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A threat assessment method of group targets based on interval-valued intuitionistic fuzzy multi-attribute group decision-making

Depeng Kong*, Tianqing Chang, Quandong Wang, Haoze Sun, Wenjun Dai

Department of Arms and Control, Academy of Army Armored Forces, Beijing, 100072, China

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ABSTRACT

Group target (GT) is consisted of multi-class weapons that can collaboratively work and it is a basic application unit in the information warfare. Assessing the threat of GT is required for the optimal decision of troop deployment. However, it is difficult to obtain a reasonable and effective threat assessment result of GT due to the uncertain battlefield information and different judgments from various decision makers (DMs). The study aims to investigate the multi-attribute group decision-making (MAGDM) method for solving the interval-valued intuitionistic fuzzy threat assessment problem of GTs without known attribute weights and DM's preference weights. Based on the assessment information of DMs, attribute weights are determined with the interval-valued intuitionistic fuzzy entropy. To derive the DM's preference weights objectively, we construct a nonlinear optimization model to minimize decision makers' overall decision-making conflict. Moreover, the artificial bee colony algorithm is introduced to solve the nonlinear constrained optimization problem in the optimization model. The decision information of multi-DM is aggregated by the interval-valued intuitionistic fuzzy weighted averaging operator (IVIFWA) with the DMs' preference weights. In order to describe the attribute closeness degree to the ideal solution, the decision-making judgment matrix is constructed according to the ideal solution closeness degree of each GT's attribute calculated with the cross-entropy distance. Subsequently, based on the decision-making judgment matrix, the threat degree is calculated according to the weighted average method with the attribute weights. Finally, a case of the threat assessment of group targets is provided to illustrate the implementation process and applicability of the method proposed in this paper.

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1. Introduction

Battle patterns have been experiencing profound changes in recent years. In the traditional mechanized warfare, weapons are loosely coupled to attack targets and the fire attacking of weapons mainly depends on their own abilities. However, in the current information warfare, weapons are tightly coupled to play the synergetic effect. As described in OODA (Observe, Orient, Decide, Act) loop, multiple weapons should be cooperated to complete a given task under the condition of informatization. The function of each weapon is closely related to that of other weapons and the overall performance of all the weapons is no longer the simply accumulated performance of each weapon. Therefore, the combat forces can be divided according to the cooperative relationship of weapons and the cooperative targets can be regarded as a group target (GT). As an important basis for combat decision-making, the combat force assessment of GTs is increasingly important in information warfare.

Target threat assessment (also denoted as threat evaluation) aims to analyze enemies' combat capability and attack-defense confrontation and obtain quantitative descriptions of the threat from enemies for decision-making [1]. Threat assessment is a high-level information fusion process, which is related to the JDL model of data fusion belonging to Level 3 [2]. The threat assessment of GTs is the foundation for troop deployment and decision-making. A battlefield GT is a multi-weapon set composed of multi-class synergetic weapons. The threat degree of GTs depends on various factors, such as terrain, combat intention, equipment structure, spirit, morale, support capability, and command and control ability. It is difficult to analyze these attributes, which should be combined with knowledge and experiences of military experts. Threat assessment of GT can be regarded as a decision-making problem. DMs judge the threat degree of GTs based on the

* Corresponding author.
E-mail address: kongdp55@163.com (D. Kong).

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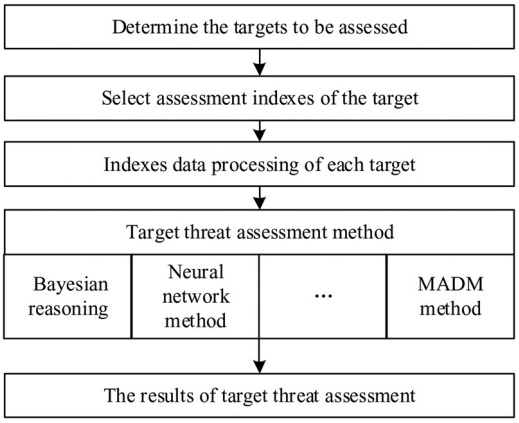

Fig. 1. Solution process of a target threat assessment problem.

information gained from battlefield situation as well as their knowledge and experiences for the force deployment and firepower striking. Due to the complexity of combat and the limitations of battlefield information perception, ambiguity and uncertainty are unavoidable in the threat assessment of GTs. Some irrational factors still exist in personal decision due to the lack of individual knowledge, ability, and experiences. Therefore, MAGDM [3] based on multi-DMs who can overcome the weakness related to personal decision is an important way to obtain scientific assessment results [4,5].

The study aims to develop an interval-valued intuitionistic fuzzy MAGDM method for the threat assessment of GTs. DMs are military experts and the alternatives are the GTs to be evaluated. In this method, weights are unknown and the determination method is important. Attribute weights are determined by interval-valued intuitionistic fuzzy entropy and DMs' preference weights are calculated by solving the nonlinear constrained optimization model with artificial bee colony algorithm. The threat degree and ranking order of all the GTs can be generated according to the decision-making judgment matrix. The proposed method can meet the requirements of the threat assessment of battlefield GTs and corresponding constraint conditions. Compared with previous studies, the method proposed in this paper has 4 key features as follows:

Firstly, we propose the concept of GT threat assessment and transform the problem of GT threat assessment into a MAGDM problem for the first time.

Secondly, the determination methods of attribute weight and the DMs' preference weight in the GT threat assessment are proposed under the condition that the weights are completely unknown. We use interval-valued intuitionistic fuzzy entropy based on DMs' decision matrix to calculate attribute weights. We establish a nonlinear constraint optimization model to determine the DMs' preference weights.

Thirdly, the improved artificial bee colony (ABC) algorithm is proposed to solve the nonlinear optimization model of DMs' preference weight. The new constraint handling approach can effectively solve the problem of equality constraints.

Fourthly, based on the aggregated decision matrix of multi DMs, we calculate the decision judgment matrix with the closeness degree to the ideal solution. GT threat degree is computed according to the weighted average of each attribute of the decision judgment matrix.

The rest of this paper is organized as follows. Section 2 presents the literature review on interval-valued intuitionistic fuzzy multi-attribute group decision-making and target threat assessment. Section 3 introduces the basic theory of IVIFS. Section 4 gives the method to determine the attribute weights and DMs' preference weights in the situation that weights are completely unknown. Section 5 introduces the threat assessment method based on multi-attribute group decision-making. In Section 6, a case of GT threat assessment is provided to verify the proposed method. Section 7 presents the comparison analysis and discussion. In Section 8, conclusions are drawn and future study directions are presented.

2. Literature review and related works

2.1. Target threat assessment

A threat is defined as an act, entity, event, or phenomenon with the potential to harm a person or object [6]. Threat assessment is a technique to evaluate the threat level of the evaluation object [7]. Target threat assessment, as one of the battlefield decisions, refers to the possible harm of the enemy's operational targets on our weapons and facilities. In reality, threat assessment is a decision-making process based on uncertain information and correlated factors.

The main process of target threat assessment is shown in Fig. 1. First of all, threat assessment needs to determine the assessment targets, such as combat weapons and threatened facilities. Then, the indexes are selected according to the characteristics of evaluation targets and the assessment indexes should be independent, complete, and feasible. Then, the data of threat assessment indexes should be processed. We need transform the evaluation data into mathematical representation, such as interval numbers, fuzzy numbers, and fuzzy language. Then, a threat assessment model is established and a target threat assessment algorithm is proposed. Finally, the threat degree of the targets is calculated.

In order to solve different problems of target threat assessment, scholars have put forward some effective methods and models. The methods of Bayesian network [8], neural network [9] and multi-attribute decision-making (MADM) [10], as the effective treatment methods, have been applied in target threat assessment. Huang et al. proposed a target threat assessment method based on intuitionistic fuzzy sets Choquet integral with intuitionistic fuzzy sets and introduced fuzzy integral into the information fusion area [1]. Wang et al. proposed a mother wavelet function selection algorithm with minimum mean squared error and then constructed MWFWNN network by using the wavelet neural networks [11]. Azimirada et al. gave a precise description of the threat evaluation process with the fuzzy sets

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