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Analysis of Piano Online Teaching System Based on Maximum Logarithm MPA Algorithm Technology

Jing Shi, Nanchang Institute of Technology, China and Christine University in the Philippines, Manila, Philippines*
Na Wan, Nanchang Institute of Technology, China
Roslina Ibrahim, Universiti Teknologi Malaysia, Malaysia

ABSTRACT

The application of computer technology has revolutionized and promoted the traditional mode of piano teaching. Nowadays, many companies and institutions have begun to apply computer technology to online piano teaching. This paper analyzes the difficulties faced by students in piano teaching and the development of piano assistant practice and summarizes the demands of parents, teachers, students, and principals for online piano teaching system. Based on this, this paper designs and implements an online piano teaching system without special hardware. This system improves the existing maximum logarithm MPa algorithm and improves the detection performance while keeping the complexity low. Combined with the special structure of parallel projection, a generalized automaton model of hybrid system is proposed, and five elements are used to describe the continuous and discrete behaviors in the hybrid subsystem. It not only keeps the advantage of low complexity of the original Max log MPa algorithm, but also obtains better detection performance.

KEYWORDS

Discrete Dynamic Modeling, Multi-User Detection, Online Piano Teaching System, SCMA

The rapid development of 5G technology and the constant change in talent market demand put forward higher requirements for the construction of online piano education in the 5G era. The optimization and reform of the piano online education construction in the 5G era can effectively integrate the teaching resources of 5G teaching technology, improve the application ability of online piano education construction (from the perspective of audio-visual and piano practice), and adapt to new market demand. However, some music education apps, such as VIP sparring, and other online piano education apps have met the needs of piano and other musical instruments. Therefore, the online music education platform has gradually attracted the attention of parents. Computer technology is widely used in various fields, and piano lessons in colleges and universities are no exception. The application of computer technology has innovated and promoted the traditional piano teaching mode,

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*Corresponding Author

such as the application and analysis of musical instrument digital interface (MIDI) music technology in piano teaching, the application of sequencer software in visual piano performance analysis, the application of spectrogram software in the analysis and teaching of multi-part piano works, and the application of sequencer and spectrogram software in the analysis of multi-part works. MIDI is the basic specification and protocol that MIDI and digital music equipment should follow. General music software and MIDI demonstration music library are used to promote piano learning. Some studies also integrate theoretical knowledge of music and its teaching methods and means, so they can penetrate and interact with each other in the process of teaching and learning and inject new vitality into piano teaching. The application of computer technology in piano education and teaching can enable more people to get training in piano knowledge and skills, expand the scope of talents in piano education and teaching, and cultivate more people who know and can play the piano.

Traditional piano teaching adopts the one-to-one teaching mode, which can better account for the development of individuality. It has its advantages, but it has its disadvantages. Computer technology has long been integrated into the teaching activities of various disciplines. Many disciplines have teaching software and computer network systems. In particular, the internet constitutes a huge information exchange and storage system and is also a huge teaching resource warehouse. Teachers and students can find very rich education and suitable learning resources. The use of computers in piano teaching is not only conducive to improving and cultivating students' music perception and understanding ability but also makes a good record for students' learning and teachers' teaching. It is conducive to promoting the development of piano teaching in China. At present, we can collect data, analyze music scores, and establish teaching files to discuss the favorable factors of computer intervention in piano teaching. In real life, the course cost, time cost, and economic cost of inviting piano basic course teachers are very high (Kim et al., 2019). Therefore, the traditional method of teaching piano cannot currently fully meet the needs of piano students.

Sparse code multiple access (SCMA) technology can transmit multiple users on a one-time-frequency resource, which has strong anti-interference to the same frequency. This makes SCMA meet the requirements of 5G large-scale connection. Literature puts forward an optimization scheme for the design of the SCMA encoder codebook (Tian et al., 2019). Literature is based on the sparsity of the SCMA codebook and adopts the detection algorithm of low-density signature code division multiple access (LDS-CDMA), namely the message passing algorithm (MPA) (Lai et al., 2018). MPA is a suboptimal multi-user detection algorithm given the edge of factor graph. The algorithm is based on the idea of iteration and finally converges through multiple iterations, which can approach the performance of the optimal maximum posterior probability algorithm. The literature proposes an improved MPA detection algorithm based on partial marginalization, which reduces the algorithm complexity at the expense of bit error rate (BER) performance (Zhang et al., 2021). In the literature, a multi-user detection algorithm of SCMA based on the Monte Carlo Markov chain was proposed, which greatly reduced the computational complexity of the multi-user detection algorithm. Moreover, this provided a new idea for SCMA multi-user detection (Pan et al., 2018). The application of error correction codes in modern communication systems has greatly improved the overall performance of the system. To achieve a low BER and channel error rate, powerful error correction codes such as turbo code and low-density parity check code are widely used in various systems (Rajasekaran et al., 2019). To further reduce the complexity of the algorithm, a log-domain maximum logarithm (MAX-Log) MPA algorithm is proposed. The algorithm has a low complexity, but the detection performance is relatively poor, and the detection performance is lost to reduce the computational complexity. To improve its detection performance, this paper adopts a simple and effective method to improve MAX-Log MPA, that is, to add an impact factor to the process of resource node message update. This impact factor not only inhibits the loss of MAX-Log MPA messages during user detection and improves the detection performance but also does not cause any burden to the SCMA system.

The main goal of designing an online piano teaching system is to address the challenges that arise from traditional face-to-face teaching, such as issues related to time, physical location, cost, and transportation (Cui & Shuang, 2019). This platform aims to leverage the rapidly expanding network as a platform for effective piano learning, taking into consideration the specific requirements of piano education by synthesizing various societal resources to facilitate successful piano learning. Based on the above analysis and introduction, this paper aims to develop a piano online teaching system based on the SCMA system multi-user detection algorithm and discrete dynamic modeling to solve the pain points faced by traditional piano teaching. The SCMA system's multi-user detection algorithm and discrete dynamic modeling can provide a complete and stable data transmission channel, enabling efficient and real-time data transmission in online piano teaching systems (Wang et al., 2019). At the same time, discrete dynamic modeling can describe and analyze the data generated by students during the practice process, thereby helping teachers better understand students' practice situations and providing more personalized teaching guidance for students.

RESEARCH METHOD

Improved Multi-User Detection Algorithm for SCMA System

SCMA System

SCMA can be considered as a code division multiple access scheme, described by a sparse codebook. The codebook is constructed based on a multi-dimensional constellation and the shaping gain helps it to be superior to the traditional scheme based on extended code. In SCMA, multiple users will use different codebooks on the same resource block for transmission. The use of a sparse codebook reduces the conflict between users, so SCMA is resilient to inter-user interference. The sparsity also benefits the complexity of the receiver, and MPA can be applied to achieve near-optimal performance. SCMA is also a kind of LDS-CDMA system technology, and its difference lies in that SCMA technology replaces data modulation by selecting user code words, and each user has his own codebook (Moltafet et al.,2019). SCMA, as a promising 5G wireless air interface technology, is a non-orthogonal multiple access technology with better spectral efficiency based on the codebook. The existing SCMA multi-user detection algorithm is mainly MPA, which is a suboptimal multi-user detection algorithm with near-optimal maximum a posteriori (MAP) probability detection algorithm performance. The traditional MAP exhaustive detection algorithm must detect the codebook combination of all users, which greatly increases the complexity of the algorithm. Compared with the traditional MAP algorithm, the MPA algorithm based on the sum-product operation is a typical multi-user detection algorithm in the SCMA system. The algorithm is implemented through message transmissions and iterative updates between nodes in the factor graph. In essence, the algorithm is based on the idea of parallel strategy.

Figure 1 and Figure 2 are schematic diagrams of the sending ends of the LDS-CDMA system and SCMA system.

As shown in Figure 1, in the LDS-CDMA system, after channel coding, the user information passes through the modulator, then undergoes sparse spread spectrum, and finally, is transmitted. In the SCMA system in Figure 2, modulation and sparse spread spectrum are unified based on codeword selection in the user codebook, and the user codebook in this process needs to be designed in advance.

Compared with the LDS-CDMA system, the SCMA system has the following two basic characteristics (Abebe & Kang, 2019):

1. SCMA system distinguishes different users by codebook and combines modulation in LDS technology with sparse spread spectrum technology to express them by sparse codebook. Based on codeword selection in the codebook, bit information sent by users can be directly mapped into codewords.
2. The receiver multi-user detection algorithm of the SCMA system is also based on the sparsity of the codebook, that is, message transmission based on edge of factor graph, and the message

Figure 1. Schematic diagram of LDS-CDMA transmitter

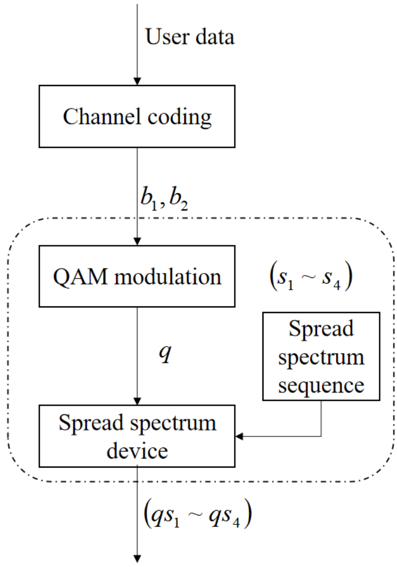
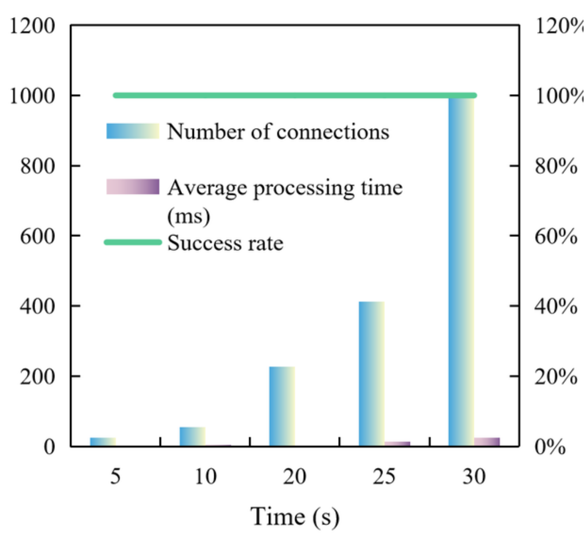


Figure 2. Schematic diagram of SCMA sender



transmission process of edge in factor graph is essentially the transmission process of codeword. Therefore, to detect a codeword message, the receiver of the SCMA system needs to know the codebook information of the sender.

Improved MAX-Log MPA Multi-User Detection Algorithm

In the actual communication system, it is difficult to achieve complete orthogonality and synchronization for the codewords between users, and multiple access interference between users is unavoidable. The application of multi-user detection technology can effectively weaken the multiple access interference, increase the system capacity, and improve the communication anti-interference ability of the system. In the multi-user detection process of the SCMA system, the MAX-Log MPA uses approximate calculation, resulting in partial message loss and poor detection performance. Therefore, the approximate method closer to the real value is derived theoretically, and an improved MAX-Log MPA algorithm is proposed.

Assuming that the channel estimation is perfect and the codebook can be used in the receiver, the detection of SCMA can be regarded as a problem of traditional multiple users' decoder, which can be solved by joint optimal MAP. Because there is a Equation 1:

$$p\left(x\middle|y\right)=\frac{p\left(x\middle|y\right)p\left(x\right)}{p\left(y\right)}\propto\left(y\middle|x\right)p\left(x\right) \tag{1}$$

A posteriori probability may be written as Equation 2:

$$p\left(x\middle|y_j,H_j\right)=p\left(x\right)\cdot\exp\left(-\frac{1}{2\sigma^2}\left\|y_j-H_jx\right\|^2\right) \tag{2}$$

If we assume that the transmission probability of each codeword is equal, the maximum a posteriori probability detection MAP is simplified to maximum likelihood (ML), as shown in Equation 3:

$$\overline{x}=\arg\min_{X\in\left(x_{j=1}^{J}\right)x_j}\left\|y_j-H_jx\right\|^2 \tag{3}$$

A decision tree algorithm is an algorithm in the field of machine learning. Its core idea is not a very complex mathematical formula but a simple logical if-then branch, which also makes it easier to understand. It is also the basis of subsequent algorithms such as random forest and gradient-boosted decision trees. The ML algorithm uses the exhaustive method to search all possible combinations of users and their codebooks (Wei et al., 2018), so the complexity of the algorithm is extremely high. The idea of the improved algorithm in this paper is to convert the EXP(exponential function) operation into the MAX(maximum value) operation and reduce the product operation to reduce the complexity of the operation. At the same time, an influence factor is added to reduce the BER of the detector by adjusting the value of the influence factor without affecting the complexity of the algorithm.

MAX-Log MPA algorithms include parallel and serial algorithms. The message-updating process from the resource node to the user node adopts the approximate calculation of max, as shown in Equation 4:

$$\log\left(\sum_{i=1}^{M^{d_f}}\exp\left(f_i\right)\right)>\max_{i=1,L,M^{d_f}}\left\{f_1,f_2,L,f_{M^{d_f}}\right\} \tag{4}$$

Using the MAX-Log operation on the MPA algorithm will inevitably cause some information loss. In addition, the complexity of the algorithm will be reduced by taking log operations and converting multiplication into addition. To solve the poor detection performance of the MAX-Log algorithm and keep its low complexity, we can get Equations 5 and 6:

$$P^{t}_{r_k \to u_j}\left(x_j\right) = 2 \times \max_{x_j}\left\{\frac{1}{2\sigma^2}\left\| y_k - \sum_{V \in \varepsilon_k} h_{kV} X_{kV} \right\| + \sum_{l \in \varepsilon_k / \{j\}} P^{t-1}_{u_l \to r_k}\left(x_j\right)\right\} \tag{5}$$

$$P^{t}_{r_k \to u_j}\left(x_j\right) = 2 \times \max_{x_j}\left\{\frac{1}{2\sigma^2}\left\| y_k - \sum_{V \in \varepsilon_k} h_{kV} X_{kV} \right\|^2 + P^{t-1}_{u_l \to r_k}\left(x_j\right) + \prod_{l \in \varepsilon_k / \{j\}} P^{t-1}_{u_l \to r_k}\right\} \tag{6}$$

Equations 5 and 6, respectively, represent improved message-updating formulas from parallel MAX-Log MPA and serial MAX-Log MPA resource nodes to user nodes.

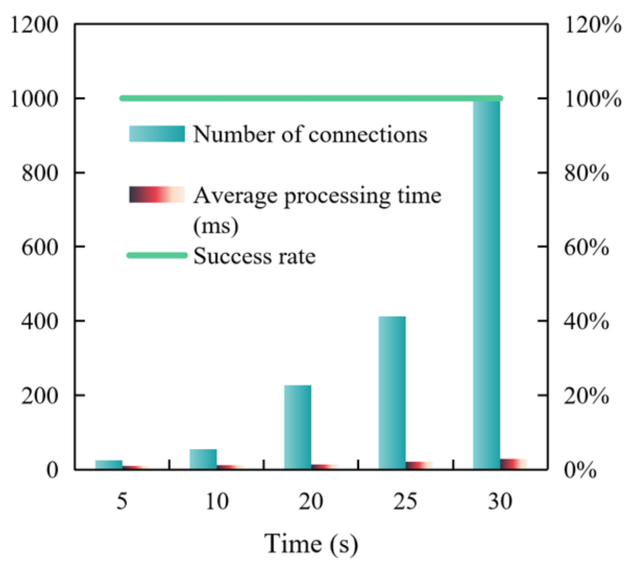
The message lost by the improved MAX-Log MPA message update formula will be smaller, which makes the message obtained in the next iteration process more reliable and has better detection performance. Therefore, the method adopted in this paper will not burden the original MAX-Log MPA algorithm, but also keep its advantage of low algorithm complexity and improve its detection performance.

Online Piano Teaching System

Overall System Requirements

The purpose of designing a piano network learning system is mainly to effectively use the high-speed network as a platform for traditional face-to-face teaching in terms of time, physics, economy, transportation, and other problems, and design an effective piano teaching platform based on the actual piano teaching situation and various social resources., and can not only effectively save social resources but also bring convenience to scholars and instructors. According to the purpose description of system design, the system mainly includes learning function, communication function, and statistical function from the perspective of function. For a piano online teaching system, the analysis of the overall needs of the system is based on students. There are five types of users of the online piano teaching system (Alnoman et al., 2019): system administrators, parents, students, teachers, and principals. Given the above analysis, the all-out system demand diagram can be determined, as shown in Figure 3.

Figure 3. Overall system demand diagram



System Function Design

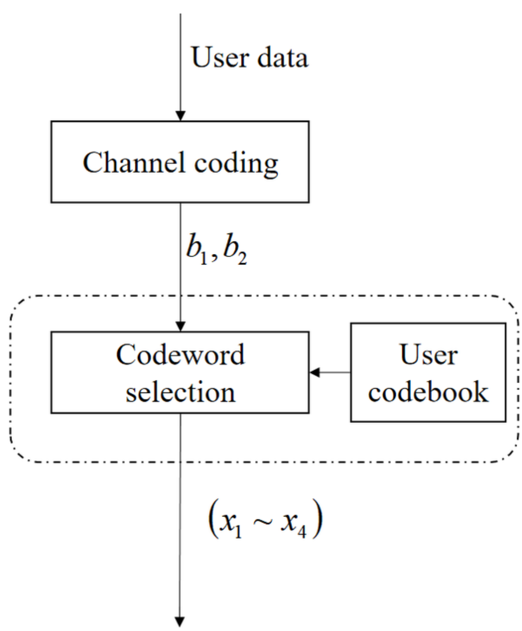
Given the analysis of system requirements in the former section, this paper divides the piano online teaching system into three terminals: client, WeChat, and web page. The client runs on an iPad and can be divided into the square module and performance module according to module function. Web pages can be divided into the score management module and data analysis module according to module functions (Saito et al., 2008). The design of system function modules is shown in Figure 4. The functional design of the system will be described in detail according to the functional modules below. Based on the three main functions, the purpose and significance of the system design, and the integrity of the system structure, considering that the system is ultimately used by users, users of different roles pay different attention to it from the perspective of user roles (Chen, 2022).

Client Functional Design

Learning is a process of "teaching + learning." From the perspective of educators, we should consider the convenience brought by the network and ensure the quality of teaching, that is, in addition to the new teaching characteristics in the information age, we should also have the teaching effect of traditional teaching methods. A new teaching concept comprehensively improves the process of "teaching + learning" from the aspects of efficiency, economy, environmental protection, convenience, and mutual benefit (Teaching, 2019). The module is primarily responsible for the social functions of students and teachers. The cover of the card is the user's avatar, and the latest tracks played by the user are displayed below the card. The user can click the card to enter the next page. At the top of the next page, they can pay attention to the users (teachers or students) of the actual page (Kamenev & Kamenev, 2021). If they click on the playing card to enter, the user can see the replay of the current performance. For this performance, the user can click like, average, or dislike.

There is a card on the right side of the client. Below the card is the name and time of the latest music score played by the current user. If the current user's identity is a student, then this card is displayed as a homework exercise. If the current user's identity is a teacher, then this card is displayed as a demonstration.

Figure 4. System function module design



When the user is a teacher, they can click the card to enter the demonstration. Teachers can add demonstration exercises to themselves. Teachers can click on the demonstration to be played to enter the performance. The only difference here is that the teacher has an additional annotation function. Teachers can annotate the key points and difficulties of the current score on the iPad. Note data and drag score data will be stored separately in the playback file. This demonstration will be presented to students when they play the same score.

WeChat Function Design

A user management module mainly includes user registration, user information modification, user binding, and other functions (Wen et al., 2021). When a user clicks on the student menu, the server will first obtain the user's WeChat openid, and then launch a query to the MySQL server to determine whether this user exists in the parent table of the MySQL database. If it does not exist, the server will initiate redirection and the page on WeChat's official account will enter the parent information completion page. Parents can edit their personal information, including the avatar name, and students' personal information, including the avatar, background picture, piano age, and name. Parents can also add and delete students (Wang, 2023).

The job module mainly consists of job arrangement and job viewing. Students' homework can be assigned by teachers or parents. The entrance of the teacher's homework management is in the homework sub-menu of the classroom menu, and the teacher can click this sub-menu to enter the avatar cards of all the students of the teacher in the default school. Since a teacher may work in several piano schools, each school has its own students.

There is a navigation bar at the bottom of the page where parents click on the student menu, which includes three buttons: Practicing Piano, Ranking, and My. The user can click Ranking to view the ranking of stars obtained by students in the same school and the ranking of current students. The user can click the classmate's card to enter the classmate's homepage. The homepage contains a list of music scores played by students. The user can click the score list to enter the recording page.

Web Page Function Design

Administrators mainly use the web page for music score management and data analysis. Administrators who need permission can register and open an administrator account so they can log in to the webpage to manage music scores and view data. There are often multiple roles in a system, and different roles have different permissions. The user's permissions cannot be fixed and can be adjusted as needed. For example, if an ordinary person is upgraded to a department head, the user's permissions in the system need to be adjusted accordingly. Therefore, the user's permissions in the system should be adjusted as needed, and this adjustment cannot be adjusted by himself; it needs to be allocated by the system administrator. Administrators can assign roles to users and change their roles. This shows the flexible distribution of user power in the system.

The music score management module is mainly composed of book management and music score management. After the administrator logs in, there is a plus button on the top left of the page, which can add books. When adding books, you need to fill in the title, alias, version number, publishing house, and barcode, and upload the cover picture. The administrator can edit the detailed information of the score by clicking Edit Score. At the top of the music score display page, the administrator can click the Add Music Score button to add music scores. To add books, you need to fill in the music score name, English name, and page number, and upload the XML file of electronic music scores and music score illustrations.

The data analysis module is mainly composed of user behavior analysis and user performance data analysis. User behavior data is displayed on the left side of the page in the form of a list. The user behavior data includes the date of data reporting, WeChat nickname, identity (user type), school, button name, and operation button number.

Nonfunctional requirements solve the issue of how to make the system run in the actual environment. It is of course very important to meet functional requirements in the process of designing solutions. However, if nonfunctional requirements are not considered, it is difficult for this solution to achieve effective results because users may find it difficult or even impossible to use the functions of the system. Many nonfunctional requirements are generally carefully designed and implemented on the underlying basic technology platform. Nonfunctional features are often more valuable than the development of the system itself because they fully reflect whether the designed system can demonstrate its value.

This project is an internet-based online piano teaching system. The core foundation is network bandwidth, which is the premise to support the feasibility of the whole project development. With the progress of the times, the current network bandwidth can completely bear the bandwidth consumed by the project operation.

Discrete Dynamic Modeling

The model of a hybrid system does not have a unified structure or form, and some mature models are aimed at a certain field or special environment (Mheich et al., 2018). According to the different modeling methods and focuses of hybrid systems, the modeling of hybrid systems is generally divided into two categories: one is to treat hybrid systems as discrete event systems and to build hybrid system models by expanding mature discrete event analysis methods, which is called "aggregation" modeling. Another method is to treat the hybrid system as a dynamic system with continuous variables and analyze the hybrid system with the traditional continuous-time modeling method, which is called "continuation" modeling.

Structure of Modeling Object

From the analysis of the internal structure and external characteristics, a hybrid system shows obvious non-homogeneous characteristics, which combine the common characteristics of discrete and continuous (Mheich et al., 2018). The motion of the continuous part can be described by the traditional differential formula, and only when a certain moment or a certain condition is reached, the motion state of the system is changed by the event trigger. This type of system is common, such as state-to-state control, variable structure control, start-up and shutdown of complex systems, monitoring, and scheduling of continuous processes, etc. The object of the generalized automata model belongs to a hierarchical hybrid system.

The hierarchical model can be represented by a nine-tuple, as shown in Equation 7.

$$H = \left(Q, \sum, \delta, X, U, f, g; \gamma, \alpha\right) \tag{7}$$

$\delta : Q \times \sum \rightarrow Q$ is the state transition mapping function of a discrete event system. Driven by event $\sigma \in \sum$, the transition from state $q_1 \in Q$ to $q_2 \in Q$ can be expressed by the transition mapping relationship of δ, as shown in Equation 8.

$$q_1 \frac{\delta}{\sigma \in \sum} q_2 \tag{8}$$

$\alpha : Q \rightarrow U$ is the mapping from discrete event state set Q to control space U, and α is a control law generator based on discrete event state structurally. It is through this mapping relationship that the discrete control mechanism dominates the dynamic behavior of the continuous controlled process.

Parallel Mapping Projection Structure

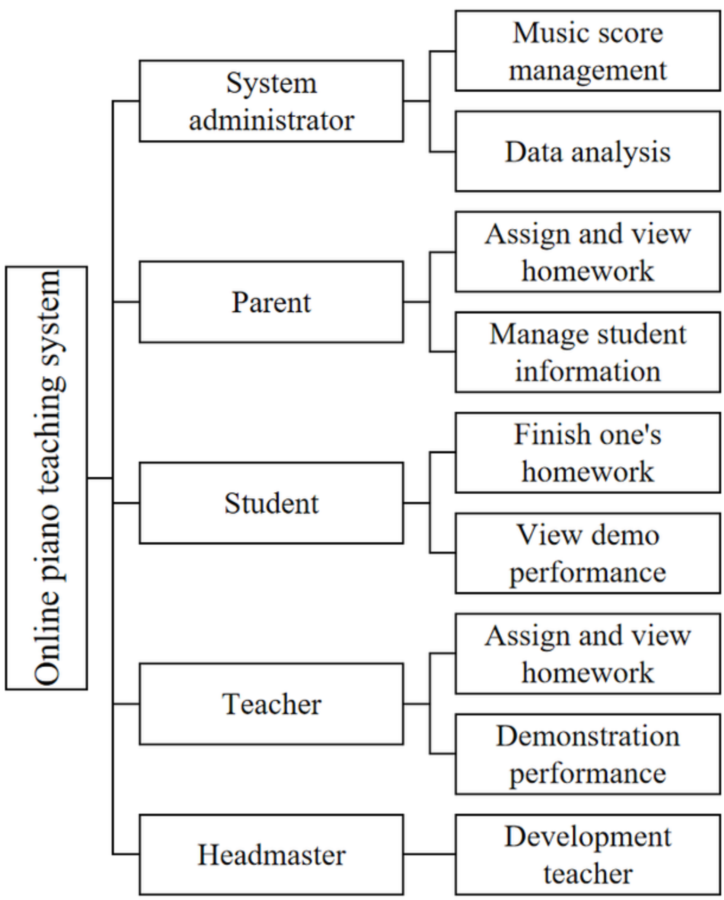
It is assumed that the evolution process of a hybrid system is represented by a multi-step sequence, and the evolution of each step includes two stages. The first stage is the dynamic process of continuous variables, which is usually described by differential formulas, and is projected as a segment on the time axis. The second stage is subject to the alternation of discrete events, and it is projected as a point on the time axis. Equation 9 can be used to express this replacement sequence of a hybrid system (Ju & Son, 2019).

$$\left\{e_{i0}, a_{i0}\right\}, \left\{e_{i1}, a_{i1}\right\}, \left\{e_{i2}, a_{i2}\right\}, \cdots \tag{9}$$

In Equation 9, $\left\{e_{i0}, a_{i0}\right\}$ represents a step in the evolution process, e_{i0} is a discrete event, which occurs and ends at an exact time point, a_{i0} is a continuous activity, which is activated at the time point when the discrete event occurs and ends after a period of time.

The timeline characteristics of the above process can also be explained by a special parallel projection structure (see Figure 5).

Figure 5. Parallel projection structure



In the projection structure of Figure 5, $p_1, p_2, \cdots, p_m$ is regarded as a local evolution process of continuous behavior.

In a local time period, it is active, and q is regarded as a discrete event process, which happens synchronously with continuous behavior, and only at the moment when the previous continuous process is terminated or the next continuous process is activated, can there be an exchange of variables between the discrete process and the continuous process. The projection structure well reflects the layered structure of a hybrid system.

Generalized Automata Model

According to the theory of continuous state space partition in parallel projection structure, the generalized automatic operation model is represented by a 5-tuple, as shown in Equation 10.

$$H = \left(V, Q, Init, E, Q_f\right) \tag{10}$$

In which V is a limited set of system variables, consisting of successive variable V_C and detached variables V_D and $V = V_C \cup V_D$; Q is a limited set of successive state spaces; $Init$ is the set of primary variable values and primary state space; $E \subseteq Q \times L \times Q_f$ is a limited set of primary event transitions, where L is a set of transition situation; Q_f is a collection of final state spaces.

In light of the definition of the prevailing automata model, the conduct of the hybrid system is described, and the initial successive state space of the system is set as q_0 and the initial value of variable V_0. q_0 and V_0 begin to change, and there are two evolution modes as follows:

In line with the definition of a transition set $E \subseteq Q \times L \times Q_f$, q_0 becomes its subsequent state through a transient transition event, and the initial value V_{D0} of discrete variables also changes with the transition event (Lyu & Wang, 2021).

There is no state transition, and the system keeps the q_0 state unchanged. The initial value V_{C0} of the continuous variable in the continuous process changes according to the definition of $g_0\left(x\right)$ in q_0, and the state transition is determined by the transition condition $halt_c\left(b_2\right)$.

RESULT ANALYSIS AND DISCUSSION

MAX-Log MPA Performance Analysis Before and After Improvement

To test the detection performance of the improved MAX-Log MPA algorithm, this paper simulates the convergence and BER based on the uplink SCMA communication system and compares the complexity of different algorithms. During the simulation process, the parameter settings are shown in Table 1.

Figures 6 and 7 show the detection performance of the improved MAX-Log MPA and original MAX-Log MPA multi-user detection algorithms when the signal-to-noise ratio (SNR) = 12dB with iteration times.

It can be seen from Figure 6 that the BER performance of the improved parallel MAX-Log MPA 3 iterations has exceeded the BER performance of the original parallel MAX-Log MPA 6 iterations, and the algorithm converges, with fewer lost messages and significantly improved BER performance.

It can be seen from Figure 7 that the BER performance of the improved serial MAX-Log MPA 2 iterations has exceeded the BER performance of the original serial MAX-Log MPA 3 iterations, and the algorithm converges, with fewer lost messages and significantly improved BER performance (Sun et al., 2020). Overall, the detection performance of MAX-Log MPA has been improved, and

Table 1. Simulation parameters

Parameters	Value
Number of users J	6
Codebook size M	4
Spread spectrum factor K	4
Overload factor λ	150%
Modulation type	QPSK
Channel model	AWGN

Figure 6. Comparison of BER with iteration times before and after parallel MAX-log MPA improvement

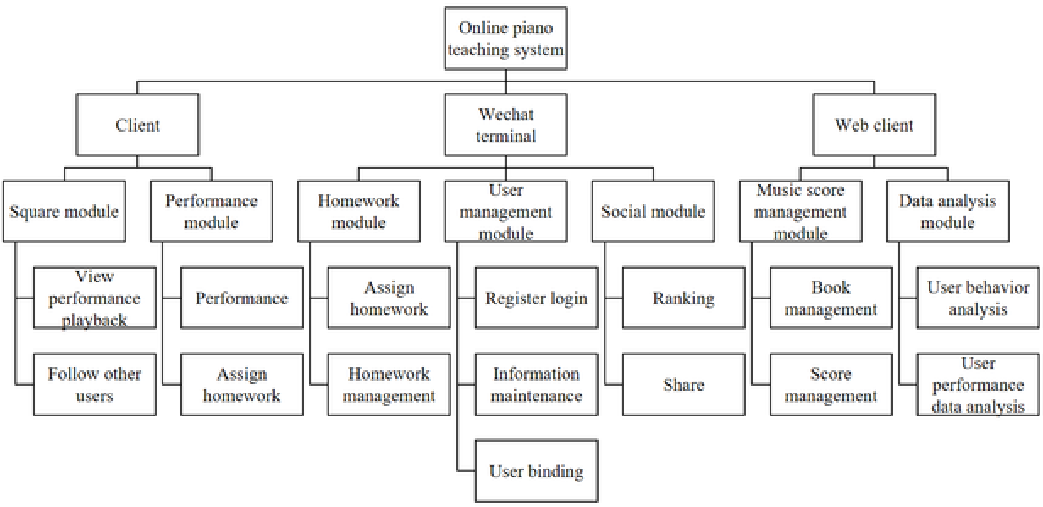
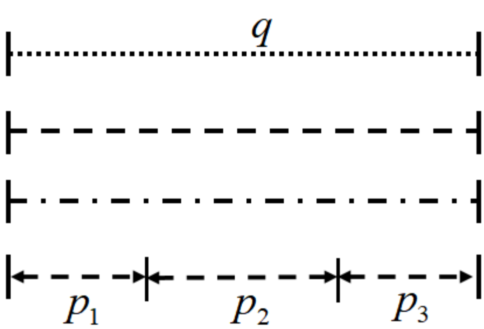


Figure 7. Comparison of BER with iteration times before and after serial log MPA improvement



fewer messages are lost when updating from resource node to user node, which provides more reliable messages for subsequent iterations, and proves the rationality of theoretical analysis.

Figures 8 and 9 show the detection performance with SNR when MAX-Log MPA reaches convergence.

Figure 8. Parallel MAX-log MPA BER comparison chart before and after improvement

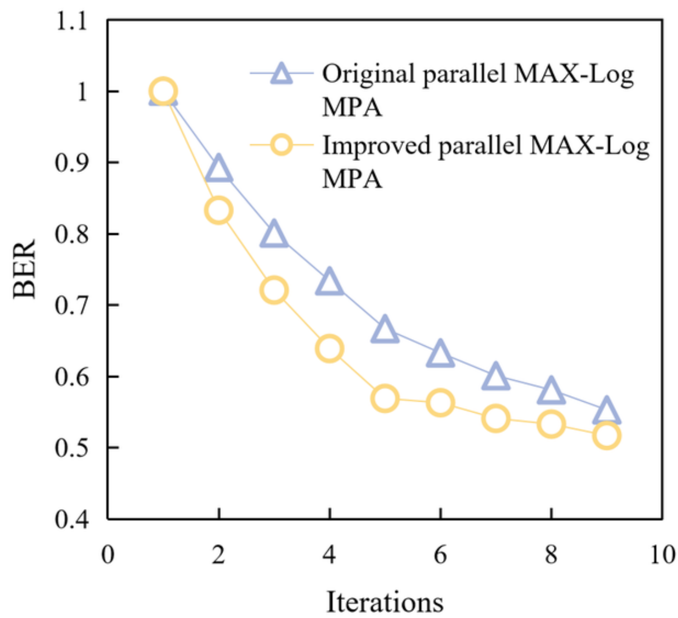
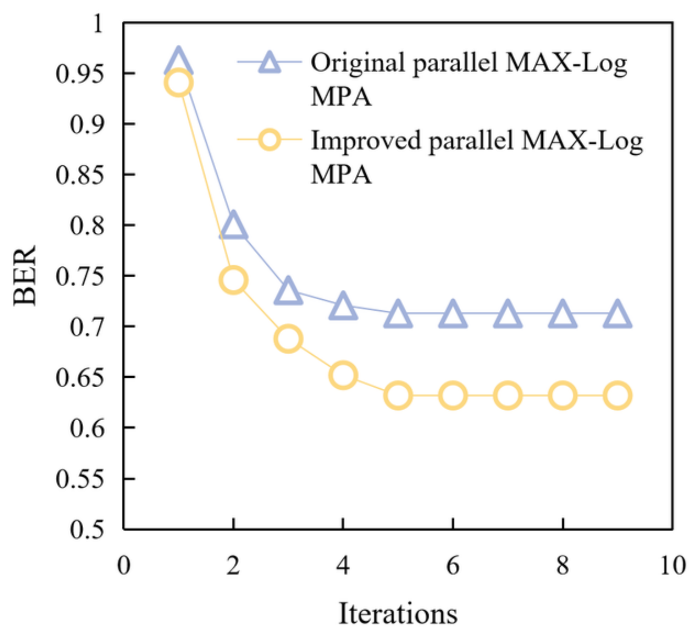


Figure 9. Comparison of serial MAX-log MPA BER before and after improvement



It can be seen from Figure 8 that the BER of the improved parallel MAX-Log MPA with three iterations is equivalent to that of the original parallel MAX-Log MPA with six iterations. The BER of the improved parallel MAX-Log MPA (six iterations) at 10dB is equivalent to the BER performance of the original parallel MAX-Log MPA (six iterations) at 12dB.

It can be seen from Figure 9 that the BER performance of the improved serial MAX-Log MPA with two iterations is equivalent to that of the original serial MAX-Log MPA with three iterations (Yan, 2022). With the increase of the SNR, the BER performance of the serial MAX-Log MPA with three iterations is getting better than that of the original serial MAX-Log MPA.

The simulation results show that the number of multipliers of the ML algorithm, MPA algorithm, and improved MAX-Log MPA algorithm is 49152, 11844, and 6912 respectively. Compared with the ML algorithm, the improved algorithm reduces the multiplier by 85.9% under the negligible BER loss. Compared with the traditional MPA algorithm, it reduces the multiplier by 41.6%. In this paper, the improved MAX-Log algorithm, whether serial or parallel, does not carry out EXP operation but converts it into MAX operation. The influence factor will not increase the additional operation burden, thus reducing the operation complexity.

System Implementation and Testing

The overall architecture of the system consists of three parts. The first part is the web backend, which includes business logic code, object storage, database, etc. The second part is the web frontend, which includes the pages displayed on the WeChat official account and the pages displayed on PC. The third part is the iPad client, where all the services related to performance are realized.

A perfect performance test of the system is an important part of system tuning. Only by exposing the system to a high-load environment can we find code problems, performance bottlenecks, and architecture design problems in the system that cannot be found under low load (Zhang, 2023).

The performance test of this system was carried out with the WRK performance test tool. The WRK performance testing tool is a high-performance stress testing tool developed based on C language. Compared with the ab stress testing tool, WRK provides multi-thread support, and the bottom layer encapsulates an epoll I/O multiplexing model, which greatly reduces the overhead of creating and scheduling a large number of threads in the ab stress testing tool.

Here, we first tested the reading ability of the system. We selected the interface to get all the books listed for the stress test. The HTTP method of this interface is collected, which only reads the database. Since the central processing unit (CPU) core number of the tester is four cores, we use eight threads and the test time is 30s. The test results are shown in Figure 10 and Figure 11. The ordinate is the number of connections opened by the WRK tool, and the abscissa is the time used under the tool connection.

From the test results, we can conclude that when the number of connections opened by the WRK tool is 100, the processing capacity of the system reaches its peak, and the average number of requests per second is the highest. When the number of connections exceeds 500, more connections will be opened as soon as possible, but the average number of requests per second of the system will be reduced, and the response time of the system will be greatly increased. At this time, the concurrent amount has reached the limit of the system, but the system still provides services stably, but the response is slow, which shows that the system is robust enough.

CONCLUSION

In response to the pain points faced by students in piano teaching and the current development status of piano-assisted practice, this article develops a piano online teaching system based on the SCMA system multi-user detection algorithm and discrete dynamic modeling. Firstly, the improved MAX-Log MPA algorithm reduces message loss caused by the approximate calculation of message updates, providing more reliable messages for future iteration processes. This method is simple and effective, maintaining the low complexity of the original MAX-Log MPA algorithm while also achieving better detection performance. Then, combined with a special parallel projection structure, a generalized automaton model for hybrid systems is proposed, and a five-tuple is used to describe the behavior of the continuous and discrete subsystems of the hybrid system. The online piano teaching

Figure 10. System read performance under long connection

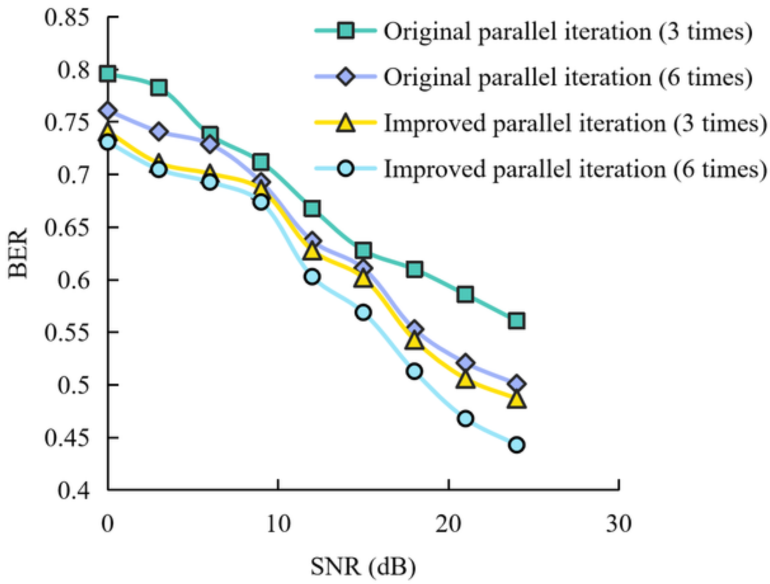
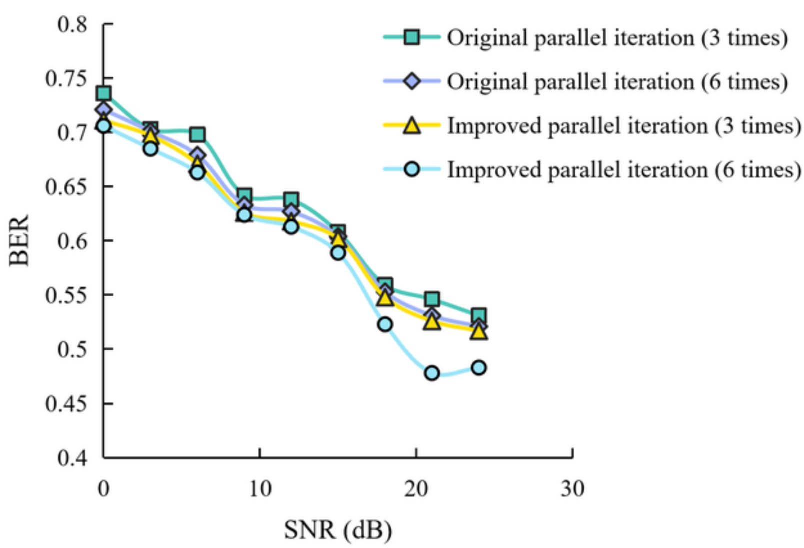


Figure 11. System reading performance under short connection



system can utilize the advantages of the SCMA system's multi-user detection algorithm and discrete dynamic modeling technology to achieve simultaneous online piano practice for multiple users and can distinguish and process data from different users, thereby providing personalized course content and feedback information for each user.

In the future, the SCMA system's multi-user detection algorithm and discrete dynamic modeling technology will bring more advantages and innovations to online piano teaching systems, help students better learn piano, and improve teaching effectiveness."

AUTHOR NOTE

The figures used to support the findings of this study are included in the article.

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Jing Shi is a professor at Nanchang Institute of Technology.

Na Wan is a professor at Nanchang Institute of Technology.