THE EMPIRICAL EVALUATION OF A MATHEMATICAL MODEL FOR INNER METRIC ANALYSIS

Anja Volk (Fleischer)
Research Group KIT-MaMuTh, Institute for Telecommunication Systems,
Technische Universität Berlin, Germany

ABSTRACT

Background. This paper introduces an experimental research approach on the relationship between a musical composition and its performance exemplified on *metric structures*.

Aims. A theoretic notion of *metric coherence* is to be tested empirically by applying it to analyses as well as within listening experiments. The latter use performances shaped on the basis of metric analyses in order to investigate the influence of different degrees of metric coherence on the perception of these metric structures within musical performances.

Method. The RUBATO-Software models the *transformative process* from the score into the physical reality of sounds on the basis of analytical data and the method of applying analytical weights in order to shape the performance. The notion of metric coherence is based upon the model of *inner* metric analysis implemented in RUBATO, which studies the metric structure of the notes without considering the time signature and bar lines. In order to gain a description in how far metric weights might help to shape a performance that elucidates the metric structure listening experiments have been conducted. Drum rhythms were played with various structures of *accentuation*, arising from metric weights of different degrees of coherence.

Results. The notion of metric coherence gives surprising insights into the understanding of metric architectures of compositions. A higher degree of coherence is detected within those works, which are typical representations of the accent scheme given by the time signature. Furthermore metric weights of higher degree of coherence led to a more convincing interpretation regarding the question in how far the metric structure was expressed properly.

Conclusions. The suggested music-theoretic notion of metric coherence is suitable for the description of the metricity of compositions and for transferring structural aspects to listeners.

1. INNER METRIC ANALYSIS: THE MODEL

Inner metric analysis is based on the detection of regularities of notes‘ onsets and ignores all information given by the time signature or bar lines, because it aims at the description of metric structures expressed by the *notes*. It is opposed to outer metric analysis, which describes the metric hierarchy given by the accent scheme of a specific time signature. Inner metric analysis instead looks for all local meters of a given piece of music, whereas a local meter denotes a set of equally spaced notes‘ onsets. The outcome of the analysis describes the metric meaning of each note in terms of the *metric weight*, which is calculated on the basis of all local meters that inherit the note‘s onset[1]. Figure 1 shows an example concerning a metric weight of a Sonata of Mozart. The length of the black lines of figure 1 represents the numerical value of the metric weight for each onset: the higher the line the greater the weight. The horizontal axis represents the time; the lines in the background mark the bar lines of the piece in order to assist for orientation.

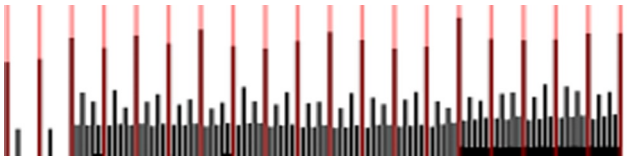

Figure 1: Excerpt from a metric weight of the entire first movement of *Mozart‘s Sonata B-flat Major K 570*, time signature: 3/4

Surprisingly we can state an obvious correspondence between inner and outer metric structure in this case although the metric weight ignores information given by the outer metric structure of the time signature. The highest layer of the metric weight is built upon the first beats of the bars, followed by the layer built upon the second and third beats, whereas the weak beats form an even lower layer. Hence the hierarchy of the outer metric structure is reflected by the inner metric structure. Many other examples of a striking correspondence between inner and outer metric structure have been detected within an explorative work with the model. Different correspondence degrees and types between inner and outer metric structure led to the definition of *metric coherence*: whenever a correspondence can be observed, metric coherence occurs (for more detailed definition see [Fleischer 2002], [Fleischer/Noll 2002], [Fleischer 2003]).

[1] Let $m_{s,p,l} = \{s + kp, k = 0, ..., l\}$ denote a local meter with a start onset s, period p and length l. We consider only maximal local meters. The local meter $m_{s,p,l}$ is maximal, if no local meter $m_{s',p',l'}$ exists which contains $m_{s,p,l}$. The weight $w(m_{s,p,l})$ of the meter $m_{s,p,l}$ is defined by $w(m_{s,p,l}) = l^{profile}$, where *profile* denotes a specific exponent which can be varied within the analysis. The weight $W_{profile,minlength}(o)$ of a note‘s onset o of the piece is calculated as the sum of the weights $w(m_{s,p,l})$ of all those local meters $m_{s,p,l}$ which contain o and fulfil $l \geq minlength$.

ISBN 3-931852-67-9
ISSN 1617-6847

2. EMPIRIC EVALUATION ON MUSICAL PIECES

In [Fleischer 2003] the empiric evaluation of the model of inner metric structure as well as of the music-theoretic term of metric coherence by means of numerous analyses of pieces of different styles is reported detailed. In the following we discuss only some examples.

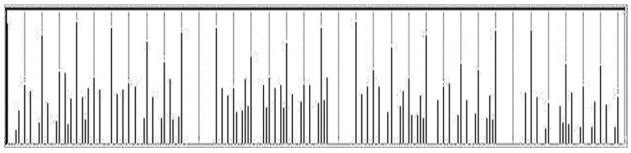

Figure 2: Metric weight of Binchois' chanson *Adieu, Adieu*

Metric coherence often can be stated in those works, which exhibit the metric hierarchy given by the time signature quite evidently. For instance, de la Motte (1981) compares three pieces of Dufay, Ockeghem, and Binchois concerning different types of compositional techniques, classified either as varietas technique or motivic development or as a mixture of both. The leading voice of Binchois' chanson *Adieu, adieu* (see [IMAGE binchoisnotes.jpg]) exhibits motivic development to a great extend according to de la Motte, whereas he soprano of the Kyrie II of Dufay's Mass *Se la face ay pale* (see [IMAGE dufaynotes.jpg]) is described as representing the varietas technique, hence repetitions of any kind are avoided.

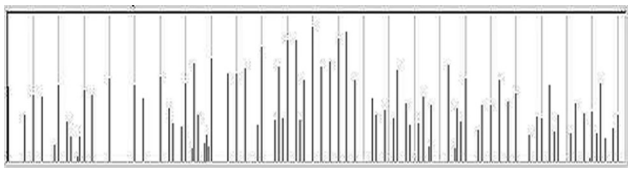

Figure 3: Metric weight of the soprano of the Kyrie II of Dufay's Mass

The metric weight of the melodic voice of Binchois' chanson (see [IMAGE binchois.jpg] and figure 2) is characterized by metric coherence whereas the weight of Dufay's piece lacks such a periodicity (see [IMAGE dufay.jpg] and figure 3). Hence the inner metric analysis reflects the characterization of these two pieces given by de la Motte. The avoiding of repetitions within the varietas technique causes a lack of a correspondence between inner metric structure and the metric hierarchy associated with the time signature in Dufay's piece, while the motivic development in Binchois' case inherits repetition causing regularities in the metric weight.

The „Pleni sunt coeli" (see [IMAGE ockeghemnotes.jpg]) from Ockeghem's Mass *L'homme armè* is classified in [de la Motte 1981] on the one hand as belonging to the varietas technique as well, on the other as showing some elements of motivic development. The metric weight of the vocal parts of Ockeghem's example shows in the last measures of the lower voice (see [IMAGE ockeghem2.jpg]) a regularity of the metric weight, whereas the upper voice is characterized by a lack of periodicity (see [IMAGE ockeghem1.jpg]), hence both tendencies are reflected by the metric weights.

Mozart's *Sonata A Major K 331* poses a question regarding the grouping structure of the very beginning. There exist at least two different approaches (see [Meyer 1973], [Gabrielsson 1987], and [Lerdahl/Jackendoff 1983]), whether the grouping might be understood as downbeat or upbeat. Furthermore in [Maurer Zenck 2001] it is argued, that the notated time signature of 6/8 in this case should be interpreted as a composed version of 3/8, e.g. two measures of 3/8 form one measure of 6/8.

Figure 4: Excerpt from a metric weight of the theme of Mozart's *Sonata A Major K 331*

Inner metric analysis (see [IMAGE mozartweight.jpg] and figure 4) confirms on the one hand the latter observation: the highest layer of weights is built upon the first and fourth beats of the bars, which gain the same weights. Hence it is possible to interpret this inner metric structure as corresponding to 3/8. On the other hand the downbeat grouping of the very beginning, which have been favored within most theoretic approaches, is confirmed by this weight as well. The greatest metric weights are situated on the *first* beats of the bars, not on the *last* beats, as has been observed in examples of a coherent upbeat structure with beginnings of the groups not coinciding with the bar lines.

3. ANALYTIC INTERPRETATION

The discussion of various metric analyses of pieces belonging to different musical styles proved the explanatory power of the term *metric coherence* regarding music-theoretical issues empirically. Thereby the description of the signs of the score and their interrelations has been in the focus of the investigation. If we consider the idea of the *analytic interpretation*, as suggested by Adorno, who argued that an analysis of the composition is an essential prerequisite of its performance, then the question arises as to how far an analysis may serve as a basis for decisions about interpretation. The shaping of interpretations on the basis of analytical data leads us to the empiric evaluation of the metric coherence within *listening experiments*.

3.1. Performance Theory

Various studies (such as in [Riemann 1884], [Adorno 1976], [Berry 1989], [Epstein 1987], [Mazzola 2002]) have contributed to a promising approach within performance theory, which defines the performer's role in the following way. The task of the performer is to elucidate the structure of a piece of music to the audience, in other words, to communicate his understanding of the piece to the listener. Since RUBATO allows the shaping of

ISBN 3-931852-67-9
ISSN 1617-6847

performances on the basis of analytic weights the question arises, in how far metric weights may help to convey metric information to the audience. RUBATO enables the user to influence the performance of a piece in very different ways (such as timing, accentuation...), hence the above mentioned question includes the search for suitable techniques: which performance parameter should be affected in which manner by the metric weights?

3.2. Complex performances

In a first approach complex performances have been shaped on the basis of various analytical weights (including melodic and harmonic weights as well) for two piano pieces (Beethoven's Pathétique and Schubert's Moment Musical op. 94 No. 6). They have been performed on a Yamaha Diskpiano and have been evaluated within listening experiments regarding their musical adequacy. Concerning the evaluation of the underlying analysis and hence the relation between the analysis and the performance it is argued that positive responses of the participants indicate, that the analysis as well as the specific way it influences the performances might transfer some proper information about the piece to the listeners. A convincing relationship between strong/week inner metric weights and a proper corresponding increasing/decreasing of timing was detected by evaluating the performances aesthetically. This result is related to the findings in [Drake/Palmer 1993].

In order to gain a precise description in how far metric weights might help to shape a performance which elucidates the metric structure to the listeners further experiments have been conducted, in which questions were formulated as if they were ear-training tasks.

3.3. Listening Experiments

The empiric evaluation of inner metric analysis via the analytic interpretation within listening experiments was based on the following question. Do metric weights with a high degree of coherence result in performances, which express the metric structure of the piece more clearly to the listener than those performances based on metric weights of a lower degree of coherence? In order to answer this question metric weights of different degrees of coherence of the same piece have been compared via the corresponding performances. Figures 5 and 6 (see also [IMAGE Credo.jpg] and [IMAGE Credoaltus.jpg]) give examples concerning the Credo fugue of Bach's B-Minor-Mass. The analysis of *all* vocal parts results in a metric weight of a high degree of coherence, whereas the analyses of the *separate* parts (one example given here concerning the alto) result in metric weights of a lower degree of periodicities observed in the weights.

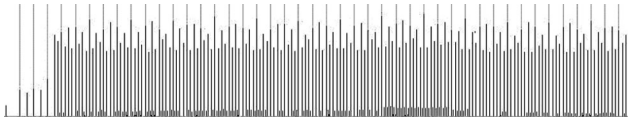

Figure 5: Metric weight of all vocal parts of the Credo

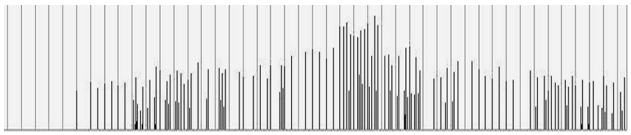

Figure 6: Metric weight of the alto of the Credo

Hence the comparison of the corresponding two performances (based on the metric weight of figure 5 or of the metric weights of the separate voices respectively) could help to answer the above-mentioned question. In addition to the Credo a second example from Bach's B-Minor-Mass was selected for the listening experiments, namely two metric weights of different degrees of coherence of the alto of the Gratias have been compared (based on the analysis of the entire voice or on the analysis of a segment respectively). Furthermore a randomly produced performance was included into the experiments, as well as a performance shaped on the basis of a metric weight of a high degree of coherence stemming from a *different* piece (the Pleni sunt coeli). The latter was chosen in order to test, in how far the performance has to convey information according to the structure of the piece or just any regular structure.

Since inner metric analysis considers only the notes' onsets, the pieces have been reduced to drum rhythms. Metric information might be conveyed by melodic events or harmonic progression to the listeners as well, hence by reducing the pieces to drum rhythms this effect was excluded. Concerning the performance parameter to be affected we have chosen dynamics: metric weights influenced the accentuation of the piece - as higher the metric weight as louder the note is performed. In the experiments all pairs of two different performances have been presented to the participants, whereas the deadpan (performance without any accentuation) was repeated in the beginning of each new pair. Participants were asked to imagine that they should have to transcribe the drum piece or to clap it, which would require some sort of structuring of the piece. Furthermore they were asked to listen to the two performances and to decide, which of them would make this task easier.

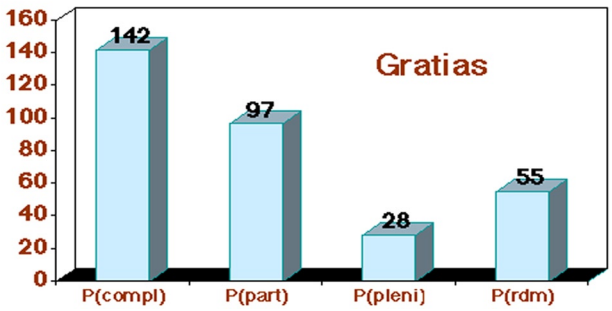

Figure 7: Results concerning the *Gratias* (number of preferences within presented pairs for each performance): *P(compl)* denotes the performance based on the metric weight of high degree, *P(part)* denotes the performance based on the metric weight of lower degree, *P(pleni)* refers to the performance shaped with the metric weight of the Pleni sunt coeli, *P(rdm)* denotes the randomly produced performance.

ISBN 3-931852-67-9
ISSN 1617-6847

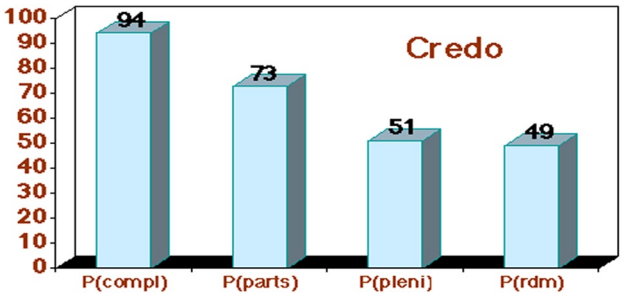

Figure 8: Results concerning the *Credo*: *P(compl)* denotes the performance based on the metric weight of all vocal parts whereas *P(parts)* denotes the performance based on the metric weights of the separate parts (lower degree of coherence), *P(pleni)* and *P(rdm)* are defined as in figure 7.

In both cases (see figures 7 and 8) the performances shaped on the basis of metric weights of the underlying piece (*P(compl)* and *P(parts)*) were preferred significantly in comparison to the performances *P(pleni)* and *P(rdm)*. Furthermore the performance *P(compl)* of the highest degree of coherence was preferred in most cases (concerning the Gratias the difference between *P(compl)* and *P(parts)* was significant).

Since performances shaped on the basis of metric weights have been preferred in comparison to the performances with a random pattern of accentuation as well as in comparison to the performances based on a coherent structure of a different piece we can conclude that metric weights indeed transfer important structural aspects of the piece to the listeners. Performances based on structural aspects, which are not in accordance with the structure of the piece (see results for *P(pleni)*) are obviously less appropriate. Furthermore performances based on metric weights of a higher degree of coherence seem to express the metric information more clearly. Hence the music-theoretic notion of metric coherence based on investigations of the score seems to be helpful regarding the conveyance of structural aspects to listeners via the analytic interpretation as well.

4. REFERENCES

1. Adorno, T. W. (1976). Der getreue Korrepetitor. Interpretationsanalysen neuer Musik. In: *Gesammelte Schriften 12*, Frankfurt M.

2. Berry, W. (1989). *Musical Structure and Performance*. Yale University Press, New Haven and London.

3. de la Motte, D. (1981). *Kontrapunkt*. Bärenreiter.

4. Epstein, D.(1987). *Beyond Orpheus*, Oxford University Press.

5. Drake, C. and Palmer, C. (1993) Accent Structures in Music Performance. In: *Music Perception*, Spring 1993, Vol 10, No.3, 343-378.

6. Fleischer, A. (2002). A model of metric coherence, *proceedings of the 2nd International Conference „Understanding and Creating Music"*, Caserta.

7. Fleischer, A. and Noll, T. (2002). „Analytical Coherence and Performance Regulation", in: Johannsen, G. and G. De Poli (Guest Editors): *Human Supervision and Control in Engineering and Music*. Special Issue, Journal of New Music Research (in print)

8. Fleischer, A. (2003). *Die analytische Interpretation, Schritte zur Erschließung eines Forschungsfeldes am Beispiel der Metrik*, dissertation.de - Verlag im Internet GmbH, Berlin.

9. Gabrielsson, A. (1987). Once Again: The Theme From Mozart's Piano Sonata in A Major (K. 331). In: *Action and Perception in Rhythm and Music*, ed.: A. Gabrielsson, Publications issued by the Royal Swedish Academy of Music No. 55, 1987, 81-103.

10. Lerdahl, F. and Jackendoff, R. (1983). *A Generative Theory of Tonal Music*. Cambridge, Massachusetts, The MIT Press.

11. Mazzola, G. (2002) *The Topos of Music*. Birkhäuser, Basel.

12. Maurer Zenck, C. (2001). *Vom Takt. Überlegungen zur Theorie und kompositorischen Praxis im ausgehenden 18. und beginnenden 19. Jahrhundert*. Wien, Böhlau.

13. Meyer, L.B. (1973). *Explaining Music. Essays and Explorations*. Chicago.

14. Riemann, H. (1884). *Musikalische Dynamik und Agogik*. Leipzig.

ISBN 3-931852-67-9
ISSN 1617-6847