The Application of Artificial Intelligence-Assisted Computer on Piano Education

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Abstract. Artificial intelligence (AI) is a very challenging and widely used computer science technology, providing diversified methods, theories and technical support for various fields. In the music education industry, the use of artificial intelligence technology has greatly enriched education and teaching, education and training, music APPs, intelligent systems, etc., and injected fresh blood into teaching activities. In recent years, piano education has been paid more and more attention in our country. How to carry out more targeted teaching and improve the efficiency of students' daily practice?It is an urgent problem to be solved in the universal education of piano. By using artificial neural network to compare the repertoire played by the learner with the original repertoire, and identify the playing fingering of the learner, it points out the problems in the practice process. It is analyzed and processed through artificial intelligence technology and gives guiding opinions for piano practice, so that the piano practitioners can solve the problems in the piano practice process more targetedly and improve the practice efficiency. This paper analyzes the application background of music artificial intelligence technology in the field of music education, and discusses and thinks about its application and influence in piano education.

Keywords: Artificial Intelligence Technology; Piano Teaching; Music Education; Music.
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1 INTRODUCTION

Hugo once said, "Human intelligence holds three keys, one for numbers, one for letters, and one for notes [1]. Knowledge, thought, and fantasy are among them." This sentence fully demonstrates the importance of music in life [2]. Music can not only help children improve their ability to appreciate beauty, but also help develop a healthy personality, and it is even more obvious for the improvement of personal temperament [3].

With the development of material life, Chiu [4] believes that more and more people begin to pay attention to early music education, but various problems often occur in the learning process. Taking the universal education of piano as an example, piano learners usually meet with teachers every week [5]. There is a back-to-class instruction, and more time is spent practicing alone [6-7]. Huang [8] believes that many piano learners will make various common mistakes in the process of practice. However, they are not aware of this. More commonly, they read the wrong music score, play the wrong keys and dial the wrong fingering. Kewalramani et al. [9] believes that if the instructor corrects, the practice effect will be greatly improved. However, piano teachers are relatively scarce. According to Lee and Lee's [10] research statistics, less than one tenth of piano learners can get practice guidance immediately. Liu and Huang’s [11] research shows that artificial intelligence technology has developed rapidly, showing high development potential in many fields. In the relatively complex Go field, Google's AlphaGo successfully defeated the world champion Li Shishi. Liu and Wang [12] believes that in the field of speech recognition, there are already relatively mature software in the market, such as Apple's Siri and Xiaomi's Xiao Ai. Music is no exception. At present, artificial intelligence can not only generate accompaniment according to a given melody, but can even generate complete repertoire independently. Therefore, artificial intelligence practice guidance is feasible under today's technical conditions, and more in-depth research can be carried out.

Sound signal processing is the primary problem of music transcription with computers. In other words, if artificial intelligence is to be used as a piano practice guide, the computer needs to understand the music first. At present, the commonly used digital signal processing methods include discrete Fourier transform, Mel spectrum and constant Q transform. According to the literature, the constant Q transform (CQT) is the transformation of music signals in the twelve-average temperament. Decomposition at the frequency point is the main method of music signal processing at present, and it is very suitable for the conversion of music signals.

In the actual activities of piano teaching, the musical tones obtained by the computer are always very complex, including the fundamental tone, a large number of overtones, and even noise, which makes it very difficult to separate the fundamental tone, but it is still possible to pass the frequency components in the musical tone Variation to find the pitch. The twelve-average law reflects the distribution of this frequency component. The frequency of all single tones in a musical tone and the average amplitude of each frequency can be obtained through constant Q transformation.

The piano is a keyboard instrument, which can also be attributed to a type of stringed instrument by hitting the keys to pull the hammers to hit the strings to produce sound. In terms of acoustic principles, the pronunciation of musical instruments is generally composed of three processes—initial vibration, stabilization, and decay. The acoustic characteristics of the sound state of the piano include: the amplitude peak value of the initial vibration process is large, the vibration head is round, and the transient time value is short; there is no stable process directly entering the decay process; the high and low frequency regions of different frequencies and the time value of the decay process The length is inversely proportional, which determines that each single tone emitted by the piano will be very clear, and the harmonics of its spectrum will be relatively small, which is suitable for artificial neural network learning.

At present, piano teaching still relies heavily on offline one-to-one teaching, requiring hands-on guidance from teachers. Artificial intelligence may be a perfect alternative. It is inexpensive and can provide instant guidance. There are also some piano practice guidance software on the market today, such as various sparring apps, which are still mainly based on one-to-one practice guidance by teachers and provide online teaching management. At the same time, there are also many online courses based on artificial intelligence technology on the market. Of course, the use in music education and teaching is no exception. Music artificial intelligence has become an essential and necessary part in the field of music education.

2 RELATED CONCEPTS AND THEORETICAL BASIS

2.1 Artificial Intelligence and Music Artificial Intelligence

(1) Artificial intelligence

In 1956, the term "artificial intelligence" officially appeared in the public's field of vision, referring to the realization of intelligent behaviors such as perception, cognition, decision-making, and action that surpass human beings on machines (computers, robots, etc.). Do what human intelligence can do. In the process of development of artificial intelligence, it has gone through three historical stages. During this process, it has experienced various voices of doubt and denial, broke through theoretical and technical barriers, and has been innovating continuously.

On the occasion of the 60th anniversary of the birth of world artificial intelligence science in 2016, Google's AlphaGO Go software and world Go champion Li Sedol staged a world-shaking "human-machine war". Artificial intelligence is also causing a new industrial revolution. In July 2021, the "National Conference on Artificial Intelligence Education in Primary and Secondary Schools" was successfully held in Beijing. The theme of the conference was "Cultivation of Innovative Talents in the Age of Intelligence", which emphasized that more attention should be paid to the education and training of primary and secondary school students. The overall improvement of innovation and creativity ability. It can be seen that in the era of rapid development of intelligence and networking, we must keep up with the trend of the times. On December 18 and 19, 2021, the 2021 "Zhixin Cup" National Artificial Intelligence Robot Innovation Competition Finals Award Ceremony and Artificial Intelligence Basic Theory Innovation Forum hosted by the Chinese Artificial Intelligence Society was held in Beijing. Breakthroughs in key technologies, intelligent robots, etc. The teams participating in this competition include well-known universities, primary and secondary schools, and enterprises. Therefore, the research on artificial intelligence technology in our country has attracted considerable attention and attention from all walks of life. Whether it is the innovation of theory or the application and breakthrough of related technologies, we need continuous efforts and actions.

(2) Music artificial intelligence

"Music artificial intelligence is a common and slightly vague concept, which can be regarded as the vertical application of artificial intelligence in the field of music. Including music generation, music information retrieval MIR (including dozens of applications), and all other music related AI involving Applications such as intelligent music analysis, intelligent music education, music score follower, intelligent mixing, music robot, music therapy based on intelligent recommendation, picture and video soundtrack and other applications.” The application of music artificial intelligence technology has also become a topic of research and discussion among scholars. topic. From October 22 to 24, 2021, the World Conference on Artificial Intelligence for Music, co-hosted by the Central Conservatory of Music and the Chinese Society for Artificial Intelligence, has attracted widespread attention in the musicology community. "The conference brings together top global music artificial intelligence experts, scholars, influential leaders in related fields, and representatives of related companies in the music industry, etc., to brainstorm and concentrate on eight poles, jointly explore the future music world, and promote the "production, learning, and development of music artificial intelligence". "Research, Application", serve Beijing, serve the national strategy, and join hands with the world in the future." ④ The conference will discuss music and artificial intelligence technology from various aspects, such as: music creation and artificial intelligence technology, music artificial intelligence from multiple perspectives, Music artificial intelligence industry-university-research and so on.

2.2 Application of Music Artificial Intelligence in Piano Education

(1) Piano sparring app based on music artificial intelligence technology

Since the 20th century, more and more students learn piano, which has gradually become a necessity for the development of the times. Parents and teachers also attach great importance to piano teaching arrangement, teaching content and teaching quality. The second is that students can use AI software to check whether they are practicing correctly during their usual piano practice, such as the Xiaoma AI sparring app, etc. The third is AI intelligent teaching, represented by The one intelligent piano. On the one hand, for the artificial intelligence team, we have seen new innovations and applications of artificial intelligence technology here. On the other hand, for teachers or parents, by using these apps for teaching or sparring, students can play in the piano class. The teaching effect of getting twice the result with half the effort. Figure 1.

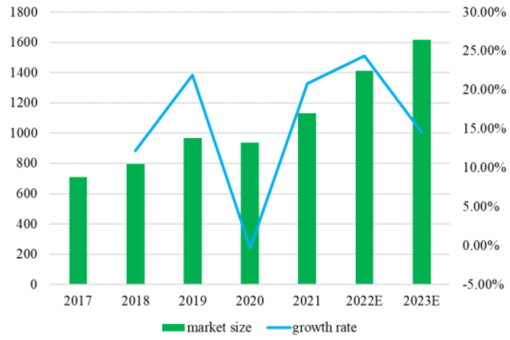

Figure 1: Development of the intelligent technology market for piano music education.

(2) Application mode of music artificial intelligence sparring app

In addition to direct live-action piano sparring practice, now more popular among students and parents is the intelligent AI sparring practice, which does not require an appointment in advance and can practice the piano at any time. These AI intelligent sparring programs are all piano sparring software jointly developed with professional AI intelligent teams and well-known piano teachers at home and abroad. Students can scan the QR code to bind themselves and the piano teacher's account together. For daily piano practice, teachers can view the data in the background, including the daily practice time, content of practice, and mistakes during practice, etc., so that they can chat with students in time for problems that arise during practice.

For some proficient pieces, students can conduct a complete performance evaluation of the music. After the evaluation, there will also be corresponding objective evaluations and feedback to the students. After continuous evaluation, students can correct the appearance of mistake.

(3) Requirements for teachers of music artificial intelligence apps

No matter what kind of piano practice app based on artificial intelligence technology, the requirements for teachers' teaching level and education are relatively high, especially for face-to-face teaching with students through video. The author once had the opportunity to serve as a piano sparring teacher in a sparring app. First, I must submit my own study and work resume, and the content of the resume should be as detailed as possible. In the second step, after the resume has passed the review, the recruitment department will organize an interview. The content and requirements of the interview are to examine the comprehensive piano teaching quality of the applied teachers, including listening, sight-reading, music score error correction, simulated class, etc. Teachers apply for piano teaching levels with different inspection content. The higher the level, the greater the difficulty of the inspection. After passing the final assessment, teachers will also be organized for training, the main content is how to use the app proficiently, the requirements for teachers during the class, and how to deal with emergencies during the class. At the end of the training, the teachers who apply for the job need to take the assessment of the simulated class again, and only after passing the assessment can they be formally admitted.

3 RELATED TECHNOLOGIES

3.1 Q Learning Algorithm

A typical algorithm in off-track policy TD learning is that the action policy μ is an ϵ-greedy policy based on the action-value function $Q(s, a)$, and the off-track policy π is a fully greedy policy based on $Q(s, a)$, This learning method is called Q-learning.

Q-learning, also known as Q-Learning, is a value function-based algorithm in reinforcement learning algorithms. Q is the symbolic representation of the state-action value function, which expresses the expectation of the agent's expected benefits after performing an action in a certain state.

The main core idea of the learning algorithm is to select the action with the greatest benefit in a certain state according to the Q value in the Q table, and the immediate benefit obtained from the environmental feedback after executing the action is used to update the Q value under the action of the state. Figure 2 shows the schematic diagram of the Q-learning algorithm.

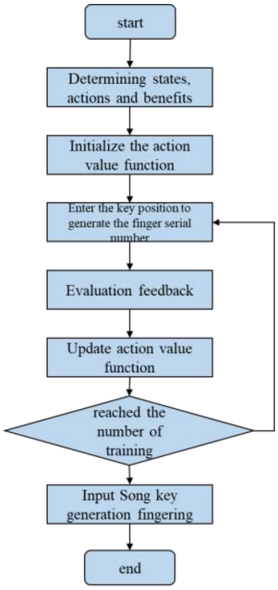

Figure 2: The steps of piano fingering generation based on Q-learning.

The goal of the Q-learning algorithm is to get the most The optimal value $Q(s, a)$, in the process of Q-learning, the action A that actually interacts with the environment at time t is generated by the policy μ, where the policy μ is an ϵ-greedy policy. The action A+1 used to update the Q value at time t + 1 is generated by a completely greedy policy π. The value of $Q(St, At)$ is updated as follows:

$$Q(S_t, A_t) \leftarrow Q(S_t, A_t) + \alpha\left[R + \gamma \max_a Q(S_{t+1}, a) - Q(S_t, A_t)\right] \quad (1)$$

where α is the learning rate and γ is the discount factor. According to this way of value updating, the value of the action A obtained by the state S according to the ϵ-greedy policy will be updated in the direction of the maximum action value in the state St+1.

The temporal difference learning task under the off-track strategy is to use the TD method to update the action value function based on the target strategy $\pi(a|s)$, and then optimize the action strategy:

$$V(S_t) \leftarrow V(S_t) + \alpha \left[\frac{\pi(A_t | S_t)}{\mu(A_t | S_t)} \left(R_{t+1} + \gamma V(S_{t+1}) \right) - V(S_t) \right] \tag{2}$$

The simplest action selection mechanism is to choose an action with the largest estimated value each time, which is also called a greedy action. If there are multiple greedy actions, choose one arbitrarily. The selection method of this greedy action is written as:

$$A_t = \arg\max_a Q_t(a) \tag{3}$$

where argmaxa is the action a that maximizes the value of $Q(a)$. The basic idea is to ensure continuous heuristics. Specifically, set ϵ to a small value, perform greedy actions with a probability of $1 - \epsilon$, and randomize a set of n actions with a probability of ϵ. to make a selection. Mathematically expressed as:

$$\pi(a|\ s) = \begin{cases} \frac{\epsilon}{n} + 1 - \epsilon \\ \qquad \frac{\epsilon}{n} \end{cases} \tag{4}$$

3.2 Monte Carlo Method

Different from dynamic programming, which evaluates a MDP with a known state transition probability or finds the optimal policy and optimal value function through policy iteration or direct value iteration, Monte-Carlo Methods (MC) A complete environmental knowledge model is not required, only experience is required.

Using Monte Carlo methods to evaluate a given policy, a complete state information based on a specific policy п can be represented as a sequence as follows: S1, A1 ,R2 ,S2 ,A2 ,...,St ,At ,Rt+ 1 ,...,Sk ~ п. Then, the harvest of state St at time t can be expressed as:

$$G_t = R_{t+1} + \gamma R_{t+2} + \cdots \gamma^{T-1} R_T \tag{5}$$

where T is the termination time. The value of a state under this strategy is:

$$v_\pi(s) = E_\pi \left[G_t | S_t = s \right] \tag{6}$$

Incremental mean is a very practical calculation method that does not need to store all historical harvests in the process of solving the mean of state harvests. The specific formula is as follows:

$$\mu_k = \frac{1}{k} \sum_{j=1}^{k} x_j \tag{7}$$

The method of incrementally realizing the average value is to use the last average value, the current state data and the total number of state data to realize the calculation of the average value of the new state harvest. When a new state data x needs to be calculated, first calculate the difference between xk and the previous average $\mu k-1$, and then use the product of the coefficient $1k$ and the difference as the error of the previous average correction, where k is the state Total data. The average value and new data in this formula are regarded as the value of the state and the harvest of the state, respectively, then the formula becomes an incremental Monte Carlo method to update the state value. Its formula is as follows:

$$N(S_t) \leftarrow N(S_t) + 1 \tag{8}$$

$$V(S_t) \leftarrow V(S_t) + \frac{1}{N(S_t)}\left[G_t - V(S_t)\right] \tag{9}$$

In some real-time or inability to count the exact number of visits to the state, a coefficient α can be used to replace the inverse of the state count, and the formula becomes:

$$V(S_t) \leftarrow V(S_t) + \alpha\left[G_t - V(S_t)\right] \tag{10}$$

It can be seen that the Monte Carlo method does not require a complete environment model and is a model-free reinforcement learning algorithm.

3.3 Temporal Difference Learning

Temporal-difference learning (TD learning) refers to learning when the state sequence is incomplete. It estimates the value of the state by estimating all the possible subsequent gains of a state in the sequence, and using the method of incremental realization of the average value. , the value of this state is continuously updated through constant interactive exploration.

Specifically, in TD learning, when estimating the value of a certain state, it is calculated by multiplying the estimated state value of the immediate reward R+1 and the next moment state S+1 by the decay coefficient γ:

$$V(S_t) \leftarrow V(S_t) + \alpha\left[R_{t+1} + \gamma V(S_{t+1}) - V(S_t)\right] \tag{11}$$

Among them, R+1+ $\gamma V(St+1)$ is called the target value of TD, and Rt+1+ $\gamma V(St+1) - V(St)$ is called TD error. Guidance refers to the process of replacing the revenue value G with the TD target value.

Once St is determined, the historical state information S1. St-1 is no longer needed to determine St+1. In mathematical form, a state St has Markov property if and only if the state transition probability from St to S+1 is equal to the state transition probability from $S1$, . . . , St to St+1:

$$P\left[S_{t+1} \mid S_t\right] = P\left[S_{t+1} \mid S_1, \ldots, S_t\right] \tag{12}$$

The return is the decaying sum of all rewards when sampling from a certain state S to the end state in a Markov reward process, denoted by G, and the mathematical expression is as follows:

$$G_t = R_{t+1} + \gamma R_{t+2} + \cdots = \sum_{k=0}^{\infty} \gamma^k R_{t+k+1} \tag{13}$$

However, there are still many inconveniences in describing the importance of a state in terms of harvesting. The harvesting values of the same state calculated from different state sequences are usually different, so harvesting cannot accurately evaluate the importance of a state. Value is a concept that accurately describes the importance of a state. It is the expectation of state harvesting in the Markov reward process. It is represented by $v(s)$, and the mathematical expression is:

$$v(s) = E\left[G_t \mid S_t = s\right] \tag{14}$$

In the above equation (14), since the immediate reward is a fixed value, the expectation of R+1 is itself. The state value expectation at the next moment can be calculated from the state probability distribution at the next moment. Then the above equation can be written as:

$$v(s) = R_s + \gamma \sum_{s' \in S} P_{SS} v(s') \tag{15}$$

The above equation (15) shows that the value of a state is obtained by calculating the probability distribution of the value of the subsequent state with decay and the sum of the immediate reward of the state, which is the Bellman equation in the Markov reward process.

4 EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Quantitative Evaluation of Piano Fingering

In order to test and verify the validity and objectivity of the established piano fingering quantitative evaluation system, the following experiments are designed to compare and analyze the fingering evaluation results. The experiment in this chapter also uses Python language to write the algorithm of the piano fingering quantitative evaluation system, and debug and implement it in the PyCharm compiler.

Judging from the experimental results in Figure 3, the average score of straight fingering is the highest, and they are all out of 5 points, which is in line with the optimal standard of natural ordering fingering; This is basically in line with the prioritization of fingering transitions between fingers; the average score of the illegal fingering category is the lowest, and each score is a negative number, which is conducive to guiding the machine to avoid using illegal fingerings during learning.

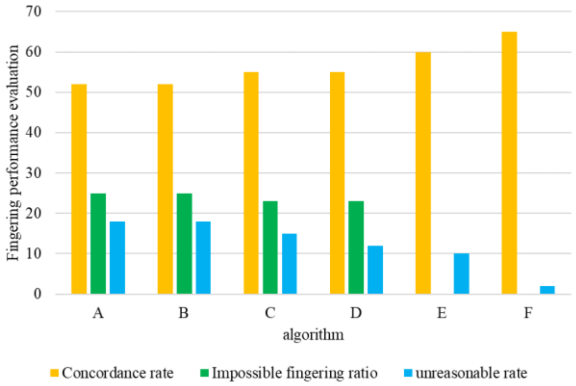

Figure 3: Comparison of various fingering scores.

As shown in Figure 3, it is the comparison of the scores of various fingerings. It can be seen that the distribution of various fingering scores is balanced but there are high and low points, which is conducive to guiding the machine to generate a reasonable and scientific fingering sequence.

The piano fingering quantitative evaluation system not only evaluates the fingering conversion of each step during the machine training process, but also evaluates the entire generated fingering sequence. The following is a selection of key sequence fragments with 10 notes, and the standard fingering sequence, general fingering sequence, and random fingering sequence are used to input the piano fingering quantitative evaluation system for scoring experiments. The statistics of the experimental results are shown in Figure 4.

Judging from the evaluation results of the different fingering sequences above, the total score and scoring rate of the standard fingering sequence are very high, and it can be seen from the scoring trend that it is rising steadily with small fluctuations; the total score and scoring rate of the general fingering sequence are higher than The standard fingering sequence is lower, and the scoring trend and scoring rate are not stable and fluctuate greatly; while the random fingering sequence has a very low total score and scoring rate, and the performance is very unstable, and the score fluctuates greatly. It can be seen that the quantitative evaluation system of piano fingering established according to the method of this paper basically conforms to the rules for the evaluation of fingering sequence, and is scientific and effective.

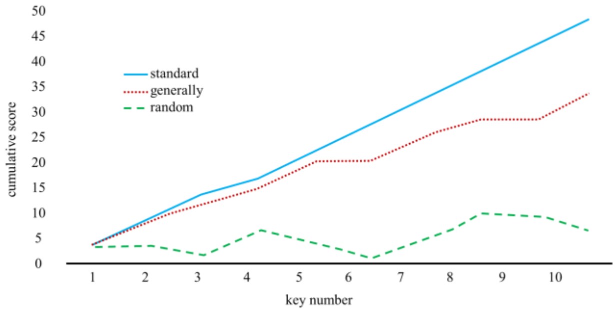

Figure 4: Cumulative score trend.

4.2 Automatic Generation Network of Piano Fingerings Based on Q-Learning

Using the key sequences of the three music clips described in this paper, the piano fingering generation experiment based on the constructed Q-learning network is used to obtain the average yield comparison statistical results, as shown in Figure 5. The average return refers to the average of the ratio of the total return to the optimal return in a training round, which reflects the average learning effect of the agent within a certain range of training steps and the quality of the result.

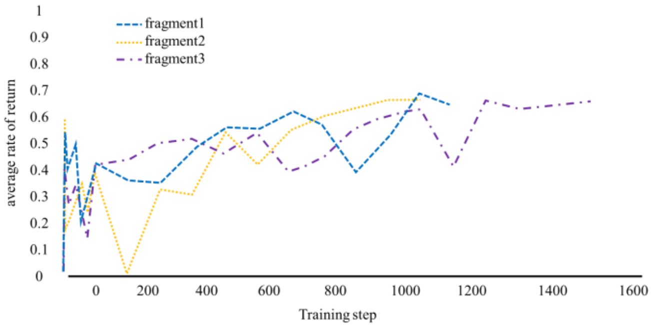

Figure 5: Comparison of the average yield of each music segment.

It can be seen from Figure 5 that when the number of training steps is relatively small, the average rate of return of each music segment is unstable, and the results are not ideal and fluctuate greatly. With the increase of the number of training steps, the fingering rules learned by the agent are getting better and better, the total income gradually increased. Due to the difference in the number of keys in each segment, the average yield tends to be stable sooner or later. It can be seen that the segment with more keys requires a larger number of training steps to ensure better experimental results.

Next, we further analyze the multi-check problem of audio-based transcription results and strategy fusion transcription results, and analyze the effect of strategy fusion in more detail. We compare the number of multi-check problems between the two in the test set of the OMAPS dataset, as shown in Figure 6: It can be seen from the figure that the multi-check errors of strategy fusion and audio transcription are reduced from 2723 to 858, and the multi-check reduction ratio is 68.6 %, effectively reducing the multi-check problem.

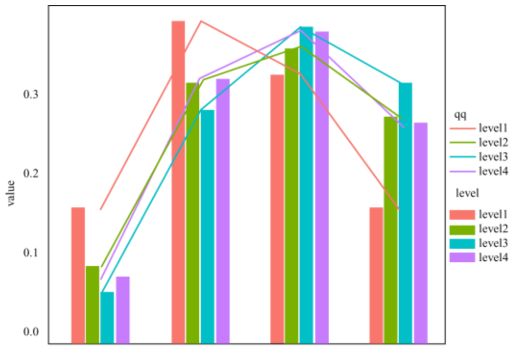

Figure 6: Multi-test distribution statistics of audio transcription and policy fusion.

Among them, the main problem of multi-octave detection in audio transcription has dropped from 1481 to 316, and the improvement is very obvious, indicating that the multi-octave correction model in our strategy fusion has played a huge role; in addition, the problem of homophonic multi-detection has also been significantly reduced, indicating that homophonic multi-detection has also been significantly reduced. The optimization module works just as well. From the above analysis, it can be concluded that the two modules of our strategy fusion have played a certain role in improving the inherent problems of audio transcription. This method of strategy fusion is feasible and effective.

Then this paper tests the training of the ELU activation function at various learning rates, as shown in Figure 7. In comparison, it is found that ELU is particularly sensitive to the learning rate, and the entire neural network is "dead" when it exceeds 0.003. In terms of accuracy and gradient change, the optimal learning rate should be between 0.001 and 0.002.

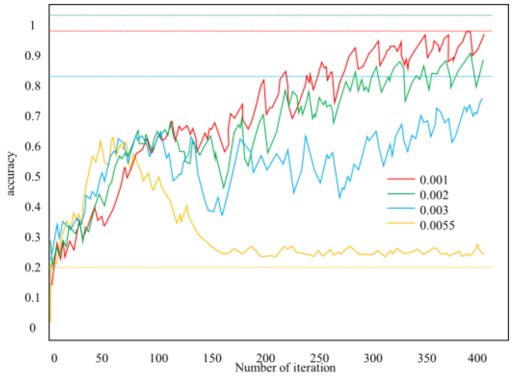

Figure 7: Experimental comparison of four learning rates under ELU conditions.

5 CONCLUSION

This paper has made a new attempt in the field of artificial intelligence, not only using technologies such as big data for teaching assistance, but also hoping to solve some difficult problems in piano practice through the advanced technology neural network in the field of artificial intelligence, so as to help piano students timely Find and correct fingering and rhythm issues in your performance. Starting from two ideas here, since video information and audio information have their own weights, the video and audio data of the performer are collected and obtained at the same time, the neural network model is trained separately to process the performance video and audio, and finally the analysis results are multimodal. Decision level fusion. It is analyzed and processed through artificial intelligence technology and gives guiding opinions for piano practice, so that the piano practitioners can solve the problems in the piano practice process more targetedly and improve the practice efficiency.

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