However, while the book is somewhat restricted in its coverage, what it does cover it covers in great depth. I would consider this book to be must-read material for those directly involved in track-following or track-seeking controller design. The structural decomposition approach employed for linear systems provides an effective development framework for the authors' robust and perfect tracking (RPT) controller. The coverage of composite nonlinear feedback, which consists of a linear controller in parallel with a nonlinear controller, is excellent, and the authors make a compelling case for its use in practice. While the Preface comments that a senior or first-year graduate course on control would be appropriate background, I found the mathematical treatment to be quite dense, and would recommend this book only to those who have had graduate courses in both linear and nonlinear control. Thankfully, all of the control approaches presented in the book have convenient Matlab implementations in the authors' downloadable toolbox.

CONCLUSIONS

As a whole, *Hard Disk Drive Servo Systems* is an invaluable addition to the practicing servo engineer's library. Its theoretical focus means that the book may find an audience outside of the disk drive industry, but its mathematical rigor may be too much for an engineer without graduate education. The book should not be misconstrued as an introductory or comprehensive book on disk drive servo control problems. Perhaps the most valuable contributions are the Matlab control toolbox and the benchmark problem. With these tools, the authors' claims can be tested and their results expanded upon.

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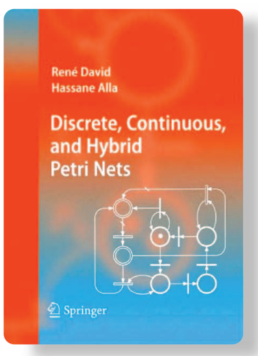

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Discrete, Continuous and Hybrid Petri Nets

by RENÉ DAVID and HASSANE ALLA

Petri nets (PNs) have been one of the most popular formalisms for modeling and analyzing discrete-event system (DES) dynamics [1]. Since the introduction in the early 1960s of the basic PN model by the German mathematician Carl Adam Petri, PNs have been studied, applied, and investigated by researchers in many engineering disciplines. This fact is reflected by the multitude of conferences and journals that constitute venues for PN-related research. Furthermore, the intensity of this research activity, combined with the diversity of the underlying applications and the methodological background of the researchers, has led to a proliferation of extensions and variations of the original model. Hence, these days, we talk about extended PNs, colored PNs, timed PNs, continuous PNs, and hybrid PNs. These variations enhance the modeling capabilities of the original framework, provide a more compact representation of the underlying dynamics, and offer approximating representations that are computationally more efficient than the original model. In other cases, such as those of marked graphs and free-choice PNs, the considered variations are actually restrictions of the original model, defined and investigated in an effort to trade modeling power and flexibility for analytical tractability.

This model proliferation has occasionally been a source of confusion and disorientation, especially for novice researchers who have to familiarize themselves with variations of apparently similar concepts, which are often presented in a haphazard manner and under different terminologies. Hence, the emergence of a textbook that seeks to establish order in this model cornucopia by organizing them in a unifying taxonomy and by establishing consistency among them is a welcome event. This contribution is even more significant when offered by two of the leading researchers in the field who have not only contributed extensively to its growth through their personal research but have also incubated an entire generation of researchers in the area. Finally, it is a delightful event when one experiences the clarity, immediacy, and engaging style of its material.

THE BOOK OBJECTIVES

As stated in the preface by René David and Hassane Alla:

> When writing this book, the authors were guided by two main goals: The first one is to start from the basics of Petri nets and to reach an accurate understanding of

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continuous and hybrid Petri nets, while preserving consistency of basic concepts throughout the book… This homogeneity of concepts provides a *unifying framework for all the models presented*. The second goal of the authors is to present a didactic tutorial which is easy to understand due to many simple examples and detailed figures.

The authors have excelled in both of these goals. The text provides the unifying perspective for all of the predominant variations of the PN modeling framework while highlighting the differentiating elements among them and the implied relationships. At the same time, the book fills a gap in the existing PN literature on continuous and hybrid PNs, two areas that seem to be picking up in research momentum and application potential.

BOOK CONTENT

The first chapter introduces the basic concepts appearing in the original PN modeling framework of autonomous and ordinary PNs. In particular, the concepts of places, transitions, arcs, markings, and transition fireability are discussed, and it is shown how these concepts can model and visualize behavioral aspects such as parallelism, concurrency, synchronization, conflict, and resource sharing. Subsequently, the second part of the chapter discusses the primary variations of the original model that can be obtained either through restriction of the underlying net structure or through extension of the model semantics and dynamics. These variations include state graphs; event or marked graphs; conflict-free, free-choice, simple and pure PNs; generalized, finite-capacity, colored, extended and priority PNs; and nonautonomous, continuous, and hybrid PNs.

Chapter 2 proceeds to a more formal characterization of the autonomous ordinary PN model and introduces the structural and behavioral properties that have been typically associated with the model. Liveness, boundedness, safety, deadlock and deadlock-freedom, quasi-liveness, reversibility, and home states are formally defined, and their meaning and significance are highlighted with pertinent examples. Invariants and their role in shaping the system dynamics are also introduced. The second part of the chapter focuses on the methodological approaches for investigating the aforementioned properties on autonomous and ordinary PNs, primarily addressing the classical approaches based on the deployment and analysis of the coverability tree, as well as algebraic techniques based on the fundamental (state) equation and the net invariants. The last part of the chapter introduces more specialized but rather classical, by now, results, such as those concerning the liveness of state graphs, event graphs, and free-choice PNs.

Chapter 3 addresses nonautonomous PNs, whose dynamics are affected by externally triggered events or the mere passage of time. The first class of these models is characterized as synchronized PNs, while the second is characterized as timed PNs. This chapter also covers a third class of nonautonomous PN models characterized as interpreted PNs. This last class highlights the ability of the PN modeling framework to support the design and deployment of logic controllers, as well as its affinity with the *Grafcet* model, which, since 1987, has evolved to an International Standard for industrial control logic specification. Through an elegant development, the authors first show how the synchronized PNs can be obtained from the original class of autonomous PNs by conditioning the firing of the net transitions to the occurrence of some external events, and, subsequently, the remaining two classes are shown to be particular variations of the synchronized PN model.

Chapter 4 deals with autonomous continuous and hybrid PNs. These PNs are introduced as a limit model for a sequence of PN models that are obtained from an initial autonomous discrete PN model by splitting each of its tokens into n parts and letting $n \to \infty$. The resulting model is suggested as a pertinent approximation of the behavior exhibited by its discrete counterpart when the number of tokens in it grows to substantially large values, thus rendering the analysis of that model practically intractable. Continuous PNs can also capture the dynamics of naturally continuous flows in a controlled network, a model that becomes even more interesting when time is introduced in it, as discussed below. On the other hand, hybrid PNs result from the integration of continuous and discrete PN modeling components in a single model, and they enable the modeling of continuous flows under different regimes, which are communicated to the model through the marking of the discrete part of the net. An interesting part of this chapter concerns the introduction and formal characterization of dynamics and properties of the continuous PN model that concern its asymptotic behavior and constitute a manifestation of Zeno's paradox in this class of systems.

Chapters 5 and 6 introduce timed dynamics respectively in continuous and hybrid PNs, while Chapter 7 further extends the model of Chapter 6 so that the firing speeds of the model transitions can depend on the net marking. The key theme for these three chapters is the development of the semantics and algorithms that enable an efficient characterization of the behavioral evolution of the considered models, at least in the cases for which this behavioral evolution is effectively computable.

A brief postface epitomizes the key aspects and intended use of the presented material, and highlights the existing relationships among the different models. Each chapter closes with a "Notes and References" section, which positions the chapter material with respect to the available literature and provides additional historical perspectives. Finally, the book is supported with 15 appendices treating topics that include regular expressions and languages, conflict resolution, elements of graph theory, Grafcet, the linearity of the fundamental equation for continuous PNs, the graph of relations among conflicts, and piecewise constant maximal firing speeds.

PRESENTATION CONSIDERATIONS

As for the second objective set by the authors, that of developing a *didactic tutorial* supported by many simple examples and detailed figures, I was impressed by the final outcome. The authors have demonstrated the ability to integrate concrete discussion focusing on motivational and explanatory examples with more theoretically abstract material in a seamless flow that makes reading the book a pleasant and captivating experience. I felt I was attending a well-planned and delivered lecture from two masters in the field. The book tends to become a little tedious in the last three chapters, but this aspect is mainly due to the nature and inherent complexity of the presented material. Furthermore, the provided illustrations and the accompanying legends are effective in elucidating the concepts and ideas discussed in the text. Several exercises provided at the end of the book together with their solutions reinforce the material presented in the chapters and demonstrate its implementation in various application contexts. Finally, three extensive case studies taken from the relevant literature further highlight the efficacy and expressive power of hybrid PNs as a modeling framework, while allowing the reader to experience some of the challenges arising from the complexity that is inherent in the real-world settings.

All the above-mentioned features make the book by David and Alla a substantial contribution to the PN-related literature. The book offers a unifying perspective and an educational basis for many developments in the field, including some novel and not-well-documented areas. Furthermore, the book's value is enhanced by its lucidity and its approachable and engaging style.

CLOSING THOUGHTS

In the last part of this review, I want to discuss some further thoughts that were instigated by the reading of the book, and, while I do not intend by any means to degrade the contributions and qualities of its material, they highlight additional challenges, or, when viewed from a more positive angle, *opportunities*, for the PN-based research community regarding the development of textbooks and broader educational material. At the very end, this book is about PN semantics and their ability to provide a detailed characterization of the evolution of the dynamics of the underlying system. The coverage of the properties of the various PN classes addressed in the text is rather low key, and confined to basic characterizations and to classical and frequently obvious results. In this way, the book seems to reinforce a perception that exists in the broader academic community that the key strength and value of the PN paradigm is its ability to provide a simulation platform with well-defined semantics and primitive constructs. In fact, this position seems to be advocated by the authors themselves, when they remark in their postface discussion on the functionality and value of the presented PN models, that:

> PNs, supporting various types of formalism, form a conceptual framework for modeling discrete event dynamic systems, called *the Petri net paradigm* … Each model has its own specific character and special fields of application. Nevertheless, *Petri nets* form a common basis: they can be likened to a "common language" allowing dialog between people with very varied training backgrounds.

My personal experiences suggest that defining PNs primarily as a modeling and simulation framework compromises their analytical value and weakens their potential for acceptance in the different curricula. This impression is especially true in recent years, where the advent of object-oriented simulation and the emergence of several commercially available simulation platforms have drawn the average modeler away from the PN paradigm, as they make it look too esoteric and nonuser friendly. In a similar vein, several research communities have opted for the definition of their own, rather ad hoc semantics, dismissing the PN modeling framework as too esoteric and cumbersome [3].

On the other hand, PNs offer extensive analytical power, especially regarding the study of the qualitative dynamics of the underlying system. This power stems from their semantic richness and specificity, as well as from their strong mathematical foundation, and it enables the formal characterization and assessment of various behavioral properties, such as choice and conflict, liveness, boundedness, safety, and deadlock-freedom. In many cases, this power also enables the explicit connection of these properties to the structure of the underlying system, an important and almost unique attribute within the scope of the most commonly used DES models. Furthermore, the last 15–20 years have seen the emergence of a large body of results that have substantially expanded the aforementioned analytical capabilities of PNs, especially for certain net classes and problems of practical interest, as demonstrated by the examples in [4]–[9]. At the same time, works such as [10]–[12] have sought to transfer to the PN modeling framework another body of results that were originally developed in the context of statistics and stochastic processes, thus enhancing their power to model and analyze the effects of the variability that is inherent in most real-world applications.

The PN community would benefit tremendously from a collective initiative that systematically takes stock of all of these more analytical developments in the field, evaluate their strengths and weaknesses, and proactively produce textbooks and other supportive educational material that would render these developments prominent and easily accessible to the broader scientific and engineering community. The book by David and Alla is a first step along these lines, since it establishes the integrity of the field and, thus, a solid basis for grounding a future effort. It remains for the PN community to exploit and transcend the potential offered by this book in order to strengthen its image within the academic community and fulfill its expected impact on the engineering practice.

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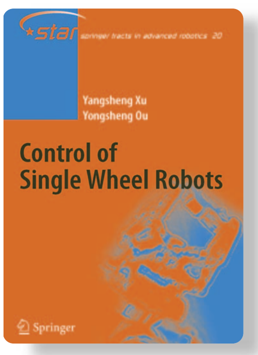

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Control of Single Wheel Robots

by YANGSHENG XU and YONGSHEN OU

There are numerous mobile robots that use wheels for propulsion and support, but almost all of them use two or more wheels. The title of this book seems to imply that there are several robots using the absolute minimum number of wheels, namely, one. In fact, the book deals with a particular type of robot consisting of a single wheel with a mechanism inside suspended from the axle providing a means for driving the wheel and containing a spinning flywheel that can be tilted to provide balance and steering. The idea for such a robot originated at Carnegie Mellon University, but the book relates the research efforts of the authors and their colleagues at the Chinese University of Hong Kong. The book describes three prototypes of this single-wheel robot but no other examples.

The authors make the case that this type of robot could be very practical since it is narrow, might be able to traverse rough terrain, and could even be made to float on water, but I doubt that many people would find these arguments convincing. Human beings can learn to ride a unicycle, but it is hard to think of a situation where the unicycle is more practical than a bicycle or other multiwheeled vehicle. Of course, a rapidly rolling wheel is stable due to gyroscopic action and could probably be steered using internal weight shifts, but stability is lost at low speeds, and the problem of maintaining an upright posture and steering at low or zero speed is not easily solved. The real interest in the book lies in the careful analysis of the dynamics of a complex multibody system as well as in the control of an unstable system.

CONTENTS

The analytical portion of the book begins in Chapter 2. Figure 2.1 shows a bewildering set of coordinate systems as well as angles and angular rates necessary to describe the system. It is always a problem for anybody to show a perspective drawing of a complex three-dimensional problem and to make clear exactly how the various angles are defined. I found it difficult to determine exactly the directions of the many vectors and hence to determine just how the angles were defined. It would have been helpful if some extra drawings showing the angles in true perspective had been shown. I used to think I could visualize vectors in three dimensions better than most people, but after some study I still was not clear on the definition of some angles.

The next step is to derive the equations of motion using a constrained generalized Lagrangian formulation. The complexity of these equations is impressive. In later studies various simplifications are made, and several computer simulations are made and compared with experiment. The remainder of the book deals with control topics.

Chapter 3 deals with model-based control considering both linearized and nonlinear versions of the equations of motion.

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