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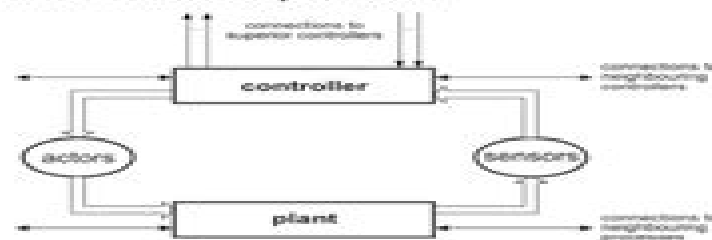
In this section we present an overview of the different control synthesis methods described in the literature focusing on an efficient method, the model-based control synthesis with Petri net models. The most discussed methods use special classes of Petri nets, such as controlled Petri nets and labelled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

R. Boel,Geert Stremersch

Synthesis And Control Of Discrete Event Systems:

　　Synthesis and Control of Discrete Event Systems Benoît Caillaud,2002-01-31 The first motivation of Synthesis and Control of Discrete Event Systems is to inform the reader of recent developments and current trends in system synthesis This is a field of active research aiming to supply efficient techniques for developing safe systems in various areas covering control of embedded and manufacturing systems distributed implementation of systems and protocols and hardware circuits In all areas considerations about distribution and care for an efficient implementation of the synthesised systems play an increasing role justified by better applicability to problems encountered in the design of practical systems The second motivation of the book which is a selection of presentations given at two workshops on synthesis of controllers and on synthesis of concurrent systems is to incite the research community to establish stronger links between two subjects that could be better related as several presentations do show The selected papers are research papers ranging from theory to practice with automata products of automata and Petri nets playing a prominent role All areas mentioned above as areas of application of system synthesis are covered by some of the selected papers **Discrete Event Systems 2004 (WODES'04)** Janan Zaytoon,2005-12-22 Approx 484 pages Discrete Event Systems R. Boel,Geert Stremersch,2000-07-31 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 *Cybersecurity of Discrete Event Systems* Rong Su,2024-09-05 This book describes analysis and control against smart cyberattacks in discrete event systems DES This is the first technical DES book to provide a thorough introduction to smart cyberattacks on supervisory control systems modelled by regular languages or finite state automata and possible resilient defence methods against smart cyberattacks Smart attacks cannot be detected by the supervisor until an irreversible process toward ensured damage occurs An attack may be conducted either in the observation channel i e the supervisor s input of the supervisor or in the command channel i e the supervisor s output or both simultaneously Therefore defence strategies against these attacks are urgently needed Rong Su provides a comprehensive overview of the latest theories and includes empirical examples to illustrate concepts and methods By centering on what information is available and how such information is used the readers are provided with methods to evaluate the cyber vulnerability of a given system and design a resilient supervisor against relevant smart attacks This book comprises two

sections Firstly Su introduces the required concepts and techniques related to DES and supervisory control Then he introduces different types of smart attacks that intercept and manipulate information in sensor and command channels in a standard closed loop control system Secondly he presents resilient defence strategies against relevant types of attacks By focusing on a conceptual introduction and systematic analysis this book provides a solid theoretical foundation for future exploration by researchers and graduate students who are interested in cybersecurity research not necessarily limited to those in the DES community To illustrate the practical relevance of this research realistic examples are used throughout this book Readers are recommended to have a background in formal language theory **Implementation and Application of Automata** Michael Domaratzki,Kai Salomaa,2011-02-04 This book constitutes the thoroughly refereed papers of the 15th International Conference on Implementation and Application of Automata CIAA 2010 held in Manitoba Winnipeg Canada in August 2010 The 26 revised full papers together with 6 short papers were carefully selected from 52 submissions The papers cover various topics such as applications of automata in computer aided verification natural language processing pattern matching data storage and retrieval bioinformatics algebra graph theory and foundational work on automata theory

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 *Formal Modeling and Analysis of Timed Systems* Kim G. Larsen,Peter Niebert,2004-04-08 This book constitutes the thoroughly refereed post proceedings of the First International Workshop on Formal Modeling and Analysis of Timed Systems FORMATS 2003 held in Marseille France in September 2003 The 19 revised full papers presented together with an invited paper and the abstracts of two invited talks were carefully selected from 36 submissions during two rounds of reviewing and improvement All current aspects of formal method for modeling and analyzing timed systems are addressed among the timed systems dealt with are timed automata timed Petri nets max plus algebras real time systems discrete time systems timed languages and real time operating systems

Lectures on Concurrency and Petri Nets Jörg Desel,Wolfgang Reisig,Grzegorz Rozenberg,2004-07-09 This tutorial volume originates from the 4th Advanced Course on Petri Nets ACPN 2003 held in Eichsttt Germany in September 2003 In addition to lectures given at ACPN 2003 additional chapters have been commissioned to give a well balanced presentation of the state of the art in the area This book will be useful as both a reference for those working in the area as well as a study book for the reader who is interested in an up to date overview of research and development in concurrent and distributed systems of course readers specifically interested in theoretical or applicational aspects of Petri nets will appreciate the book

as well **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 *Automated Technology for Verification and Analysis* Farn Wang,2004-10-11 It was our great pleasure to hold the 2nd International Symposium onAutomated Te nology on Veri cation and Analysis ATVA in Taipei Taiwan ROC October 31 November3 2004 TheseriesofATVAmeetingsisintendedforthepromotionofrelated research in eastern Asia In the last decade automated technology on veri cation has become the new strength in industry and brought forward various hot research activities in both Europe and USA In comparison easternAsia has been quiet in the forum With more and more IC design houses moving from SiliconValley to easternAsia we believe this is a good time to start cultivating related research activities in the region TheemphasisoftheATVAworkshopseriesisonvariousmechanicalandinformative techniques which can give engineers valuable feedback to fast converge their designs according to the speci cations The scope of interest contains the following research eas model checking theory theorem proving theory state space reduction techniques languages in automated veri cation parametric analysis optimization formal perf mance analysis real time systems embedded systems in nite state systems Petri nets UML synthesis tools and practice in industry *Manufacturing System* Faieza Abdul Aziz,2012-05-16 This book attempts to bring together selected recent advances tools application and new ideas in manufacturing systems Manufacturing system comprise of equipment products people information control and support functions for the competitive development to satisfy market needs It provides a comprehensive collection of papers on the latest fundamental and applied industrial research The book will be of great interest to those involved in manufacturing engineering systems and management and those involved in manufacturing research *Dependable Software Engineering. Theories, Tools, and Applications* Jun Pang,Lijun Zhang,2020-11-08 This book constitutes the proceedings of the 6th International Symposium on Dependable Software Engineering SETTA 2020 held in Guangzhou China in November 2020 The 10 full and 1 short paper included in this volume were carefully reviewed and selected from 20 submissions They deal with latest research results and ideas on bridging the gap between formal methods and software engineering Programming Languages and Systems Pierpaolo Degano,2003-03-14 Comparison is a powerful cognitive research tool in science since it does across studies to evaluate similarities and differences e g across taxa or diseases This book deals with comparative

research on plant disease epidemics Comparisons are done in specifically designed experiments or with posterior analyses From the apparently unlimited diversity of epidemics of hundreds of diseases comparative epidemiology may eventually extract a number of basic types These findings are very important to crop protection Plant disease epidemiology being the ecological branch of plant pathology may also be of value to ecologists but also epidemiologists in the areas of animal or human diseases may find interesting results applicable to their areas of research   Models and Analysis for Distributed Systems Serge Haddad,Fabrice Kordon,Laurent Pautet,Laure Petrucci,2013-02-07 Nowadays distributed systems are increasingly present for public software applications as well as critical systems software applications as well as critical systems This title and Distributed Systems Design and Algorithms from the same editors introduce the underlying concepts the associated design techniques and the related security issues The objective of this book is to describe the state of the art of the formal methods for the analysis of distributed systems Numerous issues remain open and are the topics of major research projects One current research trend consists of profoundly mixing the design modeling verification and implementation stages This prototyping based approach is centered around the concept of model refinement This book is more specifically intended for readers that wish to gain an overview of the application of formal methods in the design of distributed systems Master s and PhD students as well as engineers in industry will find a global understanding of the techniques as well as references to the most up to date works in this area   **Transactions on Computational Collective Intelligence III** Ngoc Thanh Nguyen,2011-06-01 These Transactions publish research in computer based methods of computational collective intelligence CCI and their applications in a wide range of fields such as the Semantic Web social networks and multi agent systems TCCI strives to cover new methodological theoretical and practical aspects of CCI understood as the form of intelligence that emerges from the collaboration and competition of many individuals artificial and or natural The application of multiple computational intelligence technologies such as fuzzy systems evolutionary computation neural systems consensus theory etc aims to support human and other collective intelligence and to create new forms of CCI in natural and or artificial systems This third issue contains a collection of 10 articles selected from high quality submissions addressing advances in the foundations and applications of computational collective intelligence

Computational Collective Intelligence. Semantic Web, Social Networks and Multiagent Systems Ryszard Kowalczyk,2009-09-23 Computational collective intelligence CCI is most often understood as a subfield of artificial intelligence AI dealing with soft computing methods that enable group decisions to be made or knowledge to be processed among autonomous units acting in distributed environments The needs for CCI techniques and tools have grown signi cantly recently as many information systems work in distributed environments and use distributed resources Web based systems social networks and multi agent systems very often need these tools for working out consistent knowledge states resolving conflicts and making decisions Therefore CCI is of great importance for today s and future distributed systems

Methodological theoretical and practical aspects of computational collective int ligence such as group decision making collective action coordination and knowledge integration are considered as the form of intelligence that emerges from the collabo tion and competition of many individuals artificial and or natural The application of multiple computational intelligence technologies such as fuzzy systems evolutionary computation neural systems consensus theory etc can support human and other collective intelligence and create new forms of CCI in natural and or artificial s tems **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

Formal Methods in Manufacturing Javier Campos,Carla Seatzu,Xiaolan Xie,2018-09-03 Illustrated with real life manufacturing examples Formal Methods in Manufacturing provides state of the art solutions to common problems in manufacturing systems Assuming some knowledge of discrete event systems theory the book first delivers a detailed introduction to the most important formalisms used for the modeling analysis and control of manufacturing systems including Petri nets automata and max plus algebra explaining the advantages of each formal method It then employs the different formalisms to solve specific problems taken from today s industrial world such as modeling and simulation supervisory control including deadlock prevention in a distributed and or decentralized environment performance evaluation including scheduling and optimization fault diagnosis and diagnosability analysis and reconfiguration Containing chapters written by leading experts in their respective fields Formal Methods in Manufacturing helps researchers and application engineers handle fundamental principles and deal with typical quality goals in the design and operation of manufacturing systems

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 **Deadlock Resolution in Automated Manufacturing Systems** ZhiWu Li,MengChu Zhou,2009-02-12 Deadlock problems in flexible manufacturing systems FMS have received more and more attention in the last two decades Petri nets are one of the more promising mathematical tools for tackling deadlocks in various resource allocation systems In a system modeled with Petri nets siphons are tied to the occurrence of deadlock states as a structural object The book systematically introduces the novel theory of siphons traps and elementary siphons of Petri nets as well as the deadlock control strategies for FMS developed from it Deadlock prevention methods are examined comparatively The many FMS examples presented to demonstrate the concepts and results of this book range from the simple to the complex Importantly to inspire and motive the reader s interest in further research a number of interesting and open problems in this area are proposed at the end of each chapter

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