Chapter 10
Research on Knowledge Representation and Reasoning Based on Decision Implication

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ABSTRACT

Knowledge representation and reasoning based on decision implication is to perform an extremely compact representation of the decision information implied in data, and obtain all decision information in data by means of reasoning, based on the current representation. The existing research in logic and data aspects of decision implication proposes a set of decision implications with information integrity and extreme simplicity (non-redundancy and optimality), i.e., decision implication canonical basis (DICB), which lays a solid foundation for constructing a knowledge representation and reasoning framework in formal contexts. This chapter conducts a systematic and in-depth study on the important issues of knowledge representation capability, and incomplete formal context adaptability of decision implication, and reasoning based on decision implications.

INTRODUCTION

A Brief Review of Formal Concept Analysis

Formal Concept Analysis (FCA) is an order-theoretic method for concept analysis and visualization, pioneered by Wille (Wille, 1982) in the mid-80s. A concept is a pair constituted by its extent and intent. The extent of a concept is a collection of all objects belonging to that concept and its intent is the set of all attributes common to all objects of the extent. FCA establishes the relationships between intents and extents and visualizes the generalization and specialization of concepts by means of concept lattices. Because of its strengths, FCA has been become a powerful tool for data mining (Mouakher and Yahia, 2019; Bartl and Konecny, 2019), social networks (Roth et al., 2008), software engineering (Tilley et al.,

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2005), cognition-based concept learning (Kuznetsov and Makhalova, 2018) and knowledge reduction (Konecny and Krajca, 2019; Cornejo et al., 2018).

In the study of knowledge representation and reasoning in FCA, (attribute) implication (Ganter and Wille, 1999; Qu and Zhai, 2008; Zhai et al., 2012; Ma et al., 2011; Zhai and Li, 2019) is proposed in the form of $A \rightarrow B$, meaning that if all the attributes in A are satisfied, then all the attributes in B are satisfied. Duquenne etc. (V and J-L, 1986) constructed the so-called canonical basis, which turns out to be complete and non-redundant w.r.t. implication logic (Ganter and Wille, 1999; Stumme, 1996), and minimal among all complete sets of implications. Starting from a canonical basis of a formal context, one can obtain all implications in this context by applying Armstrong rules (Armstrong, 1974).

A Brief Review of Decision Implication

Decision implication, revealing the dependency between conditions and decisions, is a knowledge representation and reasoning theory that has been developed within the case of decision-making (Zhai et al., 2014, 2015b; Li et al., 2017; Zhang et al., 2021; Zhai et al., 2015a). Compared with other decision knowledge representations, such as concept rule (Wu et al., 2009; Li et al., 2013a) and granule rule (Wu et al., 2009), decision implication has been demonstrated to possess a stronger representation ability (Zhang et al., 2020).

Zhai et al. (Zhai et al., 2014, 2015b) conducted decision implication logic, encompassing both semantic and syntactic aspects. In the semantic aspect, the research considers the soundness, completeness, and non-redundancy of decision implications, as well as decision implication basis (a most compact set of decision implications) (Zhai et al., 2015b; Nanjia et al., 2019). In a given dataset, the soundness of decision implications means that the decision implications are valid within the data, the completeness of a decision implication set implies that all sound decision implications in data can be derived from this set, and the non-redundancy of a decision implication set means that no decision implication within the set can be deduced from other decision implications in the set. In the syntactic aspect, two inference rules, namely *Augmentation* and *Combination*, are proposed, which have been demonstrated to be sound and complete w.r.t. the semantic aspect. The logic research results of decision implication can be applied to data (i.e., decision context) research (Li et al., 2017; Zhang et al., 2021; Zhai et al., 2015a). Methods for generating decision implications basis in decision contexts can be found in (Li et al., 2017; Zhang et al., 2021). Additionally, the inference strategies based on decision implications basis and inference rules are explored in (Zhai et al., 2022, 2015a; Nanjia et al., 2019).

A Brief Review of Concept Rule and Granular Rule

Granular computing is a collective term referring to theories, methodologies, techniques, and tools for the analysis of information granules encountered in problem solving (Wu et al., 2009; Li and Wu, 2017). Wu et al. (Wu et al., 2009) brought a perspective of granular computing into FCA based on the fact that concept lattice extracted from data is capable of representing all the information implied by data (Ganter and Wille, 1999). Thus, it is expected that decision implications extracted from concept lattices are also capable of representing all the information implied by decision implications. Wu et al. (Wu et al., 2009) considered such special decision implications, called concept rules, by requiring that the premises and consequences of decision implications must be intents from condition and decision