Research on intelligent decision of fire distribution in remote control weapon station

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Abstract. The complex and changeable battlefield environment and personal emotions may affect the decision-making of the battlefield. In order to reduce these effects, make the remote weapon station autonomous, fast, reasonable distribution of firepower, to achieve accurate and effective target strike. In this paper, according to the difference of attacking targets, the threat evaluation models of different targets are established, the evaluation functions of target attributes are set up, and the ranking results are compared with the commander's subjective decision-making. The evaluation results of the model are consistent with the expert evaluation results. It is proved that the remote control weapon station can overcome the subjective factors and strike the target reasonably when it distributes fire to different attacking targets according to the model, which has high reliability.

1. Introduction

In contemporary international society, the situation is complex and changeable, the domestic situation is generally stable, but there are still frictions along the border, and the environment is poor and the terrain is complex. As the main task of defense, the protection of important border areas and facilities faces great challenges. With the rapid development of big data, machine learning, artificial intelligence and other technologies, as well as the wide application of remote control weapon station in the military field, the weapon presents diversified, intelligent and unmanned development, and its performance has also been improved qualitatively. If the remote control weapon station adopts the way of separating the remote control terminal from the weapon system, the weapon system is equipped with different fire attack weapons, and the remote control terminal adopts the intelligent command and control system, the fire control system can obtain the enemy's real-time situation and weapon types (light tank, heavy tank, infantry combat vehicle, anti tank helicopter, air defense missile vehicle, artillery) according to the sight system. The threat degree of enemy target relative to our array or weapon platform can be calculated quickly and accurately, and then the command can be confirmed by remote control terminal to give fast, accurate and effective attack.

The self-judgment of threat level cannot be separated from the perception and fusion of battlefield information by a large number of sensors [1]. Replaces the way the captain makes goal observation and makes decisions with combat experience; The accurate calculation of threat degree is inseparable from the scientific and reasonable evaluation method [2], which not only solves the problems of inaccurate judgment, too long decision-making time, uncertain decision-making results, unscientific and so on caused by factors such as relying on the physical state, psychological quality and combat
experience of the vehicle commander. Moreover, it greatly simplifies the complexity of the operation, gets more time for the confirmation of the enemy's situation, shortens the time of "discovery-strike", and ensures the accuracy and effectiveness of the strike.

Based on the operational characteristics, tactical and technical performance of the unmanned remote control weapon station, Consider the self-attributes of aerial targets, this paper establishes a dynamic threat assessment model for a large number of different types of attacking targets [3], evaluates the threat degree, and carries out the intelligent auxiliary decision-making research on fire distribution [4], so as to provide technical support for the improvement of the actual combat capability of the unmanned remote control weapon station.

2. Research of fire distribution
In modern war, a variety of weapons and equipment have emerged, and combat has become a comparison of weapon types and performance. Different enemy weapons have different degrees of threat to our weapons, while Large-scale ground combat is almost impossible, replaced by unpredictable air threats, including reconnaissance aircraft, helicopters, fighters, bombers, etc. In the multi-firepower and multi-target battlefield environment, there can be many firepower distribution schemes. Different distribution schemes will produce different combat effects [5]. Therefore, for multiple threat targets, we need to effectively eliminate the threat of enemy targets, allocate weapons, and minimize our losses according to our operational capabilities and threat situation of enemy targets.

In view of the variety and complexity of the battlefield environment, in order to better determine the better attack plan, the threat degree of the target is accurately assessed, and the fire distribution is carried out according to the assessed threat degree [6].

According to the principle of "great threat of target and favorable shooting", fire distribution assigns shooting tasks to the subordinate tactical units or fire unit assigns shooting mission. The specific principles are as follows:

1. First, shoot close targets, then shot far; (2) Shoot fast targets first, then slow targets; (3) Shoot low targets first, then high targets; (4) Give priority to targets designated by superior commanders.

The fire unit fires at the air targets within the firing range and strives to make every air target fired. When there is only one group of targets coming, all fire units should carry out multi-level fire attack as long as conditions permit; When there are multiple batches of targets attacking, and there is no superior instruction to distribute fire, each fire unit fires according to the above principles. When a batch of target shooting is completed, turn the fire in time.

3. Establishment of target attribute model
There are many factors that affect the efficient air defense of our air defense weapons. As for the enemy's incoming weapons, according to their characteristics, movement characteristics and threat assessment principles, we can establish a threat assessment attribute system based on the main indicators such as target type, target size, target distance, flight speed, interference intensity, arrival time, flight height, etc. The mapping from attribute value to dimensionless threat assessment value is established. Finally, the distribution of the incoming target's firepower is determined by the threat assessment value [7-8]. The incoming target may be tactical ballistic missile, anti radiation missile, air to ground missile, cruise missile, large bomber, fighter, small aircraft, command aircraft, reconnaissance aircraft, armed helicopter, false target, unidentified aircraft, etc. This section first classifies them, and then establishes the evaluation model of different target attributes [9].

3.1. Target classification
First of all, the incoming targets are roughly classified:
X1: large bomber, cruise missile;
X2: fighter, small aircraft, command aircraft;
X3: air to ground missile, anti radiation missile and tactical missile;
X4: reconnaissance aircraft, armed helicopter;
X5: false target, decoy, unknown target.
In the background of an air defense simulation training, in t time, the relevant parameters of the air flight target [10] collected by the radar air defense system are shown in table 1.

| attribute type     | target type      | target size /m | target distance /km | flight speed /m/s | arrival time /s | flight height /m | interferenc e intensity |
|--------------------|------------------|-----------------|---------------------|------------------|-----------------|------------------|------------------------|
| X1                 | large aircraft   | 30~50           | 10~15               | 270~310          | 600~870         | 5000~10000       | medium                 |
| X2                 | small plane      | 10~20           | 9~12                | 400~500          | 1000~160        | 2000~320         | strong                 |
| X3                 | tactical missile | 1~10            | 5~9                 | 1600             | 170~880         | 400              | strong                 |
| X4                 | helicopter      | 10~20           | 11~18               | 200~350          | 250~400         | 250~300          | very strong            |
| X5                 | unknown target   | 0.5~6           | 13~18               | 280~300          | 580~790         | 3500~7000        | weak                   |

3.2. Target attribute threat assessment model
In the actual combat process, the target information can only be judged according to the radar detection information and the enemy information in ordinary times. These information can be described quantitatively or qualitatively, and the relationship between them is complex. This section describes the establishment of different threat assessment functions by different attribute information.
(1) Threat assessment value of target type:
According to the existing application examples [11], set the threat assessment values of five target types, as shown in table 2

| target type | X1 | X2 | X3 | X4 | X5 |
|-------------|----|----|----|----|----|
| relative threat level | 0.85 | 0.55 | 0.92 | 0.43 | 0.04 |

(2) Threat assessment value of target size:
The larger the target is, the more likely it is to be found, and the smaller its threat is. Then the more likely it is to be attacked. Using dimensionless normalization method, set the normalization function \( \mu (s) \) about size. Assuming that the size \( s \) is 50m, there is no threat. The closer the size is to 0, the closer the threat is to 1.
\[
\mu (s) = k_0 s + 1, \quad 0 < s \leq 50, \quad k_0 = \frac{1}{50} \tag{1}
\]

(3) Threat assessment value of target distance:
According to the principle of threat assessment, taking the target distance \( p \) as the independent variable, the threat assessment function \( \mu (p) \) about the target distance \( p \) is set,
\[
\mu (p) = e^{-k_1 p^2}, \quad -30 \leq p \leq 30, \quad k_1 = 5 \times 10^{-3} \tag{2}
\]

(4) Threat assessment value of flight speed:
According to the principle of threat assessment, taking the target speed \( v \) as the independent variable, set the threat assessment function \( \mu (v) \) about the flight speed \( v \),
\[
\mu (v) = 1 - e^{-k_2 v}, \quad v > 0, \quad k_2 = 5 \times 10^{-3} \tag{3}
\]
(5) Threat assessment value of arrival time:

According to the principle of threat assessment, taking the arrival time $t$ as an independent variable, set the threat assessment function $\mu(t)$ about the arrival time $t$,

$$\mu(t) = \begin{cases} 1 + \frac{k_3}{kt^3}, & 600 \leq t \leq 0 \vspace{0.5em} \cr e^{-k_4}, & 0 \leq t \leq 1800 \end{cases}$$

$$k_3 = 2 \times 10^{-6}, \quad k_4 = 1 \times 10^{-7} \quad \quad (4)$$

(6) Threat assessment value of flight altitude:

According to the principle of threat assessment, taking the flight altitude $h$ as an independent variable, set the threat assessment function $\mu(h)$ about the flight altitude $h$,

$$\mu(h) = \begin{cases} 1, & 0 \leq h \leq 800 \vspace{0.5em} \cr e^{kh^2}, & h > 800 \end{cases}$$

$$k_5 = 1 \times 10^{-8} \quad \quad (5)$$

(7) Threat assessment value of electronic interference intensity:

In modern warfare, electronic jamming equipment is usually equipped in weapons [12-13]. Its main task is to reduce the performance of the electronic equipment of the opposite party or completely fail, so that communication is interrupted, radar is confused, weapons are out of control, command is paralyzed, and combat effectiveness is lost; At the same time, the electronic equipment of our side can work effectively. The electronic interference intensity has become an important indicator of the threat degree of the target. The electronic interference intensity is generally divided into five grades: very strong, strong, medium, weak, and zero [14]. It is recorded as 1, 0.8, 0.5, 0.2, 0 respectively through dimensionless quantification. The electronic interference intensity of the target type is shown in table 3.

| Table 3. Electronic interference intensity of target type. |
|----------------------------------------------------------|
| target type | X1 | X2 | X3 | X4 | X5 |
| electronic interference intensity | 0.5 | 0.8 | 0.8 | 1 | 0.2 |

4. Target threat assessment model

In the traditional battle command, the threat degree of the target often depends on the judgment of the commander on the air defense combat situation and the experience of the combat training. In an air defense simulation training, the subjective threat judgment of the commander on the incoming weapons (as shown in table 4) is set to $V_j=[V_{jX1}, V_{jX2}, V_{jX3}, V_{jX4}, V_{jX5}]$.

| Table 4. Commander's subjective threat judgment to incoming weapons. |
|----------------------------------------------------------|
| target | expert decision threat value |
| X1 | 0.5~0.7 |
| X2 | 0.6~0.8 |
| X3 | 0.85~0.95 |
| X4 | 0.4~0.6 |
| X5 | 0.1~0.3 |

4.1. Calculation of weight coefficient

In modern warfare, it is more dependent on the acquisition of massive data. Through high-speed computer computing, the commander only needs to make judgments according to the calculation results, and reduce the subjective judgment of people as much as possible. For each attribute of the
incoming target, it is given different weight because of its different importance.

\[
\omega_i = \frac{1}{\sum_{j=1}^{m} D^2(a_{ij}, V_j)} = \frac{1}{\sum_{j=1}^{m} D^2(a_{ij}, V_j) \times \sum_{i=1}^{n} \sum_{j=1}^{m} D^2(a_{ij}, V_j)}
\]

(6)

\[\omega_i \geq 0 \text{ and } \sum_{i=1}^{n} \omega_i = 1, \ a_{ij} \text{ is the threat matrix of the incoming target attribute, } D(a_{ij}, V_j) \text{ is the degree of separation between } a_{ij} \text{ and } V_j.\]

In actual combat, the operational environment is changing rapidly. If we miss a moment or a little deviation, we may lose the whole battle. In this section, the weight is calculated by the normalized threat degree \( a_{ij} \) of objective target and the normalized threat degree \( V_j \) of commander's subjective judgment. However, there is a certain gap between them. In order to make the decision of commander reasonable, the selection of attribute weight vector \( \omega \) should make the total deviation \( D(a_{ij}, V_j) \) between the subjective threat degree of commander and the objective target threat degree as small as possible.

4.2. **Threat calculation**

According to the optimal weight coefficient, we can get the threat evaluation value of each attacking target. The threat assessment function \( p \) is

\[ p = \sum_{i=1}^{n} a'_{ij} \omega_i \]

(7)

The lower limit of threat degree is \( p1 \), and the higher limit is \( p2 \). According to the expectation of threat degree, it can be regarded as the comprehensive threat degree \( q \) of the incoming target:

\[ q = \frac{p1 + p2}{2} \]

(8)

5. **Target threat assessment results**

According to the air attack weapon parameters in table 1 and the target attribute threat assessment functions in table 2, table 3, formula (1), (2), (3), (4) and (5), the normalized threat assessment data of the incoming target can be obtained as shown in table 5.
Table 5. The normalized threat assessment data of the incoming target.

| attribute target | target type | target size | target distance | flight speed | arrival time | flight height | interference intensity |
|------------------|-------------|-------------|-----------------|--------------|--------------|---------------|------------------------|
|                  | X₁          | 0.85        | 0−0.4           | 0.3247~      | 0.4868~      | 0.4290~       | 0.5                    |
|                  | X₂          | 0.55        | 0.6~0.8         | 0.4868~      | 0.0060~      | 0.9440~       | 0.8                    |
|                  | X₃          | 0.92        | 0.8~0.98        | 0.6670~      | 0.9438~      | 0.2125        | 1                      |
|                  | X₄          | 0.43        | 0.6~0.8         | 0.1979~      | 0.7261~      | 1.0000        | 0.8                    |
|                  | X₅          | 0.04        | 0.88~0.99       | 0.1979~      | 0.2870~      | 0.6809~       | 0.2                    |

According to formula (6), the optimal weights of different threat assessment values are \( \omega_{i1} \) and \( \omega_{i2} \), respectively:

\[
\omega_{i1} = [0.4225, 0.0630, 0.0000, 0.0900, 0.1129, 0.0673, 0.2443],
\]

\[
\omega_{i2} = [0.1261, 0.0379, 0.4537, 0.0760, 0.0201, 0.0375, 0.2486].
\]

Through formula (7), the lower \( p_{1} \) and higher \( p_{2} \) of the threat degree of the attacking target are obtained:

\[
p_{1} = [0.1769, 0.2166, 0.2923, 0.2102, 0.1040], \quad p_{2} = [0.1911, 0.2152, 0.2786, 0.1966, 0.1185].
\]

The comprehensive threat degree \( q \) of the attacking target is obtained by formula (8):

\[
q = [0.3680, 0.4318, 0.5709, 0.4068, 0.2225].
\]

By comparing the comprehensive threat degree, the threat degree order is obtained: \( X_{3} > X_{2} > X_{4} > X_{1} > X_{5} \), the calculated threat order is within the range of expert subjective decision (table 5), which is consistent with the decision result of the combat commander.

6. Conclusion

In order to study the intelligent algorithm of weapon station fire distribution, this paper classifies the targets with obvious threat difference roughly, then studies the multiple attributes of the targets according to the large categories, establishes the threat evaluation function of different attributes, at the same time, establishes the optimal weight function according to the influence degree of each attribute on the threat degree. Finally, the threat values of different targets are obtained, Then fire distribution is carried out according to the degree of threat. The experimental results show that the evaluation results are consistent with the evaluation results of battle commanders, which can not only guide the distribution of battlefield firepower accurately and reasonably, but also can eliminate the influence of human subjective factors on command decision-making, which has high credibility and provides technical support for the decision-making research of firepower distribution.

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