Applied Soft Computing 112 (2021) 107763

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

The algorithmic composition for music copyright protection under deep learning and blockchain

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ARTICLE INFO

Article history:
Received 8 March 2021
Received in revised form 23 July 2021
Accepted 24 July 2021
Available online 12 August 2021

Keywords:
Algorithmic composition
Blockchain
Copyright protection
Deep learning
Neural network

ABSTRACT

To strengthen music copyright protection effectively, a new deep learning neural network music composition neural network (MCNN) is proposed. The probability distribution of LSTM generation is adjusted by constructing a reasonable reward function. Music theory rules are used to constrain the generated music style to realize the intelligent generation of specific music style. Then, the digital music copyright protection system based on blockchain is constructed from three perspectives of confirming right, using right, and protecting right. The validity of the model is further verified by relevant data. The results show that the composition algorithm based on deep learning can realize music creation, and the qualified rate reaches 95.11%. Compared with the composition algorithm in the latest study, the model achieves 62.4 percent satisfaction with subjective samples and a recognition rate of 75.6 percent for musical sentiment classification. It is proved that the music copyright protection model based on block chain can ensure that the copyright owners of works obtain corresponding economic benefits from various distribution channels, which is helpful to build a harmonious music market environment. In short, the innovation of this study is reflected in that it fills in the gap of detailed comparative study of the differences in the application of different models, realizes the framework of music copyright protection system, and provides convenient conditions for composers.

1. Introduction

With the progress and development of science and technology and the widespread application of electronic equipment, digital image has become an indispensable information medium in social production and people's life. Massive image data are produced every minute and every second, and then comes the need to process these data. People not only want to obtain the simple classification of the objects in the image, but also want to have more detailed understanding of the objects of interest in the image. Due to people's continuous pursuit of intelligence and automation, computers have become more than just computing tools. People do not satisfy that it can only deal with objective and regular problems, but also hope to give it some "intelligence", so that it can deal with some subjective and irregular problems, such as image and speech processing. Thus, the field of computer vision emerged.

The purpose of computer music research refers to collecting, recording, and analyzing abstract symbols in music through computer means, abstract human emotions toward music through algorithms, and generate new music [1]. At present, the emerging of computer music has broad sense and narrow sense. In a broad sense, computer is used as an auxiliary function to help composers compose music, and digital signals are used for sound analog storage instead of the original storage method. In a narrow sense, algorithms, artificial intelligence, neural networks, and other technical solutions are adopted, so that the computers have the skills to analyze and create music [2]. Due to the diversity and complexity of music, it is difficult to separate the accompaniment and the vocals with a computer for musical structures such as songs that combine multiple instruments and vocals in the early stage of research. Due to the breadth of vocal frequencies, it is difficult to match based on the frequency corresponding to the notes like a musical score [3]. In computer music, most of the music creation is using artificial intelligence and machine learning to make the computer match the corresponding pattern to compose with original single-note score as a model. Only music scores and such things are acquired, and the music audio

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https://doi.org/10.1016/j.asoc.2021.107763
1568-4946/

is not directly used as the original for analysis and creation [4]. In terms of computer music analysis, most of the research is based on the recognition of rhythms in music, which are still at the stage of theoretical foundation. The artificial intelligence composition with audio as the research object can make the computer automatically generate the permutation and combination of music fragments to generate new music audio [5]. Audio-based composition does not rely on music knowledge rules, which is passed to the audience for intuitive experience. Therefore, this type of algorithm is more practical than the traditional music-based composition method [6]. In this work, the music audio is deemed as the research object, and a new automatic music synthesis algorithm is proposed based on LSTM RNN. The rise of digital content operations has demonstrated strong development potential and accelerated the diversified development of the commercial layout of the content industry. However, it also highlights some problems in the field of digital copyright management and protection [7]. The current digital music copyright management system is mainly centralized. The strong links squeeze the weak links, resulting in a serious imbalance in the distribution of benefits. Therefore, digital copyright disputes frequently occur, and infringements have increasingly become a sharp pain point for the Internet cultural industry [8].

Many experts and scholars have analyzed the research in the field of machine-assisted creation and copyright protection. For machine learning-assisted composition, Pošcic and Krekovic (2018) used machine learning algorithms to build an intelligent creation system in the context of music creation. The system uses the combination of music and vision to increase the efficiency of music creation by collecting existing music data. It acts as an autonomous music creator without manual intervention and can generate one or more pieces of music based on manual input Type [9]. Hansen et al. (2019) applied machine learning algorithms to the field of music creation. The system uses the integration of multiple algorithms to improve the recognition accuracy of the model to a certain extent. Through the analysis of the structure of music creation, a music analysis model based on machine learning was built to enable people to quickly identify music types in a short musical background [10]. To reduce the cost of music creation, shorten the creation time, and help composers create music more easily, Shi and Wang (2020) adopted genetic algorithms and artificial neural network algorithms to develop a children's music creation system. Compared with the latest researched algorithms, the music recognition rate of this system is as high as 97.5% [11]. In the protection of music copyright, BodóCai et al. (2018) proposed to publish works on the blockchain to create an unchanging record of the original ownership. The protection of music copyright is realized by encoding "smart" contracts to license the use of works [12]. Grfdan and Ersoy (2021) proposed a music wallet model based on blockzincir for safely and legally listening to audio files. The audio files selected by the user are converted into a blockchain structure using different technologies and algorithms and are securely stored in the user's music wallet [13]. Although many scholars proposed different modes of music creation, they were basically in the theoretical stage. At present, there is no detailed comparative study on the differences in application of different models. There are many strategies for music copyright protection, but there is no system framework that is implemented, which makes it difficult for these technologies to be applied in practice. The development of logistics information search technology such as ship automatic identification system, block chain, and modern information processing technology such as big data and cloud computing has provided information technology support for the sharing and allocation of logistics resources in port groups. In addition, the upsizing of ships, the intensification and alliance of shipping enterprises, and other new transportation forms also contribute to the realization of the sharing and optimization of port group logistics resources. Based on the theory of sharing economy, the logistics resource sharing system of port group is constructed, which contains three core functions as follows, (i) the port group logistics resource sharing function for water transport, (ii) the sharing function of logistics resources of port group for cargo flow distribution between port hinterland, (iii) the route network optimization function based on port group logistics resource sharing for both ends of the sea and land.

For machine learning assisted composition, the main structure of this research is as follows. I. In the introduction, the practical significance and value of this research are noted, and the scientific issues of music creation and music copyright are clarified. II. In the literature review, current research on computer algorithmic composition and music copyright protection is summarized. III. In the related terminology, the deep learning and blockchain are proposed, and the reasons for the method adopted are explained. IV. In the model construction, the specific model construction process and specific example content involved are illustrated. V. In the results, the constructed model and digital copyright system are tested, further verifying the effectiveness of the model and system proposed in this article. VI. In the conclusion, the existing results are analyzed and compared with previous studies.

The following hypotheses are proposed. I. It is assumed that the use of machine learning can effectively improve the efficiency of composition. Then, a new algorithmic composition network is proposed. A reasonable Reward function is constructed based on the music theory rules to constrain the style and quality of the generated music. Moreover, the Reward function value is fed back to the LSTM generation network, and the network parameters are adjusted in real time to realize the intelligent generation of specific style music. II. It is assumed that music is the carrier of emotion, and music creation is realized through emotion analysis. A sentiment analysis model of classification optimization is proposed based on the random forest algorithm. The emotion of music is classified by extracting the time domain features, frequency domain features, auditory spectrogram features, and nonlinear Hurst parameters that characterize music emotions.

The main contributions of this study are as follows. I. A new algorithmic composition network is proposed from the perspective of machine learning and manual creation. A reasonable Reward functions are established using music theory rules to constrain the style and quality of the generated music. The value of the Reward function is fed back to the LSTM generation network, and the network parameters are adjusted in real time to realize the intelligent generation of specific style music. II. From subjective and objective perspectives, the subjective evaluation system based on expert scoring and the objective evaluation system based on minimum distance are constructed, respectively. Subjective evaluation is conducted from five aspects of melody, rhythm, harmony, music texture, and expression strength. In the objective evaluation, the theoretical features of the generated music are extracted, including pitch range, repeated note, vertical fourth, rhythmic variability, parallel motion, vertical tri tone, chord duration and pitch, and the minimum distance between the generated music. In addition, the characteristics of the training samples is calculated. III. A classification optimization sentiment analysis model is proposed based on random forest algorithm. Music emotion classification is completed by extracting the time domain features, frequency domain features, auditory spectrogram features, and nonlinear Hurst parameters representing music emotion. IV. A complete music copyright protection system is built using blockchain.

The limitations of this research lie in the following aspects. I. Reward function is adopted to constrain the generation of music in the network design. The reward function affects the quality of music generation, and there are bottlenecks in its construction process. The algorithmic composition process is very abstract, and how to extract effective music constraint rules is worthy of further study. II. Reasonable classification of generated music is conducive to music retrieval and search. Music sentiment classification is an important classification method. Music is an important audio form with melody, rhythm, and musical style. It is difficult to accurately express the whole emotion of music by extracting the low-level emotional features of music alone. Therefore, the high-level features of music should be discussed. Constantly researching suitable classification algorithms is also extremely important for classification.

2. Literature review

2.1. Algorithmic composition

In the field of traditional computer music, digital signal processing makes it possible to process audio. Music information retrieval is based on feature extraction, which plays an extremely important role in the field of automatic classification [14]. Lu et al. (2018) extracted the dynamic characteristics of various frequency band energy evolution over time from the audio signal and formed a short-term similarity matrix based on the state characteristics of this music. Through this similarity matrix, unsupervised learning methods (K-means and hidden Markov models) were adopted to propose the structure of music, and finally the audio summary was extracted through representative examples in each state. In addition, the similarity matrix of Mel cepstrum coefficients was utilized to compare the experimental results [15]. Mei et al. (2019) adopted Mel-frequency ceptral coefficients (MFCC) as the feature vector for audio classification, which classified audio into six categories of music, news, sports, advertising, cartoons, and movies. Support Vector Machine (SVM) was employed for classification through training. Linear predictive coding (LPC) and other acoustic features were also utilized as feature vectors for training. The results showed the outstanding performance of MFCC in audio scene classification. Finally, it was verified that the model with MFCC as the feature vector was extended to use Radical Basis Function Neural Network (RBFNN) for training [16]. The comparison of different algorithms is shown in Table 1.

Jaech and Ostendorf (2018) proposed to adopt RNN and its variants as a music language model in the field of automatic music transcription. They also proposed a generative architecture that combined these models with the predictions of acoustic classifiers. Moreover, an algorithm was proposed to perform music transcription, and the result was superior to that of the current transcription algorithm [17]. There are many applications of neural networks and audio processing. Kim et al. (2019) built an LSTM speech recognition model and obtained favorable results through large vocabulary speech recognition tasks [18]. Wang et al. (2019) proposed two neural network-based methods for automatic transcription and polyphony of piano music. They used the microphone to obtain live piano music and then translated it into notes and pitches in the score. Moreover, the experimental accuracy of the feedforward neural network and the recurrent neural network was compared. After large-scale experimental testing, the entire process was automated [19]. Neural networks were once considered unable to learn the structure of music and were not suitable for research on music composition. To solve this problem, Oore et al. (2020) used two LSTM models to train and create blues music, which were used to learn chords and melody, respectively. The output of the chord network was connected to the melody network as the input of the melody network [20]. The final experimental results showed that the system can learn the standard 12-bar blues chord bar and generate music that followed the chord law.

2.2. Music copyright

There are many studies on the adoption of blockchain in the management of digital music, but most of them were at the initial algorithm programming stage [21]. Jian et al. (2016) pointed out the dilemma faced by digital copyright protection in the current Internet era, analyzed the blockchain itself and its mechanism, and pointed out the current development status of blockchain. The work also discussed the advantages and existing problems of applying blockchain to the digital copyright protection system [22]. Qureshi et al. (2020) pointed out that the traditional digital copyright system adopted a centralized storage method, and carefully analyzed the shortcomings and drawbacks of China's traditional digital copyright management methods. In response to the above problems, a conceptual scheme for applying blockchain to copyright protection is put forward, and a feasibility analysis of the scheme is made [23]. Cai et al. (2018) pointed out the challenges faced by the current digital copyright protection mechanism. The origin and essence of blockchain and the overall data structure of blockchain were introduced, the issues in adoption of blockchain in digital copyright protection were introduced, and a brief overview of adoption examples was given [24]. Feng and Wei (2017) pointed out that digital copyright was now facing numerous dilemmas — the public's awareness of copyright protection was weak, infringement problems occurred repeatedly, and the foundation of basic value was also weak. They analyzed the advantages of applying decentralized blockchain, which were of high security and low cost. In addition, they also summed up the risks of applying blockchain-technical problems, market-oriented operation problems, and compatibility problems of copyright theory [25].

Tresise et al. (2018) mentioned that British musician Imogen Ship has begun to use blockchain to open up the battlefield for his single version of "fair trade", covering remuneration, fees, and distribution of songs [26]. Some people think that this is not only a change in listening, but also the progress and development of music life. Kostyashkin et al. (2020) explained that a company named MineLabs in New York, USA, developed a collaborative joint media metadata protocol based on blockchain. This agreement was suitable for the copyright protection of digital images, including the identification of the copyright of new works and the encryption signature of the copyright owner of the work. Metadata protection records had been created for more than two million original numbers, and the company's user base covered digital libraries in Europe and the United States [27]. The analysis content of most foreign copyright-related books is relatively comprehensive, including all copyright types involved in the production, circulation, and final consumption of music, but some will focus on a certain type of music copyright.

2.3. Summary of relative works

To sum up, deep learning can realize the learning and analysis of relevant data, especially in music creation, which has been reported by many scholars, but they did not have a complete system for composing music. Moreover, the latest composition system cannot display the learning and creation function of multiple data sets, which greatly limits the development of deep learning in the field of music creation. For blockchain, the current research stage is in the technical research and programming stage. The practical application of blockchain in major industrial sectors in China is still some way off. Entering the next stage still needs a lot of manpower, material resources, financial resources, and time cost accumulation. At present, most academic circles are still focused on the research of blockchain itself and its adoption. Few people analyzed and summarized the actual cases of applying blockchain

Table 1
Comparison of different algorithm composition methods.

Algorithm composition method	Advantage	Disadvantage
Probability model	The earliest use time, the generated model has high stability	Excessive reliance on rigorous mathematical relationships, resulting in a relatively dull and lack of theme
Genetic algorithm model	Do not need too many musical rules	There is a bottleneck in the response function, which makes it difficult to extract valuable musical ideas
Neural network model	The algorithm is more efficient	Need more data support, higher configuration requirements

to digital music rights management in China. Many problems in the field of digital music copyright protection have become increasingly prominent. At present, the exploration of digital music industry by adopting blockchain is progressing. Blockchain technology can remedy some of the law's shortcomings. This kind of distributed data storage prevails, so do the adoption of point-to-point transmission, consensus mechanism, encryption algorithm, and other new application mode of computer technology. In the future, the pan-entertainment industry is expected to build a new industrial ecosystem based on blockchain application and realize an efficient and convenient transaction mechanism. It will significantly reduce transaction costs, significantly improve the collaborative efficiency of the industrial chain, and effectively protect the interests of all participants. It will form an honest industrial ecology, create a valuable infrastructure of the pan-entertainment industry in the Internet era, and even completely change the face of the pan-entertainment industry. On the one hand, it is urgent to solve the problems of digital music copyright. On the other hand, the application of blockchain in the field of digital music copyright has increasingly attracted the attention of the music industry and copyright industry. Therefore, how to use deep learning to build an appropriate composition system and blockchain to realize the protection of music copyright is of important reference value to promote the development of the music industry.

2.4. Theoretical feasibility analysis

Music has always been loved and welcomed by people. Since ancient times, composers have been experimenting with new techniques to meet new needs. With the development of mobile Internet, the number of users of multimedia short video continues to increase. Many short videos, games, animations, etc. require a lot of original composition to support them. The cost of professional music production is high, which cannot meet the user's personalized needs for background music. Algorithmic composition is a study that minimizes human intervention according to a certain rule of creation and is also an intelligent process of music creation. With the development of the society, music has been developing in accordance with the law, especially in the continuous enrichment and application of music's melody, rhythm, harmony, polyphony, structure, form, and music. Moreover, the organization of rules between different elements can create different styles of music, such as classical, rock, jazz, rap, and hip-hop. At present, researchers have proposed a variety of methods for composing music by computer. Among them, the most influential methods are hidden Markov chain, rule-based system, music grammar, genetic algorithm, and neural network. Therefore, it is feasible to apply deep learning algorithm to music composition.

For the creators of digital music, the ideal state is to make their music works spread on the Internet to enhance the influence, thereby obtaining a certain commercial value and getting a fair distribution of income based on the commercial value. In fact, music creators alone cannot achieve such a goal, and they need to rely on the help of central institutions. The development of Internet has not only enhanced people's demand for digital music works, but also greatly reduced the cost of infringement. The infringement of digital music products is very common and extensive. On the one hand, the transmission speed and scope of digital music works are less limited by time and space compared with traditional music works, and the infringement is easier through peer-to-peer network technology. On the other hand, the public in the invisible easy to cause a lot of unintentional infringement of digital music copyright events. On the Internet, it is the frequent occurrence of infringement that makes copyright remedy particularly difficult. The application of blockchain and the registration management of music metadata will escort the protection of the legitimate rights and interests of music copyright owners. Blockchain, the underlying technology of Bitcoin, is a public chronological record of Bitcoin transactions. It is shared by all Bitcoin users and is used to verify the permanence of Bitcoin transactions and prevent double spending. According to the definition, blockchain is difficult to tamper with, decentralized, safe, and efficient, and the application of the blockchain to the protection of digital music copyright plays an important role. The transaction of digital music rights is the same, and it should protect the interests of music creators as much as possible. Therefore, on the one hand, it is necessary to reduce the cost of copyright transaction and reduce the possibility that the relative party of the transaction will transfer the cost to the music creator to damage his interests. On the other hand, it is necessary to enhance the discourse power of music creators in the copyright transaction in order to obtain the benefits consistent with their psychological expectations.

3. Related terms

3.1. Deep learning

3.1.1. Deep convolutional neural network

The human brain is an advanced information processing system, and neurons can transmit fine and accurate information, and then realize the brain's calculation and memory functions. Artificial neural network algorithm adopts the operating mechanism of the human brain, and the brain neural network is abstractly modeled from the perspective of signal processing by imitating the transmission decision principle of neurons in the brain. Different neural network models are formed by using different function mapping relations in modeling neuron relationships.

Deep convolutional neural network is a feed-forward neural network, which is an algorithm designed based on the human neural network system [28]. This structure enables convolutional neural networks to use the two-dimensional structure of the

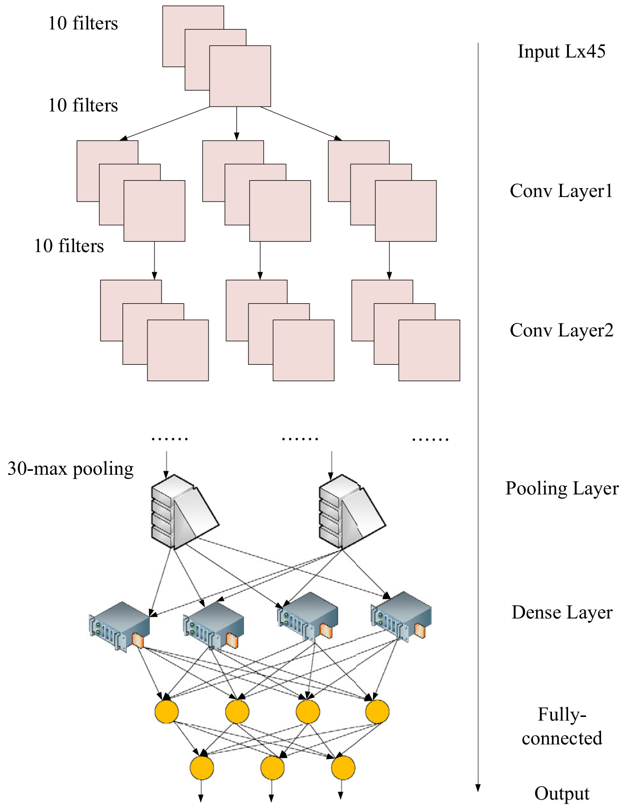

Fig. 1. Deep convolutional neural network structure diagram.

input data. Convolutional neural networks can give better results in image and speech recognition than other deep learning structures. This model can also be trained using backpropagation algorithms. Convolutional neural networks need to consider fewer parameters, making it an attractive deep learning structure.

Fig. 1 is a schematic diagram of the structure of a deep convolutional neural network model. The neural network inputs information with variable attributes and turns it into hidden features through ten convolutional hidden layers. Then, each convolutional layer applies ten filters to the data of the previous layer to generate L hidden features. Through the selection of the largest pool, each filter contains 30 maximum values, which are passed to the next layer of processors in different ways. The input node takes Softmax as the activation function, while other nodes all take ReLU as the activation function [29]. The calculation of the convolution output size is as follows.

$$N = (W - F + P)/S + 1 \tag{1}$$

In Eq. (1), the input picture size is $W\times W$, the Filter size is $F\times F$, the step size is S, and the number of pixels of padding is P.

3.1.2. LSTM

LSTM is a type of RNN network, which is often used to process and predict important events with very long intervals and delays in time series. A LSTM unit contains input gates, output gates, and forgetting gates. The input gate controls the input of the model, the output gate controls the output of the model, and the forgetting gate calculates the degree of forgetting of the memory module at the previous moment [30]. The structure of the LSTM model is shown in Fig. 2, and the specific calculation is as follows.

$$f_t = \sigma(W_f \cdot [h_{t-1}, x_t] + b_f) \tag{2}$$

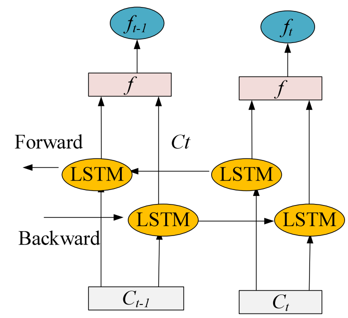

Fig. 2. LSTM neural network structure diagram.

In Eq. (2), f_t and i_t represent the forget gate and input gate at the tth step in the sentence sequence, respectively. h_{t-1}, x_t is the input music score information and training score information, respectively. C_t is the state of the neuron at time t.

$$i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i \tag{3}$$

$$C = \tanh(W_c \cdot [h_{t-1}, x_t] + b_c \tag{4}$$

$$C_t = f_t \times C_{t-1} + i_t \times C \tag{5}$$

The Sigmoid function is selected for the two gates f_t and i_t, and the value range is [0,1]. The value of the tanh function is [−1,1]. C_{t-1} is the state of the neuron at time t-1, and C_t is the state of the neuron at time t.

$$h_t = o_t \times \tanh(C_t) \tag{6}$$

$$o_t = \sigma(w_o \cdot [h_{t-1}, x_t] + b_o \tag{7}$$

o_t is the output gate to control the output degree of the word long-term information. h_t is the output of step t in the sentence sequence. This work introduces LSTM network, which can effectively solve the problem of long-term dependence on data, thereby effectively processing score data. The core of LSTM lies in the state of the cell layer. The characteristic information transmitted on the cell layer can remain unchanged for a long time throughout the entire forward process.

3.2. Blockchain technology

3.2.1. Block principle and application of block chain

Blockchain is the underlying technology of Bitcoin. It is stored in a chain of data structures connected in the order of the time the blocks were created. Each block has the same structure, consisting of a block header and a block body. The block header is used to sequentially link the current block to the previous block, while the block body mainly contains the transaction ledger, which is used to store information about transactions. Node is the smallest unit in the blockchain. A node in the blockchain system corresponds to a device in reality, an institution, a computer, or a cluster, etc. The block structure is shown in Figs. 3, and 4 is the working principal step diagrams.

In essence, blockchain is a kind of technical solution to solve the trust problem between nodes in distributed system and reduce the trust cost of node communication under the premise of mutual trust between nodes, which is similar to relational database. It is a peer-to-peer collaborative network, as well as an open and continuously growing distributed database maintained by all nodes in the system. The core of blockchain is the establishment of trust between each other in a distributed network through a hashed cryptography ledger with time-immutable features and a distributed consensus mechanism involving all or

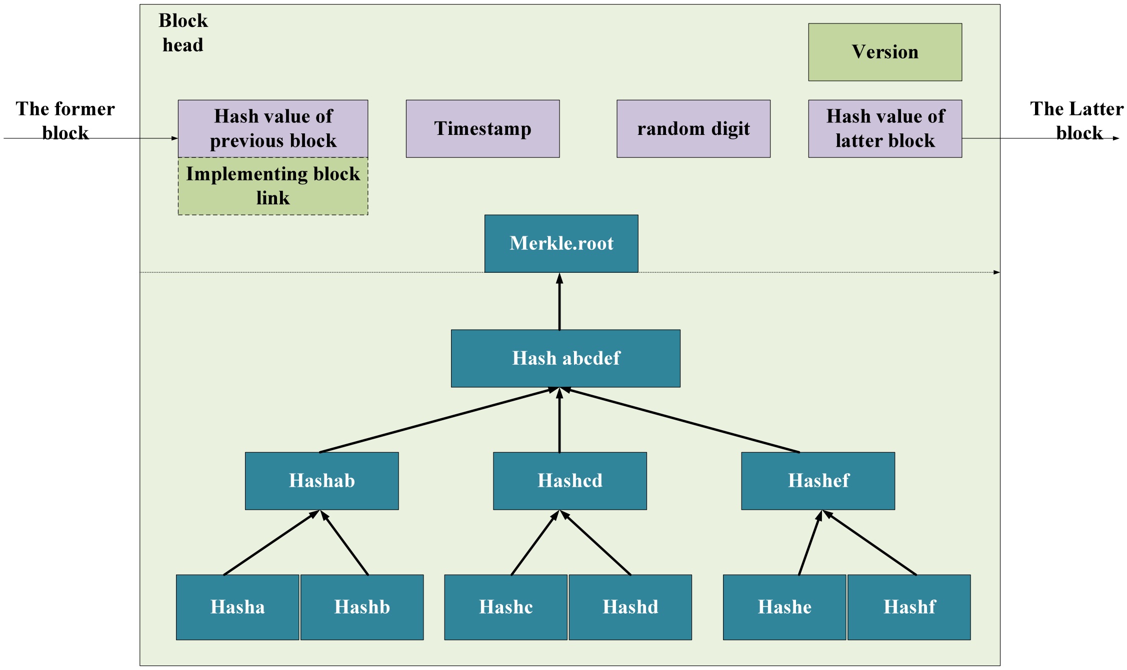

Fig. 3. Block working steps.

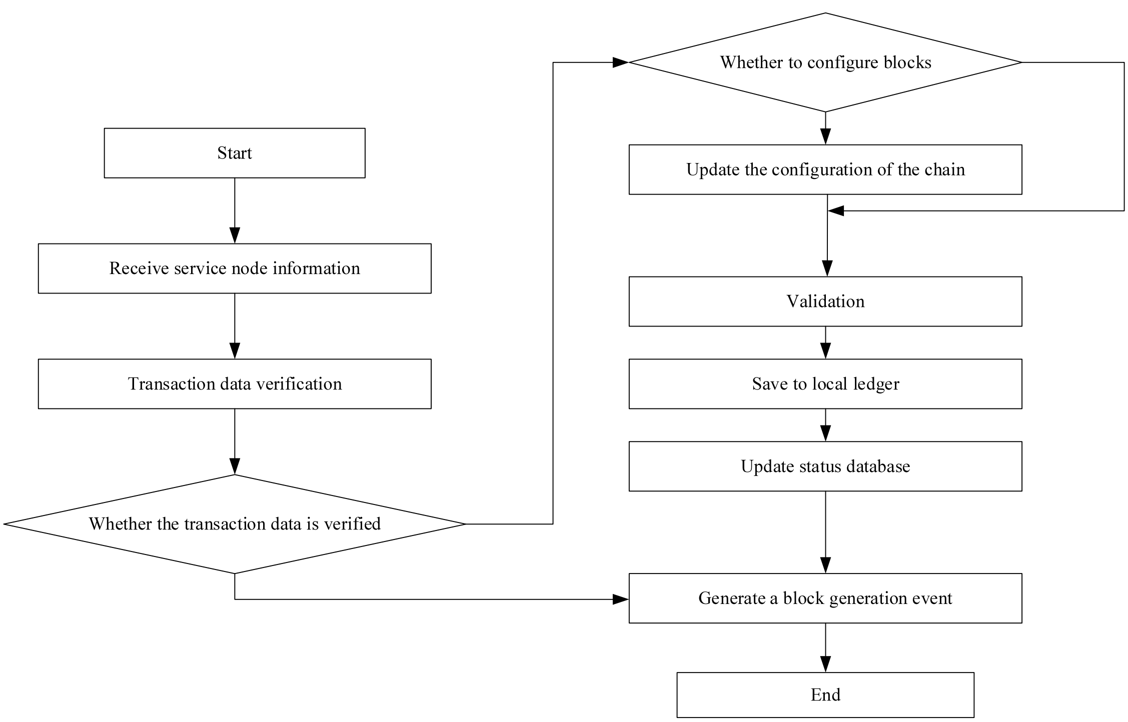

Fig. 4. Block chain working principle.

most of the nodes in the system. Thus, the communication between nodes in the system is transformed from information interconnection to value interconnection. In a blockchain system, all nodes store a complete copy of their data locally, and the content of all nodes in the system is exactly the same. It can find all records of each node in the system locally, and each node in the system can also be added with new data records locally.

Table 2 below shows the characteristics of blockchain technology in the transaction scenario, and Fig. 5 shows the application scenario of blockchain.

3.2.2. Blockchain structure

The blockchain model is the data layer, network layer, consensus layer, incentive layer, contract layer, and application layer from bottom to top. Among which, the data layer is the core advantage of blockchain, which encapsulates the blockchain structure in the blockchain system and provides functions such as asymmetric encryption and time stamping for data. The network layer is a collection of mechanisms for the operation of the blockchain system, including distributed networking mechanisms, data transmission mechanisms, and data verification mechanisms [31]. It adopts P2P technology, which has automatic

Table 2
Characteristics of blockchain technology in transaction scenarios.

Serial number	Name	Technical characteristics
1	Decentralized	The blockchain system built based on a distributed network does not centrally store data on a specific professional server or data center, but distributes the data on each node in the network. In this way, each node in the network stores the same data ledger, and the ledger on all nodes is updated synchronously. Decentralization is the disruptive feature of blockchain.
2	Information mechanism	The blockchain system based on clever mathematical principles and program algorithms has open and transparent operating rules. In the system, the nodes of both parties to the transaction can establish a trust relationship through the consensus mechanism, without the need to rely on an authoritative and reliable third-party institution for credit endorsement.
3	Open and transparent	The blockchain is completely open and transparent to the nodes in the system, which can realize the data sharing between nodes in the system.
4	Timing cannot be tampered with	The chain structure of the blockchain is formed by connecting blocks with timestamps back and forth. Therefore, the data in the blockchain has strong traceability and are easily verified for correctness. Due to the encryption and verification of data by the cryptographic algorithm and the consensus mechanism between nodes, the immutability of the blockchain is guaranteed.

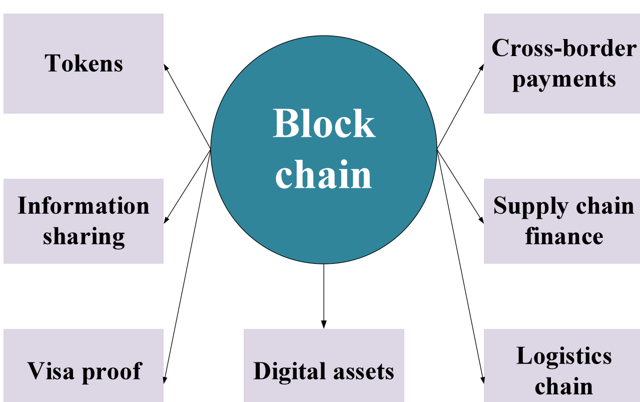

Fig. 5. Blockchain application scenarios.

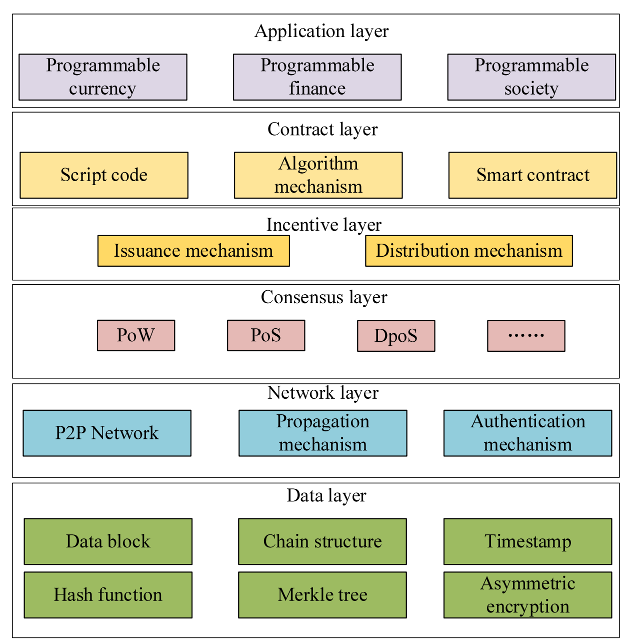

Fig. 6. The basic structural framework of blockchain.

networking function. The consensus layer is the core algorithm area of the blockchain system, which determines the accounting subject and accounting method of the blockchain system. Whether the consensus layer is advanced determines the security and reliability of the entire blockchain financial system. To encourage each node to participate in bookkeeping as much as possible, the incentive layer issues contract information in order to establish contact with the transaction parties in advance, so that the platforms of all parties can participate in the intermediate process [32]. The specific structure is shown in Fig. 6.

Fig. 7 is a schematic diagram of a blockchain data structure, where each block contains two parts. There is a block in the head of the structure that is difficult to be tampered with. The block uses the Hash algorithm to constrain the difficulty value and the random number to agree. During the transaction, Merkle is calculated and generated automatically and put in the header block, so that people can query the specific transaction information [33]. Every transaction that occurs is recorded by such a block body, and the Merkle is calculated via the Hash algorithm, which is independently named and stored.

4. Model construction

4.1. Construction of algorithmic composition model

4.1.1. Overall framework

Algorithmic composition is an abstract and complex process. How to accurately capture the theoretical characteristics of music

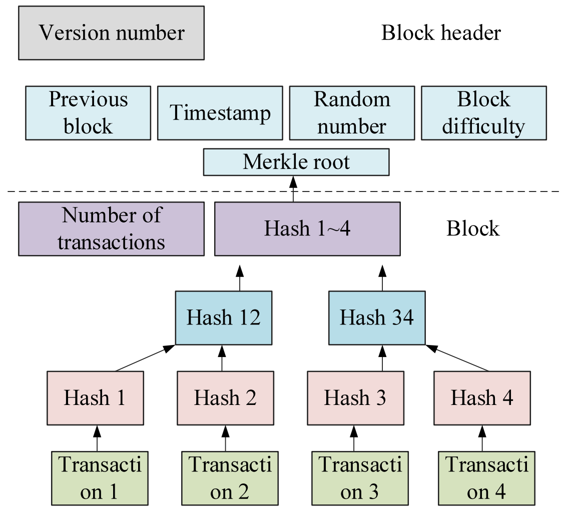

Fig. 7. Blockchain data layer structure diagram.

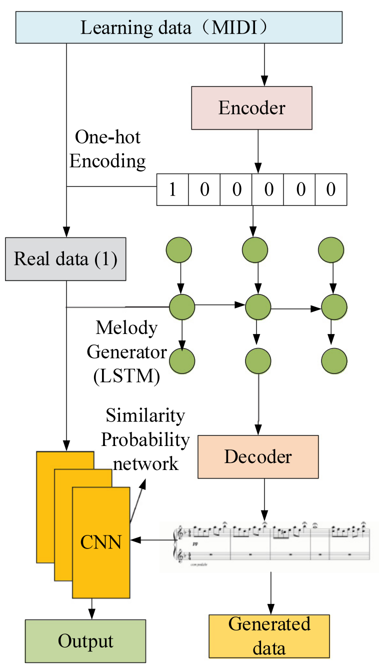

Fig. 8. Training model.

and generate diverse, smooth, and specific style and theme music is a challenging task. In view of the existing problems of the current algorithmic composition system, a new music composition neural network structure MCNN is proposed from the two perspectives of machine learning and music creation. The specific structure is shown in Fig. 8. The LSTM generation network is pre-trained by inputting the classical music database in MIDI format, and the initial notes are set to randomly generate music. Then, the generated music is collected to build a database of music generation samples, which is marked as 0. For the training data set, it is marked as 1. Moreover, a two-class model is constructed and the CNN network is pre-trained.

4.1.2. Algorithmic composition

Fig. 9 shows the music generation model. LSTM network is adopted to generate music sequences by setting the initial notes, and the Reward function is formed through weighted calculation

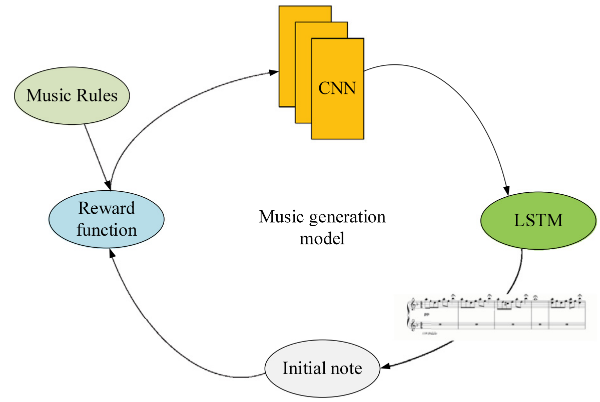

Fig. 9. Generation model.

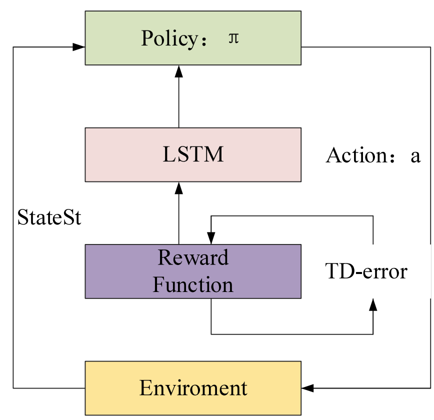

Fig. 10. The reward process of the MCNN algorithm.

with music theory rules. Moreover, the LSTM network parameters are updated and adjusted through the Reward function calculation. The CNN network identifies the label 0 of the generated music, and the generative model is optimized by the Reward function. The generated music and training samples should have a great degree of confusion, so that the recognition output probability of the classification network CNN is closer to 0.5, that is, the difference π between the generated sample and the training sample cannot be distinguished, so that music with similar style and theme is generated as the training sample.

4.1.3. Algorithm flow

In the MCNN network, the update process of the LSTM network and the Reward network is presented in Fig. 10. The strategy π/S□A is the mapping from state space to action space. At time t, the generating network selects an action according to the strategy π in the current state t/s, to generate a note. The action is executed and the stage is transferred to the next state t/s. Moreover, the reward function value Q of the action is fed back. The reward network evaluates the pros and cons of the action strategy by calculating the cumulative reward value of the action sequence. In addition, the LSTM network parameters are updated and the sequence generation strategy π is adjusted to obtain a large reward value.

Based on the time difference algorithm, the idea of deep reinforcement learning DQN (Deep Q-Network) is adopted, the Reward network is composed of a Q target network and a Q action network. The Q target network is copied from the Q action network every N step, and its value function calculation is as follows.

$$J(s,\alpha,\theta)=R+\gamma \max Q(s',\alpha',\theta')+V(s',\theta^-) \quad (8)$$

R is the reward value that is obtained by taking action α under s state, s' is the next state entered after taking the action α, α' is the next action. θ^- is the target value network parameter, γ is the discount factor, and V is the state value function. Monte Carlo tree algorithm is adopted, under s state, N actions α are sampled based on the strategy, the average reward obtained is V. The value of v is calculated according to the following equation.

$$v=\frac{1}{N}\sum_{n=1}^{N}R(s,\alpha_n,\theta^-) \quad (9)$$

In the Reward network, the Q action network and the loss function $\sigma(\theta)$ of target network is calculated as follows.

$$\sigma(\theta)=\lambda(J(s,\alpha,\theta^-)-Q(s,\alpha,\theta^-)) \quad (10)$$

θ is the target value network parameter, and λ is the discount factor of the objective function.

The pseudocode is as follows.

{

The training production strategy is $\pi(a/s_i;\theta_a)$, $Q)(s;a;\theta_v)$ is value of Reward, and θ_a is the generated network weight, θ_v is Reward network weight$_0$

1. Pre-train LSTM network weights is θ, Pre-train CNN to discriminate network weights is φ.

2. Example Initialize the Reward network weight is $\theta_v=\theta$.

3. Initializes a random action a_0.

4. According to the policy π, the sequence of actions is produced $(a_0,a_1,a_2,a_3,\ldots a_t)_0$

5. According to the time difference algorithm, Calculate the value of the target Reward function.

$$J(s,a,\theta_v^-)=R+\gamma\max(s',a',\theta_v^-)+V(s;\theta_v^-) \quad (11)$$

$$R(s,a)=\log\pi(a/s)+r_{mr}+P_{(CNN)} \quad (12)$$

6. Loss assessment of reward function:

$$L(\theta_v)=\sigma^2(\theta_v)=[J(s,a,\theta_v^-)-Q(s,a,\theta_v^-)]^2 \quad (13)$$

7. According to the gradient descent algorithm, the Reward evaluation network weight is updated

$$Q_{v+1}=Q_v+\nabla_{\theta_v}L(\theta_v) \quad (14)$$

$$\nabla_{\theta_v}L(\theta_v)=E_{s,a,r,s'}[\sigma_{\theta_v}\nabla_{\theta_v}Q(s,a;\theta_v)] \quad (15)$$

8. The network weight is generated by updating the loss function value θ_a

$$\theta_a'=\theta_a+\nabla\pi(a/s_i;\theta_a)\sigma(\theta_v) \quad (16)$$

9. Repeat the steps until convergence occurs

}

4.2. Construction of copyright protection system

4.2.1. Confirmation stage

The life cycle of digital music products includes creation, dissemination, exhibition, consumption, delivery, and participation.

Through blockchain, the personal information, time information, digital music content, and other information of the copyright owner of the work are stored in each block. The cryptography principles are adopted to generate unique digital authentication DNA for digital music works. The verification of digital copyright is implemented through public key and private key. Then, through the smart contract, the copyright owner of the work can receive the user's automatic payment through the system in the first time. Through the time stamp, encryption algorithm, and other technologies in blockchain, the rights of digital music works are confirmed in the early stage of their production. After the above-mentioned right confirmation process, the blockchain platform generates its own unique digital DNA for digital music works. Therefore, the existence of third-party intermediaries is no longer required. Blockchain can directly provide tamper-resistant certificate tracking records, ensuring the scientificity and security of the right confirmation stage (see Fig. 11).

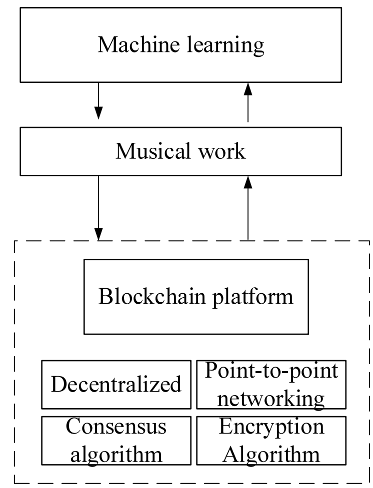

Fig. 11. Copyright protection system-right confirmation stage.

4.2.2. Right using stage

When the traditional digital music copyright is used, the various services are roughly the same, and it is necessary to fully explore the path of right using in China's digital music copyright management application system. From foreign company management models, many ways and paths of "blockchain + copyright" are found in the right using system, which is adopted in advertising and music industry chain IP incubation, as well as other types of projects, to fully expand the single right application system. Therefore, in the design of the right using stage of the digital music management application system, music-related practitioners should also broaden their horizons and actively open up market paths.

The right using stage is the core competitiveness of this application system, as illustrated in Fig. 12. Blockchain technology is employed to integrate digital music from production to marketing and other links, focusing on the core stage of the right using. As a result, the circulation speed of digital music is accelerated, and the life cycle of digital music products is prolonged, so that greater economic benefits are obtained. The conception of applying blockchain to the right using stage of China's digital music copyright management application system is implemented.

4.2.3. Right protection stage

Music works information is entered into the blockchain for storage after it is generated, and copyright information is jointly supervised by each node. Once infringement occurs, the information and data stored in the blockchain are taken as evidence for rights protection, and the problem of infringement can be prevented from the source. Therefore, the adoption of blockchain in the management of music copyright protection in China can improve the current music copyright protection system. The details are shown in Fig. 13.

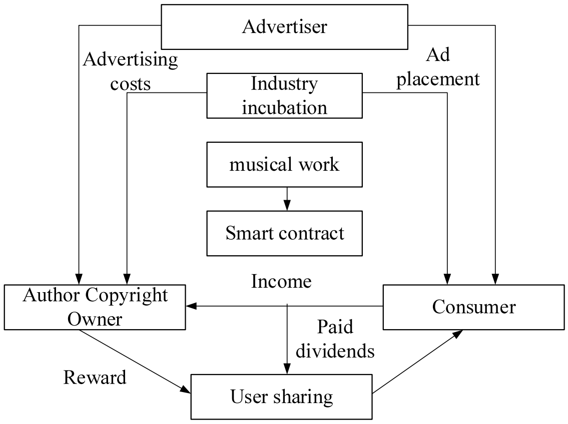

Fig. 12. Copyright protection system-right-use stage.

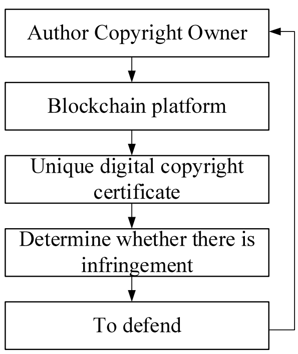

Fig. 13. Copyright protection system-rights protection stage.

4.3. Model training and verification

4.3.1. Composition evaluation

To test the generation effect of algorithmic composition, the quality of music is evaluated from subjective and objective perspectives. Objective evaluation based on the minimum distance refers to evaluation by measuring the distance between the generated sample and the training sample. It is assumed that $\alpha(x_1, x_2, \ldots, x_n)$ and $b(y_1, y_2, \ldots, y_n)$ are the eigenvector space of the generated sample and the training sample, respectively, and the Euclidean distance can be calculated according to Eq. (17).

$$d_{xy} = \sqrt{\sum_{i=1}^{n}(x_i - y_i)} \tag{17}$$

The eight features of the generated music and training data are extracted as a basis for comparison, which are range, repeated notes, vertical fourths, rhythm variability, parallel movement, vertical three tones, chord duration, and pitch. Subjective evaluation refers to the evaluation of music by people's subjective feelings. Through the formation of an expert jury, the production quality of music is evaluated from five aspects of melody, rhythm, harmony, music sense, and expression dynamics. The melody of music is adopted to measure the fluency and naturalness of the music, harmony can measure the comfort of the music, the sense of the music can express the integrity of the music, and the intensity can highlight the expressiveness of the music. Twenty professionals are invited to conduct subjective evaluations from the five indicators of music, each with a full score of ten, and professional scores based on the completeness of the performance of the generated music. When the scores are calculated, the highest score and the lowest score are removed, and then the average is calculated, as shown in Eq. (18). x represents the five parameters, namely melody, rhythm, harmony, music sense, and expression dynamics.

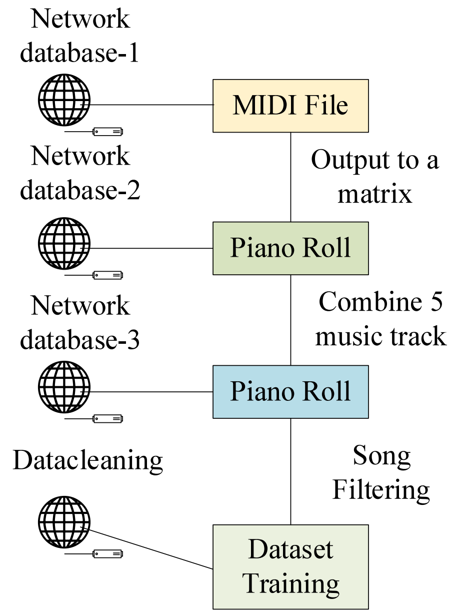

Fig. 14. Data processing flowchart.

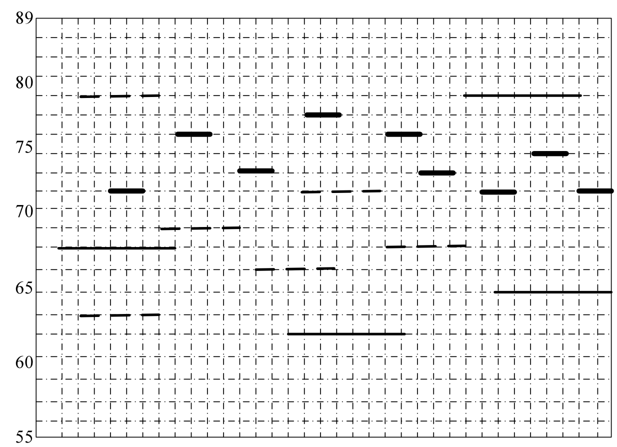

Fig. 15. Recording of piano roll music format.

$$E(x) = \frac{1}{18}\sum_{i=1}^{18} x_i \tag{18}$$

4.3.2. Data processing

In the experiment, the Classical Piano Midi Page (CPMG) data set is taken as the training sample. The database collects 9,600 music samples. The length of the music sample used in the experiment is about 20s. Fig. 14 shows the data processing process. First, the discretization algorithm is used to convert the MIDI format file into a matrix form, and then the music format of the piano roll is obtained through track fusion, as shown in Fig. 15. The row values of the matrix range from 54 to 86 represent the notes in midi music. The value of the column starts from 0 and increases by 0.05, which means that the midi music will increase every 0.05 s.

The specific algorithm pseudocode is as follows.

```
start
Input: D， m
Output: Reward Function value Q
Step1: Initialize network parameters
Step2: For i=1 to m
Pre-training LSTM network weights, pre-training CNN to discriminate network weights
Initialize Reward network weight
Initiate a random action
According to the strategy, generate action sequence
According to the time difference algorithm, calculate the value of the target Reward function:
        Do
            Q=R(s,a)=log(a/s)+r_m+P(CNN)
        End
```

4.3.3. Algorithm performance test

To verify the superiority of the MCNN algorithm, experiments are conducted based on the CPMG data set, and the results are compared with three music generation algorithms: VAE–GAN, SeqGAN, and RL-RNN. VAE–GAN adds the encoding and decoding process to the GAN network. SeqGAN introduces a reinforcement learning algorithm Policy Gradient. RL-RNN is an RNN algorithm based on Q-learning reinforcement learning. For the sequence generated by the RNN network, the action with the largest Q value is output. To ensure the objectivity of the experiment, for different algorithms, the same training set is used in the experiment, the number of network layer units is set to 512, the iterations are 3000 times, and the other used parameters are consistent.

5. Results

5.1. Selection of model parameters for algorithmic composition

Fig. 16 shows the influence of different LSTM cells on the experimental results. The more LSTM cells in the hidden layer, the stronger the ability of the LSTM network to learn abstract data features, and the more effective it is to reduce the error between the predicted value and the target value. Although the size of the hidden layer dimension has an important influence on the experimental results, the more layers of neural networks will greatly increase the amount of calculation. Finally, two layers are selected as the training process.

Figs. 17 and 18 show the effects of different iterations on the experimental results. The greater the number of iterations, the greater the number of weight parameter learning and adjustments, which can improve the accuracy of the model to a certain extent. As the number of iterations increases, the drop in loss function loss gradually slows down. Of course, an excessively large number of iterations will also bring about a greater amount of calculation, and the final number of iterations is determined as 3000.

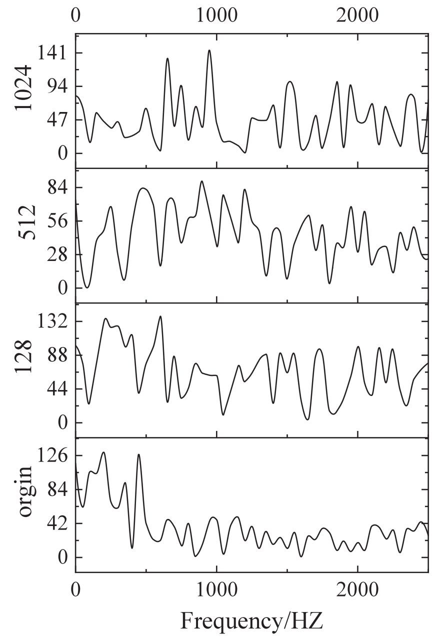

Fig. 16. The influence of different LSTM cells on experimental results.

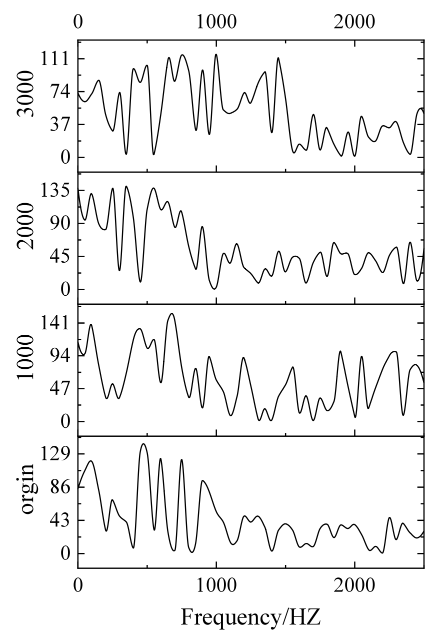

Fig. 17. The effect of different iteration times on the results.

5.2. Performance analysis of algorithmic composition model

Fig. 19 shows the result of generating a sample piano roll. The final generated piano roll format music map is complete. The number of network layer units is set to 512, and the iteration is set to 3000. As shown in the time-domain waveform diagram in Fig. 19, the frequency distribution range of the music generated by the MCNN network is basically the same as that of the training sample waveform. It also further explained that the network can learn the internal structure relationship of the training sample sequence well.

Figs. 20 and 21 show that the sample coincidence rate of the GAN algorithm is only 0.62, and the sample coincidence rate of the VAE–GAN algorithm reaches 0.81, which is higher than that of the GAN algorithm. The sample coincidence rate of the RL-RNN algorithm reaches 0.946, while the sample coincidence rate of the MCNN algorithm reaches 0.95, which is the highest, far exceeding GAN and VAE–GAN, and slightly better than RL-RNN. Therefore, the music generation algorithm based on the MCNN network basically guarantees the integrity of the generated music and improves the performance of the model.

5.3. Performance evaluation results of composition model

The MCNN-based music generation algorithm shown in Fig. 22 has advantages in the obtained results, which proves the effectiveness of the model in music generation, especially in the

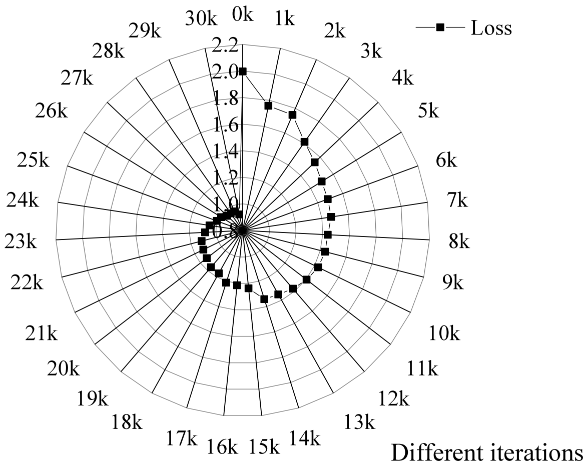

Fig. 18. The effect of the number of iterations on the loss value.

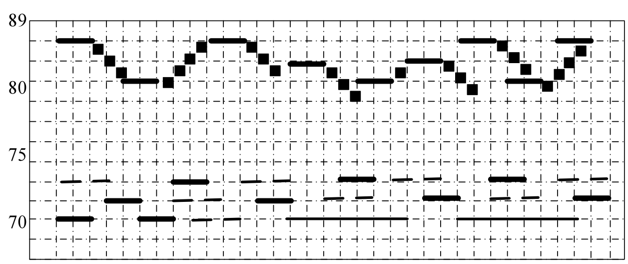

Fig. 19. Generated sample piano roll graph.

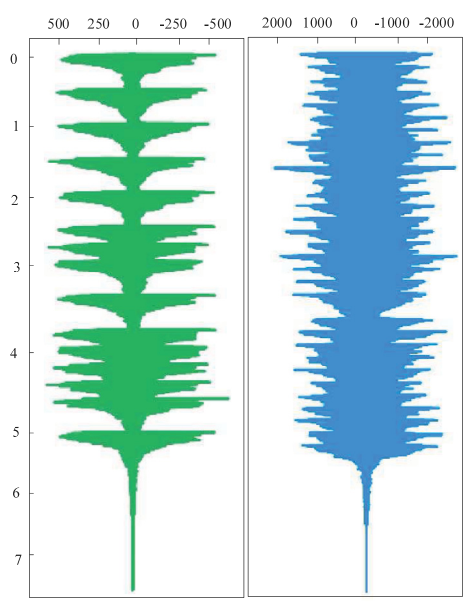

Fig. 20. Time-domain waveforms of training samples and generated samples.

aspects of harmony and music sense. The network model constructed simultaneously from the perspective of music creation and big data learning has stronger practical value. In the GAN network, the relationship between the generator and the discriminator makes the generated music sequence very similar to the training set, and the diversity is lacking.

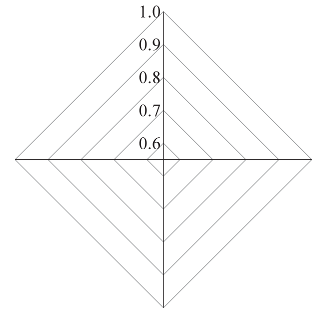

Fig. 21. Qualified rate of four kinds of algorithm in music generation.

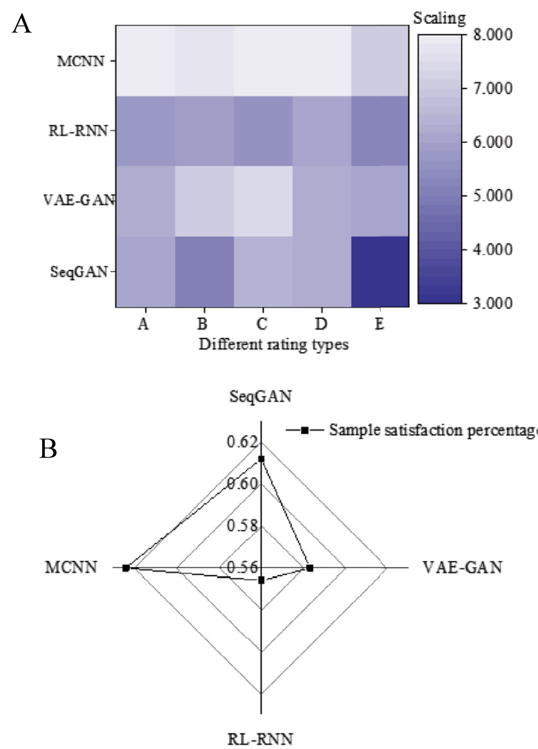

Fig. 22. Subjective verification score.

5.4. Verification of the performance of the copyyright protection system

Fig. 23 shows that virtual users of 100, 200, 300, 400, 500, and 600 are used for system testing for comparison, and the virtual user error rate under different inspection times is 0%. As the number of virtual users continues to increase, the processing value of the system is gradually increasing. The blockchain-based digital music copyright protection system proposed can accurately complete requests under concurrent operations of multiple users while ensuring a high processing speed.

5.5. Comparative analysis of copyright protection performance

Fig. 24 shows the comparison results of the proposed algorithm with other blockchain platforms. The value of the proposed algorithm is notably higher than that of other blockchain platforms. Therefore, the algorithm has higher performance, which can avoid the low throughput state to a certain extent, and is more suitable for application in digital copyright protection systems.

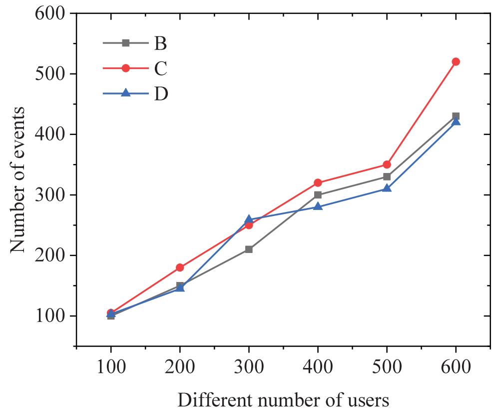

Fig. 23. Performance verification of copyright protection system. Note: B–D are different inspection times (100, 200, and 300 times).

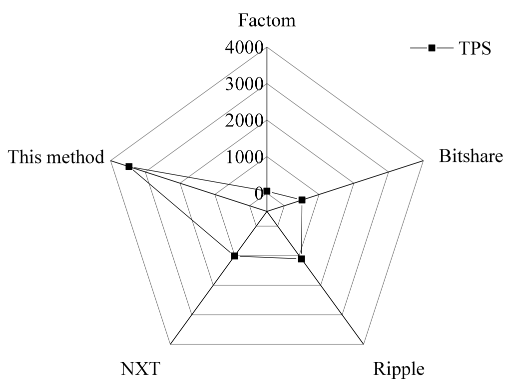

Fig. 24. Comparative analysis of copyright protection performance.

5.6. Algorithm complexity and performance comparison

Fig. 25 shows that the time domain features, frequency domain features, spectrogram features, and nonlinear Hurst parameters extracted in the experiment all play an important role in audio sentiment analysis. The random forest algorithm after weight optimization has a certain improvement in recognition rate than before optimization. Therefore, reducing the voting ability of decision trees with poor classification performance is of great significance to the classification recognition rate. The selection of decision tree samples and the selection of feature attributes are random in the random forest algorithm. Therefore, the classification results are slightly different in each experiment. Originating from the idea of integration, the random forest algorithm with optimized weights is integrated again in the experiment, and the final result is obtained according to the voting principle [34]. In terms of algorithm complexity, the model proposed can process fast, which effectively guarantees the efficiency of composition creation.

The total number of data interactions in the core consensus process of the deep learning neural network algorithm is 3n-1 times for the leader node and 3 times for the n-1 follower nodes, for a total of 6n-3 times. The overall algorithm complexity is only a multiple of n, which requires low hardware equipment.

5.7. Comparison results of performance of different algorithms

In Fig. 26, the results of this algorithm are compared with VAE–GAN, GAN, and RL-RNN. From the experimental results, the music samples generated by MCNN network have the highest compliance rate, which is far better than GAN and VAE–GAN, and slightly better than RL-RNN. The music generation algorithm based on MCNN network can basically guarantee the integrity of the generated music. In subjective evaluation, the quality of music generation is verified through the evaluation of professionals. A total of 20 music professionals from Communication University of China were invited to give a comprehensive score on the 50 samples generated by each model, and the result record is shown in Fig. 26B. The music generation algorithm based on MCNN has many advantages in the result, which proves the validity of the model in the music generation, especially in harmony and music texture. The network model constructed simultaneously from the perspectives of music creation and big data learning has strong practical value. From the principle of the algorithm, it is not difficult to find that the game relationship between generator and discriminator in the GAN network makes the music sequence generated and the training set extremely similar, and the diversity is somewhat missing. In the structure of reinforcement learning for music generation, reward function is the key to good or bad music generation. The support rate of the GANs1 model proposed by Ye (2019) was about 33.3%, the support rate of DeepBach was about 38.3%, the support rate of real songs was about 38.3%, and the support rate of reconfiguration harmony was about 33.3%. The support rate of the GANs2 model proposed is about 46.7%, which is close to 50% and far more than that of Ye's [35]. The music generated by the Zhang (2020) model is less than 50% of the satisfaction rate of the music generated by the BiLSTM-GANs under the category of piano musicians. It is much lower than the model proposed in this study [36]. Therefore, it is of great research significance to explore appropriate and efficient reward function.

5.8. Security analysis of copyright protection

In Table 2, the model proposed is analyzed through music safety performance. Sixty pieces of music content were selected and put on the Internet through different models. Finally, the piracy situation of music is observed one month later, where security is the safety protection performance of the system. The proposed deep learning + blockchain has the highest security of 72.14%, while the protection rate is for music works. The maximum music protection rate of the proposed model is as high as 82.33%. Therefore, the proposed model has high efficiency of music copyright protection (see Table 3).

Table 3
Music copyright security analysis results.

Technology	Safety	Protection rate
Deep learning	65.36%	65.23%
Big data	66.14%	69.43%
Blockchain	65.12%	70.05%
Deep learning + blockchain	72.14%	82.33%

6. Conclusion

In this work, an MCNN music generation network is constructed. First, the probability distribution of the music generation network is optimized in real time through the reward function, so that the quality of music generation is improved. The integrity of about 90% of the music samples are guaranteed, and 62.4% of the samples meet people's requirements for style music. Then, the current research status of algorithmic composition is introduced, and the commonly adopted methods are discussed and analyzed, including HMM model-based methods, music rule-based methods, genetic algorithms, and neural

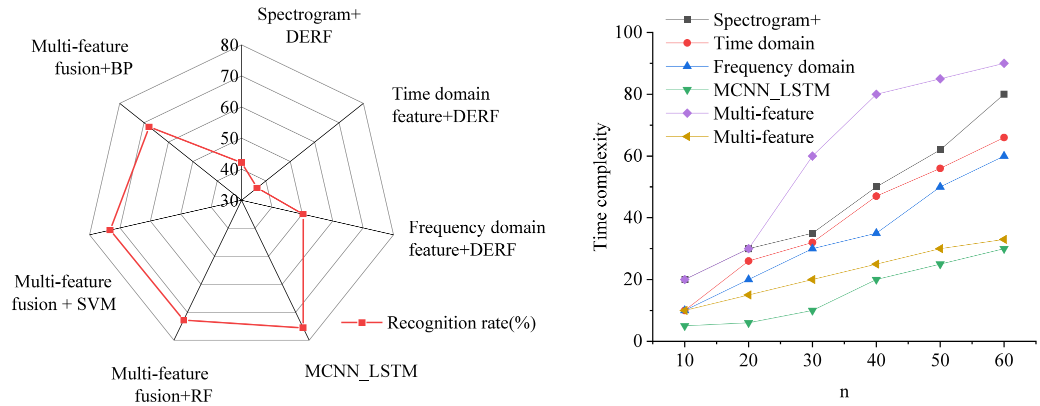

Fig. 25. Algorithm complexity and performance comparison.

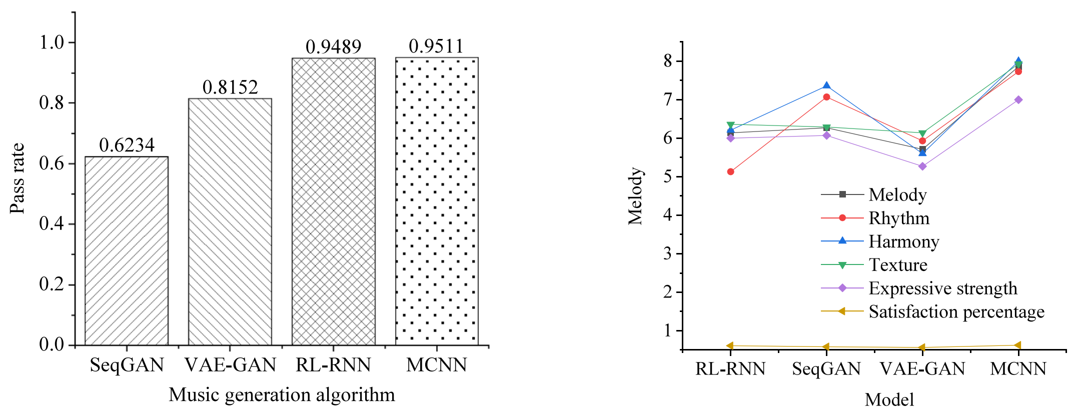

Fig. 26. Comparison results of performance of different algorithms.

network composition algorithms. Finally, the neural network is selected to realize the algorithm composition. Based on the actual operating status of digital music copyright management in China, a primary application system that applies blockchain to digital music copyright management in China is conceived. The actual utility of blockchain for digital music copyright management in China is proved to be conducive to the development of digital music copyright management in China. Although this work has constructed a composition model and copyright system, there are still many shortcomings. First of all, in practical adoptions, music styles are often diverse and constantly changing. Therefore, the construction of a multi-style and multi-themed music intelligent generation model still requires continuous exploration and research. Secondly, there are few companies in China that actually apply blockchain to digital music copyright management, and the application system concept is still in the ideal stage. Therefore, in-depth analysis will be made in these directions in the following works, to continuously improve the constructed model and system.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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