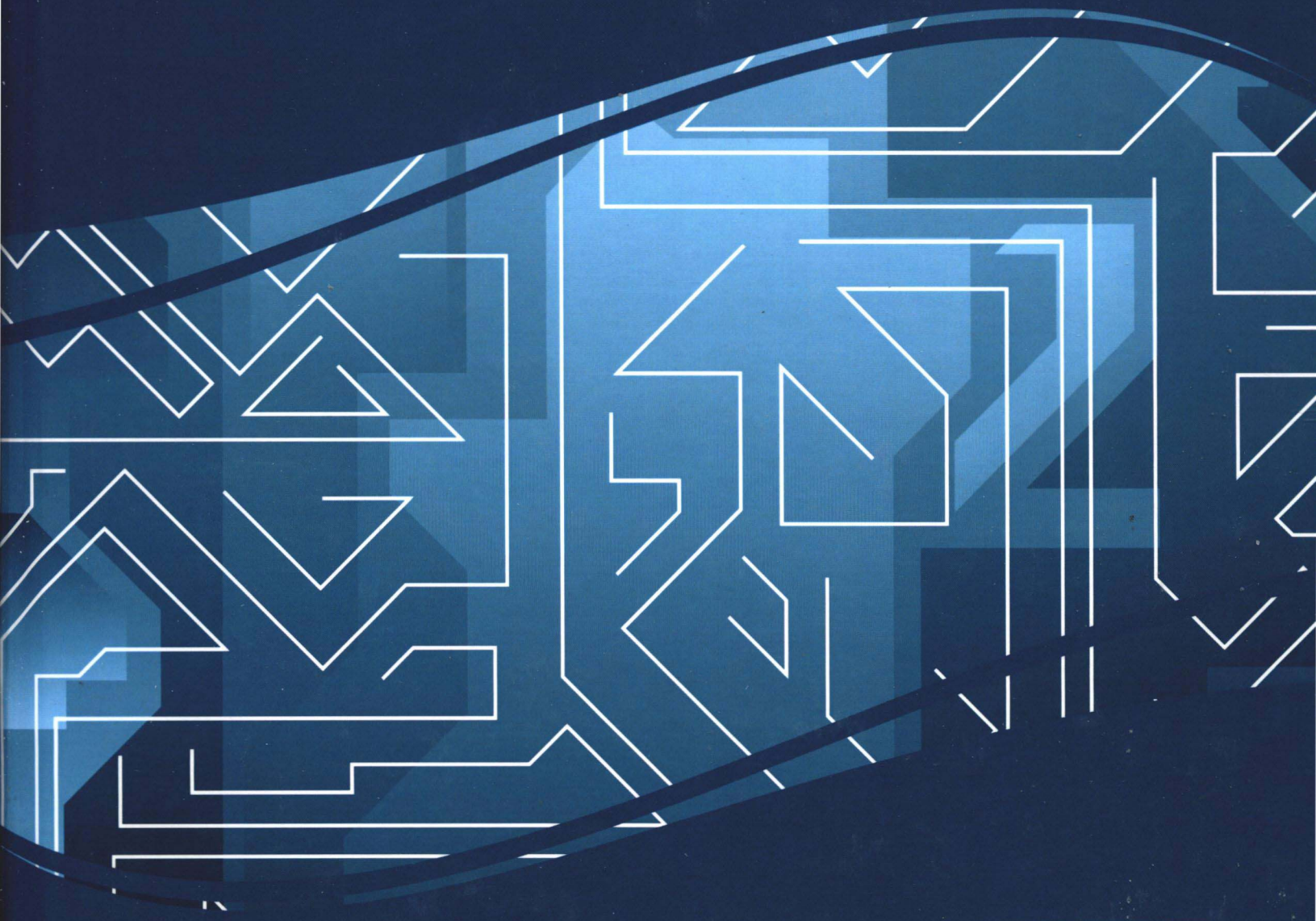
Handbook of Research on

Generalized and Hybrid Set Structures and Applications for Soft Computing



Sunil Jacob John

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Handbook of Research on Generalized and Hybrid Set Structures and Applications for Soft Computing

Sunil Jacob John
National Institute of Technology Calicut, India

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A volume in the Advances in Computational Intelligence and Robotics (ACIR) Book Series

Information Science REFERENCE
An Imprint of IGI Global

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

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Library of Congress Cataloging-in-Publication Data

Library of Congress Cataloging-in-Publication Data

Names: John, Sunil Jacob, 1973- editor.
Title: Handbook of research on generalized and hybrid set structures and applications for soft computing / Sunil Jacob John, editor.
Description: Hershey, PA : Information Science Reference, [2016] | Includes bibliographical references and index.
Identifiers: LCCN 2015043853| ISBN 9781466697980 (hardcover) | ISBN 9781466697997 (ebook)
Subjects: LCSH: Soft computing--Mathematics--Handbooks, manuals, etc. | Set theory--Handbooks, manuals, etc.
Classification: LCC QA76.9.S63 .H348 2016 | DDC 006.3--dc23 LC record available at http://lccn.loc.gov/2015043853

This book is published in the IGI Global book series Advances in Computational Intelligence and Robotics (ACIR) (ISSN: 2327-0411; eISSN: 2327-042X)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book is new, previously-unpublished material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

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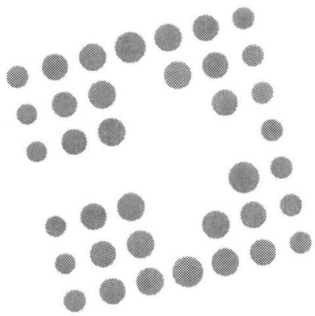

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Ivan Giannoccaro
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ISSN: 2327-0411
EISSN: 2327-042X

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Preface

The term Soft Computing refers to a collection of computational techniques which study, model, and analyze very complex systems for which the conventional methods have not yielded the best solutions. Keeping in mind that uncertainty may be present either in the data collected to solve the problem or in the knowledge or method used to solve the problem, there developed many robust computing methods to solve problems which bear uncertainty inherently. They also bring about a significant paradigm shift reflecting the fact that human mind has the remarkable ability to store and process information better than present day computers when there is a significant amount of uncertainty involved in the problem. The problem solving process in these scenarios is broadly known as reasoning under uncertainty or approximate reasoning or imprecise reasoning. Also this is the context in which Soft Computing was developed, spearheading progress towards problem solving in an uncertain environment. To deal with real life situations, soft computing proved to be much effective as the role model for soft computing is the human mind itself. The guiding principle of soft computing is exploiting tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost.

The major constituents of Soft Computing includes fuzzy logic, neuro-computing and probabilistic reasoning, with the latter subsuming genetic algorithms, belief networks, chaotic systems, and parts of learning theory. Fuzzy logic and Fuzzy set theory plays a significant role in soft computing and this stems from the fact that human reasoning is not crisp and admits degrees. Fuzzy sets and fuzzy logic, which are generalizations of sets and classical logic, are used to model vagueness which forms a major constituent in various forms of uncertainties. However, Soft Computing should not have to be limited to using fuzzy sets, but should have the freedom to draw ideas from other generalizations of sets like Rough sets, Multisets, Soft sets etc. and potential hybridizations among these. Among various other generalizations of sets, rough set theory is well developed and applications of rough sets in soft computing are well explored. But other structures like multisets, soft sets, fuzzy multisets, fuzzy soft sets etc. are still in developing stages and their applications in various soft computing scenarios need to be explored. The primary objective of this book is to gather such generalized set structures and their applications in various soft computing paradigms.

A Major problem in achieving effective computational systems is the presence of inherent uncertainty in the computational problem itself. Among various techniques proposed to address this, the technique of soft computing is of significant interest. Further, Generalized set structures like fuzzy sets, rough sets, multisets etc. have already proven their role in the context of soft computing. The computational techniques based on only one of these structures alone will not always yield the best results but a fusion of two or more of them can often give better results. Such structures are regarded as hybrid set structures. This book contains theoretical developments in generalized set structures and their hybridizations to-

gether with their applications in soft computing relating to various engineering and scientific scenarios. It is believed that developments in the fields of Soft Computing with Applications directly influence development of Multidisciplinary and Hybrid research. Thus, by publishing this book we see our mission in enabling further considerable advancements in the fields of Soft Computing of multidisciplinary and Hybrid nature. Our aim is to gather and share innovative ideas, precious knowledge and unique experiences for the benefit of researchers and explore possible prospects for development of Multidisciplinary and Hybrid research in the areas of Soft Computing with Applications.

As such, this book contains 24 chapters covering various aspects of generalized and hybrid structures from theoretical to application problems.

Fuzzy sets, intuitionistic fuzzy sets, rough sets and soft sets are extensions of the basic notion of sets as they model uncertainty in data. Following this multisets have been extended to fuzzy multisets, intuitionistic fuzzy sets, rough multisets and soft multisets. Many properties of basic sets have been extended to the context of multisets, fuzzy multisets, intuitionistic fuzzy sets, rough multisets and soft multisets. Several applications of different multisets mentioned above are found in literature. Chapter 1 by Balakrushna Tripathy gives a review of different concepts of multisets, their properties, current status and highlight their applications without going to the much of intricacies of mathematical complexities.

A brief presentation of the mathematical theory of fuzzy multisets together with fuzzy multirelations and their categorical models are provided in Chapter 2 by Apostolos Syropoulos. Models of computation based on fuzzy multisets, viz. fuzzy P systems, fuzzy chemical abstract machine and fuzzy Petri nets are discussed. These discussions justifies the fact that limits imposed by fuzzy computing conceptual devices are beyond the corresponding limits of crisp conceptual computing devices.

An attempt to combine the two concepts of Intuitionistic Fuzzy sets and Fuzzy Multisets is given in Chapter 3 by Shinoj T K and Sunil Jacob John. Most of human reasoning involves the use of variables whose values are fuzzy sets. This is the basis for the concept of a linguistic variable. But in some situations like decision making problems, the description by a linguistic variable in terms of membership function only is not adequate. There is chance of existing a non-null complement. There are situations that each element has different membership values. In such situations, Intuitionistic Fuzzy Multisets are more adequate. Here the authors present Intuitionistic Fuzzy Multisets as a tool for reasoning in such a situation through a medical diagnosis problem. As the second application, accuracy of Collaborative Robots using the concept of Intuitionistic Fuzzy Multiset is also discussed.

Image processing is a form of information processing in which both input and output are images. Most of the images contain lot of uncertainties and are fuzzy / vague in nature. Various fuzzy filtering techniques are defined for noise removal in image processing and these existing filters helps to enhance the image using only the membership values. Further, by incorporating intuitionistic fuzzy filters, vagueness and ambiguity are managed by taking the non-membership values also into consideration. Chapter 4 by C Radhika, R Parvathi and N K Visalakshy presents the results of applying different noise types to an image and investigates the results of various intuitionistic fuzzy filtering techniques. A comparison is also made on the results of all the techniques.

One of the major problems with the techniques to model uncertainty is the lack of sufficient number of parameters to deal with uncertainty. In order to add adequate number of parameters, soft sets were introduced by Molodtsov in 1999. Since then, theoretical developments on soft set has attracted the attention of researchers. However, the practical applications of any theory are of enough importance to make use of it. Chapter 5 by Balakrushna Tripathy and Arun K R gives basic definitions of soft sets and many properties are discussed together with different applications.

In Chapter 6 by Pinaki Majumdar, the notions of two hybrid structures, namely fuzzy parameterized soft sets and vague soft sets has been discussed and some operations on them are defined. Some properties of these two hybrid soft sets under these operations are also studied. Application of fuzzy parameterized soft sets and vague soft sets in decision making has also been shown. Then the notion of similarity measure between two hybrid soft sets has been introduced and their basic properties are studied. Applications of these similarity measures in various problems like medical diagnosis and decision making have been shown. The idea of entropy of a fuzzy parameterized soft set has also been introduced.

Some theoretical issues related to soft sets are discussed in Chapter 7 by K V Babitha and Sunil Jacob John. The relationship between soft set topologies and different relations are investigated and some of the properties of these soft set topologies are obtained. The concept of topology generated by relations in the context of soft sets seems to be a promising tool for further research in the area of mathematics of soft sets.

Continuing the studies related to soft topological spaces, Chapter 8 by Alaa Mohammed, Sobhy Ahmed, Ali Kandil and Osama El-Tantawy introduces the notions of γ-operation, pre open soft sets, α-open sets, semi open soft sets and β-open soft sets to soft topological spaces. Further a new soft separation axiom based on the semi open soft sets which are more general than of the open soft sets is developed. Moreover, the chapter studies supra generalized closed soft sets in a supra topological spaces and their properties in detail.

In Chapter 9, Anjan Mukherjee and Ajoy Kanti Das introduce a new sequence of fuzzy soft multi sets in fuzzy soft multi topological spaces and their basic properties are studied. The concepts of subsequence, convergence sequence and clustering are investigated in this context. A correspondence between net convergence and filter convergence in the fuzzy soft multi topological spaces is also obtained

In Chapter 10, Shyamal Mondal has introduced a new concept of two-dimensional fuzzy soft sets together with various operations, properties and theorems on them. An algorithm named 2-DFS has been developed for solving fuzzy multi-criteria assignment problems with multiple decision makers. The performance of this newly proposed method is verified by the popular Hungarian Method in the case of solving fuzzy assignment problems with single criterion and single decision maker.

Applying topological ordered spaces in rough set theory play a significant role in the problem of decision making and optimizations, where order of objects is essential in such problems. So, in Chapter 11 by Mona Hosny, Ali Kandil, Osama El-Tantawy and Sobhy Ahmed, new methods are presented to express the main concepts of rough sets in terms of (ideal) topological ordered concepts. The properties of suggested methods are studied. The introduced technique is useful because the concepts and the properties of the generated topology are applied on rough set theory and this open the way for more topological applications in rough context.

In Chapter 12 by A Zakaria, A. Kandil and M Yakout, a new definition of approximation operators and rough membership functions via ideal has been introduced. The concepts of lower and upper approximations via ideals have been studied. These new definitions are compared with Pawlak's, Yao's and Allam's definitions. It's shown that the new definitions are more general. Also, it is observed that the present method decreases the boundary region.

Hybrid set structures using rough sets are of significant importance in data classification problems. Rough approximations on hesitant fuzzy sets will give a significant boost to this area by laying theoretical foundations for this area. Hesitant fuzzy relations are the first building blocks towards this direction. So hesitant fuzzy relations and related topics have been studied in great detail in Chapter 13 by Deepak D

and Sunil Jacob John. It also establishes the definition of hesitant fuzzy rough sets and discusses their significant properties including the duality of the lower and upper approximations.

Soft set plays an important role in the theory of approximations, as parameterized family of subsets in the universe of discourse. On the other hand, neutrosophic set is based on the neutrosophic philosophy, which states that: Every idea A has an opposite anti(A) and its neutral neut(A). This is the main theme of neutrosophic sets and logics. Chapter 14 by Mumtaz Ali and Florentin Smarandache is about the hybrid structure called neutrosophic soft set. The notions of neutrosophic soft sets are defined and their properties studied. Algebraic structures associated with neutrosophic soft sets are also debated.

By using neutrosophy and quad-stage method, generalized and hybrid set can be created, whose example is creating generalized and hybrid neutrosophic set. With the help of the concepts of "generalized and hybrid set" and "library", Yuhua Fu in Chapter 15 introduces the concepts of "variation principle of set" and "variation principle of library", and establishes a kind of "partial and temporary unified theory of mathematics so far"; in which, it is the first time to put all of mathematics formulas into a multi-layer "variation principle of library".

Refined neutrosophic sets (RNS) are a generalization of a neutrosophic sets, intuitionistic fuzzy sets, fuzzy sets, intuitionistic fuzzy multi-sets and fuzzy multi-sets. Refined neutrosophic softsets (RNSS) are a generalization of a neutrosophic soft sets, intuitionistic fuzzy soft sets, fuzzy soft sets, intuitionistic fuzzy soft multi-sets and fuzzy soft multi-sets. These sets is a powerful general formal framework that has been proposed to present uncertainty, imprecise, incomplete, inaccurate and inconsistent information which exist in real life. Chapter 16 by Irfan Deli surveys concept of RNS and RNSS with basic definitions and presents an efficient approach for both. Also, the chapter introduces applications of RNS in Decision making problems and pattern recognition.

Multi-attribute decision making (MADM) play an important role in many applications. Due to its efficiency to handle indeterminate and inconsistent information, interval neutrosophic sets are widely used to model indeterminate information. In Chapter 17 by Said Broumi and Florentin Smarandache, a new MADM method based on interval neutrosophic trapezoid linguistic weighted arithmetic averaging aggregation (INTrLWAA) operator and interval neutrosophic trapezoid linguistic weighted geometric aggregation (INTrLWGA) operator is presented. Also a numerical example is provided to demonstrate the application and efficiency of the proposed method.

In Chapter 18 by Michael Gr. Voskoglou, two new fuzzy assessment models are developed, the trapezoidal (TRFAM) and the Triangular (TFAM), which are proved to be equivalent to each other. These models are new original variations of the Centre of Gravity (COG) defuzzification technique, which has been properly adapted and used in many earlier works as an assessment method. The central idea of TRFAM is the replacement of the rectangles appearing in the graph of the membership function of the COG technique by isosceles trapezoids sharing common parts.

Uncertainty analysis of any physical model in the context of decision making analysis involves of two kinds of uncertainties (1) aleatory uncertainty which is due to randomness of the parameters of models of interest and (2) the epistemic uncertainty which is due to fuzziness of the parameters of the same models. Instead of addressing both independently, which is the conventional way, Chapter 19 by Debabrata Datta, addresses these two jointly. In order to solve practical problems on uncertainty modeling, it is required to replace the abstract definition of hybrid set by fuzzy random set. Since uncertainty modeling using fuzzy random set has not been carried out so far, this chapter addresses the utility of fuzzy random set for uncertainty modeling on geotechnical and hydrological applications together with the fundamentals of fuzzy random sets and their applications in uncertainty analysis.

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Chapter 20 by Rasha Naser Majeed, Osama El-Tantawy, and Sobhy Ahmed is devoted to the study of *r*-generalized fuzzy closed sets in smooth bitopological spaces in view of the definition of Šostak, and constructs some types of fuzzy closure operators, smooth topologies, supra smooth topologies and mappings.

Recently, Wavelet Method (WM) is becoming a powerful tool to solve various types of differential equations. In this method, orthogonal wavelet functions are used as shape functions which are easier to compute. Till date WM has been used for crisp problems that is where the variables and parameters in the differential equations are considered as crisp. But generally in real world problems, every system contains uncertainty and this makes the corresponding mathematical model also uncertain. The uncertain and imprecise parameters make the system complex. Here the uncertainty has been managed by considering the parameters as interval. Accordingly, WM method is modified and Interval Wavelet Method (IWM) has been proposed. In Chapter 21 by Sukanta Nayak and S.Chakraverty, IWM has been used to investigate a simple diffusion problem and discussed in detail.

In Chapter 22 by DK Patel, Tanmoy Som and MK Singh, the widely common problem of handwritten character recognition has been tackled with multi-resolution technique using discrete wavelet transform and artificial neural networks. The technique has been tested and found to be more accurate and economic in respect of the recognition process time of the system. Features of the handwritten character images are extracted by discrete wavelet transforms used with appropriate level of multi-resolution technique, then the artificial neural networks is trained by extracted features. The unknown input handwritten character images are recognized by trained artificial neural networks system. The proposed method provides good recognition accuracy for handwritten characters with less training time, less no. of samples and less no. of iterations.

The subject STATISTICS is divided into two components: R-Statistics and NR-Statistics. The existing vast literature of the subject Statistics is of the category of "R-Statistics". Chapter 23 by Ranjit Biswas opens a new dimension in Statistics called by "NR-Statistics", which can be viewed as the sibling of the "R-Statistics". In R-Statistics the populations considered are R-populations, but the NR-Statistics deals with R-populations and NR-populations both. This chapter is just a beginning of the subject, an introducing notion. NR-Statistics is expected to be a huge subject of research to the scientists in Mathematics, Statistics, Engineering, Social Science, Medical Science, Nano-science, Cosmology, Forensic Science, Law, Sports Science, etc.

Gearboxes are employed in a wide variety of applications, ranging from small domestic appliances to the rather gigantic power plants and marine propulsion systems. Gearbox failure may not only result in significant financial losses resulting from downtime of machinery but may also place human life at risk. Gearbox failure in transmission systems of warships and single engine aircraft, beside other military applications, is unacceptable. The criticality of the gearbox in rotary machines has resulted in enormous effort on the part of researchers to develop new and efficient methods of diagnosing faults in gearboxes so that timely rectification can be undertaken before catastrophic failure occurs. Artificial intelligence (AI) has been a significant milestone in automated gearbox fault diagnosis (GFD). Chapter 24 by Anand Parey and Amandeep Singh Ahuja reviews over a decade of research efforts on fault diagnosis of gearboxes with AI techniques. Some of areas of AI in GFD which still merit attention have been identified and discussed .

Often there is a need to model, solve and analyze the problems that one come across when considering uncertain, imprecise and partial information. This book is intended to provide the reader with various Mathematical structures, their generalizations and hybridization which are useful in the context of soft

computing. Even though the particular contributions will be addressing some selected models only, but can be extended to other models and areas also. This book will certainly find an important source for graduate and postgraduate students, teachers and researchers in colleges, universities/institutes and industries in the field of various engineering as well as mathematics/applied mathematics and physics. As Soft Computing with Applications is an integral part in any novel and future oriented research in the area of uncertainty modeling, I sincerely hope that with the help of this book one will be able to build sufficient grounds for fulfillment of most brilliant and promising ideas in this area. I believe that global nature of the publisher, active participation of most prominent authors and cutting edge ideas will create a stimulating atmosphere for further active development of Generalized and Hybrid ways of research in the areas of Soft Computing with Applications.

Sunil Jacob John
National Institute of Technology Calicut, India
August 2015

Acknowledgment

I would like to express my deep sense of gratitude to all the contributors for their time and efforts for the preparation of the chapters. I am thankful to eminent members of the editorial advisory board for their encouragement and all the reviewers for giving the comments and suggestions on the chapters in time. I am indebted to Professor Dr. GRC Reddy, Director, National Institute of Technology (NIT) Calicut for his support and encouragement. The timely help and support by all my Ph.D. students and colleagues in the Department of Mathematics is commendable. I would very much like to acknowledge the encouragement, patience, and support provided by all my family members, in particular to my wife, Jinta and my son, Sujin. Finally, I am most appreciative to Rachel Ginder, Brandon Carbaugh and the personnel of IGI Global for their support during preparation of this book.

Sunil Jacob John
National Institute of Technology Calicut, India
August 2015

List of Contributors

Ahuja, Amandeep Singh / *Indian Institute of Technology Indore, India* 536
Ali, Mumtaz / *Quaid-i-azam University Islamabad, Pakistan* 280
Arun, K. R. / *VIT University, India* 65
Babitha, K. V. / *College of Engineering Vadakara, India* 118
Biswas, Ranjit / *Jamia Hamdard University, India* 490
Chakraverty, S. / *National Institute of Technology Rourkela, India* 457
Das, Ajoy Kanti / *Iswar Chandra Vidyasagar College, India* 172
Datta, Debabrata / *Bhabha Atomic Research Centre, India* 384
Deepak, D. / *National Institute of Technology Calicut, India* 265
Deli, Irfan / *Kilis 7 Aralık University, Turkey* 321
El-latif, A. M. Abd / *Ain Shams University, Egypt* 127
El-Sheikh, Sobhy A. / *Ain Shams University, Egypt* 127,223,419
El-Tantawy, Osama A. / *Zagazig University, Egypt* 127,223,419
Fu, Yuhua / *CNOOC Research Institute, China* 308
Hosny, Mona / *Ain Shams University, Egypt* 223
John, Sunil Jacob / *National Institute of Technology Calicut, India* 43,118,265
Kandil, Ali / *Helwan University, Egypt* 127,223,247
Majeed, Rasha N. / *Ain Shams University, Egypt & Baghdad University, Iraq* 419
Majumdar, Pinaki / *M. U. C. Women's College, India* 86
Mondal, Shyamal Kumar / *Vidyasagar University, India* 191
Mukherjee, Anjan / *Tripura University, India* 172
Nayak, Sukanta / *National Institute of Technology Rourkela, India* 457
Parey, Anand / *Indian Institute of Technology Indore, India* 536
Parvathi, R. / *Vellallar College for Women, India* 53
Patel, D. K. / *Indian Institute of Technology (BHU), India* 473
Radhika, C. / *Vellallar College for Women, India* 53
Said, Broumi / *University of Hassan II, Morocco* 344
Shinoj, T. K. / *National Institute of Technology Calicut, India* 43
Singh, M. K. / *Banaras Hindu University, India* 473
Smarandache, Florentin / *University of New Mexico, USA* 280,344
Som, T. / *Indian Institute of Technology (BHU), India* 473
Syropoulos, Apostolos / *Greek Molecular Computing Group, Greece* 23
Tripathy, B. K. / *VIT University, India* 1,65
Visalakshi, N. Karthikeyani / *Kongu Engineering College, India* 53

Voskoglou, Michael G. / *Graduate Technological Educational Institute (T. E. I.) of Western Greece, Greece* 366
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