

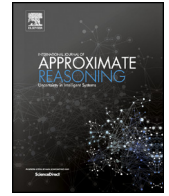


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Three-way decisions approach to multiple attribute group decision making with linguistic information-based decision-theoretic rough fuzzy set

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ABSTRACT

This paper investigates the decision-theoretic rough sets involved multiple decision-makers with linguistic evaluation information for the uncertainty and risk under the framework of three-way decisions theory. We first discuss the probabilistic rough fuzzy set model with linguistic information for the value of objects on the universe about the attribute set. Subsequently, we present the decision-theoretic rough fuzzy set with linguistic information for the loss functions. Then, we establish the three-way decisions based on linguistic information-based decision-theoretic rough fuzzy set as well as the corresponded decision rules that satisfy minimum risk are given. Furthermore, we consider a kind of multiple attribute group decision making problem with linguistic information and then present a new decision model using the decision-theoretic rough fuzzy set with linguistic information-based three-way decisions. Finally, the proposed decision model and method is applied to an emergency decision making problem of unconventional emergency events, the steps and the principle of the proposed method are illustrated by a numerical example with the background of emergency decision-making.

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1. Introduction

Theory of three-way decisions, proposed by Yao [59], is a natural extension of classic two-way decisions, whose original principle comes from Pawlak rough sets [29] and probability rough sets [6,55] with the concept of the positive, boundary and negative regions in the rough set theory as three decisions outcomes, acceptance, rejection, and further consideration (or not commitment) in a ternary classification, respectively. Considering three pairwise disjoint regions of rough sets, the basic decision procedure of three-way decisions is established and the positive rule, boundary rule and negative rule corresponding to the decision of acceptance, rejection and an abstained or non-committed [56]. In the recent years, three-way decisions theory and methodology have been applied many decision making problems under uncertainty of management science such as optimization investment decision making [43,44] information filtering and classification [7,8,11,12], medi-

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cal diagnosis in clinic [16,31], environmental management [10], decision support systems [17,20,50,51,57,58], recommender systems [19,61,67], emergency decision making [40], and etc. [3,15,25,28,30,41,60,65].

Generally speaking, there is not critical in the classical rough set model for the semantic interpretation with acceptance, non-committed and rejection of three-way decisions since there are not involve any uncertainty in positive and negative regions which requires exact results of classification and do not involve the tolerance for errors. Then probabilistic approach to rough set is proposed as an important generalization of Pawlak rough set and provides an effectiveness way to admit the tolerance for errors in classification [55]. Probabilistic rough set uses two threshold parameters α and β to solve decision problems by allowing certain acceptable level of errors. Meanwhile, the two threshold parameters α and β are interpreted as conditional probability and they also divide the universe into disjoint three parts, i.e., the (α, β) -probabilistic positive, boundary and negative regions. Then, there is a natural correspondence between the acceptance, non-committed and rejection of three-way decisions and the (α, β) -probabilistic positive, boundary and negative regions of probabilistic rough set because there are made with certain levels of tolerance for errors. As is well known, a critical issue is how to determine the pair of thresholds α and β in the probabilistic rough set theory because it will be lead to different decision results under different thresholds selection. Traditionally, all of the threshold parameters used in the existing probabilistic rough set models [11,26,39,45,62] are usually selected according to the expert's experience in advance. Thus, there is a lack of theoretical and systematic studies and justifications on the choices of the threshold parameters. In order to establish a programmatic selection method as well as a reasonable semantic interpretation for the pair of threshold parameters used in the probabilistic rough set models, another generalization of probabilistic rough set named as the decision-theoretic rough set [53,54] was proposed by using the Bayesian risk decision procedure [53,54,59]. So far decision-theoretic rough set has attracted many attentions and further enriched the theoretical framework of Pawlak rough set, and several extended forms and decision approaches have been established [1,14,18,23,27,32,36,43,63,66]. Therefore, decision-theoretic rough set naturally becomes an effectiveness theory tool to three-way decisions, i.e., the method three-way decisions based on decision-theoretic rough set.

Though three-way decisions associated the decision-theoretic rough set models and methods provide an effectively way to handle decision-making problems under uncertainty, there are many complexity and uncertainty decision scenarios could not modeling by the existing decision-theoretic rough set approaches. In general, several different departments or agents may be involved in a decision process in order to obtain the optimal decision making for the complexity and uncertainty problems. For example, for a given decision making problem of supply chain management, there will be simultaneously included the wholesaler, the retailer and the customers in the decision making process in order to obtain the maximum profit for all of three agents under the constraint conditions. Then the existing three-way decisions based on decision-theoretic rough set with single decision-maker could unable to deal with this kind of decision making problems in management sciences of reality. Moreover, there may be not give an exactly quantitative description (i.e., the real-valued, interval-valued or fuzzy-valued) for all considered attributes and they could express their opinions by individual preferences with linguistic terms such as "fair", "slightly good", "good", and etc. So, exploring multiple different agents-based decision-theoretic rough set with linguistic terms evaluation for all related attributes and its corresponded three-way decisions model and methodology is a necessity. Though there are some scholars make some preliminaries discussion for the decision-theoretic rough set with multiple agents [48] or three-way group decision making based on decision-theoretic rough set [21,22] in the recently years, there are not the related discussion for the both the classical Pawlak rough set theory as well as various generalized rough set models and methods with the linguistic information of the attributes.

On the other hand, the loss functions associated with the decision-theoretic rough set are the vital elements to determine the threshold value parameters and the decision making of three actions. Then how to select adaptable forms to express the loss functions is one of important research directions of decision-theoretic rough set. With referenced different background of decision making problems, several types values were used to express the loss functions in the existing literatures [21,22,52]. However, there may other expression forms for the loss functions such as symbol values, a utility values and preference values with linguistic information, especially when multiple decision-makers are involved in the decision making process, according to the domain knowledge and individual preference or habit of the decision-makers. Moreover, there may be a fuzzy decision object over the alternative universe for all decision-makers under the given conditions. As is well known, all the existing studies such as the multi-agent three-way decisions [52], three-way risk decisions [16], three-way group decision [21] and intuitionistic fuzzy or triangular fuzzy-based decision-theoretic rough sets [22] are considered the crisp decision object in the process of Bayesian decision procedure [53,54], i.e., the theory basis of all existing decision making models is the Yao's decision-theoretic rough set [56].

Based on the aforementioned analysis, this paper tries to make an attempt to explore the three-way decisions model and method based on decision-theoretic rough fuzzy set with multiple decision-makers and linguistic value evaluations for both the loss functions and the values of the attribute sets, i.e., there is a fuzzy decision object in the Bayesian decision procedure and also there are the linguistic-valued for every object of the universe of discourse with respect to the attribute sets. Then we will present the three-way decision model based on decision-theoretic rough fuzzy set with linguistic information. At the same time, we will establish a new approach to a kind of multiple attribute group decision making problem based on the three-way decisions with linguistic information-based decision-theoretic rough fuzzy set model.

The rest of this paper is organized as follows. Section 2 briefly reviews the Pawlak rough set, probabilistic rough set, Bayesian decision process and linguistic variable with the operations. In Section 3, we present the linguistic information-based probabilistic rough fuzzy set and linguistic information-based decision-theoretic rough fuzzy set models, respectively.

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