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How Fuzzy Concepts Contribute to Machine Learning

Springer

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To the soul of my father who taught like a loving teacher until the last moments of his life and dedicated to my mother a living statue of love.

Mahdi Eftekhari

To my parents with love, who gave me "95% help and support" and "95% mental health issues" to enable me to handle this formidable task. No, it did not make up 190%, they multitasked.

Adel Mehrpooya

To Parvin Rezaei who opened up new horizons in my life.

Farid Saberi-Movahed

To the researchers that have been studying HFS.

Vicenç Torra

Preface

The aim of this book is to introduce some new trends of research regarding the use of traditional fuzzy sets, particularly hesitant fuzzy sets, in machine learning. In data-driven systems, we often need to deal with uncertainty. This uncertainty is caused by the available data and also in stochastic elements inherent to the problems being modeled. Machine learning algorithms face these problems when building the models. Fuzzy set theory provides some tools for this purpose. In this book, we review some of the tools based on hesitant fuzzy sets that can be used in machine learning problems. This book is addressed to audiences who are interested in both machine learning and fuzzy set extensions.

The contents are organized into three parts including ten chapters in addition to a chapter on preliminaries which is an introduction to various concepts used in the next three parts. That is, Chap. 1 presents the preliminaries.

Part I focuses on the application of both fuzzy set and hesitant fuzzy set concepts in clustering algorithms and on other unsupervised learning approaches. This part begins with Chap. 2 that describes the application of hesitant fuzzy concepts to fuse the results of different clustering algorithms. This chapter also presents the concept of hesitant fuzzy partitions. Then, Chap. 3 introduces an unsupervised feature selection method based on the concepts of sensitivity and correlation. The definition of sensitivity given in this chapter is based on the gradient of density function in subtractive clustering with respect to a given feature.

Part II discusses supervised learning problems and explains cases for which fuzzy and hesitant fuzzy concepts can be used to boost the performance of supervised tasks. It is composed of Chaps. 4–7 whose description is briefly provided here. Chapters 4 and 5 study two extensions of fuzzy decision trees developed in recent years. Chapter 6 focuses on using hesitant fuzzy sets in decision trees when the data to learn the trees are imbalanced. That is, the use of fuzzy sets for imbalanced classification problems, a particular type of supervised learning tasks. More precisely, the chapter describes the use of various information gain measures to combine information, as well as the use of concepts related to hesitant fuzzy sets to combine the results of fuzzy decision trees. Then, Chap. 7 discusses the application of hesitant fuzzy sets to ensemble learning algorithms. In ensemble learning, and more particularly in dynamic ensemble selection problems, situations arise in which multiple-criteria

decision-making notions can be used. Chapter 7 concludes this part. It considers the problem of considering different machine learning algorithms as a set of experts and how to process the associated information using hesitant fuzzy elements.

Part III provides a brief survey of recent uses of hesitant fuzzy set and rough set concepts in supervised dimension reduction problems. In Chap. 8, some similarity measures as well as feature evaluation metrics are defined in form of hesitant fuzzy sets. Then these sets are applied to combine different measures and criteria of feature selection. The main idea of this chapter is to introduce some methods for combining different feature ranking algorithms and metrics via hesitant fuzzy sets. A distributed version of hesitant fuzzy-based algorithms is then provided in Chap. 9. This distributed version is appropriate for handling big data problems. Then, Chap. 10 reviews an approach to combine different rough set-based feature selection metrics through hesitant fuzzy sets. This part is concluded with Chap. 11. In this last chapter, we explain how hesitant fuzzy correlation can be used to tackle supervised feature selection issues.

All the approaches presented in this book have a common motif. They use hesitant fuzzy set concepts in machine learning problems. They consider these problems from a multi-criteria decision-making perspective. More particularly, these problems are framed considering different machine learning algorithms as experts, and then taking the results of these algorithms as expert's opinions. Then, hesitant fuzzy sets are used to combine these opinions. The algorithms presented in this book have been described and tested in a set of papers. These papers report the good performance of the approaches.

In data-driven machine learning, model building and selection is based on a set of criteria. Naturally, efficiency and accuracy is one of them. This usually implies that more complex models with more parameters perform better. This contrasts with model simplicity (and Occam's razor, as we mention in Chap. 5.1). Explainable AI, the need to build transparent models and make transparent decisions add additional constraints to how machine learning models are identified and how these models are used. Privacy regulations also add additional constraints to model building and selection. The need to consider all these aspects into account make machine learning problems challenging. In this book, we have described some of the first contributions of hesitant fuzzy sets for this complex problem. Further solutions can be developed to tackle with these other competing requirements.

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