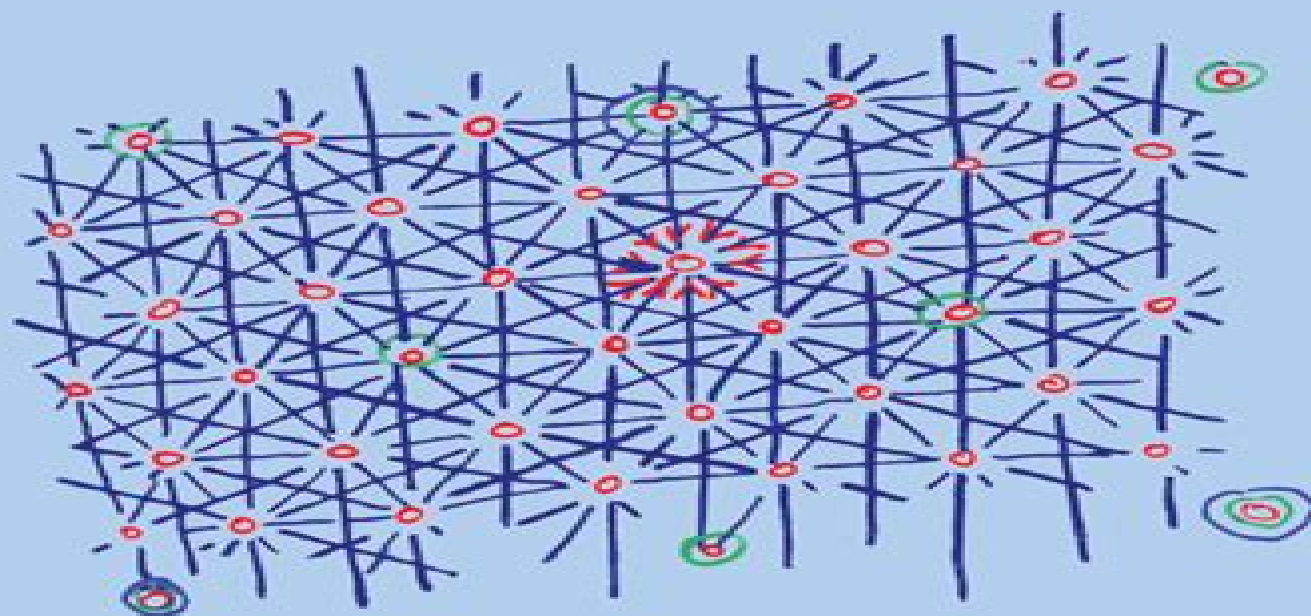


# Control Techniques FOR Complex Networks



Sean Meyn

# Control Techniques For Complex Networks

**Moises Rivas-Lopez, Wendy Flores F.**



## Control Techniques For Complex Networks:

Control Techniques for Complex Networks Sean P. Meyn, 2008      Control Techniques for Complex Networks Sean Meyn, 2008 From foundations to state of the art the tools and philosophy you need to build network models      *Methods and algorithms for control input placement in complex networks* Gustav Lindmark, 2018-09-05 The control theoretic notion of controllability captures the ability to guide a systems behavior toward a desired state with a suitable choice of inputs Controllability of complex networks such as traffic networks gene regulatory networks power grids etc brings many opportunities It could for instance enable improved efficiency in the functioning of a network or lead to that entirely new applicative possibilities emerge However when control theory is applied to complex networks like these several challenges arise This thesis consider some of these challenges in particular we investigate how control inputs should be placed in order to render a given network controllable at a minimum cost taking as cost function either the number of control inputs or the energy that they must exert We assume that each control input targets only one node called a driver node and is either unconstrained or unilateral A unilateral control input is one that can assume either positive or negative values but not both Motivated by the many applications where unilateral controls are common we reformulate classical controllability results for this particular case into a more computationally efficient form that enables a large scale analysis We show that the unilateral controllability problem is to a high degree structural and derive theoretical lower bounds on the minimal number of unilateral control inputs from topological properties of the network similar to the bounds that exists for the minimal number of unconstrained control inputs Moreover an algorithm is developed that constructs a near minimal number of control inputs for a given network When evaluated on various categories of random networks as well as a number of real world networks the algorithm often achieves the theoretical lower bounds A network can be controllable in theory but not in practice when completely unreasonable amounts of control energy are required to steer it in some direction For unconstrained control inputs we show that the control energy depends on the time constants of the modes of the network and that the closer the eigenvalues are to the imaginary axis of the complex plane the less energy is required for control We also investigate the problem of placing driver nodes such that the control energy requirements are minimized assuming that theoretical controllability is not an issue For the special case with networks having all purely imaginary eigenvalues several constructive algorithms for driver node placement are developed In order to understand what determines the control energy in the general case with arbitrary eigenvalues we define two centrality measures for the nodes based on energy flow considerations the first centrality reflects the network impact of a node and the second the ability to control it indirectly It turns out that whether a node is suitable as driver node or not largely depends on these two qualities By combining the centralities into node rankings we obtain driver node placements that significantly reduce the control energy requirements and thereby improve the practical degree of controllability      Analysis and Control of Output Synchronization for Complex Dynamical

Networks Jin-Liang Wang, Huai-Ning Wu, Tingwen Huang, Shun-Yan Ren, 2018-08-14 This book introduces recent results on output synchronization of complex dynamical networks with single and multiple weights. It discusses novel research ideas and a number of definitions in complex dynamical networks such as  $H_\infty$  output synchronization, adaptive coupling weights, multiple weights, the relationship between output strict passivity and output synchronization. Furthermore, it methodically edits the research results previously published in various flagship journals and presents them in a unified form. The book is of interest to university researchers and graduate students in engineering and mathematics who wish to study output synchronization of complex dynamical networks. *Handbook of Applications of Chaos Theory* Christos H.

Skiadas, Charilaos Skiadas, 2017-12-19 In addition to explaining and modeling unexplored phenomena in nature and society, chaos uses vital parts of nonlinear dynamical systems theory and established chaotic theory to open new frontiers and fields of study. *Handbook of Applications of Chaos Theory* covers the main parts of chaos theory along with various applications to diverse areas. Expert contributors from around the world show how chaos theory is used to model unexplored cases and stimulate new applications. Accessible to scientists, engineers, and practitioners in a variety of fields, the book discusses the intermittency route to chaos, evolutionary dynamics, and deterministic chaos, and the transition to phase synchronization, chaos. It presents important contributions on strange attractors, self-exciting and hidden attractors, stability theory, Lyapunov exponents, and chaotic analysis. It explores the state of the art of chaos in plasma physics, plasma harmonics, and overtone coupling. It also describes flows and turbulence, chaotic interference versus decoherence, and an application of microwave networks to the simulation of quantum graphs. The book proceeds to give a detailed presentation of the chaotic rogue and noisy optical dissipative solitons, parhelic-like circle, and chaotic light scattering, and interesting forms of the hyperbolic prism, the Poincaré disc, and foams. It also covers numerous application areas from the analysis of blood pressure data and clinical digital pathology to chaotic pattern recognition, to economics, to musical arts, and research. **Dynamical Behaviors of**

**Multiweighted Complex Network Systems** Jin-Liang Wang, Shun-Yan Ren, Huai-Ning Wu, Tingwen Huang, 2024-12-17 Highly comprehensive resource for studying neural networks, complex networks, synchronization, passivity, and associated applications. *Dynamical Behaviors of Multiweighted Complex Network Systems* discusses the dynamical behaviors of various multiweighted complex dynamical networks with detailed insight on synchronization for directed and undirected complex networks, CNs with multiple state or delayed state couplings, subject to recoverable attacks, along with passivity and synchronization for coupled neural networks with multiple weights, CNNMWs by virtue of devised proportional integral derivative PID controllers. The book also investigates finite time synchronization, FTS, and  $H_\infty$  synchronization for two types of coupled neural networks, CNNs, and focuses on finite time passivity, FTP, and finite time synchronization, FTS, for complex dynamical networks with multiple state derivative couplings based on the proportional derivative PD control method. Final chapters consider finite time output synchronization and  $H_\infty$  output synchronization problems and multiple

weighted coupled reaction diffusion neural networks CRDNNs with and without coupling delays Other topics covered in Dynamical Behaviors of Multiweighted Complex Network Systems include Criteria of FTP for complex dynamical networks with multiple state couplings CDNMSCs formulated by utilizing the PD controller Finite time passivity FTP concepts for the spatially and temporally systems with different dimensions of output and input FTS and finite time H infinity synchronization problems for CDNs with multiple state derivative couplings by utilizing state feedback control approach and selecting suitable parameter adjustment schemes Adaptive output synchronization and output synchronization of CDNs with multiple output or output derivative couplings and other adaptive control schemes Enabling readers to understand foundational concepts and grasp the latest research Dynamical Behaviors of Multiweighted Complex Network Systems is essential for all who study neural networks complex networks synchronization passivity and their applications **Information Computing**

**and Applications** Baoxiang Liu, Chunlai Chai, 2011-12-02 This book constitutes the refereed proceedings of the Second International Conference on Information Computing and Applications ICICA 2010 held in Qinhuangdao China in October 2011 The 97 papers presented were carefully reviewed and selected from numerous submissions They are organized in topical sections on computational economics and finance computational statistics mobile computing and applications social networking and computing intelligent computing and applications internet and Web computing parallel and distributed computing and system simulation and computing **Robust Control** Moises Rivas-Lopez, Wendy Flores F., 2016-07-06 The need to be tolerant to changes in the control systems or in the operational environment of systems subject to unknown disturbances has generated new control methods that are able to deal with the non parametrized disturbances of systems without adapting itself to the system uncertainty but rather providing stability in the presence of errors bound in a model With this approach in mind and with the intention to exemplify robust control applications this book includes selected chapters that describe models of H infinity loop robust stability and uncertainty among others Each robust control method and model discussed in this book is illustrated by a relevant example that serves as an overview of the theoretical and practical method in robust control **Complex Systems and Networks** Jinhu Lü, Xinghuo Yu, Guanrong Chen, Wenwu Yu, 2015-08-14 This elementary book provides some state of the art research results on broad disciplinary sciences on complex networks It presents an in depth study with detailed description of dynamics controls and applications of complex networks The contents of this book can be summarized as follows First the dynamics of complex networks for example the cluster dynamic analysis by using kernel spectral methods community detection algorithms in bipartite networks epidemiological modeling with demographics and epidemic spreading on multi layer networks are studied Second the controls of complex networks are investigated including topics like distributed finite time cooperative control of multi agent systems by applying homogenous degree and Lyapunov methods composite finite time containment control for disturbed second order multi agent systems fractional order observer design of multi agent systems chaos control and anticontrol of

complex systems via Parrondos game and many more Third the applications of complex networks provide some applicable carriers which show the importance of theories developed in complex networks In particular a general model for studying time evolution of transition networks deflection routing in complex networks recommender systems for social networks analysis and mining strategy selection in networked evolutionary games integration and methods in computational biology are discussed in detail

*Advances in Natural Computation, Fuzzy Systems and Knowledge Discovery* Ning Xiong, Maozhen Li, Kenli Li, Zheng Xiao, Longlong Liao, Lipo Wang, 2023-01-29 This book consists of papers on the recent progresses in the state of the art in natural computation fuzzy systems and knowledge discovery The book is useful for researchers including professors graduate students as well as R D staff in the industry with a general interest in natural computation fuzzy systems and knowledge discovery The work printed in this book was presented at the 2022 18th International Conference on Natural Computation Fuzzy Systems and Knowledge Discovery ICNC FSKD 2022 held from 30 July to 1 August 2022 in Fuzhou China All papers were rigorously peer reviewed by experts in the areas

*Nonlinear Pinning Control of Complex Dynamical Networks* Edgar N. Sanchez, Carlos J. Vega, Oscar J. Suarez, Guanrong Chen, 2021-08-19 This book presents two nonlinear control strategies for complex dynamical networks First sliding mode control is used and then the inverse optimal control approach is employed For both cases model based is considered in Chapter 3 and Chapter 5 then Chapter 4 and Chapter 6 are based on determining a model for the unknown system using a recurrent neural network using on line extended Kalman filtering for learning The book is organized in four sections The first one covers mathematical preliminaries with a brief review for complex networks and the pinning methodology Additionally sliding mode control and inverse optimal control are introduced Neural network structures are also discussed along with a description of the high order ones The second section presents the analysis and simulation results for sliding mode control for identical as well as non identical nodes The third section describes analysis and simulation results for inverse optimal control considering identical or non identical nodes Finally the last section presents applications of these schemes using gene regulatory networks and microgrids as examples

**Advances in mathematical and computational oncology, volume III** George Bebis, Dinler Amaral Antunes, Ken Chen, Mohammad Kohandel, Kathleen Wilkie, Mamoru Kato, Jinzhuang Dou, 2023-10-25

**Controllability of Complex Networks at Minimum Cost** Gustav Lindmark, 2020-04-30 The control theoretic notion of controllability captures the ability to guide a system toward a desired state with a suitable choice of inputs Controllability of complex networks such as traffic networks gene regulatory networks power grids etc can for instance enable efficient operation or entirely new applicative possibilities However when control theory is applied to complex networks like these several challenges arise This thesis considers some of them in particular we investigate how a given network can be rendered controllable at a minimum cost by placement of control inputs or by growing the network with additional edges between its nodes As cost function we take either the number of control inputs that are needed or the energy that they must exert A control input is called unilateral if it

can assume either positive or negative values but not both Motivated by the many applications where unilateral controls are common we reformulate classical controllability results for this particular case into a more computationally efficient form that enables a large scale analysis Assuming that each control input targets only one node called a driver node we show that the unilateral controllability problem is to a high degree structural from topological properties of the network we derive theoretical lower bounds for the minimal number of unilateral control inputs bounds similar to those that have already been established for the minimal number of unconstrained control inputs e g can assume both positive and negative values With a constructive algorithm for unilateral control input placement we also show that the theoretical bounds can often be achieved A network may be controllable in theory but not in practice if for instance unreasonable amounts of control energy are required to steer it in some direction For the case with unconstrained control inputs we show that the control energy depends on the time constants of the modes of the network the longer they are the less energy is required for control We also present different strategies for the problem of placing driver nodes such that the control energy requirements are reduced assuming that theoretical controllability is not an issue For the most general class of networks we consider directed networks with arbitrary eigenvalues and thereby arbitrary time constants we suggest strategies based on a novel characterization of network non normality as imbalance in the distribution of energy over the network Our formulation allows to quantify network non normality at a node level as combination of two different centrality metrics The first measure quantifies the influence that each node has on the rest of the network while the second measure instead describes the ability to control a node indirectly from the other nodes Selecting the nodes that maximize the network non normality as driver nodes significantly reduces the energy needed for control Growing a network i e adding more edges to it is a promising alternative to reduce the energy needed to control it We approach this by deriving a sensitivity function that enables to quantify the impact of an edge modification with the  $H_2$  and  $H_\infty$  norms which in turn can be used to design edge additions that improve commonly used control energy metrics

#### Complex Networks-based Control Strategies for Multi-terminal HVDC

Transmission Lines Chiara Aprile, 2015 The work proposes and analyzes complex network based controllers for HVDC transmission lines Two different control approaches are studied Distributed PID strategies which take into account just local information of the state of each single node and Global PID algorithms in which the control action for each node depends on the state of the whole network Both control techniques are tested and numerically validated on a model of the North Sea Transnational Grid which is a project of connecting already existing off shore power plants in northern Europe countries with each other and with mainland distribution stations The thesis is structured in seven chapters the first chapter is an introduction about HVDC transmission lines the second contains the main theoretical aspects of complex networks the third and fourth chapter are more technical and they are about the study case The above indicated control strategies are compared and discussed along with the simulation results in chapters five and six Finally conclusions and suggestions for

further research works are drawn in chapter seven

### **Optimization, Learning, and Control for Interdependent**

**Complex Networks** M. Hadi Amini, 2020-02-22 This book focuses on a wide range of optimization learning and control algorithms for interdependent complex networks and their role in smart cities operation smart energy systems and intelligent transportation networks It paves the way for researchers working on optimization learning and control spread over the fields of computer science operation research electrical engineering civil engineering and system engineering This book also covers optimization algorithms for large scale problems from theoretical foundations to real world applications learning based methods to enable intelligence in smart cities and control techniques to deal with the optimal and robust operation of complex systems It further introduces novel algorithms for data analytics in large scale interdependent complex networks Specifies the importance of efficient theoretical optimization and learning methods in dealing with emerging problems in the context of interdependent networks Provides a comprehensive investigation of advance data analytics and machine learning algorithms for large scale complex networks Presents basics and mathematical foundations needed to enable efficient decision making and intelligence in interdependent complex networks M Hadi Amini is an Assistant Professor at the School of Computing and Information Sciences at Florida International University FIU He is also the founding director of Sustainability Optimization and Learning for InterDependent networks laboratory solid lab He received his Ph D and M Sc from Carnegie Mellon University in 2019 and 2015 respectively He also holds a doctoral degree in Computer Science and Technology Prior to that he received M Sc from Tarbiat Modares University in 2013 and the B Sc from Sharif University of Technology in 2011

**Mathematical Reviews** ,2008

### **Applications and Science of Neural Networks, Fuzzy Systems, and**

**Evolutionary Computation II** Bruno Bosacchi, David B. Fogel, James C. Bezdek, 1999 **Communications-computers,**

**Teamed for the '90's** ,1986 Techniques of Structured Problem Solving Arthur B. Vangundy, 1988-04-30 This second edition explains demonstrates and evaluates 105 tested problem solving techniques 35 more than appeared in the first edition Having more techniques at your disposal enables you to solve a wider range of problems without wasting time looking for the best solutions In addition you will find new techniques for classifying problems to solve them faster as well as expanded discussion of proven brainstorming and brainwriting methods **Neural Networks Theory, Technology, and**

**Applications** Patrick K. Simpson, 1996



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