Research Article
Digital Development Path of Music Appreciation Based on the Kalman Filter

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For a long time, due to the influence of curriculum orientation and examination-oriented education, the learning of music appreciation courses has not been paid much attention. This makes the teaching method in music appreciation teaching single, the classroom effect cannot reach the expected learning goal, and the classroom teaching efficiency becomes low, which urgently needs a new learning method to deal with these problems. Focusing on the digital education background of the new curriculum reform, this paper investigates the teaching nature, teaching methods, teaching design and evaluation, classroom construction, and student ability development of music appreciation. In this paper, the Kalman filter algorithm is used, and the optimal transformation order determined in advance is used to suppress the noise in music and improve the sound quality of music appreciation. If the order of the full-band signal model is selected as 10, and the number of sub-bands is selected as 4, then the order of the sub-band signal model should be at least greater than or equal to 2. In the music appreciation teaching test based on the Kalman filter, it was found that 35.6% of the students believed that the music appreciation course based on the Kalman filter could completely improve the learning efficiency, and 49% of students believe that the teaching of music appreciation class based on the Kalman filter can improve a large part of the learning efficiency. Overall, 85.5% of the students believed that the music appreciation class based on the Kalman filter is of great help in improving the learning efficiency, and the Kalman filter denoising method proposed in this paper has an obvious effect, which is a new attempt to promote the digital development of music appreciation.

1. Introduction

The rapid development of information technology and Internet technology has made the traditional printed resources—musical scores, written description texts, and audio resources gradually electronic and digitized. The classification of traditional music resources is basically positioned at the level of discipline and instrumental music. These classifications are far from being able to accommodate the newly added electronic music resources so that the resources cannot be reused and dispersed in actual operation. People’s demand for music resources is not limited to teaching and daily appreciation but also includes various uses such as tourism introduction, corporate product promotion, and so on. After the informatization of music teaching resources, with the help of computer technology and the Internet, the teaching resources are quickly spread on the network. It will be more convenient for students to obtain music teaching resources and knowledge, and their learning will no longer be affected by region and time. More and more students will enjoy the convenience of educational informatization. The Kalman filter increases the sound quality of music and is more conducive to the digital development of music appreciation.

It is of great research value to explore the feasibility of music appreciation teaching and to construct a teaching method suitable for music appreciation. The purpose of John et al.’s analysis is to understand the spirituality in Jaques-Dalcroze’s selected works in music education [1]. Sarah et al. used a tailored questionnaire to investigate the level of music appreciation in SSD patients [2]. Trimble and Hesdorffer once believed that through music a lot can be learned about the origin of humans and the human brain [3]. Julia once believed that contemporary social reform can be combined
with the music appreciation career [4]. Hove et al. believed that music can be heard and felt, especially the bass frequencies [5]. However, the generalization of music appreciation in their research is not very obvious, and this paper introduces the Kalman filter to optimize it.

The Kalman filter is of great significance to the development of digital music. Richardson and Howey proposed a method for estimating cell temperature using Kalman filtering [6]. Boada et al. proposed a new method to estimate different vehicle states [7]. In order to improve the robustness and estimation accuracy, Bai et al. proposed a state-based extended Kalman filter, which has the function of estimating unknown dynamics in time [8]. Dehghannasiri et al. derived the IBR Kalman filter, which has the best performance with respect to a class of uncertain state-space models [9]. Liu et al. proposed a navigation technique based on the attenuation factor adaptive Kalman filter to suppress noise [10]. But their proposed Kalman filter is not very high in enhancing speech quality.

People’s thinking mode and evaluation criteria for music appreciation still remain at a relatively conservative level. This paper utilized the Kalman filter algorithm to explore the characteristics of the digital age of music appreciation. The digitalization and informatization of music appreciation will provide teachers with a broad resource platform. Teachers can easily obtain the educational and teaching resources they want according to their own needs and can exclusively customize teaching content according to the actual learning situation of students. In this paper, a higher-level abstract classification is carried out for classification items and is combined with the existing metadata model, and a new hierarchical model of network music resources metadata is proposed, as well as the attributes of elements, subelements at each level, and using the RDF description framework to describe the resources, it established a music resource library and classified and retrieved music emotion in the form of tags. The concept in the metadata is not clear, but also the sentiment of the retrieval keywords that the public retrieval demand located in is classified. Using the advantages of Kalman filtering, the boundaries between various categories of musical emotions are clarified, membership functions are designed, and a network music resource library is established. The music emotion is appraised according to the newly proposed metadata model and the new retrieval method. 49% of the students in the study believe that the teaching of music appreciation class based on Kalman filter can improve a large part of the learning efficiency. In the music cultural literacy survey, 11.2% of the students chose listening to music works.

2. Development Path of Digital Music Appreciation

2.1. Music Digitization Appreciation. With the rapid development of digitization and informatization of education and teaching, music teaching is gradually integrated into it. Influenced by regional and economic development, the development of digital music appreciation teaching is also different. In areas with good economic and educational conditions, the digitalization of music appreciation teaching develops rapidly, while the digitalization of music appreciation teaching in areas with relatively backward conditions is relatively slow. Music appreciation teaching generally remains on the teaching of textbook knowledge. Teachers prepare appreciation teaching content according to textbooks, and students passively receive the content prepared by teachers, lacking innovative teaching content. In the process of teaching, music teachers will encounter situations where they need to compose a piece of music for students to learn. In order to meet the needs of this aspect, the scheme of this paper includes a score editing module. Scores can be recorded in a variety of ways. At present, the most popular and common notation methods are stave and numbered notation. The musical notation method is relatively simple and easy to use, but it is more troublesome and not intuitive enough to record songs with a wide range. Although the stave notation is easy to be troubled by inaccurate reading, it has a wider application and is a notation method that music majors must master. Therefore, in the score editing module, the method of notation is adopted [11, 12].

The approximate formula can be expressed as

$$\text{mel}(f) = 259 \log (1 + 70f).$$

(1)

The frequency range of a single note is 27.5Hz–4186 Hz, and it is mostly concentrated in the low-frequency part. The MFCC (Mel Frequency Cepstrum Coefficient) is calculated by the method of filter bank, which converts the linear frequency scale into the Mel frequency scale and has equal bandwidth on the Mel frequency scale. Therefore, it reflects the distribution of the energy of the audio signal in different frequency bands, emphasizing the low-frequency part of the musical tone, thereby highlighting the information that is conducive to identification and shielding the interference of noise [13].

According to the characteristics of music appreciation teaching, the music appreciation teaching system designed in this paper should meet the following requirements.

Virtual musical instruments with good interactive effects can facilitate teachers to play to students at any time during the teaching process. Considering the real-time nature of performance, virtual musical instruments should have good interactive capabilities and easy operability.

The system should have the function of compiling scores, and in the process of teaching, the teacher can easily and quickly write suitable songs according to the content of the class and present them to the students in time. While compiling the score, it can support modification at any time, which is convenient for the interaction between teachers and students.

It provides a good way of presenting musical scores, and at the same time, it can demonstrate the individual content of musical scores in a targeted manner according to the actual situation of appreciation and teaching, so as to achieve a good combination of the whole and the parts.

It has a good musical score performance effect. On the basis of accurate performance, the sound quality of the musical score is strengthened to achieve a good sensory effect. Music is not only about the accuracy of sound but also
has extremely high requirements on sound quality, so as to produce beautiful sensory enjoyment [14].

Digital music resources are mainly disseminated on the Internet, so their classification should refer to the relevant standards of the classification system of network resources. At the same time, it investigates and sorts out several large music resource sharing websites. Due to the diversity and complexity of network resources, resources are mainly used by different search engines and retrieval systems, so the classification system is required to have a high degree of expansibility and flexibility. The traditional taxonomy mainly uses the method of marking symbols to locate the category and arrange the documents (this refers to the classification of music appreciation literature), but in the network environment, the organization of digital music resources is directly presented to users through natural language, combined with hyperlinks and screen capture. Different from the traditional literature classification method, which is mainly based on subject knowledge structure, the organization of network information resources is mainly divided into categories by subject. This division method is more in line with the cognitive structure of the general public. Due to the diverse backgrounds and purposes of users who use digital music resources, the establishment of a complete classification system can lay a solid foundation for the further promotion of digital music [15, 16].

2.2. Music Appreciation Teaching Solution. In speech signal processing, sub-band decomposition was first used in speech coding. The superiority of factor-band decomposition makes more and more scholars begin to apply sub-band decomposition technology to various directions of speech signal processing. The spectrum of the music signal is decomposed into several parts uniformly or nonuniformly, and each part corresponds to a time signal, which is called the sub-band music signal of the original music signal. The sub-band decomposition can make different processing according to the characteristics of each sub-band signal when processing the speech signal. The sub-band signal is down-sampling, the sampling interval is increased, and the correlation of the signal itself is weakened, which can generally reduce the complexity of the algorithm (referring to the resources required by the algorithm to run after it is written into an executable program). Estimation of prediction coefficients is essential for the Kalman filter speech enhancement algorithm because it is a speech enhancement method based on the speech (AR) model [17]. The Kalman filter uses the observation value to adjust the predicted value continuously and then generates new observation value for the next music appreciation budget. But in the calculation process of filtering, the error covariance matrix has multiple matrix multiplication operations. The square of the matrix dimension determines the size of the calculation, and the main part of the calculation of Kalman filter is also here. If the dimension of the error covariance matrix (each element is the covariance between individual vector elements, a natural ordering generalization from scalars to higher dimensions) can be reduced, the calculation amount of multiplication between matrices will be greatly reduced, and the calculation amount of Kalman filter will be greatly reduced. Taking this as a starting point, through sub-band decomposition, the spectral structure of the sub-band music appreciation speech is made flatter, and the correlation of the signal itself is weakened [18]. The structure diagram of the speech enhancement process is shown in Figure 1.

In the application scope of digital music appreciation teaching program, the following principles shall be followed in the design of this scheme.

Maximize the professionalism of the system and introduce the Kalman filter [19] while ensuring accuracy. Music teaching programs need to have high fault tolerance (the principle is to guide, prompt, and solve) and stability [20]. To adapt to the later development of functions and the change of digital music teaching methods, this scheme should be considered as a whole and comprehensively in the design process, giving full consideration to the scalability of the system.

Let the number of observations of music appreciation at unequal intervals be [21, 22]

\[ x^0(t) = [x^0(1), x^0(2), \ldots, x^0(n)] \].

The corresponding observation periods for music appreciation are

\[ T^0(X) = (T_1, T_2, \ldots, T_N). \]

Then the average time interval of music appreciation is

\[ \Delta t = \frac{1}{n+1} (t_n - t_1). \]

The difference of each actual observation period is [23]

\[ \Delta x^0(t_i) = \sigma_i [x^0(t_i) - x^0(t_{i-1})]. \]

The main function of the score editing module is to provide a real-time score editing environment for teachers. Its design features are as follows:

1. According to the teaching situation, the music score can be customized exclusively: The score editing module supports multifaceted settings for the score, such as clef, key signature, time signature, playback speed, number of tracks (that is the parallel “tracks” you see in sequencer software), and playing instruments. Teachers can edit the music scores they want according to the teaching content, and it is difficult to achieve in traditional music teaching.

2. Compilation is quick and easy: After the musical score is initialized, it will be presented in the form of staff (it is a notation commonly used in the world), and what the teacher has to do is to fill in the staff according to their own teaching needs.

3. Provide real-time preview function: After the score editing is completed, the teacher can preview the edited score through the temporary demonstration function provided by the editing module. According to the preview results, teachers can discover and correct problems in the score in time [24].
3. Music Appreciation Quality Optimization Based on Kalman Filtering

The speech enhancement method of fractional spectral subtraction is combined with the Kalman filter based on sub-band decomposition to achieve a greater degree of suppression of background noise and music noise. If the statistical properties of the noise are known, the Kalman filtering method can also deal with colored noise and obtain an estimate of pure music. There are 88 training samples for 88 monophononic sounds. In this paper, 88 inputs are used as the centroid set \( C \), and the function radius is calculated according to the following formula to determine the functional form of each node in the hidden layer of music appreciation [25].

\[
\delta_j = \sqrt{\frac{1}{R} \sum_{r=1}^{8} (x - a_j)^2}.
\]

The single note recognition process is shown in Figure 2. First, a suitable feature representation must be extracted from the music data. The extracted features must meet the following requirements: first, the features must be low-dimensional, especially when the real-time recognition and training data are insufficient; second, the features should be robust, such as in some music, there will be percussion and irregular sounds, and they do not form chords. If the extracted features do not have antinoise, it will affect the recognition effect; third, the feature must be a constant. Because there will be some acoustic differences due to changes in rhythm and melody etc., the extracted features must be kept in a constant state to ensure correct musical expression.

The step size is 100 ms, that is, 10 PCP frames per second, \( K \) in STFT is mapped to \( p \) in PCP, and the mapping formula is as follows:

\[
p(k) = \left\lfloor \log_2 \left( \frac{f_{sr}}{N \cdot k} \right) \right\rfloor \mod 12,
\]

where \( f_{sr} \) is the sampling rate, and \( f_{sr}/N \) represents the separation gap of the STFT domain frequency.

The linear regression model in the matrix form is

\[
y = x\beta + \epsilon.
\]

The error covariance matrix of the predicted music appreciation signal is

\[
R_{X,T,T-1} = \alpha_{T,T-1} R_{X,T,T-1} \alpha_{T,T-1}^k.
\]

The Kalman filter gain matrix is

\[
J_k = R_{x,T,T-1} \left( B_k R_{x,T,T-1} + R_{k,k} \right)^{-1}.
\]

In the Kalman filter, the model order affects both the complexity of the algorithm and the enhanced music quality. The music signal after sub-band decomposition can be estimated by a low-order signal model, which reduces the computational complexity of the Kalman filter and also reduces the description of the signal spectrum envelope. If the reduction of the calculation amount is pursued blindly and the model order value is too small, then the enhanced music signal will have serious distortion. Therefore, in the sub-band signal processing, the selection of the Kalman filter order is very critical, and it should not be too high or too low. Therefore, the sum of the order of the Kalman filter in the sub-band should be greater than or equal to the order of the full-band model, so as to ensure the quality of the music signal.

4. Results of the Exploration of the Digital Development Path of Music Appreciation

As for the question of “can the class hours of your school’s music class be guaranteed?,” 12.3% of the students thought that in two semesters, basically every music class was taken; 32.4% of students think that two semesters are only given to the previous semester; 26% of the students believed that despite taking two semesters, music classes were often occupied by other classes or washed away by other activities; 29.3% of students believed that even in one semester, music classes were often occupied by other classes or washed away by other activities, which shows that most of our schools have very few actual music lessons. The class hour survey of music class is shown in Figure 3. With the construction and improvement of the digital network platform, the development of online learning and teaching, the interaction between teachers and students, and online Q and A, students can fully understand and appreciate music. Students can study for a year or more after graduation. To be able to share music and its value through lifelong learning, and to cultivate the quality of music, is the desire of every student which motivates them to learn music. Music education is a more inclusive and broad-based comprehensive music study program.

“Which of the following links in music class do you think is more helpful to the development of your musical cultural literacy?” 11.2% of the students chose to listen to music works; 21.5% of the students chose the music element explanation; 45.3% of the students chose the cultural connotation mining; and 22% of the students chose the music practice experience. Regarding the development of musical cultural literacy, most of the students agree with the cultural connotation mining; the first is the music practice
experience; the second is the explanation of the music elements; compared with the other three, the pure music works have the smallest proportion. A more helpful survey for the development of musical cultural literacy is shown in Figure 4.

The impression survey of the music appreciation class is shown in Figure 5. Those who felt that the music class was “not interesting” and “not impressed,” each accounted for 0.16; those who felt that “only left a very relaxed impression” accounted for about 0.33; and those who believed “expanded vision of music culture” accounted for about 0.35. The findings of this survey show that if you do not study the lesson well, you will not be able to impress students, and if you can lay down your body and study it carefully, you can turn the classroom into a powerful platform for broadening the students’ musical and cultural horizons. It can be seen from this that it is very important to introduce Kalman filtering to improve the quality of digital development of music appreciation.

The envelope signal value is determined by how many fluctuating faults produced the original signal and not by the severity of the faults. If the order of the full-band signal model is selected as 10, and the number of sub-bands is selected as 4, then the order of the sub-band signal model should be at least greater than or equal to 2. By analogy, if the full-band order is selected as 16, when the sub-band number is 4, the sub-band speech model order is at least 4. In the full-
band Kalman filter algorithm, the order of the signal model is selected as 10th and 16th order, respectively, in the sub-band Kalman filter algorithm. Taking the number of sub-bands as 4 and 8 as an example, the comparison results of the algorithm calculation time are shown in Table 1.

The music signal of about five seconds is processed, and the 4-sub-band filtering technology is used. When the prediction order of Kalman filter is 4, the processing time is about 1 second longer than that of the full-band 16-order Kalman filter. Using 8-sub-band filtering processing technology, when the prediction order of Kalman filtering is 2, the processing time is increased by about 2 seconds compared with the full-band Kalman filtering, and the calculation time of the algorithm does not increase significantly.

The simulation experiments were carried out under different noise environments and different signal-to-noise ratio conditions, and denoising was carried out (the pure music signal and Kalman filter processing are shown in Figure 6(a)). Finally, for the full-band Kalman filtering, fractional spectral subtraction combined with full-band Kalman filtering and the method proposed in this paper, the denoising effect is evaluated and compared by segmental signal-to-noise ratio and PESQ. The pure voice signal used in the simulation is a PCM quantized monoaudio signal whose length is 5 seconds and the sampling size is 16 bits. The noise is taken from the standard noise library NoiseX-92. The simulation experiment is carried out in MATLABR2009a software (for engineering calculation and simulation, adding noise and processing by the method in this paper are shown in Figure 6(b)). First, the speech signal is decomposed into eight sub-bands to simulate and analyze the Gaussian white noise for different signal-to-noise ratios.

The design of music classrooms in the context of the new curriculum is best done digitally. Equip each student with a computer and music production equipment, and then connect with the teacher’s computer to form a digital music classroom. The equipment of this kind of classroom can make up for some of the limitations of traditional multimedia classrooms, provide a guarantee for students to appreciate, play, create, and sing music and can change the classroom teaching method of one-way teaching by teachers and truly realize two-way interaction and teaching students in accordance with their aptitude. In such digital teaching, the demonstration can be more delicate, the learning can be more extensive, and the evaluation can be more scientific. After setting up a special digital music classroom, in order to ensure the long-term and effective use of the equipment, the classroom should be managed and maintained by professional teachers, and it is best not to use it for other purposes. Teachers and students should also take the initiative to keep the classroom clean, tidy, and hygienic during class and also to regularly check and maintain various music equipment.

In the past five years, half of the total number of music teachers have participated in more than three teacher trainings. Among them, it is mainly the teacher training at the municipal level, followed by the teacher training at the prefecture and county levels, and a few provincial and national teacher training. Among them, the highest level of published articles is less at the national level (3.85%), and more are published at the provincial, municipal, and district levels, and there are also many teachers (38.46%) who have never published an article. The number of school leaders listening to music teacher’s classes and the organization of teaching and research activities to a certain extent explain the school management’s emphasis on music appreciation teaching. Generally speaking, the school leaders will mainly listen to music teachers three to four times each year, with more than five times or as low as one or two times less. It is worth noting that some school leaders (11.54%) have not listened to music lessons. Most schools or higher-level related departments organize music teaching and research activities only once or twice per semester, and the number of schools that can organize three to five or more teaching and research activities is very limited. Some teachers (10.69%) also reported that the school would not organize any kind of teaching and research activities. The main forms of activities carried out by schools that organize teaching and research activities are observing open classes (50.85%), group discussions (23.08%) and a small amount of class evaluation (10.38%) and expert lectures (12.69%). The music teaching and research activities are shown in Figure 7.

The usage of digital teaching equipment in the music appreciation class is shown in Table 2. Just imagine, teachers can skillfully adopt digital music teaching and change the traditional teaching mode, which will greatly enrich the teaching content. Students will naturally be satisfied with the teaching arrangement and actively participate in learning, which also promotes the cultivation of high-quality talents and the development of quality education. Of course, in order to achieve the above results, we need to strengthen the training of music teachers and improve their ability to “use multimedia teaching equipment and digital music teaching.” Although there is a long way to go, it is also a clear road for the development of ordinary high school music appreciation courses. Today is the information age, and the development of music disciplines has also taken advantage of the advantages of information technology. Modern teaching technology provides music teachers with more teaching platforms, and music teachers should learn to use multimedia teaching equipment. In teaching, he is good at giving full play to the advantages of digital music and the positive role of information technology so as to provide a richer and more interesting learning environment for students’ music appreciation class. Facts have proved that the use of multimedia technology in music teaching will greatly improve the level of music teaching and enrich the content construction of music appreciation courses.

35.6% of the students believed that the music appreciation course based on the Kalman filter could completely improve the learning efficiency, and 49% of the students believed that the music appreciation course teaching based on the Kalman filter could improve a large part of the learning efficiency. On the whole, 85.5% of the students think that the music appreciation class based on the Kalman filter has the role of auxiliary teaching, and the teacher who acts as the subject of teaching
in the classroom can never be ignored. The music appreciation class based on the Kalman filter is fully competent as a tool to assist teachers in teaching. Using Kalman filter-based music appreciation class (refers to readjusting the time in and out of the classroom to transfer learning decisions from teachers to students) for flipped classroom teaching can not only improve the effect of classroom teaching but also improve students’ learning interest and learning efficiency. The influence of Kalman filter-based music appreciation class on learning is shown in Figure 8.

5. Conclusion
As a kind of cultural existence, music plays an irreplaceable role in enhancing cultural understanding and promoting world peace. Music education, especially the classroom teaching of music, naturally has a long way to go. At the

<table>
<thead>
<tr>
<th>Number of sub-bands</th>
<th>Kalman filter prediction order</th>
<th>Buried voice signal time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4</td>
<td>8.766</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>8.984</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>9.328</td>
</tr>
<tr>
<td>Full band</td>
<td>16</td>
<td>6.203</td>
</tr>
</tbody>
</table>

Table 1: Comparison results of algorithm computation time.

Figure 6: Simulation results for white Gaussian noise with different signal-to-noise ratios. (a) Pure music signal processed with the Kalman filter. (b) Adding noise and processing with our method.

Figure 7: Music teaching and research activities.

Table 2: Usage of digital teaching equipment.

<table>
<thead>
<tr>
<th>Use or not</th>
<th>( P ) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often</td>
<td>26.7</td>
</tr>
<tr>
<td>Sometimes</td>
<td>66.3</td>
</tr>
<tr>
<td>Never</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 8: The effect of Kalman filter-based music appreciation class on learning.
same time, with the integration of various fields related to music such as artificial intelligence, data sharing, and Internet technology, spreading, sharing, and optimizing music resources through Web technology has become an increasingly pursued concept. In this paper, by introducing the Kalman filter, the sound quality of music is increased, which is more conducive to the digital development of music appreciation. By compiling questionnaires, distributing questionnaires to teachers and students participating in music appreciation teaching, collecting, sorting, and analyzing questionnaires, we can understand the subjects’ cognition, views, and opinions on music appreciation.

Data Availability
The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest
The authors declare that there are no conflicts of interest.

References
