Abstract

The article discusses collective performance of score-based music at two levels of description: collective behavior and musical score. Two specifications of the concept of coherence are presented. **Intentional coherence** applies to the intentionality of a performing ensemble and characterizes the way how distributed collective knowledge about a piece regulates a performance. **Analytical coherence** applies to the results of two or more analytical perspectives on the same score. The construction of artificial performance transformations on the basis of analytical data provides a suitable experimental approach in order to investigate the concept of analytical coherence empirically. As a special case, we present the concept of metrical coherence and apply it to choir fugues of Johann Sebastian Bach as well as to passages in the symphonies of Johannes Brahms.

1. Intentionality and communication in ensemble performance

The first chapter addresses the complexity of the main theme of this issue “Human Supervision and Control in Engineering and Music” with regard to the musical aspects, especially to ensemble performance. By portraying the orchestrion in Section 1.1 we intend to stress some characteristic features of ensemble performance which are lacking in musical machines. Section 1.2 provides heuristic considerations on ensemble performance under the perspective of collective human behavior. Section 1.3 relates these considerations to the three levels of musical communication: poetic, esthetic, and neutral.

1.1. Orchestra versus orchestrion?

A perfect example for a point where engineering and music intersect is the mechanical orchestrion. Control is provided through a pianola roll, which to a certain degree resembles a musical score. Some parts of the orchestrion are musical instruments (various types of pipes, drums, etc.) and other parts resemble human limbs. A contemporary version of an orchestrion was presented at the “Klang-Art’99,” namely an ensemble of hydraulic robots playing various kinds of instruments (The Ancestic Path). The steering was provided by a computer through MIDI-controllers. The whole event was a real time improvisation of human performers on the basis of previously programmed patterns.

Can one compare musical ensembles to an orchestrion? Many good jokes about orchestra musicians are based on the hyperbolic assumption that conducted orchestra performances are quasi mechanistic: the main difference being communicative steering (through score and gesture) instead of a mechanical or electro-mechanical one. However, instead of simply overstating “the truth” about ensemble playing, these jokes intend rather to unmask the social injustice implied in the division of labor by pointing out the deadening effect of stereotypic patterns. Hence, it is equally important to investigate the organisation of collective musical behavior on the one hand and the organisation of musical structures on the other. Although we will not be able to elaborate both approaches and to merge them within the scope of this article, we nevertheless hope to sketch some aspects of such a scientific program.

As a suitable unifying concept, which may be applied to both realms (these being collective action and musical structure) we suggest the notion of coherence. We discuss two specifications, namely **intentional coherence** as a means of addressing collective acting and **analytical coherence** as a means of addressing of musical analysis.

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1.2. Sovereignty and intentional coherence in ensemble music

What distinguishes a human musician from a musical robot is that the former may be in a quandary, as to what or how to play. The crux of human action is a degree uncertainty as to whether a particular action will contribute to the fulfillment of an intention that motivates that action. Sovereignty is a concept that grasps this phenomenon. An action may be called sovereign if the actor is certain about its outcome as a contribution to the fulfillment to given intentions.

In collective behavior many intentions emerge through various types of interaction, like manipulation and communication, i.e., intentions change dynamically. We will speak of intentional coherence, if a collective of actors is able to shape their individual intentions through their actions in such a way that the sovereignty of all these individual actions is particularly high. The hypothetical sovereignty of an imaginary robot-musician depends only on the way in which it may articulate its own part while following the conductor. But it is not influenced by the playing of other musicians, while the sovereignty of an orchestra musician typically is.

As a musical example think of the sovereignty being necessary for a performer to articulate of a locally foreign or dissonant tone (in relation to the simultaneously sounding chord), which is then resolved by of the following chords.

1.3. The communicative dimensions of musical performance

The naive assumption that a musical performance revives the same structures in a listener’s mind that originally the composer had in his own when he wrote the piece is questioned by most musicians and musicologists. Hence, in order to conceptually clarify the discourse about music and its communication, Jean Molino introduced and Jean Jacques Nattiez elaborated the distinction of three communicative levels: poetic – neutral – esthetic. The classical simple communication schema consists of the production of a message by a producer and its reception by a receiver. In a simple and idealized semiotic refinement of this schema, the message has first to be encoded into a sign by the producer and this sign has to be decoded by the receiver into an (ideally the same) message. If both communicants share the same code the communication results in an unidirectional process. Of course, during the preparation of and in ensemble playing many simple communicative acts of this kind take place.

The difference in Molino’s scheme is the observation that a given symbolic form is (a) the result of a complex process of creation (the poetic process) and (b) the point of departure for a complex process of reception (the esthetic process), but that these two processes do not necessarily correspond. The idealization of an identical message is not acceptable in this situation. Instead the single sign and single message are replaced by a neutral level of analysis, which comprises all facts immanent to the given symbolic form. These may, for example, be communicated in specialized language.

Musical compositions have a double articulation through scores and performances, and both primarily belong to the esthetic process. But in ensemble rehearsals and performances these communicative levels interact with one another. To be more precise, we must apply these levels to the collective as a whole on the one hand and to the individual musicians on the other. The crux of our subject might be re-formulated in the following way: The collective poiesis of a musical performance is manifested in a highly complex organisation of individual communicative processes between the musicians at all three levels: poetic, esthetic, and neutral. This is the very towards the classical orchestration. The notions of supervision and control must be understood as specific properties of this communicative flow at all three levels.

The notion of intentional coherence may be restated as follows: Each individual musician performs poetic acts, whose sovereignty depends among other factors on their own esthetic acts that in turn depend on the poetic acts of possibly all other musicians. According to Molino’s observation, it is not reasonable to assume that unique messages are being transmitted in this collective interaction. If all players nevertheless reach a high amount of sovereignty there must be a nontrivial relation between the variety of these acts which we call intentional coherence. Furthermore it seems reasonable to investigate such relations in terms of the neutral level of performance.

2. Interpretation and analysis of musical scores

Interestingly the term “interpretation” refers to a performance of a given score as well as to its analytical reading. This, of course, is not just an accidental homonym, but rather reveals the important role of understanding a piece of music as a prerequisite of its sovereign performance. It relates to a ramified tradition within the history of 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. Contributions to this approach have been proposed in Riemann (1884) and in Adorno (1976) and later in Berry (1989), Epstein (1987), Sundberg (1993), Mazzola (2002a) and others.

In the first section of the present chapter we address some heuristic aspects of score based performance and discuss theoretical aspects of comparing different analyses on the neutral level in the second section, while the third section deals with the special case of metric analysis.

2.1. Performance as transformation of a score

The study of analytical coherence is related to the specific communicative role of a musical score in the coordination of
a performance. In performing a composed piece of music, the score is the common prerequisite for both the conductor and the orchestra musicians: The rehearsal or concert aims towards a performance of this underlying score. In this way, a transformative process from the symbolic reality of the signs of the score into the physical reality of sounds takes place. This is the concept behind the RUBATO Workstation for Musical Analysis and Performance (see also Mazzola’s and Müller’s recent contributions in this volume as well as http://www.rubato.org). Performing a piece of music is not a question of translating single notes into a sequence of physical sounds. The odd-sounding machine driven executions of digital representations of the score (e.g., MIDI) demonstrate that this transformative process is much more complex.

We recall the formalization of this idea after discussing some aspects of ensemble performance: Naïvely, the transformation of a given score in an ensemble performance splits into several partial transformations of orchestral parts into individual physical performances (taking place at the same time in the same hall). Their interdependence goes far beyond mere synchronisation and intonation, but rather requires a deep understanding of the mutual relations of the single elements of the score within and between the orchestral parts in order to express the very complex nature of the structure of a piece of music through performance.

In order to understand the role of the conductor as a mediator between the entire score and the local parts of the musicians in the performance it may even be useful to have a look at the extreme case of a pure (idealized) free ensemble improvisation. In this case the musicians themselves determine the complexity of the music through their interaction and the emergence of intentional coherence is a collective discovery that cannot be anticipated by single individuals. Something similar also holds for the total mastery of an entire musical performance in traditional music of various cultures. Often non-improvised or partially improvised pieces are also collective discoveries rather than compositions by individuals. Often it would be rather untypical that an ensemble member practices “his/her part” alone.

Under this perspective the conductor in score-based music has to support collective discoveries which are specific to the given piece. By no means is the conductor able to control the totality of the cooperative interactions between the individuals and the subgroups of an orchestra.

His/her concrete gestural and verbal interaction with the musicians as well as “autonomous” interactions within the ensemble depend on a variety of different factors including familiarity with each other, with the piece, with the hall, and many others. On the one hand, there is a general routine of an ensemble in listening and responding to each other and coordinating intonation and timing which of course goes far beyond mere tuning and the ability to play an ostinato together. This routine is exemplified rather by the ability to extract suitable cues from an individual piece to control these parameters and hence, to establish a certain level of intentional coherence. If, on the other hand, a certain complexity of mutual response were exceeded, the collective interaction would be in need of a feedback by and the control of the conductor. We mention that his supervision often consists of giving impulses to the understanding of the piece and does not exclude the possibility of a “Socratic” dialogue about the piece while rehearsing and playing it.

The communicative complexity in the collective creation of a performance depends to a great extent on the complexity of the mutual relations of different parts within the score from which the complete piece evolves. Different types of the orchestra’s internal organization are due to different types of interrelations between the different layers of the musical structure of the piece. At this point of our study we therefore switch from the communicative creation of a performance to the more abstract concept of a transformation of a score into its performance. Analysis of the score’s structure is one of the prerequisites of localizing specific controlling processes on the basis of so called performance scores. In the concept of the RUBATO workstation and the theory behind it a performance transformation is modelled on the basis of analytical data and the method of applying analytical weights in order to shape the performance artificially. The user produces a mapping between score events and physical events on the basis of a ramified stemma of local performance scores including performance operators and analytical weights. Hence, in RUBATO the transformative process consists of detecting analytical structure within the score in terms of analytical weights and turning these into potentials of shaping forces for expressive performance.

The software RUBATO includes a specialized performance tool which is called the PerformanceRubette. This tool partially supports coherent performance strategies through a hierarchical organization of ramified local shaping operations. But beyond that there is no normative limitation to the experimental realization of performance experiments and, as a consequence, no authority that guarantees the existence of coherence between the expressions of two analytical weights through different shaping operations. The study of coherent RUBATO-performances hence refers back to the study of analytical coherence.

2.2. Coherence in analyses of musical scores

Suppose that two analytical perspectives are applied to a piece of music (e.g., melodic and metric analysis). As a result one obtains two structures A₁ and A₂ at the neutral level. On a metalevel one may investigate the results A₁ and A₂ independently from their genesis. But as soon as one observes a correspondence between these results, one has to trace the motivations for A₁ and A₂, to what degree are they independent of one another? In the context of analytical approaches on the basis of a mathematical modelling of musical and music-theoretical structures we introduce the notion of

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2 Which of course belongs to the neutral level of analysis.
analytical coherence between two results as follows. A structural correspondence between A1 and A2 is said to express analytical coherence with respect to the underlying models if this correspondence is not automatically implied by these approaches as such. In other words, the correspondence between A1 and A2 must provide additional information about the piece.

In hermeneutic analysis coherence is a prominent criterion for the very selection of particular objects of interest, say A1 and A2. The skilled hermeneutician discovers interesting structures and their coherence at once.

A very simple example of analytical coherence, in this case between diastematic shape and metric structure, is given in Figure 1: The beginning of the cello part of the 3rd movement of Brahms symphony No 2 shows a correspondence between the allocation of the lowest pitches, followed by an ascending melodic figure, and the “strong” first beats of the bars.

2.3. Inner and outer metric analysis

Metric analysis is concerned with the study of the structure of musical onsets at a given piece. Outer metric analysis interprets the actual note onsets as well as the vacant time positions in a piece in terms of metric hierarchies (e.g., Lerdahl/Jackendoff). The term outer analysis refers to a presupposed outer regular structure of musical time. For instance, a given time signature defines a certain regular accent structure upon the possible notes or onsets of a bar, independently of the actual allocation of the notes of the piece within the bars. In a 4/4 bar filled with quavers one would distinguish four metric layers: 1st layer: 1; 2nd layer: 1 and 3; 3rd layer: 1, 2, 3, 4; 4th layer: all eight quavers. Technically, a metric hierarchy of depth n consists of a metric scale \( \{ p_1, p_2, \ldots, p_n \} \) of mutually dividing periods and a common phase where all metric layers meet. The outer metric weight of an onset \( x \) is defined as the number of layers to which it belongs.\(^3\)

Inner metric analysis, instead, looks for metric regularities inside the given piece, it starts with the structure of the notes of the given composition and does not take into account the time signature and barlines. Inner metric analysis is opposed to outer metric analysis, and is based on the detection of inner local meters. A local meter denotes a sequence of notes with equally distanced onsets. In this way, inner metric analysis treats a composition as if it were written for an ensemble of metronomes. They vary in period and phase and are switched on and off whenever they can click along the onsets of the notes of the piece. The outcome of the inner metric analysis is the metric weight, defined for each onset, which represents the numerical codification of the metric meaning of each note within its context based upon the detection of the inner local meters.\(^4\)

The study of metric coherence is based on the comparison of inner and outer metric weights. A presupposition for coherence is the occurrence of regularity in the inner metric weight, i.e., the existence of weight layers corresponding to specific periods. Metric coherence is hence concerned with a metric subscale of the outer metric hierarchy being significant in the inner metric weight. Furthermore one may distinguish phase-coincidence from phase-displacement on each layer.

3. Metric coherence and performance regulation

The following examples in Sections 3.1 and 3.2 demonstrate different types of metric interplay between different voices/ parts of a piece, which can be described by inner metric structure and may help to detect the causes of different types of an orchestra’s internal organization of feedback. Finally, in Section 3.3, we refer to experimental findings and strategies in order to empirically prove and expound upon the theoretical considerations of the present paper.

3.1. Metric interplay between different voices in Bach’s Mass in B Minor

The analysis of the choir-fugue in the Credo of Bach’s Mass in B Minor results in metric weights of little regularity for the separate voices. Figure 2 gives an example for the bass. The length of the black lines of Figure 2 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 – grey lines in the background mark the barlines of the piece in order to assist for orientation. The given time signature in this case is \textit{Alta breve} (given in two semibreves per bar).

\(^3\)In Lerdahl and Jackendoff’s approach metric hierarchies are defined locally, i.e., they may change within a musical piece. Layers of hypermeasure (i.e., above the bar-layer) may include (irregular) phase shifts.

\(^4\)Let \( m_{s,p,l} = \{ s + kp, k = 0, \ldots, l \} \) denote a local meter with a start onset \( s \), period \( p \) and length \( l \). We shall consider only maximal local meters. The local meter \( m_{s,p,l} \) is maximal, if no local meter \( m_{c,p,l}' \) which contains \( m_{s,p,l} \), exists. The weight \( w(m_{s,p,l}) \) of the meter \( m_{s,p,l} \) is defined by \( w(m_{s,p,l}) = \text{profile} \), where \text{profile} denotes a specific exponent which can be varied within the analysis. The weight \( W(o) \) of an onset \( o \) of the piece is calculated as the sum of the weights \( w(m_{s,p,l}) \) of all local meters \( m_{s,p,l} \) which contain \( o \).
The few regularities of the metric weights differ in their accent hierarchy for the various voices, which often do not correspond to the outer accent hierarchy due to the time signature (another example is given in Fig. 3 for the tenor).

The typical accent structure of an Alla breve bar includes strong accents on the first and second half of each bar. \(^5\) The inner metric analysis of the tenor is not regular at all; in the case of the bass there is a regularity (although not throughout) with a period of a dotted semibreve and a phase shift of a minim. Hence both inner metric weights (cf. Figs. 2 and 3) do not correspond to the outer metric structure. Therefore metric coherence cannot be detected within the analyses of separate voices.

In contrast to this, the analysis of the whole composition with all vocal parts (Fig. 4) demonstrates a regularity of a much higher degree. It even shows a clear correspondence to the given accent hierarchy of the outer metric structure of the Alla breve bar. First and third beat of the measure get the greatest metric weight, followed by the weights of the second and fourth beat, whereas the weights of the weak beats form a much lower layer.

In this case, the inner metric analysis enlightens an obvious correspondence between the structure of onsets of the notes and the outer metric structure, even though the analytical method ignores all information about the time signature. Metric coherence can be stated within the analysis of the whole piece in contrast to the analysis of the separate voices.

Concerning the question, in how far the different layers of the score influence the interplay between the voices, one could suppose the following: A singer, knowing only his/her own part without an information about the complete piece, when coming to the rehearsal, might get lost without orientational assistance. He is now part of the structural design of the complete piece which was not detectable in his/her individual voice; it evolves only within the interplay of different voices.

Another type of interaction between different voices becomes evident through the metric design of the Confiteor-fugue (Alla breve) of the same mass. The analysis of the separate voices results in local regularities with a period of half a bar and no phase shift (i.e., great weights at the first and third beats). Furthermore this type of regularity can be observed in each voice. An example is given in Figure 5 for the first soprano.

The analysis of the whole piece with all five voices (Fig. 6) detects a stronger type of regularity in so far as the three layers of half bar period quarter period and quaver period are strictly distinct in the metric weight throughout the piece. The latter analysis therefore shows metric coherence of higher degree than those of the separate voices.

\(^5\) In the sequel we refer to these beats as the first and the third one, such as if the signature would be in 4/4.
In this case, a singer having studied only his part finds at least some traces of the metric design of the complete piece in his respective part and might be less surprised in the first rehearsal. Nevertheless the sovereignty of his/her metric feeling is improved within the collective performance.

3.2. Mutual metric backing and annihilation in Brahms’ symphonies

The symphonies by Johannes Brahms are famous examples of rhythmic-metric ambiguities, which become apparent throughout the comprehension of the metric structure of separate voices, groups of instruments and the complete works. In many cases the metric weights of various voices differ greatly in their regularities, sometimes they interact complementary in such a way that the analysis of the whole composition results in a metric weight with a lack of any clear differentiation. In this case, it could be difficult for the musician to play his own part while at the same time giving full attention to the complementary voices that act according to their own structural design. The following section will show some examples.

Figure 7 shows the metric weight with regard to all instrumental parts for the first 59 bars of the 4th movement (Alla breve) of Brahms’ Symphony No 2. Only within the first 23 bars is a regularity corresponding to the outer hierarchy of accents observable – the following part shows no regular differentiation of the weights.

In contrast to this, Figure 8 shows a differentiated weight for the wind instruments (excerpt from the same segment of the 4th movement as in Fig. 7). But as we can see, the greatest weights are located not on the first and third beat of the bar, but on the “weak” second and fourth beats. This kind of differentiation can be observed quite often within the works of Brahms and is one of the characteristics of the metric ambiguity of his Œuvre, as mentioned for instance in (Frisch, 1990) and in (Epstein, 1987).

The separate analysis of another part of this segment of the movement, the analysis of the first violins in Figure 9, results in a differentiated weight as well, but the greatest weights are located on the first and third beat of the bar, the “strong” beats.

By comparing the results of the metric analyses of this segment of the 4th movement for the different instrumental
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In the first half of the figure the greatest weight is located on the second beat of the bar, not on the first beat.

The metric weight of the string instruments in Figure 12 shows no hierarchy between the weights of the first and second beat of the measures in the first half of the section.

By comparing the results of the metric analysis of this section of the 3rd movement for the different instrumental groups we can observe that the very regular metric structures evolve within the interplay of all instruments by mutual backing.

While a musician is recommended to establish intentional coherence predominantly within his/her group in order to strengthen the sovereignty of his/her playing in the section of the second symphony (Figs. 6–8), he/she should experience his/her own part as a contribution to the interplay of all instruments in the above section of the fourth symphony.

3.3. Towards an empirical investigation

The question whether different types of analytical coherence between the score's layers and parts — as suggested with groups we can observe complementary structures between the wind instruments on the one hand and the violins on the other, whereas the combinations of all instruments as in Figure 7 result in an inner metric weight without any regular differentiation at all. The different voices interact complementarily in such a way that the analysis of the entire composition results in a metric weight with a lack of any significant differentiation whatsoever, due to mutual annihilation.

A strikingly different example concerning the metric interplay between different voices is the first part of the 3rd movement of the symphony No 4 (time signature: 2/4).

The metric weight of all instrumental parts (bars 1–92) in Figure 10 shows a regular structure which even corresponds to the metric accent of the bar. The greatest weights are located on the first beat of the bar, followed by the weights of the second beat, whereas the offbeats of the bars receive much lower weights. Metric coherence can be observed.

The metric weight of the wind instruments in Figure 11 does not show the same hierarchy within the entire section:
respect to the examples on the basis of metric weights – are significantly correlated with different kinds of collective interaction during a performance can up to now only be answered conjecturally, since no empirical investigations are known to us.

There are at least indications of the effects of how well metric structure is expressed during a performance to (passive) listeners depending on different degrees of metric coherence. These types of listening experiments have been performed by means of RUBATO-performances (for more details see Fleischer, 2002). Drum rhythms were played with various structures of accentuation, arising from metric weights of different degrees of coherence. For example, by comparing different metric weights of the same piece as in the case of the already mentioned Credo movement of Bach’s Mass in B Minor, listeners were asked which accentuation clarified a metric structure more convincingly. As the outcome of the experiment conducted with 46 persons, a relationship was detected between metric coherence and the understanding of the corresponding interpretation by the listeners. 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. This result may be taken as an indication for a relationship between analytical structures of the score and the understanding of the performed music by listeners through suitable expression of these structures within a performance.

In how far similar effects can be experimentally proven for the collective listening and playing of musical ensembles must be subject of further empirical investigations. A promising and simple setup might consist of a hybrid duet of a human musician and a computer-controlled artificial musician.

4. Conclusion

We approached the investigation of collective performance of score-based music from two sides. On the one hand attention was paid to some characteristics of the collective acting of musicians in contrast to a mechanical orchestration. On the other hand it was argued that a deeper understanding of a performance requires a profound investigation of the musical structure beyond a mere “prima-vista” reading of the score. As a bridge between the two levels of description the concept of coherence was specified in two ways. A collective of musicians achieves a high degree of intentional coherence if it is able to maximize the sovereignty of the individual acts of articulation. By applying Jean Molino’s concept of musical communication to the inner regulatory processes of a performance one concludes that intentional coherence of an ensemble cannot be established through an unidirectional hierarchy of directives. Analytical coherence occurs whenever there are correlations between the results of different analytical perspectives on the same composition, provided the fact that these correlations are not already implied by an interdependence of the underlying approaches as such. The RUBATO software offers experimental access to artificial performances that are fully controlled in terms of analytical data encoded in analytical weights. With the special case of metric weights we discussed the concept of metric coherence and thereby exemplified the general idea of analytical coherence. Comparisons of simple analytic perspectives do of course not appropriately grasp the intentional particularities of individual musicians. In other words, the two levels of description are still far from being connected in a satisfactory way. The design and execution of more elaborate experiments may nevertheless provide a suitable bottom-up approach in order to eventually develop a more precise concept of intentional coherence.

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References

Biographies of Anja Fleischer and Thomas Noll

Anja Fleischer graduated in musicology in 1996 and in mathematics in 1998 at the Humboldt University, Berlin. Since 1998 she is a member of the Interdisciplinary Research Group for Mathematical Music Theory at the Technical University in Berlin. She defended her doctoral thesis: “The analytical interpretation. Steps towards the development of a research field exemplified by metric investigations” in 2002. The doctoral thesis concerns the relationship between analytic structures of the score and the expression of these structures in a musical interpretation or performance which was experimentally tested by modelling computer-aided analyses and performances. Her main research field concerns computer-aided models for music-theoretical research and the empirical investigation of their music-theoretical signification, whereas harmonic and metric analyses are of special interest.

Thomas Noll graduated in mathematics in 1989 at the Friedrich-Schiller, Jena and did his doctorate in semiotics at the Technical University of Berlin on the morphological study of musical harmony in 1995. Since 1998 he is the leader of an interdisciplinary research group KIT-MaMuTh (www.mamuth.de) for Mathematical Music Theory at the Technical University in Berlin. His research is concerned with tone apperception, harmony and the integration of mathematical models and computer-aided experiments into music theory.