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Research Article

A Novel Method for the Comprehensive Evaluation of Aerospace Components Based on GRAAP

Guodong Xu,[1] Peng Guo,[1] Xuemei Li,[2] and Yingying Jia[1]

[1] *School of Management, Northwestern Polytechnical University, Xi'an 710129, China*
[2] *College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China*

Correspondence should be addressed to Guodong Xu; npuxgd@gmail.com

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The effective evaluation of aerospace components can strongly guarantee the normal running of spacecraft. A novel model called Grey Relational Analysis Based on the Angle Perspective (GRAAP) has been developed in this paper, which can be used to carry out evaluation for the aerospace components by comparing their relation intensities between evaluation component and reference components. Take a regular component as an example; a case study has been introduced based on GRAAP, and the results indicated that the grade of component waiting for evaluation was III, and it can be used in the low orbit spacecraft at least, such as the near earth satellite, and the results were also considered to be more objective than that from some other comprehensive methods. In addition, like other traditional GRA models, GRAAP not only can deal with the evaluation issues, but can also be used to make predictions, make classifications, and so on.

1. Introduction

The aerospace components, including electrical, mechanical, and other relative components, are the fundamental elements of spacecraft [1], and they can decide the running effects of one spacecraft. In view of their importance, all aviation agencies in the world have been doing their best to improve these components' performances in recent years [2, 3], but some particularities of aerospace industry have slowed down their improvements [4]; these particularities include the following: (1) high criteria, the complexity of running environment needs high-level and high-quality components and spacecraft; (2) high cost, the experiment and production cost of aerospace components are so high that their scrapped costs are also high; (3) small-lot production, unlike regular production, aerospace products are suitable for small-lot production; (4) strong confidentiality, most countries in the world attach great importance to the technical confidentiality of the aerospace industry and rarely provide technology transfer or communication. However, there still have sprung up some effective methods which can help aerospace agencies to improve the performance of aerospace components [5–8], some of these methods mainly focused on the evaluation of the aerospace components [9], and the effective evaluation not only can determine the components' grade and their application environment, but may be able to encourage aerospace agencies to improve the comprehensive performance of the components according to the evaluation results.

Currently, only a few countries have established their own application validation systems which can be used to carry out the evaluation for aerospace components, but it is very difficult to know about their principles due to the strong confidentiality. As the theoretical discussion, some novel methods have also been developed in recent years [10–13], such as Maderbacher et al. who proposed that the lifetime of hot forged aerospace components can be effectively evaluated by linking microstructural evolution and fatigue behavior [14] and Golfman who explored a novel technology which can be used to carry out nondestructive evaluation for aerospace components [15]; however, these studies just focused on the single index performance of one component, and we still cannot know about their comprehensive performance. Under this situation, some other methods have appeared based on the methodology of system engineering, such as

Chen et al. who proposed a novel comprehensive evaluation thought using the theory of Hall for Workshop of Meta-Synthetic Engineering (HWME) and illuminated its general idea, framework, and approaches [16] and Quan et al. who constructed a comprehensive evaluation framework for the aerospace components and demonstrated its validity from the perspective of system engineering [17]; but there are still some other problems in these methods; for example, it is usually difficult to collect enough samples needed in some methods due to the particularities of aerospace industry; the evaluation criteria, used to explain the evaluation results, are usually unreasonable enough because they were just from some experts' advice and other similar criteria, and so forth.

Based on the above research results, the aim of present studies is to explore another process for the comprehensive evaluation of the aerospace components using a novel model called Grey Relational Analysis Based on the Angle Perspective (GRAAP) developed in this paper, and this process can help us to avoid some problems existing in the aerospace components' evaluation as mentioned above. In what follows, we divide the paper into 3 sections. In the first section we mainly introduce the evaluation process based on GRAAP and, meanwhile, provide the principle and theorems of this novel model. In Section 3, take a regular component as an example; a case study is carried out. In Section 4, we conclude the paper.

2. GRAAP

Grey System Theory (GST), used to solve the decision problems with the characteristics of inefficient samples, instability, and irregularity, has been developed by some scholars; this theory can greatly utilize the partly known information in the research objects to provide supports for the decision-makers. And one important branch of GST, called Grey Relational Analysis (GRA), has been viewed as the most fundamental methodology of GST in decision-making, prediction, and so on. In view of the extensive applications, plenty of GRA models have been developed based on the grey relational axiom proposed by Professor Deng. These models can be divided into three categories according to their modeling basis. The first category, the most common category, was based on the distance between adjacent discrete values of the time series, the representative models, such as Deng's grey relational model [18], T's grey relational model [19], and the improved model of T's grey relational [20]. The second category was based on the slope of the straight line generated by the discrete values of time series; the representative models included the grey absolute degree of grey incidence model [21] and the degree of grey slop incidence [22] and so forth. The third category was based on the area surrounded by different time series, the representative studies, such as Liu who analyzed the relationship between the absolute value and the relative increment in two different time series and then presented the thought that the relational degree between different time series could be measured by the area surrounded by these time series [23], and another grey relational model established by Guimerà et al. was also based on this thought [24].

However, the modeling basis of these GRA models mentioned above has not been developed in recent years, which were still based on the above three perspectives including distance perspective, slop perspective, and area perspective; meanwhile, there are still some other problems existing in these models; for example, some models cannot make full use of the information in the research objects, and other models do not have the properties of uniqueness [25], symmetry [26], parallelism [27], and so forth. Under these situations, a novel model called Grey Relational Analysis Based on the Angle Perspective (GRAAP) will be introduced in this section; this model not only can greatly improve the accuracy and validity of the research results by making more full use of the poor information in the research objects but has the properties of normativity, uniqueness, parallelism, and order-preserving; meanwhile, it can also expand the research scope of GRA and enrich GRT. Additionally, this novel model is mainly based on two mature models by Tang [19] and Sun and Dang [20] which have been widely accepted by academic and industry, and it can make more full use of the information existing in the research object [28]; therefore, this model will be a more reasonable model. And because of its advantages, it can usually be used to make prediction, assessment, classification and so on in the engineering. And the following part will introduce its priciple, details and theorems.

2.1. Principle of GRAAP. The modeling thought of GRAAP is rooted in the traditional Grey System Theory (GST) [29]; its basic principle is to utilize the cointegrated similarity of angles to reveal the relationship between different research objects. Similar to other GRA models, GRAAP can also be used to make decisions, make predictions, and make classifications in grey system [28]. And in the system theory, one system can be divided into three categories according to their owned degree of system information; if the system information is fully known, this system will be called white system; if the information is wholly unknown, then it is called black system, and a system with partially known information is usually called a grey system [30–32]. In the real-world, there are so many time series with partially known information; they can be considered as a special grey system, and they have become one important and common research object of grey system. In this section, a two-dimension coordinate system used to explain the principle of GRAAP model will be built, its abscissa represents the accumulation of the index weight ($w_i' = \sum_{j=1}^{i} w_j$), and the ordinate represents the index value.

Assume there are two research objects X and X' with three indictors, their coordinate values in two-dimension coordinate system are $[(y_1, w_1'), (y_2, w_2'), (y_3, w_3')]$ and $[(y_1', w_1'), (y_2', w_2'), (y_3', w_3')]$, respectively, and then two curves can be created by connecting these three coordinate points of every research object (Figure 1). Meanwhile, to X, angle α will be generated between line AB and line BC, and to X', if the last coordinate point lies on the dot C', angle $\alpha' + \beta'$ will be generated between line $A'B'$ and line $B'C'$; since the line AB is parallel to the line $A'B'$, and the line BC is also parallel to the line $B'C'$, the conclusion will be $\alpha = \alpha' + \beta'$, which

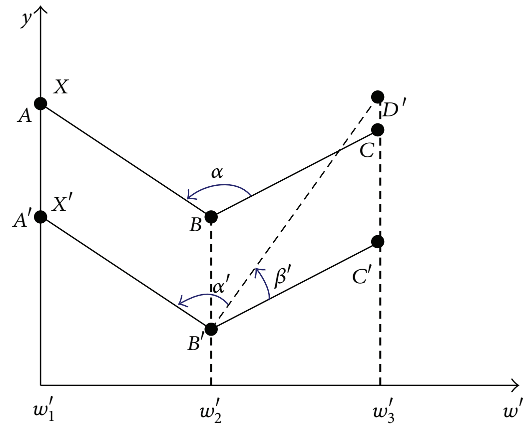

Figure 1: Principle of diagram of GRAAP model.

means the similarity of two objects is higher. However, to X', if the last coordinate point moves to the dot D', at this time, angle α' will be generated; since the line AB is parallel to the line $A'B'$, but the line BC is not parallel to the line $B'D'$, the conclusion will be $\alpha > \alpha'$, and the similarity of two objects is lower.

In the above process, the similarity of different objects mainly depends on the integral similarity of angles which were determined by their position of discrete coordinate points in two-dimension coordinate system. Based on this principle, this paper will develop a novel model called Grey Relational Analysis Based on the Angle Perspective (GRAAP). And two key challenges need to be solved in the construction of this model: one is how to transform the original data into the form of angle sets, and the other is how to calculate the grey relational coefficient between different objects.

2.2. Details of Evaluation Process Using GRAAP. The application process of traditional GRA model usually includes the normalization of original data, the confirmation of grey relational coefficient, and the calculation of grey relational degree. Based on this, the evaluation process using GRAAP will be designed as follows (Figure 2).

The details are as follows.

Step 1 (setting up the index system and collecting the experiment data). The index system is the foundation of one evaluation process, so it needs to be firstly set up according to the evaluation objective, and then the corresponding experiment data should also be collected.

In this step, some typical components also need to be selected, and they will be used as the reference objects of evaluation object (it means this object is waiting for evaluation, and it can also be called comparative object).

Step 2 (normalizing the experiment data and calculating the index weight). The experiment data must be normalized firstly because they usually have different dimensions and

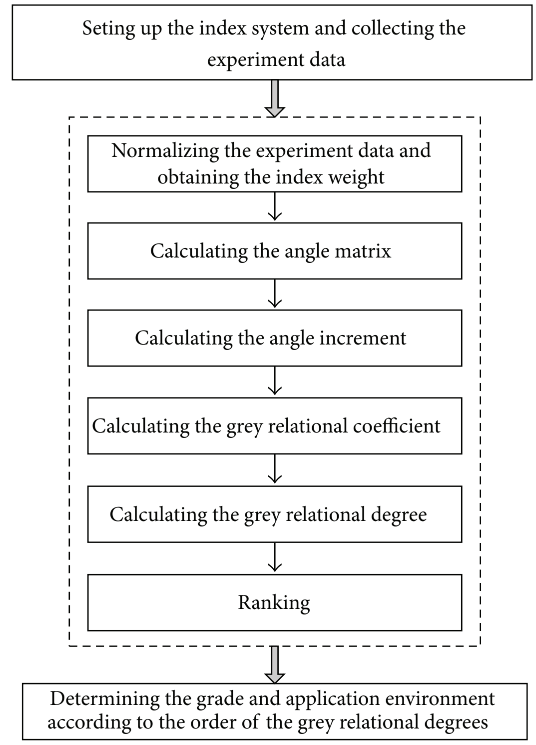

Figure 2: Evaluation process using GRAAP.

magnitudes, and this process can be carried out using the following formula:

$$r_{mk} = \frac{x_{mk} - \min}{\max - \min} \quad k = 1, 2, \ldots, n, \tag{1}$$

where m denotes the number of all research objects including evaluation object and reference objects, n denotes the number of all indictors, x_{mk} denotes the kth index value of the mth research object, max is the maximum value of all indexes of the mth research object, and min is the minimum value. And the normalized dataset can be expressed as a decision matrix,

$$R_m = \begin{bmatrix} r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}. \tag{2}$$

In addition, another matrix called weight matrix also needs to be created, and the value of its element w_n can be obtained with some traditional methods, such as AHP and PCA:

$$W = \begin{bmatrix} w_1 & w_2 & \cdots & w_n \end{bmatrix}. \tag{3}$$

Step 3 (calculating the angle matrix). In this step, the angle matrix will be obtained based on the above decision matrix and weight matrix,

$$A_m = \begin{bmatrix} \alpha_{m2} & \alpha_{m3} & \cdots & \alpha_{mn-1} \end{bmatrix}, \tag{4}$$

where α_{mi} ($i = 2, 3, \ldots, n-1$) denotes the value of counterclockwise angle between adjacent line segments of the mth research object (Figure 3).

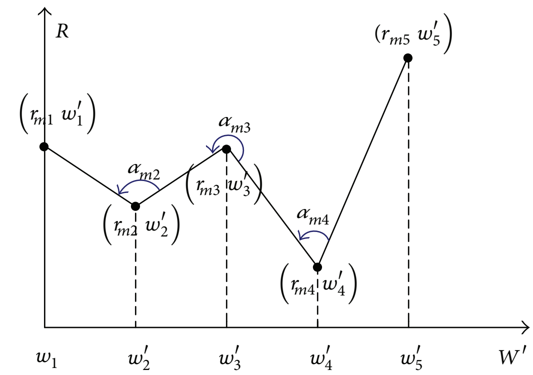

Figure 3: Angle representation of research object in two-dimension coordinate system.

In order to obtain the value of angle α_{mi}, set β_{mi} means the value of clockwise angle between adjacent line segments; then the calculation method of α_{mi} will be given as follows:

$$\alpha_{mi} = \begin{cases} \arccos\dfrac{b^2 + c^2 - a^2}{2bc} & 2 \le i \le n-1, \\ & \alpha_{mi} \le \beta_{mi} \\ 2\pi - \arccos\dfrac{b^2 + c^2 - a^2}{2bc} & 2 \le i \le n-1, \\ & \alpha_{mi} > \beta_{mi}, \end{cases} \quad (5)$$

where

$$\begin{aligned} a &= \sqrt{\left[r_{m(i+1)} - r_{m(i-1)}\right]^2 + \left(w_{i+1} - w_{i-1}\right)^2}, \\ b &= \sqrt{\left[r_{mi} - r_{m(i-1)}\right]^2 + \left(w_i - w_{i-1}\right)^2}, \\ c &= \sqrt{\left[r_{m(i+1)} - r_{mi}\right]^2 + \left(w_{i+1} - w_i\right)^2}. \end{aligned} \quad (6)$$

Step 4 (calculating the angle increment). Assume the angle matrix of one research object is $A_m = [\alpha_{m2}\ \ \alpha_{m3}\ \ \cdots\ \ \alpha_{m(n-1)}]$; its corresponding increment matrix can be obtained through the following formula:

$$\begin{aligned} Y_m &= [y_{m3}\ \ y_{m4}\ \ \cdots\ \ y_{m(n-1)}] \\ y_{mj} &= \alpha_{mj} - \alpha_{m(j-1)} \quad (j = 3, 4, \ldots, n-1). \end{aligned} \quad (7)$$

The purpose of building the increment matrix was to know about the change regularity of the angle values between the adjacent indictors of one research object, and it was also advantageous to help us to effectively obtain the grey relational coefficient and degree in the following steps.

Step 5 (calculating the grey relational coefficient). Assume there are two research objects; their increment matrices are $Y_{m-1} = [y_{(m-1)3}\ \ y_{(m-1)4}\ \ \cdots\ \ y_{(m-1)(n-1)}]$ and $Y_m = [y_{m3}\ \ y_{m4}\ \ \cdots\ \ y_{m(n-1)}]$, respectively; the following formula will be defined to calculate the relational coefficient between these two objects:

$$\xi_k = \left(1 + \frac{\left|y_{mk} - y_{(m-1)k}\right|}{2\pi} + \frac{1}{2}\left[1 - \frac{\min\left(\left|y_{mk}\right|, \left|y_{(m-1)k}\right|\right)}{\max\left(\left|y_{mk}\right|, \left|y_{(m-1)k}\right|\right)}\right]\right)^{-1}. \quad (8)$$

The purpose of building formula (8) was to effectively distinguish the grey relational coefficient generated by two different objects, and two comparative variables have been introduced into this formula, which were the subtraction variable $|y_{mk} - y_{(m-1)k}|/2\pi$ and the proportion variable $[1 - (\min(|y_{mk}|, |y_{(m-1)k}|)/\max(|y_{mk}|, |y_{(m-1)k}|))]$. When the angle increments between adjacent indictors in two research objects are equal or approximately equal, the subtraction variable and the proportion variable will be all approximately equal to 0, and the relational coefficient generated by these two objects will be largest; its value was about 1; otherwise, it will be smallest.

Step 6 (calculating the grey relational degree). Assume there are two research objects; the following formula will be defined to calculate the grey relational degree between them:

$$r = \frac{1}{n-3} \cdot \sum_{k=3}^{n-1} \xi_k. \quad (9)$$

Step 7 (ranking). All grey relational degrees between evaluation object and reference objects can be calculated using the above process, and then the order of their relationship intensities (between evaluation object and reference objects) can be ranked according to their relational degrees; the higher value indicates the higher intensity.

Step 8 (determining the grade and application environment). The grade of evaluation object should be confirmed according to the order of the grey relational degrees, and it should be the same as the object which has the highest relational degree with the evaluation object, and then its application environment can also be confirmed.

2.3. Theorem of GRAAP. Two theorems of GRAAP can be obtained as follows.

Theorem 1. *GRAAP has the property of order-preserving. In other words, the relationship intensities between different research objects should be decided by their grey relational degrees but have no relation with the sort orders of the evaluation indictors.*

The following example can illustrate the validity of this theorem.

Assume there are three research objects, and all of them have three evaluation indictors. The corresponding index values of the nth object are x_{n1}, x_{n2}, and x_{n3} ($n = 1, 2, 3$); thus, there appear to be three angles corresponding to these three research objects, that is, α_0, α_1, and α_2 (Figure 4(a)).

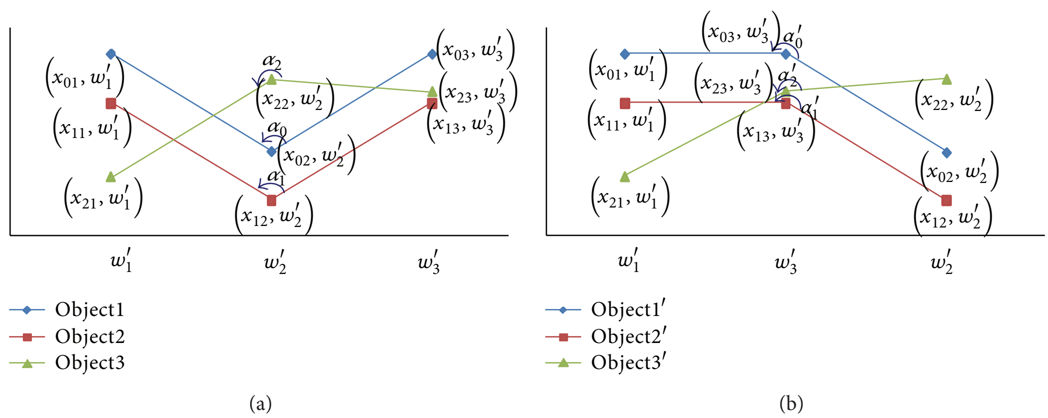

Figure 4: Angle representations of (a) three original research objects and (b) another three research objects after exchanging the order of two indictors' position of the original research objects.

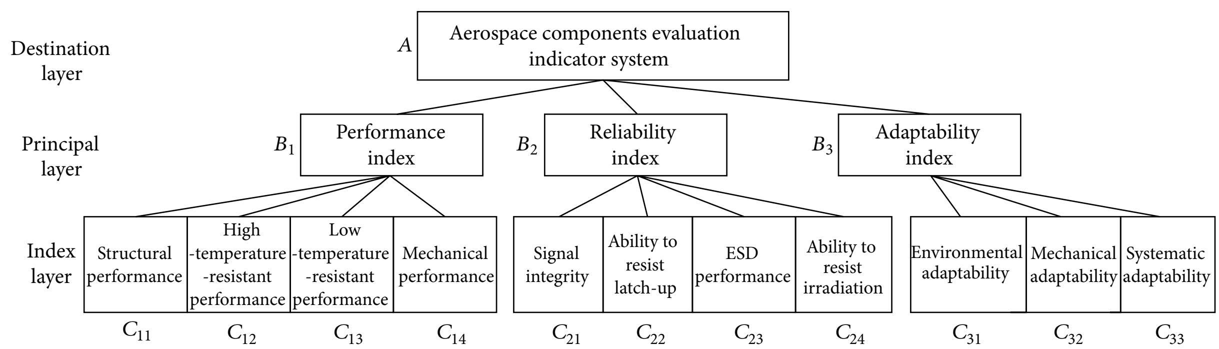

Figure 5: Hierarchical structure of index system for aerospace component.

And the first one will be considered as the evaluation object (or called comparative object); the other two ones are the reference objects.

Set $\alpha_0 = \alpha_1$, and $\alpha_0 \neq \alpha_2$; thus, we can obtain $r_1 > r_2$ based on the principle of GRAAP. And if the order of any two indictors has been exchanged, then another three angles will be generated, that is, α_0', α_1', and α_2' (Figure 4(b)); if we can prove $\alpha_0' = \alpha_1'$ and $\alpha_0' \neq \alpha_2'$, then, $r_1' > r_2'$, and this theorem will be considered to be valid.

Because $\alpha_0 = \alpha_1$, then,

$$\begin{cases} \dfrac{x_{02} - x_{01}}{w_2' - w_1'} = \dfrac{x_{12} - x_{11}}{w_2' - w_1'} \\ \dfrac{x_{03} - x_{02}}{w_3' - w_2'} = \dfrac{x_{13} - x_{12}}{w_3' - w_2'} \end{cases}$$
$$\Longrightarrow \begin{cases} x_{02} - x_{01} = x_{12} - x_{11} \\ x_{03} - x_{02} = x_{13} - x_{12} \end{cases}$$
$$\Longrightarrow \begin{cases} x_{03} - x_{01} = x_{13} - x_{11} \\ x_{02} - x_{03} = x_{12} - x_{13} \end{cases} \quad (10)$$
$$\Longrightarrow \begin{cases} \dfrac{x_{03} - x_{01}}{w_3' - w_1'} = \dfrac{x_{13} - x_{11}}{w_3' - w_1'} \\ \dfrac{x_{02} - x_{03}}{w_2' - w_3'} = \dfrac{x_{12} - x_{13}}{w_2' - w_3'} \end{cases}$$
$$\Longrightarrow \alpha_0' = \alpha_1'.$$

In the same way, we can get $\alpha_0' \neq \alpha_2'$; thus $r_1' > r_2'$ is correct, so Theorem 1 is valid.

That is to say, the evaluation results based on the above process have no relation with the order of indictors on the abscissa in two-dimension coordinate system.

Theorem 2. *GRAAP has the property of transitivity. In other words, if the relation intensities between one object and some other objects are high, then the intensities between any two ones of these objects are also high.*

This theorem can be easily obtained from the above details, so the proving process will never be given.

3. Case Study

In this section, we will take one regular aerospace component, named BXRA-11 which can be used in various environments including high, medium, and low orbits, as an example to carry out case study using the above process.

3.1. Setting Up the Index System and Collecting the Experiment Data. The hierarchical structure of the index system is shown in Figure 5; there are three hierarchies, including destination layer, principle layer, and index layer, and the comprehensive evaluation for the aerospace components will be carried out only based on the index layer according to the details of GRAAP presented in Section 2.1.

Based on the above index system, the corresponding index data have been collected from China Aerospace Science and Technology Corporation.

3.2. Normalizing the Experiment Data and Calculating the Index Weights. In this section, three typical components of BARA-11 have been selected as the reference components, and their actual application results showed that the comprehensive performance of Component I was highest, so it would be confirmed as rank I, which can be used in the high orbit spacecraft, and Component II was confirmed as rank II, which can be used in the medium orbit spacecraft, and Component III was rank III, which can be used in the low orbit spacecraft.

The different dimensions and magnitudes of experiment data determined they cannot be compared directly; therefore, normalization is necessary based on formula (1); before evaluation, the normalized results were as follows (the original data will never be given due to the confidentiality):

$$\begin{aligned} R_{\mathrm{I}} &= \left[1.000\ \ 0.8110\ \ 0.7823\ \ 0.9874\ \ 0.6230\ \ 0.7568\ \ 0.6603\ \ 0.8356\ \ 0.9980\ \ 0.9768\ \ 0.8305\right], \\ R_{\mathrm{II}} &= \left[0.6113\ \ 0.8009\ \ 0.7983\ \ 0.6231\ \ 0.6435\ \ 0.8203\ \ 0.5986\ \ 0.6408\ \ 0.6001\ \ 0.8344\ \ 0.5986\right], \\ R_{\mathrm{III}} &= \left[0.5698\ \ 0.6210\ \ 0.6006\ \ 0.3988\ \ 0.6323\ \ 0.5872\ \ 0.6000\ \ 0.3827\ \ 0.6105\ \ 0.5968\ \ 0.4012\right], \\ R_{\mathrm{Eva.Comp}} &= \left[0.7400\ \ 0.6213\ \ 0.6810\ \ 0.5008\ \ 0.7207\ \ 0.6462\ \ 0.7118\ \ 0.5250\ \ 0.6339\ \ 0.6785\ \ 0.6605\right]. \end{aligned} \tag{11}$$

As for the index weight, they have been set with the same value according to the experts' advice; that is to say, the importance of every indictor was the same in this sample, and it was shown as follows:

$$W = \left[\frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\ \ \frac{1}{11}\right]. \tag{12}$$

And in the following sections, the grade and application environment of the evaluation component will be confirmed according to the grey relational degrees between the evaluation component (or called comparative components) and these three reference components.

3.3. Calculating the Angle Matrix. The angle matrix can be calculated based on the above decision matrix and the weight matrix, and they were expressed as follows:

$$\begin{aligned} A_{\mathrm{I}} &= \left[0.5160\pi\ \ 0.3451\pi\ \ 1.7063\pi\ \ 0.2836\pi\ \ 1.6908\pi\ \ 0.3172\pi\ \ 1.5908\pi\ \ 1.6749\pi\ \ 1.6506\pi\right], \\ A_{\mathrm{II}} &= \left[1.6653\pi\ \ 1.6499\pi\ \ 0.3263\pi\ \ 0.3570\pi\ \ 1.7041\pi\ \ 0.3207\pi\ \ 1.6787\pi\ \ 0.3460\pi\ \ 1.7201\pi\right], \\ A_{\mathrm{III}} &= \left[1.6780\pi\ \ 1.6364\pi\ \ 0.2887\pi\ \ 1.6798\pi\ \ 0.3226\pi\ \ 1.6460\pi\ \ 0.2845\pi\ \ 1.6661\pi\ \ 1.6406\pi\right], \\ A_{\mathrm{Eva.Comp.}} &= \left[0.3152\pi\ \ 1.6706\pi\ \ 0.2948\pi\ \ 1.6913\pi\ \ 0.3179\pi\ \ 1.6716\pi\ \ 0.3016\pi\ \ 1.6590\pi\ \ 1.6778\pi\right]. \end{aligned} \tag{13}$$

3.4. Calculating the Grey Relational Coefficient. In this step, we can calculate the grey relational coefficients between the evaluation component and reference components according to formula (8); the results were as shown in Table 1.

3.5. Calculating the Grey Relational Degree. Finally, the grey relational degrees can be obtained with Step 6:

$$\begin{aligned} r_{C_{\mathrm{I}}C_E} &= \frac{1}{n-3}\sum_{k=3}^{n-1}\xi\left(t_k\right) = 0.4611, \\ r_{C_{\mathrm{II}}C_E} &= \frac{1}{n-3}\sum_{k=3}^{n-1}\xi\left(t_k\right) = 0.5028, \\ r_{C_{\mathrm{III}}C_E} &= \frac{1}{n-3}\sum_{k=3}^{n-1}\xi\left(t_k\right) = 0.8781. \end{aligned} \tag{14}$$

3.6. Discussion. Based on the above calculation results, the order of grey relational degrees between evaluation component and other three reference components was as follows:

$$r_{C_{\mathrm{III}}C_E} > r_{C_{\mathrm{II}}C_E} > r_{C_{\mathrm{I}}C_E}. \tag{15}$$

(1) The above result indicated the grey relational degree between reference component III and the evaluation component was highest; by contrast, the smallest degree appeared between reference component I and the evaluation component, whose value approximates to that between reference component II and the evaluation component.

(2) The validity of results obtained by GRAAP can be illustrated by Figures 6 and 7.

The clustering pedigree chart obtained by SPSS soft package (Figure 6) indicated that component III and

TABLE 1: Grey relational coefficients between evaluation component and other three reference components.

Object	ξ							
	ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	ξ_6	ξ_7	ξ_8
I versus E.C.	0.4545	0.4213	0.4134	0.4163	0.4218	0.4243	0.4749	0.6622
II versus E.C.	0.4588	0.9569	0.4604	0.4220	0.4203	0.4222	0.4248	0.4573
II versus E.C.	0.4581	0.9763	0.9954	0.9862	0.9743	0.9927	0.9796	0.6619

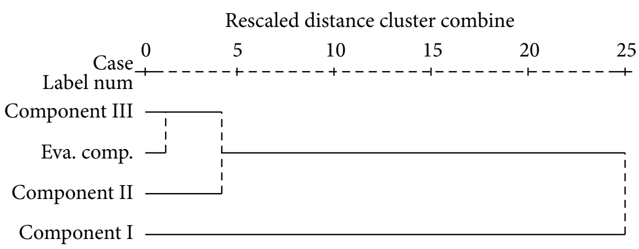

FIGURE 6: Clustering pedigree chart of four components.

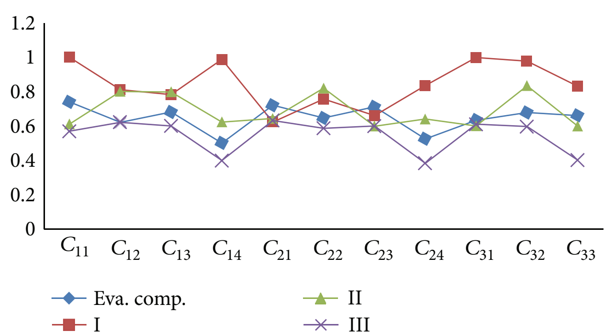

FIGURE 7: Curves generated by the normalized index values of four components.

the evaluation component have been divided into one category, which was consistent with the above results.

And compared with the similarity of the geometry curves generated by the normalized values of four components (Figure 7), the similarity between component III and evaluation component was obviously highest, and the similarity between component I and evaluation component was lowest, which were also consistent with the results obtained by GRAAP.

The above two comparative results can show that GRAAP is an effective model to some extent.

(3) The highest relational degree ($r_{C_{\text{III}}C_E} = 0.8781$) revealed the strong relation intensity between reference component III and the evaluation component, so its grade and application environment can be obtained based on component III.

And considering most index values of the evaluation component are higher than that of component III (as shown in Section 3.2 and Figure 7), the comprehensive performance of the evaluation component should be superior to component III; thus, the grade of evaluation component should be III which can be used in the low orbit spacecraft at least, such as the near earth satellite.

4. Conclusion

The principle, details, and theorems of GRAAP model have been developed in this paper, and this model can be used to deal with the evaluation issues, such as aerospace components' evaluation.

(1) GRAAP is a reasonable model, because it is rooted in GRA models and some improvements have been made in this paper. Meanwhile, Figures 6 and 7 can also intuitively demonstrate the validity of this model to some extent. And this model can also be used to make prediction, make classification, and so on.

(2) Compared with other comprehensive evaluation methods, the process in this paper has some advantages, such as the fact that it is not necessary to subjectively set the evaluation criteria which may affect the evaluation conclusions and the limited experiment data or the normalized data can be fully mined by GRAAP; thus, so much information can be obtained, and the final conclusion may be more effective.

(3) The application of GRAAP for the evaluation of aerospace components needs the support of historical data, so it is necessary for aerospace agencies to build the relative database.

(4) There are also some other problems in this paper that need to be solved in the future studies, such as the fact that the proving process of Theorem 1 may not be perfect.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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