Chapter 54
Modeling Interpretable Fuzzy Rule-Based Classifiers for Medical Decision Support

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ABSTRACT

Decision support systems in Medicine must be easily comprehensible, both for physicians and patients. In this chapter, the authors describe how the fuzzy modeling methodology called HILK (Highly Interpretable Linguistic Knowledge) can be applied for building highly interpretable fuzzy rule-based classifiers (FRBCs) able to provide medical decision support. As a proof of concept, they describe the case study of a real-world scenario concerning the development of an interpretable FRBC that can be used to predict the evolution of the end-stage renal disease (ESRD) in subjects affected by Immunoglobin A Nephropathy (IgAN). The designed classifier provides users with a number of rules which are easy to read and understand. The rules classify the prognosis of ESRD evolution in IgAN-affected subjects by distinguishing three classes (short, medium, long). Experimental results show that the fuzzy classifier is capable of satisfactory accuracy results – in comparison with Multi-Layer Perceptron (MLP) neural networks – and high interpretability of the knowledge base.

INTRODUCTION

Interpretability of fuzzy systems is really appreciated in many applications, especially in those involving high interaction with humans. For instance, decision support systems in Medicine must be easily comprehensible, both for physicians and patients, with the aim of being widely accepted and successfully applicable. Thanks to its semantic expressivity close to natural language, fuzzy logic is acknowledged for its well-known ability for linguistic concept modeling. In consequence, fuzzy logic makes easier the knowledge extraction and representation phases when dealing with complex problems. In addition, the use of linguistic variables and rules (Zadeh, 1973) allows adopting the same formalism for both expert knowledge and knowledge automatically extracted from data

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(Alonso et al., 2008). Therefore, there are many applications regarding the use of fuzzy logic in Medicine and healthcare (Abbod et al., 2001; Nauck & Kruse, 1999).

In this chapter we describe the applicability of the fuzzy modeling methodology called HILK (Highly Interpretable Linguistic Knowledge) (Alonso et al., 2008; Alonso & Magdalena, 2011c) with the aim of building highly interpretable fuzzy rule-based classifiers (FRBCs) in the context of medical decision support problems. Namely, we tackle the case study of a real-world scenario concerning the development of an interpretable FRBC that can be used to predict the evolution of the End-Stage Renal Disease (ESRD) in subjects affected by Immunoglobin A Nephropathy (IgAN). It represents a renal disease whose impact is very relevant through the world since its progress gradually leads to chronic renal failure (with the consequent recourse to renal transplant). The role of a predictive model in such a context would be to assist the physician in providing a prognosis, consisting in the evaluation of a patient's risk to reach ESRD (namely, the pathology final stage) in a shorter or longer period. Of course, the added value of this prediction should rely on the one hand on a timely information for the patient (i.e. prognosis should be available since from the initial contacts with the physician); on the other hand on the possibility to integrate the suggestions coming from the predictive system with the knowledge held by the expert (physician). This motivates the need of an interpretable predictive system. HILK enables the integration of expert knowledge with knowledge directly acquired from data, and it is implemented as a free software tool called GUAJE (Alonso & Magdalena, 2011a; Alonso & Magdalena, 2011b). Furthermore, the use of fuzzy logic let us dealing with the inherent imprecision of the predictive problem. In perspective, this may represent a relevant achievement since the obtained information could enable the discovery of new patterns underlying data, which could be useful for the physicians to propose targeted therapies.

The rest of the chapter is structured as follows. Next section provides the background regarding intelligent data analysis for medical decision support. It provides broad definitions and discussions considering not only fuzzy logic but also other techniques. Then, we go in deep with the main focus of the chapter. First, HILK methodology is sketched. Second, it is applied to solve the case study previously introduced, which is the prognosis of ESRD. Finally, the chapter ends pointing out future research directions and drawing main conclusions.

BACKGROUND

Current technology enables the acquisition and storage of large amounts of data, thus favoring the digital representation of complex phenomena in almost any field of human interest, being it scientific, commercial, engineering, etc. Medicine is one of such scientific fields where complex phenomena are most frequent, and a thoughtful comprehension of them is of prominent importance for the advance of knowledge at service of human health.

However, making sense of data is not a trivial task, especially when they describe complex phenomena. To this pursuit, Intelligent Data Analysis (IDA) is a methodology that prescribes a set of stages and techniques that can be applied for extracting useful knowledge from massive amounts of data. Nevertheless, IDA requires skillful application of the available techniques, which can only be accomplished by a careful intervention of human experts.

The objectives of IDA can be classified into three main categories (Berthold, 2010): finding patterns, finding explanations and finding predictors. Patterns are templates or prototypes that can be used to aggregate large quantities of data through simpler representations, like clusters, association rules, maps, etc. Finding patterns usually does not require the selection of a target