Preface

Lotfi Zadeh has recently pioneered a research area known as "computing with words" (CW) and explained the computational theory of perception (CTP). The objective of this new research is to build foundations for future intelligent machines and information systems that perform computations on words (names of concepts in natural language) rather than on numbers. The main notion of this approach is related to information granulation. Information granules are understood as clumps of objects (points) that are drawn together by indistinguishability, similarity, or functionality. Information granulation and methods for constructing relevant information granules are crucial for exploiting tolerance of imprecision and uncertainty to achieve tractability, robustness, and low production costs for future intelligent systems. Several approaches to the formulation of information granule concepts have been proposed so far. Granular computing (GC) is one such computing paradigm based on information granule calculi.

This book is dedicated to a newly emerging approach to CW and CTP, called rough-neurocomputing (RNC). In RNC, computations are usually performed on information granules. The foundations of RNC are built in soft computing frameworks comprising synergistic hybridization of rough set theory, rough mereology, fuzzy set theory, neural networks, and evolutionary computing.

Any approach to information granulation should make it possible to define complex information granules (e.g., granules relevant to spatial and temporal reasoning in autonomous systems). The following facts are especially important in the process of complex information granule construction:

(i) Any concept of an information granule considered should reflect and describe its inherent vagueness in formal terms.
(ii) Target granules cannot be constructed (induced) directly from input granules but rather are constructed in a many-stage process.
(iii) The schemes of new granule construction also interpreted as approximate reasoning schemes (AR schemes) should be robust with respect to input granule deviations.
(iv) For real-life applications, adaptive AR schemes become a necessity.

To deal with vagueness, one can adopt soft computing methods developed by fuzzy or rough set theoretical approaches and their different integrations. Information

granules are represented in this book by parameterized formulas over signatures of relational systems, called information granule systems. In such systems, we emphasize the role of inclusion and closeness of information granules, to a degree, on the basis of a rough mereological approach. Information granule systems are relational systems over which information granules can be interpreted. Target information granule systems represent approximation spaces. These spaces are generalizations of approximation spaces used in rough set theory. The second aspect in the above list is related to several issues, such as reasoning from measurements to perception, multilayered learning of concept approximations, and fusion of information coming from different sources. Methods of searching for AR schemes are investigated using rough mereological tools. In general, they return hierarchical schemes for constructing information granules.

Among important topics discussed in this book are different methods for specifying operations on information granules. Such operations are used for constructing relevant information granules from experimental data and background knowledge. These are the basic components of methods aimed at constructing hierarchical schemes of information granules. In the more general case, we deal with network-like structures, transforming and exchanging information granules or information about them. Such networks are called rough-neural networks (RNN), and they are a generalization of AR schemes represented by trees. One of the important aspects of the approach to information granule calculi, as described in this book, is its strong connection with multiagent systems. For example, constructing AR schemes is closely related to ideas of cooperation and conflict resolution in multiagent systems. Moreover, agents exchanging information granules and information about them perform operations on information granules represented in languages they "understand." Hence, granules received in argument ports by a given agent as arguments of his/her operation should be approximated by properly tuning the approximation spaces. These spaces create interfaces between agents. Rough-neural networks are analogous to neural networks. They perform computations on information granules. The process of tuning parameters in rough-neural networks corresponds to adjusting of weights in neural networks. Parameters of rough-neural networks are related, in particular, to approximation spaces used in their construction. By tuning these parameters, one can expect to induce relevant target information granules. The relevance of target information granules can be measured by carefully selected criteria. For example, one can use measures based on inclusion (closeness) degrees of granules and/or some other measures related to their sizes.

The methods that induce rough-neural networks using rough sets in combination with other soft computing tools create a core for RNC. These methods show that connectionist and symbolic approaches can work complementarily and not competitively. For example, derived AR schemes are aimed at representing patterns sufficiently included in target complex concepts. The structures of AR schemes are derived using both approaches. Symbolic reasoning is used to get the structure of

schemes from data and background knowledge. A connectionist approach is used for tuning the parameters of such structures.

One of the most important research directions of RNC concerns relationships between information granules and words or phrases in a natural language. Investigating such relationships leads to methods for inducing (from data and background knowledge) rough-neural networks approximating reasoning schemes in natural language. This creates a strong link between the approach presented and the approaches directed toward operating and reasoning with perception-based information, such as CW and CTP. In particular, one can interpret rough-neural networks that approximate reasoning schemes in natural language as schemes of approximate reasoning from measurement to perception.

Formally, the robustness of a rough-neural network means that such a network produces a higher-order information granule, which is a clump (e.g., a set) of information granules rather than a single granule. The inputs for such networks are clumps of deviations (up to an acceptable degree) from some standard input information granules to networks. In general, rough-neural networks should be robust with respect to different sources of noise. One of the basic research directions in RNNs that we have in mind in this book is developing strategies for adaptive rough-neural network construction.

This book presents recent advances made in RNC by researchers from different countries. In the first part, the foundations of information granule calculus are discussed. Such a calculus based on a rough mereological approach creates a basis for synthesizing and analyzing rough-neural networks. Recent results on the foundations of RNC are included. The reader can find an introduction to a rough set theoretical approach together with an explanation of why a generalization of approximation spaces, used so far in rough set theory, has been introduced. Close relationships of rough set approaches with multivalued (especially with three valued) logic are also presented. The second part shows how different integrations of soft computing tools can help to induce information granules. Special emphasis is given to methods based on hybridization of rough sets with neural techniques. Such techniques are crucial for developing RNC methods in synthesizing complex information granules. The reader can find how different approaches to constructing information granules based on fuzzy sets, rough sets, rough fuzzy sets, and other soft computing paradigms can work in synergy. Moreover, the way different approaches can be combined with symbolic approaches like nonmonotonic reasoning, deductive databases, and logic programming is presented. Methods for constructing interfaces between experimental knowledge and symbolic knowledge are discussed. The necessity of using statistical tools in information granule construction is underlined. Selected application areas for RNC and CW are discussed in the third part. Modeling methods for complex sociological situations or sociological games and semantic models for biomedical reasoning are included. Finally, the last part of the book con-

sists of several case studies illustrating recent developments based on RNC. This includes problems in signal analysis, medical data analysis, and pattern recognition.

It is worthwhile mentioning that from a logical point of view, research in RNC is closely related to the pragmatic aspects of natural language. As an example of such a pragmatic aspect investigated in RNC, one can consider the attempts made to understand concepts by means of experimental data and reasoning schemes in natural language. Another example would be communication between agents using different languages for information granule representation.

We do hope that this self-contained book will encourage students and researchers to join a fascinating journey toward building intelligent systems.

The book has been very much enriched thanks to forewords written by Prof. Zdzisław Pawlak, founder of rough set theory and Prof. Lotfi A. Zadeh, founder of fuzzy set theory and more recently of new paradigms CW and CTP. We are honored to have their contributions and we would like to express our special gratitude to both of them.

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