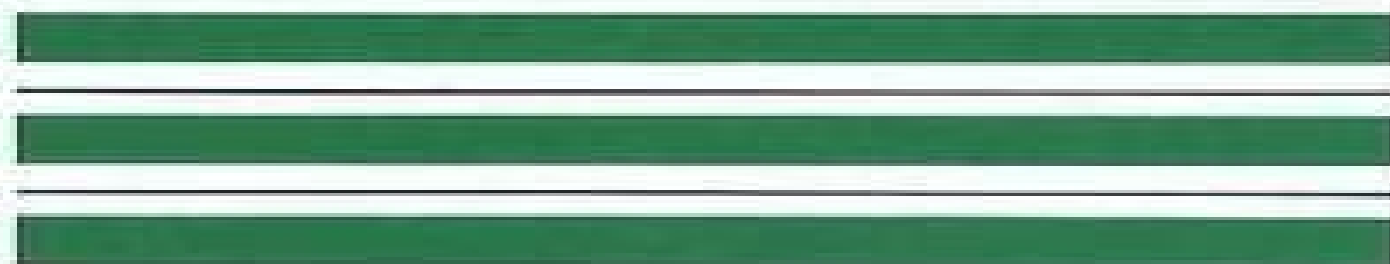


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# **Supervisory Control of Discrete Event Systems Using Petri Nets**

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**John O. MOODY**  
**Panos J. ANTSAKLIS**



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# Supervisory Control Of Discrete Event Systems Using Petri Nets

**Carla Seatzu, Manuel Silva, Jan H. van Schuppen**



## **Supervisory Control Of Discrete Event Systems Using Petri Nets:**

**Supervisory Control of Discrete Event Systems Using Petri Nets** John O. Moody, Panos J. Antsaklis, 2012-12-06  
Supervisory Control of Discrete Event Systems Using Petri Nets presents a novel approach to its subject. The concepts of supervisory control and discrete event systems are explained and the background material on general Petri net theory necessary for using the book's control techniques is provided. A large number of examples is used to illustrate the concepts and techniques presented in the text and there are plenty of references for those interested in additional study or more information on a particular topic. Supervisory Control of Discrete Event Systems Using Petri Nets is intended for graduate students, advanced undergraduates and practicing engineers who are interested in the control problems of manufacturing, communication and computer networks, chemical process plants and other high level control applications. The text is written from an engineering perspective but it is also appropriate for students of computer science, applied mathematics or economics. The book contains enough background material to stand alone as an introduction to supervisory control with Petri nets but it may also be used as a supplemental text in a course on discrete event systems or intelligent autonomous control.

**Control of Discrete-Event Systems** Carla Seatzu, Manuel Silva, Jan H. van Schuppen, 2012-07-27  
Control of Discrete event Systems provides a survey of the most important topics in the discrete event systems theory with particular focus on finite state automata, Petri nets and max plus algebra. Coverage ranges from introductory material on the basic notions and definitions of discrete event systems to more recent results. Special attention is given to results on supervisory control, state estimation and fault diagnosis of both centralized and distributed decentralized systems developed in the framework of the Distributed Supervisory Control of Large Plants (DISC) project. Later parts of the text are devoted to the study of congested systems through fluidization and over approximation, allowing a much more efficient study of observation and control problems of timed Petri nets. Finally, the max plus algebraic approach to the analysis and control of choice free systems is also considered. Control of Discrete event Systems provides an introduction to discrete event systems for readers that are not familiar with this class of systems but also provides an introduction to research problems and open issues of current interest to readers already familiar with them. Most of the material in this book has been presented during a Ph.D. school held in Cagliari, Italy, in June 2011.

**Supervision of Petri Nets** Geert Stremersch, 2012-12-06  
Supervision of Petri Nets presents supervisory control theory for Petri nets with a legal set as the control goal. Petri nets model discrete event systems, dynamic systems whose evolution is completely determined by the occurrence of discrete events. Control laws which guarantee that the system meets a set of specifications in the presence of uncontrollable and unobservable events are studied and constructed using application areas such as automated manufacturing and transportation systems. Supervision of Petri Nets introduces a new and mathematically sound approach to the subject. Existing results are unified by proposing a general mathematical language that makes extensive use of order theoretical ideas and numerous new results are described.

including ready to use algorithms that construct supervisory control laws for Petri nets Supervision of Petri Nets is an excellent reference for researchers and may also be used as a supplementary text for advanced courses on control theory

**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 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 **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 The ories and applications of synthesis have been studied and developped 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 prac tical 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 man ufacturing systems or the implementation of protocols in software or in hard ware

*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 livenessen forcing 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

Control Systems, Robotics and Automation - Volume XV Heinz D. Unbehauen,2009-10-11 This Encyclopedia of Control Systems Robotics and Automation is a component of the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias This 22 volume set contains 240 chapters each of size 5000 30000 words with perspectives applications and extensive illustrations It is the only publication of its kind carrying state of the art knowledge in the fields of Control Systems Robotics and Automation and is aimed by virtue of the several applications at the following five major target audiences University and College Students Educators Professional Practitioners Research Personnel and Policy Analysts Managers and Decision Makers and NGOs

**Supervisory Control of Concurrent Systems** Marian Iordache,Panos J. Antsaklis,2007-06-04 Increasing complexity in engineering projects raises difficult challenges in industry and requires effective tools for correct by construction design or design verification This book addresses the design of such tools for correct by construction synthesis of supervisors for systems and specifications represented in the discrete event framework The approach employed uses Petri nets as discrete event models and structural methods for the synthesis of supervisors and may lead to significant computational benefits Highlighting recent progress in the design of supervisors by structural methods the book represents a novel contribution to the field One of the main features of the presentation is the demonstration that structural methods can address a variety of supervisor specifications under diverse supervision settings The work is self contained and includes necessary background on Petri nets and supervision Requiring only basic knowledge of undergraduate level discrete mathematics the text is accessible to a broad audience Researchers and developers from various engineering fields may find effective means to reduce the complexity of design problems in the discrete event setting Graduate students may use the work as a self study reference and portions of the text may be used in advanced courses on discrete event systems

**Estimation and Inference in Discrete Event Systems** Christoforos N. Hadjicostis,2019-10-02 Estimation and Inference in Discrete Event Systems chooses a popular model for

emerging automation systems finite automata under partial observation and focuses on a comprehensive study of the key problems of state estimation and event inference The text includes treatment of current delayed and initial state estimation Related applications for assessing and enforcing resiliency fault detection and diagnosis and security privacy and opacity properties are discussed enabling the reader to apply these techniques in a variety of emerging applications among them automated manufacturing processes intelligent vehicle highway systems and autonomous vehicles The book provides a systematic development of recursive algorithms for state estimation and event inference The author also deals with the verification of pertinent properties such as the ability to determine the exact state of a system detectability the ability to ensure that certain classes of faults can be detected identified diagnosability and the ability to ensure that certain internal state variables of the system remain hidden from the outside world regardless of the type of activity that is taking place opacity This book allows students researchers and practicing engineers alike to grasp basic aspects of state estimation in discrete event systems aspects like distributivity and probabilistic inference quickly and without having to master the entire breadth of models that are available in the literature

**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

**Supervisory Control and Scheduling of Resource Allocation Systems** Bo Huang, MengChu Zhou, 2020-07-28  
Presents strategies with reachability graph analysis for optimizing resource allocation systems Supervisory Control and Scheduling of Resource Allocation Systems offers an important guide to Petri net PN models and methods for supervisory control and system scheduling of resource allocation systems RASs Resource allocation systems are common in automated manufacturing systems project management systems cloud data centers and software engineering systems The authors two experts on the topic present a definition techniques models and state of the art applications of supervisory control and scheduling problems The book introduces the basic concepts and research background on resource allocation systems and Petri nets The authors then focus on the deadlock free supervisor synthesis for RASs using Petri nets The book also investigates the heuristic scheduling of RASs based on timed Petri nets Conclusions and open problems are provided in the last section of the book This important book Includes multiple methods for supervisory control and scheduling with reachability graphs and provides illustrative examples Reveals how to accelerate the

supervisory controller design and system scheduling of RASs based on PN reachability graphs with optimal or near optimal results Highlights both solution quality and computational speed in RAS deadlock handling and system scheduling Written for researchers engineers scientists and professionals in system planning and control engineering operation and management Supervisory Control and Scheduling of Resource Allocation Systems provides an essential guide to the supervisory control and scheduling of resource allocation systems RASs using Petri net reachability graphs which allow for multiple resource acquisitions and flexible routings

**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 St phane Lafortune is Professor of Electrical Engineering and Computer Science at the University of Michigan Ann Arbor

*Application and Theory of Petri Nets and Concurrency* Jose-Manuel Colom,Jörg Desel,2013-06-19 This book constitutes the refereed proceedings of the 34th International Conference on Applications and Theory of Petri Nets and Concurrency PETRI NETS 2013 held in Milan Italy in June 2013 The 18 regular papers and 2 tool papers presented were carefully reviewed and selected from 56 submissions The book also contains 2 invited talks All current issues on research and development in the area of Petri nets and related models of concurrent systems are addressed

**Hybrid Systems V** Panos J. Antsaklis,Wolf Kohn,Michael Lemmon,Anil Nerode,Shankar Sastry,2003-07-31 This book constitutes the strictly refereed post proceedings of the 5th International Hybrid Systems Workshop held in Notre Dame Indiana USA in September 1998 The 23 revised full papers presented in the book have gone through two rounds of thorough reviewing and revision The volume presents state of the art research results and particularly addresses such areas as

program verification concurrent and distributed processes logic programming logics of programs discrete event simulation calculus of variations optimization differential geometry Lie algebras automata theory dynamical systems 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     **The Control**

**Handbook** William S. Levine, 2017-12-19 At publication The Control Handbook immediately became the definitive resource that engineers working with modern control systems required Among its many accolades that first edition was cited by the AAP as the Best Engineering Handbook of 1996 Now 15 years later William Levine has once again compiled the most comprehensive and authoritative resource on control engineering He has fully reorganized the text to reflect the technical advances achieved since the last edition and has expanded its contents to include the multidisciplinary perspective that is making control engineering a critical component in so many fields Now expanded from one to three volumes The Control Handbook Second Edition brilliantly organizes cutting edge contributions from more than 200 leading experts representing every corner of the globe The first volume Control System Fundamentals offers an overview for those new to the field but is also of great value to those across any number of fields whose work is reliant on but not exclusively dedicated to control systems Covering mathematical fundamentals defining principles and basic system approaches this volume Details essential background including transforms and complex variables Includes mathematical and graphical models used for dynamical systems Covers analysis and design methods and stability testing for continuous time systems Delves into digital control and discrete time systems including real time software for implementing feedback control and programmable controllers Analyzes design methods for nonlinear systems As with the first edition the new edition not only stands as a record of accomplishment in control engineering but provides researchers with the means to make further advances Progressively organized the other two volumes in the set include Control System Applications Control System Advanced Methods

*Coding Approaches to Fault Tolerance in Combinational and Dynamic Systems* Christoforos N. Hadjicostis, 2012-12-06 Coding Approaches to Fault Tolerance in Combinational and Dynamic Systems describes coding approaches for designing



fault tolerant systems i.e. systems that exhibit structured redundancy that enables them to distinguish between correct and incorrect results or between valid and invalid states Since redundancy is expensive and counter intuitive to the traditional notion of system design the book focuses on resource efficient methodologies that avoid excessive use of redundancy by exploiting the algorithmic dynamic structure of a particular combinational or dynamic system The first part of Coding Approaches to Fault Tolerance in Combinational and Dynamic Systems focuses on fault tolerant combinational systems providing a review of von Neumann's classical work on Probabilistic Logics including some more recent work on noisy gates and describing the use of arithmetic coding and algorithm based fault tolerant schemes in algebraic settings The second part of the book focuses on fault tolerance in dynamic systems Coding Approaches to Fault Tolerance in Combinational and Dynamic Systems also discusses how in a dynamic system setting one can relax the traditional assumption that the error correcting mechanism is fault free by using distributed error correcting mechanisms The final chapter presents a methodology for fault diagnosis in discrete event systems that are described by Petri net models coding techniques are used to quickly detect and identify failures From the Foreword Hadjicostis has significantly expanded the setting to processes occurring in more general algebraic and dynamic systems The book responds to the growing need to handle faults in complex digital chips and complex networked systems and to consider the effects of faults at the design stage rather than afterwards George Verghese Massachusetts Institute of Technology Coding Approaches to Fault Tolerance in Combinational and Dynamic Systems will be of interest to both researchers and practitioners in the area of fault tolerance systems design and control

*Discrete Event Systems: Modeling and Control* S. Balemi, P. Kozák, R. Smedinga, 2012-12-06 Research of discrete event systems is strongly motivated by applications in flexible manufacturing in traffic control and in concurrent and real time software verification and design just to mention a few important areas Discrete event system theory is a promising and dynamically developing area of both control theory and computer science Discrete event systems are systems with non numerically valued states inputs and outputs The approaches to the modelling and control of these systems can be roughly divided into two groups The first group is concerned with the automatic design of controllers from formal specifications of logical requirements This research owes much to the pioneering work of P. J. Ramadge and W. M. Wonham at the beginning of the eighties The second group deals with the analysis and optimization of system throughput waiting time and other performance measures for discrete event systems The present book contains selected papers presented at the Joint Workshop on Discrete Event Systems WODES 92 held in Prague Czechoslovakia on August 26-28 1992 and organized by the Institute of Information Theory and Automation of the Czechoslovak Academy of Sciences Prague Czechoslovakia by the Automatic Control Laboratory of the Swiss Federal Institute of Technology ETH Zurich Switzerland and by the Department of Computing Science of the University of Groningen Groningen the Netherlands

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 motivate 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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