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A Grey Relational Analysis Model of Scientific Research Ability on Music Based on AHP and Its Realization

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Abstract

In the process of analyzing scientific research ability on music, many problems present, including that indicators are not comprehensive enough, the model has much subjectivity, the evaluation results are not reliable or the value of quantity of indicators has errors. Thus, this paper proposes a grey relational analysis model of scientific research ability on music based on AHP. It selects out dominant indicators and recessive indicators to evaluate software features and hardware features. A multi-layer evaluation index system for scientific research ability on music is established. AHP is introduced to compute the weight of indicators. After standardization of indicators, a multi-scheme grey relational coefficient model and a grey relational degree model are established according to grey theory to evaluate the level of scientific research ability on music. Proved effective by the case study, this model can realize the evaluation of scientific research ability on music on the computer.

Keywords: *Music research, research ability of scientific, AHP, grey theory, grey relational analysis model*

1. Introduction

With the advancement of social and spiritual life, people developed a keen interest in music. As an integral part of music development, scientific research ability on music has received wide attention by many experts, music academies and music institutions. System, teaching, research team, professional qualities are all subject to analysis. Relevant research with fruitful results plays an active role in promoting the development of music [1-4]. Despite achievements, new requirements present themselves. Evaluation indicators are supposed to be quantified and fuzzy information needs dealing with [5-8].

Current studies about scientific research ability on music more focus on strategies to improve music classes but fail to provide an effective evaluation model for scientific research ability on music. Fuzzy information that causes some errors is left idle. As a result, indicators are not comprehensive enough, the model has much subjectivity, the evaluation results are not reliable and the value of quantity of indicators has errors. Therefore, this paper draws merits from previous studies and proposes an optimized evaluation index system for scientific research ability on music. According to grey theory [9-12], it establishes a grey relational analysis model based on AHP [13-14] and proves its efficacy through a case study.

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2. Multi-layered Evaluation Index System for Scientific Research Ability on Music

2.1 Principles for Constructing the Evaluation Index System

The evaluation of scientific research ability on music involves with multiple factors and multi-layered analysis. Fundamental principles for selecting indicators are listed below:

(1) Systematic principle: indicators should be logically related to each other. At the same time, each of them reflects the scientific research ability on music uniquely.

(2) Scientific principle: indicators should be selected according to real situation and reflect the scientific research ability on music reasonably.

(3) Comprehensive principle: indicators should be representative and reflect the scientific research ability on music comprehensively. It shouldn't prefer one aspect over another.

(4) Independent principle: it should avoid double counting to ensure the reliability of the analysis.

(5) Measurable principle: indicators should be quantified or measured effectively to ensure the reliability of the analysis.

2.2 Indicators of Scientific Research Ability on Music for Hardware Ability

Hardware features mainly consist of research platform and research result. The purpose of music research platform is to provide support to academic development and the development of music teams through music research. Research result is the production of the research. Specific indicators are shown in Table 1.

Table 1. Indicators of Scientific Research Ability on Music for Hardware Ability

Evaluation index system	First class indicators	Second class indicators	Third class indicators
Evaluation index system for scientific research ability on music based on hardware features Rh	Music research platform Rh_1	Dominant ability Rh_1^{dom}	Funding support Rh_{1-1}^{dom}
			Team building Rh_{1-2}^{dom}
			Lab development Rh_{1-3}^{dom}
		Recessive ability Rh_1^{rec}	Incentive mechanism Rh_{1-1}^{rec}
			Innovation mechanism Rh_{1-2}^{rec}
			Talent cultivation and echelon construction Rh_{1-3}^{rec}
	Research results Rh_2	Dominant ability Rh_2^{dom}	Number of research projects Rh_{2-1}^{dom}
			Number of papers and journals Rh_{2-2}^{dom}
			Number of monographs

			and compiled works Rh_{2-3}^{dom}
			Number of academic awards Rh_{2-4}^{dom}
		Recessive ability Rh_2^{rec}	Music techniques Rh_{2-1}^{rec}
			Music styles Rh_{2-2}^{rec}
			Reputation and popularity Rh_{2-3}^{rec}
			Music material collection Rh_{2-4}^{rec}
			Academic communication Rh_{2-5}^{rec}

2.3 Indicators of Scientific Research Ability on Music for Software Ability

Software features are defined as the interaction between components of hardware features and their role and function mainly presented in the process of transformation and service. Software features are important to the sustainable development of music research. Specific indicators are shown in Table 2.

Table 2. Indicators of Scientific Research Ability on Music for Software ability

Evaluation index system	First class indicators	Second class indicators	Third class indicators
Evaluation index system for scientific research ability on music based on software features Rs	Transformation and service ability of music research Rs_1	Dominant ability Rs_1^{dom}	Economic benefits Rs_{1-1}^{dom}
			Social service Rs_{1-2}^{dom}
			Integration of production and research Rs_{1-3}^{dom}
			Result transmission Rs_{1-4}^{dom}
			Excellent ratio of talents Rs_{1-5}^{dom}
			Reject ratio of talents Rs_{1-6}^{dom}
		Recessive ability Rs_1^{rec}	Transmission Rs_{1-1}^{rec}
			Mining Rs_{1-2}^{rec}
			Communication Rs_{1-3}^{rec}

			Protection Rs_{1-4}^{rec}
			Integration Rs_{1-5}^{rec}

3. Grey Relational Analysis Model for Scientific Research Ability on Music based on AHP

In the analysis, some indicators have accurate value of quantity while others have fuzzy value of quantity. As they have different scales, it is necessary to standardize them.

(1)For accurate value

Suppose the j-th indicator of the i-th object has an accurate value of quantity r_{ij} . If it is a positive indicator, its value of quantity v_{ij} after standardization is:

$$v_{ij} = r_{ij} / \left(r_{kj} \mid \max_{1 \le i \le m} \left(r_{ij} \right) \right) \tag{1}$$

If it is a negative indicator, its value of quantity v_{ij} after standardization is:

$$v_{ij} = \left(r_{kj} \mid \min_{1 \le i \le m} \left(r_{ij} \right) \right) / r_{ij} \tag{2}$$

(2). for interval value

The interval value of an indicator has two types, one of which is transfer the quantitative description of value of quantity to the interval value. The transfer principle is shown in Table 3

Table 3. Transfer Quantitative Description to Interval Value

Interval value	Ideality of positive indicators	Ideality of negative indicators
0.9-1.0	Excellent	Unbearable
0.8-0.9	Good	Undesirable
0.6-0.8	Mediocre	Poor
0.4-0.6	Poor	Mediocre
0.2-0.4	Undesirable	Good
0-0.2	Unbearable	Excellent

The other is fuzzy interval value. Suppose the interval value of quantity of the j-th indicator of the i-th object is $r_{ij} = \left[r_{ij}^{L}, r_{ij}^{R} \right]$. If it is a positive indicator, the standardized value of quantity v_{ij} is:

$$\begin{cases} v_{ij} = \left[v_{ij}^{L}, v_{ij}^{R} \right] \\ v_{ij}^{L} = r_{ij}^{L} / \left(r_{kj} \mid \max_{1 \le i \le m} \left(\left[v_{ij}^{L}, v_{ij}^{R} \right] \right) \right) \\ v_{ij}^{R} = r_{ij}^{R} / \left(r_{kj} \mid \max_{1 \le i \le m} \left(\left[v_{ij}^{L}, v_{ij}^{R} \right] \right) \right) \end{cases} \tag{3}$$

If it is a negative indicator, the standardized value of quantity v_{ij} is:

$$\begin{cases} v_{ij} = \left[v_{ij}^{L}, v_{ij}^{R} \right] \\ v_{ij}^{L} = \left(r_{kj} \mid \min_{1 \le i \le m} \left(\left[v_{ij}^{L}, v_{ij}^{R} \right] \right) \right) / r_{ij}^{R} \\ v_{ij}^{R} = \left(r_{kj} \mid \min_{1 \le i \le m} \left(\left[v_{ij}^{L}, v_{ij}^{R} \right] \right) \right) / r_{ij}^{L} \end{cases} \quad (4)$$

3.2 Grey relational coefficient

After standardization, all indicators are unified as positive indicators. The standard interval of indicator j is defined as:

$$v_{j}^{O} = \left[v_{j}^{oL}, v_{j}^{oR} \right] = \left[\max_{1 \le i \le m} \left(v_{ij}^{L} \right), \max_{1 \le i \le m} \left(v_{ij}^{R} \right) \right] \quad (5)$$

Fuzzy distance d_{ij} between the j-th indicator of the i-th object and its corresponding standard interval is:

$$d_{ij} = \left[\left| v_{ij}^{L} - v_{j}^{oL} \right|^{p} + \left| v_{ij}^{R} - v_{j}^{oR} \right|^{p} \right]^{1/p} / 2^{1/p} \quad (6)$$

In particular, if the value of quantity of the indicator is an accurate one, then fuzzy distance d_{ij} is the distance between two dots:

$$d_{ij} = \left| v_{ij} - v_{j}^{o} \right| \quad (7)$$

Thus, we can get the dominant fuzzy distance of the i-the object about indicators of hardware features $d_{ij}^{Rs^{dom}}$ and indicators of software features $d_{ij}^{Rh^{dom}}$, and the recessive fuzzy distance of the i-the object about indicators of hardware features $d_{ij}^{Rs^{rec}}$ and indicators of software features $d_{ij}^{Rh^{rec}}$.

According to grey theory, the dominant grey relational coefficient of the i-the object about indicators of hardware features $\zeta_{ij}^{Rs^{dom}}$ and indicators of software features $\zeta_{ij}^{Rh^{dom}}$, and the recessive grey relational coefficient of the i-the object about indicators of hardware features $\zeta_{ij}^{Rs^{rec}}$ and indicators of software features $\zeta_{ij}^{Rh^{rec}}$ are expressed as:

$$\zeta_{ij}^{Rs^{dom}} = \frac{\min_{1 \le i \le m} \min_{1 \le j \le n_{rsd}} \left(d_{ij}^{Rs^{dom}} \right) + \rho \max_{1 \le i \le m} \max_{1 \le j \le n_{rsd}} \left(d_{ij}^{Rs^{dom}} \right)}{d_{ij}^{Rs^{dom}} + \rho \max_{1 \le i \le m} \max_{1 \le j \le n_{rsd}} \left(d_{ij}^{Rs^{dom}} \right)} \quad (8)$$

Where n_{rsd} refers to the number of dominant indicators of hardware features. ρ Is the grey relational discrimination coefficient.

$$\zeta_{ij}^{Rh^{dom}} = \frac{\min_{1 \le i \le m} \min_{1 \le j \le n_{rhd}} \left(d_{ij}^{Rh^{dom}} \right) + \rho \max_{1 \le i \le m} \max_{1 \le j \le n_{rhd}} \left(d_{ij}^{Rh^{dom}} \right)}{d_{ij}^{Rh^{dom}} + \rho \max_{1 \le i \le m} \max_{1 \le j \le n_{rhd}} \left(d_{ij}^{Rh^{dom}} \right)} \quad (9)$$

Where n_{rhd} refers to the number of recessive indicators of hardware features.

$$\zeta_{ij}^{Rs^{rec}} = \frac{\min_{1 \le i \le m} \min_{1 \le j \le n_{rsr}} \left(d_{ij}^{Rs^{rec}} \right) + \rho \max_{1 \le i \le m} \max_{1 \le j \le nn_{rsr}} \left(d_{ij}^{Rs^{rec}} \right)}{d_{ij}^{Rs^{rec}} + \rho \max_{1 \le i \le m} \max_{1 \le j \le nn_{rsr}} \left(d_{ij}^{Rs^{rec}} \right)} \quad (10)$$

Where n_{rsr} refers to the number of dominant indicators of software features.

$$\zeta_{ij}^{Rh^{rec}} = \frac{\min_{1\le i\le m}\min_{1\le j\le n_{rhr}}\left(d_{ij}^{Rh^{rec}}\right) + \rho \max_{1\le i\le m}\max_{1\le j\le n_{rhr}}\left(d_{ij}^{Rh^{rec}}\right)}{d_{ij}^{Rh^{rec}} + \rho \max_{1\le i\le m}\max_{1\le j\le n_{rhr}}\left(d_{ij}^{Rh^{rec}}\right)} \tag{11}$$

Where n_{rhr} refers to the number of recessive indicators of software features.

3.3 Weight of Indicators based on AHP

Hardware features and software features pose influence on scientific research ability on music to a different degree. Dominant indicators and recessive indicators have different importance. This paper employs AHP to get the weight of indicators.

First of all, construct the judgment matrix A:

$$A = \begin{bmatrix} & r_1 & r_2 & \cdots & r_n \\ r_1 & a_{11} & a_{12} & \cdots & a_{1n} \\ r_2 & a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ r_n & a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{12}$$

a_{ij} Refers to relevant importance of indicator r_i to indicator r_j. The judgment scale adopts 1-9 ratio scale, as is shown in Table 4.

Table 4. Judgment Ratio Scale

Ratio scale a_{ij}	Meanings
1	r_i is as important as r_j
3	r_i is slightly more important than r_j
5	r_i is more important than r_j
7	r_i is much more important than r_j
9	r_i is extremely more important than r_j
2, 4, 6, 8	In between
Reciprocal value	$a_{ij} = 1/a_{ji}$

The weight of indicator r_i is:

$$w_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \Big/ \sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \tag{13}$$

If it is in line with the consistency, then we can get the weight sequence of indicators $W = (w_1, w_2, \cdots, w_n)$. There is:

$$\begin{cases} CI = \left(\lambda_{max} - n\right) / n - 1 \\ CR = CI / RI \end{cases} \tag{14}$$

Where, λ_{max} the maximum eigenvalue of judgment A.

3.4 The Realization of Grey Relational Model for Scientific Research Ability on Music

After the weight and grey relational coefficient are acquired, the grey relational degree σ_i^{Rh} of hardware features is:

$$\begin{cases} \sigma_i^{Rh} = w_{Rh_1} * \sigma_i^{Rh_1} + w_{Rh_2} * \sigma_i^{Rh_2} \\ \sigma_i^{Rh_1} = w_{Rh_1^{dom}} * \sum_{j=1}^{3} \left(w_{Rh_{1-j}^{dom}} * \zeta_{ij}^{Rh_1^{dom}} \right) + w_{Rh_1^{rec}} * \sum_{j=1}^{3} \left(w_{Rh_{1-j}^{rec}} * \zeta_{ij}^{Rh_1^{rec}} \right) \\ \sigma_i^{Rh_2} = w_{Rh_1^{dom}} * \sum_{j=1}^{4} \left(w_{Rh_{2-j}^{dom}} * \zeta_{ij}^{Rh_2^{dom}} \right) + w_{Rh_1^{rec}} * \sum_{j=1}^{5} \left(w_{Rh_{2-j}^{rec}} * \zeta_{ij}^{Rh_2^{rec}} \right) \end{cases} \tag{15}$$

Where, $\sigma_i^{Rh_1}$, $\sigma_i^{Rh_2}$ refer to first class grey relational degree; w_{Rh_1} , w_{Rh_2} , $w_{Rh_1^{dom}}$, $w_{Rh_1^{rec}}$, $w_{Rh_{1-j}^{dom}}$ and $w_{Rh_{1-j}^{rec}}$ are weight of indicators in the corresponding layer.

The grey relational degree σ_i^{Rs} of software features is:

$$\begin{cases} \sigma_i^{Rs} = \sigma_i^{Rs_1} = w_{Rs_1^{dom}} * \sigma_i^{Rs_1^{dom}} + w_{Rs_1^{rec}} * \sigma_i^{Rs_1^{rec}} \\ \sigma_i^{Rs_1^{dom}} = \sum_{j=1}^{6} \left(w_{Rs_{1-j}^{dom}} * \zeta_{ij}^{Rs_1^{dom}} \right) \\ \sigma_i^{Rs_1^{rec}} = \sum_{j=1}^{5} \left(w_{Rs_{1-j}^{rec}} * \zeta_{ij}^{Rs_1^{rec}} \right) \end{cases} \tag{16}$$

Where, $\sigma_i^{Rs_1}$ refer to first class grey relational degree; $\sigma_i^{Rs_1^{dom}}$ and $\sigma_i^{Rs_1^{rec}}$ refer to second class grey relational degree. $w_{Rs_1^{dom}}$, $w_{Rs_1^{rec}}$, $w_{Rs_{1-j}^{dom}}$ and $w_{Rs_{1-j}^{rec}}$ are weight of indicators in the corresponding layer.

The comprehensive weighed grey relational degree σ_i is:

$$\sigma_i = w_{Rh} * \sigma_i^{Rh} + w_{Rs} * \sigma_i^{Rs} \tag{17}$$

Rank according to comprehensive weighed grey relational degree from the biggest to the smallest. Thus, scientific research ability on music is measured.

4. Case Study

Periodical performance reviews for talents from an academy of music is studied as the case to check the model and the algorithm. Under the evaluation index system, obtain the value of quantity of indicators. And obtain weighed of indicators based on AHP, as is shown in Table 5 and 6.

Table 5. Value of Quantity of Indicators of Hardware Features

First class indicators	Weight	Second class indicators	Weight	Third class indicators	Initial value of quantity		
					Object I	Object II	Object III
Rh_1	0.333	Rh_1^{dom}	0.751	Rh_{1-1}^{dom}	0.9	0.9	1.0
				Rh_{1-2}^{dom}	0.9-1.0	0.7-0.8	0.8-0.9
				Rh_{1-3}^{dom}	0.8-0.9	0.6-0.7	0.9-1.0
		Rh_1^{rec}	0.249	Rh_{1-1}^{rec}	0.9-1.0	0.8-0.9	0.8-0.9
				Rh_{1-2}^{rec}	0.8-0.9	0.8-0.9	0.9-1.0
				Rh_{1-3}^{rec}	0.8-0.9	0.9-1.0	0.7-0.8
Rh_2	0.667	Rh_2^{dom}	0.751	Rh_{2-1}^{dom}	6	8	8
				Rh_{2-2}^{dom}	36	24	26
				Rh_{2-3}^{dom}	3	2	1
				Rh_{2-4}^{dom}	4	3	4
		Rh_2^{rec}	0.249	Rh_{2-1}^{rec}	0.9-1.0	0.8-0.9	0.7-0.8
				Rh_{2-2}^{rec}	0.9-1.0	0.7-0.8	0.8-0.9
				Rh_{2-3}^{rec}	0.7-0.8	0.9-1.0	0.8-0.9
				Rh_{2-4}^{rec}	0.9-1.0	0.8-0.9	0.8-0.9
				Rh_{2-5}^{rec}	0.9-1.0	0.7-0.8	0.8-0.9

Table 6. Value of Quantity of Indicators of Software Features

Second class indicators	Weight	Third class indicators	Initial value of quantity		
			Object I	Object II	Object III
Dominant ability Rs_1^{dom}	0.751	Rs_{1-1}^{dom}	0.7-0.8	0.9-1.0	0.8-0.9
		Rs_{1-2}^{dom}	0.9-1.0	0.6-0.7	0.8-0.9
		Rs_{1-3}^{dom}	0.8-0.9	0.9-1.0	0.6-0.7
		Rs_{1-4}^{dom}	0.9-1.0	0.6-0.7	0.8-0.9
		Rs_{1-5}^{dom}	0.35	0.28	0.24
		Rs_{1-6}^{dom}	0.05	0.10	0.12
Recessive ability Rs_1^{rec}	0.249	Rs_{1-1}^{rec}	0.9-1.0	0.8-0.9	0.7-0.8
		Rs_{1-2}^{rec}	0.8-0.9	0.8-0.9	0.9-1.0
		Rs_{1-3}^{rec}	0.7-0.8	0.9-1.0	0.8-0.9
		Rs_{1-4}^{rec}	0.9-1.0	0.8-0.9	0.7-0.8
		Rs_{1-5}^{rec}	0.9-1.0	0.8-0.9	0.6-0.7

According to grey relational analysis model for scientific research ability proposed in this paper, we can get grey correlation coefficient of different layers, as shown in Table 7 and 8.

Table 7. Grey Relational Coefficient of Indicators of Hardware Features

First class indicators	Relational degree			Second class indicators	Relational degree			Third class indicators	Relational degree		
	Object I	Object II	Object III		Object I	Object II	Object III		Object I	Object II	Object III
Rh_1	0.222	0.156	0.259	Rh_1^{dom}	0.501	0.259	0.626	Rh_{1-1}^{dom}	0.500	0.500	1.000
								Rh_{1-2}^{dom}	1.000	0.333	0.500
								Rh_{1-3}^{dom}	0.500	0.250	1.000
				Rh_1^{rec}	0.166	0.208	0.152	Rh_{1-1}^{rec}	1.000	0.500	0.500
								Rh_{1-2}^{rec}	0.500	0.500	1.000
								Rh_{1-3}^{rec}	0.500	1.000	0.333
Rh_2	0.554	0.307	0.378	Rh_2^{dom}	0.617	0.328	0.450	Rh_{2-1}^{dom}	0.286	1.000	1.000
								Rh_{2-2}^{dom}	1.000	0.231	0.265
								Rh_{2-3}^{dom}	1.000	0.231	0.130
								Rh_{2-4}^{dom}	1.000	0.286	1.000
				Rh_2^{rec}	0.216	0.133	0.116	Rh_{2-1}^{rec}	1.000	0.500	0.333
								Rh_{2-2}^{rec}	1.000	0.333	0.500
								Rh_{2-3}^{rec}	0.333	1.000	0.500
								Rh_{2-4}^{rec}	1.000	0.500	0.500
								Rh_{2-5}^{rec}	1.000	0.333	0.500

Table 8. Grey Relational Coefficient of Indicators of Hardware Features

Second class indicators	Relational degree			Third class indicators	Grey relational coefficient		
	Object I	Object II	Object III		Object I	Object II	Object III
Rs_1^{dom}	0.605	0.396	0.249	Rs_{1-1}^{dom}	0.333	1.000	0.500
				Rs_{1-2}^{dom}	1.000	0.250	0.500
				Rs_{1-3}^{dom}	0.500	1.000	0.250
				Rs_{1-4}^{dom}	1.000	0.250	0.500
				Rs_{1-5}^{dom}	1.000	0.333	0.242
				Rs_{1-6}^{dom}	1.000	0.333	0.146
Rs_1^{rec}	0.191	0.149	0.120	Rs_{1-1}^{rec}	1.000	0.500	0.333
				Rs_{1-2}^{rec}	0.500	0.500	1.000
				Rs_{1-3}^{rec}	0.333	1.000	0.500
				Rs_{1-4}^{rec}	1.000	0.500	0.333
				Rs_{1-5}^{rec}	1.000	0.500	0.250

With the weight of hardware features and software features taken into account, we can get the comprehensive weighed grey relational degree of each indicator, namely, $\sigma_1 = 0.786$, $\sigma_2 = 504$, $\sigma_3 = 503$. By comparing the three, we can judge that object I is the optimal one and conductive to later research.

5. Conclusion

This paper proposes an optimized evaluation index system for scientific research ability on music and conducts the analysis from the scientific, comprehensive and systematic view. According to grey theory, a grey relational analysis model is established based on AHP. Its efficacy has been proved through a case study. Compared to previous research, this paper innovates in two ways. One is the construction of the evaluation index system. The other is the model is simple, practical and reliable. It is easy to achieve on the computer. With the algorithm and the model, the research focus shall be shifted to realize the evaluation through the intelligent design system on the computer. With computer-aided analysis, the evaluation of scientific research ability on music can be better fulfilled.

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