Journal of Combinatorial Mathematics and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Combinatorial Press

Research on the model of piano practice time allocation and performance effect evaluation based on integer programming

Jing Fan[1,✉]

[1] *College of Music and Dance, Fuyang Normal University, Fuyang, Anhui, 236000, China*

ABSTRACT

In this paper, the problem of piano practice time allocation is categorized as an integer planning problem, and focuses on 0-1 integer planning in integer planning. Based on the advantageous information in the 0-1 integer programming problem, the value of feasible solutions and the index set corresponding to the feasible solutions are proposed to realize the piano practice time allocation based on integer programming. For the evaluation of piano playing effect, a piano playing effect evaluation method based on the extraction of musical melody features is proposed, which adopts the base note cycle extraction algorithm based on the short-time autocorrelation method to extract the base note of the musical melody, and improves the linear scaling algorithm to solve the problem of uneven playing speeds and so on. In the piano practice practice allocation experiment, the average allocation time of player A applying the time allocation method of this paper is 2516s, which is higher than that of player B with the traditional allocation time, and the average concentration time accounts for 98.53% of the average time, which is better than that of player B's 95.43% share. Compared with the traditional manual evaluation method, the evaluation results of this paper's piano playing effect evaluation method in different test times sum up to 1, and the evaluation effect is better.

Keywords: integer programming, musical melody feature extraction, fundamental cycle extraction algorithm, piano playing

1. Introduction

In the teaching of piano performance in colleges and universities, the words “performance” and “playing” reveal the dual requirements of musical expressiveness and skills and techniques, respectively [1-2]. Skills and techniques form the basis of piano performance, and are the techniques that students must be proficient in, while musical expression is the soul of performance, which gives emotion and depth to the work, and makes each performance have unique personality and expression [3-5]. This requires that piano lessons need to start from the characteristics of the students, try to

✉ Corresponding author.
E-mail address: fanny9047@163.com (J. Fan).

Received 15 January 2024; Revised 25 March 2024; Accepted 30 November 2024; Published Online 15 April 2025.
DOI: 10.61091/jcmcc127a-311

correctly guide the students in piano practice, and teachers should do their best to help students achieve good results in the shortest possible time.

Piano teaching practice has proved that even if one is a piano playing genius, one's fingers cannot be flexible and powerful without formal training in basic skills. Basic skills is a very important part of piano playing, good basic skills, is indispensable to the player, including the correct timing of the fingers [6-7]. The playing of high lifting fingers includes two basic movements of high lifting and key lowering, and the high lifting is for better key lowering [8]. In the process of playing, it is necessary to master the principle of "fast up, fast down, fast and tight, fast and loose", and allow enough time for relaxation until the arm muscle movement is fully mastered and can be adjusted freely [9-11]. Music is the art of time, and the control of time will ultimately be reflected in the control of rhythm [12]. Therefore, establishing a mathematical model to optimize the time allocation of the player in piano practice and giving scientific and reasonable performance assessment can strengthen the basic practice of their high lifting fingers, so as to exercise the students' piano exploration skills in order to reflect the value of the existence of music [13-15].

In this paper, integer planning is introduced to realize the formulation of the allocation scheme of piano practice time based on the advantageous information of 0-1 integer planning in integer planning, and the evaluation method of piano playing effect based on the extraction of music melody features is proposed to assist piano teaching. For the 0-1 integer planning in integer planning, the superior solution is obtained by virtue of the advantageous information therein. The feasible index set is brought into the original problem to find the feasible solution of the original problem, and the optimal solution of the original problem is transformed into the index set corresponding to the search optimal solution. In the evaluation of piano playing effect, the extraction of music melody is used as the basis of evaluation, and the extraction of music melody is divided into three parts: preprocessing, base note extraction, and melody matching. The preprocessing part mainly includes pre-emphasis, window framing and noise reduction. As for the base note extraction, this paper proposes an improved base note period extraction algorithm based on the short-time autocorrelation method, on the basis of the traditional method, preprocessing is carried out to realize the accurate extraction of the base note period. The matching criterion of linear scaling is improved, and a multi-segmented linear scaling algorithm with limited threshold is proposed to improve the poor linear scaling effect caused by the problem of playing speed. Finally, the effectiveness of the proposed integer programming-based piano practice time allocation method and piano performance evaluation method is examined through piano practice time allocation experiments and piano performance evaluation experiments, respectively.

2. Piano practice time allocation method based on integer programming

Integer planning is an important research branch in mathematical planning, and many practical application problems in real life can be summarized as integer planning problems, such as the piano practice time allocation problem studied in this paper. This paper focuses on the 0-1 integer planning problem in the integer planning problem, and proposes the advantageous information in the 0-1 integer planning problem as the basis for the allocation of piano practice time.

2.1 Principles of integer programming

In linear programming problems, the optimal solution is not restricted to be an integer or a decimal, but in real-world application scenarios, some of the decision variables must take integer values, such as the number of cars to be selected, the number of people to be dispatched, and so on. Such problems are known as integer planning problems. In integer programming, if all decision variables can only take integers, this is pure integer programming [16]. If the integer requirement is restricted to only some of the decision variables, this is mixed integer planning.0-1 integer planning is a special case of integer planning in which the integer decision variables of 0-1 integer planning can only be taken as 0 or 1.Integer planning problems which so far could not find a solution in polynomial time are NP-hard problems.

0-1 integer programming has an important position in integer programming because many practical problems, such as the feature selection problem and the VaR minimum portfolio optimization problem, are 0-1 integer programming problems. The exact algorithm for the 0-1 programming problem is the branch-and-bound method, and there are also heuristic search algorithms for various special cases. In the next section, we will introduce the exact algorithms and the heuristic search algorithms commonly used to solve the 0-1 programming problem. Next, we will introduce the exact solution algorithms and heuristic search algorithms commonly used to solve 0-1 programming problems.

2.1.1. Branching and delimitation. The branching delimitation algorithm is carried out with a search decision tree as the core, the original problem can be regarded as the root node of the search decision tree, and the branching is to split the original problem into several subproblems [17]. The original problem is the parent node of the search decision tree and the subproblems are the children of the parent node. The process of branching is the process of adding child nodes to the decision tree. And bounding is the process of checking the upper and lower bounds of the subproblems during the branching process, and if the subproblems fail to produce a better solution than the currently searched optimal one, then this branch is cut. Until all subproblems fail to produce a better solution, the algorithm ends. Algorithmic procedure for the branch-and-bound algorithm (using minimization problem $\min imizef(x)$ as an example).

1) Using a heuristic, find a solution to the optimization problem x_h. Store its value, $B = f\left(x_h\right)$. (If no heuristic is available, set B to infinity.) B will represent the best solution found so far and will be used as an upper bound on the candidate solutions.

2) Initialize the queue to hold partial solutions, but do not assign any problem variables.

3) Loop until the queue is empty:

(1) Remove a node N from the queue.

(2) If N represents a single candidate solution x and $f(x) < B$, then x is by far the best solution. Record and set $B = f(x)$

(3) Otherwise, branch on N to produce a new node N_i. For each new node:

If lower bound $\left(N_i\right) > B$, do nothing; since the lower bound of this node is greater than the upper bound of the problem, it will never lead to an optimal solution and can be discarded.

Otherwise, deposit N_i into the queue.

2.1.2. Cutting plane method. The basic idea of the cut-plane method is to solve the linear programming problem corresponding to the integer programming problem without considering the effect of the integer constraints on the decision variables for the time being [18]. If the optimal solution of the linear programming problem is exactly the integer solution, which satisfies the integer constraints, then this solution is the optimal solution of the integer programming problem. Otherwise, a constraint called cut plane is added.

The algorithmic procedure of the cut plane method is that:

1) Temporarily disregard the integer constraints on the variables and solve the linear programming problem corresponding to the original problem by the simplex method, if the problem has no feasible solution or the optimal solution is already integer then stop, otherwise go to the next step.

2) Find, add a cut constraint to the integer planning constraints, the feasible domain of the above linear programming problem "cut" to make it smaller, and then return to step 1.

2.2 Advantageous information in 0-1 integer planning problems

The 0-1 integer planning problem as a special kind of integer planning problem has a wide range of application scenarios in reality, and most of the 0-1 integer planning problems are NP-hard. This means that the exact solution algorithm cannot obtain the optimal solution of the problem in finite time, so many scholars are devoted to find an efficient search strategy to solve such problems.The general form of the 0-1 integer programming problem is:

$$\begin{gathered}\max(\min) S = c_1x_1 + c_2x_2 \ldots + c_nx_n \\ s.t. a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \le (=,\ge) b_1 \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \le (=,\ge) b_2 \\ \ldots\ldots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \le (=,\ge) b_m \\ x_1, x_2, \ldots, x_n \in \{0,1\}\end{gathered} \tag{1}$$

In general, integer decision variables x_i with a value of 1 are of more interest because a 1 in an integer decision variable means that the variable and the constraints associated with this variable can have an effect on the objective function. In fact, since the integer decision variable x_i can only take either 0 or 1 in the 0-1 integer programming problem, the distribution of x_i taking 0 corresponds to the known distribution of x_i taking 1. We call the subscript i corresponding to the integer decision variable x_1 that takes 1 an index, and the distribution of x_i taking 1 can be represented by the set of indexes Ω composed of indexes i. For a 0-1 integer programming problem with n integer decision variables, the number of index sets Ω should be 2^n since each integer decision variable takes either 0 or 1. An index set Ω corresponding to x, the distribution of taking 1 is called a feasible index set if it satisfies the constraints of the problem. A feasible index set can be brought into the original problem to find a feasible solution of the original problem, so a feasible index set corresponds to a feasible solution of the original problem. Searching for the optimal solution of the original problem translates into searching for the index set corresponding to the optimal solution. For single-objective optimization problems, the solutions can be compared with each other. For example, if there are p solutions to a minimax optimization problem, and the $i(1 \le i \le p)$th solution is smaller than the $j(1 \le j \le p)$th solution, we consider that the ith solution is better than the jth solution, and accordingly the indexing set corresponding to the ith solution is better than the indexing set of the jst solution.

In a concrete instance of a 0-1 integer programming problem that satisfies the Big Pit Conjecture, for a given near-optimal solution S and the set of indices I_S corresponding to S, Equation $\left|\Omega_{S^*} \cap \Omega_S\right| / \left|\Omega_{S^*}\right| \ge 0.8$ holds, where I_s. Denotes the set of indices corresponding to the optimal solution S^* of the problem. Accordingly, this paper makes the conjecture that for a specific instance of a 0-1 integer programming problem, the event $\left|\Omega_{S^*} \cap \Omega_{S_1}\right| > \left|\Omega_{S^*} \cap \Omega_{S_2}\right|$ occurs with high probability if the absolute value of the difference between the two feasible and optimal solutions of the problem is known $\left|S^* - S_1\right| < \left|S^* - S_2\right|$. That is, the closer a given solution is to the optimal solution, the higher the overlap between the corresponding index set and the optimal solution index set should be. Therefore the advantageous information of a feasible solution of the 0-1 integer programming problem proposed in this paper includes at least the value of the feasible solution and the index set corresponding to that feasible solution.

The classic 0-1 backpack problem is used to illustrate the help that dominant information can provide when we solve this type of 0-1 integer programming problem. Let us assume that there are 4 items, each corresponding to weights $w_1 = 4$, $w_2 = 5$, $w_3 = 3$, and $w_4 = 1$, and prices $p_1 = 8$, $p_2 = 6$, $p_3 = 5$, and $p_4 = 4$, and that the maximum weight that the backpack can carry is $W = 10$. The problem can then be expressed as:

$$\max \sum_{j=1}^{4} p_j x_j$$
$$s.t. \sum_{j=1}^{4} w_j x_j \le W,\ x_j \in \{0,1\} \tag{2}$$

3. Experiments on piano practice time allocation based on integer programming

This chapter focuses on the observation and analysis of two piano learners' time allocation problems in piano practice, observing how the piano learners plan and utilize their piano practice time, and exploring the effectiveness of the integer planning-based piano practice time allocation method proposed in this paper.

3.1 Basic information on the subject of observation

The two observation subjects in this study are students of the piano major of the W Conservatory of Music in the class of 2023, and will be named Player A and Player B. Player A will use the piano practice time allocation method based on integer programming proposed in this paper to allocate piano practice time, while Player B will maintain the original allocation scheme to allocate piano practice time. In order to avoid the error caused by the singularity of the sample, Player A and Player B will be invited to perform piano practice three times respectively.

3.2 Piano practice time utilization analysis

The specific time allocation data of Player A and Player B during piano practice were obtained from the piano practice video data, as shown in Table 1. From the data in the table, it can be seen that the average allocation time of player A is 2516s, and the average allocation time of player B is 2233s, which is less than that of player A on average. The table presents only the statistics of the allocated time for piano practice as a whole, but there is a part of time that is not related to practice in the whole piano practice process, which is different from the focused time. In the next section, the non-practice-related time is subtracted from the statistics of piano practice time.

Table 1. Time allocation data

Practice	Practice links	A player		B player	
		Duration(s)	Percentage (%)	Duration(s)	Percentage (%)
The first practice	Slow practice	43	1.71%	86	3.65%
	One-handed practice	1800	71.66%	1478	62.65%
	Rhythm practice	560	22.29%	709	30.06%
	Comprehensive exercises	109	4.34%	86	3.65%
	Total	2512	100%	2359	100%
The second practice	Slow practice	275	11.72%	129	5.72%
	One-handed practice	772	32.91%	1632	72.34%
	Rhythm practice	1153	49.15%	346	15.34%
	Comprehensive exercises	146	6.22%	149	6.60%
	Total	2346	100%	2256	100%
The third practice	Slow practice	728	27.06%	768	36.85%
	One-handed practice	935	34.76%	985	47.26%
	Rhythm practice	893	33.20%	308	14.78%
	Comprehensive exercises	134	4.98%	23	1.10%
	Total	2690	100%	2084	100%

The practice focus times of Player A and Player B in the three piano exercises are shown in Table 2. From the data in the table, it can be seen that after subtracting the time unrelated to practice from the time allocated for practice, the practice focus time of Player A in the three piano exercises was higher than that of Player B, respectively 216s, 183s and 645s. The average focus time of Player B accounted for 95.43% of the average time, and the average focus time of Player A accounted for 98.53% of the average time. Obviously, when adopting the piano practice time allocation method based on integer planning proposed in this paper, player A is able to arrange the piano practice sessions more scientifically and rationally, and the concentration on piano practice has been significantly improved, and the allocation of piano practice time is better than that of player B.

Table 2. Practice concentration time

	A player			B player		
	The first practice	The second practice	The third practice	The first practice	The second practice	The third practice
Practice allocation time (s)	2512	2346	2690	2358	2255	2084
Practice irrelevant time (s)	50	36	25	112	128	64
Practice concentration time (s)	2462	2310	2665	2246	2127	2020
Average concentration time(s)	2479			2131		
Percentage of average concentration time(%)	98.53%			95.43%		

4. Piano Performance Effectiveness Assessment Model

In this paper, we study a method of evaluating piano playing effect based on music melody, and propose a feature extraction method of piano melody, which is used as a basis to realize the evaluation of the piano player's playing ability, and to achieve the purpose of assisting piano teaching.

In this paper, the process of piano performance information processing is divided into three steps: pre-processing, base note extraction and melody matching.

4.1 Pre-processing

The preprocessing part includes operations such as pre-emphasis, windowing and framing, and noise reduction.

1) Pre-emphasis. The purpose of pre-emphasizing the input speech signal is mainly to weight the high-frequency part of the speech, to remove the influence of the sound gate excitation and the mouth and nose radiation, and to make the spectrum of the signal flat. In this paper, the pre-emphasis is realized in the computer after digitizing the speech signal and before the parameter analysis by using a first-order FIR high-pass digital filter with 6dB/octave to enhance the high-frequency characteristics, whose expression is shown in Equation (3):

$$H(Z) = 1 - uZ^{-1} \tag{3}$$

where u is the pre-emphasis factor.

2) Adding window and frame splitting. For the selection of the window function, due to the more severe spectral leakage of the rectangular window, we use the smoother Hamming window, whose expression is shown in Equation (4) (where N is the frame length):

$$w(n)=\begin{cases}0.54-0.46\cos\left[\frac{2\pi n}{N-1}\right],0\le n\le N-1\\ 0,\ Other\end{cases} \tag{4}$$

3) Noise reduction. There are various methods for suppression of additive noise in speech signals. In this paper, we use the minimum mean square error estimation enhancement method, which is an estimation method that is insensitive to the specific distortion criterion and a posteriori probability, and can effectively reduce the interference of music noise.

4.2 Base Tone Extraction

The short-time autocorrelation function is the most commonly used feature function for short-time correlation analysis of signals. The music signal $s(m)$ is intercepted by a window of length N as a section of the windowed signal $S_n(m)$, which is divided into frames, $S_n(m)$ is a signal within a frame, and the autocorrelation function $R_n(k)$ of $S_n(m)$ is defined as:

$$R_n(k)=\sum_{m=0}^{N-k-1}S_n(m)S_n(m+k) \tag{5}$$

where $k=(-N+1)\sim(N-1)$.

Since the short-time autocorrelation function of the signal peaks at integer multiples of the fundamental period, the fundamental period value can be extracted by detecting the position of the peak. Base tone extraction based on the short-time autocorrelation method is a relatively common base tone extraction algorithm at present, but this method has obvious defects.

1) The vocal tract resonance peaks sometimes seriously affect the harmonic structure of the excitation signal.

2) The speech signal itself is quasi-periodic, and the peak point or over-zero point of its waveform is affected by the resonance peak structure and noise.

In view of this, we propose an improved fundamental period extraction algorithm based on the short-time autocorrelation method, which is preprocessed on the basis of the traditional method to realize the accurate extraction of the fundamental period. In this paper, the speech signal is first processed by center clipping, and at the same time, on the basis of the center clipping method, the three-level clipping method is used, which greatly saves the computation time.

The center clipping function is shown in equation (6):

$$f(x)=\begin{cases}x-x_L & (x>x_L)\\ 0 & (-x_L\le x\le x_L)\\ x+x_L & (x<-x_L)\end{cases} \tag{6}$$

The three-level clipping function is shown in equation (7):

$$f(x)=\begin{cases}1 & (x>x_L)\\ 0 & (-x_L\le x\le x_L)\\ -1 & (x<-x_L)\end{cases} \tag{7}$$

Experiments show that by estimating the fundamental period of the clipped sequence $f(x)$ with the short-time autocorrelation function, the peaks at the period positions are sharper, which can effectively reduce the octave or half-frequency errors, while the computation time will be greatly reduced.

Based on the above processing, the fundamental frequency of each frame of the playing signal can be better found out, and then converted into semitone units using the following formula:

$$Semitone = 12 \times \log_2\left(freq / 440\right) + 69 \tag{8}$$

where $freq$ is the fundamental frequency value in units of Hz.

A note will always continue for a number of frames, and after obtaining the pitch of each frame, a weighted eigenvalue approach can be taken to obtain the pitch of each note. Let a note consists of n frames, the pitch of each frame is $P_1, P_2, \cdots, P_n$, then the weight of each frame is defined as follows:

$$\omega_i = 1 - \cos\left(2\pi \times i / (n+1)\right) 1 \le i \le n \tag{9}$$

The weights of the frames with the same pitch are accumulated, and the one with the largest weight is the pitch of the whole note, which leads to the pitch contour.

4.3 Melody Matching

Once the pitch contour is obtained, we can perform melody matching with the songs in the music database, and each song in the music database must also be converted into the form of a pitch contour beforehand. The purpose of melody matching is to find the target pitch contour that is most similar to the clip we are playing. The size of the similarity depends on the distance function we use, the smaller the distance, the higher the similarity.

The simplest and most efficient matching algorithm without note-cutting is linear scaling, which is based on the principle of searching for songs in the database by stretching or contracting the pitch contour of the performance clip in a linear fashion, and the algorithmic process is as follows [19].

1) Using interpolation, the pitch contour of the performance clip is linearly stretched or contracted, e.g., the stretching ratio can be from 0.5 to 1.5, with a jump distance of 0.25, yielding a total of 5 versions.

2) These 5 processed pitch contours were compared with the pitch contour of a song in the song database, and 5 distances were obtained, and the one with the smallest distance was taken as the distance between the pitch contour of the performance clip and the song.

3) All the songs in the song database are compared and the shortest distance is both the best match to the performance clip.

The matching accuracy of the linear contraction algorithm depends on the jump distance of the expansion coefficient, the smaller the jump distance is, the matching accuracy will increase, but the matching time will increase linearly after reaching a threshold value. At the same time, when the performance speed is different, the effect of linear scaling will be greatly affected. Based on these two problems, this paper improves the matching criterion of linear scaling, and proposes a multi-segmented linear scaling algorithm with a limited threshold. The specific steps are as follows.

1) Given a threshold value of α, the threshold value should not be too large and should be measured by the actual quality of the performance clip. The higher the quality of the performance clip, the smaller the threshold value, and vice versa. However, the threshold value should not be too large. Experiments have shown that if the threshold value is too large, the matching time will increase linearly.

2) According to threshold α, the target pitch contour and the pitch contour of the performance clip are cut into α segments, and the first segment is processed first.

3) Use linear interpolation to linearly extend or contract the pitch contour of the performance clip, and the jump distance θ is judged according to the size of the threshold, and the jump distance θ and the threshold α are always positively and inversely proportional to each other. A selection method is given in this paper.

$$\theta = \left(\sigma_2 - \sigma_1\right) / (\alpha - 1) \tag{10}$$

σ_2 and σ_1 denote the scaling ratio, which is generally selected between 0 and 2, and the scaling ratio selected in this paper ranges from 0.5 to 1.5.

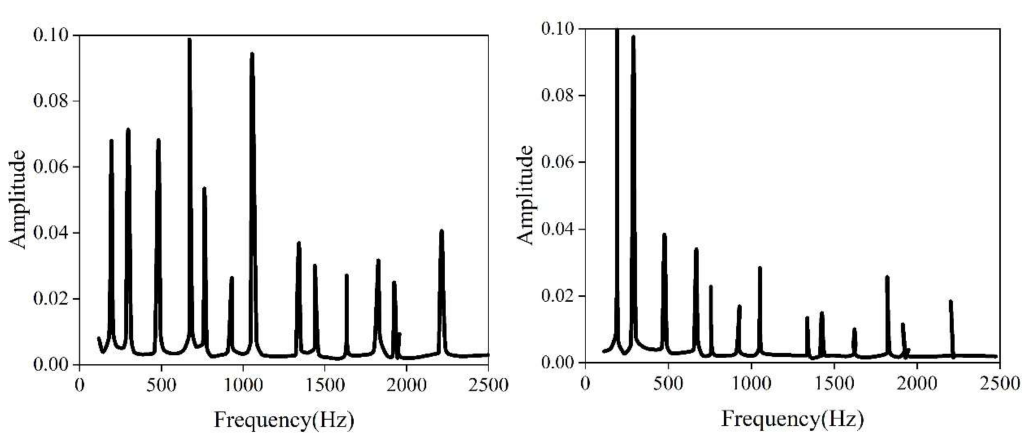
4) Compare the n telescoped performance segments with the pitch contour data of a song in the song database, obtain n distances, and take the smallest value thereof as the minimum distance $Dist_1$ between the target pitch contour and the pitch contour of the performance segment.
5) The operations of steps 3) and 4) are repeated for the subsequent $\alpha - 1$ segments, and the minimum distance $Dist_1, Dist_2, \cdots, Dist_\alpha$ of the $\alpha - 1$ segments is obtained.
6) Sum all the independent minimum distances to get the final distance $DistSum = Dist_1 + Dist_2 + \cdots + Dist_\alpha$.
7) Carry out steps 1) to 6) operations with all songs in the database, in order to play the consistency of the clip matching process, you should select the same threshold α and skip distance θ as the above operations, and then get m and $DistSum$.
8) Compare m to $DistSum$, the smallest is the target song we want to retrieve.
The experiment proves that the algorithm can well solve the problems of jump distance selection and uneven playing speed.

5. Experiments to assess the effectiveness of piano playing

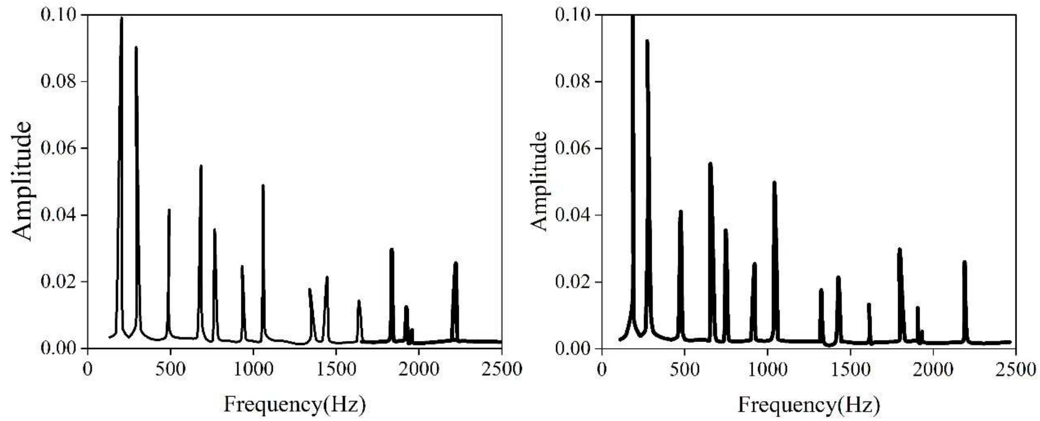
In order to verify the proposed music melody feature extraction method and the effect of piano performance evaluation based on it, this chapter will conduct a piano performance effect evaluation experiment. In this experiment, A performer from W Conservatory of Music will be invited to perform three sets of piano solos. At the same time, 10 ordinary students will be invited as the public judges of piano performance, and 2 music teachers will be invited as the professional judges to evaluate the piano pieces played by Player A. The traditional artificial evaluation of the piano playing effect will be obtained, and the evaluation results will be compared with the evaluation results of the piano playing effect evaluation method proposed in this paper, so as to validate the evaluation effect of the piano playing effect of the method in this paper.

5.1 Note Fragment Preprocessing

Before formally evaluating the piano playing effect of Player A, the note fragments of Player A's piano playing are preprocessed using the music melody feature extraction method proposed in this paper. The effect of the preprocessing stage of a selected note fragment is shown in Fig. 1. Figures a, b and c show the spectra of the note fragment at different moments, and it can be seen that the frequency positions of the peaks in the spectra of different frames of the same note fragment are basically unchanged, but there are differences in the amplitude of each frequency. Figure d shows the mean value spectrum obtained at different moments of the spectrum, using the mean value method to smooth the changes in amplitude at different moments.



(a)The spectrum of the first frame (b)The spectrum of the second frame



(c)The spectrum of the third frame (d)Multiframe mean spectrum

Fig. 1. The effect of note fragment preprocessing stage

Minimum mean square error estimation of speech enhancement method is used to reduce the interference of music noise. Select a note fragment of a certain left-hand note harmonic smoothing before and after the amplitude is shown in Figure 2. The curves are the envelopes of the harmonic amplitudes before and after smoothing respectively, as shown in the figure, the neighboring amplitudes of the 4th and 8th harmonics of this note are significantly smaller than its value, indicating that this harmonic may overlap with the harmonics of other notes, and its amplitude is close to the neighboring harmonic amplitudes after smoothing to achieve the effect of reducing the effect of overlapping amplitudes.

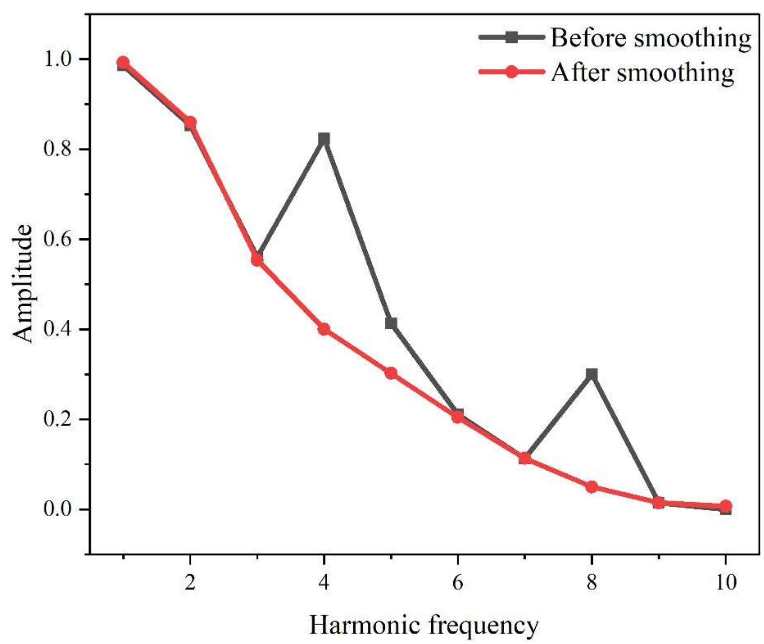


Fig 2. The amplitude before and after harmonic smoothing

5.2 *Evaluation of Piano Performance Effectiveness*

Ten public judges and two professional judges were invited to score the three sets of piano pieces played by A. A total of two tests were conducted, and the pieces played by A were named as A1~3. According to the piano playing effect, the evaluation grade was categorized into 0 to 5, and the higher the grade, the better the playing effect. The results of the evaluation using the evaluation structure of the proposed piano playing effect evaluation method and the traditional manual evaluation are shown in Table 3. From the data in each column of the table, the difference between this paper's piano performance effect evaluation method and the traditional manual evaluation method of inviting judges to evaluate the piano performance effect in the same test is no more than 1, which indicates that the piano performance effect evaluation results of the two are basically the same. From the data in each row of the table, the total difference of the evaluation results of this paper's piano performance effect evaluation method in facing the same piano piece in different test times is 1, while the total difference of the evaluation results of the traditional manual evaluation method is 2, which indicates that the traditional manual evaluation method is not as stable as the piano performance effect evaluation method proposed in this paper, the reason is that the human's subjective feeling is more likely to lead to different results of the evaluation results of the same piece in facing the same piece for many times. The reason is that human subjective feeling is more likely to lead to the evaluation of the same piece of music several times with different results.

Table 3. The evaluation of piano performance

Playlist	Evaluation method	First Test	Second Test
A1	The method of this paper	2	2
	Traditional methods	3	2
A2	The method of this paper	4	4
	Traditional methods	4	5
A3	The method of this paper	2	3
	Traditional methods	2	2

6. Conclusion

The research topic of this paper is mainly divided into two modules, one is the allocation of piano practice time, and the other is the evaluation of piano playing effect. For the piano practice time allocation problem, this paper summarizes it as an integer programming problem, proposes the value of feasible solutions based on the advantageous information in the 0-1 integer programming problem, realizes the piano practice time allocation based on the piano practice time allocation, and also proposes the evaluation method of the piano playing effect based on the extraction of musical melody features.

Piano practice time allocation experiments are conducted to explore the effectiveness of the piano practice time allocation method based on integer programming proposed in this paper. The average allocation time of player A, who applied the method of this paper for piano practice time allocation, was 2516s, which was higher than that of player B, who did not apply the method of this paper. In the three piano practice sessions, the practice concentration time of Player A was higher than that of Player B by 16s, 183s, and 645s, respectively, and the average concentration time accounted for as much as 98.53% of the average time. In terms of the performance of piano practice concentration, Player A gained a significant improvement, verifying the utility of this paper's method in rationally allocating piano practice time.

Player A was invited to perform three sets of piano solos, and the performance effects of the three sets were evaluated by utilizing the proposed piano performance effect assessment method and the traditional manual assessment method. The difference between this paper's method and the traditional manual evaluation method is no more than 1, and this paper's method outperforms the traditional manual evaluation method, which has a difference of 2, when the difference of the results of the same piece of piano music is totaled to 1 in different test times.

References

[1] Arshinova, I. (2022). Elements of piano education and the evolution of piano pedagogy. Journal for the Interdisciplinary Art and Education, 3(2), 81-97.

[2] Zhang, L. X. (2019, June). The "four main factors theory" of piano teaching and its systematic thinking. In 2nd International Seminar on Education Research and Social Science (ISERSS 2019) (pp. 161-164). Atlantis Press.

[3] Griffith, K. R., Ramos, A. L., Hill, K. E., & Miguel, C. F. (2018). Using equivalence-based instruction to teach piano skills to college students. Journal of Applied Behavior Analysis, 51(2), 207-219.

[4] Hu, Z. (2018, November). Research on the Present Situation of Piano Education in Colleges and Universities. In 2018 5th International Conference on Education, Management, Arts, Economics and Social Science (ICEMAESS 2018) (pp. 791-796). Atlantis Press.

[5] Parmar, P., Reddy, J., & Morris, B. (2021, October). Piano skills assessment. In 2021 IEEE 23rd international workshop on multimedia signal processing (MMSP) (pp. 1-5). IEEE.

[6] Li, L. (2018). Study on the innovation of piano teaching in normal colleges and universities. Creative Education, 9(5), 697-701.

[7] Dinov, M. (2023). THE ROLE OF FINGERING IN CREATING MUSIC ON THE PIANO. Facta Universitatis, Series: Visual Arts and Music, 041-050.

[8] Telles, A. (2021). Piano fingering strategies as expressive and analytical tools for the performer. Contemporary Piano Music: Performance and Creativity, 151.

[9] Reid, H. (2020). Teaching piano to young beginners. Music Teacher, 99(2), 1-1.

[10] Tsutsumi, H., Nishino, H., & Kagawa, T. (2018, May). A tactile assistance for improving fingering skill in piano performance. In 2018 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW) (pp. 1-2). IEEE.

[11] Li, Y. (2023). The Left Hand Training Strategy in Piano Performance Teaching. Advances in Educational Technology and Psychology, 7(7), 81-87.

[12] Yutong, S. (2023). Study on the importance of left hand playing skills in cello teaching. Frontiers in Educational Research, 6(10).

[13] Nakamura, E., Saito, Y., & Yoshii, K. (2020). Statistical learning and estimation of piano fingering. Information Sciences, 517, 68-85.

[14] Xu, M. (2018). The high finger piano technique in China: past, present, and future. DMA diss., University of Iowa, Spring.

[15] Kim, S., Park, J. M., Rhyu, S., Nam, J., & Lee, K. (2021). Quantitative analysis of piano performance proficiency focusing on difference between hands. PloS one, 16(5), e0250299.

[16] Han Zhou. (2024). Bidding decision optimization based on integer programming method - a case study of virtual company of Ewood Technology Company. International Journal of Mathematics and Systems Science(8).

[17] Andrew C. Pangia & Margaret M. Wiecek. (2024). A branch-and-bound algorithm for parametric mixed-binary nonlinear programs. Journal of Global Optimization(prepublish),1-25.

[18] Ye Zhenzhang,Haefner Bjoern,Quéau Yvain,Möllenhoff Thomas & Cremers Daniel. (2022). A Cutting-Plane Method for Sublabel-Accurate Relaxation of Problems with Product Label Spaces. International Journal of Computer Vision(1),346-362.

[19] Nadizar Giorgia,Sakallioglu Berfin,Garrow Fraser,Silva Sara & Vanneschi Leonardo. (2024). Geometric semantic GP with linear scaling: Darwinian versus Lamarckian evolution. Genetic Programming and Evolvable Machines(2).