Adaptive Musical Expression from Automatic Realtime Orchestration and Performance

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Abstract. When scoring an interactive scene or narration music has to follow its events and development organically. Approaches toward musical nonlinearity are needed. Therefore, the means of orchestration and expressive performance provide a big potential that has not been tapped even a little yet. In this paper we will show how to translate them into the interactive context. But to change musical expression it is not feasible to simply switch hard between different instrumentations and performative styles. We introduce and discuss a new style-independent method for organic and musically believable transitions of compositional and performative expression characteristics.

Keywords: Interactive Media Music, Music Adaption, Orchestration, Expressive Performance.

1 Introduction

Music that is applied to different media (e.g., text, dramatic plot, moving image) fulfills a multitude of functions. Especially in the film medium the bandwidth of its narrative functions is extensive: it mediates mood, cross references, emotionalizes, comments, affects the attention of the audience, establishes continuity, structure, and form etc. [1]. The use of music in interactive media, for instance, computer games, artistic and multimedia installations, is aimed at the same tasks. An overview and critical discussion of narrative music concepts for interactive media and stories is given in [2].

But when scoring interactive media a main challenge arises from an ontological differentness. In contrast to the interactive scenario, music is statically predefined, its playback is extensively linear and unable to organically follow short-term changes in the interactive context. It appears as permanently cut fragments without coherence and reveals an indifferent relation to the interactive scene. While film music coped with this well-known excoriated teething troubles half a century ago [3,4,5], interactive media music still suffers from it.

Though music does not have to be linear and musical structure offers a lot of starting points to promote adaptability, few has been done in this area yet. After an overview of approaches to music adaption in Section 2 we will give a

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short music theoretical discussion in Section 3 to introduce the musical basis for our approach to organically change musical expression characteristics in realtime during playback in Section 4. Section 5 provides a conclusion.

2 Overview Music Adaption

To link music and interactive scene it is always necessary to gear into the currently playing musical material. According to the type of intervention three different strategies can be differentiated: compositional approaches, generative, and a hybrid combination of both.

The **compositional approaches** leave the process of creating art at the real artist, i.e., the human composer. All musical material is precomposed; realtime adaptions are of an arranging nature. The composer enables this by specific architectural inner musical features. To rearrange the sequential order of musical sections (cf. classic musical dice games [6,7,8,9]) their melodic, harmonic and metric connectivity must be postulated. Fading techniques and the combination of simultaneously playing tracks (as applied in [10,11]) premise that they harmonize tonally and metrically with each other.

By contrast, **generative approaches** take over the composition process and create musical data in realtime. Changes can be induced by the manipulation of parameters that affect the behaviour of functional and algorithmic descriptions [12,13,14] or aspects of the internal representation of contrapuntal styles (e.g., neural networks [15] or knowledge bases [16,17,18]) that regulate the generation process. Other music generators are based on templates (e.g., melodic fragments, harmonic progression patterns) that specify a more or less rough direction of the generation process and constitute another way for interaction [19,20,21].

To combine both, the unsurpassable artistic quality of human composed music and the higher flexibility of generative approaches, the mixture of both, the **hybrid approaches**, pursue the strategy to adapt precomposed pieces of music in realtime to transition seamlessly between the running musical material and that of another piece [22,23,24,25] or to change the expressive character of the one running piece.[1]

In this last field the *CMERS* system of Steven R. Livingstone constitutes one of the most sophisticated solutions [26,27]. A number of compositional and performative attributes, namely major/minor mode, average pitch, harmonic complexity, tempo, dynamics, and articulation were mapped onto the emotive load of (western tonal) music which can be changed according to these attributes in order to achieve a different character of expression within the same piece of music. Since emotional changes were less significant when the performance was "too mechanical"[28], it was further "humanized" by the application of Anders Fribergs *KTH* rule system [29,30].

The present paper is engaged in this field, the adaption of performative expression characteristics of a piece, and will elaborate and discuss a new approach

[1] The representation format has to allow such in detail manipulations, as *MIDI*, for instance, does. Wave based formats (Wave, MP3, Ogg Vorbis etc.) are less applicable.

based on musical orchestration principles. The next section will introduce the theoretical background.

3 Musical Issues

Up to now, few attention has been given to aspects of the inner-musical coherence when adapting a piece of music. How to transition different performance styles without conflicting with the work's compositional architecture? How to effect organic changes within the compositional material? These are the most relevant questions and prominent problems in music adaption, since they directly affect the believability and success of any changes. Beyond the matter of emotionality it is also essential for the music's symbolic charge, tonality, and in consequence its transparence, comprehensibility, and psychomotor impact (consider the rhythmic stumbling when variations conflict with the metric order).

In [31] we elaborated a structure protective adaption policy for the creation of transitions between different pieces. These partly apply to inner-musical transitions as well, but need further supplementation and specification for this special situation which is less an instance of a contrapuntal compositional task than a performative and orchestrational one. Hence, musical orchestration principles provide numerous important cues for structure-aware inner-musical transition techniques.

The following subsections will provide an introduction to the topic of orchestration and implicate the role of the expressive performance.

3.1 Orchestration: A Concretion

First of all we have to distinguish the terms *orchestration* and *instrumentation* that may not be confused in our further descriptions. With our definition we follow the one of musicologist Ertuğrul Sevsay [32].

Instrumentation is concerned with the combination of alike or different instruments in order to achieve a desired tonality and timbre. Issues are dynamic balance, timbral contrasts or similarity, articulation, the use of different pitch registers and playing techniques of instruments.

Orchestration deals with aesthetic aspects of a composition's instrumentation in order to create, increase, or decrease contrasts between musical sections to realize or emphasize its musical charge, mood, or general character. Since timbre is easier perceived than formal aspects orchestration is an essential tool for the clarification of musical form and the establishment of transparency. When developing transition techniques for different orchestrations of a composition this has to be kept in mind.

Thus, instrumentation comprises the technical implementation of aesthetic intentions in orchestration. This paper deals with both. Further detailed introductions to instrumentation and orchestration can be found in [32,33,34].

As articulation and dynamics were already mentioned as a matter of instrumentation the performative aspects of music cannot be ignored. The next subsection will focus on the means of an expressive performance.

3.2 Expressive Performance

The expressive performance of a piece of music goes beyond the 'right notes at the right time'. Each musician adds further performative content to the musical raw material to emphasize artistic intentions and to mediate musical content and form. These performative means of expression are:

Dynamics comprises 'loudness' instructions (step dynamics) and continuous changes between different loudness levels (crescendo, decrescendo). Dynamic bows are important means to articulate melodic phrases. Furthermore, an orchestral crescendo is a popular means in film music to lead into dramatic scenes.

Tempo describes the beat count per time unit (e.g., 100 beats per minute). Just like dynamics it features two different shapes, stepwise and continuous (ritardando, accelerando) tempo changes. The active work with subtle acceleration, slowing, and delay resolves the impression of a mechanical performance and is important for the figuration of climaxes, melodic destinations, and structural borders. The work with tempo can influence the perception of the pace of a scene (flowing, hastening, or static).

Emphasis of beats in a bar can be regarded as a micro-dynamical scheme that defines (several) weightings within each bar. A relatively flat scheme can create a majestic or equably fluent pace depending on the underlying tempo and metric density. Strong emphasis differences establish a more rhythmic and agile shape.

Articulation describes the way a note is formed. It can affect its dynamic emphasis (e.g., accent, marcato, sforzato) and its length (e.g., staccato, tenuto, legato). Articulation has a major impact on the character of music; a cantabile melodic line (legato) becomes more snappy with a staccato articulation.

Tuning has to be considered especially for the interpretation of several ethnic musics in proper style. The equally tempered scale is not the only temperament; for medieval music the just temperament is more appropriate; several 20th/21st century composers intentionally put instruments out of tune to achieve a special timbre (e.g., in several cues of the Sauron/Mordor theme in Howard Shore's *The Lord of the Rings* scores).

Effects can be classified into two categories, technical and articulational effects. The technical effects (e.g., hall, echo, flanging) are created in the sound studio or are a result of the acoustic situation at the location of performance. Acoustics is an important means to mediate breadth, wideness, or intimate nearness. Articulational effects (glissando, triller, bend, fall, vibrato) are performed by the musician. Both fill the performance with life and presence.

Beside these intentionally applied means of expressive performance there is a further unconscious aspect influencing the audible result. Human musicians cannot play and reproduce a piece of music as perfect as a computer. There are little variances in all aspects of the performance, the synchrony of parts, and timbre. These depend highly on the musical context (Is it difficult to play? Was the previous tempo faster or slower than the new one? Does the part play at the borders

of the instruments gamut or on a comfortable level?) and are less significant with professional musicians. However, the problem of *humanization* can be regarded as independent from artistic intentions irrespective of exceptions where the composer plays on (in-)abilities of particular musicians to achieve some uncertain effects. Thus, it will play no further role in the following considerations.

The next section will describe and discuss our approach towards a smooth musical nonlinearity by means of orchestration and expressive performance.

4 Automatic Adaption of Musical Expression

One and the same composition can be orchestrated and performed in very different ways. While the instrumentation and performance data for each version can be created statically in advance by the composer, editor, performer, and/or (at least partly by) a performance system [30,35] the transitions between them are triggered by interaction. They can arise at any position and from very different musical contexts. Creating predefined transitions would considerably raise the practical effort and limit the bandwidth of expression within each version; static transitions are insufficient! The possibilities of human musicians end at the point were transitions have to be created in realtime during playback. In this Section we will describe our approach to this problem of which Figure 1 gives a system overview.

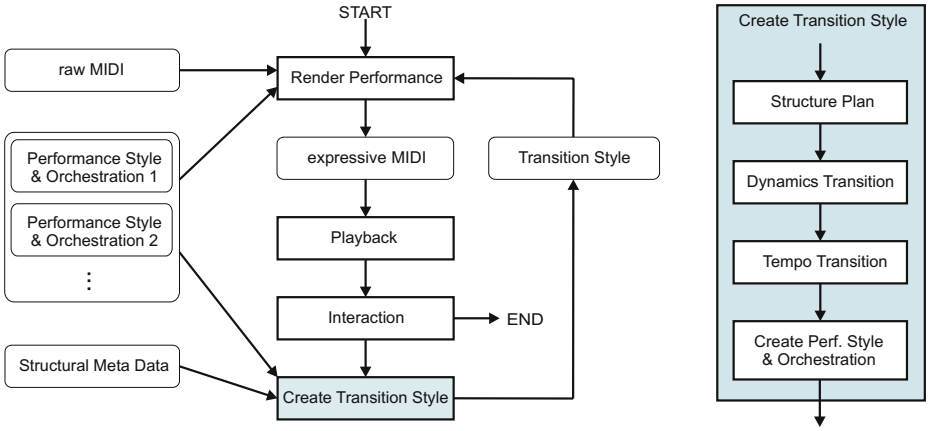

Fig. 1. A system overview of the approach to realtime adaptive orchestration and performance

All implementations were done in C++. As a MIDI-API we used MidiShare [36] which also includes a realtime processing system for MIDI messages. Since the MIDI standard does only support stepwise but no continuous tempo changes, except with lots of very small steps, we implemented an own tempo representation and associated time conversion algorithms for continuos nonlinear tempo progressions.

4.1 Aims

Good transitions melt organically into the music, thus, they seem to be precomposed as well. Therefore, they must not conflict with the musical material. This applies all the more for orchestration and performance, since they are aimed at the reflection and emphasis of this material. Thus, the use of transitional means has to *be justified in the compositional structure*.

Furthermore, a successful transition has to *be efficient* in the way that it varies the running material as little as necessary to get a proper connection to the target material to strengthen the overall coherence.

In the interactive context *latency* is another matter of importance and a fundamental conflict arises: musical change processes need a certain time (the longer the smoother). On the other hand, big latencies are disadvantageous for interactivity, hence, unwanted. Transitions have to take place in the time frame conceded by the application and it must be possible to adapt also a running transition (transition out of a transition) in order to provide the *flexibility* to follow short-term interactions musically.

4.2 Preconditions

An interactive scene is accompanied by different instrumentations of one and the same composition. These emphasize different aspects, e.g., different themes linked to specific elements of the scene while others are masked out, weaved into the accompanying texture, or muted. The same applies to multiple different performance styles that define the way each part should be played. These information are given in separate meta files accompanying the raw MIDI data and are rendered into an expressive MIDI sequence directly before starting the playback.

These different performance styles are stored in an XML data structure comprising information about tempo, dynamics, articulation, and emphasis schemes. Moreover, they declare parts/tracks to be looped, played back only once, or muted in that particular style. The styles do not only describe performative details, but implicate also orchestrational intentions. Different instrumentations, their particular dynamic balance and playing techniques are implemented, e.g., by means of dynamics and articulation.

Per piece of music there is one more file providing information about the time signature and macrostructure locally for each part, or globally for all. Three macrostructural levels are differentiated (listed in decreasing granularity): section structure, phrase structure, and figure structure (motif level). Since, e.g., the last note of a phrase is often already the first note of the next, structural elements are not mutually exclusive, in no strict hierarchical order, and can overlap. This has also been considered in the design of the representation format.

4.3 Approach

To change the style of performance the MIDI data has to be re-rendered. But instead of directly changing the MIDI data a new performance style, the *transition*

style, is created that imports the elapsed beginning of the piece in the current style and the forthcoming rest of the piece in target style. The *transitional section* itself with its certain timely extend is situated intermediate. On the basis of this new style the raw MIDI data can be re-rendered very fast during playback. Since the *transition style* is virtually an autonomous self-contained style it can be the starting point of further transitions, even out of the running one (see the postulate of flexibility in Section 4.1). At the end of the piece, when it is going to be looped, the raw MIDI data is rendered completely in the actual target style.

To create the *transitional section* a systematic approach is implemented. On the basis of musical meta-structure the best suitable start and end points of the transition are determined. According to them the transition of dynamics and tempo is planned in detail. The following explanations will address these aspects. Merely articulation and emphasis scheme are switched directly at the end point, since any interpolations would produce pallid softened results, which is not desired. The switch, in contrast, is a further musically reasonable emphasis on the point where the target style is reached, mediating the impression of deliberate intention.

Structure Planning. Two different application-given latency specifications have to be held: the *begin latency* marks the maximum duration until the transition has to start and the *maximum transition duration* delimitates its timely extent.

Within these latencies the nearest structural borders and their suitability are determined. Structural beginnings are most interesting for new cues of muted parts and for the beginning and end of the transition of already playing parts. Phrase and section beginnings are preferred transition target points (strong ends). If none can be found within the latencies the beginning of the next figure is chosen. It still represents a new content-related beginning, even if not as strong as sections and phrases (weak end). Beginnings are suitable transition target points because from then on a new compositional material starts in the new style; the performative style change reflects compositional structure, thus, appears more appropriate and believable. Structural endings are only interesting to end running parts, since they literally come to an end at these points and should not begin something new.

Such structural borders can not always be found within the latency demands. In this case metrical attributes provide the basis of further planning: If no structure-related starting points can be found within the begin latency the transition begins immediately at the current playback position (weak start). If structural end points are out of range the last emphatic beat within the latency is chosen, which is usually the first beat in the last feasible bar (weak end). Thus, the transition is as long and smooth as possible and its end is placed at an accentuation still providing the feeling of target orientation.

This structural plan forms the basis when applying articulation and emphasis changes and planning the details to transition dynamics and tempo.

Dynamics Transition. Real music instruments usually cannot fade in from or out to zero; normally there is a clearly audible point when they start playing

or stop. New cues for muted parts and endings for running parts by fading, in contrast, produce a more mechanical unnatural impression and should be avoided as far as possible and reserved only as a makeshift in the case of weak borders (this rule does not apply to transitional (de-)crescendos of running parts that play on). If strong entry and exit points were found the parts start/stop directly. Those that stop do additionally lower their volume to $4/5$ of the original level to dynamically trace the gesture of ending; even if this still results in a crescendo it is nonetheless a reserve in the context of the other parts and the musical flow.

For the transition of ongoing parts the dynamics instruction in the target style that is nearest to the structural transition end and inside the latency is chosen as target of the dynamics transition. Its predecessor in the current style marks the starting point. If no dynamics instruction can be found, start and end points are identical to their pendants from the structure plan. The transition between different dynamic levels is generally done with a smooth (de-)crescendo, unless the target instruction defines step dynamics. In this case two different target values are possible, the lower and the upper value of the step. Following the postulate of efficiency (as little change as necessary; see Section 4.1) the value that is nearest to the target value in the current style is chosen.

Tempo Transition. Different tempi are transitioned in the same way as dynamics. But while dynamics can be treated exclusively for each part, tempo must always be global for all parts to keep them synchronous. Therefor, the earliest structural transition start and the latest end point over all parts (unification of the structure plans of each part) is taken as the basis of the tempo transition plan.

4.4 Results

Since a music theoretical analysis provides a substantially more precise armamentarium to discuss the performative and orchestrational quality of transitions than a user study with musically more or less well trained participants we concentrate on a music theoretically shaped discussion in the following.

The approach outlined in this Section opens up a multitude of new possibilities to composers and orchestrators for scoring interactive media. Adaptive expressive performance and orchestration are mighty tools that can shed very different lights on a composition. Combined with the principles of *elastic scoring* (a part can have different instrumentations, expansion and reduction of the number of parts, see [37,38]) and *building set music* or the baroque manner of *rural composition* (optional parts that can be left away, see [10,39]) it is even possible to, beyond timbral changes, flex the compositional form.

All the different versions of a piece of music can be prepared manually by a human artist or (semi-)automatically even during its performance, thus, high artistic quality can be provided. They can be transitioned with much better musical sensibility now. Transitions at strong structural borders (section and phrase borders) are relatively direct, since they fall together with the end and beginning of formally self-contained form elements. At weak positions these changes are done more carefully and unobtrusively.

The independent treatment of tempo and dynamics according to their own structure helps to give the transition a less constructive mechanical impression. It melts more organically with the structural transition plan that only gives a rough orientation. Thereby, e.g., the upbeat character of a figure (its structural borders are not identical with its gestural stress point) can be kept.

However, the current tempo and dynamics transition strategy is to adapt only the region between two instructions, i.e., one (de-)crescendo, ritardando, accelerando or constant area. This approach has its limits: adaptions of very fine granular tempo or dynamics maps produce quite sudden rapid changes that conflict especially with smooth transitions. This can be resolved by carefully interpolating or damping the values of all previous instructions within the transition borders toward the target value of the transition. Therefor, we suggest a potential interpolation to be able to parametrically steer the subtleness of divergence.

These considerations lead to a further question: Do tempo and dynamics transitions need a certain minimum length? In the case of stepwise changes the answer is no. But for continuous changes the overall frequency and amplitude of changes should be taken into consideration. Very different tempi and dynamics need more time to transition smoothly than small nuances.

In the outlined approach we left away the performative aspects of tuning and effects. Thus, following a few remarks on this: It is not suggested to interpolate two different tuning systems during the transition since this produces new and generally unintended tunings that could conflict with compositional intentions. It is recommended to switch them at the structural end of the transition where the target style is achieved, just like emphasis and articulation. Consequently, articulational effects should be handled in the same way, while technical and acoustic effects should be transitioned gradually to add or remove them smoothly to/from the performance.

Aside from dynamics, articulation is another mighty instrument to realize *micro orchestration*, i.e., subtle color variation details, and it can even be "misused" to mute individual notes in order to add or remove, e.g., passing notes or melody variations. Actually, this *mute articulation* provides an interface for nonlinear melodies, articulational effects, and in a harmonic context it can be used to switch between different modes: According to the current performance style a part can play the major or minor third of a triad.

Furthermore, a special performance style that mutes all parts, defines a slow tempo, and lowers the dynamic level can be "misused" in the way that a transition to this style is equal to ending the piece. In case of weak transition end borders it results in a fade-out, but at strong end borders the parts stop directly. Combined with the ritardando and decrescendo a believable finishing gesture is obtained. This works best when all parts have synchronous end points and the transition is not too short to give tempo and dynamics enough time.

In several test scenarios our transition technique has shown a strong stability over the density and completeness of structural meta data. Even in the complete absence of such information the results, although less structure-based, do still

bare a diffuse structure consistency because of the orientation on emphatic stress points and the slight independence of tempo and dynamics planning, which still reflect the compositional structure as described in Section 3.

Since the performative attributes and the way they are handled is largely style-independent, a good stability is also given over different musical styles. Problems may arise with contemporary musical forms. An extensive analysis of stylistic compatibility and the bandwidth of expression that is possible within one composition constitutes a direction of future investigations.

5 Conclusions

The potential of a nonlinear orchestration is largely unexplored, yet. One and the same piece of music can cover a wide range of expression by different orchestration and performance style renderings. We have elaborated and discussed an approach to transition them coherently to resolve the most prominent problem of inconsistency of style changes. Therefor, the structure of the piece of music and its consequential performance attributes played the fundamental role. Hence, the transitions do no longer conflict with the formal structure of the piece and incorporate into it.

By interaction-driven musical change processes a new structural layer emerges that is linked to the interactive context/narration. In the same way as music constitutes the inner structure of films, which is much harder to mediate by visual means, it enriches the interactive medium, helps for a better understanding of narrative coherencies, and mediates nonvisual and nonverbal annotations and connotations. By coherent transition techniques these emanate organically from the musical flow and are more successful because of their stronger believability.

Future work has to musicologically investigate the compositional possibilities opened up by the presented approach. Music/performance production tools for users without XML-programming knowledge (musicians are nonprogrammers in general) are needed. Furthermore, the focus will be on the exploration and development of further approaches to open musical form structures for nonlinearity.

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