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Analysis of Guqin Playing Techniques Based on Artificial Intelligence

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Abstract: The Guqin art form is one of China's oldest musical traditions and is recognized as a significant part of the world's intangible cultural heritage. Numerous ancient scores have survived to the present day, but only a select few have been adapted for contemporary music. While ancient Guqin scores can be translated into modern numbered or staff notation, their rhythmic elements cannot be accurately replicated. The process of converting these scores into a simplified Guqin notation presents challenges, particularly in selecting appropriate fingerings. To address the issues related to playing ancient scores and transferring new ones, this paper introduces a triple representation method for Guqin score knowledge using knowledge mapping technology. It transforms the simplified Guqin notation into a text format, exemplified by the Ming Dynasty's "Magic Secret Score." A computer-editable text corpus of Guqin is created, and various tags are applied to the text. A word cloud visualization of the "Magic Secret Score" text spectrum is generated using a word cloud tool. The frequency of different right-hand fingerings in the "Magic Secret Score" is analyzed. By examining the temporal characteristics of the music, the paper extracts the timing relationships of right-hand fingerings from the text corpus and identifies various performance templates using the KMP pattern matching algorithm. Specifically, it analyzes 64 different right-hand finger techniques. Additionally, the frequency of string combinations in the "Magic Secret Score" is recorded, providing essential guidelines for future intelligent music transfer reasoning. The experimental findings indicate that there are specific constraints on the timing of fingerings and string usage in musical tones, with the maximum length of reusable fingering timing templates being no more than 25.

Keywords: Guqin musical score; Knowledge graph; Relation extraction; Word cloud

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1. Introduction

Digital heritage refers to the information that exists in digital form or is digitized. Human digital heritage is extremely rich, and the purpose of digital heritage protection is the reuse of heritage. Music is the common spiritual wealth of mankind. Guqin is one of the oldest plucked instruments in China, with a history of more than 3000 years of cultural heritage. It is one of the second batch of UNESCO "representative works of human oral and intangible heritage" [1].

The inheritance of human music culture has experienced different ways, such as oral inheritance, music score inheritance, analog signal inheritance, digital signal inheritance, and so on. Before the Han Dynasty, the

art of Guqin was passed down orally; after the Warring States Period, it was gradually passed down by character notation, and in the late Tang Dynasty, Cao Rou deleted the character notation and recorded the score of Guqin by reducing the character notation. There are more than 150 kinds of ancient scores, 658 pieces of Qin music, and 3365 pieces of Qin scores, among which the Magic Secret Score of the Ming Dynasty is the first collection of music scores published in China and the earliest in the world [2].

Scholars from various countries have studied the diversity and complexity of digital heritage from multiple perspectives. Such as digital heritage protection platform construction [3], interactive documentary [4], mobile interaction [5], and so on. The exploration of Guqin art by modern scholars focuses on the collection and integration of Guqin data [6], the coding of musical notation [7], the manual playing of Guqin minus musical notation [8], the restoration of musical notation [9], and the automatic generation of musical passages [10], the input system of Guqin minus musical notation [11], the modeling of Guqin timbre [12], the reconstruction of Guqin ancient musical notation [13], and the study of Guqin rhythm [14,15], Guqin aesthetic research [16], Guqin creation [17], Guqin perception [18], etc.

Although there are more than 3000 pieces of Guqin music, there are less than 100 pieces of Guqin music played by modern pianists. A large number of ancient music needs to be recorded by senior pianists. The way of recording is generally to use the pitch spectrum, such as the numbered musical notation or the staff. The numbered musical notation and the staff are the way of recording the pitch of music, while the Guqin musical notation records the fingering of performance. Guqin score is the conversion process from the fingering score of Guqin to the pitch score. With the emergence of a large number of Guqin audiences, the repertoire of Guqin has been gradually expanded, and some music scores of numbered musical notation and staff notation need to be converted into Guqin fingering scores for dissemination, which can greatly enrich the repertoire of Guqin. Therefore, there is a transformation process between the fingering spectrum and the pitch spectrum, as shown in **Figure 1** below.

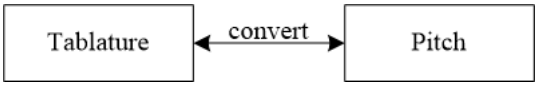

Figure 1. Transformation between music score forms

Knowledge mapping is a technical method to describe the relationship between knowledge and model everything in the world with a graph model. The analysis methods of knowledge mapping include knowledge representation, knowledge acquisition, knowledge processing, and knowledge utilization. Knowledge representation is a method and technology that uses computer symbols to describe and represent the knowledge in the human brain to support the machine in simulating the human mind for reasoning. Knowledge processing includes knowledge extraction, knowledge fusion, and other requirements, while knowledge utilization focuses on knowledge map completion, reasoning, retrieval, and analysis [19].

Yang [20] believed that the music domain knowledge map aims to integrate music domain information and resources, extract music knowledge contained in metadata, audio, video, pictures, and text, and then represent it in a structured and semantic way according to the model defined by the music domain ontology.

The application research of knowledge mapping mainly includes the use of knowledge mapping technology to analyze the papers of music education conferences [21,22] and the research status of basic music education [23,24].

This paper uses knowledge mapping technology to explore the musical tone pattern of Guqin fingering score, provides high-level music knowledge for intelligent transfer score, and then analyzes the representation and acquisition of knowledge mapping, the extraction of musical tone timing knowledge of string order pattern and fingering pattern, and so on. Taking the most representative and the first complete Guqin score collection in the

existing Guqin score, the Ming Dynasty Guqin music collection "Magic Secret Score," as the experimental object, the results of music score knowledge extraction are analyzed.

2. Knowledge mapping technology of piano score

The next step is to establish the musical tone model of Guqin fingering score, and then propose the extraction model of the temporal relationship between musical tones.

2.1. Guqin knowledge map representation and storage

The Guqin knowledge map representation method integrates RDF technology and computer-editable text representation technology [25]. RDF is an international standard for mapping knowledge domains developed by W3C. It uses triples to store knowledge and supports different serialization formats, such as RDF/XML, Turtle, N-Triple, etc.

By analyzing the information organization of Guqin music collection, we can get the triple representation of Guqin knowledge map represented by RDF technology. The general Guqin music collection has the name of the music collection, such as the Ming Dynasty Qin score "Shenqi Mipu." The music collection is called "Shenqi Mipu," which is divided into three volumes, containing a catalogue of 64 Guqin pieces. A music score of a piece of music includes a music label having general information about the music, and tone information with a time stamp on a time axis. The music label of a piece of music contains the title and composition information of the music, as well as the structural marks of the music, such as the repetition marks of the passage. The music score of Guqin has the creator of the music and the description of the background of the creation (that is, inscriptions and postscripts), and some Guqin songs also contain the creator of the lyrics, which constitutes the triad of creative information. The title of a piece has a major heading for the title and a minor heading for the passage, as well as a sequential time stamp between these minor headings.

Each musical tone in the zither music is represented by the notation symbols and the string order of the unique reduced notation of the zither. These notation symbols can be divided into left-hand symbols and right-hand fingering. These fingering symbols and string order marks constitute more than one thousand different musical tones. The left-hand symbols include three kinds of timbre notation characters, namely, scattered tone, pressed tone, and overtone. The default timbre of Guqin is a pressed tone. Both scattered tone and overtone have specific notation characters. The left hand has many fingering methods, which can form a large number of rich timbres with the emblem on the strings. See **Figure 2 (b)** and **Figure 3 (a)** for RDF triples of musical tones. It is a typical musical notation character. The text notation of this notation character is "big finger six or seven emblems pick six strings," the left-hand fingering is "big," the emblem position is "six or seven," the string order is "six," and the right-hand fingering is "pick."

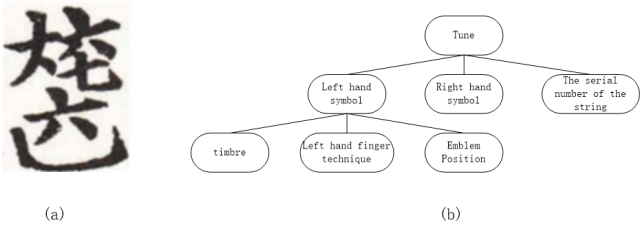

Figure 2. Knowledge map RDF triples of musical tones

Each entity in the RDF triple of Guqin is stored by using the computer-editable text score technology of Guqin [26], and the entity example is shown in **Figure 2 (a)**. Computer-editable text notation (CTT) uses commas to segment every entity in the music, including album name, volume name, music catalogue, music title, author, preface and postscript, subtitle, music structure marks, and musical tone information. The music information, such as the music list, the music title, and the time stamp of the music note, is marked in the natural order of the text format.

2.2. Knowledge extraction of musical tone relationship

Knowledge extraction is an important technology to realize automatic construction of large-scale knowledge map. The data sources of knowledge extraction include structured data, unstructured data and semi-structured data, and different data characteristics correspond to different knowledge extraction technologies. The common knowledge extraction technologies for unstructured data include entity extraction, relation extraction, and event extraction, and the knowledge extraction technologies for structured data include direct mapping and R2RML language proposed by W3C.

The editable text score of Guqin music is unstructured data. The common methods of entity extraction from unstructured data include rule-based method, statistical model-based method, and deep learning-based method. The relation extraction of unstructured data is to extract the semantic relation between two or more entities from the text. The common methods include template-based method, supervised learning-based method, and weakly supervised learning-based method [19].

When the fingering score of Guqin score and the general pitch score are transformed, the entity that easily causes ambiguity is the musical tone. The musical tone of Guqin minus word score is marked by fingering, while the musical tone of pitch score is composed of four basic elements: pitch, duration, timbre, and intensity. There is no one-to-one correspondence between the fingering in minus word score and the four elements of pitch score. Especially when there is a pitch spectrum to the fingering spectrum, a designated pitch of music, in the fingering spectrum of Guqin, can have up to thirteen different fingering playing methods, such as the main palace tune, the music “feather” on Guqin includes a scattered tone, six overtones and six notes, a total of thirteen different playing methods, a pitch spectrum corresponds to all different fingering spectrum. However, a large number of fingering scores do not conform to the rules of Guqin performance. Guqin experts are needed for selection.

At present, the conversion process of new Guqin scores is mostly based on the conversion of pitch scores into fingering scores by senior pianists according to playing rules and commonly used playing modes. Therefore, the statistical model method based on the text score of Guqin and the extraction of musical tone relationship based on the performance mode are the auxiliary means to improve the efficiency of the transfer score.

For the extraction method of musical tone relationship, this paper uses the KMP pattern matching algorithm of strings to extract different performance templates and obtain the frequency of different templates, which provides the necessary rules for future research of music transfer inference.

3. Experimental results based on “Shenqi Mipu”

This paper uses one of the most famous Guqin music collections—the “Magic Secret Score” compiled by Zhu Quan in the Ming Dynasty as the experimental material, first of all, using the computer-editable text score technology to convert the music score of the “Magic Secret Score” into a text score, and manually input all the

information of the "Magic Secret Score," including the cover, catalogue, the preface and postscript of the music, the reduced word score of the music and other information.

3.1. Statistical information of the text spectrum of "Shenqi Mipu"

The method comprises the following steps of: firstly, converting a reduced word score music score of the magic secret score into a text score which can be edited and processed by a computer by utilizing a computer editable text score technology, manually inputting and completing a whole music score collection of the magic secret score, distinguishing a musical tone score word from other music score information by using left and right square brackets, dividing different musical tone score words by using commas, and corresponding to different vertical column information in the music score by a carriage return.

After the input is completed, after the non-music semantic information such as commas and left and right square brackets are removed, through simple statistics, the entire computer-editable text score of the Magic Secret Score contains 136,069 words in total, wherein the reduced words representing the musical tones contain 48,486 words, and the word cloud distribution diagram of the reduced words of the musical tones is shown in **Figure 3**.

Figure 3. Cloud diagram of frequent words of commonly used minus words in "Shenqi Mipu"

See **Tables 1** and **2** for the number of basic fingerings of left and right hands in "Shenqi Mipu." Comparing **Table 1** and **Table 2** with **Figure 4**, it can be found that the word cloud in **Figure 4** can better visualize the frequency of different spectrum characters.

Table 1. Frequency of using the basic fingering of the right hand in "Shenqi Mipu"

By name	Picking direction	Fingering	Number of occurrences	Proportion
Big finger	Inward	Bo	315	1.98%
Big finger	Outward	Toh	26	0.16%
Index finger	Inward	Wipe	1422	8.96%
Index finger	Outward	Pick	4702	29.62%
Middle finger	Inward	Hook	6333	39.90%
Middle finger	Outward	Pick	887	5.59%
Ring finger	Inward	Hit	1964	12.37%
Ring finger	Outward	Pick	223	1.40%

Table 2. Frequency of basic fingering of the left hand in "Shenqi Mipu"

By name	Big finger	Index finger	Middle finger	Ring finger	Kneel and point
Number of occurrences	5384	632	863	3917	230
Proportion	48.83%	5.73%	7.83%	35.52%	2.09%

3.2. Extraction of time sequence relationship

In the music score of Guqin, the musical tone is the result of a playing composed of fingering and string order, and the musical tone relationship template is the extraction of the timing relationship between the fingering template and the string order template. In this experiment, the relationship between each right-hand basic score word and each string in the "Magic Secret Score" is extracted, because music is a time art, and the flow of its music on the time axis produces different melodies. Therefore, the relation extraction of the musical tone template is the temporal relation extraction of the musical tone.

Taking eight right-hand basic fingering spectrum characters as an example, spectrum character strings obtained by extracting all right hand basic fingering combinations in "Shenqi Mipu" according to the time sequence relationship form a spectrum character string set, all spectrum character substrings with the length not exceeding a given length are extracted from the spectrum character string set, and then the KMP algorithm is used for searching the occurrence frequency of each spectrum character substring contained in the spectrum character string set.

The experiment is carried out on the spectrum character substrings with no more than 30 spectrum characters. The spectrum character substrings with different lengths appear differently in the spectrum character string set of "Shenqi Mipu." The number of different spectrum character substrings with the same length and the total number of all spectrum character substrings with the same length that appear in the spectrum character string set are counted, and **Figure 4** is obtained.

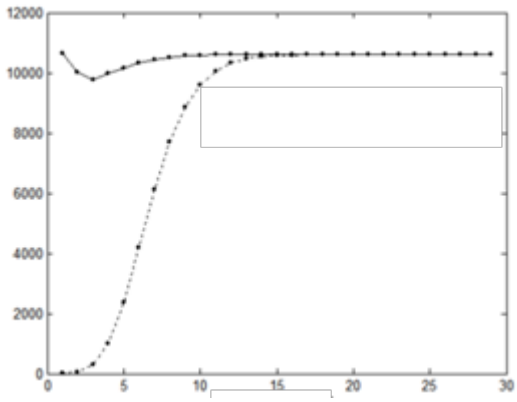

Figure 4. The number of combinations and the total number of occurrences of spectral word substrings of different lengths of the right-hand basic spectrum

In **Figure 4,** the horizontal axis is the length of the spectrum word substring, and the vertical axis has two values, one is the number of different spectrum word substrings with the same length appearing in the "Shenqi Mipu," that is, the number of different spectrum word substrings obtained by combining spectrum words, which is represented by a dotted line in the figure, and the other is the total number of all spectrum word substrings with

the same length appearing in the "Shenqi Mipu," that is, the solid line in the figure. Two conclusions can be drawn from this: one is that with the increase of the length, the fluctuation of the total number of all different substrings in the "Shenqi Mipu" tends to be horizontal, indicating that the new long substring will only appear once in the "Shenqi Mipu." Secondly, in the "Shenqi Mipu," when the length of the spectrum character string is between 1 and 25, the total number of different spectrum character substrings with the same length and all different spectrum character substrings is different, the dotted line and the solid line in **Figure 4** do not coincide, and when the length is greater than 26, they are the same, that is, the dotted line and the solid line in **Figure 4** coincide.

Table 3 specifically counts the frequency of the combination of the right-hand basic spectrum characters in the "Shenqi Mipu" when the length of the substring is 2. There are only three kinds of right hand fingering combinations that appear more than 1000 times in the two adjacent tones of "Shenqi Mipu," namely "pick hook," "pick hook," and "pick hook," which shows that the possibility of fingering "pick hook" is the greatest after the right hand fingering "pick" is emphasized in the Guqin music score, and the fingering "pick hook" appears in all three combinations. It shows that the right hand is the most commonly used fingering, which is also consistent with the convenience of human fingers. In addition, some combinations do not appear, such as "Tuo Tuo," which shows that such combinations can not appear in the transfer spectrum.

Table 3. Frequency of right-hand basic spectrum character combination

First second	Bo	Toh	Wipe	Pick	Hook	Pick	Hit	Pick
Bo	4	0	22	50	70	0	107	9
Toh	0	0	0	3	5	1	1	1
Wipe	14	0	37	285	280	27	60	7
Pick	78	3	161	511	1559	99	610	76
Hook	6	6	301	1287	1112	440	437	28
Pick	0	1	42	168	329	56	37	10
Hit	87	1	132	760	271	19	168	30
Pick	23	0	15	34	40	1	48	1

Guqin has seven strings, the seven empty strings play different pitches of scattered tones, and the seven strings will produce different timbres and pitches under different techniques of pressing and overtones, so the order and frequency of different strings in the music are different. Obviously, the number of times two adjacent strings appear in the music score of Magic Secret Score is also different. **Figure 5** illustrates the number of occurrences of two adjacent strings in the anteroposterior relationship, wherein the X axis and the Y axis are the string sequences 1 to 7 corresponding to the "1234567" of the string, the string of the X axis is in the front, the string of the Y axis is in the back, and the Z axis corresponds to the number of occurrences of different string sequence combinations in the Magic Secret.

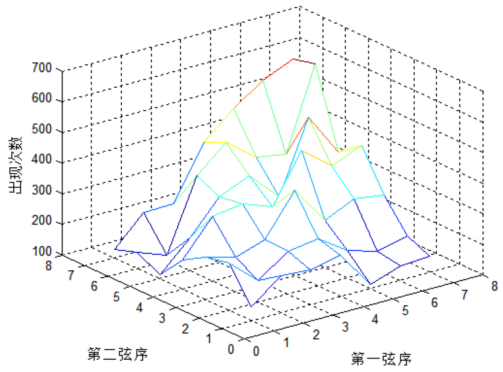

Figure 5. Frequency of the combination of two adjacent strings

It can be seen from **Figure 5** that the frequency of the occurrence of the same string in the front and back strings is less, and the frequency of the occurrence of the same string in the front and back strings is less when the difference in the string order of the two strings is large.

4. Conclusion

The protection of digital heritage is based on numerous examples, and this paper provides a musical tone timing template for the transfer from pitch spectrum to Guqin music score through the extraction of the musical tone timing relationship in Guqin example music score, and also designs a human-computer interactive transfer assistant system to improve the efficiency of the transfer.

Although the study of playing score and turning score of Guqin is two different directions of score transformation, its core elements are still to serve the performance of music, through the combination of ergonomics and other related constraints, it provides a good research example for the application of artificial intelligence technology such as knowledge mapping in the field of music and art.

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Disclosure statement

The authors declare no conflict of interest.

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