Preface

Complex Network Analysis falls under the subject area of Network Science, a rapidly emerging area of interest for both theory and practice. With the phenomenal growth of the Internet, web, social networks, information on biological networks, etc., it is imperative that we need algorithms to analyze such large-scale networks, visualize and extract useful information (like communities in the networks, robustness to information diffusion, diameter of the network, etc). Network Science deals with the analysis and visualization of large complex network graphs and the development of efficient algorithms to study the characteristics of networks involving hundreds and thousands of nodes.

Network Science falls within the realm of "Big Data Computing" where the Big Data is the larger graphs that model complex real-world networks (like social networks, biological networks, Internet, web, citation networks, etc). The book includes chapters presenting research advances in the algorithms and measures for analyzing large-scale complex networks and the visualization of such networks. The book presents applications of the theoretical algorithms and graph models to analyze real-world networks and characterize the topology and behavior of these networks. The chapters also explore the use of network science paradigms (like centrality measures, community detection algorithms and etc) in some of the prominent types of computer networks such as wireless sensor networks, body area networks, etc as well as for health-care related applications.

The overall objective of this book is to provide a thorough description of the different aspects of the state-of-the-art research in complex network analysis and its applications to diverse network domains. Ours is the first such book to present a comprehensive discussion of the various state-of-the-art graph models, algorithms, analysis measures and tools that are available for network science research and practice. It will be a one-stop reference for both beginners and professionals in network science and will be a good guiding material for further research in academics as well as for implementing the theory, algorithms, models and analytical measures for practical applications.

We anticipate the target audience of the book to be both students and faculty pursuing research in academics as well as industry practitioners and business professionals. The book will be structured in such a way that it discusses both the theory as well as practical aspects of network science research for a wide variety of network domains, attracting audience from diverse quarters. Also, there are not many books that present the research advances in this area; most of the books in network science are like textbooks suited primarily for graduate-level and senior-level undergraduate courses and present information from a teaching perspective. The proposed book will present information from a research perspective and kindle interest in the mind of the reader to further extend an existing research work and/or develop innovative ideas. Nevertheless, all the basic background information that are needed by a reader to understand the research concepts and ideas will be covered in the beginning of the chapters as well as through certain stand-alone tutorial-style chapters that will present both the theory behind the graph models, algorithms and analysis measures as well as on the use of state-of-the-art tools and cyber infrastructure for network modeling, analysis and visualization. Hence, in terms of market value, we anticipate the proposed book to serve as a valuable source of reference for students pursuing research in undergraduate and graduate levels and be a recommended book for advanced elective/research-oriented special topics courses as well as be a good source of reference and citation for faculty and professionals in university and industry pursuing research in network science.

A high-level overview of the 17 chapters in this book are as follows. Chapters 1-2 focus on distributed graph theory algorithms for vertex cover and k-connectivity. Chapters 3-6 focus on structural analysis of complex networks from the points of view of link prediction, robustness to node failures, motifs, homophily and k-core decomposition. Chapters 7-9 focus on generative models for complex networks and their characteristics. While Chapters 7 and 8 focus on classical random network and scale-free network graph models, Chapter 9 proposes a novel generation model for heterogeneous complex networks. Chapters 10-11 focus on social network analysis and algorithms for community detection. Chapters 12-13 discuss the use of evolution dynamics and its applications for complex network analysis to unravel the hidden relations in these networks. Chapters 14-17 discuss the applications of the methods for complex network analysis for healthcare applications, wireless sensor networks and academic program design. We now briefly describe the contributions of each of the chapters.

A vertex cover for a graph is a set of vertices such that for every edge in the graph - at least one of its two end vertices are in the vertex cover. In Chapter 1 titled, "On Vertex Cover Problems in Distributed Systems," the authors Can Umut Ileri, Cemil Aybars Ural, Orhan Dagdeviren and Vedat Kavalci discuss the applications of vertex cover in various types of communication networks such as wireless sensor networks. The authors discuss the applications of vertex cover for link monitoring, clustering, backbone formation and data aggregation management. The authors also survey some important distributed algorithms to determine approximations to vertex cover for communication networks.

A graph is k-connected if it remains connected after the removal of k-1 nodes. It is imperative to analyze the k-connectivity of complex real-world networks and investigate measures to improve the k-connectivity of these networks. In Chapter 2 titled, "On K-Connectivity Problems in Distributed Systems," the authors Vahid Khalilpour Akram and Orhan Dagdeviren review the centralized and distributed algorithms for detection and restoration of k-connectivity in graphs and distributed systems. The authors compare these algorithms from the perspective of complexity, accuracy and efficiency.

In Chapter 3 titled, "Link Prediction in Complex Networks," the authors Manisha Pujari and Rushed Kanawati propose a new link prediction approach based on supervised rank aggregation and deals with the challenges in link prediction for real-world networks in two ways. While one of the approaches extends the set of attributes for any two nodes in a multiplex network that have a layered structure, with each layer having different kinds of links between the same set of nodes; the second approach is to use community information from sampling of existing links to deal with the problem of class imbalance. The experiments have been conducted based on networks extracted from the well-known DBLP bibliographic database.

Structural controllability deals with network robustness in the presence of node and link failures. In Chapter 4 titled, "Design of Structural Controllability for Complex Network Architecture," the authors Amitava Mukherjee, Ayan Chatterjee, Debayan Das and Mrinal Naskar propose an efficient heuristic to determine the minimum number of driver nodes that are needed for complete structural control. The authors also propose a novel approach to address the vulnerability of real-world complex networks and enhance the robustness of these networks, prior to an attack or failure. Simulation results in Chapter 4 reveal that dense and homogeneous networks are more robust and easier to control with fewer driver nodes, while the sparse and heterogeneous networks are relatively less robust and would need more driver nodes for structural control.

Motifs are small sub graph patterns that occur significantly more often than expected at random. In Chapter 5 titled, "Triadic Substructures in Complex Networks," the author Marco Winkler investigates whether motifs occur homogeneously or heterogeneously distributed over a graph, and observes that the distribution is more heterogeneous - bound to the proximity of only very few nodes. The authors also studies graphs with respect to homogeneity and homophily of their node-specific triadic structures, and these two features have been observed to be characteristic of the networks' origins. In addition, the chapter also explains that information on a graph's node-specific triadic structure can be used to detect groups of structurally similar vertices.

Graph coarsening is the problem of grouping vertices together and building condensed, smaller graphs from these groups. In Chapter 6 titled, "Characterization and Coarsening of Autonomous System Networks: Measuring and Simplifying the Internet," the authors Alberto Garcia-Robledo, Arturo Diaz-Perez and Guillermo Morales-Luna study the correlation between various well-known complex network metrics for the Internet and methodologically identify a subset of non-redundant and potentially independent metrics that can be used to coarse the Internet at the Autonomous System (AS) level. The authors present graph coarsening algorithms to exploit the k-core decomposition of graphs to preserve relevant complex network properties.

Graph models play a central role in the description and characterization of real-world complex networks. Among the various graph models, random network models have attracted considerable attention. In Chapter 7 titled, "Connectivity and Structure in Large Networks," the author Rupei Xu presents a general framework to compare the strength of various models for generating random network graphs and discusses results about the equality, inequality and proper containment of certain model classes. The chapter also focuses on random graph models that arise via generalized geometric constructions as these graphs can very well capture wireless communication networks.

The well-known SIR model (SIR - Susceptible, Infected, Removed) and other existing models for the analysis of spread of communal diseases (in the field of epidemiology) are more tailored to random network graphs. However, it is not possible to model varying probabilities of infection or immunity per node or random network graphs. In Chapter 8 titled, "A Study of Computer Virus Propagation On Scale Free Networks Using Differential Equations," the author Mohammad S. Khan presents an analysis of the computer virus propagation using the pSEIRS model that takes into account the probabilities of infection and is more suitable for the real-world scale-free networks. The pSEIRS model assumes the death rate and excess death rate to be constant for infective nodes as well as assumes the latent and immune period to be constant; on the other hand, the model assumes the infection rate to be a function of the size of the total population and the size of the infected population.

Complex networks are observed to exhibit the small-world phenomenon, scale-free power-law degree distribution, high average clustering coefficient and emergence of community structure. In Chapter 9 titled, "SNAM - A Heterogeneous Complex Networks Generation Model," the authors Bassant Youssef, Scott Midkiff and Mohamed Rizk observe that most of the complex network generative models that have been proposed in the literature do not incorporate the above statistical properties as well as neglect the heterogeneous nature of network nodes. The authors propose a novel "settling node adaptive model (SNAM)," that reflects the above statistical properties as well as reflects the heterogeneous nature of the network nodes. The authors also present a case study using a Facebook dataset to illustrate the potential use of SNAM in modeling online social networks.

Social network analysis looks at the mapping and measurement of connections and interactions between people, groups, organization and other connected entities in a social environment. However, the real-world social networks are typically dense connected graphs with huge volume of data. In Chapter 10 titled, “Social Network Analysis,” the authors Paramita Dey and Sarbani Roy study network characteristics commonly used to explain social structures. The authors discuss all important aspect of social networking and analyze them through a real-time example. The analysis identifies some important parameters like the number of clusters, group formation, node degree distribution and seed nodes, etc that can be used further for feature extraction.

Community detection is a problem of great interest in complex network analysis. There is a strong need for efficient techniques for optimal community detection. In Chapter 11 titled, “Evolutionary Computation Techniques for Community Detection in Social Network Analysis,” the authors Abhishek Garg, Anupam Biswas and Bhaskar Biswas study the applicability of evolutionary computation techniques such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) as well as their numerous variants for community detection. The authors also identify various issues with community detection and discuss how the evolutionary computation techniques can handle these issues.

In Chapter 12 titled, “Differential Evolution Dynamic Analysis in the Form of Complex Networks,” the authors Ivan Zelinka and Lenka Skanderova present a novel method for analysis of the dynamics of evolutionary algorithms in the form of complex networks. The authors discuss the analogy between individuals in populations in an arbitrary evolutionary algorithm and vertices of a complex network as well as between edges in a complex network and communication between individuals in a population. The authors also discuss the dynamics of the analysis.

In Chapter 13 titled, “On Mutual Relations Amongst Evolutionary Algorithm Dynamics, its Hidden Complex Network Structures: An Overview and Recent Advances,” the author Ivan Zelinka explores mutual relations among evolutionary computation algorithms and their dynamics, deterministic chaos and complex networks. The objective of this chapter is to explore the applicability of evolutionary algorithms for complex network analysis and unravel their hidden structures in an efficient fashion.

In Chapter 14 titled, “Wireless Body Area Network for Healthcare Applications,” the author Danda Rawat provides a thorough survey of current technologies for Wireless Body Area Networks (WBAN) in the healthcare sector. The chapter discusses details of several existing WBAN-related projects along with their applications. The chapter discusses the use and design of medical sensors in WBAN as well as provides a comparison of WBAN and WSN.

Chapter 15 titled, “Application of Biomedical Image Processing in Blood Cell Counting using Hough Transform,” considers blood stream as a complex network of red blood cells (RBCs), white blood cells (WBCs) and platelets. The authors Manali Mukherjee, Kamarujjaman Sk and Mausumi Maitra discuss the use of the Hough Transform feature extraction technique to process microscopic images of blood cells for counting. The Hough transform technique finds imperfect instances of objects within a certain class of shapes by a voting procedure carried out in a parameter space to identify conditions leading to low blood counts.

Chapter 16 titled, “A Hybrid Complex Network Model for Wireless Sensor Networks and Performance Evaluation,” models telecommunication networks as a complex network and quantifies the terms clustering coefficient and average diameter of the entire network for distributed communication. The authors Peppino Fazio, Mauro Tropea, Salvatore Marano and Vincenzo Curia propose the use of “Hybrid Data

Mules" to enhance the connectivity and scalability of the network. The mules are equipped with special wireless devices using two different transmission standards.

In Chapter 17 titled, "A Network Analysis Method for Tailoring Academic Programs," the authors Luis Casillas, Thanasis Daradoumis and Santi Caballe propose a complex network-based approach for tailoring academic programs to provide a practical and automated method to discover and organize knowledge milestones. The chapter explores the use of information and communication technologies that would create adaptive, flexible, ubiquitous, asynchronous, collaborative, hyper-mediated and personalized strategies for representation and visualization of information from a complex network point of view.

With the phenomenal growth of various state-of-the-art networking domains (social networks, wireless networks, web) and the enriched information available on classical networks (like biological networks), it becomes imperative that we need a comprehensive book to address the analysis of all of these networks from both theoretical and practical standpoint. The existing books in Network Science are primarily written by some of the prominent academic researchers in this area and hence these books focus mainly on their proposed algorithms and analysis for network science as well as applied only to a particular domain of networks like biological networks or social networks. Our book fills this void as it brings together chapters from a diverse set of researchers working on various domains of networks, and hence will be a good source of information for analysis of a variety of networks. Readers will become knowledgeable in the algorithms, methodologies and tools that are suitable for analyzing diverse categories of networks and will be able to appropriately apply them depending on the context of the network under study. We anticipate our book will be a highly cited one in future conference proceedings and journal articles in the area of Network Science and will be a valuable source of information for students, researchers, industry practitioners and business professionals.

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