On the Analysis of Voicing Novelty in Classical Piano Music

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Abstract. Musical composition can be viewed as an act of conditional problem solving, the realization of musical ideas by arranging notes spatially and temporally. The resulting creations may constitute the unique style of the composer. In this paper we focus on how chord voicing – the expression of chords by choosing and stacking musical notes – has evolved in western classial piano music using large-scale music data sets. Our results shows that the level and variety of voicing novelty have increased throughout history. We also find that some composers exhibit a high level of voicing novelty due to the utilization of innovative pitch class sets, while others actually have pushed the boundaries of voicing with traditional pitch class sets. This study helps us to probe the emergence of expression of musical style on note level and to understand the evolutionary pattern of note arrangements.

Keywords: Musical style, Voicing, Evolution, Novelty

1 Introduction

Musical composition can be viewed as a process of conditional problem solving: Composers' creations reflect their musical ideas by way of the selection and arrangements of such musical elements as melody, rhythm, harmony, and structure, which results the creations manifesting their particular musical styles [1]. In this paper we investigate in particular **chord voicing** – how musical notes are vertically arranged to express a given harmonic scheme – which is the core element of harmonic progression often called the the fundamental task in Western musical composition [2]. For example, a fundemantal voice-leading rules in classical music of dominant to tonic chord is realized in different ways: A Pitch Class set (hereafter PC-set) movement from $\{G, B, D\}$ to $\{C, E\}$ can be written either as $(G3, D4, B4)$ followed by $(C3, E4, C5)$ or as $(B2, G3, D5)$ followed by $(C3, E3, C5)$ chosen by the composer.

By uncovering the historical compositional patterns of voicing, here we inspect how they developed over time. Previous works on musical novelty showed the stylistic evolution or the sweetspot in terms of success, including Park *et al.* [3] who showed that musical periods can be characterized by the novelty and influence of composers of each era. Similarly, the predictability of subsequent chords is measured by exploring chord transition probability [4], whereas the time of musical revolutions can be traced where novelty of harmonic and timbre properties change drastically [5]. Other symbolic features such as melodic intervals [6] or triads [7] are also shown to be effective for identifying styles and distinguishing musical eras. Weiß *et al.* [8] observed that the frequency of tritones and tonal complexity have steadily increased over the history of Western classical music. Nakamura and Kaneko [9] developed a statistical evolutionary model that fits the frequency data of tritones and that of non-diatonic motions where the creators and the evaluators coevolve through a function of novelty and typicality in a process of social selection. Finally, O'Toole and Horvát [10] used audio features to evaluate novelty and asserted that optimal level of differentiation is needed to become the most popular song. Few, however, have explicitly examined chord voicing (the vertical placement of pc-sets), with Harrison and Pearce [2] being an exception who introduced a computational framework of voicing. They suggested a mathematical model to calculate the probability of choosing the next voicing given current voicing according to pre-defined perceptual rules of chord voicing. In this paper, we try to investigate the very fundamental aspect of voicing; We hypothesize that novel ways of placing notes have been developed that characterize the style of composer and musical era.

2 Methodology

2.1 Dataset

The data used in our analysis were collected mainly from three online sources[1], and consist of 1 017 piano compositions by 40 historically prominent composers in MIDI format. We follow the common convention of dividing the history of classical music into the following five periods: Baroque, Classical, Romantic, Post-romantic, and Modern, and specifically use All Music Guide [2] to tag the year of compositions and the era to which the composers belong.

2.2 Key Normalization

The objective of key normalization is to treat the notes equally that serve identical harmonic functions, irrespective of their absolute pitch, to promote consistency. For example, the harmonic role of the chord $C = \{C, E, G\}$ in C major is identical to that of the chord $F = \{F, A, C\}$ in F major. The key of each composition in the dataset was estimated using a the Krumhansl-Schmuckler key detection algorithm [11]. This algorithm compares the pitch class distribution of a given piece of music with the key profiles obtained from music-cognitive experiments [12], and selects the key with the highest Pearson correlation among the 24 possible key. If the highest Pearson correlation coefficient value refers to an outlier among the values for the whole song, key normalization was not performed since the algorithm's key estimation is unreliable. Any number that falls outside of the first quartile (Q1) or above the third quartile (Q3) by more than

[1] http://www.piano-midi.de, https://www.classicalarchives.com, http://www.kunstderfuge.com
[2] http://www.allmusic.com

1.5 times the interquartile range (IQR=Q3-Q1) was considered an outlier. After each composition's key was estimated, all non-outlier major compositions were transposed to C major, and minor compositions to A minor (Fig. 1). It is clear from Fig. 1 that the comparatively high non-diatonic frequency is a result of outlier songs that would have chromatic scales or key modulation.

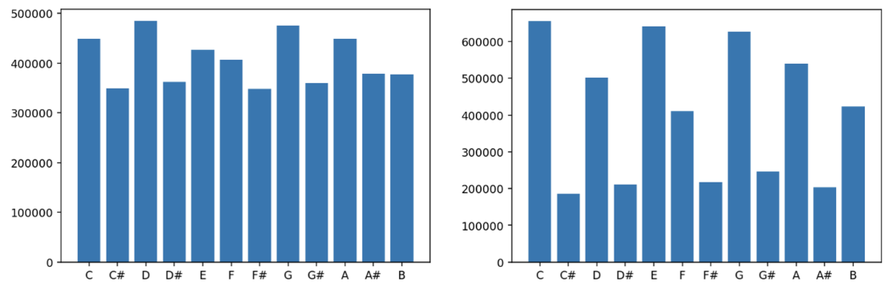

Fig. 1. Pitch Class distribution of the compositions before (left) and after (right) key normalization.

2.3 Encoding of Voicing

Voicing refers to the simultaneous vertical placement of notes in relation to each other [13] or assigning pitch heights to pitch classes [2] [3]. To conduct voicing analysis, we first encode each musical composition as a series of group of notes played simultaneously (which we call codewords) [14]. Next, we focus on the voicing of each codeword to calculate the novelty of voicing used by composers. While there is an issue of not being able to clearly distinguish between voicing and harmonic skeleton [2], here we model a composer as choosing the pc-set first then subsequently determining the voicing as an elaboration or an embellishment.

Voicing Encoding Given a PC-set Regarding the voicing as an implementation of pc-set, we can express the probability of choosing a voicing v_i given a pc-set s_i as

$$P(v_i|s_i) = \frac{z(s_i \to v_i) + \alpha(s_i \to v_i)}{\sum_{v \in V(s_i)} z(s_i \to v) + \alpha(s_i \to v)}, v_i \in V(s_i), \quad (1)$$

where $V(s_i)$ is the set of all possible voicings for a pc-set s_i, $z(s_i \to v_i)$ the number of occurrences of voicings v_i that have a pc-set s_i, and α is a constant representing an uninformed prior, a type of additive Laplace smoothing. Setting $\alpha = 1$ means that every conceivable voicing element in $V(s_i)$ has a finite chance of being chosen [3]. Let

[3] Another definition of voicing, a placement of notes among various instruments, does not fit to our analysis since we only address musical pieces for piano solo.

us take an example of a pc-set $s_i = \{C, E, G\}$. This pc-set's possible voicings $V(s_i)$ includes $v_i = (C4, E4, G4), (E4, G4, C5), (C3, E3, G3)$ etc. The total number of all possible voicings is equal to the number of piano key combinations available in a given pc-set. Note that the two voicings $(C4, E4, G4)$ and $(C3, E3, G3)$ differ by an octave. To discard octave position and only handle the relative spacing between notes, we use the voicing notation as the pitch interval between adjacent notes starting from bass note (Fig. 2).

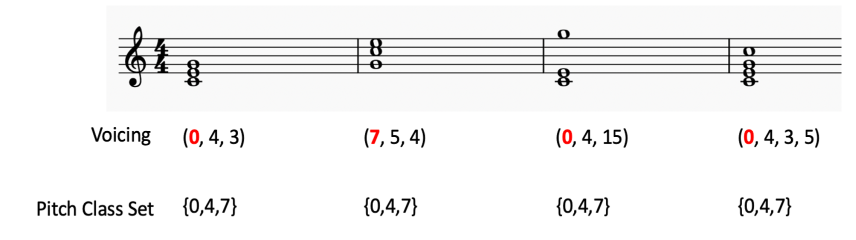

Fig. 2. Example of voicing and pc-set notation

2.4 Calculating Voicing Novelty

To see how the voicing style has evolved, we first measure the novelty of voicing. Representing a composition as a sequence of codewords (configuration of voicings) $\zeta = \{v_1, v_2, \ldots, v_m\}$, we can write the generation probability of ζ as first-order Markov chain

$$\Pi(\zeta) = P(v_1|s_1)P(v_2|s_2)\ldots P(v_m|s_m). \tag{2}$$

Its log inverse is the magnitude of surprise in information theory. We can thus quantify the novelty in voicing as an average unexpectedness of all voicings in a composition normalized by the length of a composition m:

$$Novelty(\zeta) = \frac{1}{m} log \frac{1}{\Pi(\zeta)} = \frac{1}{m} \left[\sum_{k=1}^{m} log \frac{1}{P(v_k|s_k)} \right] \tag{3}$$

2.5 Calculating PC-set Novelty

Here we discuss the pc-set and compare it with voicing novelty. pc-set novelty measures how novel the current codeword's pc-set is when the preceding codeword's pc-set is given. Representing a composition as a sequence of codewords' pc-set, $\zeta = \{s_1, s_2, \ldots, s_m\}$, the probability of choosing a pc-set s_{i+1} after a pc-set s_i is written as,

$$P(s_{i+1}|s_i) = \frac{z(s_i \rightarrow s_{i+1}) + \alpha(s_i \rightarrow s_{i+1})}{\sum_{k \in S} z(s_i \rightarrow k) + \alpha(s_i \rightarrow k)}, s_i \in S, \tag{4}$$

where S is the set of all possible pc-sets, $z(s_i \rightarrow s_{i+1})$ the number of occurrences of pc-set transition from s_i to s_{i+1}. Then the pc-set novelty can be acquired by plugging Eq. 5 into Eq. 6.

$$\Pi(\zeta) = P(s_1)P(s_2|s_1)\ldots P(s_m|s_{m-1}) \tag{5}$$

$$Novelty(\zeta) = \frac{1}{m} log \frac{1}{\Pi(\zeta)} = \frac{1}{m}\left[log \frac{1}{P(s_1)} + \sum_{k=1}^{m-1} log \frac{1}{P(s_{k+1}|s_k)}\right] \tag{6}$$

3 Results

By examining the usage patterns of both the pc-set and the voicing of codewords, we investigate the composing style of Western classical composers. In the data set the total number of codewords is 1 230 441, and its unique number of pc-set and voicing set were 4 071 and 209 439, respectively. Note that we only include the codewords that consist of at least two notes. PC-set distribution is significantly skewed, which suggests that only a tiny portion of pc-set are employed for composition while the majority is rarely used (Fig. 3). The distribution of voicing is less skewed than that of the pc-set; the maximum frequency of voicing usage is less than 10^2 whereas the highest frequency of the pc-set is much more than 10^4. We decide to display the voicings of both {0,4,7} and {0,4,9} since they are the tonic chords of the normalized key and are included in the top five most often used pc-sets (Table. 1). The second column shows the top five voicings of pc-set {0,4,7} (i.e. {C,E,G}) and the third column shows the top five voicings of pc-set {0,4,9}, i.e. {C,E,A}.

Table 1. Top five frequently used pc-sets and voicings of two representative pc-sets.

Rank	PC-set	Voicing of {0,4,7}	Voicing of {0,4,9}
1	{0,4,7}	(4,3,5)	(0,4,5)
2	{0,4}	(0,4,3)	(9,3,4)
3	{0,4,9}	(7,5,4)	(4,5,3)
4	{0,7}	(0,7,9)	(9,3,4,5)
5	{4,7}	(0,4,3,5)	(9,7,8)

The heterogeneity in the use of pc-sets provides clues for interpreting the two novelties that we ultimately seek to analyze. Fig. 4 displays pc-set novelty and voicing novelty for composers, arranged chronologically based on the average years of birth and death. Composers like Couperin and Handel showed a high level of pc-set novelty

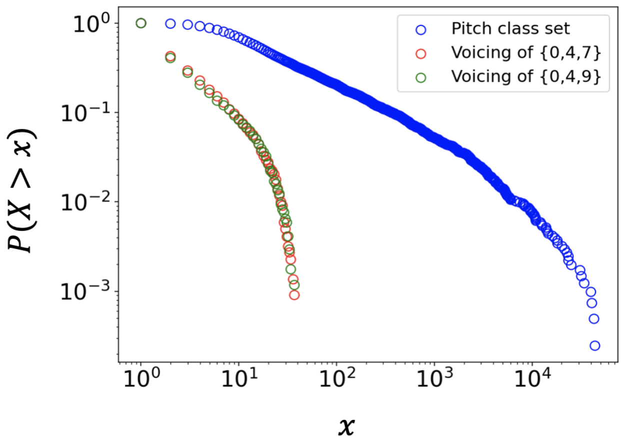

Fig. 3. The cumulative distribution on a log-log scale of the occurrences of pc-sets, voicing of {0,4,7}, and voicing of {0,4,9}. The frequency of pc-sets or voicing is represented on the horizontal axis, while the cumulative probability is represented on the vertical axis.

in their works due to the advantages of their time, and this remained consistent until later composers such as Elgar, Berg, Schoenberg, and Messiaen introduced new pc-sets, leading to greater variation. This figure agrees with Figure 1 (a) of Nakamura and Kaneko [9] which depicts the steadily increasing mean and standard deviation of tritone frequency, as tritone is one of the examples of historically important pc-sets. Similarly, increasing voicing novelty in later generations is a noticeable trend, with some prominent composers exemplifying it. When several new pc-sets are employed, the voicing novelty can rise only by virtue of the pc-set itself, or it can also increase if unique vertical arrangements are made using traditional pc-sets. These are the two scenarios where voicing novelty can be high. In order to identify the driving cause behind high voicing novelty, we computed the new pc-set ratio and new voicing ratio for each song. New pc-set ratio is the unique number of new pc-sets that were not used in the previous songs divided by the total unique number of pc-sets in a given song. It refers to the ratio of innovative pc-sets that the composer has chosen. New voicing ratio is the unique number of voicings for which the pc-set has already been used in previous songs but the present voicing is used for the first time in a given song, divided by the total unique number of voicings in a given song. The new voicing ratio serves as a metric to gauge the extent of reconfiguration undergone by existing pc-sets, as it specifically signifies the proportion of instances involving entirely novel voicings. According to Figure 4, while Handel exhibited the highest degree of pc-set novelty among all composers, benefiting from an early temporal advantage, Bach, despite sharing a similar advantage, displayed significantly lower pc-set novelty. This observation highlights Bach's propensity for predominantly composing using existing pc-sets. Composers such as Elgar, Berg, and Schoenberg, despite being situated in subsequent eras, stand out as instances where both the new pc-set ratio and new voicing ratio are elevated, resulting in pronounced levels of pc-set novelty and voicing novelty. With the exception of a few later composers who introduced a significant number of new pc-sets, the majority enhanced the novelty of chordal expressions by creatively reconfiguring existing pc-set tones. Brahms compared to Beethoven serve as an example. Despite using a smaller percentage of new pc-set than Beethoven, Brahms had a greater new voicing ratio than Beethoven, which resulted in a higher level of voicing novelty (Figure 4). In this way, through the comparison of the ratios and novelty values of new pc-sets and voicings in each composition, it becomes possible to explore how the chordal expression in Western classical piano music has evolved uniquely for each composer.

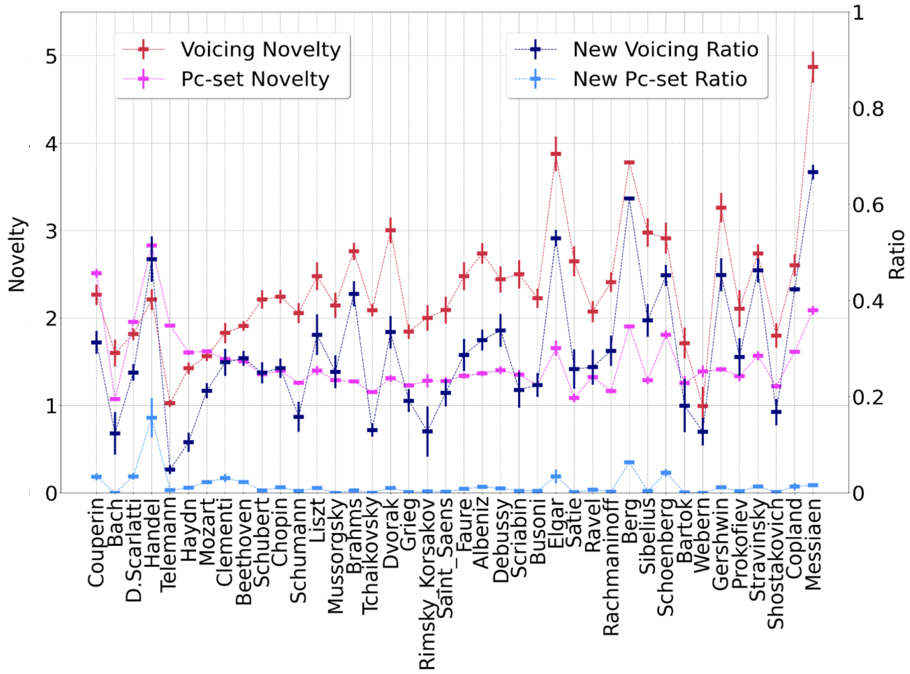

Fig. 4. Voicing and pc-set novelties in comparison to the new voicing ratio and new pc-set ratio.

4 Conclusion

In this paper, we studied the compositional style of Western classical piano pieces, with a particular focus on chord voicing – the vertical arrangement of notes within a set of pitch classes. Despite using the same set of pitch classes, altering the octave's location, the arrangement's sequence, or the distance between notes might result in a significantly different sound. We first encoded the voicing for each codeword, computed the voicing novelty, and then looked at the historical evolution of voicings to understand how composers chose and arranged notes. In Western classical piano music, voicing novelty exhibited a consistent upward trend over time, accompanied by an increasing divergence among composers. Early composers introduced a number of popular pc-sets that were widely used by later composers. Later composers mainly increased the novelty of the song by vertically arranging the pre-existing pc-set, with the exception of Elgar, Berg, and Schoenberg who used a sizable portion of novel pc-sets. Our examination of compositional trends among different composers reveals distinct patterns of novelty in their approach to chordal expression in Western classical piano music. As our study continues, we plan to explore the historical evolution of compositional style and how composers create their unique styles through influence scores of voicing, contributing to the understanding of musical styles at the note level using symbolic music data.

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