Linear correlation analysis of ammunition storage environment based on Pearson correlation analysis

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Abstract. The problem of the reliability of ammunition storage environment is a hot topic in the field of modern military research, and the key is to find out the main factors that affect the reliability of ammunition sensitive components. Grey relational entropy analysis method can find out the order of influencing factors, but it can't judge the influence size and correlation. Pearson analysis method can analyze linear correlation factors better. Therefore, this paper proposes that for the complex problems such as the influence factors of ammunition storage environment, Pearson correlation analysis method can be used to find out the linear correlation factors. Then the grey correlation entropy method is used to find out the other factors. It can lay the foundation for the follow-up analysis of the main factors. Through the comparison and analysis of the actual examples, it is found that the ranking of the influencing factors ranking by the two methods has high consistency. But Pearson method can find the linear correlation factors.

1. Introduction
As the final means to destroy enemy targets, ammunition needs to be used in different operational areas and platforms. And with the characteristics and needs of the development of modern war, ammunition must have a certain amount of reserves. With the storage time prolonging, its performance gradually decreases. Under the influence of environmental factors, this process is accelerated. Analyzing the influence of environmental factors on ammunition has also become a hot issue in various countries. At present, the main problems of ammunition storage are that the storage environment is becoming more and more complex, which involves more and more influencing factors. Therefore, in the increasingly complex battlefield environment to find out the main factors affecting ammunition reliability has become the key.

At present, the research on the influence of ammunition storage environment factors mainly focuses on the influence of a single environmental factor [1-10]. However, few methods are used to find out the main factors from complex environment. The influence factors of ammunition storage were analyzed by grey relational entropy analysis method in reference [11]. However, it is not easy to directly judge the influence and correlation of each factor when analyzing such problems. In this paper, an analysis method combining Pearson correlation with grey correlation entropy is proposed.
2. Analysis method

2.1. Grey correlation entropy
Grey correlation analysis method uses "grey correlation degree" to measure the degree of correlation between factors. The higher the value is, the greater the closeness between the two factors is, and vice versa.

Grey relational entropy is the disadvantage of considering the grey relational grade. After obtaining the correlation degree of each factor, the entropy correlation degree is continued. The correlation degree is expressed by entropy. It can better describe the relationship between factors when dealing with discrete series, and the results are more accurate.

2.2. Pearson correlation analysis
In statistics, Pearson correlation coefficient is used to measure the linear correlation between two variables, and its value is between -1 and 1. The numerical value is 1, which means that two variables can be represented by the straight line equation, and the two variables are positively correlated. The coefficient value of -1 means that the two variables can also be expressed by linear equation, but they are negatively correlated. The closer the absolute value of the coefficient to 0 means that the linear correlation between the two variables is smaller, and the closer the absolute value of the coefficient to 1 means the higher the linear correlation between the two variables.

Suppose there are two sequences: \( a = (a(1), a(2), \ldots, a(n)) \) and \( b = (b(1), b(2), \ldots, b(n)) \). According to the principle of statistics, the correlation coefficient between the two sequences can be expressed as follows:

\[
r(a, b) = \frac{\text{cov}(a, b)}{\sqrt{D(a)D(b)}} = \frac{\sum_{i=1}^{n}(a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\sum_{i=1}^{n}(a_i - \bar{a})^2 \sum_{i=1}^{n}(b_i - \bar{b})^2}}
\]

(1)

Where \( \bar{a} \) and \( \bar{b} \) are the average values of the two sequences respectively, and \( n \) is the number of samples of the two sequences. The range of correlation coefficient \( r \) is \(-1 \leq r \leq 1\).

In the actual analysis, due to the influence of sample size, the calculated results may have randomness. In order to ensure the accuracy of the conclusion, the results need to be tested.

In this paper, the correlation coefficient is tested by t-test. The steps are as follows:

First, the t value of the correlation coefficient \( r \) is calculated:

\[
t = \frac{r}{\sqrt{\frac{n-2}{t_{n-2}}}}
\]

(2)

Secondly, according to the given saliency level and degree of freedom (n-2), find the corresponding critical values in the t distribution table. Secondly, according to the given significance level and degree of freedom, the corresponding critical value \( t_{n-2} \) (or \( p \) value) in the distribution table is found. If \( |t| > t_{n-2} \) (or \( p < a \)), \( r \) is statistically significant; if \( |t| < t_{n-2} \) (or \( p \geq a \)), \( r \) is not statistically significant.

2.3. Pearson correlation analysis
The two methods are compared, and table 1 is obtained. As can be seen from table 1, the difference between the two methods is quite different, and the parameters of the two have different properties. In terms of analysis objects, Pearson correlation analysis mainly focuses on continuous variables. The application range is relatively narrow. The grey correlation entropy is a variable in the system, and its continuity is not required. In relation, Pearson correlation analysis of the linear relationship between variables, grey correlation entropy can be used to analyze the more complex relationship between variables in the system. There are also differences in the measurement standard of parameters between the two.
Table 1 Method comparison

| Method                     | Illustrate                                                                 | Analysis Object          | Target Parameters                                      | Computing Method                                                                 |
|----------------------------|----------------------------------------------------------------------------|--------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------|
| Pearson correlation analysis | Pearson correlation mainly analyzes the linear correlation between the two variables. | Continuous variable      | Pearson correlation coefficient (values between -1 and 1) | \[ r(a, b) = \frac{\text{cov}(a, b)}{\sqrt{D(a)D(b)}} = \frac{\sum_{i=1}^{n}(a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\sum_{i=1}^{n}(a_i - \bar{a})^2 \sum_{i=1}^{n}(b_i - \bar{b})^2}} \] |
| Grey correlation entropy    | Grey relational entropy analysis is to reflect the correlation degree of the data series of reference factors and comparative factors with the "entropy" method. | Comparative factors and reference factors in the system | Grey correlation entropy (its value has non negative, extremum, symmetry.) | \[ r_1[x_1(k), x_i(k)] = \frac{\min_{1 \leq j \leq n}[x_1(k) - x_j(k)] + p_{max} \max_{1 \leq j \leq n}[x_1(k) - x_j(k)]}{|x_1(k) - x_i(k)| + p_{max} \max_{1 \leq j \leq n}[x_1(k) - x_j(k)]} \]
                                                                                       |                          | H = - \sum_{j=1}^{n}(x_{ij} - 1nx_i)               |                                                     |

Therefore, when studying the environmental factors of ammunition storage, Pearson correlation analysis can be used to find out the environmental factors which have significant linear correlation with ammunition reliability. Then the grey relational entropy is used to analyze other complex environmental factors. The two methods are combined to analyze the environmental factors comprehensively. To provide scientific guidance for the army to manage ammunition. Through the development of corresponding plans and programs, so as to ensure the operational performance of ammunition.

3. Case illustrate

The following also takes some environmental factors in reference [11] which have a direct impact on ammunition reliability for comparative analysis. Also, the annual number of scrapped ammunition in an island warehouse is taken as a reference.

The number of ammunition scrapped is set as reference sequence \( X_0 \), days with temperature higher than 30 °C \( X_1 \), annual average precipitation \( X_2 \), annual average salt spray concentration \( X_3 \), annual average total radiation \( X_4 \), annual average relative humidity \( X_5 \). The sequences are shown as follows.

\[
\{X_0(k)\} = \{X_0(1), X_0(2), X_0(3), X_0(4), X_0(5), X_0(6)\}
\{X_1(k)\} = \{X_1(1), X_1(2), X_1(3), X_1(4), X_1(5), X_1(6)\}
\{X_2(k)\} = \{X_2(1), X_2(2), X_2(3), X_2(4), X_2(5), X_2(6)\}
\{X_3(k)\} = \{X_3(1), X_3(2), X_3(3), X_3(4), X_3(5), X_3(6)\}
\{X_4(k)\} = \{X_4(1), X_4(2), X_4(3), X_4(4), X_4(5), X_4(6)\}
\{X_5(k)\} = \{X_5(1), X_5(2), X_5(3), X_5(4), X_5(5), X_5(6)\}
\{X_s(k)\} = \{X_s(1), X_s(2), X_s(3), X_s(4), X_s(5), X_s(6)\}
\]

3.1. Results of grey relational entropy analysis

The results of grey correlation entropy in reference [11] are as follows:

\[ H_1 = 1.7408, H_2 = 1.7466, H_3 = 1.7814, H_4 = 1.7365, H_5 = 1.7319. \]
According to the grey entropy ranking, the influence degree of environmental factors on ammunition reliability in the island is as follows: annual average salt spray concentration > annual average precipitation > days with temperature higher than 30 °C > annual average total radiation > annual average relative humidity.

Salt spray concentration is the main factor affecting ammunition storage reliability.

3.2. Pearson correlation analysis results

The results are shown in Table 2.

| Parameter | X1  | X2  | X3  | X4  | X5  |
|-----------|-----|-----|-----|-----|-----|
| Pearson correlation coefficient | 0.518 | -0.395 | 0.873 | -0.106 | -0.078 |
| sig       | 0.293 | 0.438 | 0.023 | 0.841 | 0.883 |
| Sample size | 6   | 6   | 6   | 6   | 6   |

From Table 2, it can be concluded that the order of correlation between the influencing factors and the target parameters is as follows: X3 > X1 > X2 > X4 > X5.

The results of Table 2 are as follows: the linear relationship between the number of scrapped ammunition and the concentration of salt spray is highly correlated and significant; the linear relationship between the number of scrapped ammunition and the days when the temperature is greater than 30 ° C is moderate, but not significant; the linear relationship between the number of scrapped ammunition and precipitation is low, and the correlation is not significant; there is no linear correlation between the number of scrapped ammunition and the total radiation and relative humidity.

The results show that except for the linear relationship between salt spray concentration and the number of abandoned ammunition, the linear relationship between other factors and the number of scrapped ammunition is not significant. Therefore, the salt spray concentration is the main factor affecting the ammunition storage reliability.

3.3. Results comparison

It can be seen that salt spray concentration is the main factor in the two sequences. The order of the days with precipitation and temperature above 30 ° C was different, but the influence degree was in the top three items. The order of total radiation and relative humidity was the same. And it is consistent with the objective facts, so both conclusions have certain reference value.

Although the results are similar, but a careful study of the data obtained by Pearson correlation analysis shows that only the concentration of salt spray has a significant linear relationship with the number of abandoned ammunition. Grey relational entropy method is more difficult to find linear correlation factors, and is more suitable for complex factors.

4. Conclusion

In this paper, Pearson correlation analysis method is proposed to analyze ammunition storage reliability. By comparing with grey correlation entropy analysis method, it is found that Pearson method can find out linear correlation factors. Due to the different application scope of the two methods, Pearson correlation analysis method can be used to find out the linear correlation factors when studying the influence factors of ammunition storage environment. Then the grey correlation entropy method is used to find out the other factors. Combined with these two analysis methods, targeted measures are taken to ensure the safety and reliability of ammunition.
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