

Preface

Distributed Sensor Networks (DSN) are large-scale, autonomous, resource-constrained systems used for gathering data in an intelligent manner. Described by Business week as one of the twenty-first century, DSN technology is stepping out its cradle of laboratories and research papers, and finding increasing number of applications.

Often powered by advances in the miniaturization of Microelectronic and Mechanical Structure (MEMS), a DSN is composed of many tiny sensor nodes, all of which have capabilities for sensing, computing, and communication. Sensor nodes are often low cost, low power, and small size, and frequently remain untethered and unattended after deployment. Wireless Sensor Network (WSN) typically consists of large number of various kinds of unstructured environments. Usually, a sensor node has a communication range of less than 100 ft. Sensor nodes can be deployed on the ground, in the soil, underwater, in the air, in vehicles, or in buildings.

The detection and identification methods must be robust and secure for persistent and pervasive operations under uncertainty, resource constraints, and known and unknown operational, environmental, and adversarial perturbations. This necessitates the development of sensor networks that autonomously form collaborative clusters for reliable time critical response to natural and man-made disasters and to more general battlefield environments and are backed by strong processing power of cyber systems.

In this monograph, the *Mathematical Theories of Distributed Sensor Networks* are presented. In [Chap. 1](#), we provide an introduction to the DNS. This Introduction chapter has been designed to clarify the importance and position of the area of sensor networks in the context of the network design as its containing field of research.

Energy efficiency is one of the most critical issues in DNS. Efficient time complexity of algorithms which are running in different parts of a DSN for various purposes has a vital role in optimizing the energy consumption of the network. For example, a poor-quality routing algorithm may lead to node congestion and a huge energy wastage. In the “Optimization Methods” part, we will address two famous optimization problems in the context of DSNs in detail: art-gallery problem and wideband source localization using acoustic sensor networks.

One of the most famous *coverage problems* is called the *gallery-guarding* problem or generally, *Art-Gallery Problem*. In [Chap. 2](#), we will see an efficient approximation algorithm which makes an acceptable solution for the gallery-guarding problem in 3-D when the boundary of guarded region is in the form of a polygonal mesh.

Another optimization problem which will be addressed in this book is the wideband source localization using acoustic sensor networks in the presence of nonuniform noise variances.

In [Chap. 3](#), we present a solution to the problem based on two source localization algorithms called Stepwise-Concentrated Maximum-Likelihood (SC-ML) and Approximately Concentrated Maximum-Likelihood (AC-ML).

In Part II of the monograph, we focus on the coverage and connectivity problems in the context of DNS. Coverage problem is one of the fundamental issues in DSNs. In this problem, the goal is to determine how well a set of sensors can monitor a given area. In addition, the connectivity problem in DNS is to determine whether the graph representation of the network is connected or not.

In [Chap. 4](#), we address the coordinate-free coverage problems in DSNs via Homology.¹ Moreover, in [Chap. 5](#), some discussions regarding the coverage assessment and target tracking in 3-D domains will be presented.

Finally, in Part III (last) of the book, an interesting security problem in DSNs will be addressed. More specifically, we propose a novel stochastic preserving scheme of location privacy either for a static or for a mobile sensor node. After describing the proposed scheme, we present the privacy assessment of the method using some mathematical tools.

Features

Here are the unique aspects of our book which address the oblivious network routing problems:

- (1) The book specifies the importance and position of the DNS in the context of the network design as it contains the field of research. To do this, numerous concepts in this area are defined precisely using the mathematical tools.
- (2) The book provides the basics and mathematical foundations needed to analyze and address many problems in DNS. More specifically, it introduces some advanced data structures and tools (in graph theory and probability theory) which will be deployed for analysis and design of high-performance DNS.

¹ Homology is a certain general procedure to associate a sequence of abelian groups or modules with a given mathematical object such as a topological space or a group.

Intended Audience

This monograph is suitable for senior undergraduate students, graduate students, and the researchers working in the related areas.

Authors' Credentials

S. S. Iyengar is a Distinguished Ryder Professor and Director of the School of Computing and Information Sciences at the Florida International University and is the founding Director of the FIU-Discovery Lab. Iyengar is a pioneer in the field of distributed sensor networks/sensor fusion, computational aspects of robotics, and high-performance computing. Iyengar has published over 500 research papers and has authored/co-authored/edited 18 books published by John Wiley and Sons, Prentice Hall, CRC Press, Springer Verlag, etc. These publications have been used in major universities all over the world.

His research publications are on the design and analysis of efficient algorithms, parallel computing, sensor networks, and robotics. In 2014, Dr. Iyengar was elected to the rank of NAI (National Academy of Inventors) Fellow for demonstrating a highly prolific sprint of innovation in creating/facilitating outstanding inventions that have made a tangible impact on quality of life, economic development, and the welfare of society.

In addition, Dr. Iyengar was awarded the 2014 IBM Faculty Award for fostering collaboration between researchers at leading universities worldwide and those in IBM Research, development and services organizations and prompting courseware and curriculum innovation to stimulate growth in disciplines and geographies that are strategic to IBM. He is also a member of the European Academy of Sciences, a Fellow of IEEE, a Fellow of ACM, a Fellow of AAAS, and a Fellow of Society of Design and Process Program (SPDS), Fellow of Institution of Engineers (FIE), awarded a Distinguished Alumnus Award of the Indian Institute of Science, Bangalore, and was awarded the IEEE Computer Society Technical Achievement for the contributions to sensor fusion algorithms and parallel algorithms. He is a Golden Core member of the IEEE-CS, and he has received a Lifetime Achievement Award conferred by the International Society of Agile Manufacturing (ISAM) in recognition of his illustrious career in teaching, research, and a lifelong contribution to the fields of Engineering and Computer Science at Indian Institute of Technology (BHU). Iyengar and Nulogix were awarded in the 2012 Innovation 2 Industry (i2i) Florida competition. Iyengar received Distinguished Research Award from Xaimen University, China, for his research in Sensor Networks, Computer Vision, and Image Processing. Iyengar's landmark contributions with his research group are the development of grid coverage for surveillance and target location in DNS and Brooks Iyengar fusion algorithm.

He has also been awarded honorary Doctorate of Science and Engineering from an institution. He serves on the advisory board of many corporations and universities in the world. He has served on many National Science Boards such as NIH—National Library of Medicine in Bioinformatics, National Science Foundation review panel, NASA Space Science, Department of Homeland Security, Office of Naval Security, and many others. His contribution was a centerpiece of this pioneering effort to develop image analysis for our science and technology and to the goals of the US Naval Research Laboratory. The impact of his research contributions can be seen in companies/National Labs like Raytheon, Telecordia, Motorola, the United States Navy, DARPA agencies, etc. His contribution includes DARPAS's program demonstration with BBN, Cambridge, Massachusetts, MURI, researchers from PSU/ARL, Duke, University of Wisconsin, UCLA, Cornell University, and LSU.

He is also the Founding Editor of International Journal of Distributed Sensor Networks. He has been the Editor for many IEEE Journals (IEEE Transactions on Computers, etc.). He is presently the Editor of ACM Computing Surveys and other journals. Also he is the founding director of the FIUs Discovery Laboratory. His research work has been cited over extensively in Wikipedia and in other places. Iyengar has graduated over 45 Ph.D. students, 100s of Masters Students, and a large number of postdoctoral fellows at various institutions in the world. He also had many undergraduate students working on his research projects.

His fundamental work has been transitioned into unique technologies. The impact of his work is significant and can be seen in several areas of computer science. His work had been the fundamental in the development of technological innovations in several organizations around the world. All through his three-decade long professional career, Iyengar has devoted and employed algorithmic morphology in a unique way for quantitative understanding of computational processes for many applications.

Kianoosh Gholami Boroojeni is a Ph.D. student of computer science at FIU. He received his B.Sc. in University of Tehran, Iran (2012). His research interests include algorithms and combinatorial optimization.

During the first year of Kianoush's graduate years, he has submitted many peer-reviewed journal papers and a book to the Springer publications. Currently, Kianoosh is collaborating with Dr. S. S. Iyengar on some optimization problems in the context of oblivious network design.

N. Balakrishnan is an Associate Director and Professor at Department of Aerospace Engineering and Supercomputer Education and Research Centre, Indian Institute of Science. His research interests include “numerical electromagnetic,” “multi-parameter radars,” and “signal processing.”

Professor Balakrishnan is the Fellow of Third World Academy of Sciences, Indian National Science Academy, Indian Academy of Sciences, Indian National Academy of Engineering, National Academy of Sciences, Allahabad, and Institution of Electronic and Telecommunication Engineers. His publications include 19 books and many peer-reviewed journal papers.

Mathematical Theories of Distributed Sensor Networks

Iyengar, S.S.; Boroojeni, K.G.; Balakrishnan, N.

2014, XIV, 153 p. 39 illus., 31 illus. in color., Hardcover

ISBN: 978-1-4419-8419-7