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Three-way decisions with intuitionistic fuzzy decision-theoretic rough sets based on point operators

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Abstract
Three-way decisions with decision-theoretic rough sets (DTRSs) as a typical risk decision method, are generated by Bayesian decision theory and have three kinds of decision strategies, i.e., the acceptance decision, the deferment (non-commitment) decision and the rejection decision. The construction of three-way decisions under the complex decision-making context creates enormous challenges. The determination of loss function is one of key steps. In this paper, we discuss the decision principles of three-way decision rules based on the variation of loss functions with intuitionistic fuzzy sets (IFSs). More specifically, we introduce the intuitionistic fuzzy point operator (IFPO) into DTRSs and explore three-way decisions. Firstly, we construct a loss function matrix with the point operator and analyze its corresponding properties. IFPO implies one type of variation modes for the loss functions of three-way decisions. With respect to the point operator, we show that the prerequisites among loss functions still hold in each stage. Secondly, given the loss functions, we construct the corresponding three-way decision model and deduce three-way decisions. Finally, with the aid of information entropy theory, we further investigate which stage may be most suitable to make the decision. This study extends the range of applications of three-way decisions to the new intuitionistic fuzzy environment.

Keywords: Three-way decisions, Decision-theoretic rough sets, Intuitionistic fuzzy sets, Point operator

1. Introduction
As a risk decision-making method, three-way decisions [12, 22, 44] are composed of the acceptance decision, the deferment (non-commitment) decision and the rejection decision. Different situations may have different interpretations of these decisions. Unlike a certain decision making, three-way decisions newly increase a deferment strategy. The idea of three-way decisions is consistent with human’s cognitions to solve the problem in the real world. Since it was proposed by Yao [41, 42], it has attracted the attention of researchers and has been applied in many fields, such as investment decision-making [26], information filtering [17], text classification [18], risk decision-making [19], cluster analysis [24, 48], government decision-making [28], web-based support systems [40], approximations of fuzzy sets [8], etc. Three-way decisions can provide a semantic mechanism to help us make a more reasonable decision.

In view of the researches of three-way decisions, the most typical model is decision-theoretic rough sets (DTRSs) [10, 15, 19, 45]. As an extension model of rough sets [31], DTRSs vastly push the development of three-way decisions [21, 34, 4], [50]. In light of Bayesian decision procedure [7], DTRSs were proposed by Yao et al. [41, 42] in the rough set context. Considering three pairwise disjoint regions of rough sets (i.e., the positive region POS(C), the boundary region BND(C) and the negative region NEG(C)), Yao [44, 45, 46] constructed three-way decisions with DTRSs and provided the corresponding interpretations. Three-way decisions with DTRSs are deduced based on the minimum of the overall risk and generate three types of decision rules [44]. The rules derived from the positive region produce the acceptance decisions. The rules coming with the negative region give rise to the rejection decisions, while the rules

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