115–126.

[Mosterman and Biswas, 1999] Mosterman, P. and Biswas, G. (1999). A Java implementation of an environment for hybrid modeling and simulation of physical systems. In *International Conference on Bond Graph Modeling (ICBGM '99)*, pages 157–162. San Francisco.

[Mosterman et al., 1998] Mosterman, P., Otter, M., and Elmqvist, H. (1998). Modeling Petri Nets as Local Constraint Equations for Hybrid Systems Using Modelica. In *Proceedings of SCS Summer Simulation Conference*, pages 314–319, Reno, Nevada.

[Mosterman et al., 2002] Mosterman, P., Remelhe, M. P., Engell, S., and Otter, M. (2002). Simulation for analysis of aircraft elevator feedback and redundancy control. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*. Springer-Verlag.

[Mosterman, 1999] Mosterman, P. J. (1999). An overview of hybrid simulation phenomena and their support by simulation packages. In *Hybrid Systems Computation and Control (HSCC'99)*, LNCS 1569. Springer-Verlag.

[Mosterman, 2000a] Mosterman, P. J. (2000a). HYBRSIM - a modeling and simulation environment for hybrid bond graphs. *Journal of Systems and Control*.

[Mosterman, 2000b] Mosterman, P. J. (2000b). Implicit modeling and simulation of discontinuities in physical system models. In Engell, S., Kowalewski, S., and Zaytoon, J., editors, *The 4th International Conference on Automation of Mixed Processes: Hybrid Dynamic Systems*, pages 35–40.

[Mosterman, 2001] Mosterman, P. J. (2001). MASIM. Technical Report DLR-IB-, DLR Oberpfaffenhofen, Oberpfaffenhofen, Germany.

[Mosterman and Biswas, 1995] Mosterman, P. J. and Biswas, G. (1995). Modeling discontinuous behavior with hybrid bond graphs. In *1995 International Workshop on Qualitative Reasoning*, pages 139–147, Amsterdam. University of Amsterdam.

[Mueller, 1996] Mueller, K. (1996). *Entwurf robuster Regelungen*. B.G. Teubner Stuttgart.

[Müller, 2002] Müller, C. (2002). *Analyse und Synthese diskreter Steuerungen hybrider Systeme mit Petri-Netz-Zustandsraummodellen*, volume 930 of *Fortschritt-Berichte VDI Reihe 8*. VDI-Verlag, Düsseldorf, Germany.

[Müller et al., 2002] Müller, C., Orth, P., Abel, D., and Rake, H. (2002). Synthesis of a discrete control for hybrid systems by means of a petri-net-state-model. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Müller et al., 2001] Müller, C., Orth, P., and Rake, H. (2001). Analyse und Synthese diskreter Steuerungen hybrider Systeme mit einem Petri-Netz-Zustandsraummodell. In Schnieder, E., editor, *Engineering komplexer Automatisierungssysteme*, EKA 2001, pages 113–131, Braunschweig, Germany.

[Müller and Rake, 1999] Müller, C. and Rake, H. (1999). Modellbildung und Analyse hybrider Systeme mit Petri-Netzen und geschalteten Differentialgleichungen. In Schnieder, E., editor, *Entwicklung und Betrieb komplexer Automatisierungssysteme*, EKA '99, pages 233–246, Braunschweig, Germany.

[Müller and Rake, 2000] Müller, C. and Rake, H. (2000). A Petri Net-State-Model for the Analysis and the Control Synthesis of Hybrid Technical Systems. In *Proceedings Hybrid Dynamic Systems*, ADPM 2000.

[Münnemann and Enste, 2001] Münnemann, A. and Enste, U. (2001). Systemtechnische integration gehobener regelungsverfahren. *atp - Automatisierungstechnische Praxis*, 43(7):40–48.

[Nagel and Schreckenberg, 1992] Nagel, K. and Schreckenberg, M. (1992). A cellular automaton model for free-way traffic. *Journal Phys.*, 2:2221.

[Naur, 1966] Naur, P. (1966). Proof of algorithms by general snapshots. *BIT (Nordisk tidskrift for informationsbehandling)*, 6(4):310–316.

[Nenninger, 2001] Nenninger, G. (2001). *Modellbildung und Analyse hybrider dynamischer Systeme als Grundlage für den Entwurf hybrider Steuerungen*. VDI.

[Nenninger et al., 2000] Nenninger, G., Frehse, G., and Krebs, V. (2000). Hybrid regions of attraction of piecewise affine hybrid systems. In *4th Conference on Automation of Mixed Processes: Hybrid Dynamic Systems ADPM 2000*, pages 87–92.

[Nenninger and Krebs, 1998] Nenninger, G. and Krebs, V. (1998). Analysis of hybrid systems using hybrid dynamical models. In *Hybrid Dynamical Systems: 3rd International Conference on Automation of Mixed Processes*, pages 428–431.

[Nenninger and Krebs, 2002] Nenninger, G. and Krebs, V. (2002). Reachability analysis and control of a special class of hybrid systems. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Nenninger et al., 1999] Nenninger, G., Schnabel, M., and Krebs, V. (1999). Modellierung, simulation und analyse hybrider dynamischer systeme mit netz-zustands-modellen. *Automatisierungstechnik*, 47(3):118–126.

[Nenninger et al., 2001] Nenninger, G. M., Nixdorf, B., Krebs, V. G., and Lunze, J. (2001). Erreichbarkeitsanalyse hybrider Systeme. *at - Automatisierungstechnik*, 49(2):75–85.

[Nerode and Kohn, 1993] Nerode, A. and Kohn, W. (1993). Models for hybrid systems: Automata, topologies, controllability, observability. In Grossmann, R., Nerode, A., Ravn, A., and Rischel, H., editors, *Lecture Notes in Computer Science: Hybrid Systems*, volume 736, pages 317–356. Springer Verlag.

[Nicol and Miner, 1995] Nicol, D. M. and Miner, A. S. (1995). The fluid stochastic petri net simulator. In *Proc. Sixth International Workshop on Petri Nets and Performance Models - PNPM'95*, pages 214–215, Durham, North Carolina, USA. IEEE-CS Press.

[Ning, 1998] Ning, B. (1998). Absolute braking and relative distance braking train operation control modes in moving block systems. In *Computers in Railways VI*, pages 991–1001. Lisbon.

[Nixdorf and Lunze, 2000] Nixdorf, B. and Lunze, J. (2000). KONDISK benchmark of an automated manufacturing cell. Technical report, Technical University of Hamburg-Harburg. (in German).

[Nordwig, 2000] Nordwig, A. (2000). the zooed homepage. Technische Universität Berlin. ISTI. `http://swt.cs.tu-berlin.de`.

[Nordwig, 2002] Nordwig, A. (2002). Formal integration of structural dynamics into the object-oriented modeling of hybrid systems. In *Proceedings of the European Simulation Multi-Conference '02*. to appear.

[Nöth, 1998] Nöth, G. (1998). Randbedingungen für den einsatz von regelungstechnischen methoden. In *GMA-Kongress'98 Meß- und Automatisierungstechnik, VDI Bericht 1397*. VDI-Verlag.

[Nytsch-Geusen, 2001] Nytsch-Geusen, C. (2001). *Berechnung und Verbesserung der Energieeffizienz von Gebäuden und ihren energietechnischen Anlagen in einer objektorientierten Simulationsumgebung*. PhD thesis, TU Berlin.

[Osder, 1999] Osder, S. (1999). Practical view of redundancy management application and theory. *Journal of Guidance, Control, and Dynamics*, 22(1):12–21.

[Otter et al., 1999] Otter, M., Elmqvist, H., and Mattson, S. (1999). Hybrid modeling in Modelica based on the synchronous data flow principle. CACSD'99, Hawaii, USA.

[Otter et al., 2000] Otter, M., Remelhe, M., Engell, S., and Mosterman, P. (2000). Hybrid models of physical systems and discrete controllers. *at-Automatisierungstechnik*, 48:426–437.

[Owicki and Gries, 1976] Owicki, S. S. and Gries, D. (1976). An axiomatic proof technique for parallel programs I. *Acta Informatica*, 6:319–340.

[Pachl, 1999] Pachl, J. (1999). *Systemtechnik des Schnieneverkehrs*. B. G. Teubner, Stuttgart.

[Panreck, 1999] Panreck, K. (1999). Systembeschreibungen zur Modellierung komplexer Systeme. *at - Automatisierungstechnik*, 47(4):157.

[Pappas et al., 2000] Pappas, G. J., Lafferriere, G., and Sastry, S. (2000). Hierarchically consistent control systems. *IEEE Transactions on Automatic Control*, 45:6:1144–1160.

[Park and Barton, 1997] Park, T. and Barton, P. (1997). Implicit model checking of logic based control systems. *AIChE Journal*, 43(9):2246–2260.

[Pawletta and Lampe, 2001] Pawletta, T. and Lampe, B. (2001). KONDISK project report no. la $724/8 - 2$ — Modeling and simulation of modular-hierarchical systems with discret event oriented structure dynamics. Technical report, University of Rostock. (in German).

[Pawletta et al., 1996] Pawletta, T., Lampe, B., Pawletta, S., and Drewelow, W. (1996). An object oriented framework for modeling and simulation of variable structure systems. In Ingalls, V., Cynamon, J., and Saylor, A., editors, *SCS Summer Simulation Conf., Portland, Oregon*, pages 8–13. SCS International.

[Pawletta et al., 2002] Pawletta, T., Lampe, B., Pawletta, S., and Drewelow, W. (2002). A DEVS-based approach for modeling and simulation of structure dynamics in hybrid systems. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Pawletta et al., 2001] Pawletta, T., Lampe, B., Pawletta, S., Drewelow, W., and Schildmann, P. (2001). Modeling of temporal objects with self-dynamics in hybrid systems. In Panreck, K. and Dörrscheidt, F., editors, *15th Symp. of Simulation, Paderborn*, Frontiers in Simulation, pages 73–78, Ghent, Belgium. SCS Publishing House. (in German).

[Pawletta et al., 1994] Pawletta, T., Pawletta, S., and Dimitrov, E. (1994). Modeling and simulation of structure variable systems. In Kampe, G. and Zeitz, M., editors, *Progress in Simulation*, pages 59–64. Vieweg Publisher. (in German).

[Pawletta et al., 1997] Pawletta, T., Pawletta, S., Schildmann, P., and Drewelow, W. (1997). Interactive modeling and simulation of time-invariant system structures. In Kuhn, A. and Wenzel, S., editors, *Progress in Simulation*, pages 649–655. Vieweg Publisher. (in German).

[Paynter, 1961] Paynter, H. M. (1961). Analysis and design of engineering systems. *The M.I.T. Press, Cambridge, Massachusetts*.

[Pearson, 1984] Pearson, R. (1984). Modern control: Why don't we used it? *InTech*, 11:47–49.

[Pereira Remelhe, 2001] Pereira Remelhe, M. (2001). Simulation and visualization support for user-defined formalisms using meta-modeling and hierarchical formalism transformation. In *Proc. of the 2001 IEEE Int. Conf. on Control Applications*, pages 750–755.

[Pereira Remelhe et al., 2001] Pereira Remelhe, M., Deparade, A., and Engell, S. (2001). Integration und Synchronisierung von diskreten Beschreibungsformen und kontinuierlichen Systemmodellen in Modelica. In Panreck, K. and Dörrscheidt, F., editors, *Simulationstechnik, ASIM 2001, 15. Symposium*, pages 95–100. ASIM, SCS.

[Pereira Remelhe and Engell, 2000] Pereira Remelhe, M. and Engell, S. (2000). Structuring discrete event models in Modelica. In *4th Int. Conf. on Automation of Mixed Processes (ADPM´2000)*, pages 147 –152.

[Péter et al., 2000] Péter, I., Pretschner, A., and Stauner, T. (2000). Heterogeneous development of hybrid systems. In *Proc. GI workshop Rigorose Entwicklung software-intensiver Systeme*, pages 83–93.

[Petri, 1962] Petri, C. (1962). *Kommunikation mit Automaten*. Number 2 in Schriften des IIM. Institut für Instrumentelle Mathematik, Bonn.

[Petterson, 1999] Petterson, S. (1999). *Analysis and Design of Hybrid Systems*. Ph. d. dissertation, Chalmers University of Technology.

[Petzold, 1982] Petzold, L. R. (1982). A description of DASSL: A differential/algebraic system solver. Technical Report SAND82-8637, Sandia National Laboratories, Livermore, California.

[Philips et al., 1999] Philips, P., Weiss, M., and Preisig, H. A. (1999). Control based on diskrete-event models of continuous systems. In *Proceedings of the European Control Conference 1999*.

[Plank, 1997] Plank, J. (1997). *State Events in Continous Modelling and Simulation*. PhD thesis, Technical University of Vienna.

[PNO, 1999] PNO (1999). Profibus-pa profile for process control devices, revision 3.0. Technical report, PNO, Karlsruhe.

[Pnueli, 1977] Pnueli, A. (1977). The temporal logic of programs. In *Proceedings of the 18th IEEE Symposium on Foundations of Computer Science (FOCS 1977)*, pages 46–57.

[Pnueli, 1981] Pnueli, A. (1981). The temporal logic of concurrent programs. *Theoretical Computer Science*, 13:45–60.

[Pnueli, 1984] Pnueli, A. (1984). In transition for global to modular temporal reasoning about programs. In *Logics and Models of Concurrent Systems*, volume 13 of *NATO ASI-F*. Springer-Verlag.

[Prähofer, 1991] Prähofer, H. (1991). *System Theoretic Foundations for Combined Discrete-Continuous System Simulation*. PhD thesis, Johannes Kepler University of Linz.

[Prähofer, 1996] Prähofer, H. (1996). An environment for DEVS-based multi-formalism modeling und simulation in C++. In *6th Annual Conference on AI, Simulation and Planning in High Autonomy Systems*, page 8pp. SCS International, San Diego.

[Prähofer and Zeigler, 1992] Prähofer, H. and Zeigler, B. (1992). Modelling and simulation. In Pichler, F. and Schwaertzel, H., editors, *CAST - Methods in Modelling*, pages 123–241. Springer Publisher, Berlin.

[Pretschner, 2001] Pretschner, A. (2001). Classical search strategies for test case generation with Constraint Logic Programming. In *Proc. Formal Approaches to Testing of Software*, pages 47–60.

[Pretschner et al., 2001] Pretschner, A., Lötzbeyer, H., and Philipps, J. (2001). Model Based Testing in Evolutionary Software Development. In *Proc. 11th IEEE Intl. Workshop on Rapid System Prototyping*, pages 155–160.

[Pretschner et al., 2000] Pretschner, A., Slotosch, O., and Stauner, T. (2000). Developing Correct Safety Critical, Hybrid, Embedded Systems. In *Proc. New Information Processing Techniques for Military Systems, NATO Research*.

[Preußig, 2000] Preußig, J. (2000). *Formale Überprüfung der Korrektheit von Steuerungen mittels rektangulärer Automaten*. PhD thesis, Department of Chemical Engineering, University of Dortmund, Germany. (in German).

[Preußig et al., 1998] Preußig, J., Kowalewski, S., Henzinger, T., and Wong-Toi, H. (1998). An algorithm for the approximate analysis of simple rectangular automata. In *Proc. 5th Int. School and Symposium on Formal Techniques in Fault Tolerant and Real Time Systems, Lyngby, Denmark, 1998*, Lecture Notes in Computer Science 1486, pages 228–240. Springer.

[Preußig et al., 1999] Preußig, J., Stursberg, O., and Kowalewski, S. (1999). Reachability analysis of a class of switched continuous systems by integrating rectangular approximation and rectangular analysis. In Vaandrager, F. W. and van Schuppen, J. H., editors, *Hybrid Systems: Computation and Control, Proc. 2nd Int. Workshop, HSCC'99, Berg en Dal, The Netherlands, March 1999*, Lecture Notes in Computer Science 1569, pages 209–222. Springer.

[Preußig and Wong-Toi, 2000] Preußig, J. and Wong-Toi, H. (2000). An procedure for the reachability analysis of rectangular automata. In *Proc. American Control Conference*, pages 1674–1678.

[Queille and Sifakis, 1982] Queille, J.-P. and Sifakis, J. (1982). Specification and verification of concurrent systems in CESAR. In Dezani-Ciancaglini, M. and Montanari, U., editors, *Proceedings of the 5th International Symposium on Programming, Turin, April 6–8, 1982*, pages 337–350. Springer-Verlag.

[Raisch et al., 2001] Raisch, J., Iitgin, A., and Moor, T. (2001). Hierarchical strategies for hybrid process control problems. In *Proceedings of the European Control Conference 2001*, pages 2534–2539.

[Raisch et al., 2000] Raisch, J., Itigin, A., and Moor, T. (2000). Hierarchical control of hybrid systems. In Engell, S., Kowalewski, S., and Zaytoon, J., editors, *Proc. 4th International Conference on Automation of Mixed Processes: Dynamic Hybrid Systems*, pages 67–72. Shaker Verlag.

[Raisch and O'Young, 1997] Raisch, J. and O'Young, S. (1997). A totally ordered set of discrete abstractions for a given hybrid or continuous system. In Antsaklis, P., Kohn, W., Nerode, A., and Sastry, S., editors, *Hybrid Systems IV*, volume 1273 of *LNCS*, pages 342–360. Springer-Verlag.

[Raisch and O'Young, 1998] Raisch, J. and O'Young, S. (1998). Discrete approximation and supervisory control of continuous systems. *IEEE Trans. Automatic Control*, 43(4):569–573.

[Rakoto-Ravalontsalama and Aguilar-Martin, 1998] Rakoto-Ravalontsalama, N. and Aguilar-Martin, J. (1998). Diagnosing uncertain parameters to improve hybrid process model. In *Hybrid Dynamical Systems. 3rd International Conference on Automation of Mixed Processes*, pages 49–53, Reims.

[Ramadge and Wonham, 1987] Ramadge, P. J. and Wonham, W. M. (1987). Supervisory control of a class of discrete event systems. *SIAM J. Control and Optimization*, 25:206–230.

[Ramadge and Wonham, 1989a] Ramadge, P. J. and Wonham, W. M. (1989a). The control of discrete event systems. *Proceedings of the IEEE*, 77:81–98.

[Ramadge and Wonham, 1989b] Ramadge, P. J. and Wonham, W. M. (1989b). Modular control of discrete event systems. *Maths. of Control, Signals & Systems*, 1:1:13–30.

[Rational, 1999] Rational (1999). *Unified Modeling Language*. Version 1.3.

[Rational UML, 1997] Rational UML (1997). Unified modeling language, version 1.1. Rational Software Corporation.

[Rausch and Hanisch, 1995] Rausch, M. and Hanisch, H.-M. (1995). Netz-condition/event-systeme. In Schnieder, E., editor, *Entwurf komplexer Automatisierungssysteme - Methoden, Anwendungen und Tools auf der Basis von Petrinetzen und anderer formaler Beschreibungsmittel*, pages 55–71, Braunschweig.

[Raymond et al., 1998] Raymond, P., Weber, D., Nicollin, X., and Halbwachs, N. (1998). Automatic testing of reactive systems. In *Proc. 19th IEEE Real-Time Systems Symposium*.

[Rebolledo, 2002] Rebolledo, M. (2002). Development of a Concept for the Handling of Vagueness in the SQMA Modeling Approach. Diplomarbeit, Institut für Automatisierungs- und Softwaretechnik (IAS), Universität Stuttgart.

[Reisig, 1985] Reisig, W. (1985). *Petri Nets, An Introduction*. EATCS, Monographs on Theoretical Computer Science. Springer Verlag, Berlin.

[Remelhe et al., 2002] Remelhe, M. P., Engell, S., and Otter, M. (2002). An environment for integrated object–oriented modeling of systems with complex continuous and discrete dynamics. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Royce, 1970] Royce, W. W. (1970). Managing the development of large software systems: Concepts and techniques. In *Proc. IEEE WESTCON*.

[Rudie and Wonham, 1992] Rudie, K. and Wonham, W. M. (1992). Think globally, act locally: decentralized supervisory control. *IEEE Transactions on Automatic Control*, 37:11:1692–1708.

[Ruhl, 1999] Ruhl, H. (1999). Konzeption und implementierung einer visualisierungssoftware für den modellprozess ”drei-tank-system”. Diplomarbeit, Institut für Automatisierungs- und Softwaretechnik (IAS), Universität Stuttgart.

[Rumbaugh, 1991] Rumbaugh, J. (1991). *Object-Oriented Modeling and Design*. Prentice-Hall Inc., New Jersey.

[Schätz and Pretschner, 2002] Schätz, B. and Pretschner, A. (2002). Model based development of embedded systems. Submitted to Model-Driven Approaches to Software Development, OOIS’02.

[Schildmann, 2000] Schildmann, P. (2000). Benchmarks for the simulator prototype MATSIM-2. Technical report, University of Rostock. (in German).

[Schiller, 1997] Schiller, F. (1997). *Diagnose dynamischer Systeme auf der Grundlage einer qualitativen Prozessbeschreibung*. Dissertation, TU Hamburg-Harburg.

[Schlegl et al., 1997] Schlegl, T., Buss, M., and Schmidt, G. (1997). Development of numerical integration methods for hybrid (discrete-continuous) dynamical systems. In *Proceedings of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics AIM’97 (Tokyo, Japan, Paper No. 154)*.

[Schlegl et al., 2002] Schlegl, T., Buss, M., and Schmidt, G. (2002). Hybrid control of multi-fingered dextrous hands. *This volume*.

[Schlegl et al., 2000] Schlegl, T., Schnabel, M. K., Buss, M., and Krebs, V. G. (2000). State Reconstruction and Error Compenstation in Discrete-Continuous Control Systems. *at - Automatisierungstechnik*, 48(9):439–447.

[Schnabel, 2001] Schnabel, M. (2001). *Diskret-kontinuierliche dynamische Systeme: Steuerung und Beobachtung*. VDI.

[Schoenebug et al., 1996] Schoenebug, E., Heinzmann, F., and Feddersen, S. (1996). *Genetische Algorithmen und Evolutionsstrategien*. Addison-Wesley.

[Schuerr, 1994] Schuerr, A. (1994). Logic based structure rewriting systems. In *Lecture Notes in Computer Science*. Springer Verlag.

[Schuler, 1992] Schuler, H. (1992). Was behindert den praktischen einsatz moderner regelungstechnischer methoden in der prozessindustrie? *atp - Automatisierungstechnische Praxis*, 34(3):116–123.

[Schumacher et al., 1999] Schumacher, J., Morse, A., Pantelides, C., and Sastry, S., editors (1999). *Special Issue on Hybrid Systems*, volume 35 of *Automatica*.

[Schütt, 1990] Schütt, H. (1990). *Entwicklung und Erprobung eines sehr schnellen, bitorientierten Verkehrssimulationssystems für Straßennetze*. PhD thesis, TU Hamburg-Harburg.

[SDL92, 1992] SDL92 (1992). Specification and Description Language SDL, blue book. CCITT Recommendation Z.100.

[Seebeck, 1998] Seebeck, J. (1998). *Modellierung der Redundanzverwaltung von Flugzeugen am Beispiel des ATD durch Petrinetze und Umsetzung der Schaltlogik in C-Code zur Simulationssteuerung*. Diplomarbeit, Arbeitsbereich Flugzeugsystemtechnik, Technische Universität Hamburg-Harburg.

[Seiche, 1991] Seiche, W. (1991). *Analyse und Synthese diskret gesteuerter Systeme mit Petri-Netzen*, volume 269 of *Fortschritt-Berichte VDI Reihe 8*. VDI-Verlag, Düsseldorf, Germany.

[Seiche and Abel, 1993] Seiche, W. and Abel, D. (1993). Entwurf verklemmungsfreier Steuerungen auf der Grundlage einer graphentheoretischen Petri-Netz-Analyse. *Automatisierungstechnik*, (41):88–93.

[Selic et al., 1994] Selic, B., Gullekson, G., and Ward, P. T. (1994). *Real-Time Object-Oriented Modeling*. John Wiley & Sons Ltd, Chichester.

[Simon, 2001a] Simon, C. (2001a). Developing software controllers with petri nets and a logic of actions. In *IEEE International Conference on Robotics and Automation, ICRA 2001*, Seoul, Korea.

[Simon, 2001b] Simon, C. (2001b). *A Logic of Actions and Its Application to the Development of Programmable Controllers*. PhD thesis, Universität Koblenz-Landau.

[Simon et al., 2002] Simon, C., Lautenbach, K., Hanisch, H.-M., and Thieme, J. (2002). Using parameterized timestamp petri nets in automatic control. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Simon et al., 1997] Simon, C., Ridder, H., and Marx, T. (1997). The petri net tools neptun and poseidon. Fachberichte Informatik 15–97, Universität Koblenz-Landau, Institut für Informatik, Rheinau 1, D-56075 Koblenz.

[Simon and Thieme, 1999] Simon, C. and Thieme, J. (1999). Transformation zeitbewerteter netzmodelle. Fachberichte Fakultät Elektrotechnik 3–99, Otto-von-Guericke-Universität Magdeburg, Institut für Automatisierungstechnik, Postfach 4120, D-39016 Magdeburg.

[Six, 1996] Six, J. (1996). Abstandhaltung und Streckenleistungsfähigkeit. *Signal+Draht*.

[Smith, 1995] Smith, H. (1995). *Monotone Dynamical Systems*. American Mathematical Society, Providence.

[Smith et al., 2001] Smith, M. A., Moor, T., and Anderson, B. D. O. (2001). Restricted reachability operators: safe approximations in the presence of disturbances. Technical report, RSISE, Australian National University. Submitted to the 15th IFAC World Congress.

[Sreenivas and Krogh, 1991a] Sreenivas, R. S. and Krogh, B. H. (1991a). On condition/event systems with discrete state realizations. *Discrete Event Dynamic Systems: Theory and Application 1*, pages 209–236.

[Sreenivas and Krogh, 1991b] Sreenivas, R. S. and Krogh, B. H. (1991b). Petri net based models for condition/event systems. *Proceedings of 1991 American Control Conference*, 3:2899–2904.

[Stauner, 2001] Stauner, T. (2001). *Systematic development of hybrid systems*. PhD thesis, Technische Universität München.

[Stauner, 2002] Stauner, T. (2002). Discrete-Time Refinement of Hybrid Automata. In *Proc. HSCC'02*. To be published.

[Stauner et al., 2001] Stauner, T., Pretschner, A., and Péter, I. (2001). Approaching a Discrete-Continuous UML: Tool Support and Formalization. In *Proc. UML'2001 workshop on Practical UML-Based Rigorous Development Methods*, pages 242–257.

[Steffen, 2001] Steffen, T. (2001). Rekonfiguration linearer system durch eine ergänzung des reglers. Technical report, Ruhr University Bochum, Institute for Automation and Computer Control.

[Stiver and Antsaklis, 1993] Stiver, J. A. and Antsaklis, P. J. (1993). On the controllability of hybrid control systems. In *Proc.* 32^{nd} *IEEE Conf. on Decision and Control*, pages 294–299, San Antonio, Texas.

[Strikwerda, 1989] Strikwerda, J. C. (1989). *Finite Difference Schemes and Partial Differential Equations*. Wadsworth & Brooks/Cole.

[Stursberg, 2000a] Stursberg, O. (2000a). *Analyse gesteuerter verfahrenstechnischer Prozesse durch Diskretisierung*. PhD thesis, Department of Chemical Engineering, University of Dortmund, Germany. (in German).

[Stursberg, 2000b] Stursberg, O. (2000b). Analysis of switched continuous systems based on discrete approximation. In *Proc. 4th Int. Conf. on Automation of Mixed Processes*, pages 73–78.

[Stursberg and Engell, 2001] Stursberg, O. and Engell, S. (2001). Optimized startup-procedures of processing systems. In *Proc.* 6^{th} *IFAC Symp. Dynamics and Control of Process Sys.*, pages 231–236.

[Stursberg and Engell, 2002] Stursberg, O. and Engell, S. (to appear in July 2002). Optimal control of switched continuous systems using mixed-integer programming. In *Proc.* 15^{th} *IFAC World Congress on Automatic Control*.

[Stursberg and Kowalewski, 1999] Stursberg, O. and Kowalewski, S. (1999). Approximating switched continuous systems by rectangular automata. In *Proc. European Control Conference*. CD-ROM, file 1014–4.

[Stursberg and Kowalewski, 2000] Stursberg, O. and Kowalewski, S. (2000). Analysis of controlled hybrid processing systems based on approximation by timed automata using interval arithmetics. In *Proc. 8th IEEE Mediterranean Conference on Control and Automation*. CD-ROM, file TA1–3.

[Stursberg et al., 2000] Stursberg, O., Kowalewski, S., and Engell, S. (2000). On the generation of timed discrete approximations for continuous systems. *Mathematical and Computer Modelling of Dynamical Systems*, 6(1):51–70. Special Issue on "Discrete Event Models of Continuous Systems".

[Stursberg et al., 1997] Stursberg, O., Kowalewski, S., Hoffmann, I., and Preušsig, J. (1997). Comparing timed and hybrid automata as approximations of continuous systems. In Antsaklis, P., Kohn, W., Nerode, A., and Sastry, S., editors, *Hybrid Systems IV*, volume 1273 of *LNCS*, pages 361–377. Springer-Verlag.

[Stursberg and Panek, 2002] Stursberg, O. and Panek, S. (to appear in 2002). Control of switched continuous systems based on disjunctive formulations. In 5^{th} *Int. Workshop on Hybrid Systems: Computation and Control*, LNCS. Springer.

[Sussmann, 1999] Sussmann, H. (1999). A maximum principle for hybrid optimal conrol problems. In *Proc.* 38^{th} *IEEE Conf. Decision and Control*, pages 425–430.

[Sydow, 1995] Sydow, A., editor (1995). *Proceedings of the 5th International IMACS-Symposium on Systems Analysis and Simulation (SAS'95)*. Gordon and Breach Publishers.

[Tavernini, 1987] Tavernini, L. (1987). Differential automata and their discrete simulators. *Nonlinear Analysis, Theory, Methods, and Applications*, 11:665–683.

[Thieme, 2002] Thieme, J. (2002). *Symbolische Erreichbarkeitsanalyse und automatische Implementierung struktureller, zeitbewerteter Steuerungsmodelle*. PhD thesis, Martin-Luther-Universität Halle-Wittenberg, Mathematisch-Naturwissenschaftlich-Technische Fakultät.

[Thieme and Lüder, 1999] Thieme, J. and Lüder, A. (1999). Transformation von netzmodellen zur analyse technischer systeme. Fachberichte Fakultät Elektrotechnik 2–99, Otto-von-Guericke-Universität Magdeburg, Institut für Automatisierungstechnik, Postfach 4120, D-39016 Magdeburg.

[Thomas, 1996] Thomas, C. (1996). An object oriented approach to modeling and simulation of complex systems. Progress reports of VDI, series 20, no. 208, VDI Publisher. (in German).

[Thomas, 1995] Thomas, J. (1995). *Numerical Partial Differential Equations: Finite Difference Methods*. Springer.

[Tittus et al., 1994] Tittus, M., Egardt, B., and Lennartson, B. (1994). Hybrid systems in process control. In *3rd IEEE Conference on Decision and Control*, pages 3587–3595.

[Todsiev, 1963] Todsiev, E. P. (1963). *The action-point model of the driver-vehicle-system*.

[Tomlin, 1999] Tomlin, C. (1999). Towards efficient computation of solutions to hybrid systems. In *Proceedings of the 38th IEEE Conference on Decision and Control (Phoenix, AZ)*, pages 3532–3537.

[Tomlin et al., 1999] Tomlin, C., Lygeros, J., and Sastry, S. (1999). A game theoretic approach to controller design for hybrid systems. In 2^{nd} *Int. Workshop on Hybrid Systems: Computation and Control*, volume 1569 of *LNCS*, pages 76–90. Springer.

[Tomlin et al., 2000] Tomlin, C., Lygeros, J., and Sastry, S. (2000). A game theoretic approach to controller design for hybrid systems. *Proceedings of the IEEE*, 88(7):949–970.

[Treseler, 2001] Treseler, H. (2001). *Ein Rechnerwerkzeug zur formalen Verifikation diskret gesteuerter verfahrenstechnischer Prozesse*. PhD thesis, Department of Chemical Engineering, University of Dortmund, Germany. (in German).

[Trontis and Spathopoulos, 2001] Trontis, A. and Spathopoulos, M. (2001). Target control for hybrid systems with linear continuous dynamics. In *Proc.* 40^{th} *IEEE Conf. on Decision and Control*, pages 1229–1234.

[Turing, 1949] Turing, A. M. (1949). On checking a large routine. In *Report of a Conference on High Speed Automatic Calculating Machines*, pages 67–69, Cambridge. University Mathematics Laboratory.

[Uebel, 2000] Uebel, H. (2000). Durchsatz von Strecken und Stationen bei Bahnen. In *Gesamtverkehrsforum 2000*, number 1545 in VDI Berichte, pages 257–275. VDI-Verlag, Düsseldorf.

[Uhrmacher and Arnold, 1994] Uhrmacher, A. M. and Arnold, R. (1994). Distributing and maintaining knowledge: Agents in variable structure environment. In *5th Annual Conference on AI, Simulation and Planning in High Autonomy Systems*, pages 178–194.

[Utkin, 1992] Utkin, V. (1992). *Sliding Modes in Control Optimization*. Springer Verlag.

[Vaandrager and van Schuppen, 1999] Vaandrager, F. and van Schuppen, J., editors (1999). *Hybrid Systems – Computation and Control, Proc. 2nd Int. Workshop HSCC'99, Berg en Dal, The Netherlands, March 1999*, volume 1569 of *Lecture Notes in Computer Science*. Springer.

[van der Schaft and Schumacher, 2000] van der Schaft, A. and Schumacher, H. (2000). An introduction to hybrid dynamical systems. In *Lecture Notes in Control and Information Sciences*, volume 251. Springer Verlag.

[van der Schaft and Schumacher, 2000] van der Schaft, A. and Schumacher, H. (2000). *An Introduction to Hybrid Systems*, volume 251 of *Lecture Notes in Control and Information Science*. Springer, London.

[van der Schaft and Schumacher, 1996] van der Schaft, A. J. and Schumacher, J. M. (1996). The complementary-slackness of hybrid systems. *Math. Contr. Signals Syst.*, (9):266–301.

[Vecchietti and Grossmann, 1999] Vecchietti, A. and Grossmann, I. (1999). Logmip: A disjunctive 0-1 nonlinear optimizer for process system models. *Comp. and Chemical. Eng.*, 23:555–565.

[Verghese et al., 1981] Verghese, G. C., Lévy, B. C., and Kailath, T. (1981). A generalized state-space for singular systems. *IEEE Transactions on Automatic Control*, 26(4):811–831.

[Vidal, 1993] Vidal, R. (1993). *Applied Simulated Annealing*. Springer, Berlin.

[Vidal et al., 2001] Vidal, R., Schaffert, S., Shakernia, O., Pappas, G., and Sastry, S. (2001). Decidable and semi-decidable controller synthesis for classes of discrete-time hybrid systems. In *Proc.* 40^{th} *IEEE Conf. Decision and Control*, pages 1243–1248.

[von Stryk, 2000] von Stryk, O. (2000). Numerical hybrid optimal control and related topics. Habilitation Dissertation, Technische Universität München.

[von Stryk, 2001] von Stryk, O. (2001). User's guide for DIRCOL version 2.1: A direct collocation method for the numerical solution of optimal control problems. Technical report, Simulation and Systems Optimization Group, Technische Universität Darmstadt. WWW: www.sim.informatik.tu-darmstadt.de/sw/.

[von Stryk and Bulirsch, 1992] von Stryk, O. and Bulirsch, R. (1992). Direct and indirect methods for trajectory optimization. *Annals of Operations Research*, 36:357–373.

[von Stryk and Glocker, 2000] von Stryk, O. and Glocker, M. (2000). Decomposition of mixed-integer optimal control problems using branch and bound and sparse direct collocation. In *ADPM – 4th Int'l Conf. on Automation of Mixed Processes: Hybrid Dynamic Systems*, pages 99–104.

[von Stryk and Glocker, 2001] von Stryk, O. and Glocker, M. (2001). Numerical mixed-integer optimal control and motorized traveling salesmen problems. *APII – JESA (Journal européen des systèmes automatisés – European Journal of Control)*, 35(4):519–533.

[Vries et al., 2000] Vries, R. d., Tretmans, J., Belinfante, A., Feenstra, J., Feijs, L., Mauw, S., Goga, N., Heerink, L., and Heer, A. d. (2000). Côte de Resyste in Progress. In *Progress 2000 – Workshop on Embedded Systems*, pages 141–148.

[W3C, 1998] W3C (1998). Extensible markup language XML. `http://www.w3.org/TR/REC-xml`.

[Walsh et al., 1994] Walsh, G., Tilbury, D., Sastry, S., Murray, R., and Laumond, J.-P. (1994). Stabilization of trajectories for systems with nonholonomic constraints. *IEEE Transactions on Automatic Control*, 39:216–222.

[WG6, 1999] WG6, I. T. (1999). Function blocks for industrial-process measurement and control systems. Technical report, Committee IEC 61499-1.

[WG7, 1999] WG7, I. S. C. (1999). Function blocks for process control. Technical report, Committee IEC 61804-1.

[Wiedemann, 1974] Wiedemann, R. (1974). *Simulation des Straßenverkehrsflusses*, volume 8 of *Schriftenreihe des Instituts für Verkehrswesen der Universität Karlsruhe*.

[Wiedemann, 1991] Wiedemann, R. (1991). Modelling of rti-elements on multi-lane roads. In of the European Community, C., editor, *Advanced Telematics in Road Transport*, Brussels.

[Wieting, 1996] Wieting, R. (1996). Modeling and simulation of hybrid systems using hybrid high-level nets. In *8th European Simulation Symposium ESS'96*, volume 1, pages 96–100.

[Wieting, 1998] Wieting, R. (1998). *Modellbildung und Simulation mit hybriden höheren Netzen*. PhD thesis. ISBN 3-8265-3291-0.

[Willems, 1989] Willems, J. C. (1989). Models for dynamics. *Dynamics Reported*, 2:172–269.

[Willems, 1991] Willems, J. C. (1991). Paradigms and puzzles in the theory of dynamic systems. *IEEE Transactions on Automatic Control*, 36:258–294.

[Williams, 1978] Williams, H. P. (1978). *Model Building in Mathematical Programming*. J. Wiley P., 1^{st} edition.

[Wolf, 2001] Wolf, A. (2001). *Components and Interfaces for Modeling and Simulation of Continuous-Discrete Systems*. PhD thesis, Technical University of Magdeburg. (in German).

[Wöllhaf, 1995] Wöllhaf, K. (1995). *Object Oriented Modeling and Simulation of Multi-Product Batch Plants*. PhD thesis, University of Dortmund. (in German).

[Wolter, 1999] Wolter, K. (1999). *Performance and Dependability Modelling with Second Order Fluid Stochastic Petri Nets*. Shaker, Aachen.

[Wolter, 2001] Wolter, K. (2001). A performability model for a hybrid reactor system. In Djemame, K. and Kara, M., editors, *Proc. 17th annual UK Performance Engineering Workshop*, pages 13–22, Leeds, UK.

[Wolter et al., 2002] Wolter, K., Zisowski, A., and Hommel, G. (2002). Performability models for a hybrid reactor system. In Engell, S., Frehse, G., and Schnieder, E., editors, *Modelling, Analysis, and Design of Hybrid Systems*, Lecture Notes in Control and Information Science. Springer. (This volume).

[Wolter and Zisowsky, 2001] Wolter, K. and Zisowsky, A. (2001). Performance evaluation. *On Markov Reward Modelling with FSPNs*, 44:165–186.

[Wong and Wonham, 1996] Wong, K. C. and Wonham, W. M. (1996). Hierarchical control of discrete-event systems. *Discrete Event Dynamic Systems*, 6:241–306.

[Wonham, 1999] Wonham, W. M. (1999). Notes on control of discrete event systems. Technical report, Department of Electrical & Computer Engineering, University of Toronto. Downloadable on http://odin.control.toronto.edu/DES/.

[Xu and Antsaklis, 2001] Xu, X. and Antsaklis, P. (2001). An approach for solving general switched linear quadratic optimal control problems. In *Proc.* 40^{th} *IEEE Conf. Decision and Control*, pages 2478–2483.

[Yovine, 1997] Yovine, S. (1997). Kronos: a verification tool for real-time systems. *Software Tools for Technology Transfer*, 1(1,2):123–133.

[Zaytoon, 1998] Zaytoon, J., editor (1998). *3rd Int. Conf. on Automation of Mixed Processes: Hybrid Dynamic Systems (ADPM'98), Reims, France*. Université de Reims.

[Zeigler, 1976] Zeigler, B. (1976). *Theory of Modelling and Simulation*. John Wiley & Sons.

[Zeigler, 1984] Zeigler, B. (1984). *Multifacetted Modelling and Discrete Event Simulation*. Academic Press, Inc.

[Zeigler, 1990] Zeigler, B. (1990). *Object-Oriented Simulation with Hierarchical, Modular Models*. Academic Press, Inc.

[Zeigler and Prähofer, 2000] Zeigler, B. and Prähofer, H. (2000). *Theory of Modelling and Simulation*. Academic Press, London, second edition.

[Zhang and Cassandras, 2001] Zhang, P. and Cassandras, C. (2001). An improved forward algorithm for optimal control of a class of hybrid systems. In *Proc.* 40^{th} *IEEE Conf. Decision and Control*, pages 1235–1236.

[Zhivoglyadov and Middleton, 1999] Zhivoglyadov, P. and Middleton, R. (1999). A novel approach to systematic switching control design for a class of hybrid systems. In *Proc. of the 38th International Conference on Decision and Control, CDC'99*. IEEE Press.

[Zhu, 2001] Zhu, P. (2001). *Betriebliche Leistung von Bahnsystemen unter Störungsbedingungen*. VDI-Verlag, Düsseldorf.

[Zimmermann et al., 2000] Zimmermann, A., German, R., Freiheit, J., and Hommel, G. (2000). Petri net modelling and performability evaluation with timenet 3.0. In *Proc. 11th Int. Conf. on Computer Performance Evaluation; Modelling Techniques and Tools*, number 1786 in LNCS, pages 188–202, Schaumburg, IL, USA.

[Zisowsky, 1998] Zisowsky, A. (1998). Entwurf und implementierung eines verfahrens für die transiente analyse fluider stochastischer petri-netze. Master's thesis, TU Berlin.