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# **Petri Net Synthesis for Discrete Event Control of Manufacturing Systems**

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**MengChu Zhou  
Frank DiCesare**



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# Petri Net Synthesis For Discrete Event Control Of Manufacturing Systems

**Jordi Cortadella, Wolfgang Reisig**



## **Petri Net Synthesis For Discrete Event Control 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

**Modeling and Control of Discrete-event Dynamic Systems** Branislav Hruz,MengChu Zhou,2007-08-17 Discrete event dynamic systems DEDs permeate our world They are of great importance in modern manufacturing processes transportation and various forms of computer and communications networking This book begins with the mathematical basics required for the study of DEDs and moves on to present various tools used in their modeling and control Industrial examples illustrate the concepts and methods discussed making this book an invaluable aid for students embarking on further courses in control manufacturing engineering or computer studies

Manufacturing Systems Control Design Stjepan Bogdan, Frank L. Lewis, Zdenko Kovacic, Jose Mireles, 2006-08-02 This book covers all the steps from identification of operations and resources to the transformation of virtual models into real world algorithms The matrix based approach presented here is a solution to the real time application of control in discrete event systems and flexible manufacturing systems FMS and offers a sound practical basis for the design of controllers for manufacturing systems

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 *Property-Preserving Petri Net Process Algebra in Software Engineering* Hejiao Huang, 2012 Annotation In a component based approach for system design one of the difficult problems is how to prove the correctness of the created components This volume presents a component based methodology for the creation and verification of design specifications **System Modeling and Control with Resource-Oriented Petri Nets** MengChu Zhou, Naiqi Wu, 2018-09-03 Petri nets are widely used in modeling analysis and control of discrete event systems arising from manufacturing transportation computer and communication networks and web service systems However Petri net models for practical systems can be very large making it difficult to apply such models to real life problems System Modeling and Control with Resource Oriented Petri Nets introduces a new resource oriented Petri net ROPN model that was developed by the authors Not only does it successfully reduce model size but it also offers improvements that facilitate effective modeling analysis and control of automated and reconfigurable manufacturing systems Presenting the latest research in this novel approach this cutting edge volume provides proven theories and methodologies for implementing cost and time saving improvements to contemporary manufacturing systems It provides effective tools for deadlock avoidance deadlock free routing and deadlock free scheduling The authors supply simple and complex industrial manufacturing system examples to illustrate time tested concepts theories and approaches for solving real life application problems Written in a clear and concise manner the text covers applications to automated and reconfigurable manufacturing systems automated guided vehicle AGV systems semiconductor manufacturing systems and flexible assembly systems Explaining complex concepts in a manner that is easy to understand the authors provide the understanding and tools needed for more effective modeling analysis performance evaluation control and scheduling of engineering processes that will lead to more flexible and efficient manufacturing systems Optimal Supervisory Control of Automated Manufacturing

Systems Yufeng Chen,Zhiwu Li,2013-01-23 This monograph presents the state of the art developments in the design of behaviorally and structurally optimal liveness enforcing Petri net supervisors with computationally tractable approaches It details optimal supervisory control problems arising in automated production systems and outlines a methodology to achieve the optimality purposes of deadlock prevention via converting a variety of problems under consideration into integer linear programming models The book includes a reference bibliography at the end of each chapter and a complete index

Introduction to Discrete Event Systems Christos G. Cassandras,Stéphane Lafortune,2021-11-11 This unique textbook comprehensively introduces the field of discrete event systems offering a breadth of coverage that makes the material accessible to readers of varied backgrounds The book emphasizes a unified modeling framework that transcends specific application areas linking the following topics in a coherent manner language and automata theory supervisory control Petri net theory Markov chains and queueing theory discrete event simulation and concurrent estimation techniques Topics and features detailed treatment of automata and language theory in the context of discrete event systems including application to state estimation and diagnosis comprehensive coverage of centralized and decentralized supervisory control of partially observed systems timed models including timed automata and hybrid automata stochastic models for discrete event systems and controlled Markov chains discrete event simulation an introduction to stochastic hybrid systems sensitivity analysis and optimization of discrete event and hybrid systems new in the third edition opacity properties enhanced coverage of supervisory control overview of latest software tools This proven textbook is essential to advanced level students and researchers in a variety of disciplines where the study of discrete event systems is relevant control communications computer engineering computer science manufacturing engineering transportation networks operations research and industrial engineering Christos G Cassandras is Distinguished Professor of Engineering Professor of Systems Engineering and Professor of Electrical and Computer Engineering at Boston University Stéphane Lafortune is Professor of Electrical Engineering and Computer Science at the University of Michigan Ann Arbor

### **Petri Nets for Systems Engineering**

Claude Girault,Rüdiger Valk,2013-03-14 Formal methods for the specification and verification of hardware and software systems are becoming more and more important as systems increase in size and complexity The aim of the book is to illustrate progress in formal methods based on Petri net formalisms It contains a collection of examples arising from different fields such as flexible manufacturing telecommunication and workflow management systems The book covers the main phases in the life cycle of design and implementation of a system i e specification model checking techniques for verification analysis of properties code generation and execution of models These techniques and their tool support are discussed in detail including practical issues Amongst others fundamental concepts such as composition abstraction and reusability of models model verification and verification of properties are systematically introduced

### Applications and Theory of Petri

Nets 2004 Jordi Cortadella,Wolfgang Reisig,2004-09-21 This book constitutes the refereed proceedings of the 25th

International Conference on Applications and Theory of Petri Nets ICATPN 2004 held in Bologna Italy in June 2004 The 19 revised full regular papers and 5 revised tool presentation papers presented together with 6 invited papers were carefully reviewed and selected from 62 submissions All current issues on research and development in the area of Petri nets are addressed in particular concurrent systems design and analysis modular systems development formal specification model validation model checking workflow management flow charts networking formal methods in software engineering etc

**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

**Lectures on Petri Nets II: Applications** Wolfgang Reisig, Grzegorz Rozenberg, 1998-11-04 The two volume set originates from the Advanced Course on Petri Nets held in Dagstuhl Germany in September 1996 beyond the lectures given there additional chapters have been commissioned to give a well balanced presentation of the state of the art in the area Together with its companion volume Lectures on Petri Nets I Basic Models this book is the actual reference for the area and addresses professionals students lecturers and researchers who are interested in systems design and would like to learn to use Petri nets familiar with subareas of the theory or its applications and wish to view the whole area interested in learning about recent results presented within a unified framework planning to apply Petri nets in practical situations interested in the relationship of Petri nets to other models of concurrent systems

**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 *Information Infrastructure Systems for Manufacturing II* John J. Mills, Fumihiko Kimura, 2013-03-09 In this global society manufacturers compete in many ways and information infrastructures play a critical role in ensuring the right information is available at the right time and the right place to support informed decision making The traditional approach that assumes all information can be located on a single mainframe and accessed by everybody in the enterprise has fallen by the wayside and new infrastructures supporting extended or virtual enterprises and globally distributed supply chains are becoming increasingly vital to successful competitive organizations Functions data and information must be made be available to all without regard to location accessibility or the ability to view in a native format This book is a result of a conference which brought together a number of leading experts from around the world that work on topics related to the design implementation and use of information infrastructures for manufacturing These experts presented their views on the state of the art and on a wide variety of topics related to the title The topics range from the establishment of a generic enterprise framework which can be used for the design of a supporting information infrastructure to details of how geometric surfaces should be merged together Although not an exhaustive publication we believe that the publications in this book represent the state of the art in this research is essential reading for anyone who is attempting the design or development of an information infrastructure for all aspects of Manufacturing Sustainable Manufacturing Systems: An Energy Perspective Lin Li, MengChu Zhou, 2022-11-03 Sustainable Manufacturing Systems Learn more about energy efficiency in traditional and advanced manufacturing settings with this leading and authoritative resource Sustainable Manufacturing Systems An Energy Perspective delivers a comprehensive analysis of energy efficiency in sustainable manufacturing The book presents manufacturing modeling methods and energy efficiency evaluation and improvement methods for different manufacturing systems It allows industry professionals to understand the methodologies and techniques being embraced around the world that lead to advanced energy management The book offers readers a comprehensive and systematic theoretical foundation for novel manufacturing system modeling analysis and control It concludes with a summary of the insights and applications contained within and a discussion of future research issues that have yet to be grappled with Sustainable Manufacturing Systems answers the questions that energy customers managers decision makers and researchers have been asking about sustainable manufacturing The book s release coincides with recent and profound advances in smart grid applications and will serve as a practical tool to assist industrial engineers in furthering the green revolution Readers will also benefit from A thorough introduction to energy efficiency in manufacturing systems including the current state of research and research methodologies An exploration of the development of manufacturing methodologies including mathematical modeling for manufacturing systems and energy efficiency characterization in manufacturing systems An analysis of the applications of various methodologies including electricity demand response for manufacturing systems and energy control and optimization

for manufacturing systems utilizing combined heat and power systems A discussion of energy efficiency in advanced manufacturing systems like stereolithography additive manufacturing and cellulosic biofuel manufacturing systems Perfect for researchers undergraduate students and graduate students in engineering disciplines especially for those majoring in industrial mechanical electrical and environmental engineering Sustainable Manufacturing Systems will also earn a place in the libraries of management and business students interested in manufacturing system cost performance and energy management **Max-Plus Linear Stochastic Systems and Perturbation Analysis** Bernd F. Heidergott, 2006-12-26

During the last decade the area of stochastic max plus linear systems has witnessed a rapid development which created a growing interest in this area This book provides a thorough treatment of the theory of stochastic max plus linear systems Max plus algebra is an algebraic approach to discrete event systems DES like queuing networks that are prone to synchronization Perturbation analysis studies the sensitivity of the performance of DES with respect to changes in a particular system parameter The first part of the book addresses modeling issues and stability theory for stochastic max plus systems The second part of the book treats perturbation analysis of max plus systems a calculus for differentiation of max plus systems is developed This calculus leads to numerical evaluations of performance indices of max plus linear stochastic systems such as the Lyapunov exponent or waiting times New Frontiers in Applied Artificial Intelligence Leszek

Borzemski, Adam Grzech, Moonis Ali, 2008-06-17 The 21st International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems IEA AIE 2008 held in Wroclaw Poland was an international scientific forum for researchers in the field of applied artificial intelligence The presentations of the invited speakers and the authors focused on developing and employing methods and systems to solve real life problems in all applied intelligence areas The IEA AIE conference series chaired by Moonis Ali has a very long tradition and it is the first time it was hosted in Poland We received 302 papers from 52 countries Each paper was sent to at least three Program Committee members for review Although the general quality of the submissions was very high only 90 best papers were selected for oral presentation and publication in the LNAI proceedings The papers in the proceedings cover the following topics computer vision fuzzy system applications robot manufacturing data mining and knowledge discovery neural network machine learning natural language processing Internet application e learning heuristic search application systems agent based system evolutionary and genetic algorithms knowledge management and other applications These papers highlight new trends and frontiers of applied artificial intelligence and show how new research could lead to new and innovative applications We hope you will find these works useful and inspiring for your own research We would like to express our sincere thanks to the Program Committee members and all the reviewers for their hard work which helped us to select the highest quality papers for the conference

European Control Conference 1993 , 1993-06-28 Proceedings of the European Control Conference 1993 Groningen Netherlands June 28 July 1 1993 *Petri Nets in Flexible and Agile Automation* MengChu Zhou, 2012-12-06 Over the past



two decades research in the theory of Petri nets and the development of graphical tools has yielded a powerful methodology. The contributions in *Petri Nets in Flexible and Agile Automation* present theoretical development of Petri nets as well as in industrial applications to areas such as discrete event control design scheduling performance evaluation and deadlock avoidance. These contributions also include comparative studies of Petri nets and other approaches. A primary theme of this book is to provide a unified approach to the applications of Petri nets in flexible and agile automation and in that regard a common notation and terminology is used. The book also allows readers to evaluate the benefits and applicability of state of the art Petri net methods and apply CAD tools to problems of interest. *Petri Nets in Flexible and Agile Automation* is not only an essential reference for researchers it is also a very useful tool for engineers analysts and managers who are responsible for the design implementation and operation of the next generation of manufacturing systems.

Integration of Software Specification Techniques for Applications in Engineering Hartmut Ehrig, Werner Damm, Jörg Desel, Martin Große-Rhode, Wolfgang Reif, Eckehard Schnieder, Engelbert Westkämper, 2011-04-05. This book constitutes the documentation of the scientific outcome of the priority program Integration of Software Specification Techniques for Applications in Engineering sponsored by the German Research Foundation DFG. It includes main contributions of the projects of the priority program and of additional international experts in the field. Some of the papers included were presented at the related Third International Workshop on the topic INT 2004 held in Barcelona Spain in March 2004. The 25 revised full papers presented together with 6 section introductions by the volume editors were carefully reviewed and selected for inclusion in the book. The papers are organized in topical sections on reference case study production automation reference case study traffic control systems petri nets and related approaches in engineering charts verification and integration modeling.

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