Performance evaluation of man-portable devices based on the cloud center of gravity

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Abstract: In order to accurately assess the performance of man-portable devices, a method of evaluating the performance of man-portable devices based on the cloud center of gravity evaluation method is proposed. Firstly, a performance evaluation index system was constructed by analyzing the factors affecting the performance of man-portable devices. Then, using the cloud center of gravity judgment method, a man-portable device performance evaluation model is established and the weighted deviation is applied to determine the evaluation results. Finally, using examples, we verify the feasibility and effectiveness of the method. The research work provides ideas and references for scientific assessment of the performance of man-portable equipment, and further provides a theoretical basis for the modification and development of this type of equipment.

1. Introduction

A manpack is a tool used by a soldier to carry weapons and equipment and household goods, and is generally divided into combat and life carriers [1]. As shown in Figure 1. As an indispensable equipment for soldiers in combat, the ability of manpack directly affects the effectiveness of manpack, therefore, the military of various countries have made it the focus of manpack equipment research and development. At present, the manpack has developed into a manpack that integrates various functions such as carrying, protection, module, and lightness, and is an important part of the manpack integrated combat system [2]. Scientific and objective assessment of the performance of man-portable equipment is necessary for equipment design and improvement, as well as for the reasonable equipping of troops and the efficient use of man-portable equipment.
There are numerous factors affecting the performance of man-portable devices and most of them are difficult to quantify, and the evaluation results are highly influenced by subjective factors. To understand the problem of difficult assessment of determinisitc evaluation, literature [3] and literature [4], introduced cloud models into the field of evaluation to achieve scientific assessment of qualitative evaluation; literature [5] and literature [6], used cloud model fitting operations to assess maintenance and security effectiveness and navigation risk, and literature [7] and literature [8], used cloud center of gravity evaluation method to assess the hazard level and missile system effectiveness. In this paper, the cloud center of gravity evaluation method is used to assess the performance of man-portable gear.

This paper is organized as follows. The performance evaluation index system for man-portable devices is proposed in Section 2, and its selection process is explained in detail. In Section 3, we proposed the cloud center of gravity judging method, and then, a practical example is provided for demonstrating the effectiveness the proposed method in Section 4. Section 5 concludes this paper.

2. Constructing a performance evaluation index system for man-portable devices

Performance evaluation of man-portable equipment refers to the process and results of judging the inherent capability of man-portable equipment using the cloud center of gravity evaluation method. The method, the process and results of judging the inherent capability of the manpack, so as to discover the shortcomings of the equipment performance and provide a theoretical basis for its design improvement. In the evaluation, whether the index system is established scientifically and reasonably directly affects the results of the evaluation [9].

2.1. Analysis of factors affecting the performance of man-portable devices

The manpack is composed of combat carry and life carry, and its performance is influenced by the performance of both. Combat Carry Performance C1 refers to the ability of combat carriers to provide combat support to soldiers in combat, training, and duty missions, and is influenced by factors such as protection C11, modularity C12, tacticality C13, comfort C14, and weight C15. Protection refers to the ability of the carrier to protect against bullet, thorn, and fragmentation damage, which determines the user's own safety; modularity refers to the ability of the carrier to adapt to different combat tasks by replacing different external components, which affects the scope of use of the carrier; tacticality refers to the ability of the carrier to achieve the tactical intent in combat, which reflects the suitability of the carrier for the user; comfort is the intuitive feeling of the user. Comfort, which is the user's intuitive feeling, determines whether the carrier can be worn for a long time; Self-weight, which refers to the weight of the carrier itself, affects the user's mobility, physical agility and carrying capacity under the condition that the user has a certain weight capacity. Life Carriers Performance C2 refers to the ability of life carriers to provide life support to soldiers in combat, and is influenced by their manning effectiveness C21, carrying capacity C22, and load-bearing capacity C23. Personnel effectiveness [10] refers to the adaptability of the carry gear to the soldier, reflecting the "good use or bad use" of the carry gear and affecting the soldier's feeling of use; carrying capacity refers to the ability of the number of items and equipment that can be loaded in the carry gear to meet the soldier's operational needs, affecting the durability of combat; load-bearing capacity refers to the ability of the carry gear to be stressed without breaking or fracturing, determining the operational strength of the carry gear. Determine the strength of the carrier.

2.2. Construction of performance evaluation index system for man-portable devices

In accordance with the principles of simplicity, measurability, objectivity, completeness, and independence [11], the performance evaluation index system of man-portable devices was compiled by combining the above-mentioned influencing factors, as shown in Figure 2.
2.3. Classification of performance evaluation indicators for man-portables

In order to calculate the performance evaluation indicators of man-portable devices, the three levels of indicators in Figure 2 are divided into effectiveness and cost indicators. Protection $C_{11}$, modularity $C_{12}$, tactility $C_{13}$, comfort $C_{14}$, manning effectiveness $C_{21}$, carrying capacity $C_{22}$, and weight capacity $C_{23}$, the larger the value of the indicator, the better it is for effectiveness; the smaller the value of the self-weight $C_{15}$ indicator, the better it is for cost.

3. Cloud center of gravity judging method

3.1. Fundamentals of cloud center of gravity judging method

A cloud is a model of uncertainty transformation between some qualitative concept represented by linguistic values and its quantitative representation\(^{[12]}\). The numerical characteristics of the cloud are represented by three values of expectation $E_x$, entropy $E_n$, and superentropy $H_e$, which constitute the mapping between the qualitative understanding and the quantitative representation of each other. Among them, $E_x$ is the position of the center of gravity of the cloud, which is the value that best represents the qualitative concept in the domain and is the highest point in the cloud map; $E_n$ is the uncertainty measure of the qualitative concept, which reflects the range of values that can be accepted by the linguistic value in the domain and reflects the width of the cloud; $H_e$ is the entropy of entropy, which reflects the degree of dispersion of the cloud and determines the thickness of the cloud in the cloud map.

The cloud center of gravity can be expressed as $T = a \times b$, where $a$ represents the position of the cloud center of gravity, i.e., the desired value, $b$ denotes the height of the center of gravity of the cloud, which is generally taken as a constant value\(^{[13]}\). When the cloud center of gravity is judged, the cloud model is used to realize the quantification of qualitative indicators, and the state of multiple indicators is represented by a composite cloud, and the deviation of the cloud center of gravity of this composite cloud from the ideal state is obtained, and the weighted summation is carried out to obtain the deviation of the whole system, and it is input to the cloud generator to activate the corresponding cloud objects and obtain the evaluation results\(^{[14]}\)\(^{[15]}\). The basic principle of cloud center of gravity is shown in Figure 3.

![Figure 3. Cloud Center of Gravity Schematic](image)

3.2. Steps of cloud center of gravity judging method

**Step 1:** Find the cloud model representation of each indicator of the man-portable device

There are both quantitative and qualitative indicators in the man-portable tool index system. Multiple state values of each indicator are obtained through simulation and expert evaluation, and the qualitative comments are expressed in a cloud model expectation, and $n$ group of state values is selected to form a decision matrix, then the indicator cloud model is\(^{[13]}\):

$$E_x = (E_{x_1} + E_{x_2} + \ldots + E_{x_n})/n$$

$$E_n = (\max(E_{x_1}, E_{x_2}, \ldots, E_{x_n}) - \min(E_{x_1}, E_{x_2}, \ldots, E_{x_n}))/6$$

(1) (2)
where: $E_{x_1}, E_{x_2}, \ldots, E_{x_n}$ and denotes multiple state values of the same indicator.

**Step 2:** AHP method to find the weight of man-portable gear indicator

The judgment matrix $R$ was obtained by consulting experts and comparing the eight secondary indicators two by two using the 1-9 scale method. $r_{ij}$ denotes the relative importance of $r_i$ to $r_j$.

$$R = (r_{ij})_{8x8} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \quad (3)$$

Based on the judgment matrix, solve for the largest eigenroot $\lambda_{max}$ and the corresponding eigenvector $W$.

$$RW = \lambda_{max} W \quad (4)$$

The resulting feature vector $W$ is normalized to the weight vector of each indicator.

$$w_i = W / \sum_{i=1}^{n} W_i \quad (5)$$

To ensure the reliability of the weights, the consistency test is performed on the judgment matrix.

$$CR = CI / RI \quad (6)$$

Where $CI = (\lambda_{max} - n) / (n-1)$, which is the judgment matrix consistency index, $RI$ is the correction factor, its value is shown in Table 1. $CR$ is the judgment matrix random consistency ratio, when $CR < 0.1$, the matrix meets the consistency requirements.

**Step 3:** Representation of the status of the man-portable system

The $P$ indicators can be represented by $P$ cloud model, then the system state reflected by $P$ indicators can be represented by an $P$-dimensional integrated cloud. Then the $P$-dimensional integrated cloud center of gravity vector $T$ is:

$$T = (T_1, T_2, \ldots, T_p) \quad (7)$$

where: $T_i = a_i \times b_i (i = 1, 2, \ldots, p)$, $a_i = (E_{x_1}^0, E_{x_2}^0, \ldots, E_{x_p}^0)$ denote the cloud center of gravity position vector, $b = (b_1, b_2, \ldots, b_p)$ is the cloud center of gravity height vector, here let $b_i = w_i$.

When the state of the system changes, the change in its center of gravity $T'$ can be expressed as $T' = (T_1', T_2', \ldots, T_p')$.

**Step 4:** Measure the cloud center of gravity variation with weighted deviations

Let the ideal state cloud center of gravity vector $T^0 = a^0 \times b^0 = (T_{1}^0, T_{2}^0, \ldots, T_{p}^0)$. Similarly, the $P$-dimensional integrated cloud center of gravity vector $T = (T_1, T_2, \ldots, T_p)$ for a given state is obtained. Normalize the current integrated cloud vector $T$ to:

$$T_i^G = \begin{cases} (T_i - T_{i}^0) / T_{i}^0 & T_i < T_{i}^0 \\ (T_i - T_{i}^0) / T_{i} & T_i \geq T_{i}^0 \end{cases} \quad i = 1, 2, \ldots, p \quad (8)$$

$T^G = (T_1^G, T_2^G, \ldots, T_p^G)$ is obtained, and $T_i^G$ is a dimensionless scalar at this point. Using the weighted deviation $\theta$ to measure the difference in cloud center of gravity between the two states, so:

$$\theta = \sum_{i=1}^{p} (w_i T_i^G) \quad (9)$$

**Step 5:** Implementing a rubric set for man-portable device evaluation using cloud model
A rubric set consisting of 11 rubrics was used: \( V = (v_1, v_2, \ldots, v_{11}) = (\text{none, very poor, very bad, poor, bad, fair, good, better, very good, excellent, wonderful}) \). The 11 rubrics are placed on a continuous linguistic scale and each rubric is implemented in a cloud model to form a cloud generator for qualitative reviews. This is shown in Figure 4.

The assessment result is determined by the weighted deviation degree \( \theta \). Let the attribution degree \( e \) be: \( e = 1 - |\theta| \). The larger \( e \) means the closer the desired state is to the ideal state, the better the evaluation result. The attribution degree \( e \) is input into the cloud generator, and the rubric with larger activation degree is the assessment result.

4. Performance evaluation example for man-portable devices

4.1. Determine the different status values for each indicator of the man-portable device

Taking a certain type of man-portable device as an example, multiple state values of each indicator are obtained by using simulation and expert judgment, and four groups of state values of indicators are selected for the convenience of calculation, as shown in Table 1.

| Indicators | \( C_{11} \) (level) | \( C_{12} \) | \( C_{13} \) | \( C_{14} \) | \( C_{15} \) (kg) | \( C_{21} \) | \( C_{22} \) | \( C_{23} \) |
|------------|-----------------|---------|---------|---------|---------------|---------|---------|---------|
| 1          | 3               | better  | better  | Very good| 3.2           | better  | Very good| Very good|
| 2          | 2               | good    | Very good| excellent| 2.8           | better  | Very good| Very good|
| 3          | 3               | better  | Very good| Very good| 3.2           | Very good| Very good| excellent|
| 4          | 4               | Very good| good    | Very good| 4.5           | Very good| better   | Very good|
| Ideal state| 6               | wonderful| wonderful| wonderful| 2.5           | wonderful| wonderful| wonderful|

4.2. Calculation of metrics cloud model digital features

Representing the set of rubrics in a cloud model, the expected value \( E_X \) of the linguistic values (none, very poor, very bad, poor, bad, fair, good, better, very good, excellent, wonderful) is \((0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1)\), and using \( E_X \) to represent the qualitative rubrics, the decision matrix \( R \) is obtained as

\[
R = \begin{bmatrix}
3 & 0.7 & 0.7 & 0.8 & 3.2 & 0.7 & 0.8 & 0.8 \\
2 & 0.6 & 0.8 & 0.9 & 2.8 & 0.7 & 0.8 & 0.8 \\
3 & 0.7 & 0.8 & 0.8 & 3.2 & 0.8 & 0.8 & 0.9 \\
4 & 0.8 & 0.6 & 0.8 & 4.5 & 0.8 & 0.7 & 0.8
\end{bmatrix}
\]

According to equations (1) and (2), the \( E_X \) and \( E_N \) of each indicator cloud model are obtained, as shown in Table 2.

| Indicators | \( C_{11} \) | \( C_{12} \) | \( C_{13} \) | \( C_{14} \) | \( C_{15} \) (kg) | \( C_{21} \) | \( C_{22} \) | \( C_{23} \) |
|------------|-------------|-------------|-------------|-------------|---------------|---------|---------|---------|
| \( E_X \)  | 3           | 0.7         | 0.725       | 0.825       | 3.425         | 0.758   | 0.775   | 0.825   |
| \( E_N \)  | 0.333       | 0.033       | 0.033       | 0.017       | 0.283         | 0.033   | 0.033   | 0.033   |

4.3. Calculation of index weights

Construct a judgment matrix based on expert judgments
According to equations (4) to (6), the weight vector of each index is: 
\[ w_i = (0.0701, 0.1709, 0.2619, 0.1709, 0.0714, 0.1260, 0.0600, 0.0688) \] .

**4.4. Calculating the system-weighted deviation**

Using the eight-dimensional integrated cloud to represent the system state, according to equation (7), the eight-dimensional weighted integrated cloud center of gravity vector \( T \), ideal state weighted integrated cloud center of gravity vector \( T_0 \) is:

\[
T = (0.2103, 0.1196, 0.1899, 0.1410, 0.2445, 0.0955, 0.0465, 0.0568)
\]
\[
T_0 = (0.4206, 0.1709, 0.2619, 0.1709, 0.1785, 0.1260, 0.0600, 0.0688)
\]

Normalized by equation (8), we get
\[ T^G = (-0.50, -0.30, -0.27, -0.17, 0.27, -0.24, -0.225, -0.17) \].

From equation (9), it is obtained that \( \theta = -0.222 \)

**4.5. Determining assessment results**

According to \( e = 1 - |\theta| \), the attribution degree is 0.778. Input \( e \) into the cloud generator, activate the comment "better" and "very good", and activate the degree of "very good" more than "better", then the performance evaluation result of this type of man-portable is "very good". Analysis and evaluation results can be obtained: protective index and self-measurement index cloud center of gravity vector deviation is large, indicating poor performance of the index, but the weight is low, the impact on the performance of the load is not significant, the improvement is not significant. The cloud center of gravity deviation of the three indicators of tactics, comfort, and manning effectiveness is similar to the system deviation, so the improvement of the performance of these three indicators can help this type of man-portable device improve its performance.

**5. Conclusion**

This paper introduces cloud theory into the performance evaluation of man-portable devices, which effectively solves the problem that qualitative indicators are difficult to evaluate correctly. This paper introduces cloud theory into the performance evaluation of man-portable devices, which effectively solves the problem that qualitative indicators are difficult to evaluate correctly, and the process is simple and easy, and the evaluation results are basically consistent with the evaluation of officers and soldiers using this type of man-portable devices, which shows that the evaluation method is correct and feasible. The analysis of the results can provide theoretical basis and scientific guidance for the design improvement of such equipment and help optimize the performance of the equipment. The next step will be to conduct an in-depth study on the establishment of a metrics system in conjunction with the task and the full utilization of cloud model information.
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