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This book offers a concise and in-depth exposition of specific algorithmic solutions for distributed optimization based control of multi-agent networks and their performance analysis. It synthesizes and analyzes distributed strategies for three collaborative tasks: distributed cooperative optimization, mobile sensor deployment and multi-vehicle formation control. The book integrates miscellaneous ideas and tools from dynamic systems, control theory, graph theory, optimization, game theory and Markov chains to address the particular challenges introduced by such complexities in the environment as topological dynamics, environmental uncertainties, and potential cyber-attack by human adversaries. The book is written for first- or second-year graduate students in a variety of engineering disciplines, including control, robotics, decision-making, optimization and algorithms and with backgrounds in aerospace engineering, computer science, electrical engineering, mechanical engineering and operations research. Researchers in these areas may also find the book useful as a reference. This book includes extended and revised versions of a set of selected papers from the 3rd International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH 2013) which was co-organized by the Reykjavik University (RU) and sponsored by the Institute for Systems and Technologies of Information, Control and Communication (INSTICC). SIMULTECH 2013 was held in cooperation with the ACM SIGSIM - Special Interest Group (SIG) on SImulation and Modeling (SIM), Movimento Italiano Modellazione e Simulazione (MIMOS) and AIS Special Interest Group on Modeling and Simulation (AIS SIGMAS) and technically co-sponsored by the Society for Modeling & Simulation International (SCS), Liophant Simulation, Simulation Team and International Federation for Information Processing (IFIP). This proceedings brings together researchers, engineers, applied mathematicians and practitioners working in the advances and applications in the field of system simulation. This monograph explores the synchronization of large-scale, multi-agent dynamical systems in the presence of disturbances, delays, and time-varying networks. Drawing upon their extensive work in this area, the authors provide a thorough treatment of agents with higher-order dynamics, different classes of models for agents, and the underlying networks representing the agents’ actions. The high technical level of their presentation and their rigorous mathematical approach make this a timely and valuable resource that will fill a gap in the existing literature. Divided into two sections, the first part of the book focuses on state synchronization of homogeneous multi-agent systems. The authors consider state synchronization by determining control strategies for both continuous- and discrete-time systems that achieve state synchronization under both full- and partial-state coupling. The chapters that follow examine multi-agent systems with both linear and nonlinear time-varying agents, input-delays for continuous- and discrete-time systems, and communication delays for continuous-time systems. The second part of the book is dedicated to regulated output synchronization of heterogeneous multi-agent systems with linear and nonlinear agents. Both sections of the book include performance considerations in H2- and H-infinity norms in the presence of external disturbances. Research on synchronization of multi-agent systems has been growing in popularity and is highly interdisciplinary, with applications to automobile systems, aerospace systems, multiple-satellite GPS and high-resolution satellite imagery, aircraft formations, highway traffic platooning, industrial process control with multiple processes, and more. Synchronization of Multi-Agent Systems in the Presence of Disturbances and Delays will therefore be of interest to upper-level graduate students, researchers, and engineers in industry working on interconnected dynamical systems. This book presents a framework for the control of networked systems utilizing submodular optimization techniques. The main focus is on selecting input nodes for the control of networked systems, an inherently discrete optimization problem with applications in power system stability, social influence dynamics, and the control of vehicle formations. The first part of the book is devoted to background information on submodular functions, matroids, and submodular optimization, and presents algorithms for distributed submodular optimization that are scalable to large networked systems. In turn, the second part develops a unifying submodular optimization approach to controlling networked systems based on multiple performance and controllability criteria. Techniques are introduced for selecting input nodes to ensure smooth convergence, synchronization, and robustness to environmental and adversarial noise. Submodular optimization is the first unifying approach towards guaranteeing both performance and controllability with provable optimality bounds in static as well as time-varying networks. Throughout the text, the submodular framework is illustrated with the help of numerical examples and application-based case studies in biological, energy and vehicular systems. The book effectively combines two areas of growing interest, and will be especially useful for researchers in control theory, applied mathematics, networking or machine learning with experience in submodular optimization but who are less familiar with the problems and tools available for networked systems (or vice versa). It will also benefit graduate students, offering consistent terminology and notation that greatly reduces the initial effort associated with beginning a course of study in a new area. This book contains three well-written research tutorials that inform the graduate reader about the forefront of current research in multi-agent optimization. These tutorials cover topics that have not yet found their way in standard books and offer the reader the unique opportunity to be guided by major researchers in the respective fields. Multi-agent optimization, lying at the intersection of classical optimization, game theory, and variational inequality theory, is at the forefront of modern optimization and has recently undergone a dramatic development. It seems timely to provide an overview that describes in detail ongoing research and important trends. This book concentrates on Distributed Optimization over Networks; Differential Variational Inequalities; and Advanced Decomposition Algorithms for Multi-agent Systems. This book will appeal to both mathematicians and mathematically oriented engineers and will be the source of inspiration for PhD students and researchers. Significant progress has been made on nonlinear control systems in the past two decades. However, many of the existing nonlinear control methods cannot be readily used to cope with communication and networking issues without nontrivial modifications. For example, small quantization errors may cause the performance of a "well-designed" nonlinear control system to deteriorate. Motivated by the need for new tools to solve complex problems resulting from smart power grids, biological processes, distributed computing networks, transportation networks, robotic systems, and other cutting-edge control applications, Nonlinear Control of Dynamic Networks tackles newly arising theoretical and real-world challenges for stability analysis and control design, including nonlinearity, dimensionality, uncertainty, and information constraints as well as behaviors stemming from quantization, data-sampling, and impulses. Delivering a systematic review of the nonlinear small-gain theorems, the text: Supplies novel cyclic-small-gain theorems for large-scale nonlinear dynamic networks Offers a cyclic-small-gain framework for nonlinear control with static or dynamic quantization Contains a combination of cyclic-small-gain and set-valued map designs for robust control of nonlinear uncertain systems subject to sensor noise Presents a cyclic-small-gain result in directed graphs and distributed control of nonlinear multi-agent systems with fixed or dynamically changing topology Based on the authors' recent research, Nonlinear Control of Dynamic Networks provides a unified framework for robust, quantized, and distributed control under information constraints. Suggesting avenues for further exploration, the book encourages readers to take into consideration more communication and networking issues in control designs to better handle the arising challenges. This brief introduces a class of problems and models for the prediction of the scalar field of interest from noisy observations collected by mobile sensor networks. It also introduces the problem of optimal coordination of robotic sensors to maximize the prediction quality subject to communication and mobility constraints either in a centralized or distributed manner. To solve such problems, fully Bayesian approaches are adopted, allowing various sources of uncertainties to be integrated into an inferential framework effectively capturing all aspects of variability involved. The fully Bayesian approach also allows the most appropriate values for additional model parameters to be selected automatically by data, and the optimal inference and prediction for the underlying scalar field to be achieved. In particular, spatio-temporal Gaussian process regression is formulated for robotic sensors to fuse multifactorial effects of observations, measurement noise, and prior distributions for obtaining the predictive distribution of a scalar environmental field of interest. New techniques are introduced to avoid computationally prohibitive Markov chain Monte Carlo methods for resource-constrained mobile sensors. Bayesian Prediction and Adaptive Sampling Algorithms for Mobile Sensor Networks starts with a simple spatio-temporal model and increases the level of model flexibility and uncertainty step by step, simultaneously solving increasingly complicated problems and coping with increasing complexity, until it ends with fully Bayesian approaches that take into account a broad spectrum of uncertainties in observations, model parameters, and constraints in mobile sensor networks. The book is timely, being very useful for many researchers in control, robotics, computer science and statistics trying to tackle a variety of tasks such as environmental monitoring and adaptive sampling, surveillance, exploration, and plume tracking which are of increasing currency. Problems are solved creatively by seamless combination of theories and concepts from Bayesian statistics, mobile sensor networks, optimal experiment design, and distributed computation. This book uses rigorous mathematical analysis to advance opinion dynamics models for social networks in three major directions. First, a novel model is proposed to capture how a discrepancy between an individual's private and expressed opinions can develop due to social pressures that arise in group situations or through extremists deliberately shaping public opinion. Detailed theoretical analysis of the final opinion distribution is followed by use of the model to study Asch's seminal experiments on conformity, and the phenomenon of pluralistic ignorance. Second, the DeGroot-Friedkin model for evolution of an individual's social power (self-confidence) is developed in a number of directions. The key result establishes that an individual's initial social power is forgotten exponentially fast, even when the network changes over time; eventually, an individual's social power depends only on the (changing) network structure. Last, a model for the simultaneous discussion of multiple logically interdependent topics is proposed. To ensure that a consensus across the opinions of all individuals is achieved, it turns out that the interpersonal interactions must be weaker than an individual's introspective cognitive process for establishing logical consistency among the topics. Otherwise, the individual may experience cognitive overload and the opinion system becomes unstable. Conclusions of interest to control engineers, social scientists, and researchers from other relevant disciplines are discussed throughout the thesis with support from both social science and control literature. This interdisciplinary thesis involves the design and analysis of coordination algorithms on networks, identification of dynamic networks and estimation on networks with random geometries with implications for networks that support the operation of dynamic systems, e.g., formations of robotic vehicles, distributed estimation via sensor networks. The results have ramifications for fault detection and isolation of large-scale networked systems and optimization models and algorithms for next generation aircraft power systems. The author finds novel applications of the methodology in energy systems, such as residential and industrial smart energy management systems. This book provides the mathematical foundations of networks of linear control systems, developed from an algebraic systems theory perspective. This includes a thorough treatment of questions of controllability, observability, realization theory, as well as feedback control and observer theory. The potential of networks for linear systems in controlling large-scale networks of interconnected dynamical systems could provide insight into a diversity of scientific and technological disciplines. The scope of the book is quite extensive, ranging from introductory material to advanced topics of current research, making it a suitable reference for graduate students and researchers in the field of networks of linear systems. Part I can be used as the basis for a first course in Algebraic System Theory, while Part II serves for a second, advanced, course on linear systems. Finally, Part III, which is largely independent of the previous parts, is ideally suited for advanced research seminars aimed at preparing graduate students for independent research. "Mathematics of Networks of Linear Systems" contains a large number of exercises and examples throughout the text making it suitable for graduate courses in the area. This book deals with averaging dynamics, a paradigmatic example of network based dynamics in multi-agent systems. The book presents all the fundamental results on linear averaging dynamics, proposing a unified and updated viewpoint of many models and convergence results scattered in the literature. Starting from the classical evolution of the powers of a fixed stochastic matrix, the text then considers more general evolutions of products of a sequence of stochastic matrices, either deterministic or randomized. The theory needed for a full understanding of the models is constructed without assuming any knowledge of Markov chains or Perron–Frobenius theory. Jointly with their analysis of the convergence of averaging dynamics, the authors derive the properties of stochastic matrices. These properties are related to the topological structure of the associated graph, which, in the book's perspective, represents the communication between agents. Special attention is paid to how these properties scale as the network grows in size. Finally, the understanding of stochastic matrices is applied to the study of other problems in multi-agent coordination: averaging with stubborn agents and estimation from relative measurements. The dynamics described in the book find application in the study of opinion dynamics in social networks, of information fusion in sensor networks, and of the collective motion of animal groups and teams of unmanned vehicles. Introduction to Averaging Dynamics over Networks will be of material interest to researchers in systems and control studying coordinated or distributed control, networked systems or multiagent systems and to graduate students pursuing courses in these areas. Distributed controller design is generally a challenging task, especially for multi-agent systems with complex dynamics, due to the interconnected effect of the agent dynamics, the interaction graph among agents, and the cooperative control laws. Cooperative Control of Multi-Agent Systems: A Consensus Region Approach offers a systematic framework for designing distributed controllers for multi-agent systems with general linear agent dynamics, linear agent dynamics with uncertainties, and Lipschitz nonlinear agent dynamics. Beginning with an introduction to cooperative control and graph theory, this monograph: Explores the consensus control problem for continuous-time and discrete-time linear multi-agent systems Studies the H_∞ and H2 consensus problems for linear multi-agent systems subject to external disturbances Designs distributed adaptive consensus protocols for continuous-time linear multi-agent systems Considers the distributed tracking control problem for linear multi-agent systems with a leader of nonzero control input Examines the distributed containment control problem for the case with multiple leaders Covers the robust cooperative control problem for multi-agent systems with linear nominal agent dynamics subject to heterogeneous matching uncertainties Discusses the global consensus problem for Lipschitz nonlinear multi-agent systems Cooperative Control of Multi-Agent Systems: A Consensus Region Approach provides a novel approach to designing distributed cooperative protocols for multi-agent systems with complex dynamics. The proposed consensus region decouples the design of the feedback gain matrices of the cooperative protocols from the communication graph and serves as a measure for the robustness of the protocols to variations of the communication graph. By exploiting the decoupling feature, adaptive cooperative protocols are presented that can be designed and implemented in a fully distributed fashion. An increasing complexity of models used to predict real-world systems leads to the need for algorithms to replace complex models with far simpler ones, while preserving the accuracy of the predictions. This three-volume handbook covers methods as well as applications. This third volume focuses on applications in engineering, biomedical engineering, computational physics and computer science. A comprehensive review of the state of the art in the control of multi-agent systems theory and applications The superiority of multi-agent systems over single agents for the control of unmanned air, water and ground vehicles has been clearly demonstrated in a wide range of application areas. Their large-scale spatial distribution, robustness, high scalability and low cost enable multi-agent systems to achieve tasks that could not successfully be performed by even the most sophisticated single agent systems. Cooperative Control of Multi-Agent Systems: Theory and Applications provides a wide-ranging review of the latest developments in the cooperative control of multi-agent systems theory and applications. The applications described are mainly in the areas of unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs). Throughout, the authors link basic theory to multi-agent cooperative control practice — illustrated within the context of highly-realistic scenarios of high-level missions — without losing site of the mathematical background needed to provide performance guarantees under general working conditions. Many of the problems and solutions considered involve combinations of both types of vehicles. Topics explored include target assignment, target tracking, consensus, stochastic game theory-based framework, event-triggered control, topology design and identification, coordination under uncertainty and coverage control. Establishes a bridge between fundamental cooperative control theory and specific problems of interest in a wide range of applications areas Includes example applications from the fields of space exploration, radiation shielding, site clearance, tracking/classification, surveillance, search-and-rescue and more Features detailed presentations of specific algorithms and application frameworks with relevant commercial and military applications Provides a comprehensive look at the latest developments in this rapidly evolving field, while offering informed speculation on future directions for collective control systems The use of multi-agent system technologies in both everyday commercial use and national defense is certain to increase tremendously in the years ahead, making this book a valuable resource for researchers, engineers, and applied mathematicians working in systems and controls, as well as advanced undergraduates and graduate students interested in those areas. Distributed Coordination of Multi-agent Networks introduces problems, models, and issues such as collective periodic motion coordination, collective tracking with a dynamic leader, and containment control with multiple leaders, and explores ideas for their solution. Solving these problems extends the existing application domains of multi-agent networks; for example, collective periodic motion coordination is appropriate for applications involving repetitive movements, collective tracking guarantees tracking of a dynamic leader by multiple followers in the presence of reduced interaction and partial measurements, and containment control enables maneuvering of multiple followers by multiple leaders. This thesis investigates the role of duality and the use of approximation methods in cooperative optimization and control. Concerning cooperative optimization, a general algorithm for convex optimization in networks with asynchronous communication is presented. Based on the idea of polyhedral approximations, a family of distributed algorithms is developed to solve a variety of distributed decision problems, ranging from semi-definite and robust optimization problems up to distributed model predictive control. Optimization theory, and in particular duality theory, are shown to be central elements also in cooperative control. This thesis establishes an intimate relation between passivity-based cooperative control and network optimization theory. The presented results provide a complete duality theory for passivity-based cooperative control and lead the way to novel analysis tools for complex dynamic phenomena. In this way, this thesis presents theoretical insights and algorithmic approaches for cooperative optimization and control, and emphasizes the role of convexity and duality in this field. This book constitutes the proceedings of the 17th International Conference on Practical Applications of Agents and Multi-Agent Systems, PAAMS 2019, held in Ávila, Spain, in June 2019. The 19 regular and 14 demo papers presented in this volume were carefully reviewed and selected from 55 submissions. They deal with the application and validation of agent-based models, methods, and technologies in a number of key applications areas, including: Agronomy and Internet of Things, coordination and structure, finance and energy, function and autonomy, humans and societies, reasoning and optimization, traffic and routing. This edited volume includes thoroughly collected on sensing and control for autonomous vehicles. Guidance, navigation and motion control systems for autonomous vehicles are increasingly important in land-based, marine and aerial operations. Autonomous underwater vehicles may be used for pipeline inspection, light intervention work, underwater survey and collection of oceanographic/biological data. Autonomous unmanned aerial systems can be used in a large number of applications such as inspection, monitoring, data collection, surveillance, etc. At present, vehicles operate with limited autonomy and a minimum of intelligence. There is a growing interest for cooperative and coordinated multi-vehicle systems, real-time re-planning, robust autonomous navigation systems and robust autonomous control of vehicles. Unmanned vehicles with high levels of autonomy may be used for safe and efficient collection of environmental data, for assimilation of climate and environmental models and to complement global satellite systems. The target audience primarily comprises research experts in the field of control theory, but the book may also be beneficial for graduate students. An introduction to the analysis & design of dynamic multiagent networks. These have a wide range of applications in science & engineering, including mobile sensor networks, distributed robotics, quantum networks, networked economics, biological synchronization & social networks. Develops foundational concepts, key operational and design principles, and interdisciplinary applications for cyber-physical systems. The two-volume set of LNCS 10941 and 10942 constitutes the proceedings of the 9th International Conference on Advances in Swarm Intelligence, ICSI 2018, held in Shanghai, China, in June 2018. The total of 113 papers presented in these volumes was carefully reviewed and selected from 197 submissions. The papers were organized in topical sections namely: multi-agent systems; swarm robotics; fuzzy logic approaches; planning and routing problems; recommendation in social media; predication; classification; finding patterns; image enhancement; deep learning; theories and models of swarm intelligence; ant colony optimization; particle swarm optimization; artificial bee colony algorithms; genetic algorithms; differential evolution; fireworks algorithm; bacterial foraging optimization; artificial immune system; hydrologic cycle optimization; other swarm-based optimization algorithms; hybrid optimization algorithms; multi-objective optimization; large-scale global optimization. This treatment of modern topics related to mathematical systems theory forms the proceedings of a workshop, Mathematical Systems Theory: From Behaviors to Nonlinear Control, held at the University of Groningen in July 2015. The workshop celebrated the work of Professors Arjan van der Schaft and Harry Trentelman, honouring their 60th Birthdays. The second volume of this two-volume work covers a variety of topics related to behavioral systems and robust control. After giving a detailed account of the state-of the art in the related topic, each chapter presents new results and discusses new directions. As such, this volume provides a broad picture of the theory of behavioral systems and robust control for scientists and engineers with an interest in the interdisciplinary field of systems and control theory. The reader will benefit from the expert participants' ideas on exciting new approaches to control and system theory and their predictions of future directions for the subject that were discussed at the workshop. Classical vehicle dynamics, which is the basis for manned ground vehicle design, has exhausted its potential for providing novel design concepts to a large degree. At the same time, unmanned ground vehicle (UGV) dynamics is still in its infancy and is currently being developed using general analytical dynamics principles with very little input from actual vehicle dynamics theory. This technical book presents outcomes from the NATO Advanced Study Institute (ASI) 'Advanced Autonomous Vehicle Design for Severe Environments', held in Coventry, UK, in July 2014. The ASI provided a platform for world class professionals to meet and discuss leading-edge research, engineering accomplishments and future trends in manned and unmanned ground vehicle dynamics, terrain mobility and energy efficiency. The outcomes of this collective effort serve as an analytical foundation for autonomous vehicle design. Topics covered include: historical aspects, pivotal accomplishments and the analysis of future trends in on- and off-road manned and unmanned vehicle dynamics; terramechanics, soil dynamic characteristics, uncertainties and stochastic characteristics of vehicle-environment interaction for agile vehicle dynamics modeling; new methods and techniques in on-line control and learning for vehicle autonomy; fundamentals of agility and severe environments; mechatronics and cyber-physics issues of agile vehicle dynamics to design for control, energy harvesting and cyber security; and case studies of agile and inverse vehicle dynamics and vehicle systems design, including optimisation of suspension and driveline systems. The book targets graduate students, who desire to advance further in leading-edge vehicle dynamics topics in manned and unmanned ground vehicles, PhD students continuing their research work and building advanced curricula in academia and industry, and researchers in government agencies and private companies. This book highlights cutting-edge research in the field of network science, offering scientists, researchers, students and practitioners a unique update on the latest advances in theory and a multitude of applications. It presents the peer-reviewed proceedings of the IX International Conference on Complex Networks and their Applications (COMPLEX NETWORKS 2020). The carefully selected papers cover a wide range of theoretical topics such as network models and measures; community structure, network dynamics; diffusion, epidemics and spreading processes; resilience and control as well as all the main network applications, including social and political networks; networks in finance and economics; biological and neuroscience networks and technological networks. In this book for the first time two scientific fields - consensus formation and synchronization of communications - are presented together and examined through their interrelational aspects, of rapidly growing importance. Both fields have indeed attracted enormous research interest especially in relation to complex networks. In networks of dynamic systems (or agents), consensus means to reach an agreement regarding a certain quantity of interest that depends on the state of all dynamical systems (agents). Consensus problems have a long history in control theory and computer sciences, and form the foundation of the field of distributed computing. Synchronization, which defines correlated-in-time behavior between different processes and roots going back to Huygens to the least, is now a highly popular, exciting and rapidly developing topic, with applications ranging from biological networks to mathematical epidemiology, and from processing information in the brain to engineering of communications devices. The book reviews recent finding in both fields and describes novel approaches to consensus formation, where consensus is realized as an instance of the nonlinear dynamics paradigm of chaos synchronization. The chapters are written by world-known experts in both fields and cover topics ranging from fundaments to various applications of consensus and synchronization. This thesis contributes to the development of a cooperative control theory for homogeneous and heterogeneous multi-agent systems consisting of identical and non-identical dynamical agents, respectively. The goal is to explain fundamental effects of non-identical agent dynamics on the behavior of a distributed system and, primarily, to develop suitable control design methods for a wide range of multi-agent coordination problems. Output synchronization problems as well as cooperative disturbance rejection and reference tracking problems in multi-agent systems are investigated. Suitable controller design methods for networks consisting of identical or non-identical linear time-invariant systems, linear parameter-varying systems, and selected classes of nonlinear systems are developed. These controller design methods provide a solution to a wide variety of distributed coordination and cooperative control scenarios. This monograph introduces novel methods for the control and navigation of mobile robots using multiple-1-d-view models obtained from omni-directional cameras. This approach overcomes field-of-view and robustness limitations, simultaneously enhancing accuracy and simplifying application on real platforms. The authors also address coordinated motion tasks for multiple robots, exploring different system architectures, particularly the use of multiple aerial cameras in driving robot formations on the ground. Again, this has benefits of simplicity, scalability and flexibility. Coverage includes details of: a method for visual robot homing based on a memory of omni-directional images; a novel vision-based pose stabilization methodology for non-holonomic ground robots based on sinusoidal-varying control inputs; an algorithm to recover a generic motion between two 1-d views and which does not require a third view; a novel multi-robot setup where multiple camera-carrying unmanned aerial vehicles are used to observe and control a formation of ground mobile robots; and three coordinate-free methods for decentralized mobile robot formation stabilization. The performance of the different methods is evaluated both in simulation and experimentally with real robotic platforms and vision sensors. Control of Multiple Robots Using Vision Sensors will serve both academic researchers studying visual control of single and multiple robots and robotics engineers seeking to design control systems based on visual sensors. This handbook is the definitive reference for the interdisciplinary field that is ocean engineering. It integrates the coverage of fundamental and applied material and encompasses a diverse spectrum of systems, concepts and operations in the maritime environment, as well as providing a comprehensive update on contemporary, leading-edge ocean technologies. Coverage includes an overview on the fundamentals of ocean science, ocean signals and instrumentation, coastal structures, developments in ocean energy technologies and ocean vehicles and automation. It aims at practitioners in a range of offshore industries and naval establishments as well as academic researchers and graduate students in ocean, coastal, offshore and marine engineering and naval architecture. The Springer Handbook of Ocean Engineering is organized in five parts: Part A: Fundamentals, Part B: Autonomous Ocean Vehicles, Subsystems and Control, Part C: Coastal Design, Part D: Offshore Technologies, Part E: Energy Conversion This thesis analyzes and explores the design of controlled networked dynamic systems - dubbed semi-autonomous networks. The work approaches the problem of effective control of semi-autonomous networks from three fronts: protocols which are run on individual agents in the network; the network interconnection topology design; and efficient modeling of these often large-scale networks. The author extended the popular consensus protocol to advection and nonlinear consensus. The network redesign algorithms are supported by a game-theoretic and an online learning regret analysis. This book constitutes the proceedings of the 18th Russian Conference on Artificial Intelligence, RCAI 2020, held in Moscow, Russia, in October 2020. The 27 full papers and 8 short papers presented in this volume were carefully reviewed and selected from 140 submissions. The conference deals with a wide range of topics, including data mining and knowledge discovery, text mining, reasoning, decisionmaking, natural language processing, vision, intelligent robotics, multi-agent systems,machine learning, AI in applied systems, and ontology engineering. This contributed volume presents some of the latest research related to model order reduction of complex dynamical systems with a focus on time-dependent problems. Chapters are written by leading researchers and users of model order reduction techniques and are based on presentations given at the 2019 edition of the workshop series Model Reduction of Complex Dynamical Systems – MODRED, held at the University of Graz in Austria. The topics considered can be divided into five categories: system-theoretic methods, such as balanced truncation, Hankel norm approximation, and reduced-basis methods; data-driven methods, including Loewner matrix and pencil-based approaches, dynamic mode decomposition, and kernel-based methods; surrogate modeling for design and optimization, with special emphasis on control and data assimilation; model reduction methods in applications, such as control and network systems, computational electromagnetics, structural mechanics, and fluid dynamics; and model order reduction software packages and benchmarks. This volume will be an ideal resource for graduate students and researchers in all areas of model reduction, as well as those working in applied mathematics and theoretical informatics. This book celebrates Professor Mathukumalli Vidyasagar’s outstanding achievements in systems, control, robotics, statistical learning, computational biology, and allied areas. The contributions in the book summarize the content of invited lectures given at the workshop “Emerging Applications of Control and Systems Theory” (EACST17) held at the University of Texas at Dallas in late September 2017 in honor of Professor Vidyasagar’s seventieth birthday. These contributions are the work of twenty-eight distinguished speakers from eight countries and are related to Professor Vidyasagar’s areas of research. This Festschrift volume will remain as a permanent scientific record of this event. This monograph presents new model-based design methods for trajectory planning, feedback stabilization, state estimation, and tracking control of distributed-parameter systems governed by partial differential equations (PDEs). Flatness and backstepping techniques and their generalization to PDEs with higher-dimensional spatial domain lie at the core of this treatise. This includes the development of systematic late lumping design procedures and the deduction of semi-numerical approaches using suitable approximation methods. Theoretical developments are combined with both simulation examples and experimental results to bridge the gap between mathematical theory and control engineering practice in the rapidly evolving PDE control area. The text is divided into five parts featuring: - a literature survey of paradigms and control design methods for PDE systems - the first principle mathematical modeling of applications arising in heat and mass transfer, interconnected multi-agent systems, and piezo-actuated smart elastic structures - the generalization of flatness-based trajectory planning and feedforward control to parabolic and biharmonic PDE systems defined on general higher-dimensional domains - an extension of the backstepping approach to the feedback control and observer design for parabolic PDEs with parallelepiped domain and spatially and time varying parameters - the development of design techniques to realize exponentially stabilizing tracking control - the evaluation in simulations and experiments Control of Higher-Dimensional PDEs — Flatness and Backstepping Designs is an advanced research monograph for graduate students in applied mathematics, control theory, and related fields. The book may serve as a reference to recent developments for researchers and control engineers interested in the analysis and control of systems governed by PDEs. Dancing humanoids, robotic art installations, and music generated by mathematically precise methods are no longer science fiction; in fact they are the subject of this book. This first-of-its-kind anthology assembles technical research that makes such creations possible. In order to mechanize something as enigmatic and personal as dance, researchers must delve deeply into two distinct academic disciplines: control theory and art. Broadly, this research uses techniques from the world of art to inspire methods in control, enables artistic endeavours using advanced control theory and aids in the analysis of art using metrics devised by a systems theoretic approach. To ensure that artistic influences are well represented, the individual chapters are focused so that they relate their contribution to the arts meaningfully and explicitly. Specially composed introductions set up the contributions either in terms of inspiration by artistic principles or their contribution to the arts through new analysis tools. To facilitate this, the majority of the chapters are authored jointly by experts in control theory and by artists, including dancers, choreographers, puppeteers and painters. Connections between controls and art then permeate the text so that these important relationships play a central role in the book. Controls and Art surveys current projects in this area—including a disco dancing robot, a reactive museum exhibit and otherworldly music—and illuminates open problems and topics for research in this emerging interdisciplinary field. It will draw attention both from experts in robotics and control interested in developing the artistic side of their creations and from academics studying dance, theater, music and the visual arts with an interest in avant-garde means of production. This book mostly results from a selection of papers presented during the 11th IFAC (International Federation of Automatic Control) Workshop on Time-Delay Systems, which took place in Grenoble, France, February 4 - 6, 2013. During this event, 37 papers were presented. Taking into account the reviewers' evaluation and the papers' presentation the best papers have been selected and collected into the present volume. The authors of 13 selected papers were invited to participate to this book and provided a more detailed and improved version of the conference paper. To enrich the book, three more chapters have been included from specialists on time-delay systems who presented their work during the 52nd IEEE Conference on Decision and Control, which held in December 10 - 13, 2013, at Florence, Italy. The content of the book is divided into four main parts as follows: Modeling, Stability analysis, Stabilization and control, and Input-delay systems. Focusing on various topics of time-delay systems, this book will be interesting for researchers and graduate students working on control and system theory. With the unifying theme of abstract evolutionary equations, both linear and nonlinear, in a complex environment, the book presents a multidisciplinary blend of topics, spanning the fields of theoretical and applied functional analysis, partial differential equations, probability theory and numerical analysis applied to various models coming from theoretical physics, biology, engineering and complexity theory. Truly unique features of the book are: the first simultaneous presentation of two complementary approaches to fragmentation and coagulation problems, by weak compactness methods and by using semigroup techniques, comprehensive exposition of probabilistic methods of analysis of long term dynamics of dynamical systems, semigroup analysis of biological problems and cutting edge pattern formation theory. The book will appeal to postgraduate students and researchers specializing in applications of mathematics to problems arising in natural sciences and engineering. This book establishes an important mathematical connection between cooperative control problems and network optimization problems. It shows that many cooperative control problems can in fact be understood, under certain passivity assumptions, using a pair of static network optimization problems. Merging notions from passivity theory and network optimization, it describes a novel network optimization approach that can be applied to the synthesis of controllers for diffusively-coupled networks of passive (or passivity-short) dynamical systems. It also introduces a data-based, model-free approach for the synthesis of network controllers for multi-agent systems with passivity-short agents. Further, the book describes a method for monitoring link faults in multi-agent systems using passivity theory and graph connectivity. It reports on some practical case studies describing the effectivity of the developed approaches in vehicle networks. All in all, this book offers an extensive source of information and novel methods in the emerging field of multi-agent cooperative control, paving the way to future developments of autonomous systems for various application domains. This monograph represents the outcome of research effort of the authors on scalable synchronization of large-scale multi-agent systems (MAS). Cooperative control of multi-agent systems has been growing in popularity and is highly interdisciplinary in recent years. The application of synchronization of MAS includes automobile systems, aerospace systems, multiple-satellite GPS, high-resolution satellite imagery, aircraft formations, highway traffic platooning, industrial process control with multiple processes, and more. Most of the proposed protocols in the literature for synchronization of MAS require some knowledge of the communication network such as bounds on the spectrum of the associated Laplacian matrix and the number of agents. These protocols suffer from scale fragility wherein stability properties are lost for large-scale networks or when the communication graph changes. In the past few years, the authors of this monograph have worked on developing scale-free protocol design for various cases of MAS problems. The key contribution of the monograph is to offer a scale-free design framework and provide scale-free protocols to achieve synchronization, delayed synchronization, and almost synchronization in the presence of input and communication delays, input saturation and external disturbances. The scale-free design framework solely is based on the knowledge of agent models and does not depend on information about the communication network such as the spectrum of the associated Laplacian matrix or size of the network. Drawing upon their extensive work in this area, the authors provide a thorough treatment of agents with higher-order dynamics, different classes of models for agents, and the underlying networks representing actions of the agents. The high technical level of their presentation and their rigorous mathematical approach make this monograph a timely and valuable resource that will fill a gap in the existing literature. The thesis presents new results on multi-agent formation control, focusing on the distributed stabilization control of rigid formation shapes. It analyzes a range of current research problems such as problems concerning the equilibrium and stability of formation control systems, or the problem of cooperative coordination control when agents have general dynamical models, and discusses practical considerations arising during the implementation of established formation control algorithms. In addition, the thesis presents models of increasing complexity, from single integrator models, to double integrator models, to agents modeled by nonlinear kinematic and dynamic equations, including the familiar unicycle model and nonlinear system equations with drift terms. Presenting the fruits of a close collaboration between several top control groups at leading universities including Yale University, Groningen University, Purdue University and Gwangju Institute of Science and Technology (GIST), the thesis spans various research areas, including robustness issues in formations, quantization-based coordination, exponential stability in formation systems, and cooperative coordination of networked heterogeneous systems. 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.

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