

# **Studies in Fuzziness and Soft Computing**

Volume 341

## **Series editor**

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The series “Studies in Fuzziness and Soft Computing” contains publications on various topics in the area of soft computing, which include fuzzy sets, rough sets, neural networks, evolutionary computation, probabilistic and evidential reasoning, multi-valued logic, and related fields. The publications within “Studies in Fuzziness and Soft Computing” are primarily monographs and edited volumes. They cover significant recent developments in the field, both of a foundational and applicable character. An important feature of the series is its short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

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Editors

# Fuzzy Logic in Its 50th Year

New Developments, Directions  
and Challenges

 Springer

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*This book is dedicated to a pioneer of the fuzzy set theory, Prof. I. Burhan Turksen.*



Prof. I. Burhan Turksen

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# Preface

The fuzzy set theory, founded by Lotfi A. Zadeh in 1965, had covered a lot of ground with excellent successes in almost all branches of science. Especially, fuzzy control technologies provided definite evidences to prove its power and usability in the solutions of real-life problems. These evidences caused the harsh criticisms to lose their value within the 50 years of the fuzzy set theory.

This book aims at presenting the latest position of the fuzzy set theory within the science branches and drawing the frame of its expansion. In our book, the new extensions of fuzzy sets are summarized by their pioneers: Intuitionistic fuzzy sets by Atanassov (Chapter “[Mathematics of Intuitionistic Fuzzy Sets](#)”), hesitant fuzzy sets by Torra (Chapter “[A Review of Hesitant Fuzzy Sets: Quantitative and Qualitative Extensions](#)”), etc. Later, the position of the fuzzy set theory within earth and space sciences, human sciences, etc., is summarized. The last section of the book includes some applications of the fuzzy set theory.

The first chapter is on the emergence of fuzzy sets from a historical perspective. It tries to suggest some reasons why the fuzzy set theory came to life 50 years ago by pointing out the existence of streams of thought in the first half of the twentieth century in logic, linguistics, and philosophy, which paved way to the idea of moving away from the Boolean framework, through the proposal of many valued logics and the study of the vagueness phenomenon in natural languages.

The second chapter is on fuzzy decision-making. The chapter presents the pioneers of fuzzy decision-making: researchers, universities, and countries, and the media publishing fuzzy decision-making papers including the journals, books, and proceedings. It also includes numerical examples of decision-making problems with their solutions.

The third chapter is on mathematics of Intuitionistic Fuzzy Sets (IFSs). Short firsthand remarks on the history and theory of IFSs are given. Influences of other areas of mathematics for development of the IFSs theory are discussed. On the basis of results in IFSs theory, some ideas for development of other mathematical areas are offered.



The fourth chapter presents some comments on ordinary reasoning with fuzzy sets. It tries to serve as a theoretical support for computing with words, but, and specially, to motivate young researchers to go further in its extension towards the different types of commonsense reasoning.

The fifth chapter includes a review of hesitant fuzzy sets. Many researchers have paid attention to it and have proposed different extensions both in quantitative and qualitative contexts. Several concepts, basic operations, and its extensions are revised in this chapter.

The sixth chapter is on type-1 to type-n fuzzy logic and systems. The motivation for using fuzzy systems, the mathematical concepts of type-1 to type-n fuzzy sets, logic, and systems as well as their applications in solving real-world problems is presented.

The seventh chapter is on fuzzy sets in earth and space sciences. It reviews and analyzes the papers utilizing fuzzy logic in earth and space science problems from Scopus database. The graphical and tabular illustrations are presented for the subject areas, publication years, and sources of the papers on earth and space sciences.

The eighth chapter is on fuzzy sets and fuzzy logic in the human sciences. It surveys the history of fuzzy set applications in the human sciences, and then elaborates the possible reasons why fuzzy set concepts have been relatively under-utilized therein.

The ninth chapter is on fuzzy entropy used for predictive analytics. It develops models for predictive maintenance in a big data environment. The authors apply interval-valued fuzzy sets and various entropy measures defined on them to perform feature selection on process diagnostics. They show how these models can be utilized as the basis for decision support systems in process industries to aid predictive maintenance.

The 10th chapter is on fuzzy sets in agriculture. It aims at contributing to a refinement of review studies by applying fuzzy sets, fuzzy logic, and fuzzy cognitive mapping to the exploration of agriculture modeling and management.

The 11th chapter is on solving a multiobjective truck and trailer routing problem with fuzzy constraints. The fuzzy model is generalized in this work from a multiobjective approach by incorporating an objective to minimize the violation of constraints. We present and discuss the computational experiments carried out to solve the multiobjective truck and trailer routing problem with fuzzy constraint using benchmark instances with sizes ranging from 50 to 199 customers.

The 12th chapter is on health service network design under epistemic uncertainty. It provides a comprehensive review of the related literature to the HSND problem after explaining health, health system, and HSND problem briefly. The review is followed by a typical mathematical model for the concerned problem. Finally, a fuzzy programming approach is described in brief and different fuzzy measures, i.e., possibility, necessity, and credibility measures are applied to the compact form of the proposed mathematical programming model.

The 13th chapter is on robotics and control systems. It presents fuzzy control techniques as well as fuzzy mathematical scheduling model for an m machine

robotic cell with one manipulator robot. Furthermore, it proposes an integrated fuzzy robotic control system, in which the fuzzy optimization model is solved at every predetermined period of time such as beginning of shifts or days, etc. Then based upon on the solutions obtained, input parameters, and unpredictable disturbances, the autonomous fuzzy control is executed at each unit of time. These two modules transfer information and feedback to each other via an intermediate collaborative module.

The 14th chapter is on the usage of fuzzy sets in the evaluation of socio-ecological systems through an interval-valued intuitionistic fuzzy multi-criteria approach. It demonstrates how to incorporate fuzzy sets theory into social sciences. An illustrative example which consists of a wide variety of social actors is used to evaluate sustainable management options based on interval-valued intuitionistic fuzzy TOPSIS method.

The 15th chapter is on the survey on models and methods for solving fuzzy linear programming problems. The solution approaches are divided into four areas: (1) Linear Programming (LP) problems with fuzzy inequalities and crisp objective function, (2) LP problems with crisp inequalities and fuzzy objective function, (3) LP problems with fuzzy inequalities and fuzzy objective function, and (4) LP problems with fuzzy parameters.

The 16th chapter is on applications of fuzzy mathematical programming approaches in supply chain planning problems. It aims to provide the useful and updated information about different sources and types of uncertainty in supply chain planning problems and the strategies used to confront with uncertainty in such problems. A hyper methodological framework is proposed to cope with uncertainty in supply chain planning problems.

We hope that this book will provide a useful resource of ideas, techniques, and methods for the development of the fuzzy set theory. We are grateful to the referees whose valuable and highly appreciated works contributed to select the high quality chapters published in this book. We would like to also thank Prof. Janusz Kacprzyk, the editor of Studies in Fuzziness and Soft Computing at Springer for his supportive role in this process, and to Assoc. Prof. Sezi Cevik Onar for her help to accelerate the processes to catch the deadlines.

Cengiz Kahraman  
Uzay Kaymak  
Adnan Yazıcı

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