Applying Inner Metric Analysis to 20th century compositions

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Abstract

With this paper we contribute to the Workshop on Computational Music Analysis applying *Inner Metric Analysis* to 20th century pieces. Inner Metric Analysis assigns to each note of a piece a metric weight. The analysis is based on the detection of regular pulses created by the onsets of notes. Metrical strict pieces, such as Renaissance madrigals or ragtimes, often lead to metrical profiles that correspond to the accent schema of the notated bar lines. Hence these pieces are characterized as being *metric coherent* since the notes generate a metrical structure that is in sink with the abstract grid of the bar lines (see (2)). Compositions of the 20th century very often do not follow such a strict metricity. The metric profiles therefore give interesting insights into the time organization of these pieces far beyond the notated bar lines. We will also apply the processive approach to the proposed pieces (Volk 2005) in order to study how the metric structure evolves over time while listening to the music.

1 Inner Metric Analysis

With this paper we contribute analyses of Skrjabin's Op. 65 No. 3, Webern's op. 27 and Xenakis' *Keren* to the Workshop on Computational Music Analysis. We use *Inner Metric Analysis* (IMA) in order to describe the metric-rhythmic structure of these pieces. IMA describes the *inner* metric structure of a piece of music generated by the actual notes *inside* the bars as opposed to the *outer* metric structure associated with a given abstract grid such as the bar lines. The method is based on metric weight profiles generated for all notes. The underlying principle is the detection of regular pulses created by the onsets of notes.

The details of the model have been described in (2) or (1). The general idea is to search for all pulses (chains of equally spaced events) of a given piece and then to assign a *metric weight* to each note. The pulses are chains of equally spaced onsets of the notes of the piece called *local meters*. Let On denote the set of all onsets of notes in a given piece. We consider every subset $m \subset On$ of equally spaced onsets as a local meter if it contains at least three onsets and is not a subset of any other subset of equally spaced onsets. Let k denote the number of onsets a local meter consists of minus 1. Hence k counts the number of repetition of the period (distance between consecutive onsets of the local meter) within the local meter. The metric weight of an onset is then calculated as the weighted sum of the length k of all local meters m_k that coincide at this onset.

Let $M(\ell)$ be the set of all local meters of the piece of length at least ℓ. The general metric weight of an onset, $o \in On$, is as follows:

$$W_{\ell,p}(o) = \sum_{\{m \in M(\ell): o \in m_k\}} k^p. \tag{1}$$

A further refinement of the metric weight is the calculation of the spectral weight (see (6)) which is based on the extension of the local meters throughout the entire piece, denoted as $ext(m_{s,d,k}) = \{s + id, \forall i\}$. Each local meter $m_{s,d,k}$ contributes to the spectral weights of the events t in its extension $t \in ext(m_{s,d,k})$. The spectral weight is defined as:

$$SW_{\ell,p}(t) = \sum_{\{m \in M(\ell): t \in ext(m)\}} k^p. \tag{2}$$

The spectral weight reflects the most dominant metric characteristic of a piece because it ignores local changes and is in most cases very stable throughout the entire piece. In contrast to this the metric weight is sensitive to local changes in the metric structure of a piece. For the analyses in this paper we have chosen $\ell = p = 2$.

2 Analytic Results

2.1 Skrjabin's op. 65 No. 3

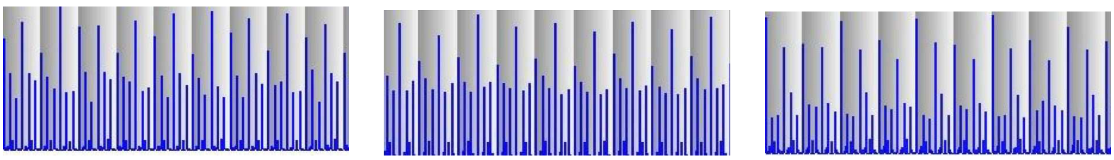

Figure 1: Excerpt from the analysis of the entire piece showing bars 1-16: spectral weights for both hands (left picture), right hand (middle picture) and left hand (right picture). The higher the line, the greater the corresponding weight. The background gives the location of the bar lines.

Skrjabin's op. 65 No. 3 is notated as 2/4. However, in many parts of the piece either the left or the right hand performs a continuous movement in eighth note triplets. Therefore the layers of the spectral weight profiles in figure 1 show a subdivision of the two main beats into three eighth notes each with great weights on the first and second quarter notes of the bars and lower weights on the second, third, fifth and sixth eighth notes of the bars. The spectral weight of both hands (left most picture in figure 1) shows that in almost each bar the second beat has an even greater weight than the first beat. The spectral weight of the right hand (middle picture in figure 1) makes this distinction between the layers of the second and first beats even more obvious. In the spectral weight of the left hand (right picture in figure 1) the relation of the first and second beat alters every bar indicating a grouping into two bars. In every second bar the first beat gains the greater weight, while in the other bars the weights tend to fall on a nearly equal level.

The excerpts of the metric weights of the entire piece in figure 2 make this difference in the metric structures of the right and left hand more explicit. The metric weight of the left hand exhibits clearly a grouping into two bars with greater weights on the first beat of every other bar. The right hand distinguishes only two layers: the weights of the second bar form the highest layer, all other weights form the second layer. Hence the left hand is characterized by a metric structure that is in sink with the typical accent schema of a 2/4, while the right hand has a strong accent on the second beat. Skrjabin's etude hence follows the tendency often observed in analyses of piano music, that the left hand is responsible for creating a stable metric that corresponds to the notated time signature structure while the right hand has more freedom.

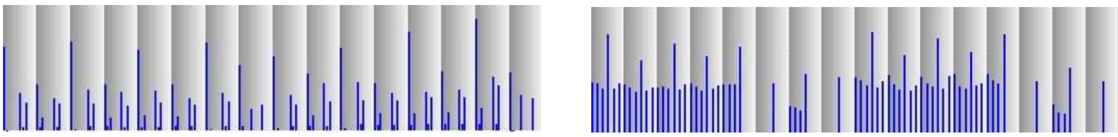

Figure 2: Excerpts from the metric weights of the entire piece for the left hand (left) and the right hand (right)

2.2 Webern's Op. 27, 2nd movement

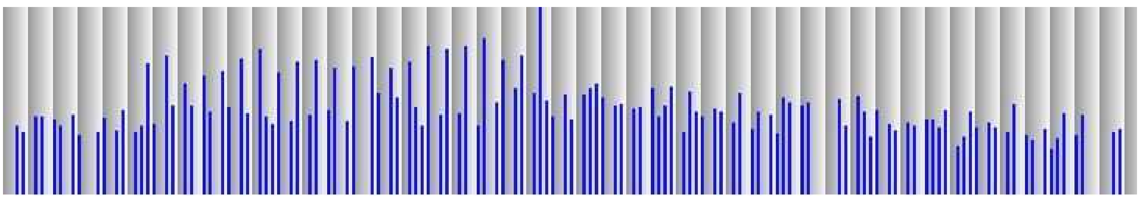

Figure 3: Metric weights for both hands

Davin Lewin argues in (4) and (3) that this piece notated in 2/4 is easier to be perceived as 3/8. The metric weight of the piece shown in figure 3 confirms that the notes do not generate weight layers that correspond to the typical accent structure of a 2/4. On the other hand, the interpretation of the same weight as 3/8 (see figure 4) reveals within the first part of the piece weight layers that confirm Lewin's observation. Every first beat of these bars gains a greater weight.

The processive approach according to (8) that models the unfolding of metric hierarchy over time while listening to the piece reveals another interesting aspect that is hidden in the analysis of the entire piece discussed so far. Figure 5 shows three excerpts of the processive approach. The top picture shows a periodicity in the weight layers such that every second beat in the 3/8 bars gains the greatest metric weight. This structure is later on reinterpreted: the middle and bottom

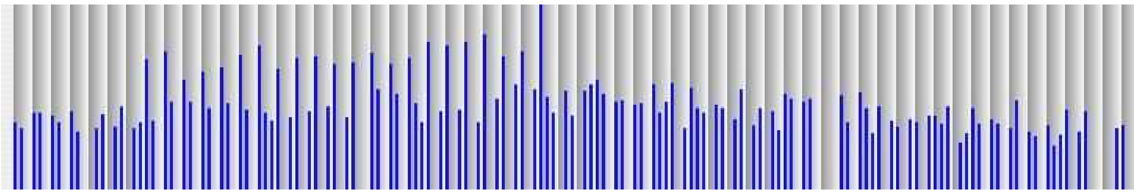

Figure 4: Metric weights for both hands, interpreted as 3/8

pictures in figure 5 show that the new incoming notes change the metric interpretation towards a great metric weight on the *first* beats of all bars, gradually reinterpreting the events of the past with great accents on the *second* beat.

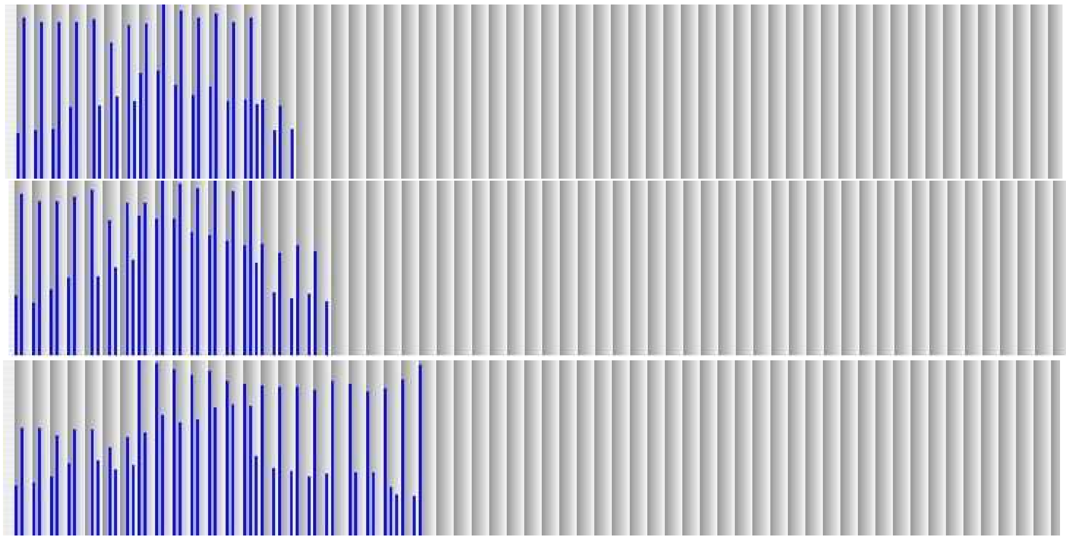

Figure 5: Processive approach to Webern's Op. 27

In contrast to Skrjabin's etude, the inner metric structure of this piano variation by Webern does not show any correspondence with the typical weight layers of the notated 2/4 bar. In the first half of the piece the weight layers correspond to a 3/8, while the second half does not exhibit any weight layers.

2.3 Xenakis' Keren

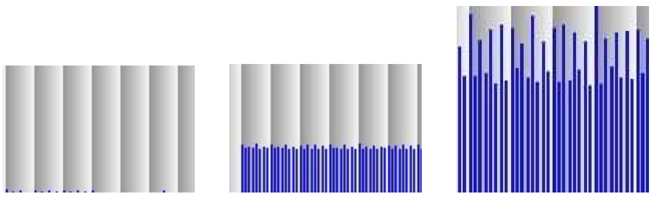

Figure 6: Excerpts from metric weight of the entire piece (left: bars 4ff, middle: bars 24ff, tight bars 37ff)

Xenakis' *Keren*[1] consists of segments of very different onset density. For instance, bars 23-28 and bars 35-42 contain a continuous chain of 32nd notes. Hence they form two very long local meters with respective great metric weights on these notes. The other areas in the piece do not contain such long local meters and have therefore in contrast to this very low metric weights. Figure 6 shows excerpts from these different areas with extremely different weights.

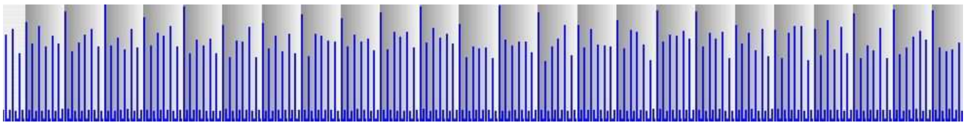

Figure 7: Excerpt from spectral weight of bars 1-23, interpreted as 6/16

In order to avoid the influence of the local meters in bars 23-28 and bars 35-42 on the entire piece we analyze the sections of bars 1-23 and bars 43-63 separately.

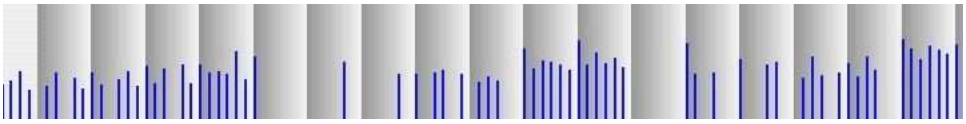

Figure 8: Excerpt starting bar 1 from metric weight of bars 1-23, interpreted as 6/16

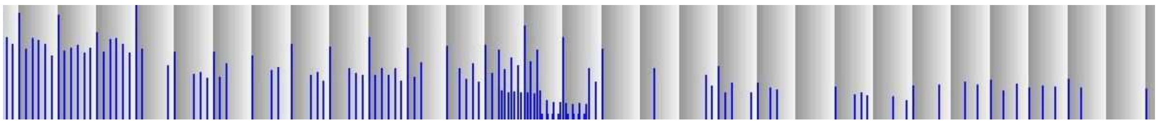

Figure 9: Excerpt starting bar 12 from metric weight of bars 1-23, interpreted as 6/16

The spectral weight of bars 1-23 in figure 7 is characterized by a weak periodicity: slightly greater weights are located on every sixth sixteenth note.

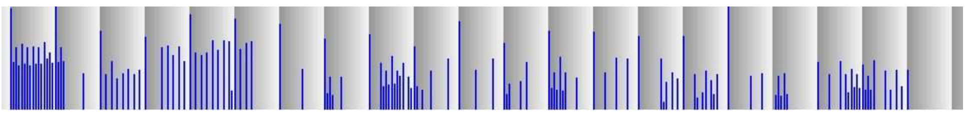

Figure 10: Metric weight bars 43-63

The metric weights of the bars 1-23 make clear that the regularity in the spectral weight derives from the influence of bars 12 and following. The metric weight within the bars 1-11 (figure 8) shows hardly any periodicity, while the metric weight within the bars 12-23 (figure 9) shows a greater metric weight on every sixth sixteenth note.

[1] I would like to thank Chris Share (Sonic Arts Research Centre at Queen's University Belfast) for encoding this piece.

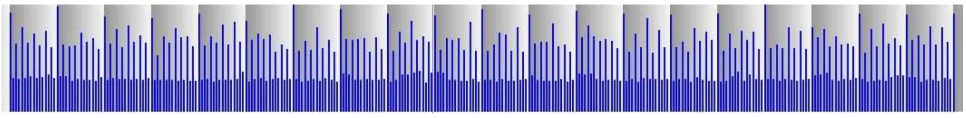

Figure 11: Spectral weight bars 43-63

On the other hand, the weights of the segment of bars 43-63 does show a regular pattern (see figures 10 and 11) that is even in sink with the notated bar lines: the first beat in each bar gains the greatest metric weight. However, the typical great weights on the second beats of the notated 4/4 bar is missing. Hence, the bar lines in this piece might serve more as a help for orientation for the performer than as an information about the metricity of this piece. Nevertheless at least in the last bars there is surprisingly a correspondence between the metric structure expressed by the notes and the bar lines.

2.4 Comparison of the results

The comparison between the analytic results of the pieces by Skrjabin, Webern and Xenakis shows that Skrjabin's etude is metrically the most strict piece. In the first segment also Webern's piece exhibits weight layers, but they are not in sink with the bar lines. This leads to the question, whether Webern intentionally created a conflict between the notated 2/4 and the intended 3/8 (for arguments in favour of the 2/4 see (3)). Xenakis' piece shows the least weight layers indicating that this piece performs a considerable freedom from any strict metrical schema.

References

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