

# Preface

*Would You tell me, please, which way I ought to go from here?  
That depends a good deal on where You want to get to, said the  
Cat. I don't much care where—said Alice. Then it doesn't matter  
which way You go, said the Cat.*

[Lewis Carroll. Alice's Adventures  
in Wonderland]

*In this Work when it shall be found that much is omitted, let it not  
be forgotten that much likewise is performed.*

[Samuel Johnson]

This book may be regarded as a sequel to “Approximate Reasoning by Parts” in this Series. The topic of granular computing in classifier synthesis, mentioned in the former book, among other themes, is fully developed in this book. The idea came to the first author in the early 1990s when, in cooperation with Prof. Andrzej Skowron, he proposed to modify the proposition put forth 30 years earlier and converted into Fuzzy Set Theory by Prof. Lotfi Asker Zadeh of the partial membership in a concept, by discussing a partial containment in its most general features.

When attempting at formalization of partial containment, our attention was turned to the theory of mereology created by Stanislaw Leśniewski, an eminent member of the famous Warsaw Logical School; the basic notion of a part in that theory was extended to the notion of a part to a degree subjected to some axiomatic postulates.

In this way the theoretical proposition of Rough Mereology came into effect, and along with it expectations that it may open up a new venue for approximate reasoning under uncertainty. The primitive construct in it, called a *rough inclusion* (1994) does reflect most general and universally true properties of partial inclusion on concepts and its relations to the fuzzy idea were clearly recognized, cf., Prof. Achille Varzi's statement'...*which results in a fuzzification of parthood that parallels in many ways to the fuzzification of membership in Zadeh's (1965) set theory, and it is this sort of intuition that also led to the development of such formal theories as Polkowsky and Skowron's (1994) rough mereology...* (Stanford Encyclopedia of Philosophy. <http://plato.stanford.edu/entries/mereology>).

The first author recognized the potential of the new theory not only in applications to classical already topics of mereotopology and mereogeometry, but also in

a more recent area of granular computing, introduced by Prof. Lotfi A. Zadeh, see *Outline of a new approach to the analysis of complex systems and decision processes, IEEE Trans. on Systems, Man, and Cybernetics, SMC-3, 28–44, 1973*.

The idea of granular computing, extended later by Prof. L.A. Zadeh to the idea of *computing with words* see L.A. Zadeh *Computing with Words. Principal Concepts and Ideas. Springer 2012* turned out to become an attractive methodology in intelligent algorithm theory, see the list of principal monographs in reference to Chap. 1. Granules of knowledge are defined as aggregates (or, *clumps*) of objects drawn together by a similarity relation, a good example can be an indiscernibility class in a decision system, see Prof. Z. Pawlak's *Rough Sets: Theoretical Aspects of Reasoning about Data, Kluwer 1991*, or, a fiber of a fuzzy membership function, see L.A. Zadeh *Fuzzy sets, Information and Control 8, 338–353, 1965* in both theories one computes not with single objects but with their classes, i.e., granules.

Rough Mereology is especially suited toward granular theory as its precise assumptions allow for a formal theory of granules. The aggregate (or, formally the mereological class in the sense of Leśniewski) of all things included in the given thing (the *granule center*) to a degree of at least  $r$  forms a granule in the sense of Prof. L.A. Zadeh, i.e., a collection of things drawn together by a similarity. A topological character of granules which resemble neighborhoods allows for applications in not only classifier synthesis but, e.g., in behavioral robotics.

The notion of a granule is developed in Chap. 1 and a similarity relation underlying it is modeled on a tolerance relation, or a weaker form of it, called a weak tolerance relation. As such it does encompass some strategies for intelligent algorithms construction like, e.g., indiscernibility relations in information/decision systems.

One of the upshots of rough mereological granular concept theory was presented by the first author at GrC conferences in Beijing (1995) and Atlanta (1996) which consisted of the idea of granular classification. It was proposed to preprocess data (a decision system, a data table) by forming for a given real number  $r \in [0, 1]$  the set of granules to this degree about data and representing each granule by a new data averaged in a sense over the granule. From the collection of granules, a covering of the universe of objects is selected by some strategy and obtained in this way new data set called a *granular reflection* of the original data set undergoes a classification process with some classification algorithms. Expectations that this method of data treatment should reduce noise, decrease ambiguity in data, and in effect increase quality of classification measured, e.g., by standard factors like accuracy and coverage were taken to test with real data.

At this stage new concepts were introduced, in an essential part by the second author, like ideas of concept-dependent granulation, layered, or multi-stage granulation, and applications to the missing values problems. Concept-dependent granulation consists in forming granules within the decision class of the center of the granule which yields a greater number of smaller but more compact with respect to similarity in question granules. Layered granulation consists in the repeated granulation process up to the stable data set. The idea for a treatment of missing values consists in treating the missing value as a value of an attribute on its

own and forming granules in order to assign in place of the missing value a value assigned by some averaging process over the granule.

These ideas were put to test in many research and conference papers with some real data but it is now that the authors undertake the task of as complete as possible verification of those ideas with numerous real data available in the University of California at Irvine Data Mining Repository. As classifying algorithms a kNN classifier as well as the Naive Bayes classifier have been applied due to the well-known least error property of the latter and the asymptotic convergence to it of the former.

Complexity issues were also instrumental in the choice of algorithms for classification: a full rough set exhaustive classifier turned out to be too time-consuming on some parameterized variants of granular classification.

A most striking feature of the granular approach seems to be the fact that granular reflections yield classification results as good or in some cases better than in the non-granulated case with much smaller sizes of data sets and appropriately smaller numbers of classifying rules. It seems that these facts predestine this approach to such applications like tele-medicine or other emergency events where the simplicity and compactness of diagnostic systems are of vital importance.

The book consists of 11 chapters and an appendix. The first chapters provide an introductory background knowledge. Similarity relations which serve as the means for granule formation are formally discussed as tolerance or weak tolerance relations in Chap. 1 along with a formal idea of a tolerance granule. Chapter 2 is devoted to mereology and rough mereology. Basics of machine learning are discussed in Chap. 3 with emphasis on Bayesian and kNN classifiers and asymptotic properties of classifiers. Classification problems are discussed in detail in Chap. 4 along with a validation scheme known as cross-validation (CV).

The experimental part extends over Chaps. 5–9. In Chap. 5, a study of granular coverings is presented aimed at estimating the impact of a covering strategy on the quality of classification. Sixteen covering strategies are examined on all 13 data sets and best strategies are applied in the following chapters. Chapter 6 brings forth results of classifying in granular and non-granular cases by means of kNN classifier applied to the multi-layer granulation, whereas Chap. 7 shows analogous results for Naive Bayes classifier. In Chap. 8, the problem of missing values is studied by perturbing randomly in 5 or 10 % all 13 data sets and recovering the data by four strategies for missing value treatment.

Chapter 9 is devoted to classifiers employing additional parameters of  $\varepsilon$  and catch radius, based on weak rough inclusions which diffuse the indiscernibility relations. In Chap. 10, a study of effects of granulation on entropy of data and noise in them is presented. This study leads to parameters maximizing the noise reduction, reduction in size between the first and second granulation layers as well as reduction in number of pairs of indiscernibility classes with a given mereological distance. Chapter 11 called Conclusions brings an analysis of relations among optimal granulation radius and radii defined in Chap. 10. It is shown that radii of maximal noise reduction and maximal size decrease between first and second layers of granulation are fairly close approximators to the optimal granulation radius. In

the Appendix that follows, main parameters concerning the distribution of values of attributes are collected and visualized like the central class, intersections with other classes, etc., which parameters bear on characteristics of granular reflections in terms of granule size and distribution.

The applied algorithms are illustrated with simple hand examples with the intention that the book may serve also as a text for students or other people wanting to acquaint themselves with these techniques.

The authors express the hope that this work will be useful for researchers in granular computing in that it will illuminate the techniques based on rough inclusions and will, by this, stimulate further progress in this area.

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This book is dedicated to Prof. Lotfi Asker Zadeh, whose insight brought into the realm of approximate reasoning the idea of partial membership.

The authors would like also to recall on this occasion the memory of Prof. Helena Rasiowa (1917–1994), an eminent logician and one of the founders of Theoretical Computer Science in Poland, on the 20th anniversary of her departure.

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