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Analysis of Music Evolution based on Hybrid AHP Model

Jingjing Hu[1], Zhan Si[2], Meiqi Zhang[3,*], Mingliang Song[4]

[1]School of computer science and Engineering, Northeastern University, Shenyang 110167, China

[2]College of Chemical Engineering, Shenyang University of Chemical Technology, Shenyang 110027, China

[3]College of business administration, Chengdu Jincheng College, Chengdu 610097, China

[4]School of Information Engineering, Shenyang University of Chemical Technology, Shenyang 110027, China

Abstract

Music, as an important part of human cultural heritage, has a profound impact on human life and changes with the evolution of society. Therefore, we develop a method to quantify the evolution of music, and propose an improved hybrid AHP model, which is used to analyze the evolution of music and artists over time in segments. With the help of All_Music public data set, this paper analyzes the influence of previous music on new music and music artists, describes the changes of music genres, and explains how music evolves with the changes of society. This work has certain enlightening significance for the fields of music, history and social sciences.

Keywords

Analytic Hierarchy Process; Process Eigenvector; Musical Artist; Genre; Influence.

1. Introduction

Music has been formed and developed in the development of human society, and its evolutionary process complements and develops together with the progress of human civilization [1]. In the process of exploring the development of society, exploring the role of music has also become an important point to study the development of history. From another dimension, the evolution and development of music is the result of the mutual influence of music artists and the influence of social phenomena on music creation. Due to the similarity of music, the influence factors and the degree of influence among music artists can be captured by analyzing the influence of songs on the network and the music characteristics of songs. Alternatively, a better understanding of the approach that music evolves over time might be indicated.

2. Our Work

In this article, we make some assumptions:

1. music influence network is a directed network.

2. The abstracted data on the musical characteristics of each artist and song is reliable.

To improve the efficiency of the model and make the model application results can better reveal the law of music development, we proposed an improved MIXED AHP model, which was used for section analysis and the evolution of music and artists over time. The important points of each section are data pre-processing, data selecting and orderly data analysis. The similarity of different artists and genres was evaluated and represented by equilibrium coefficient and correlation coefficient. The empirical results show that the analysis and trend prediction of

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music characteristics can reveal the regular and predictable development of music in history, and has a good correlation with the development of the artist. On this basis, the data processing method of principal component analysis (PCA) and the similarity measurement parameters is combined to the evaluation model of music feature influence. We take an actual data set as the minimum unit, make a cluster analysis of processable data, and work out an influence evaluation system.

The specific work is as follows:

1. Build the model and form the 'music influence' network, establish a similarity estimation model and an analytic hierarchy model.
2. Preliminary processing of the data.
3. Determine solution ideas according to different solving problems and make instance analysis.

3. Establishment of Model

3.1. Build Music Network Maps

The music network map is taken as the research object, and the node attributes of the network are marked by the music characteristics. The sub-net of the network is extracted as the application scope of the model, and the similarity measurement model and improved analytic hierarchy process are combined to explore the music influence sub-network, so as to improve the reliability of the model.

At the same time, the method of principal component analysis and factor analysis is applied to the data processing, and the R clustering of data is realized by using SPSS software to verify the accuracy of data dimension reduction, and the Q clustering analysis of the data is done, which is used as the basis for evaluating the similarity model together with the genres.

3.1.1. Music with Artists as Nodes Influences the Network Graph

An artist's network graph defined by musical features can indirectly reflect the influence of musical features themselves. Music affects the network diagram, as shown on 'influence_data' for processing, because the sample size is relatively large data sets, all data are processed, process the results would not intuitive and clear, here we will use on the study of music influence to improve the level of model in the network analysis comparatively typical local sub-net. The sample network diagram can roughly reflect the relationship between artists.

Figure 1. Network of influences between artists

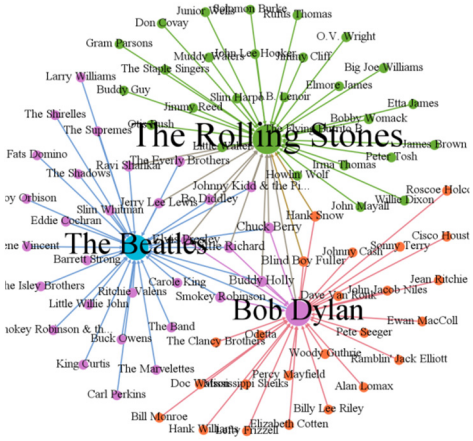

Figure 2. The Influence of 500 Random Artist

ISSN: 2688-9323

3.1.2. Weighted Genres Influence the Network Graph

Artists are classified according to their different genres. Genre can be indirectly defined by the musical characteristics of artists. Therefore, music characteristics can be studied in reverse with the help of existing music genres, which can be used as an application example of similarity evaluation model to calculate the musical influence reflected by the influence of genres. The following conclusion is drawn from the 'influence_data' data set.

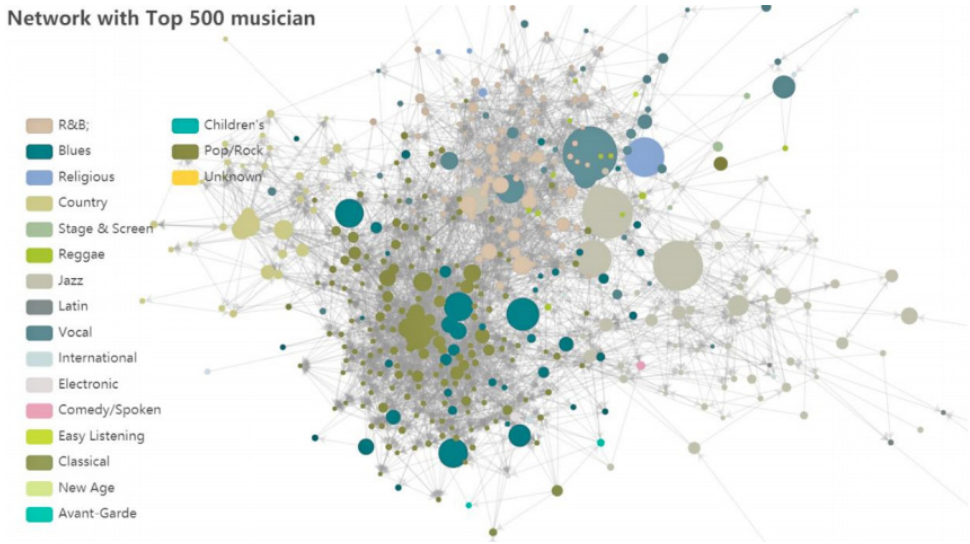

Figure 3. Influence Network with Weight

As the figure above, a node in the network represents an artist, and the size of the node represents the influence of the artist. The greater the influence, the larger the node.

3.2. Similarity Evaluation Model

3.2.1. Construction and Processing of Music Index System

The index system is composed of a series of indexes that can fully reflect the essential attributes or characteristics of the evaluated object, which is the premise and basis for the evaluation of the research object. The rationality and comprehensiveness of the index system directly affect the accuracy of the evaluation results. Since all the characteristics related to music have been given, this paper will choose and reject the corresponding indicators in the analysis of specific problems, and the data used in the evaluation model will be more practical and accurate.

The music feature data in the data set given by the topic are combined to form the music feature description space vector $M=[m_1, m_2, m_3, ..., m_n]$, which is used as the music feature description for artists, songs and genres [2]. The components of vector M are not the same for different data sets. At the same time, standardization and dimensionality reduction are carried out for the specific application of personality indicators to reduce the auto-correlation of features, enhance the effect of the model, facilitate data visualization and avoid model over-fitting.

3.2.2. Similarity Evaluation Model

The measurement of similarity is generally divided into two methods: distance measurement method and similarity function method [3]. in this paper, two measurement methods are combined to improve the accuracy of similarity measurement. The whole model uses the square Euclidean distance to calculate the distance between two vectors, and uses the correlation coefficient to describe the correlation between two vectors. According to the characteristics of vectors in the space described by music features, the similarity degree of two vectors cannot be determined only by the distance between two vectors, and the distance

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cannot reflect the directivity, that is, the dimensional difference of the vectors themselves. In fact, when we say that music has similarity, it means that the overall characteristics of music are similar, which can be reflected by the similarity function. So this article use the compromise strategy, through the calculation of Euclidean distance of two vector calculation of two vectors on the space distance, through the calculation of similarity function of two vector similarity degree (parallel), by a specific balance the relationship between the balance coefficient, finally combined with the comprehensive results of punish coefficient serve as two different music feature similarity between objects, specific formula model are defined as follows:

$$\eta = \alpha \cdot D(x,y) + \beta \cdot \frac{1}{sim(x,y)} + \gamma \tag{1}$$

$$D(x,y) = \sum_{i=0}^{n} (x_i - y_i)^2 \tag{2}$$

$$sim(x,y) = \frac{cov(x,y)}{\sqrt{cov(x,x) \cdot cov(y,y)}} \tag{3}$$

$$cov(x,y) = \frac{1}{n-1} \sum_{i=0}^{n} (x_i - \overline{x}) \cdot (y_i - \overline{y}) \tag{4}$$

cov(x, y) is the final similarity index. The similarity between vector and itself is 1, and the similarity between different vectors is greater than 1. The larger the similarity index value is, the smaller the similarity between two vectors is.

3.3. Hierarchical Model

Analytic Hierarchy Process (AHP) is an evaluation method that combines qualitative and quantitative analysis methods for multi-objective decision making [4] .Processing 'Influence_data' in this paper, by constructing "influencers" and "followers" and its related feature index of the hierarchical analysis model establish judgment matrix, then by calculating the maximum eigenvalue and corresponding eigenvector of the judgment matrix, determine the relative "influence degree" of various music indexes is determined., which is to explore the influence of indicators have bigger influence on the followers. Finally, test the consistency of the result.

3.3.1. Model Application Steps

1.Establishment of hierarchical structure model.

2.Construction of judgment matrix.

3. Calculation of hierarchical single sorting and its consistency test.

4. Calculation of hierarchical total ranking and its consistency test.

5. If necessary, the judgment matrix and hierarchical ordering model should be modified and adjusted.

3.3.2. Establishment of Judgment Matrix

Assume a certain level is $a = [a_1, a_2, \ldots, a_n]$, compare a_i with a_j, then determine the degree of importance of each index in this layer to an index in its upper layer, derive the judgment matrix A, a_{ij} means that the importance of the a_i to a_j. The judgment scale is the quantitative scale of the relative importance.

ISSN: 2688-9323

Table 1. Scale Meaning of AHP

Determine scale	definition
9	The i factor is absolutely more important than the j factor
7	The i factor is much more important than the j factor
5	The i factor is more important than the j factor
3	The i factor is slightly more important than the j factor
1	The i factor is just as important as the j factor
2 4 6 8	The importance of factors i and j is between the two adjacent judgment scales mentioned above

A judgment matrix of order n, $A(a_{ij})_{n\times n}$, was established according to the judgment scale.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = (a_{ij})_{n\times n} \text{ ,s. t. } a_{ij} > 0; a_{ij} = 1/a_{ji}\,; a_{ii} = 1 \quad (5)$$

3.3.3. Determination of Importance

According to the similarity model, the similarity between this layer and an index of the upper layer is respectively calculated. Based on this, and according to the expert group judgment, the pairwise comparison of the importance of music index from top to bottom is made by connecting relevant experts, and the judgment matrix is constructed.

3.3.4. Hierarchical Sorting and Consistency Test

After the construction of the single-layer judgment matrix, the maximum eigenvalue λ_{max} of A and its corresponding eigenvector ξ were calculated and judged, and then the eigenvector was normalized to obtain the ranking weight of the importance of each evaluation index in the same layer relative to an index in the upper layer, and the hierarchical single ranking was conducted. Consistency test is needed for the constructed judgment matrix. According to the principle of AHP, the difference between λ_{max} and n can be used to test the consistency.

The calculation consistency index is defined as:

$$C.I. = \frac{\lambda_{max}}{n-1} \quad (6)$$

The consistency index CR was defined as:

$$CR = \frac{C.I.}{C.R.} \quad (7)$$

C.R. is the randomness index in the formula.

When CR is less than 0.1, the consistency of the judgment matrix is within a reasonable range; otherwise, it should be modified [4]. for the judgment matrix whose order is no more than 2, the consistency test is not needed. In order to obtain the ranking weight of each index of the lowest level for the general target, the hierarchical total ranking should also be calculated, and the total ranking weight should be combined from top to bottom to combine the single ranking weight of the hierarchical. Hierarchy total sorting also needs to do consistency test, the test method is the same as above.

ISSN: 2688-9323

3.3.5. Classification of Music Index Clustering Benchmark

Due to the same level of music index correlation, in order to make the evaluation result is reasonable and have comparable, through R type cluster method, the index of music, the music characteristic index dimension reduction, each dimension can be regarded as a benchmark, to the maximum extent after considering the dimension reduction factor reflects the combination of the original variables, take the factor variable number is 4, the fourth factor variable FAC_1, FAC_2, FAC_3, FAC_4.

3.3.6. Indicator Status Value

The ratio of the original index to its upper index is defined as the index state value.

If the index is a positive index, the status value of the index I is:

$$S_{pos\_i} = \frac{S_{orig\_i}}{S_{base\_i}} \times 100 \tag{8}$$

S_{orig_i} the original value of item I, S_{base_i} is the reference value of the evaluation index in item i.

If the indicator is a reverse indicator, the indicator state value becomes:

$$S_{pos\_i} = \frac{S_{base\_i}}{S_{orig\_i}} \times 100 \tag{9}$$

3.3.7. Comprehensive Score

Assume that the total ranking weight of each index at the bottom level to the general target calculated by AHP is $W = [w_1, w_2, \dots, w_2]$. The status value of each indicator is $S = [s_1, s_2, \dots, s_2]^T$. Then the final comprehensive score is$V = WS = \sum_{i=1}^{n} w_i s_i$.

4. Model Implementation

4.1. Artist Similarity Analysis

To compare the similarity between the same genre and the similarity between different genres, we select artists from the pop/rock category for similarity measurement (e. g. choose the artist_id which is equal to 74), and then extract the other types of artist data for similarity measurement calculation.

Table 2. Comparison between genres artists

Genre	Artist_id	FAC1_1	FAC2_1	FAC3_1	FAC4_1	Similarity
Pop/Rock	74	1.039687	-0.01223	0.709929	-0.06615	
Pop/Rock	335	-0.0391	-0.18649	-0.62828	1.038417	2.369845
Pop/Rock	441	1.022854	-0.09526	0.082188	-0.42156	1.330452
Pop/Rock	589	-1.5514	0.387093	-0.70248	1.255867	9.210854
Pop/Rock	1098	1.267267	-1.1542	-0.22958	-0.11569	10.91131
Pop/Rock	1113	0.995133	0.003946	-0.51274	0.262517	2.993745
Pop/Rock	1498	1.440766	-0.73703	0.115866	-1.30348	5.601924
R&B	1190	-0.41945	0.442022	-0.24101	0.273307	6.342668
Classical	1589	-4.04427	-1.81976	-0.68314	-0.11982	20.51711
Country	1433	0.36685	0.390203	-0.62249	-0.03533	22.81016
Electronic	1611	0.39776	1.852658	-0.58626	-0.02023	3.382045
International	1266	-2.13486	0.262333	0.956323	-2.34249	28.00236
jazz	1163	-0.70236	-1.66255	-0.00584	1.526097	19.54945
Latin	1097	0.381416	1.830373	0.084686	0.876891	11.44112

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In the similarity calculation formula, let α be 1, β be 1, γ be 0. According to the similarity measurement formula, the smaller the calculation result is, the more similar the two artists are. The similarity between the artists and themselves is 1, and the absolute value of the similarity between different artists is greater than 1. The larger the similarity measurement value is, the smaller the similarity is. The final data is shown in Table 2.

In Table 2, each row of values is calculated for similarity with the values in the first row, and the final result is presented in the last column. According to the observational data, artists of the same type are more similar than artists of different types.

4.2. Genre Similarity Analysis

In addition, we calculate the similarities of a genre with each other and showed the result with the heat-map. As can be seen from the above two figures, Latin, R&B, Pop/Rock and Country are the genres with high similarities to each other, while Comedy/Spoken has relatively different musical characteristics compared with other genres, and it is clustered finally.

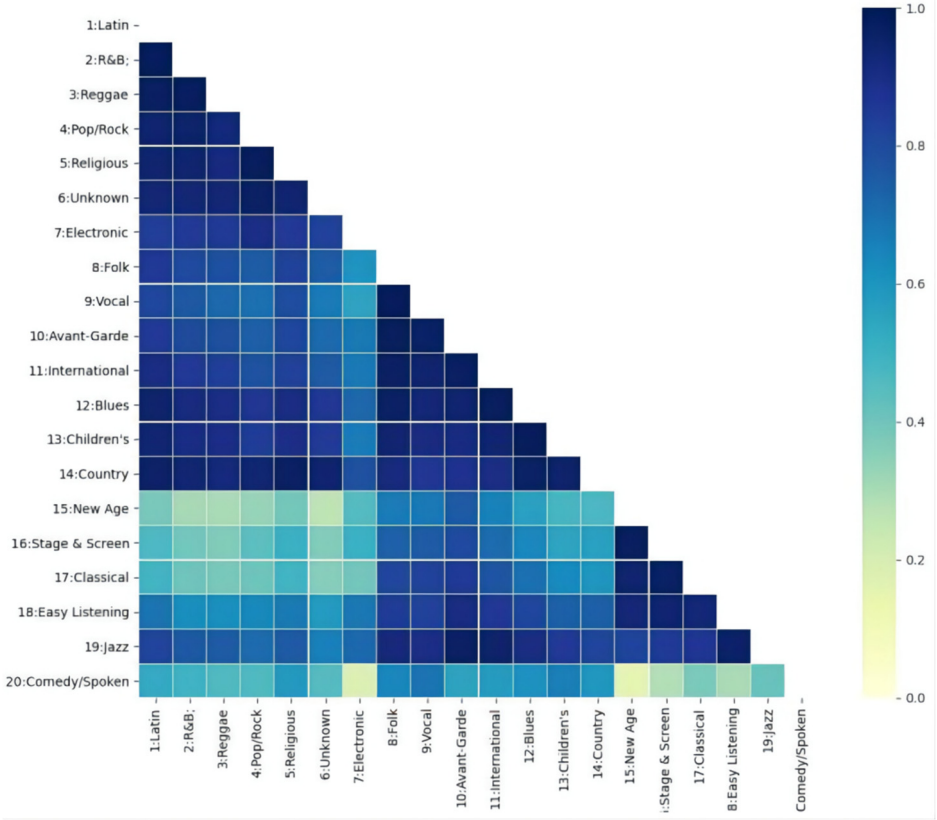

Figure 4. Similarity between Genres

The following conclusions can be drawn from the data in these figures.

1. Pop/Rock, Country and Internetional all have strong danceability.
2. Pop/Rock is artists' most inspired area of music.
3. Pop/Rock, Electronic, Comedy/Spoken and et al. have higher energy values than Jazz, Vocal, New Age and Classical and et al.
4. Valence values of Stage&Screen, New Age and Classical were lower in all genres.
5. The tempo, mode and key values cannot be used as a genre distinguishing component.
6. Comedy/Spoken has the strongest liveness and speechiness characteristic.
7. The more popular genres of music among all genres are Pop/Rock, R&B, Electronic and Reggae.

ISSN: 2688-9323

8. Pop has the largest number of artists, but it is not the most popular category. Being followed by artists does not affect the preferences of the public.

4.3. Influencer Analysis

In order to judge whether the "influencer" influences the creation of the followers in a practical sense, we take Artist -- an artist whose ID is 335 as an example and compare his values with those of his followers and 'influencers'. The comparison results are shown in Table 3.

Table 3. Comparison of influencers and followers

Artist_id	Similarity	Type
335	1	
94792	4.2146144	follower
99508	11.147283	follower
355412	7.2927477	follower
681154	7.6529265	follower
803009	24.062824	follower
862855	3.1987253	follower
911827	2.300763	follower
998969	5.0612926	follower
71209	8.481074	influencer
397880	2.2597	influencer
208582	3.4193042	influencer
66915	2.9885446	influencer
25462	3.564787	influencer
378288	3.3541333	influencer
91438	12.532785	influencer
838272	21.063397	influencer

As can be seen from the table, an 'influencer' can influence his followers in a practical sense, but this does not necessarily mean that the music created by the followers is very similar to that of the influencer. According to the analysis of the characteristics of various music genres in Case One, we can also get the influence degree of different music characteristics on music genres.

By looking at each element of the network diagram, combining with statistical analysis of the data and using network operations research and other knowledge, we obtained the ranking of the influence of artists.

Table 4. Sort of artist's influence

Artist_name	Artist_id	Influencer_count	Follower_count
The Beatles	754032	615	31
Bob Dylan	66915	389	29
The Rolling Stones	894465	319	39
David Bowie	531986	238	25
Led Zeppelin	139026	221	24
Jimi Hendrix	354105	201	32
The Kinks	100160	192	8
The Beach Boys	41874	186	13
Hank Williams	549797	184	3

ISSN: 2688-9323

In the above table, the ranking of influences is based on the number of followers an artist has over the span of a year in the data set provided by the question. From 'influence_data', it can be concluded that there are 31 artists whose artist_id is 754032. The similarity measurement of these 31 artists and The Beatles is conducted to determine the importance of the influencer of The Beatles to The Beatles, and the influencer is substituted into the hierarchical model.

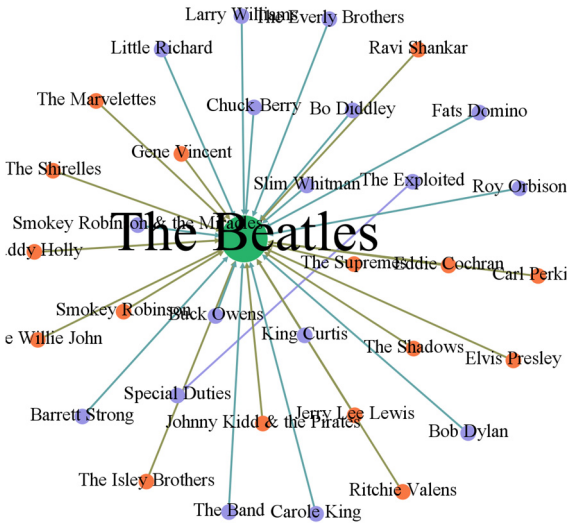

Figure 5. Sub-net map of the most influential artist

To analyze the choice of the most influential artists, through studying the features of other artists on the degree of its influence, to reflect the music influences of Internet on the artists, artists, The Beatles influence is bigger, so its characteristics, according to the estimate should be evident in the representative, more practical significance.

In this case analysis, the various variable elements are divided into three layers, among which the music features are in the scheme layer, the influencer are in the criterion layer, and the followers are in the destination layer. According to the similarity model and expert group judgment, the specific weight of each layer is determined. k_{ij}reflects the importance of the JTH music index on the I influencer.$w_i$reflects the importance of item I on followers.

The influence of music is shown in the following model:

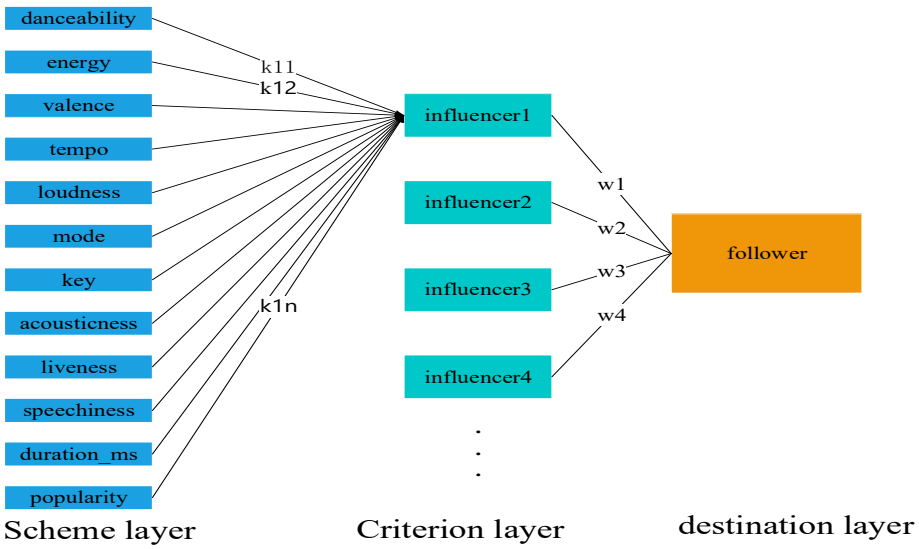

Figure 6. The influence model of music

ISSN: 2688-9323

For music feature layer due to the original music feature variables and more dimensional inconsistencies, we make the data easy to handle and better reflect characteristic, therefore the first to feature do standardized processing, and then using the principal component analysis and factor analysis, and other R type cluster method to dimension data, use various methods to demonstrate the validity of classification here, when we analysis using data obtained by the principal factor analysis research of follow-up work. The four variables after dimensionality reduction are FAC1, FAC2, FAC3 and FAC4 respectively. Meanwhile, the similarity model is used to screen out the top five influencers that are most similar to The Beatles from the numerous influencers of The Beatles (since the fifth influencer is used after that, the other influencers are less similar to The Beatles).

The model is simplified as follows:

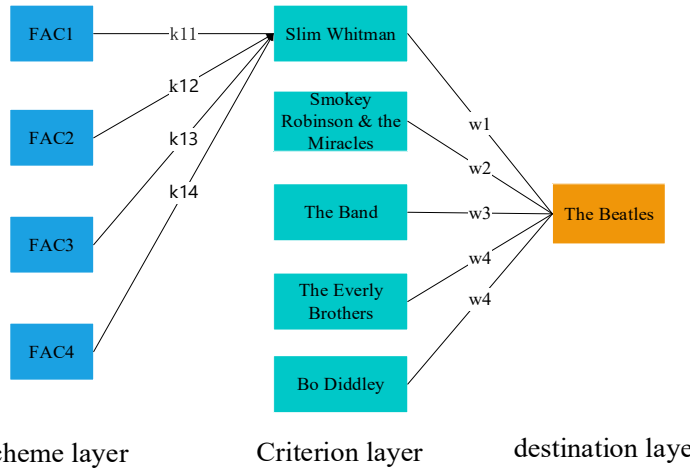

Figure 7. The simplified model of music influence

First, study the Criterion layer and Destination layer, compare and score two by two, and get the judgment matrix:

$$A1 = \begin{bmatrix} 1 & 2 & 3 & 6 & 7 \\ 1/2 & 1 & 3 & 5 & 6 \\ 1/3 & 1/3 & 1 & 4 & 5 \\ 1/6 & 1/5 & 1/4 & 1 & 1 \\ 1/7 & 1/6 & 1/5 & 1 & 1 \end{bmatrix} \tag{10}$$

Normalization and consistency test were carried out on the judgment matrix, and Ci =0.0387 and Cr =0.0345 were obtained. Therefore, the consistency of the matrix was acceptable. The ranking of the influence layer to the follower layer is obtained by single sorting: [0.4257, 0.3055, 0.1676, 0.0534,0.0478].

Finally,the hierarchical single sorting of Scheme layer elements for influencer is obtained in the same way.It can be concluded that in The music influence network between artists, The most infectious musical features are Danceability, Tempo and Valence. Meanwhile, according to the network diagram, the most influential artist is The Beatles from the perspective of followers. It concludes that Slim Whitman had the greatest influence on The Beatles.

4.4. Music Revolution Analysis

For the analysis of music evolution process, we use the method of data statistics to analyze the rise and decline of a genre. Firstly, we create a method to judge the rise and decline of a genre:

ISSN: 2688-9323

Sum over the popularity of each song in the genre and take the result as the popularity of the genre. The formula is as follows:

$$Genre\ popularity = the\ sum\ of\ popularity\ of\ each\ song\ in\ the\ genre\ during\ this\ period \quad (11)$$

In-depth analysis shows that the change of total popularity cannot reflect the rise and decline of a genre. The main influencing factor of popularity is the times of playing during a certain period of time. The development of science and technology and the change of the number of musicians can greatly affect the popularity of the genre. Therefore, during a certain time, the proportion a certain genre takes in all genres' popularity is taken as a measure to judge the rise and decline of genres, and the formula is as follows:

$$Genre\ Rise\ and\ decline = Genre \cdot \frac{Popularity}{Total} \cdot Popularity \quad (12)$$

Make a curve of the rise and decline of genres with time, as shown in the following figure:

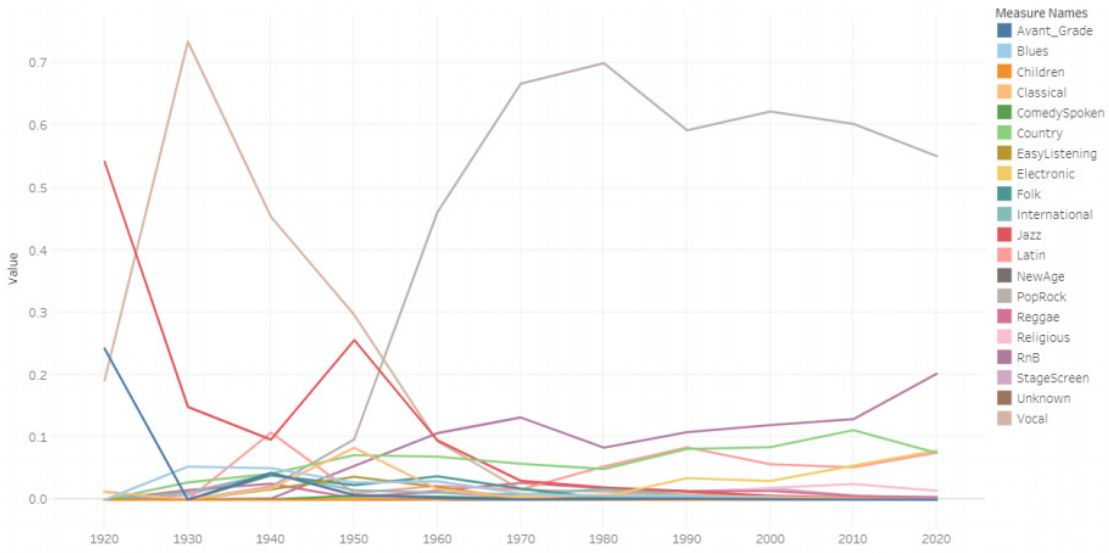

Figure 8. The Rise and Fall Degree of All Genres from 1921 to 2020

Analyzing the images, we can conclude the following viewpoints:

1. In the last century, jazz genre prevailed, vocal and international were also popular, and other genres of music only take a small proportion.
2. In the 1920s, vocal flourished, while jazz and international declined rapidly.
3. After entering the 1930s, vocal declined after a short period of glory. Latin gradually developed during this period and reached its peak in the late 1930s, but even at its peak, the popularity of this genre was still small.
4. After entering the 1940s, jazz ushered in its revival, and classical began to rise. In the late 1940s, these two schools reached their peak. At the same time, the pop/rock genre began to flourish, developing as fast as rockets, and began to occupy a large proportion of popularity in the 1960s. Since then, there has been no large-scale change in music genres' popularity.
5. From the figure, we can also tell that R&B, country and electronic genres are slowly rising in twists and turns, while Folk and easy-listening genres are basically stable.

ISSN: 2688-9323

In order to further study the changes of genres with time, we analyze the similarity of all songs every five years. Since each song is described by 14 parameters, in order to have a better visualization, we carry out principal component analysis on its parameters, reduce the dimensions of parameters and draw two-dimensional images. Selecting images of typical ages for analysis Selecting images of 1940 and 1945 are as follows:

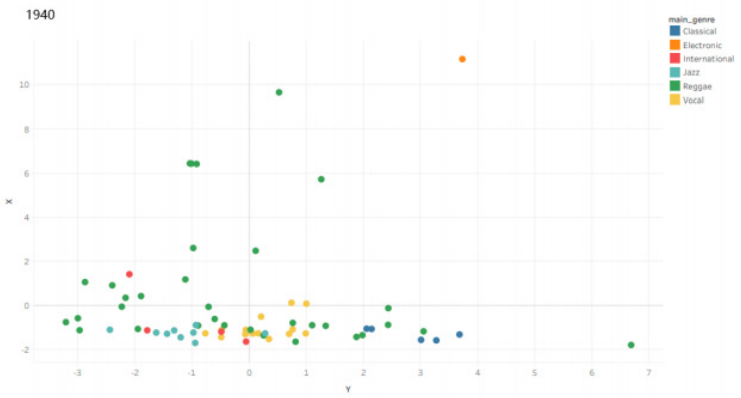

Figure 9. The Distribution of Music After PCA Dimension Reduction

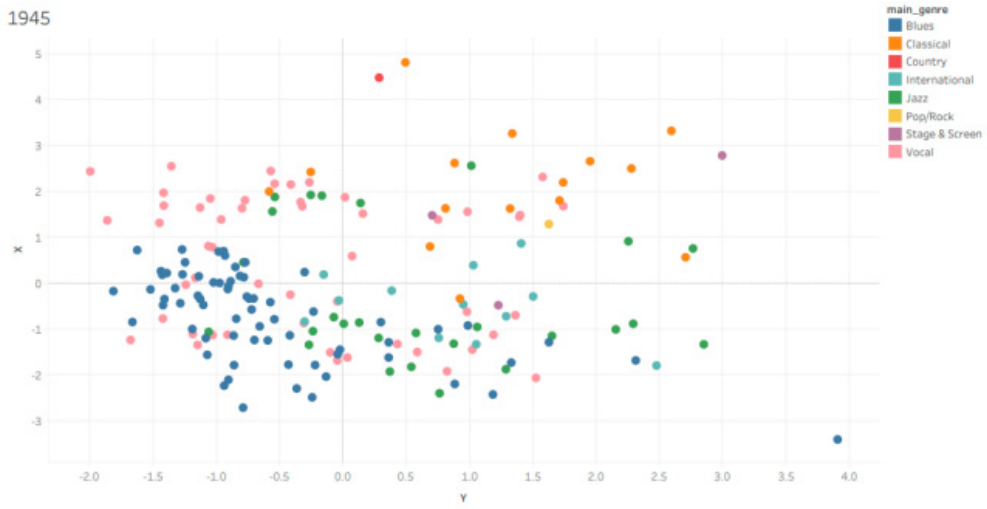

Figure 10. The Distribution of Music After PCA Dimension Reduction

We can find that the music session won another vigorous development in 1945. By consulting historical data, we can find that a world war took place in 1940, which caused serious damage to the development of music. In 1945, when the war ended and the world restored a culture of peace, the number of songs surged during this period [5].

At the same time, we found that electronic music appeared in 1940. Looking up the music history [6], we find that LesPaul made a historic reform to electric guitar in 1940, which solved the sound effect problems existing before and reduced the volume of electric guitar, making it more portable. Therefore, electric guitar was popularized.

Then, the curve of a certain genre's parameters changing with time is analyzed. Taking pop/rock as an example, the main influencing parameters of pop/rock are determined by entropy analysis, and then we draw the curve of main parameters with respect to time.

ISSN: 2688-9323

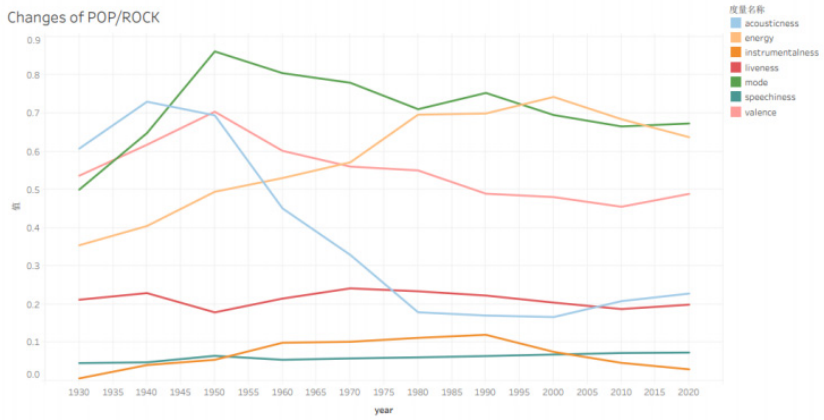

Figure 11. The Changes of Some Important Indices about POP/ROCK from 1930 to 2020

We can tell those changes in pop/rock related factors can also reflect changes in the environment. First of all, we can see that acousticness declined obviously in 1940, which we think was caused by the promotion of electric guitar during this period. Similarly, from 1940 to 1945, people's negative emotions increased due to the World War II, which led that liveness declined significantly. By reason and the foregoing, we believe that our model can reflect the influence of environmental changes on music.

5. Conclusion

By constructing music network model, this paper to study the effect of music and its change law thesis mainly adopts the hierarchical analysis and similarity assessment model of comprehensive model to realize the research of the network, has good adaptability, can expand the scope of its use This paper adopts the influence of the evaluation model can be used to implement to other similar network is analyzed, by means of hierarchical analysis to grasp the main influencing factors, so as to realize the comprehensive grasp the law of the development of the network.

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