Extracting Decision Rules for Cooperative Team Air Combat Based on Rough Set Theory

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Abstract: In order to reduce redundant features in air combat information and to meet the requirements of real-time decision in combat, rough set theory is introduced to the tactical decision analysis in cooperative team air combat. An algorithm of attribute reduction for extracting key combat information and generating tactical rules from given air combat databases is presented. Then, considering the practical requirements of team combat, a method for reduction of attribute-values under single decision attribute is extended to the reduction under multi-decision attributes. Finally, the algorithm is verified with an example for tactical choices in team air combat. The results show that, the redundant attributes in air combat information can be reduced, and that the main combat attributes, *i.e.*, the information about radar command and medium-range guided missile, can be obtained with the algorithm mentioned above, moreover, the minimal reduced strategy for tactical decision can be generated without losing the result of key information classification. The decision rules extracted agree with the real situation of team air combat.

Key words: cooperative team air combat; rough set theory; attribute reduction; tactics rule

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摘 要: 为了对空战过程中大量的冗余信息进行约简, 以提高空战决策的实时性, 将粗糙集理论引入到编队协同空战战术决策研究中, 提出了一种用于提取空战关键信息和战术决策规则的属性约简算法。并将单一决策属性下的属性值约简方法推广, 讨论了更适于编队作战分析的多决策属性下的属性值约简问题。最后, 通过一个编队空战战术选择示例对该算法进行了验证, 结果表明: 空战的冗余信息是可以约简的; 此算法可提取出对空战起主要作用的属性, 即雷达/中距弹信息; 并且在保证空战关键分类结果不变的情况下, 可生成用于战术决策的最小简化策略, 所提取的决策规则与编队空战的实际相符合。

关键词: 编队协同空战; 粗糙集; 属性约简; 战术规则

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In modern air-to-air combat environments, the typical pattern of fighter group operations is cooperative team air combat (CTAC), which can significantly increase the fighter group's total capability of detecting, tracking and attacking targets. After the adversary teams and ours reach to the stated fighting air-ranges, several fighter teams of both sides fight against each other in a certain domain beyond visual ranges or in short ranges. During the air combat (AC), the cooperative information between the leader aircraft and wingman, and the tactical cooperative information among teams are necessary to the pilots. Furthermore, the cooperation between fighters require that team pilots share the most important information of both sides in real-time so that correct decision can be made while AC situation is rapidly changing. However, under the condition of hi-tech AC in the future, such factors as high-strength electronic interference, *etc*, will result in

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the increase of uncertain information as to the number of targets, enemy tactics and operation situation, which will influence the validity of our decision in AC[1].

Rough set theory, proposed by Z. Pawlak in early 1982, is a new mathematical tool in dealing with imprecision and uncertainty[2,3]. The most remarkable characteristic of this theory is that it does not require any additional empirical information such as probability in statistics and grades of membership in fuzzy set theory to analyze practical problems. Therefore, it is convenient to describe and deal with the uncertainties of practical problems[4]. In recent years, great attention has been paid to rough set theory by scholars from various countries due to its widely application to artificial intelligence areas, such as decision-support system, reasoning rules extracting and data mining, *etc*[5].

In this paper, rough set theory is introduced to the tactical decision analysis in CTAC system, which is the main pattern of fighter group operation in modern times and in the future. An algorithm of attribute reduction for extracting key combat information and generating tactical rules is presented by using concept of core in rough set theory. Then, considering the practical requirements of team combat, a method for reduction of attribute values under multi-decision attributes is studied. Finally, the algorithm mentioned is verified by using an example for tactical choices in team AC. The proposed method in this paper is a helpful try to the research of communication and command system of CTAC under condition of hi-tech.

1 Some Notions of Rough set Theory

1.1 Information system and its expression

An information system is a quadruple

$$S = \langle U, A, V, f \rangle$$

where $U = \{x_1, x_2, \cdots, x_n\}$ is a finite set of objects (or states). $A = C \cup D$ is a finite set of attributes and A is divided into two sets, conditional attributes C and decision attributes D; V is a set of attribute values, and $V = \bigcup_{a \in A} V_a$, V_a is the value domain of a; $f: U \times A \to V$ is called an information function assigning a value of attributes for every state, where $f(x, a) \in V_a$. An information system can be represented in terms of a data table of attribute values (also called information table), and the information about attributes and states can be represented in terms of columns and rows in the table, respectively. An attribute corresponds with an equivalence relation and an information table can be regarded as a family of equivalence relation.

1.2 Indiscernible relation and approximations of sets

$x, y \in U$ is called indiscernible to $a \in A$ in S, denoted by $(x, y) \in A_{ind}$, if and only if $f(x, a) = f(y, a)$ for $\forall a \in A$, where A_{ind} is an intersection of all appointed equivalence relations in A.

Assume $R \subseteq A$, $x \in X \subseteq U$, and $[x]_R$ be defined as an equivalence class of x in relation R_{ind}; U/R is a family of all equivalence classes of R, and Φ is an empty set, then

$$R_\cdot(X) = \{x \in U: [x]_R \subseteq X\} \tag{1}$$

$$R^\cdot(X) = \{x \in U: [x]_R \cap X \neq \Phi\} \tag{2}$$

are called the R-lower and R-upper approximation of X, respectively.

$$B_R(X) = R^\cdot(X) - R_\cdot(X) \tag{3}$$

is called the boundary region of X to R.

If $B_R(X) = \Phi$, then X is exact with respect to R; in the opposite case, X is referred to as rough to R, and the set X can be approached only by the R-lower and R-upper approximation.

1.3 Dependency of attributes

To evaluate the dependency of decision attributes D on conditional attributes C in information table, an index of dependency is given by

$$r_C(D) = |P_C(D)| / |U| \tag{4}$$

where, $|\cdot|$ denotes a base of set, $P_C(D)$ is C-positive region of D which contains all objects that can be classified to one class of the classification U/D by attributes C.

If $r_C(D) = 1$, it is said that D depends completely on attributes C, *i.e.*, $C \to D$ can be satisfied.