Preface

Wireless Sensor Networks (WSNs) are rapidly becoming a technological cornerstone for modern societies. These collections of autonomous and distributed nodes capable of sensing, communication, processing, and even self-organization continue to earn notoriety as they serve as the backbone of emerging intelligent information-driven paradigms such as the *Internet of Things* [7, 12, 22], *Vehicular Clouds* [6, 19], or *Cyber-Physical Systems* [2, 4]. Over the last two decades, we have witnessed a plethora of developments related to theoretical innovations in WSNs that touch all aspects of their multilayered design, from more robust physical and medium access layers [23] to more efficient energy conservation [15, 18, 21] and self-organization protocols [5, 25]. The number of published surveys reporting successful WSN applications to dissimilar domains [1, 8–10, 20] is frankly overwhelming.

Computational Intelligence (CI) is a very active research discipline that encompasses a plethora of methodologies that draw inspiration from natural and social processes to model and solve a variety of challenging real-world problems [11, 13]. The appeal behind CI techniques revolves around the fact that they take into account the imprecise, vague, and uncertain knowledge that is often present in any realistic world model. Through the abstraction and simulation of intelligent systems such as bird flocks, fish schools, ant colonies, immune system cells, neural connections, and other highly parallel and distributed processes, the overhead imposed by the computational intractability of NP-hard optimization problems and, more recently, the emergence of Big Data [16], has been reasonably alleviated. The term CI is not indicative of a single methodology; rather, it describes a large umbrella under which several biologically and socially motivated techniques have emerged [11]. The CI field has outgrown its traditional foundations (centered around *artificial neural networks*, *fuzzy systems* and *evolutionary computation*) to embrace other related approaches that also pursue the same goals of tractability, robustness, and low solution cost [11, 13], including but not limited to: *rough sets*, *multi-valued logic*, *connectionist systems*, *swarm intelligence*, *artificial immune systems*, *granular computing*, *game theory*, *deep learning*, and the *hybridization* of the aforementioned systems.

CI techniques have much to offer to WSN in terms of the realization of periodical yet vital tasks such as *sensor node localization*, *data collection and aggregation*, *energy-aware routing/broadcasting*, and *sensor relocation* [14]. The interplay between both fields of study is growing in vitality and spills over other closely related areas such as *bio-inspired computing*, *robotics and vehicular systems*, thus crystallizing the foundations of an exciting multidisciplinary arena. *Bio-inspired networking* [3, 24] is a recently coined term that attempts to capture the impact of a large subset of CI methodologies to interconnected systems.

This volume is another initiative undertaken to emphasize the increasingly important role that CI methods are playing in solving a myriad of entangled WSN-related problems. The book serves as a guide for surveying several state-of-the art WSN scenarios in which CI approaches have been employed. The chapters in this volume do not offer an exhaustive picture of the rich landscape of CI-WSN applications given the breadth and depth of this interplay, with many problems rapidly arising as the pace of technology accelerates. The reader will find in this book how CI has contributed to solve a wide range of challenging problems, ranging from balancing the cost and accuracy of heterogeneous sensor deployments to recovering from real-time sensor failures to detecting attacks launched by malicious sensor nodes and enacting CI-based security schemes. Network managers, industry experts, academicians and practitioners alike (mostly in computer engineering, computer science, or applied mathematics) will benefit from the spectrum of successful applications reported in this volume. Senior undergraduate or graduate students may discover in this volume some problems well suited for their own research endeavors.

Volume Organization

Chapter 1 entitled "A Genetic Programming Approach to Cost-Sensitive Control in Wireless Sensor Networks" employs Genetic Programming (GP) to find suitable sensor control strategies that balance the accuracy of the measurements needed to monitor a certain region and the cost of powering these devices. In networks supporting multiple sensor types (a.k.a. heterogeneous WSNs), it is therefore desirable to develop cost-sensitive control algorithms that sample more expensive sensors only when necessary. The proposed solution has a twofold nature. First, a hierarchical method is proposed where GP solutions are sorted in a hierarchy of layers based on the cost of the sensors they use. Switching to the next more expensive layer takes place only if the prediction variance indicates uncertainty at lower layers. Second, the authors introduce non-hierarchical models that automatically select sensors based on both cost and accuracy. In experiments using a synthesized dataset and ten real datasets, the hierarchical method is shown to have significantly lower prediction costs than the non-hierarchical method.

Wireless Mesh Networks (WMNs) are a particular type of WSN whose topology can vary from a simple star network to an advanced multi-hop one. The main topological feature is that nodes are organized in a mesh topology, thus making WMNs a reliable infrastructure through the redundancy of multi-hop communications. In Chapter 2 "A Study on Performance of Hill Climbing Heuristic Method for Router Placement in Wireless Mesh Networks", the authors put forth an approach based on Hill Climbing (HC), a simple local search method, to quickly identify near-optimal router locations in a WMN so as to improve its Quality of Service (QoS) in terms of maximizing the network connectivity and client coverage. The ensuing bi-objective optimization problem is tackled via the HC heuristic method, whose performance is investigated under different distributions of client mesh nodes.

Chapter 3 titled "An Automated Irrigation System Based on a Low-Cost Microcontroller for Tomato Production in South India" introduces a practical result on a fuzzy logic-based irrigation controller for growing vegetables. The system consists of a feedback fuzzy logic controller that records key parameters with sensors, ZigbeeGPRS remote monitor, and a database. Based on the crop yield, the fuzzy logic controller acquires data from the sensors and applies fuzzy rules to determine a suitable irrigation time. A MaxMin inference engine and a Mamdani-type fuzzy inference system were adopted in order to make the best decision for each situation. The proposed system was developed and tested for the growth of tomato plants. It saves 50–60 % of the water utilization as well as the energy generation cost.

Chapter 4 "Artificial Neural Network Based Real-Time Urban Road Traffic State Estimation Framework" unveils a methodology that utilizes the existing cellular network infrastructure for road traffic data collection with a three-layer neural network model to estimate the complete link traffic state. The inputs to the neural network (NN) model include the probe vehicle's position, timestamps, and speeds. The framework integrates different modules that resort to different models in the process of traffic state estimation. Real A-GPS data gathered using A-GPS mobile phone on a moving vehicle on the set of chosen roads is used to evaluate the NN model. The trained NN is also used to estimate the road link speeds and compares them with ground truth speed (aggregate edge states) on a 10-min interval per hour. The estimation accuracy indicated that reliable link speed estimation can be generated and used to determine real-time urban road traffic conditions.

WSNs are subject to an ample range of potential attacks originated by malicious sensors. These attacks range from passive eavesdropping to active interfering and tampering of the communication. Chapter 5 "Attack Detection Using Evolutionary Computation" is concerned with the detection of such active attacks using the restricted capabilities of the sensor nodes. The underlying idea is that each sensor node is equipped with a simple intrusion detection system (IDS), hence an entire area can be monitored for malicious behavior in a distributed fashion. The automatic configuration of the IDS parameters is entrusted to *Multi-Objective Evolutionary Algorithms* (MOEAs) and illustrated via the selective forwarding attack and the delay attack. The proposed optimization framework provides Pareto front approximations consisting of different IDS settings with respect to three objectives, i.e., false positives, false negatives, and memory consumption. Furthermore, the authors discuss various attacker strategies and the robustness of the IDS settings found for a specific attacker strategy in cases where another attacker strategy is enacted.

Chapter 6 "Computational Intelligence Based Security in Wireless Sensor Networks: Technologies and Design Challenges" reviews the application of CI techniques to developing security schemes for WSNs. Fuzzy sets, rough sets, neurocomputing and evolutionary approaches are among the formalisms that have been proposed to enable WSNs with security features. There is broad uncharted territory when it comes to designing CI-based security systems for WSNs.

Wireless Visual Sensor Networks (WVSNs) are a type of WSNs that are heavily used for sensitive applications such as video surveillance and monitoring. To overcome the typical constraints of a WVSN in terms of its limited memory, energy, and bandwidth, Compressed Sensing (CS) techniques are brought into place with the aim of reconstructing sparse signals using very few measurements. Anomaly detection can then be accomplished in a more efficient manner using CS. Chapter 7 "Efficient Anomaly Detection System for Video Surveillance Application in WVSN with Particle Swarm Optimization" employs the popular Particle Swarm Optimization (PSO) metaheuristic algorithm to optimize the minimum number of compressed measurements and the routing of the information towards the destination. The proposed system is capable of detecting targets with fewer measurements and transmitting the required compressive measurements for reconstruction with less energy, thereby increasing the network lifetime.

Mobile robots are brought into a WSN to perform a wide range of tasks that optimize the WSN operation and extend its lifetime. One example of this is the replacement of damaged sensors with other functional, passive ones already deployed in the monitoring region. This problem has been recently studied under the name of *Robot-Assisted Sensor Relocation* (RASR) and cast as a combinatorial optimization problem. Chapter 8 entitled "Planning Robust Sensor Relocation Trajectories for a Mobile Robot with Evolutionary Multi-objective Optimization" extends the previous RASR formulation by actively considering the current energy levels of the participating passive sensors as well as the ideal locations for their deployment as additional decision objectives. This results in more robust sensor relocation trajectories to be pursued by the mobile robot. The authors explore six prominent MOEA implementations and discuss their performance with WSNs of varying sizes, inflicted damage levels, and passive sensor densities. They also tailor a recently proposed Risk Management Framework to proactively detect sensors that are at a high risk for failure and replace them before any network coverage is lost.

Future Challenges

The new generation of wireless networking involving the Internet of Things, Cyber Physical Systems etc., will result in *higher rate integrated communications*. Understanding and managing the complexity of such networks' bandwidth, capacity, security and Quality of Service (QoS) requirements will all be significant research challenges.

Currently we are also experiencing an *explosion of mobile data traffic*, characterized by the 4 V's Big Data vector: volume, velocity, variety, and veracity [16]. So, designing suitable frameworks to handle such Big Data in a wireless environment using appropriate Computational Intelligence tools will be a real challenge. Important aspects revolve around *real-time distributed control, processing and visualization* of these data streams in order to generate *actionable intelligence* that can better assist the decision-making process. A *risk-aware view* [17] of the WSN-monitored environment is not only beneficial but necessary in order to emphasize on the events of interest and declutter the operator's workspace.

We hope that the suite of technical contributions gathered in this book help drive further momentum into many theoretical and practical aspects of the wonderful synergy between CI methods and the WSN realm. Enjoy the reading!

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May 2016

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http://www.springer.com/978-3-319-47713-8

Computational Intelligence in Wireless Sensor Networks
Recent Advances and Future Challenges
Abraham, A.; Falcon, R.; Koeppen, M. (Eds.)
2017, XV, 210 p. 91 illus., Hardcover
ISBN: 978-3-319-47713-8