

Statistical analysis of Bach's Well-tempered Clavier

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Abstract: Bach's Well-tempered Clavier is the greatest work of Bach keyboard music, it contains 48 preludes and fugue, it is one of Bach's representative works of music creation. This paper firstly inputs MIDI data of Bach's Well-tempered Clavier, and then constructs the analysis model of Bach's Well-tempered Clavier. The experimental results show that the envelope of the number of occurrences of each musical note is in the shape of a double hump, indicating that the statistical number of musical notes played by the right hand or the left hand should be in the shape of a single camel peak in the musical range.

1. Introduction

The best known of Bach's clavier works is the famous set of preludes and fugues called The Well-Tempered Clavier. Part I was completed at Cöthen in 1722, and Part II was completed at Leipzig around 1740. Each part consists of twenty-four preludes and fugues, one prelude and one fugue in each of the twelve major and minor keys.

Bach's Well-tempered Clavier stands at the core of baroque keyboard music and has been a model and inspiration for performers and composers ever since it was written. It contains 48 preludes and fugues, it is the peak of Bach's musical creation, the work has an important position in the western music world[1], commonly known in English as the 48 preludes and fugues, are at the centre of European civilisation, and are the beloved property of generations of people all over the world. Hans Guido Von Bulow likened it to the musical "Old Testament bible"[2].

The Well-tempered Clavier is a collection of two pieces written by Bach for keyboard instruments, the first of which was completed around 1722 and was mainly used for teaching purposes. The second was assembled in Leipzig in 1740. Each episode has 24 preludes and fugues in 24 major and minor keys. Each prelude is in the same key as the fugue, but the theme is not related. The prelude is free in form and the fugue shows Bach's superb contrapuntal creation skills. the Well-tempered Clavier confirmed the superiority of the Well Temper, further established the western mode of large and small, for the creation of the equal temperament, set up a model, its influence is extremely far-reaching.

Due to its outstanding status in the field of music and art, the research on Bach's Well-tempered Clavier has been a hot topic with abundant research results and materials. As of June 2022, known in China online (www.cnki.net) queries to related to the average of the piano theme 132 papers, which involved the texts of

Bach's Well-tempered Clavier fugue related with 50 references, prelude to related with 45 references, the average law related with 22 references, and works BWV849 related with 13 references, There are 13 literature related to polyphonic music, 11 literatures related to piano music, 11 literatures related to keyboard instruments, 8 literatures related to duotemperament, 6 literatures related to homophonic music, 5 literatures related to polyphonic works, and many literatures related to other topics. At the research level, basic research accounted for the majority, with 94 and 24 literary works.

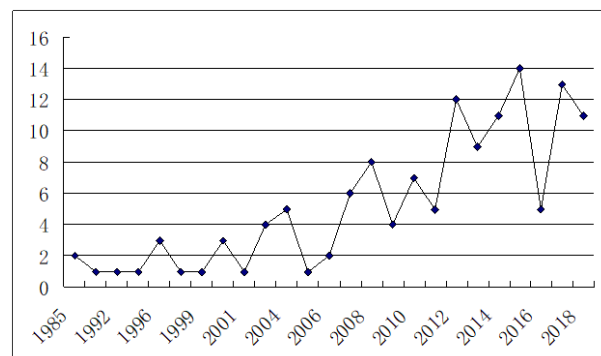


Figure 1. The number of documents of Bach's Well-tempered Clavier by CNKI in recent 35 years.

In www.cnki.net, the most recent 35 years the average piano album in related research results shows the tendency of increase year by year, visible Figure 1 the research achievements of the average of the piano, increasing in number, from the nineties of the 20th century random single digits, research achievements to the 21st century in the past ten years, In the past ten years, the annual number of achievements reached about ten pieces, and the researchers' research enthusiasm for Bach's Well-tempered Clavier increased with each passing day.

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In the research literature about Bach's Well-tempered Clavier, the researchers have studied the historical influence, creation techniques, performance techniques, educational methods, fugue, prelude and so on. Pan Jie [3] expounded the rigor and accuracy of fugue structural thinking, as well as the historical origin and social background of the formation of such thinking mode through the analysis of fugue in Bach's Well-tempered Clavier. It shows that the fugue in the baroque period is the concentrated embodiment of the rationalist thinking mode of European music.

In terms of influence, Ye Dongying [4] believes that Bach's great influence on later generations is self-evident in western classical music. It is no exaggeration to call him the father of music. Although Beethoven has "music saint", but in his later years, Beethoven increasingly revered Bach, in the works more and more frequent use of fugue and other polyphonic techniques, showing traces of imitation of Bach. From Polish piano poet Frederic Chopin, German composer Johann Hindimith to Russian master Sergei Shostakovich, musicians of different nationalities and backgrounds all followed Bach's 48 pieces to write masterpieces out of respect for Bach. 48 can be regarded as a model for later generations in terms of musical form, composition techniques and emotional expression. Of course, these later imitations are by no means pure imitations, but fully show the composer's own individuality, originality, nationality and characteristics of their own times. Bach is like a fertile soil, from which the composers of later generations have absorbed rich nutrition and produced fruitful results.

In terms of performance, Cui Xiufeng [5] believes that the works has strong artistic charm, and proves the feasibility of Well Temper from the perspective of practice, creating an artistic conception full of beauty and expressing delicate and moving emotions. In order to better deduce the connotation and emotion of the works, in the process of playing, a lot of attention to the relevant elements. Attention should be paid to the level of voice parts, rhythm and touch keys, rational use of pedals, grasp the sense of structure, and experience religious meaning.

In terms of teaching, Li Yifan [6] believes that learning Bach's Well-tempered Clavier is of special significance for improving polyphonic playing techniques. Therefore, there is no dispute today about whether to learn Bach polyphonic works for non-piano major students with poor foundation and late contact with piano in the music department of normal universities, which can be clearly seen in the piano teaching syllabus of normal universities. Although students majoring in piano in the music department of normal university, Bach's set has become a must-play textbook. And points out some practice methods: 1. Play each part separately to understand the overall layout of the tune and the development of each detail. 2. Determine the correct fingering. 3. It is also a good practice to practice two parts in a group. 4. Sing one part with your mouth and play another part on the instrument. 5. Take turns to highlight a part as you play the whole piece.

In the study of polyphonic techniques, Zou Shu [7] believes that The Collection of the Well-tempered Clavier is a representative work of Bach's polyphonic music.

There are 48 preludes and fugues in the two volumes, all of which are arranged in 24 semitones. In fugue with the same tonality and standard form, Bach adopts different polyphonic techniques, and his ability to control the technique is unique. In this paper, two fugues in C minor in the works are taken as objects, and the characteristics of polyphonic thinking are compared from four aspects: theme form, tonality, counterpoint and interposition.

In terms of aesthetic influence, Wang Site [8] thought for a long time many people believe that Bach's Well-tempered Clavier feat only on the practical application and the music form of Well Temper, but on the average of the piano music structure and contents of the analysis we can see, the people think that is the most limited form of fugue, Bach gives their largest free, show the endless changes, and includes a variety of genres, the expression of the most basic human emotions and humanistic spirit. This unique spirit of innovation made Bach not understood by his contemporaries. Bach uses fugue, the most formal music genre, to express the full and distinct musical image. He innovates the form to enrich the connotation. His inspiration is like a spring gushing, and in turn requires the development and breakthrough of the form. This non-acoustic factor refers to the spiritual connotation in music works, and Bach's Well-tempered Clavier can be regarded as a classic for hundreds of years, because of its immortal spiritual content, expressing the rich emotions of human beings and expressing the essence of humanistic spirit.

2. Data and methodology

Musical Instrument Digital Interface (MIDI) is a standard to transmit and store music, originally designed for digital music synthesizers. MIDI does not transmit recorded sounds. Instead, it includes musical notes, timings and pitch information, which the receiving device uses to play music from its own sound library. MIDI was proposed in the early 1980s to solve the communication problem between electroacoustic instruments. MIDI is one of the most popular digital music formats in the music industry. Almost all music software supports MIDI, which uses digital control signals of musical notes to record music.

Bach's Well-tempered Clavier is one of the most widely circulated piano works, and the music information contained in it can be expressed by MIDI information. In order to facilitate the intelligent analysis of the music information of Bach's Well-tempered Clavier, the complete MIDI file of Bach's Well-tempered Clavier should be obtained first. The MIDI file set of the works is obtained by using the score set of the works published by authoritative music publishing house through manual input, which provides data for the intelligent analysis of the works.

If the analysis model is implemented in MATLAB language, then the MIDI data interface corresponding to MATLAB is required. The data interface can read MIDI file data and convert it to the required data type. Here, the MIDI data type is converted to matrix data. The matrix data structure is shown in Table 1:

Table 1. Converted MIDI data structures.

Serial No.	Duration	MIDI channel	MIDI pitch	intensity	Time serial number	Time duration
0	0.9000	1.0000	64.0000	82.0000	0	0.5510
1.0000	0.9000	1.0000	71.0000	89.0000	0.6122	0.5510

Each row in the table contains seven columns of data, and each row represents the information of a musical note. The first column represents the start of the note in the metronomic ordinal number, the second column represents the duration of the musical note in the metronomic value, and the third column represents the MIDI channel (the value is: 1-16), the fourth column represents the MIDI pitch, where the central C (C4) is 60, and the fifth column describes the speed of the key at which the note is pressed, in other words, the volume at which the note is played (0-127). The last two columns correspond to the first two (start of beat, duration of beat), except that seconds are used instead of beats.

Beat ordinal numbers starting from 0, put the number according to the piece a clap, if music is a quarter notes or duration longer music, then its ordinal number is an integer, if music is a quaver, then its ordinal number is 0.5 for the mantissa, if music is semiquaver, then its ordinal number is 0.25 for the tail, so on, demisemiquaver, the mantissa is 0.125, 64 minutes of music, the mantissa is 0.0625, and so on.

When analyzing data, analysis model needs to be designed according to certain analysis purpose, and the information exchange between analysis model and data needs to design specific software interface. Software interface is a method of information exchange provided by software for a specific application. In the design of intelligent analysis model of the works, because its data type is MIDI data, it is necessary to design the specific data interface of the language used in the analysis model.

3. Statistical results

Tables and figures are commonly adopted methods for presenting specific data or statistical analysis results. Figures can be used to display characteristics and distributions of data, allowing for intuitive understanding through visualization and thus making it easier to interpret the statistical results.

Using the designed MIDI data interface, statistical analysis can be carried out on the music of Bach's Well-tempered Clavier according to the analysis model. Figure

3 below is the statistical result of the music of the Fugue in C major.

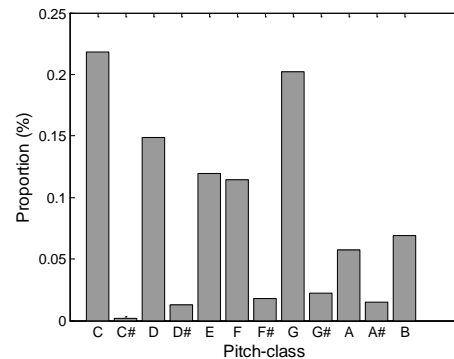


Figure 2. Pitch Distribution bar chart (Fugue in C major).

As shown in Figure 2, note C is used the most times, which is consistent with the tonality of this note. Meanwhile, note G occupies the second place, which is the pure fifth of note C.

The piano function displays traditional piano notes, because it's intuitive to use it to show the progression of musical notes under the music's timeline. Figure 3 is the piano curtain music illustration of a fugue in C major.

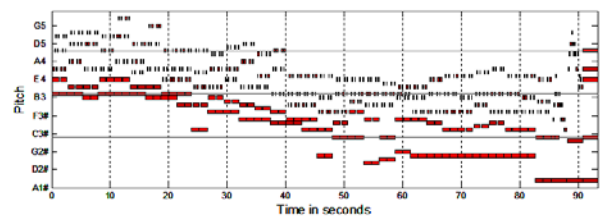


Figure 3. Music Illustration under piano Curtain (Fugue in C major).

Table 2 and Figure 4 show the statistics and diagrams of various musical sounds in the works. X-axis in Figure 4 shows the names of musical notes, and Y-axis shows the frequency of occurrence of corresponding musical notes. As shown in Table 2, #g1 appears most frequently, followed by # a. The range of these musical notes are from great A to small c.

Table 2. Statistics are made on the various musical sounds in Bach's Well-tempered Clavier.

Note	Times	Note	Times	Note	Times
a1	1	#d3	1901	a4	2620
#a1	0	e3	1887	#a4	2783
b1	1	f3	2119	b4	2583
c2	58	#f3	2015	c5	2643
#c2	62	g3	2314	#c5	2554
d2	123	#g3	2318	d5	2234
#d2	162	a3	2133	#d5	2113
e2	216	#a3	2295	e5	1735

f2	272	b3	2057	f5	1452
#f2	330	c4	2312	#f5	1314
g2	549	#c4	2002	g5	948
#g2	599	d4	2238	#g5	785
a2	726	#d4	2368	a5	534
#a2	938	e4	2220	#a5	349
b2	1066	f4	2679	b5	208
c3	1275	#f4	2322	c6	96
#c3	1414	g4	2732	#c6	2
d3	1709	#g4	2910		

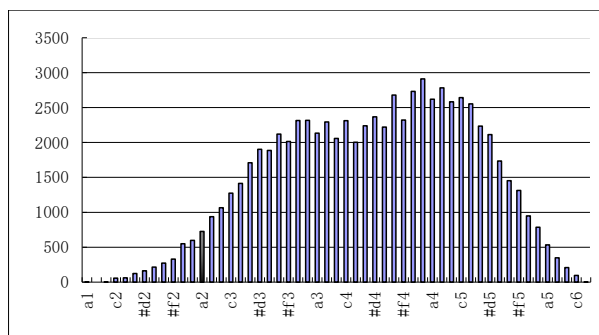


Figure 4. The number of occurrences of all notes in Bach's Well-tempered Clavier.

Piano music is played with the left hand and the right hand, all in Figure 4 the emergence of various music is both statistics, Figure 4 occurrences of the envelope is bimodal hump shape, separate the right hand or left hand play the music of count in a tone should be in the range in camel peak shape, the total after the bimodal hump shape.

4. Discussion

The music practice in Europe has experienced a process of change from monophonic music to multi-voice music, from Pythagorean tuning to just intonation and then to the 12-tones equal temperament. Bach was living in the era of the rise of the Well-temper. The emergence of Bach's Well-tempered Clavier established the position of the Well-temper to a certain extent, and the homophonic music was gradually accepted by composers.

This paper makes data visualization and statistical analysis on MIDI data of Bach's Well-tempered Clavier, and uses these MIDI data to analyze tonality and musical form in the future.

Acknowledgments

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