Chapter 17
Granular Synthesis of Rule–Based Models and Function Approximation Using Rough Sets

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ABSTRACT

This chapter suggests a new method to develop rule-based models using concepts about rough sets. The rules encapsulate relations among variables and give a mechanism to link granular descriptions of the models with their computational procedures. An estimation procedure is suggested to compute values from granular representations encoded by rule sets. The method is useful to develop granular models of static and dynamic nonlinear systems and processes. Numerical examples illustrate the main features and the usefulness of the method.

1. INTRODUCTION

Information granules are key components of knowledge representation and processing. Granular computing forms a unified conceptual and computing platform that benefits from existing and known concepts of information granules in the realm of set theory, fuzzy sets and rough sets. The comput-
ing framework that includes these concepts comprises the emerging paradigm of granular computing. Granular computing identifies essential commonalities between diversified problems and technologies, gives a better grasp to the role of interaction between various formalisms, and brings together the existing formalisms of interval analysis, fuzzy sets and rough sets under the same roof. Moreover, it helps to build heterogeneous and multifaceted models, acknowledges the notion of variable granularity covering from numerical entities to abstract information granules, and is a fundamental paradigm of abstraction (Pedrycz and Gomide, 2007).

The description of information granules usually is imprecise. One mechanism to approach imprecision is to look at the descriptions as an approximation and use lower and upper bounds. Intervals are examples of such a mechanism. However, often imprecision is caused by the conceptual incompatibilities between the description of a notion with respect to a collection of simpler notions. The notion may either fully cover or have limited overlaps with simpler notions. In this case, the notion, when characterized in terms of the simpler notions, does not lend itself to a unique description and the best we can do is to give an approximation in the form of some boundaries. Rough Set Theory (Pawlak, 1982) offers the appropriate formal and computational framework to approximation.

Rule-based models (Hofestädt and Meinecke, 1995) play a fundamental role in system modeling. In general, rules encapsulate relations among variables and give a mechanism to link granular descriptions of systems with their computational procedures. For instance, many rule-based models can uniformly approximate continuous functions to any degree of accuracy on closed and bounded sets. Another important issue concerns rule-based interpolation. Methods of interpolative reasoning are particularly useful to reduce complexity of rule-based models (Pedrycz and Gomide, 2007).

Due to its own nature, rule-based systems rely on the computation with information granules. Information granules are in the center of the development of the individual rules. There are two main schemes to construct rule-based models, expert knowledge-based and data-driven, respectively. There are several hybrid schemes that could be somewhere in between. Knowledge-based development assumes that an expert can provide domain knowledge. Experts are individuals who can quantify knowledge about the basic concepts and variables to solve a problem and link them in the form of a set of rules. Knowledge-based approach has some advantages: knowledge becomes available and information granules help to the quantification process. However, in many applications the information required to develop the rules may not be easily available and humans may be unable to extract all relevant knowledge from large amount of data. In these circumstances, data-driven computational procedures must be used to extract knowledge and to encode it in the form of rules. Data-driven development is guided by the use of data. The resulting design captures the structure existing in the data themselves. Rules derived from data should provide a model to describe the underlying behavior mirrored by the data.

This chapter suggests a new data-driven method to develop rule-based models based on rough set theory. The method is useful to develop granular models of static and dynamic nonlinear systems and processes. We assume that the rule-based model is a granular representation of a function. More importantly, we shown that the behavior captured by the rules provides information to estimate the values of the function embedded in the set of rules. An estimation procedure is suggested to compute function values from its granular representation encoded by the set of rules. Therefore, differently from most classic and alternative modeling schemes such as interpolation and approximation using, for example, neural networks and fuzzy systems, the method developed in this chapter simultaneously offers a granular model of a system and a mechanism to compute system output estimates.
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