

# MODEL-BASED CONTROL SYNTHESIS FOR DISCRETE EVENT SYSTEMS

Mourad Chouikha, Eckehard Schnieder  
Institute of Control and Automation Engineering  
Technical University of Braunschweig  
Langer Kamp 8  
D-38106 Braunschweig, Germany  
Phone.: +49-0531-391-76 67  
Fax: +49-0531-391-51 97  
E-Mail: {chouikha, schnieder}@ifra.ing.tu-bs.de

Bernhard Ober  
Siemens AG  
Automation and Drives  
P.O. Box 3220  
D-91050 Erlangen, Germany  
Phone.: +49-9131-7-24876  
Fax: +49-9131-7-31509  
E-Mail: bernhard.ober@ERL6.siemens.de

## ABSTRACT

In control engineering models of the controlled systems are the basis for controller synthesis as well as for analytical or simulative examination of open or closed-loop behaviour. This model-based methodology is being transferred into automation engineering by means of a development environment for the programming of logical controllers. Petri net models of the controlled system allow an automatic computation of the control algorithm. The control algorithms which are equally represented as Petri nets are then automatically translated into code for programmable logic controllers (PLC's).

**Keywords** Petri nets, Modelling, Synthesis, Code Generation, PLC.

## 1. INTRODUCTION

The aim of modelling in automation engineering is to describe a process with a formal language, which allows us to generate control algorithms and to simulate, analyse and verify the controlled system by exploiting the structural and dynamic properties of the description language. In the literature several special classes of Petri nets, various kinds of condition/event systems, temporal logic, boolean differential calculus or some combinations of these are employed. For a selection see [3], [4], [5] and [7]. In this context Petri nets have many advantages over other description languages. Indeed the graphic notation of Petri nets allows an easy and intuitive modelling of systems. Petri net models are generally more compact and more powerful. The algebraic foundation of Petri nets facilitates efficient analysis and synthesis, for which a large number of tools exists.

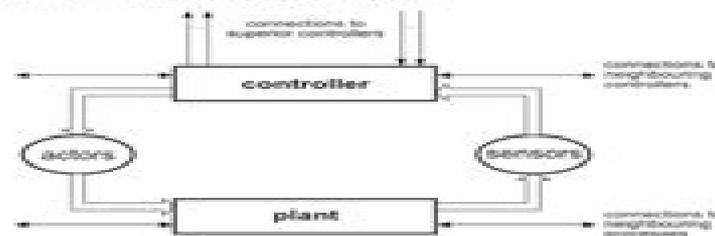
In this section we present an overview of the different control synthesis methods described in the literature focusing on an efficient method, the model-based control synthesis with Petri net models. The most discussed methods use special classes of Petri nets, such as controlled Petri nets and labelled nets.

The main design approaches for the control of discrete event systems using Petri nets are [2]:

- *controlled behaviour approach,*
- *logic controller approach and*
- *control theoretic approach.*

In the controlled behaviour approach the model describes the behaviour of the plant and the controller joined together. For the implementation the control algorithm has to be extracted from the combined model.

The logic controller approach tries to define the input-output behaviour of the controller, which satisfies all the system requirements. Using this method the control program can be deduced directly from the obtained I/O-behaviour. This approach leads to the physical implementation of the control program, but simulation is required to validate the closed-loop behaviour.



**Fig. 1: STRUCTURE OF AUTOMATION SYSTEMS**

The control theoretic approach has been investigated by numerous research teams and is getting more and more popular. The approach adopts the controller synthesis paradigm from control theory for continuous systems. A decomposition of an automation system leads to a structure very similar to a control loop in control

# Synthesis And Control Of Discrete Event Systems

**James F. Davis, George  
Stephanopoulos, Venkat  
Venkatasubramanian**



## **Synthesis And Control Of Discrete Event Systems:**

Synthesis and Control of Discrete Event Systems Benoît Caillaud, Philippe Darondeau, Luciano Lavagno, Xiaolan Xie, 2013-04-17 This book aims at providing a view of the current trends in the development of research on Synthesis and Control of Discrete Event Systems Papers collected in this volume are based on a selection of talks given in June and July 2001 at two independent meetings the Workshop on Synthesis of Concurrent Systems held in Newcastle upon Tyne as a satellite event of ICATPN ICACSD and organized by Ph Darondeau and L Lavagno and the Symposium on the Supervisory Control of Discrete Event Systems SCODES held in Paris as a satellite event of CAV and organized by B Caillaud and X Xie Synthesis is a generic term that covers all procedures aiming to construct from specifications given as input objects matching these specifications Theories and applications of synthesis have been studied and developed for long in connection with logics programming automata discrete event systems and hardware circuits Logics and programming are outside the scope of this book whose focus is on Discrete Event Systems and Supervisory Control The stress today in this field is on a better applicability of theories and algorithms to practical systems design Coping with decentralization or distribution and caring for an efficient realization of the synthesized systems or controllers are of the utmost importance in areas so diverse as the supervision of embedded or manufacturing systems or the implementation of protocols in software or in hardware

*Discrete Event Systems* R. Boel, Geert Stremersch, 2012-12-06 Discrete Event Systems Analysis and Control is the proceedings of WODES2000 the 5th Workshop on Discrete Event Systems held in Ghent Belgium on August 21-23 2000 This book provides a survey of the current state of the art in the field of modeling analysis and control synthesis of discrete event systems lecture notes for a mini course on sensitivity analysis for performance evaluation of timed discrete event systems and 48 carefully selected papers covering all areas of discrete event theory and the most important applications domains Topics include automata theory and supervisory control 12 Petri net based models for discrete event systems and their control synthesis 11 max and timed automata models 9 applications papers related to scheduling failure detection and implementation of supervisory controllers 7 formal description of PLCs 6 and finally stochastic models of discrete event systems 3

**Discrete Event Systems 2004 (WODES'04)** Janan Zaytoon, 2005-12-22 Approx 484 pages

*Petri Net Synthesis for Discrete Event Control of Manufacturing Systems* MengChu Zhou, F. Dicesare, 2012-12-06 Petri Net Synthesis for Discrete Event Control of Manufacturing Systems develops two essential resource sharing concepts parallel and sequential mutual exclusions and theoretical results in Petri synthesis A parallel mutual exclusion PME is defined to model a resource shared by independent distributed processes and a sequential mutual exclusion is a sequential composition of PMEs modeling a resource shared by sequentially related processes A hybrid synthesis methodology for Petri net models and controllers is proposed using top down modular and bottom up design ideas and the mutual exclusion theory An aggregate Petri net model is refined by replacing places and or transitions with basic design modules which are mathematically and

graphically described Petri net design methods are presented for such buffers as automatic storage and retrieval systems Using the proposed method synthesizes both Petri net structure and feasible initial markings guaranteeing that resulting Petri nets have desirable system properties such as freedom from deadlock and cyclic behavior A Petri net controller is extended to error recovery for automated manufacturing systems The theory can guarantee that the desired system properties achieved by the original design will be preserved when the controller is augmented to deal with an error in the prescribed methods Control code has been directly generated from Petri net definitions The algorithm and implementation details are given for a flexible manufacturing system Using the approach presented in Petri Net Synthesis for Discrete Event Control of Manufacturing Systems engineers and research workers can develop their own discrete event control applications and experiments

**Supervisory Control of Discrete-Event Systems** W. Murray Wonham, Kai Cai, 2018-08-17 This book shows how supervisory control theory SCT supports the formulation of various control problems of standard types like the synthesis of controlled dynamic invariants by state feedback and the resolution of such problems in terms of naturally definable control theoretic concepts and properties like reachability controllability and observability It exploits a simple abstract model of controlled discrete event systems DES that has proved to be tractable appealing to control specialists and expressive of a range of control theoretic ideas It allows readers to choose between automaton based and dually language based forms of SCT depending on whether their preference is for an internal structural or external behavioral description of the problem The monograph begins with two chapters on algebraic and linguistic preliminaries and the fundamental concepts and results of SCT are introduced To handle complexity caused by system scale architectural approaches the horizontal modularity of decentralized and distributed supervision and the vertical modularity of hierarchical supervision are introduced Supervisory control under partial observation and state based supervisory control are also addressed in the latter a vector DES model that exploits internal regularity of algebraic structure is proposed Finally SCT is generalized to deal with timed DES by incorporating temporal features in addition to logical ones Researchers and graduate students working with the control of discrete event systems or who are interested in the development of supervisory control methods will find this book an invaluable aid in their studies The text will also be of assistance to researchers in manufacturing logistics communications and transportation areas which provide plentiful examples of the class of systems being discussed

*Formal Methods in Manufacturing Systems: Recent Advances* Li, Zhiwu, 2013-05-31 Evolving technologies in mass production have led to the development of advanced techniques in the field of manufacturing These technologies can quickly and effectively respond to various market changes necessitating processes that focus on small batches of multiple products rather than large single product lines Formal Methods in Manufacturing Systems Recent Advances explores this shifting paradigm through an investigation of contemporary manufacturing techniques and formal methodologies that strive to solve a variety of issues arising from a market environment that increasingly favors flexible systems over traditional ones This book

will be of particular use to industrial engineers and students of the field who require a detailed understanding of current trends and developments in manufacturing tools This book is part of the Advances in Civil and Industrial Engineering series collection

**Controller Synthesis for Parameterized Discrete Event Systems**, 2009 Discrete event systems are a special type of dynamic systems The state of these systems changes only at discrete instants of time and the term event is used to represent the occurrence of discontinuous changes These systems are mostly man made and arise in the domains of manufacturing systems traffic systems database management systems and communication protocols This thesis investigates the control of parameterized discrete event systems when specifications are given in terms of predicates and satisfy a similarity assumption For systems consisting of similar processes under total or partial observation conditions are given to deduce properties of a system of  $n$  processes from properties of a system of  $n_0$  processes with  $n > n_0$  Furthermore it is shown how to infer a control policy for the former from the latter while taking into account interconnections between processes This study is motivated by a weakness in current synthesis methods that do not scale well to huge systems

AICHE Symposium Series American Institute of Chemical Engineers, 1997

*Hardware and Software: Verification and Testing* Ofer Strichman, Rachel Tzoref-Brill, 2017-11-11 This book constitutes the refereed proceedings of the 13th International Haifa Verification Conference HVC 2017 held in Haifa Israel in November 2017 The 13 revised full papers presented together with 4 poster and 5 tool demo papers were carefully reviewed and selected from 45 submissions They are dedicated to advance the state of the art and state of the practice in verification and testing and are discussing future directions of testing and verification for hardware software and complex hybrid systems

**Formal Methods for Industrial Critical Systems** Gwen Salaün, Bernhard Schätz, 2011-09-19 This book constitutes the proceedings of the 16th International Workshop on Formal Methods for Industrial Critical Systems FMICS 2011 held in Trento Italy in August 2011 The 16 papers presented together with 2 invited talks were carefully reviewed and selected from 39 submissions The aim of the FMICS workshop series is to provide a forum for researchers who are interested in the development and application of formal methods in industry It also strives to promote research and development for the improvement of formal methods and tools for industrial applications

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**Control Law Synthesis for a Discrete Event System** J. Gunnarsson, J. Plantin, 1994 Balanced Automation Systems Luis M. Camarinha-Matos, Hamideh Afsarmanesh, 2013-06-05 Towards Balanced Automation The concept

Manufacturing industries worldwide are facing tough challenges as a consequence of the globalization of economy and the openness of the markets Progress of the economic blocks such as the European Union NAFTA and MERCOSUR and the global agreements such as GATT in addition to their obvious economic and social consequences provoke strong paradigm shifts in the way that the manufacturing systems are conceived and operate To increase profitability and reduce the manufacturing costs there is a recent tendency towards establishing partnership links among the involved industries usually

between big industries and the networks of components suppliers To benefit from the advances in technology similar agreements are being established between industries and universities and research institutes Such an open cooperation network may be identified as an extended enterprise or a virtual enterprise In fact the manufacturing process is no more carried out by a single enterprise rather each enterprise is just a node that adds some value a step in the manufacturing chain to the cooperation network of enterprises The new trends create new scenarios and technological challenges especially to the Small and Medium size Enterprises SMEs that clearly comprise the overwhelming majority of manufacturing enterprises worldwide Under the classical scenarios these SMEs would have had big difficulties to access or benefit from the state of the art technology due to their limited human financial and material resources

**Mathematical Foundations of Computer Science** ,2003    **Computations on Distributed Discrete-event Systems** Kurt Ryan Rohloff,2004    *First International Workshop on Intelligent Manufacturing Systems (IMS-EUROPE 1998)* ,1998    Proceedings of the ... Conference on Information Sciences and Systems ,1994    SCAI-95 Agnar Aamodt,Jan Komorowski,1995    First International Conference on Intelligent Systems in Process Engineering James F. Davis,George Stephanopoulos,Venkat Venkatasubramanian,1996

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