

Generating of Metrical Hierarchies using Inner Metric Analysis by Volks

The paper introduces a model of Inner Metric Analysis and is based on detecting the pulses on onsets by assigning a metric weight. They discussed different aspects of the model and examples of symphonies, sonatas, fugues, and ragtimes.

The Inner Metric Analysis, which is base of this research, is a mathematical model which generates metrical hierarchies by considering the actual notes and ignoring the grid of the bar lines. It produces a metric weight profile for all onsets of a piece of music and is based on the idea of score events with equal distances that form a pulse or a layer.

In general, points in which many pulses coincide are mentioned as strong beat, and those in which few pulses coincide as weak beats. In this model specific type of pulses are considered and regarding the notes, their onset is studied. Among the set of onsets, subsets of equally spaced onsets are candidates for the considered pulses that are called *local meters*. A local meter should have at least three onsets, and should be maximal, i.e. it shouldn't be a subset of any other such subset or local meter. Each local meter is identifies by three parameters: the starting point or its first onset (s); the distance between consecutive onsets of the local meter (d) or the period; and the number of repetitions (k) of the period. The local meter is shown as $m_{s,d,k}$ and its phase is calculated as $ph = s \text{ modulo } d$. A *metric weight* is assigned to each onset based on the amount of local meters than coincide at a given point. Points or onsets that many pulses coincide get a greater weight as the longer repetitions. The weight w_p of a local meter $m_{s,d,k}$ is $w_p(m_{s,d,k}) = k^p$ and for most of this paper p is considered 2. The metric weight of each onset is the sum of weights of all the local meters that inhere the onset. Another variable is introduced as the minimum length of the local meters (l) and the local meters shorter than l are not considered. Let $M(l) = \{ m_{s,d,k} : k \geq l \}$, the general metric weight of an onset (o) is:

$$W_{l,p}(o) = \sum_{\{m \in M(l) : o \in m\}} k^p$$

Spectral weight is another type of weights and is a refinement of the metric weight. it is based on the extension of each local meter throughout the entire piece and is calculated as: $\text{ext}(m_{s,d,k}) = \{s + i \times d, \text{ for all } 'i's\}$

The spectral weight is:

$$SW_{l,p}(t) = \sum_{\{m \in M(l) : t \in \text{ext}(m)\}} k^p$$

In weight profiles higher lines correspond to greater weights and the background indicates the bar lines. Their studies showed that the bar lines are not automatically considered by the players most of the times and therefore they are not so important.

A Notion of Metric Coherence

Engineering Approaches to Music Perception & Cognition

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Homework # 4
Feb. 10, 2005

The metric and spectral weights are referred as *inner* metric structure and those associated with bar lines are referred as *outer* metric structures. Studies show that **in many cases**, there is a correspondence between inner and outer metric structures, although no information about the bar line is included in the inner metric analysis. So *metric coherence* is defined as a presupposed occurrence of regularity in metric weight, i.e. the notes of a piece express a metric structure that is related to the metric structure given by the bar lines. While this is seen in Schumann's Walzer as well as ..., it is not the case for many other pieces including Bach's B Minor Mass. In the examples mentioned in the paper, lack of coherence is because weight layers do not exist, not because the weight layers have a different periodicity than those in bar lines.

To **compare** metric weights and spectral weights several aspects are considered, including: the amplification of layers in the spectral weights, the sensitivity of the metric weights of the metric state changes, and **local vs. global impact of syncopation**, which will be referred to in the following paragraphs.

Spectral weights are based on the extension of all local meters throughout the entire piece and they consider range of the influence of pulses. Metric weight has a more local perspective at each point of the scores, while the spectral weight considers more global information.

In many cases, layers are more distinctly appeared in the spectral weights than in the metric weights, which is due to amplification of layers. Also, in a piece which is built of sections with a low amount of regularities in the metric weight, the spectral weight is able to amplify weak periodicities of the metric weight. This might be because the rhythmic grouping structure of the different sections does not change over time.

In some examples of fugues, layers are very stable throughout the entire piece and in some others layers are distinctive in some parts and less apparent in others. The latter type of interplay of voices is called *mutual metric backing* as opposed to *metric annihilation* that the interplay of voices tends towards the **decreasing of coherence compared to coherence of single voices**.

Metric weights are more sensitive to local changes of the rhythmic grouping in a piece than spectral weights and the effects on the two weights will be different. Usually there is an interaction between the rhythmic grouping and the inner metric structure. If the inner metric structure of a section changes significantly, the spectral weight might wipe out the metric characteristics of adjacent sections.

To study impacts of syncopation ragtime genre with 2/4 meter is chosen and comparing metric and spectral weights in different pieces helps to differentiate between different amounts of syncopation present in those.

Revisiting Tapping to Ragtime using Inner Metric Analysis

Authors conducted a listening experiment, in which they applied Inner Metric Analysis to ragtimes, to illustrate its potential usage to understanding of perceptual phenomena. They chose piano ragtime genre because of the conventional harmony, based on tonic, dominant, and subdominant chords in major, simple harmonic progressions in the left

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hand and a clear duple meter. They studied role of pitch information by using two versions of ragtime: one with pitch information and in the other one there was no variation in pitch, only a rhythmic piece. Results showed that the existence of pitch information didn't affect the tapping of the listeners, but a great decrease was observed when the left hand was removed and only the right hand remained. To understand the reason, some studies were conducted to investigate effects of isolated dimensions.

The analysis of the left hand vs. right hand showed that the inner metric structure of the left hand describes the down beat pulse and most of the listener tapped on that. Experiments showed that in 5/7 of cases the left hand is characterized by metric coherence. The number of notes per onsets and the pitch information were less likely to be effective than the inner metric structure of the left hand.

Although the model worked when the information was present in rhythmic information and there was no varying pitch, it fails when the information is carried by pitches and the rhythm is only a continuous motion of equally spaced onsets. This model is absolutely working differently on different genres of music.