RHYTHMIC PATTERNS IN RAGTIME AND JAZZ

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ABSTRACT

This paper presents a corpus-based study on rhythmic patterns in ragtime and jazz. Ragtime and jazz are related genres, but there are open questions on what specifies the two genres. Earlier studies revealed that variations of a particular syncopation pattern, referred to as 121, are among the most frequently used patterns in ragtime music. Literature in musicology states that another pattern, clave, is often heard in jazz, particularly in songs composed before 1945. Using computational tools, this paper tests three hypotheses on the occurrence of 121 syncopation and clave patterns in ragtime and jazz. For this purpose, we introduce a new data set of 252 jazz MIDI files with annotated melody and metadata. We also use the RAG-collection, which consists of around 11000 ragtime MIDI files and metadata. Our analysis shows that syncopation patterns are significantly more frequent in the melody of ragtime pieces than in jazz. Clave on the other hand is found significantly more in jazz melodies than in ragtime. Our findings show that the frequencies of rhythmic patterns differ significantly between music genres, and thus can be used as a feature in automatic genre classification.

1. INTRODUCTION

Ragtime and jazz are two related genres, both often referred to as "syncopated music". However, one would not classify Scott Joplin's "The Entertainer" as jazz, neither would one call Miles Davis a ragtime composer. Yet it is difficult to pinpoint the differences between ragtime and jazz.

From musicological literature, there is evidence that both genres have some characteristic rhythmical patterns. One particular syncopation pattern is considered typical for ragtime (Berlin, 1980), while the clave pattern would be more typical for jazz music (Washburne, 1997). In this paper, we study these patterns by testing musicological hypotheses on data sets of ragtime and jazz music. For this purpose, we introduce JAGAD, a new data set with 252 MIDI files of jazz songs and annotated melody.

We analyze rhythmical patterns taking a corpus-based approach. A corpus-based study is a fast and data-rich way of analyzing rhythmical patterns in many MIDI files. Our research contributes to the fields of Musicology and Music Information Retrieval (MIR). The results can for example be used for automated genre classification, an important task in MIR: if the frequency of occurrences of rhythmical patterns differs significantly between two genres, then this could be used as a new musically meaningful feature, improving music genre classification.

This study builds on earlier research by Volk & de Haas (2013) and Koops et al. (2015). Both studies took a corpus-based approach investigating specific syncopation patterns in ragtime. Volk & de Haas (2013) tested hypotheses about the occurrence of different variations of the same syncopation pattern in ragtime during different periods of the ragtime era (1890 – 1919) and the modern period (1920 – 2012), using a data set of 11591 MIDI files of ragtime pieces. Koops et al. (2015) showed that this syncopation pattern is highly important for the ragtime genre, being among the most frequently used patterns compared to all other patterns.

Contribution. The contribution of the paper is twofold. First, we test and confirm musicological hypotheses about the occurrence of syncopation patterns and the clave pattern in ragtime and jazz melodies using a data-rich approach, thereby contributing to the fields of musicology and Music Information Retrieval (MIR). Second, we introduce JAGAD, a newly collected data set of 252 jazz songs with annotated melody. This data set is not only useful for our current study, but can also be of great use in additional analysis of the jazz genre or in future research on automated melody finding.

2. CHARACTERISTICS OF RAGTIME AND JAZZ

In this section we describe characteristics of ragtime and jazz, focusing on common rhythmical patterns of each genre according to musicology.

2.1 Ragtime

Ragtime was the first black music of the United States that achieved wide commercial popularity (Schaefer & Riedel, 1973). Berlin (1980) researches different theories as to what contributes to ragtime as a genre, such as coon-songs, cakewalk and two-steps. As a possible source of the ragtime rhythm, he mentions dance music of the Caribbean or South America, such as danzas, habaneras and tangos. Hendler (2010) mentions four musical forms that are related to ragtime. The main two roots of ragtime are the quadrille and march. A quadrille is a French contradance - Jelly Roll Morton claimed to have written the famous Tiger Rag from an old quadrille. The march and ragtime are similar in structure. The next related musical element is the cinquillo, which is a syncopated rhythm from the Caribbean. The fourth and last root of ragtime mentioned by Hendler are British popular melodies.

Nowadays, most people associate ragtime with piano music, as they know Scott Joplin's piano piece "The Entertainer", which has become widely known after it was used as film score for "The Sting". Contemporaries of the rag-

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time period perceived ragtime more as a vocal form. There also exist instrumental ragtime pieces, but piano pieces and vocal songs can be considered the two main instrumentation categories of ragtime (Berlin, 1980).

Berlin (1980) distinguishes three subgroups of piano ragtime: piano renditions of ragtime songs; "ragged" versions of preexisting unsyncopated music and original ragtime compositions. Piano renditions of ragtime songs were not always syncopated. In the second group, existing unsyncopated music, for example marches, popular songs, folk songs and pieces of classical music, was given a syncopated rhythm. But the lion's share of ragtime music comes under the third category: original ragtime compositions for piano. The best-known composers are Scott Joplin, James Scott and Joe Lamb.

In ragtime, the melody usually is the highest pitched line. In case of a piano piece, this is the right hand part of the piece. The accompaniment in the left hand is characterized by stable rhythmical patterns that follow the beat.

2.1.1 The 121 syncopation pattern

Musicologists and ragtime fans have argued that rhythmical patterns and syncopation provide the most distinct features of the ragtime genre. A specific syncopation pattern that is considered important in ragtime by Berlin (1980) is 'short-long-short' or 121 syncopation. The 121 pattern appears as ♪♩♪ in 4/4 meter or as ♫♬ in 2/4 meter.

Berlin (1980) distinguishes three variants of 121 syncopation in ragtime. The two types that emerge as most important, are untied and tied syncopation. In **untied** syncopation, a pattern does not pass over a bar line and starts on a strong metrical position. In 2/4 meter, the pattern starts either on the first or on the second quarter note position. In 4/4 meter, the pattern starts on the first or third quarter note position. **Tied** syncopation refers to a pattern starting on a weak metrical position. That is, in 2/4 meter it starts at the second or fourth eighth note position and in 4/4 meter it starts at the second or fourth quarter note position. This way, tied syncopation either connects the two halves of a measure, or it connects the second half of a measure to the first half of the next measure. The third pattern is **augmented** syncopation and differs from the other two as it augments the 121 to the length of a complete bar. Figure 1 illustrates these patterns, here in 4/4 meter. On the right of the figure, the patterns are notated in the "onset representation". This is a string with four entries per quarter note. This means that each sixteenth note is represented by one character. If a sixteenth note has an onset, i.e. the start of a note, then the corresponding character is a one. On the other hand, if the sixteenth note has no onset, then the corresponding character is a zero. The dot is a wild-card that matches anything. We use this representation to find patterns in the preprocessed MIDI-files.

2.2 Jazz

The origins of jazz form a contentious subject among musicians, critics and academics. The general belief is that jazz harmonies are based on European practices and that jazz

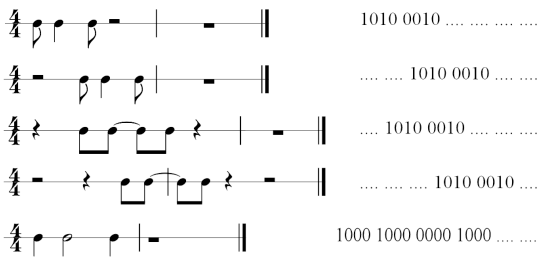

Figure 1: Syncopation patterns. From top to bottom: two variants of untied syncopation, two variants of tied syncopation, augmented syncopation

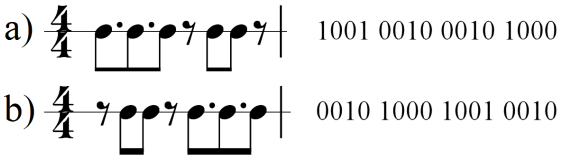

Figure 2: Clave patterns: forward (a) and reverse (b)

rhythm came from Africa. However, Washburne (1997) and Hendler (2005) throw light on the Caribbean contribution to jazz. The Caribbean influences on jazz are particularly well audible by the rhythm patterns, as we will see in Section 2.2.1.

Just like ragtime, jazz can be played on a piano. However, it is also commonly played by a jazz ensemble, for example a jazz trio or a bigband.

In contrast to ragtime, it is not always the upper voice that has the melody. For example, the string bass began to be used as a solo instrument, generally from the 1940s on (Kemfeld, 1995).

2.2.1 Clave pattern

In his study of the Caribbean contribution to the genre, Washburne (1997) claims that the clave rhythm is often heard in jazz. This rhythm consists of a syncopated and an unsyncopated part. There are two directions: in forward (or 3-2) clave the syncopated part comes before the unsyncopated part; in reverse (or 2-3) clave it is the other way around. The prototypical patterns of forward and reverse clave are illustrated in Figure 2a and Figure 2b respectively. However, a lot of variations on this pattern are considered as clave. Though Washburne (1997) provides some guidelines, it is not evident to determine if a music phrase or bar is in clave - even for trained listeners.

For this reason,Vurkaç (2012) analyzed the clave and from his research, a new data set was developed, which can be downloaded from the UCI learning repository (Lichman, 2013) [1] . This data set contains 10800 bars in onset notation. Each bar has a label of four bits, indicating the clave direction. 0 0 1 0 and 0 1 0 0 are the clave directions forward and reverse, respectively. The neutral category, labeled 1 0 0 0, refers to patterns that do not detract

[1] https://archive.ics.uci.edu/ml/datasets/Firm-Teacher_Clave-Direction_Classification

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Bar onsets	Label	Type
1 1 1 1 0 1 1 1 0 1 1 0 0 1 1 1	**0 0 0 1**	Incoherent
1 1 1 1 0 1 1 1 0 1 1 0 0 1 0 1	**0 0 0 1**	
1 1 0 0 0 1 1 0 0 1 1 0 0 0 1 1	**0 0 0 1**	
1 0 0 1 0 0 1 0 0 0 1 0 1 0 0 1	**0 0 1 0**	Forward
1 0 0 1 0 0 1 0 0 0 1 0 1 0 0 0	**0 0 1 0**	
1 1 1 1 1 0 0 0 1 0 1 0 1 1 1 1	**0 0 1 0**	
0 0 1 0 1 0 0 0 1 0 0 1 0 0 1 0	**0 1 0 0**	Reverse
1 1 1 0 1 0 0 1 1 1 1 1 1 0 1 1	**0 1 0 0**	
0 0 1 0 0 1 1 1 0 1 0 1 0 0 0 1	**0 1 0 0**	
0 1 1 0 0 0 1 0 0 0 0 1 0 0 1 0	**1 0 0 0**	Neutral
0 0 0 1 0 1 1 1 1 1 1 1 1 0 0 1 1	**1 0 0 0**	
0 0 0 1 1 1 1 1 0 0 0 1 0 0 0 1	**1 0 0 0**	

Table 1: Examples from the UCI clave direction data set

from clave, but do not establish or support any clave direction either. The incoherent category (0 0 0 1) refers to patterns that, in addition to not being in either clave direction, actively oppose the establishment of such. Vurkaç determined these categories based on both double-blind listening tests and informal interviews with four professional master-musicians, as well as decades of studying the music. Table 1 shows three examples per class of the data set. Note that the data set does not give a label for all possible onset combinations: $2^{16} = 65536 > 10800$.

Washburne (1997) points out that the clave pattern is found in several aspects of jazz music: (1) in the rhythmic breaks, for example just before a solo section; (2) in the accompaniment by the rhythm section; (3) in repetitive horn backgrounds or riffs; (4) **in the melody**; and (5) in the phrasing. In this paper, we investigate the occurrence of the clave pattern in the melody of jazz and ragtime pieces.

From his search for samples throughout jazz history, Washburne (1997) observed that some styles incorporate the clave rhythm to a greater extent than others. The pattern is found more often in early jazz (until 1945) than in later styles.

3. A CORPUS BASED STUDY ON RHYTHM PATTERNS IN RAGTIME AND JAZZ

From the characteristics of ragtime and jazz, as described in the previous chapter, three hypotheses about rhythmic patterns in the melodies of ragtime and jazz songs arise.

First, we have seen that tied, untied and augmented 121 syncopation patterns occur frequently in the melody of ragtime songs. We suppose that this is typical for ragtime. That leads to the first hypothesis:

Hypothesis 1 *Tied, untied and augmented 121 syncopation patterns occur more frequently in the melody of ragtime songs than in the melody of jazz songs.*

The second hypothesis is based on the observation by Washburne (1997) that it is easier to find examples in the clave pattern in jazz before 1945 than in jazz of later periods. We wonder if this applies to the frequency of the pattern in the melody too. So the next hypothesis is:

Hypothesis 2 *The clave pattern occurs more frequently in the melody of early jazz pieces (before 1945) than in the melody of later jazz pieces (after 1945).*

In our literature study, we have seen that Caribbean rhythm patterns have influenced both ragtime and jazz. However, we encountered the clave pattern particularly in literature about jazz, and to a lesser degree in books on ragtime. We therefore presume that the clave is more typical for jazz. This leads to our third and final hypothesis:

Hypothesis 3 *The clave pattern occurs more frequently in the melody of jazz pieces than in the melody of ragtime pieces.*

We take a corpus-based approach to test our hypotheses. To this end, we collect two data sets: one with ragtime and one with jazz pieces. Our preprocessing step results in a collection of labeled onsets of 240 jazz and 2579 ragtime songs. The next step is pattern recognition, in which our algorithm calculates for each pattern the proportion of bars in which this pattern occurs. The remainder of this section explains these steps in detail.

3.1 Data set collection

The ragtime data set is a subset of the RAG-collection, as introduced before by Volk & de Haas (2013) and Koops et al. (2015). The complete collection contains 11591 MIDI files of ragtime music. Metadata is added to this data set using a ragtime compendium, consisting of around 15000 ragtime compositions.

Since there were no comparable data sets available for jazz music, we collected a new data set, called JAGAD (Jazz stAndard Gioia Annotated Data set). It should be a collection of songs that is representative for the jazz genre, and of a suitable size: it should consist of sufficient songs to test the significance of aforementioned hypotheses.

The Jazz Standards by Ted Gioia (Gioia, 2012) is a comprehensive guide that lists 252 important jazz compositions. For our data set, we extracted relevant metadata from all songs in this book: the title, composer, lyricist (if applicable) and year of first publication. Subsequently, we located the MIDI files through an extensive web search. As there exist many websites of jazz MIDI files, we were able to find a suitable MIDI for each song. The files have various instrumentations: for example jazz trio, solo piano or big band. In all cases, we chose MIDI's where the melody is clear in at least one channel.

As a next step, the MIDI data has to be prepared for the pattern recognition step. Data preparation consists of melody finding, quantization and filtering of relevant songs.

3.2 Melody finding

Melody finding of the ragtime data set is done automatically, using the skyline algorithm with dip detection, as described by Volk & de Haas (2013). This algorithm takes the highest sounding note when multiple notes sound simultaneously. To overcome that the highest notes from the accompaniment are classified incorrectly as part of the

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melody at sections where there is no melody, their algorithm sets a lower limit: all notes below the middle C are classified as accompaniment. Also, after performing the skyline algorithm, notes that are characterized by an interval down greater than 9 semitones followed by an interval up greater than 9 semitones are removed. Despite its simplicity, this algorithm works very well for the ragtime genre: evaluating this algorithm on a 435-piece subset of the RAG-collection yields an F-measure of 0.978.

The skyline algorithm is based on the assumption that the melody is (almost) always in the higher-pitched notes. As this is not always the case in jazz (for example in a baritone saxophone solo), the skyline algorithm is unsuitable for extracting the melody in jazz songs. There are no other melody extraction algorithms of which a comparably high accuracy on jazz songs is known. That is why we annotate the melody of the jazz data set by hand. To this end, we use the MuseScore [2] software, which makes it possible to listen to the music and examine a score, generated by the program, at the same time. For each MIDI file, we store the first and last bar number of the melody in a certain channel. This way one or more tuples (barStart, barEnd, channelNr) are associated with each MIDI file. In the following, we only consider the notes that are at that moment part of a melody channel.

The resulting melodies are not always monophonic, so in the "melody channel" it is still possible that two or more notes sound together. In order to extract the rhythm, the melody channel has to be reduced to a monophonic line. For this purpose, we apply the skyline algorithm (introduced as "all mono" by Uitdenbogerd & Zobel (1999)) to the melody notes.

3.3 Quantization

The next step is quantization. A MIDI file consists of note on and note off messages, each starting at a certain time after the previous message. To be able to perform the pattern finding step, we need to translate MIDI timing information into a sixteenth note grid. Our algorithm extracts the note on messages, which correspond to the onset of the note, and quantizes using four bins per quarter note: each onset is assigned to the nearest sixteenth note, as described by Koops et al. (2015). This way, a piece in 4/4 time is represented as a list of 16-character onset strings.

3.4 Filtering relevant songs

Finally, only the relevant songs, that can be matched to the 121 syncopation and clave patterns, are filtered.

In earlier work by Volk & de Haas (2013) and Koops et al. (2015), ragtime songs in 2/2, 2/4 and 2/2 are selected, which have only one meter and start at MIDI tick 0. Furthermore, only rags with a normalized average quantization error up to and including 2% of the corpus are selected. This preprocessing step leads to a list of onsets of 2579 rags.

[2] https://musescore.org/

For the jazz data set, we exclude songs that are not in 4/4 time. This is the case for 12 of the 252 jazz pieces. Omitting these pieces, we have our final preprocessed dataset of onsets of 240 jazz songs.

3.5 Pattern recognition

After creating and preprocessing the data sets, we proceed to the next step: pattern finding, in which we calculate the proportion of bars in which syncopated 121 patterns and the clave patterns appear.

For the tied, untied and augmented 121 syncopation patterns, pattern recognition is straightforward: our algorithm matches each bar (and the first half of the next bar) to each of the patterns and keeps up counters for each of the three 121 syncopation patterns. Then, the results are averaged by dividing each counter by the number of bars of the song.

For matching the clave pattern, a bit more work needs to be done. We use the UCI data set mentioned in Section 2.2.1. For each song, our algorithm counts the number of bars that are in the UCI data set (nrSpecified) and the number of bars that are labeled as forward (nrForward) and reverse (nrReverse) clave. For each song, three real values are calculated, indicating the amount of clave:

$$\text{claveForward} = \frac{\text{nrForward}}{\text{nrSpecified}} \quad (1)$$

$$\text{claveReverse} = \frac{\text{nrReverse}}{\text{nrSpecified}} \quad (2)$$

$$\text{maxClave} = \max(\text{ClaveForward}, \text{ClaveReverse}) \quad (3)$$

4. RESULTS

Having computed the proportion of each pattern per piece, we can now statistically test the three hypotheses introduced in Section 3.

4.1 121 syncopation patterns - ragtime versus jazz

To compare 121 syncopation patterns in the melody of ragtime and jazz music, we analyze ragtime and jazz separately. Table 2 shows the average and median of the proportions of bars in which each variation of the 121 syncopation pattern occurs in ragtime and jazz. In the ragtime data set, on average 15% of the bars contain a tied pattern; in the jazz data set, this is only 1.2%. For the untied patterns, the difference is only a bit smaller: 12% in ragtime as opposed to just 1.5% in jazz. The augmented pattern is not seen very often in the ragtime part (4.0%), but even less in the jazz part: 0.3%.

Note that the syncopation patterns occur so little in jazz that all median values are zero. Figure 3 is a box plot that compares the syncopated patterns in ragtime (blue) and jazz (black).

The jazz and ragtime dataset are very different in size. Therefore, to test the statistical significance of the difference in 121 patterns in the ragtime and jazz dataset, we perform bootstrapping for each of the three 121 syncopation patterns. We compare the 240 jazz pieces with 240 uniformly randomly sampled ragtime pieces, and repeat this

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		Tied	Untied	Augmented
Ragtime	Average	0.1497	0.1197	0.0398
Jazz	Average	0.0123	0.0153	0.0030
Ragtime	Median	0.0842	0.0828	0
Jazz	Median	0	0	0

Table 2: Syncopation patterns in ragtime and jazz: average and median of the proportion of bars with the respective pattern, over all songs of the genre.

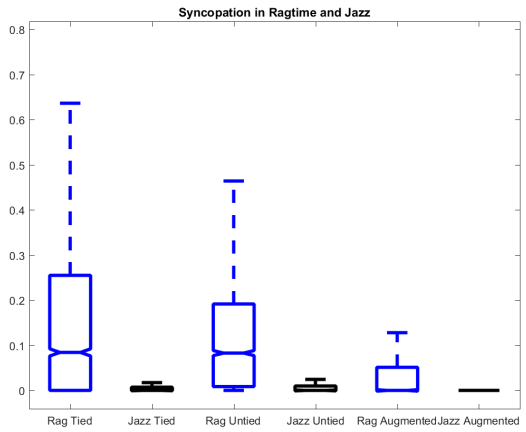

Figure 3: Syncopation in ragtime and jazz

process ten times. Testing for significance using Wilcoxon rank-sum tests for each 121 syncopation pattern, we find a significant difference with $p \ll 0.01$ for every random sample. Therefore, we can conclude that all three 121 syncopation patterns occur significantly more frequently in the melody of ragtime than in jazz pieces, so we accept Hypothesis 1.

4.2 Clave pattern - early versus late jazz

In order to test if the clave pattern occurs more frequently in the melody of early jazz pieces than in the melody of later jazz pieces (Hypothesis 2), we divide the jazz data set into early (year < 1945) and late (year ≥ 1945) jazz. Our data set consists of 148 early jazz pieces and 92 songs of late jazz. We examine the differences between early and late jazz in the proportion of forward clave, reverse clave and the maximum of both directions.

From the results plotted in Figure 4, we see clearly that there is no difference in the use of the clave pattern in the melody of jazz before and after 1945. Forward clave seems to occur a bit more often in early jazz (blue) while reverse clave occurs a bit more frequent in late jazz (black). When we look at the maximum of both directions, the percentage of clave bars is even very similar.

To test for significant differences, we use bootstrapping for each of the three clave pattern variants. We compare the 92 late jazz pieces to a uniform random sample of 92 early jazz pieces. Performing in total 30 Wilcoxon rank-sum tests (for each clave variation and for each random sample) reveals that the differences are not significant: $p >$

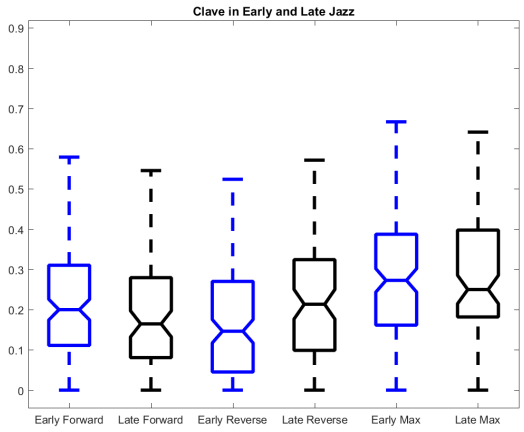

Figure 4: Clave pattern in early (before 1945) and late (from 1945) jazz

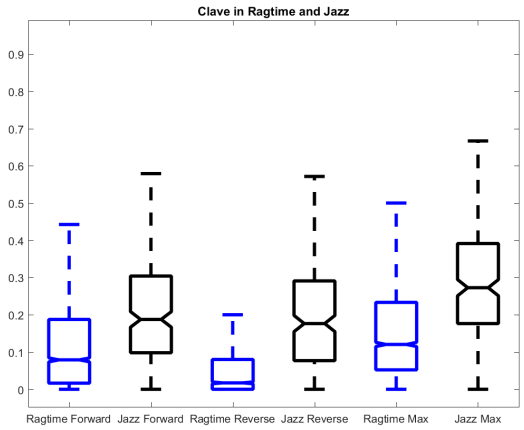

Figure 5: Clave pattern in ragtime and jazz

0.05 for all samples.

To conclude, our hypothesis that the clave pattern is more used in early jazz than in late jazz seems not to be acceptable when examining just the melody. We find this outcome somewhat surprising, as it does not correspond to earlier observations by Washburne (1997).

4.3 Clave pattern - ragtime versus jazz

For our final hypothesis, we compare our ragtime to our jazz data set. In Figure 5 we see clearly that all clave pattern directions occur more in jazz than in ragtime. This difference is most obvious when looking at the maximum of both directions: in ragtime, on average 16% of the bars has the largest clave direction; for jazz, this is as much as 29%. Again, we perform bootstrapping and compare the 240 jazz pieces to a uniform random sample of 240 ragtime pieces using Wilcoxon rank-sum tests. We can conclude that these differences are highly significant with $p \ll 0.01$ for all 30 samples. So we accept Hypothesis 3: the clave pattern occurs more frequently in the melody of jazz pieces

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than in the melody of ragtime pieces.

5. DISCUSSION AND CONCLUSION

In this paper, we investigated the occurrence of several rhythm patterns of ragtime and jazz melodies. We performed a corpus-based study, using computational tools, contributing to the fields of musicology and Music Information Retrieval. As part of our research, we introduced JAGAD, a new data set of 252 jazz MIDI files with annotated melody.

Based on literature research in musicology, we formulated three hypotheses. After performing our corpus-based study, we accepted two hypotheses and rejected a third. The tied, untied and augmented 121 syncopation patterns, as mentioned by Berlin (1980), occur significantly more in ragtime than in jazz. Clave patterns on the other hand occur more frequently in jazz than in ragtime. These outcomes can be used in an automated genre classifier by adding features for the frequencies of syncopation and/or clave patterns: songs with many syncopation patterns are more likely to be ragtime, while songs with many clave patterns are more likely to be jazz. Our last hypothesis, which states that clave patterns are more frequent in early jazz than in late jazz, could not be confirmed.

This research is a next step in the study of typical rhythmic patterns in ragtime and jazz. To investigate if tied and untied syncopation patterns and the clave pattern are truly characteristic for ragtime and jazz respectively, more research on the frequency of these patterns in other genres is needed.

Finally, it would be interesting to examine the frequency of the clave pattern in jazz in other aspects than just the melody. This pattern may occur more often in for example the rhythm or brass section. It is possible that we find a bigger difference between early and late jazz here, which would be in favor of Washburnes hypotheses.

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