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Research and Application of Warship Multiattribute Threat Assessment Based on Improved TOPSIS Gray Association Analysis

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ABSTRACT

Multitarget threat evaluation of warship air attacks is one of the most urgent problems in warship defense operations. To evaluate the target threat quickly and accurately, an air attack multitarget threat evaluation method based on improved TOPSIS gray relational analysis is proposed. This method establishes threat assessment system of five attributes of target type, anti-jamming ability, heading angle, altitude, and speed. The weight coefficient of each index of the warship is obtained by combining the entropy weight method with the analytic hierarchy process. Topsis can make full use of the information of the original data, and its results can accurately reflect the gap between various evaluation schemes. The weighted Mahalanobis distance and comprehensive gray correlation between the attribute to be evaluated and the positive and negative ideal states are calculated by the improved TOPSIS gray correlation method. The target threat degree to be evaluated is obtained by combining the two methods. Finally, an example is given to prove the effectiveness of the evaluation model.

KEYWORDS

Combined Weight, Gray Relational Analysis, Improve Topsis, Threat Assessment

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INTRODUCTION

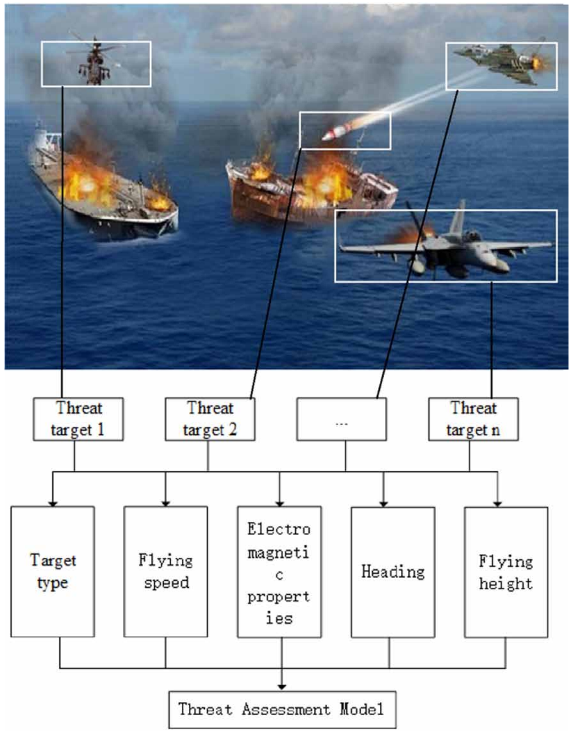
In recent years, the international situation has become increasingly severe, especially digitalization, so that a variety of information is integrated (Pan et al. 2021); the maturity of the Internet of Things technology and its application in military operations, which has increased the level of military threats. So that sensor networks, the Internet, and mobile communication networks are all closely integrated (Yang, Li, Kong, Wang, & Chen, 2018), through sensors, military equipment can intelligently sense the current situation (Yang et al. 2018). The threat of naval warfare has continued to increase, and warships are facing increasingly advanced weapon threats. Therefore, multiattribute threat assessment has become one of the key factors for a successful defense. Warship multiattribute threat assessment refers to the use of the collected target data by the combat command system to make the threat decision analysis of the multiple threat attributes of the attacking target according to the established algorithm model. In multiattribute threat assessment, warships are simultaneously affected by multiple factors, including target type, anti-jamming capability, heading angle, altitude, and speed. The threat assessment model needs to quickly and accurately analyze the threat of the target to the surface warship according to the obtained information and the current situation.

In the threat target assessment of multiattribute decision-making, the main method is to use the entropy method to construct a threat assessment matrix and objectively analyze the quantified data (Zhaowang, Kou, Wang, & Wang, 2009) to obtain the weight of each threat factor. However, in practical applications, the total use of the entropy weight method makes the evaluation result more objective and biased. (Qin et al. 2020) combines analytic hierarchy process (AHP) and the entropy weight method to establish warship missiles' performance index system structure. The experimental results show that evaluating the warship missile combat system is more accurate using the combination weighting method. In this paper, the combined weighting method based on the entropy weight method and the analytic hierarchy process is used to comprehensively determine the weight of each threat factor. In solving the actual problem of naval air raid target threat assessment, based on the combination of entropy and the analytic hierarchy process, the weight of each attribute of the air raid target is analyzed, and a hierarchical and scientific evaluation system model is established. It considers the characteristics of such complex problems when the warship intercepts air targets. In the traditional multiattribute target evaluation problem, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) algorithm is usually used to determine the weight (Li, Yuan, & Chen, 2020). In the literature (Geng, Zhang, & Hao, 2011), the establishment of TOPSIS's multitarget decision analysis method is mainly used to determine air threat targets. Quick decision supports. Among them, the TOPSIS method can reflect the overall situation and conduct a comprehensive evaluation, and has universal applicability (Chen, 2021), while gray relational theory is an analysis method for processing uncertain information (Wu, Wang, Yang, Li, & Yang, 2018). In this article, a threat assessment model based on improved TOPSIS gray correlation analysis is constructed to more accurately distinguish the weight of threat factors, and the weighted Mahalanobis distance is used to improve the TOPSIS gray correlation analysis method to calculate the comprehensive gray correlation degree of each threat factor. The weighted Mahalanobis distance between each factor and the positive and negative absolute ideal state replaces the original algorithm's Euclidean distance to improve the calculation result's comprehensive closeness.

Multithreat Factor Analysis and Threat Attribute Modeling in the Air

Through the analysis of air raid weapons and the study of modern air-raid combat methods, a variety of threat factors for surface warships mainly include the target type, target airtime, target anti-electromagnetic interference characteristics, target heading angle, and target height. Therefore, threat assessment needs to be optimized according to the current state of the warship and the acquired target information, to infer the target's threat to the surface warship (Shi, Li, Du, Ma, & Li, 2016). The structure diagram of its multitarget threat assessment is shown in Figure 1.

Figure 1. Multitarget Threat Assessment Model Structure



Figures Target Type Threat Attributes

Combined with expert analysis and air combat analysis, the incoming targets faced by surface warships are mainly divided into three categories: missiles, aircraft, and unclear flying targets. Among them, missile targets can be divided into large warship missiles, medium and small warship missiles, and electronic pulse bombs; aircraft mainly include large bombers with large bombs, fighters, drones with small bombs, early warning aircraft, electronic combat aircraft, and other early warning and jamming aircraft types; unidentified flying targets mainly include unknown aircraft types, decoys and false targets. Table 1 shows the specific characteristics of each military target.

According to experts and reference papers (Zhang, Jiang, & Luo, 2010; Sun & Xie, 2019), threat attribute values of common threat target types are quantified. Among the air target threats, $Class_i$ indicates the category of the i-th target, and $\mu(Class_i)$ indicates the threat attribute value of this category. According to the target characteristics of the category, the degree of threat, and the difference in combat methods, the threat attribute value of the target category is quantified in the following settings:

$$\mu(Class_i) = \begin{cases} 1, Class_i \in A_1 \\ 0.95, Class_i \in B_1 and B_2 \\ 0.9, Class_i \in A_2 \\ 0.8, Class_i \in A_3 and B_3 \\ 0.7, Class_i \in C \end{cases} \tag{1}$$

Table 1. Multitarget Type Threat Attribute

Target category	Main type	Threat level
Class A	Large warship missile A_1	The damage effect on the warship is obvious; hitting one causes serious damage to the ship.
	Small and medium warship missile A_2	The damage to the warship is light, and it can resist multiple missiles.
	Electronic pulse bomb A_3	Destroy the warship's communication and defense capabilities, with little impact on the warship itself.
Class B	Large bomber B_1	Mount multiple missiles at the same time, the bombing effect is obvious, and the direct threat to the ship is greater.
	Fighter B_2	Mainly used to seize air supremacy, a direct threat to warships.
	UAV and other models B_3	As an early warning or wingman interference, it is used in conjunction with other aircraft, which are a general threat to warships.
Class C	Unidentified flying target	Cannot be recognized by the warship's own target recognition equipment.

Target Speed

In the threat assessment of warship strikes, target speed plays an important role and is a key indicator in measuring the threat degree of military weapons in various countries, and it has an important influence on analyzing the damage performance of target weapons. With the continuous development of military weapons in various countries and the continuous research and development of ultrahigh-speed weapons, many weapons with high-speed flying speeds will be used in modern air-to-sea warfare. Therefore, the faster the target's flight speed, the lower the stability of the warship's air-to-air weapon system to intercept and counterattack the target, and the more obvious the damaging effect on the warship will be. In evaluating the threat attribute of the target flight speed, the speed threat unit is m/s. Combined with the analysis of the flight weapon parameters of various countries, the $speed$ range is set to [0,1500], where $\mu\left(speed\right)$ represents the target speed threat attribute value. The specific threat attribute value calculation formula is as follows:

$$\mu\left(speed\right)=\begin{cases}\dfrac{speed_0}{640}, 0 \le speed_0 \le 80 \\ \dfrac{speed_0-10}{560}, 80 < speed_0 \le 220 \\ \dfrac{speed_0+200}{1120}, 220 < speed_0 \le 500 \\ \dfrac{speed_0+250}{1200}, 500 < speed_0 \le 800 \\ \dfrac{speed_0+6500}{8000}, 800 < speed_0 1500\end{cases} \tag{2}$$

Target Anti-Electromagnetic Interference Characteristics

In the actual air raid battlefield, air targets usually adopt special designs, such as the stealth coating of fifth-generation fighters, electromagnetic interference, etc., to counter the lock-on strikes and interference of counterattack incoming targets. The stronger the anti-electromagnetic interference ability of the air target is, the greater the threat ability to surface warships. Target electromagnetic interference can be divided into strong electromagnetic interference, weak electromagnetic interference, centimeter wave radar signals, millimeter-wave radar signals, and airborne fire control radar signals. The fundamental characteristics and effects are shown in Table 2.

Classify modeling based on the strength of the anti-jamming signal and the electromagnetic characteristics of the guided radar signal, where $\mu(Genre_i)$ indicates the anti-electromagnetic interference attribute value of the target, as follows:

$$\mu(Genre_i) = \begin{cases} 1, Genre_i \in EA_1 \\ 0.95, Genre_i \in EB_1 \\ 0.9, Genre_i \in EC \\ 0.85, Genre_i \in EA_2 \\ 0.8, Genre_i \in EB_2 \end{cases} \tag{3}$$

Target Course Angle

The threat target heading angle indicates the angle between the target's entering heading and the surface warship's heading. Therefore, it is an important indicator for judging the attack intention of an air target. The heading angle range is [0,180], and its attribute value can be quantified as:

$$\mu\left(Angle\right) = \begin{cases} \dfrac{125 - 2angle}{125}, 0 \le angle \le 5 \\ \dfrac{135 - 4angle}{125}, 5 < angle \le 30 \\ \dfrac{235 - 2angle}{625}, 30 < angle \le 90 \\ \dfrac{270 - 2angle}{1125}, 90 < angle \le 180 \end{cases} \tag{4}$$

Table 2. Main Characteristics and Influence of Various Electromagnetic Signals

Electromagnetic signal	Category	Influence
Strong electromagnetic interference	EA_1	Warship-borne radar is difficult to detect and identify.
Weak electromagnetic interference	EA_2	Warship-borne radar is difficult to stabilize and struggles to lock the target.
Millimeter-wave radar	EB_1	The warship has been locked, and it is difficult to interfere with the implementation with high accuracy.
Centimeter wave radar	EB_2	The warship has been locked, and the accuracy is relatively low.
Fire control radar	EC	The warship has been locked and must be prepared for mobile defense.

Target Height

In the attribute of target flight height, the lower the flying height of an incoming target, the more difficult it is for surface warships to detect, respond to and track the target in time, and the greater the threat. However, at the same altitude, the threat levels of aircraft and warship missiles are different. For example, warship missiles usually pose the greatest threat to warships during sea-skimming flight, while aircraft flying altitudes are usually over 200m above the sea surface. Therefore, under the condition of ensuring the accuracy of the quantified attribute value, the aircraft target and the missile target are modeled separately. When the aircraft's flying altitude is higher than 200 m, the threat attribute value conforms to the Cauchy distribution:

$$\left(h_{pi}\right)=\begin{cases} 1, h_{pi}<200 \\ \dfrac{1}{1+\alpha_{i}\left(h_{pi}-100\right)}, h_{pi}\geq 200 \end{cases} \tag{5}$$

where h_{pi} represents the flying height of the i-th aircraft target; α_i is the threat coefficient of the target flight altitude of the aircraft; $\mu(h_{pi})$ indicate the threat attribute value of the target flight altitude of the aircraft based on the experience of military experts and the principles of combat tactics; and α_i takes the value $10^{-1.5}$.

For a missile target, the warship missile flight height is usually higher than 3m. Therefore, when the missile flight height is higher than 3 m, the target threat attribute value satisfies the normal distribution:

$$\mu\left(h_{mi}\right)=\begin{cases} 1,\ 0<h_{mi}\leq 3 \\ e^{-\beta_i\left(h_{mi}-3\right)}, h_{mi}>3 \end{cases} \tag{6}$$

where h_{mi} indicates the flight height of the i-th missile target, β_i represents the threat coefficient of the flying height of the missile target, $\mu(h_{mi})$ represents the threat attribute value of the missile target's flight altitude, which is obtained based on the experience of military experts and the principles of combat tactics, and β_i takes the value $10^{-1.5}$.

Improved TOPSIS Gray Correlation Threat Assessment Model

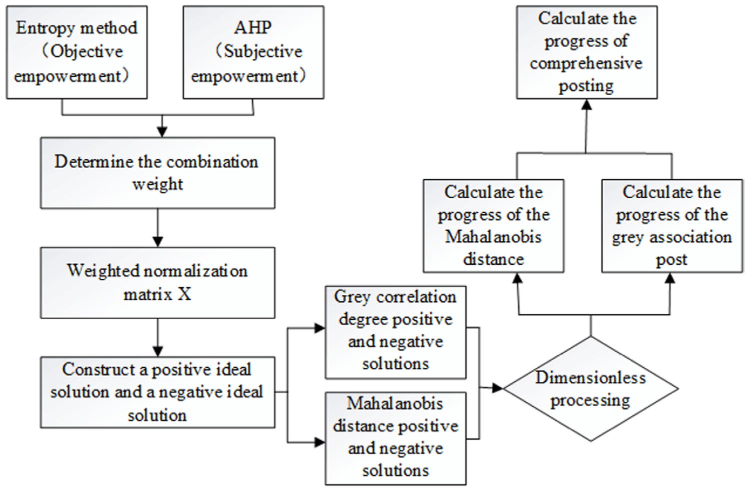
According to the multitarget threat attribute model established in the first section, the improved TOPSIS gray correlation threat assessment model is used to comprehensively evaluate the multitarget threat attributes and determine the threat degree of each air strike target to the warship. The process of building a threat assessment model is shown in Figure 2.

Basic Principles of Combined Weighting Based on the Entropy Method and Analytic Hierarchy Process

Entropy Method

Shannon first proposed information entropy in 1948 to represent the average amount of information after excluding redundancy in the information (Tribus & McIrvine, 1971). The entropy weight method uses entropy to judge the degree of dispersion of a certain category. With the decrease in information entropy, the dispersion degree of this category increases, the value of information utility increases, the weight of information in threat assessment also increases, and vice versa. Conversely, when the

Figure 2. Multitarget Threat Assessment Model



information entropy value increases, it shows that the dispersion degree of the category decreases, the information utility value decreases, and the weight in threat assessment decreases. Therefore, the entropy weight method is an objective method to determine the weight of a certain attribute, free from human intervention, and the data changes in the decision matrix determine its weight. The steps of using information entropy to determine the objective weight of each attribute are as follows.

Construct a threat assessment decision matrix through m targets, and n threat attributes to form an original data matrix $Z = \left(r_{i,j}\right)_{m\times n}$:

$$Z = \begin{bmatrix} r_{1,1} & r_{1,2} & \cdots & r_{1,m} \\ r_{2,1} & r_{2,2} & \cdots & r_{2,m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n,1} & r_{n,2} & \vdots & r_{n,m} \end{bmatrix} \tag{7}$$

i=1, 2, n, j=1, 2... m; among them, $r_{i,j}$ is the evaluation value of the i-th item under the j-th threat attribute.

The threat attribute data of targets are normalized, and the proportion of the data of the i-th item under the j-th threat attribute P_{ij} is obtained:

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{8}$$

Calculate the entropy e_j of each threat attribute:

$$e_j = -K\sum_{i=1}^{n} P_{ij} lnP_{ij} \tag{9}$$

when $P_{ij} = 0$, $P_{ij} lnP_{ij}$ =0, $k = \frac{1}{lnm}$ and $0 \le e_j \le 1$.

Calculate the entropy weight of the j-th attribute:

$$\omega_j = \frac{1 - e_j}{\sum_{j=1}^{n} \left(1 - e_j\right)} \tag{10}$$

Among them $\sum_{j=1}^{n} \omega_j = 1$.

Analytic Hierarchy Process (AHP)

The analytic hierarchy process is a comprehensive evaluation method of system analysis and decision-making proposed by Professor T. L. Saaty, which reasonably solves the quantitative processing process of qualitative problems. When determining the weight of threat attributes, it is easy to reflect the subjective intention of the decision-maker, and it is a method of calculating subjective weight determined by man. In calculating the weight of the analytic hierarchy process, a large amount of combat experience and expert decision-making systems are needed to analyze the weight of threat attributes. This paper uses the entropy weight method and the analytic hierarchy process to calculate the weight of target threat attributes.

Combination Weighting Method to Determine the Comprehensive Weight of Threat Attributes

In the multitarget threat analysis method, the subjective weighting method assigns weights according to subjective importance the decision-makers attach to each attribute, and the objective weighting method determines the weights based on the data information contained in the decision-making problem itself, which has a certain degree of one-sidedness (Wu et al. 2018). To reduce the subjective arbitrariness of weights and improve the objectivity of the obtained weights, the entropy method and the AHP method are integrated linearly to obtain more objective and accurate threat attribute weights, making a more scientific and effective evaluation of multitarget threats. The formula for calculating the combined weight is as follows:

$$\begin{cases} \omega_i = \alpha \omega_{Ai} + \beta \omega_{Ei} \\ \alpha + \beta = 1 \end{cases} \text{, i=1, 2..., n} \tag{11}$$

where ω_i is the combined weight value of the i-th threat attribute, ω_{Ai} represents the entropy weight value of the i-th attribute, and ω_{Ei} represents the subjective weight value of the i-th attribute; α, β represent represent the degree of preference for the objective and subjective weights of threat attributes, respective in the multitarget threat model, generally $\alpha = 0.4$ taking, $\beta = 0.6$.

Improved TOPSIS Gray Relational Model

Improved TOPSIS Model

The TOPSIS algorithm is a very effective multiobjective decision analysis method in system engineering. The original data information can be fully utilized by TOPSIS, so that the results can be accurately reflected. It is widely used in multiattribute evaluation and decision-making because it can make a comprehensive and objective analysis and evaluation of threat targets. The basic modeling process is as follows: After the threat assessment matrix is established, the original data matrix is unified with threat attribute types to obtain the normalized matrix. The normalized matrix is then standardized to eliminate the influence of each threat attribute dimension and then the best and worst plans among the limited plans are developed. Because of the TOPSIS algorithm, it is necessary to calculate the Euclidean distance between each target and the optimal scheme and the worst scheme to obtain the relative proximity of each target object to the optimal scheme. However, the calculation of Euclidean distance has the problem of equal treatment of the difference between different threat attributes, which fails to accurately represent the actual situation. Therefore, Mahalanobis distance is introduced to replace the Euclidean distance to calculate the relative closeness, which can eliminate the interference between the threat attributes and is not measured. In addition, advantages such as the program's influence make the results more scientific and reasonable.

TOPSIS Gray Relational Degree Algorithm

In gray correlation analysis, the geometric relationship between the target threat attribute data and the generated geometric shape similarity is compared and analyzed, and the similarity between the curves is used to measure the correlation degree (Kuo, Yang, & Huang, 2008). In the TOPSIS gray relational degree algorithm, the specific implementation is shown below.

Multiply the original threat attribute decision matrix Z and the result of the combined entropy weight to construct a weighted standardized threat attribute decision matrix X:

$$X = \begin{bmatrix} x_1(n) & x_1(n) & \cdots & x_1(n) \\ x_2(n) & x_2(n) & \cdots & x_2(n) \\ \cdots & \cdots & \cdots & \cdots \\ x_m(n) & x_m(n) & \cdots & x_m(n) \end{bmatrix} \tag{12}$$

where $X_j = Z_{ij} \times \omega_j, \omega_j$ represents the weight of threat attribute j.

Construct positive and negative ideal solutions. The mechanism of TOPSIS is to select the positive and negative optimal solutions, by detecting the proximity of the object to be evaluated to the optimal solution and the worst solution, the sample to be evaluated is scored:

$$\begin{cases} Positive\,ideal\,solution\,X^+ = \left\{\max\limits_{1\le i\le n} x_{ij} \mid j = 1,2,\ldots,m\right\} \\ Negative\,ideal\,solution\,X^- = \left\{\min\limits_{1\le i\le n} x_{ij} \mid j = 1,2,\ldots,m\right\} \end{cases} \tag{13}$$

The traditional TOPSIS algorithm has a reverse problem, that is, the ideal solution and the change in the weight index will change the target ranking result and affect the accuracy of decision-making. Therefore, an improved method is proposed. This method considers that there are absolute states between the positive and negative ideal solutions, and the evaluated object is always in the absolute state. Therefore, the positive and negative ideal solutions of the target to be evaluated can be expressed as:

$$\begin{cases} Positive\,ideal\,solution\,X^+ = \left\{1,1,\ldots,1\right\} \\ Negative\,ideal\,solution\,X^- = \left\{0,0,\ldots,0\right\} \end{cases} \tag{14}$$

In the gray correlation algorithm, determine the threat target $X_i = \left(x_{i1}, x_{i2}, \ldots, x_{im}\right)$ by determining the gray correlation coefficient $\varepsilon_{i,j}^{\pm}$ of the threat attribute to determine the threat attribute value X_{ij} and positive or negative. The degree of closeness between the ideal solutions is $X^{\pm}$, and the calculation formula for the specific gray correlation degree is as follows:

$$\varepsilon_{i,j}^{+(-)} = \frac{\min_i \min_j \Delta_{i,j}^{+(-)} + \rho \max_i \max_j \Delta_{i,j}^{+(-)}}{\Delta_{i,j}^{+(-)} + \rho \max_i \max_j \Delta_{i,j}^{+(-)}} \tag{15}$$

$$\Delta_{ij}^{+(-)} = \left| X_{ij}^{+(-)} - X_{ij} \right| \tag{16}$$

where i represents the number of threat attribute sequences, j represents the dimension of threat attribute sequences, $\varepsilon_{i,j}^{\pm}$ is the correlation coefficient between X_{ij} and $X_{i,j}^{\pm}$, ρ represents the resolution coefficient and $\rho \in \left[0,1\right]$, ρ usually takes 0.5 in the calculation of gray relational degree.

At this time, the gray correlation degree between a threat target X_i and the optimal solution $X^{+(-)}$ is:

$$\eta_i^{+(-)} = \frac{1}{m} \sum_{j=1}^{m} \varepsilon_{i,j}^{+(-)} \tag{17}$$

Calculate the Mahalanobis distance from each threat attribute A_i of the target to the positive and negative ideal solutions. As a distance measure, Mahalanobis distance improves the related problem of the inconsistency of various dimensions in Euclidean distance. In calculating the Mahalanobis distance of each threat attribute, the covariance matrix represents the covariance matrix composed of the gray incidence matrix and the optimal and worst solutions. Among them, the Mahalanobis distance between the i-th threat attribute and the optimal solution and the worst solution is:

$$\begin{cases} d_i^{+} = \sqrt{\left(\varepsilon_{i,j}^{+} - X_0^{+}\right)^T \left(U^{+}\right)^T W \left(\Lambda^{+}\right)^{-1} U^{+} \left(\varepsilon_{i,j}^{+} - X_0^{+}\right)} \\ d_i^{-} = \sqrt{\left(\varepsilon_{i,j}^{-} - X_0^{-}\right)^T \left(U^{-}\right)^T W \left(\Lambda^{-}\right)^{-1} U^{-} \left(\varepsilon_{i,j}^{-} - X_0^{-}\right)} \end{cases} \tag{18}$$

where: d_i^{+}, d_i^{-} represents the Mahalanobis distance between the i-th attribute value sample, the optimal solution and the worst solution; W represents the diagonal matrix formed by the weight of the feature index; Λ^{+}, Λ^{-} represents the eigenvalues of the positive and negative covariance matrices; and U^{+}, U^{-} represents the orthogonal basis composed of the eigenvectors corresponding to the eigenvalues of the positive and negative covariance matrices.

Comprehensive closeness calculation. The construction process of comprehensive closeness:

$$\begin{cases} P_i = \dfrac{d_i^{-}}{d_i^{+} + d_i^{-}} \\ Q_i = \dfrac{\eta_i^{-}}{\eta_i^{+} + \eta_i^{-}} \end{cases} \tag{19}$$

where P_i, Q_i respectively represent the closeness of Mahalanobis distance and the degree of gray relevance, and the closeness formula of the comprehensive gray relevance and Mahalanobis distance is:

$$\mu(A_i) = aP_i + \left(1 - a\right)Q_i \tag{20}$$

where a is 0.5.

Experimental Example Verification

To verify the rationality of the multiattribute threat assessment model in this article, a part of the warship threat data set of a certain area force is used as a calculation example to perform state assessment, achieve the evaluation index of multiple target threat attributes, combination weights, Mahalanobis weighted distance, and comprehensive threat assessment.

Calculation of Results

According to the original data of multiple targets, we show their threat attributes in Table 3.

According to formulas 1 to 6, the specific score of each target threat attribute is calculated, and the data are combined and weighted. After the normalized value of each threat attribute, we show the value in Table 4.

Table 3. The Threat Attribute Value of Each Target

Target type	Target speed (m/s)	Target anti-electromagnetic interference	Target heading angle	Target heigh t (m)
Large warship missile 1	200	EB1	30	10
Medium warship missile 1	300	EB1	30	10
Fighter 1	200	EA2	60	8000
Fighter 2	300	EA1	30	10000
Large warship missile 2	200	EB2	150	7
Medium warship missile 2	300	EB2	150	7

Table 4. The Normalized Value of Each Attribute

Target type	Target speed (m/s)	Target anti-electromagnetic interference	Target heading angle	Target height (m)
0.105	0.146	0.036	0.119	0.168
0.095	0.192	0.036	0.119	0.168
0.100	0.146	0.032	0.042	0.098
0.100	0.192	0.038	0.119	0.080
0.105	0.146	0.030	0.223	0.185
0.095	0.192	0.030	0.223	0.185

According to formula (18), the weighted Mahalanobis distance between the target to be assessed and the positive and negative samples can be determined. According to formula (17), the gray correlation degree of the threat attributes of each target can be calculated. We show the results in Table 5.

Finally, calculate the comprehensive closeness target of each target according to formulas (19,20) and evaluate the threat degree of each target according to the comprehensive closeness degree. The larger the score, the higher the threat of the target to surface warships, and the smaller the score. The smaller the threat, compared with the traditional TOPSIS algorithm, Figure 3 and Table 6 show the comprehensive posting progress of each target.

The data in Table 6 show that the traditional TOPSIS method and the improved TOPSIS gray correlation analysis are consistent, and the two targets with a higher degree of threat are two fighter targets with obvious attack intentions. However, the difference in closeness between the improved model and the TOPSIS model is small. The threats of the two targets are close to each other among the actual parameters, and obviously, the improved model is more in line with the actual situation. The threat levels of the six attack targets are ranked as follows: target 3>target 4>target 6>target

Table 5. Comprehensive Correlation Degree of Threat Attributes of Each Target

Target	Weighted Mahalanobis distance		Gray relational degree	
	Positive ideal solution	Negative ideal solution	Positive ideal solution	Negative ideal solution
Goal 1	1.459	1.409	0.783	0.607
Goal 2	2.240	1.776	0.809	0.637
Goal 3	0.491	1.078	0.612	0.923
Goal 4	1.008	1.132	0.631	0.758
Goal 5	2.424	2.694	0.870	0.496
Goal 6	1.061	1.543	0.939	0.519

Figure 3. The Comprehensive Closeness of Each Target

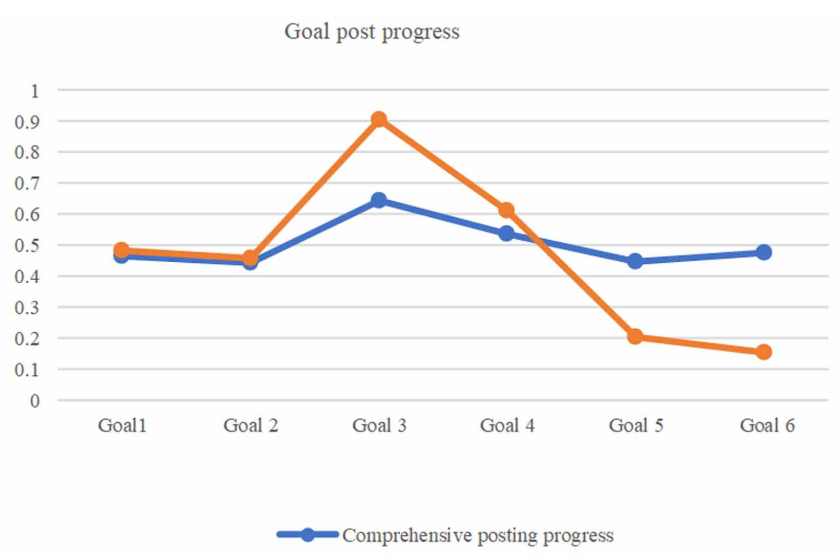


Table 6. Ranking Results of Comprehensive Closeness Degree of Each Target

Goal	Comprehensive closeness	Traditional TOPSIS closeness	State sorting
Goal 1	0.464	0.481	4
Goal 2	0.441	0.456	6
Goal 3	0.644	0.902	1
Goal 4	0.537	0.611	2
Goal 5	0.445	0.205	5
Goal 6	0.474	0.152	3

1>target 5>target 2. According to the data obtained by the improved model, the attack intention of target 3 and target 4 is the most obvious, and the priority of warship interception defense is the highest, and a response should be made in time; target 1, target 2, target 5, and target 6 are relatively low in threat and close to each other. Therefore, you can decide promptly according to the situation.

CONCLUSION

In this paper, a warship multitarget threat assessment model based on the improved TOPSIS gray correlation degree is proposed, which simulates the situation of warship air raids, extracts various parameters, and establishes a threat assessment system from multiple angles.

Through the combination of the subjective analytic method of expert evaluation and the entropy method of objective weighting, the combination weighting method has both the advantages of the subjective weighting method and objective weighting method, reduces its inherent defects, and improves the rationality of the comprehensive threat attribute weight. In addition, the weighted Mahalanobis distance is used to measure the similarity between the target to be evaluated and the positive and negative ideal samples so that the comprehensive evaluation results are more accurate and objective.

Based on traditional gray correlation analysis, improved TOPSIS gray correlation analysis obtains the comprehensive correlation degree of threat attributes. The improved model proposed in this paper concludes that the target threat degree ranking result is closer to the actual air attack battlefield situation and provides a more accurate solution for multitarget threat assessment. Therefore, the model remains potentially invaluable in a similar evaluation process.

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