



Analysis of the Application of Popular Singing in Musical Singing in a Multimedia Environment with Collaborative CAD

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Abstract. With the development of musicals, the singing methods of musicals have also gone through a long road of development. With the increase of musicals in people's lives, more and more people are involved in the study and performance of musicals, which has injected new vitality into the development of musicals. At the same time, people pay more and more attention to the unique singing methods of musicals. In the multimedia environment, this paper starts with analyzing musical singing methods and forms, the relationship between popular singing methods and musicals, and the application of popular singing methods in musicals with examples of musical singing. Based on this, a music feature extraction algorithm is proposed. In this algorithm, the pitch sequence of songs is extracted from humming segments and then transformed into a melody outline sequence after regularization, merging, and segmentation. Then, this sequence is transformed into melody contour features using the standard pitch difference table generated by standard pitch. This study will further improve the teaching of musical singing and lay a foundation for the formation of musical singing teaching modes with local characteristics.

Keywords: Multimedia; Musical; Feature extraction; Collaborative CAD

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1 INTRODUCTION

The musical drama is a musical performance theme that evolved from the operetta. Usually, in the process of musical performance, various songs are organically combined, and this mode presents different audio-visual experiences to the audience [16]. Different from popular music singing, musical singing is a relatively new musical form. And this form is getting more and more attention from the audience. Musicals are popular and developed in Europe. It first evolved from opera-love and operetta, integrating drama, music, singing, and dancing into one [8]. Musical singing styles are different, including operetta singing style, jazz-based singing style, country music-based singing style, rock music-based singing style, classical music and pop music fusion singing style,

pop music popular singing style, etc. [19]. With the increasing frequency of international exchanges and the collision between Eastern and Western cultures, musicals are widely spread and studied worldwide. In recent years, with the deepening of cultural exchanges between China and the West, more and more people have liked and loved musical singing, a unique way of expression, and have gradually participated in the learning process of musical singing. According to past musical performances, most musical performances have bel canto and pop [18], including musical singing and performance. Among them, the musical forms include classical, popular, and so on, and performing is more complex than singing alone. We should focus on three primary vocal skills when singing musicals: breathing, true and false voice conversion, and enunciation. At present, many art colleges are studying musicals. Studying the singing methods and performance forms of musicals is of great significance for understanding and recognizing musicals and then learning and mastering musicals better.

With the development of musicals, the singing methods of musicals have also gone through a long road of development. In the early days, the singing form of musicals was always based on bel canto [23]. With the advancement of people's aesthetic appreciation of musical singing, a single bel canto can no longer meet people's needs at the fundamental level. Therefore, to explore more possibilities and enrich the expressive techniques of musicals, singers began to study more musical singing methods. Thus, based on Bel Canto, musical shows diversified singing styles and performance forms in artistic form, musical form, and subject range [20]. Some singers began to try to combine bel canto with popular singing. The singing methods of musicals are from the original single bel canto, similar to operetta, to the coexistence of jazz, pop, rock, and other singing methods. On this basis, a mainstream musical method was formed, based on Bel Canto and integrated with various singing characteristics. This kind of singing method skillfully combines classical and modern, which makes the singing and teaching range of musicals wider and, therefore, breaks the traditional singing style and teaching mode of musicals [7]. Musical performance includes a combination of singing songs, dialogue, and stage design. Compared with popular music, musical singing requires different control of the performers' stage. Strive for innovation and keep pace with the times, which is the progress of musicals with the progress of the times. In the multimedia environment, this paper analyzes the application of popular singing in musical singing, which has theoretical and practical significance.

Information retrieval technology has developed for decades as an essential information collection method. With the development of computer hardware and software technology and the Internet, the object of information retrieval has developed from single-text information to two-dimensional multimedia information such as images, audio, and video [22]. In the retrieval mechanism based on melody, the main research contents are melody feature extraction, feature representation, and feature matching engine. Melody extraction is a hot and challenging task in music information retrieval. As an element of music, melody plays a vital role in understanding music semantics and distinguishing different music works [3]. Music melody is the sequence of fundamental frequency values corresponding to the pitch of tonic, which can be used to describe the content of music as the middle and high semantics of music. It can be used as a front-end or intermediate processing step for related applications such as humming retrieval systems, music genre classification, and music emotion recognition. Pop singing is mainly based on various styles of pop music. When singing, electronic sound amplifying equipment is used to regulate the timbre, and it is widely used in today's musical stage performances. This paper proposes a music feature extraction algorithm under the multimedia environment to analyze the deep application of popular singing in musical singing. Its main work and possible innovations are as follows:

1. Following the pace of the times, this paper analyzes the application of popular singing in musical singing from the perspective of a multimedia environment. The research draws some conclusions that hope to be helpful to the teaching of musical singing in the future.

2. This paper proposes a music feature extraction algorithm. In this algorithm, the pitch sequence of songs is extracted from humming segments and then transformed into a melody outline sequence after regularization, merging, and segmentation. Then, this sequence is transformed into melody contour features using the standard pitch difference table generated by standard pitch.

2 RELATED WORK

In China, musicals, a unique art form, have received increasing attention in recent years. Not only have some excellent American and British musicals been introduced, but even some central and local literary and art groups have begun to create and stage musicals with Chinese characteristics. In addition, there are many articles about studying and interpreting musicals in the music theory circle.

Langlois et al. pointed out that traditional music can no longer meet people's needs. The masses like musical theatre and pop music singing, and the popularity of these two kinds of singing is still deepening [12]. Jerde et al. studied the fusion of bel canto and process singing in musical theatre singing and explored the path to carry out fusion teaching in a targeted manner [5]. Hahne et al. analyzed the specific expressions and singing forms of musicals and analyzed the particular application of bel canto and pop singing in musicals to discuss how to teach bel canto and pop singing in the teaching of musicals [4]. The literature underscores the importance of cross-disciplinary collaborations, showcasing how musicians, visual artists, and technologists collaboratively contribute to innovative and captivating multimedia musical experiences. Additionally, cultural and genre-specific considerations play a pivotal role, with studies examining variations in the effectiveness of Collaborative CAD across different musical genres and cultural contexts. As this field continues to evolve, staying abreast of recent publications and advancements remains critical for understanding the multifaceted dynamics at the intersection of popular singing, multimedia, and technology in live musical performances. Gfeller et al. discuss how pop singing is used in musical arias to create characters. These include the relationship between the musical style and character shaping in the works and the importance of character shaping in the selection and singing of musicals [2]. Kirchberger et al. pointed out that musical theatre, a unique art form, not only absorbs elements of contemporary popular music but also inherits some features of classical music; it caters to the development of the trend of the times and thus begins to move towards a comprehensive and pluralistic direction in singing. Development [9]. Maekaku et al. started by analyzing the singing methods and expressions of musicals, the relationship between bel canto, popular singing, and musicals, as well as the application of these two singing methods in musicals, and analyzed the relationship between bel canto and popular singing in musicals. Some problems of fusion singing [13]. In the research process, Jj et al. found that pop music singing and musical theatre singing are inseparably related, and the singing methods of the two complement each other [6]. Miranda et al. believe that due to the unique artistic expression of musicals and their diversity, their singing style and singing skills must be diverse [14]. Zhang et al. further elaborated on the relationship between the two and the role of popular singing in musicals through various characteristics of musicals [24]. It is analyzed from the creative attributes of musicals, the production methods of musicals, and the means of stage performance of musicals. Nekola et al. first decomposed the sound source components containing the main melody feature from the mixed audio to eliminate the influence of the accompaniment, then performed pitch estimation, and finally used the dynamic programming method to track the main melody [15]. Kumaraswamy et al. designed and implemented a melody-based music retrieval test system and analyzed and evaluated the experimental data through different tests [11]. To improve pitch estimation accuracy, Digeser et al. proposed a melody extraction algorithm based on higher harmonics' stability and timbre characteristics from the

perspective of the stability of higher harmonics and timbre characteristics [1]. Kroher et al. fit a pitch model with existing spectral information [10]. For example, the Gaussian mixture model uses the maximum posterior probability to estimate the probability of the main melody pitch of each frequency, which is used as the pitch saliency feature and then estimates the best melody line.

3 METHODOLOGY

3.1 Analysis of Musical Singing Style

Since the birth of the musical, it has become one of the most valuable tools for expressing people's imagination [25]. Musical is a form of singing and a stage performance, which pays more attention to music than performance. A musical is composed of music, drama, dance, and other kinds of art, but people always remember the songs in the musical most deeply. At first, the musical was based on Bel Canto, but with the continuous development of musicals, to gain a larger market and meet the aesthetic needs of more people, musicals began to seek breakthroughs and changes constantly. A variety of styles and expressions are gradually integrated into musical singing. Its singing style has gone through a long road of development, and the musical singing style has also changed from the original single bel canto, dominated by operetta, to the coexistence of various singing styles such as jazz, country, rock, and pop. The musical's artistic comprehensiveness determines the formation of this diversified singing style, the plot's richness, and the actors' personalities [21]. Different from opera, musical is a variety of art forms such as music, dance, performance, drama, and dance beauty, which are closely combined with a unified idea. All artistic means in musicals should meet the needs of the plot; instead of interrupting the plot with more decorations, they should promote the development of the plot. Its vocal music singing combines many other musical styles, thus having diversified artistic forms. Instead of traditional dance and simple stage techniques, musicals show different styles in musical form.

From the development track of musicals, its singing style is inseparable from the development of popular singing. The popularity of music is developed in the process of music art's constant life and popularization, and it is the witness of people's spiritual and cultural living standards [17]. Its singing rhythm and melody are relaxed and natural, and its content closely relates to people's lives. Popular singing uses real voice as the primary singing method, which requires the sound to be natural and similar to speech. When singing a work, the expression and catharsis of emotions should be given first, and the sound is not required to be completely unified. The popular musical, with its modern and popular singing and strong appreciation, caters to the increasingly critical tastes of today's audience, making it one of the representative plays of today's fashion taste. From the way of music creation, most music in musicals is easy to understand, and popular singing is naturally the most suitable for such musical dramas. The technical changes in popular singing often include the conversion of true voice, falsetto voice, true and false voice, and the use of guttural voice. This has been widely reflected in the singing of musicals, and the natural relaxation and varied voices of musical actors are the best manifestation of the application of popular singing methods. According to the demands of different musical scripts and plots, to shape the characters in various types of musicals, the vocal techniques and singing styles adopted will be adjusted differently to meet the emotional demands. The singing methods in musicals are quite different from those in musicals. Based on Bel Canto, it developed Bel Canto and integrated it with jazz, rock, pop, and other singing methods. With the increasing appreciation level of the audience, a good musical should not only keep the old audience but also meet the aesthetic needs of young people. As a comprehensive stage art, musicals are constantly developing, and creative consciousness and expression are changing each day, among which singing expression is closely related to popular singing methods.

The related music often combines various forms and styles to express the stage stories, especially opera, operetta, and jazz. At the same time, different musicals require different characters and expressions in script arrangement and plot expression. This special art form of musicals determines that its singing style must be diverse; even in the same musical or song, there can be many different singing styles. His singing methods are highly particular. With the wide application of modern acoustics, the distance between the singing of classical bel canto and the modern audience is getting farther and farther. As the most suitable singing method for modern high-tech sound reinforcement equipment, popular singing is more widely used in musical performances, and even the same actor plays different roles in the same musical, which can show different timbres through the regulation of tuning equipment. This kind of expression means can bring the audience new enjoyment. Popular singing has formed its independent vocal system, just like traditional singing methods such as bel canto and national singing. There is no fixed pattern, and the singing style pursues nature and randomness, emphasizing singing with one's truest voice, thus embodying the individuality and characteristics of the voice, revealing feelings naturally. The performance is highly impromptu and provocative. Although there are many similarities between musical and pop music singing, there are also some differences.

3.2 Analysis of the Application of Popular Singing in Musical Singing

With the continuous development of music, it is gradually developing towards commercialization. Under the market's action, musicals are finally closely combined with popular singing, which makes more and more people accept and begin to study. It is no longer confined to a small area but has become a popular form of music. At the same time, the development of modern music also determines that it must be popular, modern, and famous. Based on this, this paper analyzes the application of popular singing in musical singing from the perspective of a multimedia environment. This paper constructs a music feature extraction model. The model is divided into pitch saliency enhancement and optimal melody tracking processes. The energy spectrum density features and the initial pitch saliency information are input into CNN (Convective Neural Network), and the deeper melody features are extracted to enhance the pitch saliency representation. Here, CNN can also be regarded as a coding layer, which extracts specific music information and codes it into the CRF (Conditional Random Fields) layer. The CRF layer learns melody features and smooth pitch constraints in pitch space to get the best melody line. Figure 1 shows the CNN-CRF model.

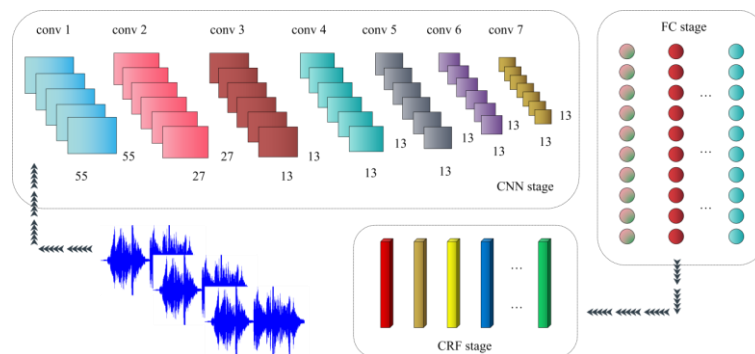


Figure 1: CNN-CRF model.

Some pre-processing work is usually done before melody extraction from music signals. An equal-loudness filter processing method for music signals is proposed to enhance the frequency component of melody from the perspective of human auditory perception. The filter can improve the frequency components that are sensitive to human hearing but weaken insensitive ones. The

spectrum transformation module needs to frame and window the signal and then perform time-frequency transformation to obtain the spectrum representation of each frame signal. Because the centroid of the spectrum can better reflect the brightness of sound, it is widely used in digital audio and music signal processing as a measure of music timbre. Its mathematical definition is as follows:

$$C_t = \frac{\sum_{n=1}^N M_t[n] \cdot n}{\sum_{n=1}^N M_t} \quad (1)$$

In the formula, $M_t[n]$ represents the amplitude of the Fourier transform of the t th frame at the frequency group n . Spectral flux is generally used to determine an audio signal's timbre or whether it is articulated. Its mathematical definition is as follows:

$$F_t = \sum_{n=1}^N (N_t[n] - N_{t-1}[n]) \quad (2)$$

For signal $s(t)$ with period T , it can be decomposed into sinusoidal series:

$$F_t = \sum_{n=1}^N (N_t[n] - N_{t-1}[n]) \quad (3)$$

Where $f = 1/T$, is the frequency of $s(t)$. Take the greatest common divisor of all peaks as the final pitch detection result, that is, all peaks are its multipliers. IIT provides sufficient frequency resolution to distinguish different notes while maintaining enough time resolution to track fundamental frequency changes within a short window of about 50ms to 100ms is generally selected. Finally, for the Fourier transform $X(k)$ of a given single frame, it will be normalized to form an amplitude spectrum:

$$X_m(k) = 2 \frac{|X(k)|}{\sum_{n=0}^{M-1} \omega(n)} \quad (4)$$

Then, all local maximum peaks and their frequency positions k_m in $X_m(k)$ are searched, and the obtained values are used for subsequent processing. The pitch detection function of the autocorrelation function can be expressed as:

$$R_i(k) = \sum_{m=1}^{N-m} y_i(m) y_i'(m+k) \quad (5)$$

$$y_i'(x) = C[z_i(x)] = \begin{cases} 1 & z_i(x) > C_L \\ 0 & |z_i(x)| \leq C_L \\ -1 & z_i(x) < -C_L \end{cases} \quad (6)$$

Among them, $z_i(x)$ represents the i th frame signal after the time series $w(t)$ of the audio signal is windowed and divided into frames and C_L represents the threshold level. To detect audio sequence $w(t)$ endpoints mark the beginning as:

$$S(i) \quad i = 1, 2, 3, \dots, n \quad (7)$$

After the notes are divided, the endpoints and the start points of the notes can be in a one-to-one correspondence. Suppose $T(i)$ represents the pitch period of the i th note in the original audio, according to the short-term stationarity of the music. In that case, the autocorrelation function is solved by the following formula in the form of a long window:

$$Seg(i) = w[S(i) + len] \quad (8)$$

The flow of music recognition and melody extraction is shown in Figure 2.

Using the spectral peak frequency \hat{f}_i and amplitude \hat{a}_i obtained by the spectral processing module, the pitch saliency is calculated:

$$S(b) = \sum_{h=1}^{N_h} \sum_{i=1}^I e(\hat{a}_i) \cdot g(b, h, \hat{f}_i) \cdot (\hat{a}_i)^\beta \quad (9)$$

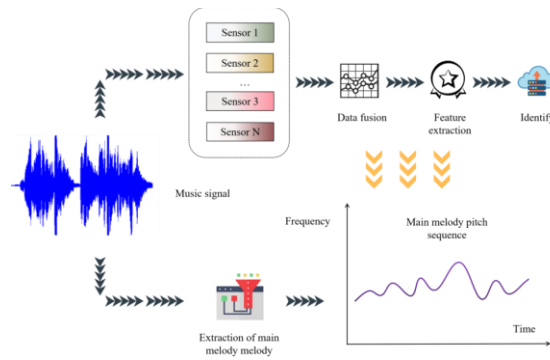


Figure 2: Music recognition and melody melody extraction.

Where N_h represents the maximum number of harmonics, I represent the number of peaks obtained, and β represents the amplitude compression parameter. And $g(b, h, \hat{f}_i)$ is a weight function; $e(\hat{a}_i)$ is an amplitude threshold function, which is defined as:

$$e(\hat{a}_i) = \begin{cases} 1, & \text{if } 20 \log_{10}(\hat{a}_M/\hat{a}_i) < \gamma \\ 0, & \text{other} \end{cases} \quad (10)$$

When the h -th harmonic of interval b is the instantaneous frequency \hat{f}_i of the peak p_i , the weighting function will assign a weight to the peak. The allocated size is:

$$g(b, h, \hat{f}_i) = \begin{cases} \cos^2\left(\delta \cdot \frac{\pi}{2}\right) \cdot \alpha^{h-1}, & \text{When } |\delta| \leq 1 \\ 0, & \text{When } |\delta| > 1 \end{cases} \quad (11)$$

The absolute value cap B open paren f hat sub i. over h, close paren minus b, and end absolute value over 10, which represents the semitone distance between the harmonic frequency f hat sub i. over h and the center frequency of the interval b; alpha represents serval—the harmonic weight parameter.

4 RESULT ANALYSIS AND DISCUSSION

In the final analysis, the music of musicals is also a kind of drama music. Although its musical structure is more popular than opera, it also contains drama clues, characters, and contradictory development. When we use popular singing in musical singing, we must also take this into account to better complete the characterization. In this paper, from the perspective of a multimedia environment, a music feature extraction algorithm is proposed to analyze the application of popular singing in musical singing. In this paper, the information on 50-note frequencies is analyzed in the range of 55 Hz to 1976 Hz, and an additional label is set to represent the melody-free frame. The network output size of each time dimension is 64 dimensions. Calculate the initial features of each 50ms music signal and input it into the network, in which the initial pitch saliency features account for one channel of information and the energy spectrum density features account for three channels of information. Finally, the network will output a melody map with a size of 45×60, containing a complete melody line. The training results of the algorithm are shown in Figure 3.

Calculate the incremental sequence between pairs of standard pitch sequences to obtain the pitch contour. This contour sequence will be used as a quantization standard for calculating the pitch contour of other humming music segments. Table 1 shows the experimental results of this algorithm under specific iteration steps.

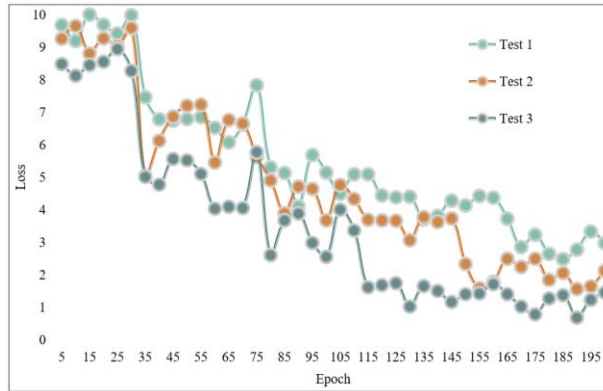


Figure 3: Training results of the algorithm.

<i>Iterations</i>	<i>Training loss value</i>	<i>Training accuracy</i>	<i>Test accuracy</i>
100	0.3942	82.87%	83.89%
200	0.2184	85.76%	86.75%
300	0.1479	88.84%	89.24%
400	0.0435	90.94%	92.33%
500	0.0312	93.67%	93.62%
600	0.0105	96.54%	95.49%

Table 1: Experimental results of the algorithm in this paper under specific iteration steps.

By analyzing the essential characteristics of the accompaniment melody tracks misjudged as the main track, this paper finds that these accompaniment tracks use a vibrato-like way, that is, two tones with a second or second interval alternate with each other to form accompaniment. In this case, supplemented by other processing methods, it can also be distinguished by the interval mean and variance statistics change. Test sets are used for experiments to detect the influence of different algorithms on the results more clearly and intuitively. The error of the test set is shown in Figure 4. The accuracy of the test set is shown in Figure 5.

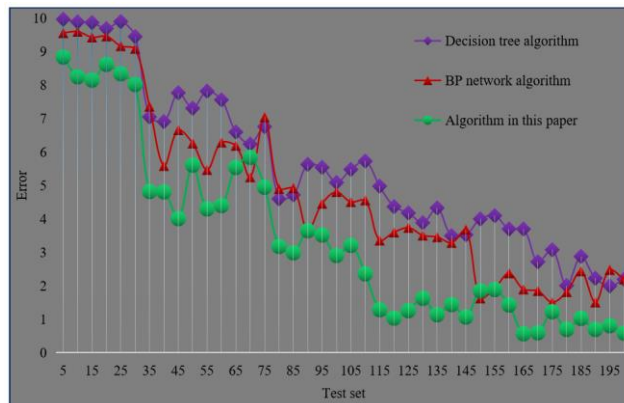


Figure 4: Error result of test set.

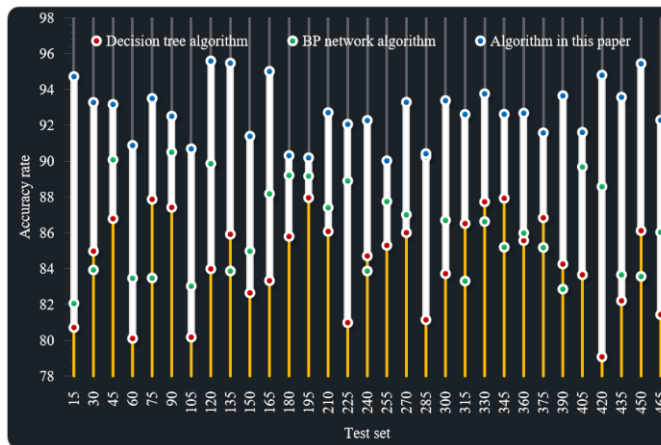


Figure 5: Accuracy result of test set.

There are two main melody extraction targets. (1) Output the correct melody pitch: when the output falls within the half semitone range of the label, it is considered that the model estimates the melody pitch correctly. If it is not in this interval range, it is considered that the model misestimates the melody pitch. (2) Judging the melody frame: when the frame has a melody, the estimated value of melody pitch is output; When there is no melody in this frame, 0 is output as the pitch value. Different people sing the same song with different frequencies, but the singers will try their best to make the fluctuation of pronunciation consistent with the score of the song, so the continuous increment of pitch, that is, pitch contour, is used as the search criterion. That is to say, the change between tones is more critical than the tones' value. After a song excludes rhythm, the change between scores is the song's essence. Table 2 shows the accuracy of this algorithm on different data sets.

<i>Dataset A</i>	<i>Accuracy</i>	<i>Dataset B</i>	<i>Accuracy</i>
1	96.84%	1	92.09%
2	95.96%	2	92.15%
3	96.27%	3	93.01%
4	94.99%	4	94.10%
5	96.87%	5	92.58%

Table 2: The accuracy of this algorithm on different data sets.

This paper chooses frequency domain analysis as the primary feature extraction method. Regarding the frequency domain method, it is easy to produce sub-pitch errors, so this paper adopts two methods in speech recognition to reduce noise and segment the endpoints, making the final pitch sequence more accurate. Figure 6 compares the accuracy of different algorithms on data set A. Figure 7 compares the accuracy of different algorithms on data set B.

Simulation experiments on different data sets show that the accuracy of music feature extraction can reach 96.88%. Compared with the traditional algorithm, this algorithm improves the accuracy by 12.57%. All kinds of simulation experiments in this section show the algorithm's superior performance. It can effectively analyze the application of popular singing in musical singing.

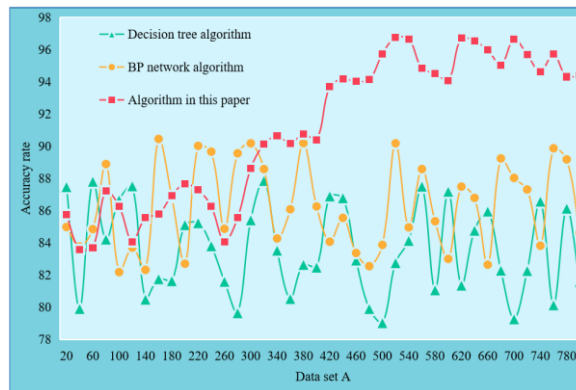


Figure 6: Accuracy comparison of the algorithm on data set A.

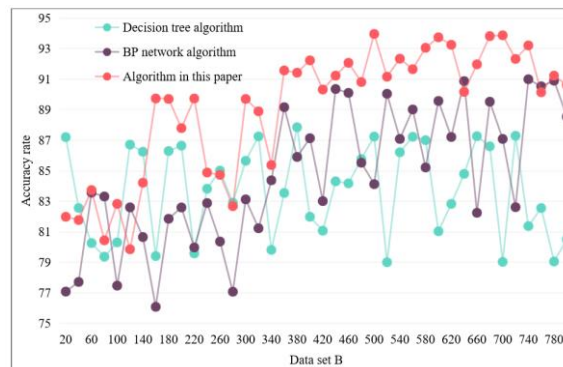


Figure 7: Accuracy comparison of algorithms on data set B.

5 CONCLUSIONS

Since its birth, the musical is a new comprehensive art inextricably linked with pop music. This paper starts by analyzing musical singing methods and forms, the relationship between popular singing methods and performances, and the application of popular singing methods in musical performances with examples. Based on this, a music feature extraction algorithm is proposed. Show people's lives in musicals on the stage, and as popular music that can best reflect all aspects of people's lives, it plays an essential role in the development of musicals. Musical and pop music are paid more and more attention in today's multimedia environment. Musical plays and pop music are both music-centered and have various forms. In this paper, the in-depth study of popular singing will better serve the expression of musical singing, which is conducive to creating local musical works and teaching musical majors. To lay a foundation for forming musical singing teaching mode with local characteristics. To further select the melody pitch contour, a dynamic time warping algorithm is proposed to calculate the similarity between melody and non-melody pitch contour to remove the non-melody pitch contour. Simulation experiments on different data sets show that the proposed algorithm improves the accuracy by 12.57%. To realize the inheritance of musical singing and simultaneously help musicals show new vitality in generate under the development background of a new era. In the future, deeper music theory will be used to extract the main melody.

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