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Zero-Sum Matrix Game with Payoffs of Dempster-Shafer Belief Structures and Its Applications on Sensors

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Abstract: The zero-sum matrix game is one of the most classic game models, and it is widely used in many scientific and engineering fields. In the real world, due to the complexity of the decision-making environment, sometimes the payoffs received by players may be inexact or uncertain, which requires that the model of matrix games has the ability to represent and deal with imprecise payoffs. To meet such a requirement, this paper develops a zero-sum matrix game model with Dempster–Shafer belief structure payoffs, which effectively represents the ambiguity involved in payoffs of a game. Then, a decomposition method is proposed to calculate the value of such a game, which is also expressed with belief structures. Moreover, for the possible computation-intensive issue in the proposed decomposition method, as an alternative solution, a Monte Carlo simulation approach is presented, as well. Finally, the proposed zero-sum matrix games with payoffs of Dempster–Shafer belief structures is illustratively applied to the sensor selection and intrusion detection of sensor networks, which shows its effectiveness and application process.

Keywords: sensor selection; intrusion detection; matrix game; imprecise payoff; Dempster–Shafer evidence theory; belief function

1. Introduction

Uncertainty extensively exists in numerous scientific and engineering fields. Among a variety of fundamental problems related to uncertainty, how to express the uncertain information is one of the first issues. Usually, uncertainty contains randomness, fuzziness, ambiguity, and so on. From the perspective of semantics or linguistics, Klir and Yuan [1] have identified three basic types: fuzziness, discord and non-specificity, where fuzziness stands for the unclearness or indistinctness about objects' characters, discord in the conflict or randomness to an object and non-specificity in the diversity of possible results. The discord and non-specificity are unified as ambiguity [2]. Probability theory, fuzzy set [3], rough set [4], Dempster–Shafer evidence theory [5,6] and the maximum-entropy approach [7,8], to name but a few [9], are some of representative theories or approaches to deal with uncertain information. Especially, due to providing feasible ways to represent and synthesize uncertain information, Dempster–Shafer evidence theory has attracted increasing interest in many fields, such as surveillance [10], intrusion detection [11], etc. As attempts to improve conventional Dempster–Shafer evidence theory, generalized evidence theory [12] and D numbers [13–18] have also received researchers' attention recently. Among them, the model of D numbers, which generalizes belief structures, is a relatively novel means to represent uncertain information by overcoming the exclusiveness hypothesis and completeness constraint in Dempster-Shafer theory.

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