MODELING A PROCESSIVE PERSPECTIVE ON METER IN MUSIC

Anja Volk
University of Southern California
Integrated Media Systems Center

ABSTRACT

This paper aims at the description of the metric structure of music in terms of a processive or temporal approach. While many models in the metric domain assume a relatively consistent metric structure throughout the piece, the experience of listening to a complex piece of music often differs from that assumption. The processive approach applied in this paper is interpreted as the unfolding of the metric hierarchy over time while listening to the piece. We base our investigations on the model of Inner Metric Analysis that describes the metrical hierarchy of a piece of music independently of the bar lines. Using the cumulative and sliding window approaches that characterize the metric process through the piece we can distinguish between stable succession of events and abrupt or gradual changes that can serve as a description of the dynamic process taking place while listening to the music.

1. INTRODUCTION

The metric structure of a piece of music is often assumed to be stable throughout the entire piece. This assumption is appropriate for some musical genres (such as dance music) but wrong for others. For instance, Brahms' compositions are well-known for very complex metric processes that are characterized by significant changes and disruptions within the metrical flow (see [5]). In this paper we address this question of how a piece might smoothly or abruptly change from one metrical state to another by following Hasty's idea of a processive approach to rhythm and meter between the poles of persistence and change (see [3]).

In order to model this processive approach we apply the model of Inner Metric Analysis based on MIDI which has been proven to be sensitive to subtle changes in the metric structure of music. The model has been applied to complex musical pieces, such as symphonies or choral music and has been successfully tested in listening experiments (see [2] and [5]) as well as for classification tasks (see [1]).

2. INNER METRIC ANALYSIS

2.1. The concept

Inner metric analysis (see [4], [2]) 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 model assigns a metric accent to each note of the piece. One example of such an accent pattern in Figure 1 shows the result of an analysis of the soprano part of Thomas Morley's Madrigal *Sing we and chant it* (time signature 3/4). [1] For each note a line depicts the accent (metric weight) such that the higher the line, the higher the corresponding weight. The background gives the bar lines for orientation. The typical metric hierarchy associated with a 3/4 time signature is clearly reflected by the metric layers evoked by the notes of this piece (first beat of all bars form highest layer, followed by the second and third beats, weak eighth notes form lowest layer). In [2] such a relationship between inner and outer metric structure has been characterized as *metric coherence*.

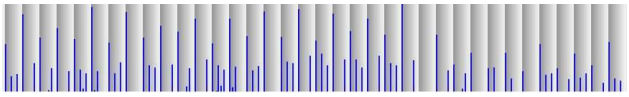

Figure 1. Metric analysis of Thomas Morley's Madrigal: *Sing we and chant it* (soprano part)

Another example in Figure 2 shows the analysis of the right hand part [2] of Scott Joplin's *Nonpareil Rag* (time signature 2/4). Despite the many syncopations, great accents are assigned to the beginnings of all bars. On the other hand the syncopation prevents great accents on the second beat of all bars, as would be typical for a 2/4 bar.

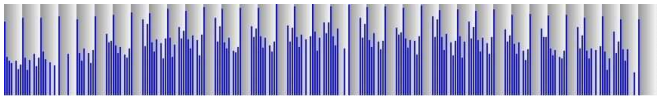

Figure 2. Metric analysis of the right hand part of Joplin's *Nonpareil Rag*

The accent pattern of the first section of the third movement of Haydn's Sonata Op. 39 in 3/4 in Figure 3 gives an example that is not characterized by the typical metric layers of the 3/4 such as Morley's madrigal. Section 3.3 will give details as to why these metric layers are not generated in this case.

These examples show the sensitivity of the model towards the metric structure generated by the notes that may correspond to or differ from the normative metric state given by the bar lines. The Haydn example points to complex metrical structures where the different layers do not

[1] The figure shows an excerpt for the beginning.
[2] We have chosen an excerpt from the beginning of the piece.

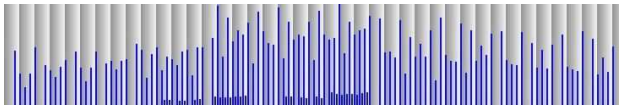

Figure 3. Metric analysis of Joseph Haydn's Sonata Op. 39, 3. mvmt., bars 1-40

line up nicely with the bar lines and prevent metric coherence as can often be found in the music by Brahms, Bach or Stravinsky.

2.2. The calculation of the metric weights

The details of the model have been described in [2], [5] or [1], we will give in this section just a short overview. The general idea behind the model is the search for all pulses (chains of equally spaced events) of a given piece and the assigning of 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 of 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. The metric weight of an onset is calculated as the weighted sum of the length k of all local meters m_k that coincide at this onset, where k denotes the number of onsets the local meter consists of minus 1.

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:

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

The parameters p and ℓ in equation 1 have been chosen in all examples of this paper equal to 2.

3. THE PROCESSIVE APPROACH

3.1. Stability of the metrical state over the course of the piece

The metric weights displayed in Figures 1 and 2 give examples of stable metric hierarchies of the entire piece, since the metric layers do not change. The last bars in Figure 1 mark a subtle local change when all weights drop to a lower level.

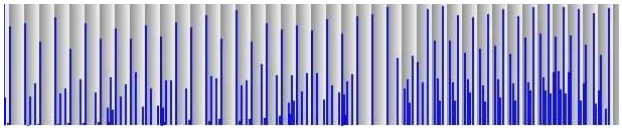

Figure 4. Metric weight of the melody in the first 54 bars in Brahms' Third Symphony, 3. mvmt

However, such a stability is not always the case. The inner metric structure shifts dynamically to changes according to the inner grouping of the notes. An example of such a shift is given in Figure 4 that displays the metric weight of the melody in the first 54 bars in the third movement of Brahms' Third Symphony (time signature 3/8). The highest layer is located in the beginning of the piece on the first beat of the bars, but shifts towards the last beat of the bars in the second half of the picture. This shift reflects a change in the grouping towards a repetitive syncopation, where the last eighth note of each bar is tied to the first note of the following bar.

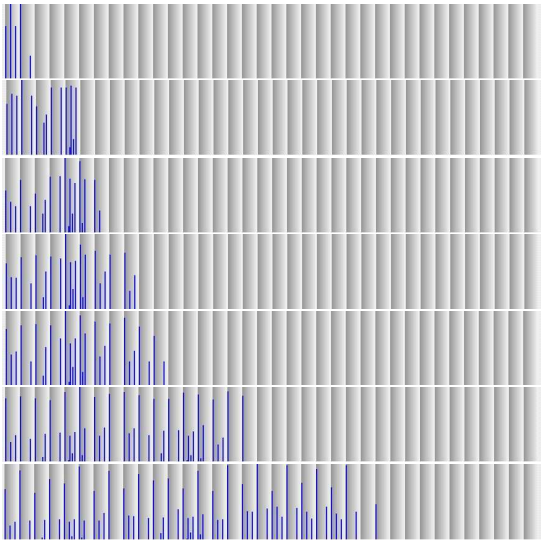

Figure 5. The cumulative window approach: Snapshots from *Sing We and Chant it*

According to this analysis the piece is divided into two regions of stable metric states. Since inner metric analysis considers all relations between all notes of the entire piece, the weights discussed so far represent a certain kind of a "frozen" structure, where each local detail depends on its relations to all other events. This approach is valid in terms of an in-depth music theoretic analysis that aims at a large scope of mutual relations in the piece going beyond punctual attention in a limited local region. However, while listening to a piece of music this maximum amount of information might not always be present. Hence in the following we attempt to model the unfolding of the metric structure over time according to a processive approach. Within the processive approach we assume that not all information about the piece is available simultaneously, but by going through the piece we access only the past of or a small window around the current event.

3.2. The cumulative window approach

In a first attempt we model the metric process unfolding over time by going through a piece in terms of a cumulative window analysis that considers all relation of the current event to the past events. Hence for a piece consisting of n onsets $o_t \in On, t = 1, \ldots, n$ we gain $n - 2$ analysis windows w_t each containing the analysis of all onsets $o_1, o_2, \ldots, o_t$ at the time point t.

In figure 5 some snapshots of windows w_t in this process are shown for the soprano part of Morley's madri-

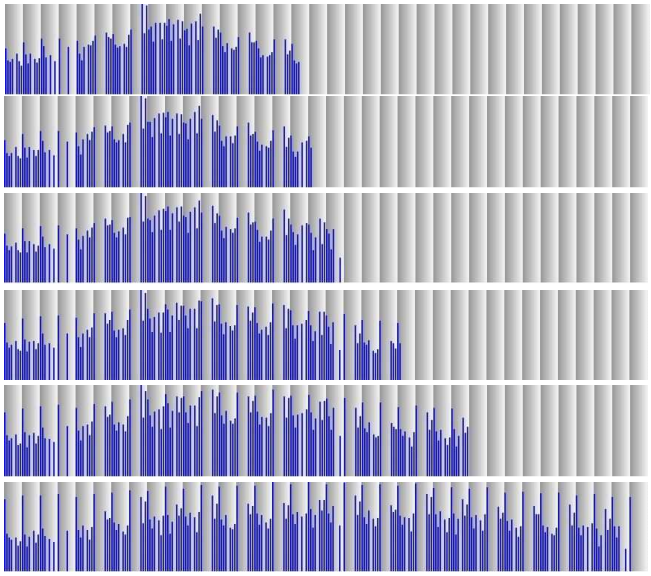

Figure 6. The cumulative window approach: Snapshots from the *Nonpareil Rag*.

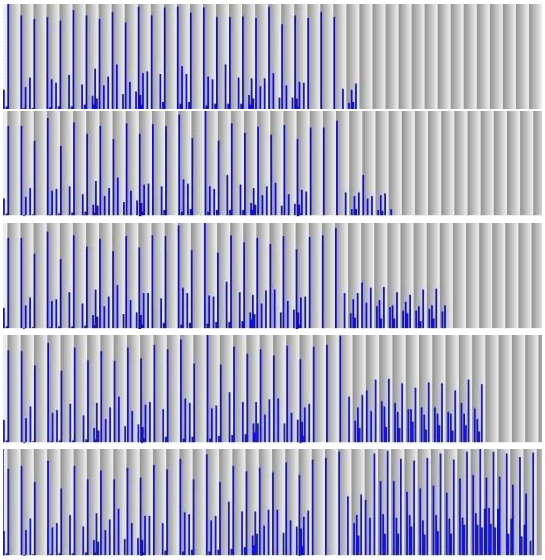

Figure 7. The cumulative window approach: Snapshots from Brahms Third Symphony.

gal. The initial process (here documented with the first three pictures from the top of Figure 5) is characterized by abrupt changes within the accent pattern of consecutive weight windows w_t and w_{t+1}. But starting with the fourth displayed window, the stable grouping of the metric weights into the hierarchical levels of the 3/4 time signature as observed in Figure 1 is replicated in each step. Hence the stability of the "frozen" structure is replicated in the processive approach as the similarity of the metric structure across the growing windows.

In contrast to Morley's madrigal the metric characteristics of the *Nonpareil Rag* with the great weights on the first beats of all bars is achieved relatively late within the processive approach. Even after 16 bars from the beginning (top picture of Figure 6) only the first four bars show a modest peak on the first beats of the bars. The following windows (from top to down) in Figure 6 reflect a cumulative strengthening of the role of these onsets within the first bars by constantly growing weights, while such a prominence cannot be observed in the bars that follow bar 6. However, in the fourth and fifth pictures from above the weights of the first beats in the last bars of each window begin to grow. While approaching the end of the piece even the middle part starts to assign great weights to the first beats of the bars (lower most picture). Hence in contrast to the processive approach applied to Morley's madrigal the stable metric hierarchy is achieved relatively late in the process and new events significantly change the metric interpretation of the past along this process.

Another question within the processive approach is as to how changes within the metric structure observed in the "frozen" structure of the entire piece are being reflected, such as the shift within the metrical state of the piece by Brahms in Figure 4. The latter abruptly changes the grouping of the accent pattern in bar 26. Figure 7 gives some excerpts of the cumulative analyses starting shortly after bar 26. The first picture on the top of Figure 7 reflects a sudden drop of the weights after the change to a very low level. The following windows show a cumulative growing and reorganizing into the new grouping structure with great weights on the third beats. This might indeed correspond to a listener's experience at a point of change in a piece of music: while the new events are easily recognized as not fitting to the previous patterns, it takes a while to orientate within the newly established patterns.

3.3. The sliding window approach

In the cumulative window approach all information about the past are considered at the current event. But while listening to a piece we might lose sight of events in the past that are too far away. The sliding window approach therefore shifts both the starting and end points of the windows.

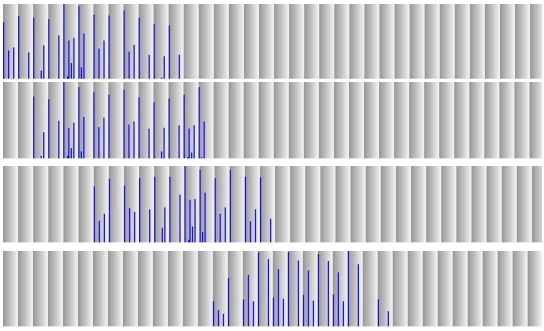

Figure 8. The sliding analytical windows for *Sing We and Chant it*.

In Figure 8 we can observe that the inner metric grouping is stable even along the sliding analytical windows [3] when applied to Morley's madrigal, as long as the window is contained in the first 24 bars (before the level of

[3] The displayed examples are excerpts of the stepwise forward motion through the piece. All steps in between not listed show the same pattern.

the weights drop as observed in Figure 1). The lower most picture in Figure 8 contains an analytic window that crosses this boundary which results for this window in a very different accent pattern that has not been observed in the cumulative analysis approach. This confirms again the great metric stability of this piece in the first part while a subtle change takes place after bar 24.

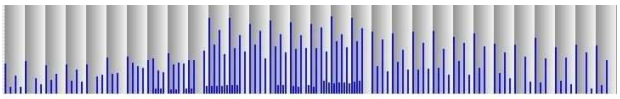

Figure 9. Metric weight of Haydn's Sonata without local meters of period 3, interpreted as 4/4

In the following we apply the sliding window approach to the Haydn Sonata discussed in section 2.1. The "frozen" structure in terms of the analysis of the entire piece in Figure 3 does not show a correspondence to the typical metrical pattern of a 3/4 bar. By excluding all local meters of period 3 in Figure 9 and excluding all local meters of period 4 in Figure 10 we gain metric patterns that correspond to a 4/4 and 3/4 respectively. Hence the competing roles of pulses of periods 3 and 4 prevent the emergence of a periodicity in the metric weight that correspond to the outer metric structure.

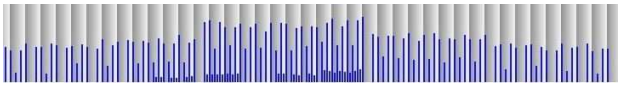

Figure 10. Metric weight of Haydn's Sonata without local meters of period 4.

The "frozen" structure as described by the analysis of the entire section in Figure 3 performs a simultaneous overlap of the competing patterns in the section. In contrast to this, the excerpts from the sliding window approach given in figure 11 show that from the temporal perspective these patterns do not coexist at every point in time. The given excerpts are characterized by very different weight pattern including one window (the third from above) where a correspondence to a 3/4 can be observed, while the second and fourth windows from above perform a periodicity that corresponds to a 2/4 or 4/4. The upper most window shows a very distinct pattern that can be interpreted according to a hypermeter of 3/2.

Hence the processive approach allows to unfold patterns that seem to coexist in the frozen structure of the analysis of the entire piece into successive pattern changes that might describe the experience of a complex metric structure while listening to the piece in terms of disruption and re-orientation in a more appropriate way.

4. CONCLUSION

This paper applied Inner Metric Analysis within a processive approach that addresses a linear listening process through the piece. By comparing these processes we can distinguish between pieces that achieve a stable metric structure at a very early stage and others that achieve this

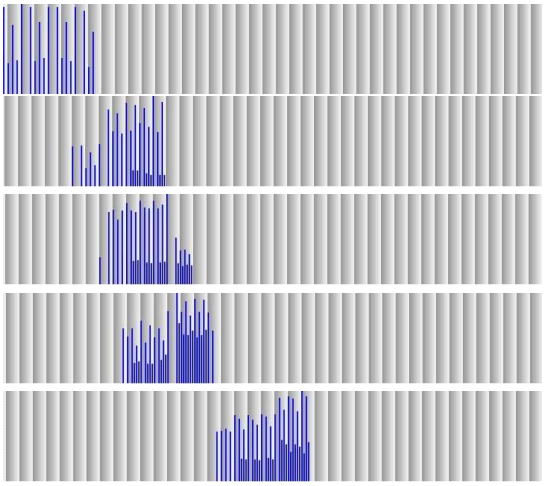

Figure 11. The sliding analytical windows: Haydn's Sonata Op. 39

only gradually along a very long process. Hence pieces that exhibit a similar regular and stable metric structure in the "frozen" version of the meter, can be very different within the processive approach. Furthermore, sudden changes within the analysis of the entire piece may be replaced by a gradual reorganization of the new metric hierarchy along the processive approach. Hence the proposed approach might be an appropriate way to describe the dynamic processes taking place while listening to the music.

5. REFERENCES

[1] Chew, E., Volk, A., and Lee, C. "Dance Music Classification Using Inner Metric Analysis". In *Proceedings of the 9th INFORMS Computer Society Conference*. Kluwer, 2005, pp. 355-370.

[2] Fleischer, A. "Die analytische Interpretation. Schritte zur Erschließung eines Forschungsfeldes am Beispiel der Metrik". dissertation.de - Verlag im Internet Gmbh, Berlin, 2003.

[3] Hasty, C.F. *Meter as Rhythm*. Oxford University Press, 1997.

[4] Mazzola, G. *The Topos of Music*. Birkhäuser, Basel, 2002.

[5] Volk, A. "Metric Investigations in Brahms' Symphonies". in Mazzola, G., T. Noll and Lluis-Puebla, E. (eds): *Perspectives of Mathematical and Computer-Aided Music Theory*, epOs Music, Osnabrück, 2004, pp. 300-329.