Stochastic Hybrid Systems:
Modeling, analysis, and applications to networks and biology

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Stochastic Hybrid Systems

Leonhard Asselborn

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Stochastic Hybrid Systems ,2010   **Theory of Hybrid Systems: Deterministic and Stochastic** Mohamad S. Alwan,Xinzhi Liu,2018-10-04 This book is the first to present the application of the hybrid system theory to systems with EPCA equations with piecewise continuous arguments The hybrid system paradigm is a valuable modeling tool for describing a wide range of real world applications Moreover although new technology has produced and continues to produce highly hierarchical sophisticated machinery that cannot be analyzed as a whole system hybrid system representation can be used to reduce the structural complexity of these systems That is to say hybrid systems have become a modeling priority which in turn has led to the creation of a promising research field with several application areas As such the book explores recent developments in the area of deterministic and stochastic hybrid systems using the Lyapunov and Razumikhin Lyapunov methods to investigate the systems properties It also describes properties such as stability stabilization reliable control H infinity optimal control input to state stability ISS stabilization state estimation and large scale singularly perturbed systems   Stochastic Hybrid Systems Henk A.P. Blom,John Lygeros,2006-07-28 This volume presents a number of fundamental theoretical advances in the area of stochastic hybrid systems motivated primarily from applications to air traffic management Air traffic is arguably the most challenging application area for stochastic hybrid systems since it requires handling complex distributed systems multiple human in the loop elements and hybrid dynamics The editors have collected key contributions which define the state of the art present novel directions and highlight emerging application areas   *Stochastic Hybrid Systems* Henk A.P. Blom,2006-06-19 Stochastic hybrid systems involve the coupling of discrete logic based continuous and probabilistic phenomena Because of their versatility and generality methods for modelling and analysis of stochastic hybrid systems have proved invaluable in a wide range of applications including finance air traffic control biology telecommunications and embedded systems Success stories in these application areas have made stochastic hybrid systems a very important rapidly growing and dynamic research field since the beginning of the century bridging the gap between stochastic analysis computer science and control engineering This volume presents a number of fundamental theoretical advances in the area of stochastic hybrid systems motivated primarily from applications to air traffic management Air traffic is arguably the most challenging application area for stochastic hybrid systems since it requires handling complex distributed systems multiple human in the loop elements and hybrid dynamics The editors have collected key contributions which define the state of the art present novel directions and highlight emerging application areas   **Analysis of Stochastic Hybrid Systems** Alessandro Abate,2004   *Stochastic Hybrid Systems* Christos G. Cassandras,John Lygeros,2018-10-03 Because they incorporate both time and event driven dynamics stochastic hybrid systems SHS have become ubiquitous in a variety of fields from mathematical finance to biological processes to communication networks to engineering Comprehensively integrating numerous cutting edge studies Stochastic Hybrid Systems presents a captivating treatment of some of the most

ambitious types of dynamic systems Cohesively edited by leading experts in the field the book introduces the theoretical basics computational methods and applications of SHS It first discusses the underlying principles behind SHS and the main design limitations of SHS Building on these fundamentals the authoritative contributors present methods for computer calculations that apply SHS analysis and synthesis techniques in practice The book concludes with examples of systems encountered in a wide range of application areas including molecular biology communication networks and air traffic management It also explains how to resolve practical problems associated with these systems Stochastic Hybrid Systems achieves an ideal balance between a theoretical treatment of SHS and practical considerations The book skillfully explores the interaction of physical processes with computerized equipment in an uncertain environment enabling a better understanding of sophisticated as well as everyday devices and processes *Stochastic Reachability Analysis of Hybrid Systems* Luminita Manuela Bujorianu,2012-04-23 Stochastic reachability analysis SRA is a method of analyzing the behavior of control systems which mix discrete and continuous dynamics For probabilistic discrete systems it has been shown to be a practical verification method but for stochastic hybrid systems it can be rather more As a verification technique SRA can assess the safety and performance of for example autonomous systems robot and aircraft path planning and multi agent coordination but it can also be used for the adaptive control of such systems Stochastic Reachability Analysis of Hybrid Systems is a self contained and accessible introduction to this novel topic in the analysis and development of stochastic hybrid systems Beginning with the relevant aspects of Markov models and introducing stochastic hybrid systems the book then moves on to coverage of reachability analysis for stochastic hybrid systems Following this build up the core of the text first formally defines the concept of reachability in the stochastic framework and then treats issues representing the different faces of SRA stochastic reachability based on Markov process theory martingale methods stochastic reachability as an optimal stopping problem and dynamic programming The book is rounded off by an appendix providing mathematical underpinning on subjects such as ordinary differential equations probabilistic measure theory and stochastic modeling which will help the non expert mathematician to appreciate the text Stochastic Reachability Analysis of Hybrid Systems characterizes a highly interdisciplinary area of research and is consequently of significant interest to academic researchers and graduate students from a variety of backgrounds in control engineering applied mathematics and computer science The Communications and Control Engineering series reports major technological advances which have potential for great impact in the fields of communication and control It reflects research inindustrial and academic institutions around the world so that the readership can exploit new possibilities as they become available **On Detection, Estimation, and Control of Stochastic Hybrid Systems** Gary Kalmanovich,1995 Control of Stochastic Hybrid Systems Based on Probabilistic Reachable Set Computation Leonhard Asselborn,2018 *On Singularly Perturbed Stochastic Hybrid Systems* Ching-Chih Tsai,1991 **Control of Stochastic Hybrid Systems based on Probabilistic Reachable Set Computation** Leonhard

Asselborn,2018-09-17 This thesis proposes an algorithmic controller synthesis based on the computation of probabilistic reachable sets for stochastic hybrid systems Hybrid systems consist in general of a composition of discrete and continuous valued dynamics and are able to capture a wide range of physical phenomena The stochasticity is considered in form of normally distributed initial continuous states and normally distributed disturbances resulting in stochastic hybrid systems The reachable sets describe all states which are reachable by a system for a given initialization of the system state inputs disturbances and time horizon For stochastic hybrid systems these sets are probabilistic since the system state and disturbance are random variables This thesis introduces probabilistic reachable sets with a predefined confidence which are used in an optimization based procedure for the determination of stabilizing control inputs Besides the stabilizing property the controlled dynamics also observes input constraints as well as so called chance constraints for the continuous state The main contribution of this thesis is the formulation of an algorithmic control procedure for each considerd type of stochastic hybrid systems where different discrete dynamics are considered First a control procedure for a deterministic system with bounded disturbances is introduced and thereafter a probabilistic distribution of the system state and the disturbance is assumed The formulation of probabilistic reachable sets with a predefined confidence is subsequently used in a control procedure for a stochastic hybrid system in which the switch of the continuous dynamics is externally induced Finally the control procedure based on reachable set computation is extended to a type of stochastic hybrid systems with autonomously switching of the continuous dynamics **Probabilistic Reachability for Stochastic Hybrid Systems** Alessandro Abate,2007 *Compositional Modelling of Stochastic Hybrid Systems* Stefan Nicolaas Strubbe,2005 *Scalable Safety Verification of Stochastic Hybrid Systems* Ratan Lal,2021 Stochastic hybrid systems consist of software controlled physical processes where uncertainties manifest due to either disturbance in the environment in which the physical systems operate or the noise in sensors actuators through which they interact with the software The safety analysis of such systems is challenging due to complex dynamics uncertainties and infinite state space This thesis introduces fully automated methods for bounded unbounded safety analysis of certain subclasses of the stochastic hybrid systems against given safety specifications Our first contribution is to compute the maximum minimum bounded probability of reachability of polyhedral probabilistic hybrid systems where plant dynamics are expressed as a set of linear constraints over the rate of state variables and uncertainties are involved in discrete transitions represented as discrete probability distributions over the set of locations modes Our broad approach is to encode all possible bounded probabilistic behaviors into an appropriate logic along with the given safety specifications Then we perform optimization over all possible behaviors for the maximum minimum probability via state of the art optimization solvers The second contribution is to present fully automatic unbounded safety analysis of the polyhedral probabilistic hybrid systems PHS We present a novel counterexample guided abstraction refinement CEGAR algorithm for polyhedral PHS Developing a CEGAR algorithm for the polyhedral PHS is complex owing to

the uncertainties in the discrete transitions and the infinite state space due to the real valued variables We present a practical algorithm by choosing a succinct representation for counterexamples an efficient validation algorithm and a constructive method for refinement that ensures progress towards the elimination of a spurious abstract counterexample The third contribution is to extend unbounded safety analysis to the class of linear probabilistic hybrid systems PHS Developing an abstraction for the linear PHS is a challenge when the dynamics is linear because the solutions are exponential and require solving exponential constraints to construct the finite state MDP Hence we consider a hierarchical abstraction where we first abstract a linear PHS to a polyhedral PHS using hybridization and then apply predicate abstraction to construct the finite state MDP Finally we consider uncertainties in plant dynamics and develop an abstraction based method for both bounded unbounded safety analysis of linear stochastic systems The bounded safety analysis is similar to the encoding in bounded model checking where we encode bounded stochastic behaviors instead of continuous behaviors and solve the encoding using a semi definite program solver For the unbounded safety analysis we abstract the linear stochastic system into a finite state system and analyze its safety using graph search algorithms **Qualitative Properties of Stochastic Hybrid Systems and Applications** Mohamad Alwan,2011 Hybrid systems with or without stochastic noise and with or without time delay are addressed and the qualitative properties of these systems are investigated The main contribution of this thesis is distributed in three parts In Part I nonlinear stochastic impulsive systems with time delay SISD with variable impulses are formulated and some of the fundamental properties of the systems such as existence of local and global solution uniqueness and forward continuation of the solution are established After that stability and input to state stability ISS properties of SISD with fixed impulses are developed where Razumikhin methodology is used These results are then carried over to discussed the same qualitative properties of large scale SISD Applications to automated control systems and control systems with faulty actuators are used to justify the proposed approaches Part II is devoted to address ISS of stochastic ordinary and delay switched systems To achieve a variety stability like results multiple Lyapunov technique as a tool is applied Moreover to organize the switching among the system modes a newly developed initial state dependent dwell time switching law and Markovian switching are separately employed Part III deals with systems of differential equations with piecewise constant arguments with and without random noise These systems are viewed as a special type of hybrid systems Existence and uniqueness results are first obtained Then comparison principles are established which are later applied to develop some stability results of the systems *Formal Verification and Control of Stochastic Hybrid Systems: Model-based and Data-driven Techniques* Ameneh Nejati,2023 **Stochastic Hybrid Systems : Stability and Stabilization** Boukas, El Kébir,Groupe d'études et de recherche en analyse des décisions (Montréal, Québec),2004 **Applications of Perturbation Analysis in Stochastic Hybrid Systems** Julia L. Fleck,Christos G. Cassandras,2016-10-18 **Robust Execution for Stochastic Hybrid Systems** Lars Blackmore,2008-12-01 cont For an important class of hybrid discrete continuous system

known as Jump Markov Linear Systems the resulting deterministic optimization can be posed as a Mixed Integer Linear Program and solved to global optimality using efficient commercially available solvers Our second contribution is active hybrid estimation subject to state plan constraints Exact hybrid state estimation in stochastic hybrid systems is in general intractable Tractable approximate hybrid estimation methods can lose track of the true hybrid state In this thesis we develop an active hybrid estimation capability which probes the system in order to reduce uncertainty in the hybrid state This approach generates control sequences to minimize the probability of approximate hybrid estimation losing the true mode sequence while ensuring that the state plan is satisfied subject to chance constraints In order to make this problem tractable we develop an analytic upper bound on the probability of losing the true mode sequence and use a convex constraint tightening approach to approximate the chance constraints in the problem Our final contribution is a novel hybrid model learning approach Specifying accurate hybrid system models is essential for accurate estimation and control but is also extremely challenging The hybrid executive must therefore determine hybrid system models from observed data In this thesis we present an approximate Expectation Maximization method for hybrid model learning this method extends prior approaches to deal with mode transitions that depend on the continuous state **Stochastic Hybrid Systems with Renewal Transitions** Mohammad Soltani,2018 Stochastic dynamics of several systems can be modeled via piecewise deterministic time evolution of the state interspersed by random discrete events Within this general class of systems we consider time triggered stochastic hybrid systems TTSHS where the state evolves continuously according to a linear dynamical system Discrete events occur based on an underlying renewal process timer and the intervals between successive events follow an arbitrary continuous probability density function Moreover whenever the event occurs the state is reset based on a linear affine transformation that allows for inclusion of state dependent and independent noise terms Traditional analysis of stochastic hybrid systems SHS relies heavily on various Monte Carlo simulation techniques which come at a significant computational cost Since one is often interested in computing only the lower order moments of the state variables much time and effort can be saved by directly computing these statistical moments without having to run Monte Carlo simulations Unfortunately moment calculations in SHS can be non trivial due to the problem of unclosed dynamics the time evolution of lower order moments of the state space depends on higher order moments In such cases moments are usually approximated by employing closure schemes that close the system of differential equations by approximating higher order moments as nonlinear functions of lower order moments The key contribution of this thesis is to develop novel methods for different classes of TTSHS for obtaining exact analytical expressions for the steady state moments along with derivation of necessary and sufficient conditions for the stability of statistical moments The method developed here is applied to a wide range of problems from systems biology to nano sensors Moreover we used TTSHS as an efficient tool to design a controller in the presence of disturbance noise and random discrete events in a system Finally for SHS models which cannot be solved

analytically we develop a new moment closure approach to approximate their moments with low approximation error

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