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Rule acquisition and optimal scale selection in multi-scale formal decision contexts and their applications to smart city

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Abstract

In order to enrich the existing rule acquisition theory in formal decision contexts, this study puts forward three new types of rules: decision association rules, non-redundant decision association rules and simplest decision association rules. Then, we analyze the relationship among these three types of rules, and develop methods to acquire them from single-scale formal decision contexts. Some numerical experiments are also conducted to compare the performance of the method of acquiring the simplest decision association rules with that of the existing one of acquiring the non-redundant decision rules. Moreover, the new three types of rules are employed to introduce three types of consistencies in multi-scale formal decision contexts. In addition, the notion of an optimal scale is defined by each type of consistency, and how to select an optimal scale is investigated as well. Finally, two applications in smart city for the proposed rule acquisition and optimal scale selection methods are applied to smart city.

Keywords: Multi-scale formal decision context; Concept lattice; Rule acquisition; Optimal scale selection

1. Introduction

Formal concept analysis (FCA), proposed by Wille [54], is an effective mathematical tool for knowledge processing and conceptual data analysis. Formal contexts, formal concepts and concept lattices [12] are three basic notions in this theory. The concept lattice of a formal context reflects the relationship of generalization and specialization among the formal concepts. To handle uncertainty, FCA has been extended with fuzzy sets [4, 7], interval-valued fuzzy sets [8], bipolar fuzzy sets [45], linked fuzzy sets [46], possibility theory [10] and rough sets [51, 61, 63]. To handle incomplete data, large data and multi-source data , FCA has been augmented with incomplete contexts [18, 22, 26, 44], granular computing [5, 26, 55, 56, 58, 70], multi-scale contexts [14, 31] and triadic contexts [48]. In recent years, knowledge reduction in FCA [42, 52], three-way FCA [37, 38, 47], and concept learning [27, 28] have received much attention. So far, its applications cover many domains such as data mining [2], machine learning [19] and knowledge discovery [9, 36, 59]. In FCA, a useful way of characterizing dependencies between the attributes of a formal context is via implications [13, 30] or association rules [35]. Note that directly acquiring these types of rules from a formal context takes a lot of calculations and the number of rules is usually large. So, how to efficiently mine implications or association rules from a formal context and eliminate superfluous rules has been discussed by many scholars (e.g., [3, 40, 64]). Zhai et al. [65] investigated this issue in generalized formal contexts.

Formal decision contexts were proposed by Zhang and Qiu [69] to make certain decision analysis. Considering that rule acquisition is one of the main purposes in the analysis of formal decision contexts, many studies (e.g., [43, 53]) have been made on it. Up to now, there are several types of rules in formal decision contexts. For example, Zhang and Qiu [69] proposed decision rules in formal decision contexts based on conditional formal concepts and decision formal concepts. Li et al. [23] put forward the notion of non-redundant decision rules and a method for

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