Contents

Preface.

Chapter 1. Introduction.

1.1. Digital communities and a fundamental quest for human-centric systems.
1.2. A historical overview: towards a non-Aristotelian perspective of the world.
1.3. Granular Computing.
   1.3.1. Sets and interval analysis.
   1.3.2. The role of fuzzy sets: a perspective of information granules.
   1.3.3. Rough sets.
   1.3.4. Shadowed sets.
1.4. Quantifying information granularity: generality versus specificity.
1.5. Computational Intelligence.
1.6. Granular Computing and Computational Intelligence.
1.7. Conclusions.
Exercises and problems.
Historical notes.
References.


2.2. Interpretation of fuzzy sets.
2.3. Membership functions and their motivation.
2.4. Fuzzy numbers and intervals.
2.5. Linguistic variables.
2.6. Conclusions.
Exercises and problems.
Historical notes.
References.


3.1. A generic characterization of fuzzy sets: some fundamental descriptors.
3.2. Equality and inclusion relationships in fuzzy sets.
3.3. Energy and entropy measures of fuzziness.
3.4. Specificity of fuzzy sets.
3.5. Geometric interpretation of sets and fuzzy sets.
3.7. Characterization of the families of fuzzy sets.
Chapter 4. The Design of Fuzzy Sets.

4.1. Semantics of fuzzy sets: some general observations.
4.2. Fuzzy set as a descriptor of feasible solutions.
4.3. Fuzzy set as a descriptor of the notion of typicality.
4.4. Membership functions in the visualization of preferences of solutions.
4.5. Nonlinear transformation of fuzzy sets.
4.7. Saaty’s priority method of pairwise membership function estimation.
4.8. Fuzzy sets as granular representatives of numeric data.
4.9. From numeric data to fuzzy sets.
4.10. Fuzzy equalization.
4.11. Linguistic approximation.
4.13. Conclusions.
Exercises and problems.
Historical notes.
References.


5.1. Standard operations on sets and fuzzy sets.
5.2. Generic requirements for operations on fuzzy sets.
5.3. Triangular norms.
   5.3.1. Defining t-norms.
   5.3.2. Constructors of t-norms.
5.4. Triangular conorms.
   5.4.1. Defining t-conorms.
   5.4.2. Constructors of t-conorms.
5.5. Triangular norms as a general category of logical operators.
5.6. Aggregation operations.
   5.6.1. Averaging operations.
   5.6.2. Ordered weighted averaging operations.
   5.6.3. Uninorms and nullnorms.
   5.6.4. Symmetric sums.
   5.6.5. Compensatory operations.
5.7. Fuzzy measure and integral.
5.8. Negations.
5.9. Conclusions.
Exercises and problems.
Historical notes.
Chapter 6. Fuzzy Relations.

6.1. The concept of relations.
6.2. Fuzzy relations.
6.3. Properties of the fuzzy relations.
6.4. Operations on fuzzy relations.
6.5. Cartesian product, projections and cylindrical extension of fuzzy sets.
6.6. Reconstruction of fuzzy relations.
6.7. Binary fuzzy relations.
Exercises and problems.
Historical notes.
References.

Chapter 7. Transformations of Fuzzy Sets.

7.1. The extension principle.
7.2. Compositions of fuzzy relations.
   7.2.1. sup-t composition.
   7.2.2. inf-s composition.
   7.2.3. inf-s composition.
7.3. Fuzzy relational equations.
   7.3.1. Solutions to the estimation problem.
   7.3.2. Fuzzy relational system.
   7.3.3. Relation-relation fuzzy equations.
   7.3.4. Multi-input, single-output fuzzy relational equations.
   7.3.5. Solution of the estimation problem for equations with inf-s composition.
   7.3.6. Solution of the inverse problem.
   7.3.7 Relation-relation fuzzy equations.
   7.3.8. Multi-input, single-output fuzzy relational equations.
   7.3.9. Solvability conditions for maximal solutions.
7.4. Associative Memories.
   7.4.1. sup-t fuzzy associative memories.
   7.4.2. inf-s fuzzy associative memories.
7.5. Fuzzy numbers and fuzzy arithmetic.
   7.5.1. Algebraic operations on fuzzy numbers.
   7.5.2. Computing with fuzzy numbers.
   7.5.3. Interval arithmetic and α-cuts.
   7.5.4. Fuzzy arithmetic and the extension principle.
   7.5.5. Computing with triangular fuzzy numbers.
6. Conclusions.
Exercises and problems.

Historical notes.
Chapter 8. Generalizations and Extensions of Fuzzy Sets.

8.1. Fuzzy sets of higher order.
8.2. Rough fuzzy sets and fuzzy rough sets.
8.3. Interval-valued fuzzy sets.
8.4. Type-2 fuzzy sets.
8.5. Shadowed sets as a three-valued logic characterization of fuzzy sets.
   8.5.1. Defining shadowed sets.
   8.5.2. The development of shadowed sets.
8.6. Probability and fuzzy sets.
8.7. Probability of fuzzy events.
8.8. Conclusions.
Exercises and problems.
Historical notes.
References.


9.2. Fuzzy sets and their interfacing with the external world.
   9.2.1. Encoding mechanisms.
   9.2.2. Decoding mechanisms.
9.3. Encoding and decoding as an optimization problem of vector quantization.
   9.3.1. Fuzzy scalar quantization.
   9.3.2. Forming the mechanisms of the fuzzy quantization: beyond a winner-takes-all scheme.
   9.3.3. Coding and decoding with the use of fuzzy codebooks.
9.4. Decoding of a fuzzy set through a family of fuzzy sets.
   9.4.1. Possibility and necessity measure in encoding of fuzzy data.
   9.4.2. The design of the decoder of fuzzy data.
9.5. Taxonomy of data in structure description with shadowed sets.
Exercises and problems.
Historical notes.
References.


10.1. The architectural blueprint of fuzzy models.
10.2. Key phases of the development and use of fuzzy models.
10.3. Main categories of fuzzy models: an overview.
10.4. Verification and validation of fuzzy models.
   10.4.1. Verification of fuzzy models.
   10.4.2. Training, validation, and testing data in the development of fuzzy models.
10.4.3. Validation of fuzzy models.
10.5. Conclusions.
Exercises and problems.
Historical notes.
References.


11.1. Fuzzy rules as a vehicle of knowledge representation.
11.2. General categories of fuzzy rules and their semantic.
11.3. Syntax of fuzzy rules.
11.4. Basic Functional Modules: Rule base, Database, and Inference scheme.
   11.4.1. Input interface.
   11.4.2. Rule base.
   11.4.3. Main types of rule bases.
   11.4.4. Data base.
   11.4.5. Fuzzy inference.
11.5. Types of Rule-Based Systems and Architectures.
   11.5.1. Linguistic fuzzy models.
   11.5.2. Functional (local) fuzzy models.
11.5.3. Gradual fuzzy models.
11.6. Approximation properties of fuzzy rule-based models.
11.7. Development of Rule-Based Systems.
   11.7.1. Expert-driven development.
   11.7.2. Data-driven development.
11.10. The curse of dimensionality in rule-based systems.
11.11. Development scheme of fuzzy rule-based models.
Exercises and problems.
Historical notes.
References.

Chapter 12. From Logic Expressions to Fuzzy Logic Networks.

12.1. Introduction.
12.2. Main categories of fuzzy neurons.
12.2.1. Aggregative neurons.
12.2.2. Referential (reference) neurons.
12.3. Uninorm-based fuzzy neurons.
   12.3.1. Main classes of unineurons.
   12.3.2. Properties and characteristics of the unineurons.
   12.4.1. Logic processor in the processing of fuzzy logic functions: a canonical realization.
12.4.2. Fuzzy neural networks with feedback loops.
12.5. The development mechanisms of the fuzzy neural networks.
   12.5.1. The key design phases.
   12.5.2. Gradient-based learning schemes for the networks.
12.7. From fuzzy logic networks to Boolean functions and their minimization through learning.
12.8. Interfacing the fuzzy neural network.
12.9. Interpretation aspects - a refinement of induced rule-based system.
12.10. Reconciliation of perception of information granules and granular mappings.
   12.10.1. Reconciliation of perception of information granule.
   12.10.2. The optimization process.
   12.10.3. An application of the perception mechanism to fuzzy rule-based systems.
   12.10.4. Reconciliation of granular mappings.
12.11. Conclusions.
Exercises and problems.
Historical notes.
References.

Chapter 13. Fuzzy Systems and Computational Intelligence.

13.1. Computational Intelligence.
13.2. Recurrent neurofuzzy systems.
   13.2.1. Recurrent neural fuzzy network model.
   13.2.2. Learning algorithm.
13.3. Genetic fuzzy systems.
13.4. Coevolutionary hierarchical genetic fuzzy system.
13.5. Hierarchical collaborative relations.
13.6. Evolving fuzzy systems.
   13.6.1. Functional fuzzy model.
   13.6.2. Evolving participatory learning algorithm.
13.7. Conclusions.
Exercises and problems.
Historical notes.
References.


14.1. The cluster-based representation of the input - output mappings.
14.4. Architecture of granular models based on conditional fuzzy clustering.
14.5. Refinements of granular models.
   14.5.1. Bias of granular neurons.
   14.5.2. Refinement of the contexts.
14.6. Incremental granular models.
   14.6.1. The principle of incremental fuzzy model and its design and architecture.
Chapter 14. Human-centric fuzzy clustering.
  14.7.1. Fuzzy clustering with partial supervision.
  14.7.2. The development of the human-centric clusters.
  14.7.3. Proximity-based fuzzy clustering.

Chapter 14. Participatory learning in fuzzy clustering.


Chapter 15. Relational ontology in information retrieval.
  15.1.1. Fuzzy relational ontological model.
  15.1.2. Information retrieval model and structure.
  15.1.3. Documents representation.
  15.1.4 Query representation.
  15.1.5. Information retrieval with relational ontological model.

Chapter 15. Multiagent fuzzy systems.
  15.2.1 Agents and multiagents.
  15.2.2 Electricity market.
  15.2.3 Genetic fuzzy system.

Chapter 15. Distributed fuzzy control.
  15.3.1 Resource allocation.
  15.3.2 Control systems and economy.

Chapter 15. Fuzzy market-based control.

Chapter 15. Conclusions.

Appendix A: Mathematical Prerequisites.

Appendix B: Neurocomputing.

Appendix C: Biologically Inspired Optimization.