Aerial Target Threat Evaluation Method

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Starting with the systematic analysis of aerial target threat assessment problem of warship aerial defence combat, thoroughly studied the essential procedure of aerial target threat assessment under the system-combat condition of synthesis shipborne electronic war weapon, ship-to-air missile and aerial defence gun. Based on this, in view of the system aerial defence decision-making features, the aerial target threat assessment model was built under the system combat mode based on two-level decision-making. In this way, the aerial target threat assessment method of warship system aerial defence combat was put forward. Finally, a real example explained it effective.

Keywords: Aerial Target Threat Assessment; System Combat; Warship Aerial Defence.

1. Introduction

With the development of information and missile technology, air defense combat has become the main combat surface ships to save your life tasks. Surface ships to threaten air strikes target assessment, for a reasonable allocation of the follow-up objectives, in order to organize effective resistance using ship-borne weapon system against air defense priority. In complex electromagnetic environments, battle mode and battle thoughts changed deeply. The surface warship air defense changed the focus on anti air missile and anti-air gun hard weapons, and weakening the electronic warfare weapon into putting greater emphasis on hard and soft weapon system air defense efficiency. Therefore, effectively assessing the threat of air strikes target to shipboard weapon system in air defense is one of the most important problems in the field [1-5].

At present, individually considered carrier "hard" arms and "soft" weapon research on target threat assessment in air defense combat has had some results [4-10], but using ship-borne "soft" and "hard" air defense weapons system researched relatively little in the field. Aim at the characteristics of ship-borne air defense combat, research targets threat evaluation issues in ship system air defense. Using a combination of multiple attribute decision making based on the theory of set up aerial targets threat evaluation model, and proposed an aerial targets threat evaluation method based on two-level decision making. For solving shipboard weapon system threat assessment in air defense combat provides new ideas.

2. The Threat Assessment Process of Ship System Air Defense Operations

Shipboard weapon system air defense targets threat evaluation which is the decision problem judging the air force will be “when”, “where”, and “how” posed a threat and threat level. “When” and “where” is the embodiment of the intention of the air forces, how to constitute the threat and what threat they pose is the embodiment of the air force's capabilities. Threat assessment is considered combat intentions and capabilities of the air forces ' threat level. For a batch of air attack target, only if the target with intent to damage and attack the ship at the same time, it can be said the target pose a threat to the ship. With damage capacity only, and not with intent or with intent to attack without killing ability, usually does not pose a threat to ships.

Meanwhile, System air defense is shipborne weapon system organized by commander, the collaborative electronic warfare commander for weapon systems and “hard” weapon systems officers to make joint decisions. In the decision-making process, it need merging data chain information, intelligence information, and vessel information, even subjective experience, knowledge, and other factors of at all levels commanders. The decision-making process of identifying aerial targets threat to ships, determining combat scheme is a hierarchical distributed decision making[1-3]. Different levels of commanders concern the size and operational goals and information needs with different granularities. The top decision analysis based on the composition of more lower groups analysis. The result of entire collaborative decision making is given by the Supreme Commander in the organizational structure.

So this also determines the aerial targets threat evaluation under the condition of system combat is a bottom up, from local to global, layer-by-layer analysis of the decision-making process. At this hierarchical decision-making process, the underlying policy makers are the arms sector commanders, including ECM commander, anti air missile commander and anti-aircraft gun Commander, upper-level decision makers is the combat commander. They evaluate threat assessment respectively from a local and overall situation.

The process of air target threat assessment of shipboard weapon system air defense is shown in Fig1.

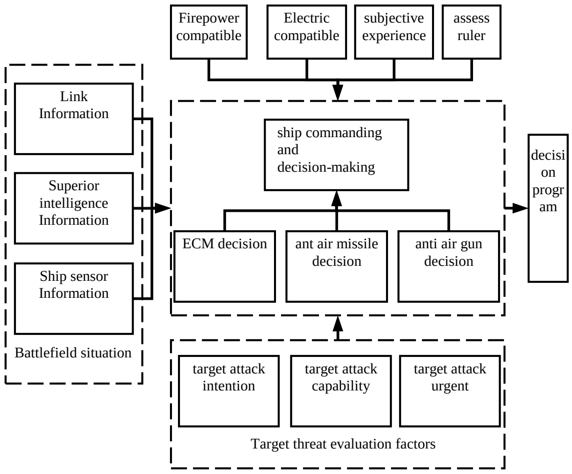

Fig.1. threat assessment process of shipboard weapon system air defense

In Fig1, the first surface ship commanders at all levels according to the various shipboard sensor, superior intelligence, data link information to get all the air target information. After real-time data fusion processing, a dynamic update situation map of the integrated battlefield is forming. Then, the Commander according to the target attacking intent, urgency and damage ability to the ship identified the target threat level to the ship. The ship commander integrates by combining the information and the threat level given by weapon systems commanders. Determine the threat level in the light of the process of evaluation rules and even the commander's own subjective experience of integrated assessment of the threat level.

3. Ship System Air Defense Warfare Target Threat Evaluation Model

3.1. Determine aerial targets threat evaluation factors

Aerial targets threat degree is relative, primarily by our air defense weapon system capacity and air targets of attacks intent. The ship has active, passive electronic countermeasures systems, anti-air missiles, anti-air guns and other air defense weapons systems. But the warship major combat missions are different, their weapon equipment will not be the same. Under normal circumstances, based on the target recognition and data fusion, by battle-field situation analysis we will usually be able to get the target inherent information such as the type, carrying weapons and equipment type and quantity, mode of attack, attack, interference and anti-jamming capability and so on, as well as bearing, distance, course, altitude, speed, fairway crosscut.

It can be seen that there are many factors affecting the air targets threat, if describe a given threat changes function fully, it is very difficult. Therefore, from the perspective of shipboard weapon system air defense operations, the aerial targets threat degree evaluation should consider the following 3 main factors, which also includes a number of sub-factors of each factor:

(1)Judge target attacking intention: Synthesize judgment mainly according to enemy combat thinking, combat mode, attack styles, the enemy commander's character, object type, object compose, target course, speed, distance, altitude, bearing, course shortcut and changing information. Because of flexibility tactics and uncertainty battlefield information, it is difficult to estimate the target intention accurately. Usually depending on the commanders' experience, subjective judgment and analysis of current status and historical information, estimate the possibilities of target attacking ships comprehensively.

(2) Target damage capacity: determined primarily by the target type. If the target type is different, then its flight performance, carrying weapons, type, quantity, attack mode and attack range is not the same, and thus the threat level there is a big difference to the ship.

(3) Urgency of target: the urgency of targets includes threat direction and threats time, it is judged mainly by ship-borne air defense weapons, target distance and speed. The shorter coming time of target to surface ships is, the shorter time of fire distribution and fire preparation for the commander is, and the more urgent target threat is. This is a relative process, and it is against confrontation. Only account of attacking intent, damage capability and system combat capability of the ship borne weapon fully, it can get correct results.

3.2. Aerial targets threat evaluation model

3.2.1. Problem description

When considering shipboard weapon system air defense, air target threat assessment is due to multiple attribute decision making problems.

Order $M=\{1,2,\ldots,m\}$, $N=\{1,2,\ldots,m\}$. Assume:There are m air strikes targets,write as $A=\{a_1,a_2,...,a_m\}$;there are n evaluation properties of air targets, write as U={u_1,u_2,...,u_n};use AHP method[11],make sure the weight of properties (u_j,j∈N) is w_j, w_j∈[0,1], $\sum_{i=1}^{n} w_j = 1$.

As know：Ship commanders observe air target orientation, distance, altitude, heading, speed, and size information, and then analysis, forecasts and estimates to all air strikes target. Then we can get the target ($a_i, i \in M$) on the property's ($u_j, j \in N$) assessed value (x_i^j). All assessment results (x_i^j, $i \in M$, $j \in N$) form a multiple attribute decision making matrix ($X = \left[x_i^j \right]_{m \times n}$).

The target threat assessment of multiple attribute decision making problems is to obtain the air attacks target threat rank by a decision matrix.

3.2.2. Threat assessment method

Currently ships air target threat estimation research methods can be divided into three categories: from the perspective of fuzzy set method from probability theory and research methods from the planning theory and research methods. In order to solve the above problem, we solved problem by TOPSIS method.

First, because many properties of different physical dimensions have an impact on decision making, the need for multiple attribute decision making matrixes is normalized. Common property types are cost-efficiency properties, attributes, and efficiency is the property that is property of the property value, the more the better, costs property refers to property values as small as possible the property

This paper uses the standard formula is in Eq.1:

$$\begin{cases} y_i^j = x_i^j \Big/ \sqrt{\sum_{i=1}^{m} \left(x_i^j\right)^2}, & \textit{benefit attribute} \\ y_i^j = \left(1/x_i^j\right) \Big/ \sqrt{\sum_{i=1}^{m} \left(1/x_i^j\right)^2}, & \textit{cost attribute} \end{cases} \tag{1}$$

By Eq.1 calculation of standardized decision matrix ($Y = \left(y_i^j\right)_{m \times n}$) can be obtained. According to the basic idea of TOPSIS method gives the following definition, as shown below.

If $j \in N$, $E_j^+ = \max_i(y_i^j)$, $E_j^- = \min_i(y_i^j)$, then $E^+ = \left\{E_1^+, E_2^+, ..., E_n^+\right\}$ is ideal solution, also say that aerial targets threat degree is max. And then $E^- = \left\{E_1^-, E_2^-, ..., E_n^-\right\}$ is minus ideal solution, also say that aerial targets threat degree is min.Clearly, the assessment targets closer to E^+, the threat of aerial target (a_i) is more and vice versa, the assessment targets closer to E^-, the aerial targets (a_i) threat degree is less.

For evaluation to assess the aerial targets threat degree, introduce index of relative closeness now.

Select the weighted Euclidean distance, calculate the bias ($D_i^+(a_i, E^+)$) of a_i and E^+, calculate the bias ($D_i^-(a_i, E^-)$) of a_i and E^- , shown as below:

$$D_i^+(a_i, E^+) = \sqrt{\sum_{j=1}^{n} \left[w_j (y_i^j - E_j^+) \right]^2}$$

$$D_i^-(a_i, E^-) = \sqrt{\sum_{j=1}^{n} \left[w_j (y_i^j - E_j^-) \right]^2} \ .$$

In this way, according to the following Eq.2 can be obtained the relative closeness of aerial target (a_i) to E^+ index (α_i) are as follows:

$$\alpha_i = D_i^-(a_i, E^-) / H_i \quad (2)$$

In formula $H_i = D_i^+(a_i, a^+) + D_i^-(a_i, a^-)$ .Then, sort by size calculated values of α_i, you can get all the aerial targets threat degree sort, the first α_i values greater target (α_i) more threatening.

3.3. Target threat evaluation model

For surface ships, the same air for ECM soft due to the fight against weapons systems and ship for hard combat weapons such as surface-to-air missiles, anti-aircraft gun, the threat level is not the same. For incoming missiles, soft combat system focuses on missile guidance and hard-fighting weapons will focus on factors such as speed, charge. In shipboard weapon system combating, the assessment of the air targets' threat is considered soft and hard weapon system's result of targets threat level assessment.

It is assumed that a certain type of warship weapon system q weapon systems. Order $Q = \{1, 2, ..., q\}$, $M = \{1, 2, ..., m\}$. Assume weapon subsystem (k , $k \in Q$). The target weights of evaluation results is $c(k)$, $c(k) \in [0,1]$, $\sum_{k=1}^{q} c(k) = 1$; Each weapon subsystem evaluates target threat in accordance with section 2.2 air strikes target the way of assessing the magnitude of the threat. Weapons systems (k , $k \in Q$) about the target(a_i , $i \in M$) relative similarity index values is $\left[\alpha_i(k) \right]_{q \times m}$.

In this way, according to the following Eq5 assess air targets (a_i , $i \in M$) integrated threat level (F_i) . $F_i = \sum_{k=1}^{q} c(k) \alpha_i(k)$, $i \in M$. Thus, according to the calculated F_i values in descending order, you can get all the air target threat rank for surface ships, that is standing in the front of the air targets threat, the greater.

4. Instance Analysis

Calculation and analysis of a large number of examples in this paper examined the validity of the method. A small numerical examples are given to illustrate this problem.

Assume one ship consists of 3 weapon subsystems. Evaluation of each weapon system on an empty goal weights respectively are $c(1) = 0.35$, $c(2) = 0.2$, $c(3) = 0.45$.

There are four air strikes target $A = \{a_1, a_2, a_3, a_4\}$ ={bombers, anti-ship missiles, fighters, AEW}. The air target has 3 property evaluations, $U = \{u_1, u_2, u_3\}$ ={damage capacity, attach intention, attack urgent}, and $w_1 = 0.3$, $w_2 = 0.3$, $w_3 = 0.4$.

A subsystem estimates each evaluation of air target attribute value as shown in table 1.

Table 1 properties for each target value

property / target	U1(damage capacity)	U2(attach intention)	U3(reach time)
a1	0.9	0.75	420
a2	1	0.46	300
a3	0.9	0.68	270
a4	0.8	0.05	180

According to the standard Eq.1, the normalized value property of each target can be calculated as shown in table 2.

Table 2 standardization of each target attribute value

property / target	U1(damage capacity)	U2(attach intention)	U3(reach time)
a1	0.4985	0.6738	0.3039
a2	0.5538	0.4133	0.4255
a3	0.4985	0.6109	0.4728
a4	0.4431	0.0449	0.7092

The ideal solution is, $E^+ = \left\{E_1^+, E_2^+, ..., E_n^+\right\} = \{0.5538, 0.6738, 0.7092\}$. The minus ideal solution is, $E^- = \left\{E_1^-, E_2^-, ..., E_n^-\right\} = \{0.4431, 0.0449, 0.3039\}$.

Calculated the deviations between the ideal solution (E^+) and minus ideal solutions (E^-) of each assessment air targets.

$D_1^+(a_1, E^+) = 0.1629$, $D_2^+(a_2, E^+) = 0.1378$, $D_3^+(a_3, E^+) = 0.0978$, $D_4^+(a_4, E^+) = 0.1916$, $D_1^-(a_1, E^-) = 0.1894$, $D_2^-(a_2, E^-) = 0.1252$, $D_3^-(a_3, E^-) = 0.1835$, $D_4^-(a_4, E^-) = 0.1621$.

Then, calculated relatively close index value of each assessment target. $\alpha_1 = 0.5375$, $\alpha_2 = 0.4761$, $\alpha_3 = 0.6522$, $\alpha_4 = 0.4584$.

In accordance with the relative closeness of each assessment objective indexes sort by size, it can be obtained the aerial targets threat degree sort given by the weapons subsystems $a_3 \succ a_1 \succ a_2 \succ a_4$.

Now, suppose that calculated in accordance with the above process of each air weapons systems evaluated the relative closeness of the target index.

$$[\alpha_i(k)]_{3\times4} = \begin{bmatrix} 0.5375 & 0.4761 & 0.6522 & 0.4584 \\ 0.8125 & 0.3506 & 0.6120 & 0.1987 \\ 0.5031 & 0.4230 & 0.4431 & 0.3011 \end{bmatrix}.$$

Finally, can confirm targets threat degree. $F_1 = 0.5770$, $F_2 = 0.4771$, $F_3 = 0.5501$, $F_4 = 0.3357$

Sorting according to size of the result, and that can be the target of my ship's integrated threat: $a_1 \succ a_3 \succ a_2 \succ a_4$.

Warship air defense commanders can target according to the aerial targets threat evaluation results due to allocation decisions. Each weapons system after getting the target distribution commands issued by the naval command, according to calculations by the aerial targets threat evaluation results for firepower allocation decision-making.

5. Summary

Modern naval warfare, surface ships to carry out naval tasks in the process, defense against aerial targets through to the end. Therefore, this study has important theory research and application of military significance. Currently, the combat study of ships soft and hard weapon system is still in the exploratory stage. Based on this, the first ship system of air defense combat aerial targets threat evaluation in-depth analysis of the problem. Further study on the basis of this assessment of the air targets ' threat factors, the model of target threat assessment is built based on two-level decision making t in system air defense operation. Calculation shows that the proposed method is simple, workable, so as to address the threat assessment of warship air defense combat offers a new way.

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