Composition and Arrangement Techniques for Music in Interactive Immersive Environments

Axel Berndt, Knut Hartmann, Niklas Röber, and Maic Masuch
Department of Simulation and Graphics
Otto-von-Guericke University of Magdeburg
P.O. Box 4120, D-39016 Magdeburg, Germany
http://games.cs.uni-magdeburg.de/

Abstract. Inspired by the dramatic and emotional effects of film music, we aim at integrating music seamlessly into interactive immersive applications — especially in computer games. In both scenarios it is crucial to synchronize their visual and auditory contents. Hence, the final cut of movies is often adjusted to the score or vice versa. In interactive applications, however, the music engine has to adjust the score automatically according to the player's interactions. Moreover, the musical effects should be very subtle, i. e., any asynchronous hard cuts have to be avoided and multi-repetitions should be concealed.

This paper presents strategies to tackle the challenging problem to synchronize and adapt the game music with non-predictable player interaction behaviors. In order to incorporate expressive scores from human composers we extend traditional composition and arrangement techniques and introduce new methods to arrange and edit music in the context of interactive applications. Composers can segment a score into rhythmic, melodic, or harmonic variations of basic themes, as known from musical dice games. The individual parts of these basic elements are assigned to characterize elements of the game play. Moreover, composers or game designers can specify how player interactions trigger changes between musical elements. To evaluate the musical coherency, consistency, and to gain experience with compositional limitations, advantages and possibilities, we applied this technique within two interactive immersive applications.

1 Introduction

In movies and theater, directors and composers employ musical elements and sound effects to reinforce the dramatical and emotional effects of pictures: scores can bring a new level of content and coherency into the story-line, can invert the picture's statement, or can insert elements of doubt or parody. However, these effects have to be very subtle as they are intended to be perceived subconsciously. Only in this way — through by-passing the process of concentrated listening and intellectual understanding — the music can establish it's emotional power (cf. [10, pg.22ff]).

In the post-processing of movies, directors, cutters, and composers cooperate to intensify their emotional impact. One — very critical — aspect of this procedure is the careful synchronization of the visual and auditory contents. Usually, the final cut of movies is done according to the underlying score.[1]. Hence, musical structures become a pattern for scene cuts and transitions. Often, pictures and music seem to be of a piece: *scene* and *content transitions* (actions and events within a scene) melt in the music. In the opera this is even more extreme: nothing happens without a musical trigger. This is only possible due to the static nature of these linear media: all transitions are known and have been adjusted with the score.

In interactive immersive applications such as computer games, however, the music engine has to adjust the score automatically according to the player's interactions. Very often pre-composed musical elements or pre-arranged sound effects are triggered by some elements of the game play. This problem is intensified by the asynchrony between game elements and player interactions: very often the music engines of computer games simply disrupt the currently playing music regardless of its musical context in order to start the next piece of music. These *hard cuts* destroy inner musical structures that we are used to hear and thus eventually break the game's atmosphere. Because of music cultural typification and preparatory training of the listener he perceives music with a certain listening consuetude. He is used to hear musical structure even unconsciously. That is why humans would recognize hard cuts even while hearing some piece of music for the very first time. In addition, the succeeding music requires at least a few seconds to evolve its own atmosphere — time of an atmosphere-less bald spot. All these factors lower the immersion of the user into the virtual world, which is particularly dangerous in all application domains where music is used to intensify the immerse of the user into a virtual environment.

To solve this antagonism between static musical elements within dynamic interactive environments one may be tempted to formalize music composition and delegate the creation of background music to automatic real-time generators. Even though the development of automatic composition systems has been one of the first challenges tackled by researchers within the field of artificial intelligence (see for instance Hiller's & Isaacsons' automated composed string quartet "Illiac Suite" [8] and the overview articles [16, 4]), the qualitative problem is apparently clear. Despite of the long research tradition, the majority of these systems are specialized to a single musical style (e. g., chorales in the style of Johann Sebastian Bach [5, 6]) or tootles more or less pseudo randomly tunes (due to the lack of high-level musical evaluation criteria for optimization methods [3, 7, 13, 11] or machine learning techniques [21]; due to the application of stochastic methods such as Markov chains [8]). Another conflict with our intention to integrate expressive musical elements in interactive immersive applications results from a major strategy of research in computer music: researchers manually extract rules or constraints from textbooks on music theory or develop algorithms which automatically

[1] Schneider describes this from the composer's point of view [19] and Kungel goes deep into the practical details considering also the cutter's concerns [10].

extract them from a corpora of compositions and use them to generate or evaluate new tunes. But as any composer will notice, a pure adherence to these rules neither guarantees vivid compositions nor do great compositions follow rules in all respects. An agile musical practice constantly defines new musical patterns and breaks accepted rules in order to achieve expressiveness and a novel musical diction. Therefore, we decided not to replace the human composer by an automatism. The music should still be written by an artist, but it has to be composed in a way that it is re-arrangeable and adaptable in order to adapt the game's music with non-predictable player interaction behaviors.

The following sections describe one way to achieve this goal. The compositional roots of our approach are introduced in Sec. 2. Sec. 3 describes a music engine which acts like a kind of real-time arranger. Sec. 4 demonstrates the application of this technique within two interactive immersive applications. Sec. 5 summarizes this paper and motivates directions for future research.

2 Compositional Roots

Compositional and arranging techniques as well as the musical practice already offer a number of methods which can be used to make music more flexible and to adjust the length of musical elements to a performance of unpredictable length. There are two basic problems in the synchronization between musical and performance elements: (i) the duration of a given musical element might not suffice or (ii) the performance requires a thematic break within a piece.

There are several strategies of composers and musicians which are useful to tackle the **first problem:** *to remain at some musical idea while keeping the musical performance interesting.*

The simplest solution is to extend the length of a musical element — the whole piece or just a segment of it can be repeated or looped. This practice is used to accompany e. g., folk dances, where short melodic themes are usually repeated very often. The *infinite loop* is also known from the first video games and can still be found in recent computer games. Examples therefore are Super Mario Bros., the games of the Monkey Island and the Gothic series.

By exploiting the different timbres of the instruments in an orchestra the *instrumentation* or *orchestration* opens up a second dimension. The composers of *building set movements* actually surpass the instrumentation technique [12]: their music can be performed by all notated parts at once or just by a few of them. Different combinations are possible and can be used to vary the performance of different verses. Nonetheless, every part-combination sounds self-contained and complete. This composition manner has its roots in the baroque practice of *rural composition.* Baroque composers like Valentin Rathgeber (1682–1750) [17] wrote such music with reducible choirs and instrumentations for congregations with minor performance potentials. Today this acquirement is nearly extinct.

In the whole polyphonic music there is not always just one leading part with an own melodic identity. Heinrich Schütz (1585–1672) already taught his students to compose in *multiple counterpoint*, i. e., the parts can be interchanged [15]. Every voice has its individual identity. Ergo the soprano can be played as a tenor, the bass as soprano and so on. Here every voice can be the upper one, can be "melody". Johann Sebastian Bach (1685–1750) demonstrates this impressively in his multi-counterpoint fugues.

Musical dice games show another way to bring more flexibility into the music. The basic principle is that composers create groups of interchangeable musical elements which are randomly selected during a performance. Johann Philipp Kirnberger's (1721–1783) [9] and Wolfgang Amadeus Mozart's (1756–1791) [14] dice games base upon a common harmonic structure: all interchangeable group elements are short (just one bar) and are based on the same underlying harmonies. In order to "compose" a new piece, the player selects elements from sixteen melody groups by throwing a dice. Jörg Ratai [18] extends this idea by exploiting chord substitutions and harmonic progressions, so-called *jazz changes.* The basic compositional principle is to replace elements within a harmonic context by appropriate substitutions (e. g., borrowed chords). While the basic blocks of Ratai's *jazz-dice* contains manually composed harmonic variations, Steedman [20] proposed an automatic system employing recursive rewriting rules. Even though Ratai's system is based on a simple 12-bar blues schema, it achieves an enormous harmonic variance.

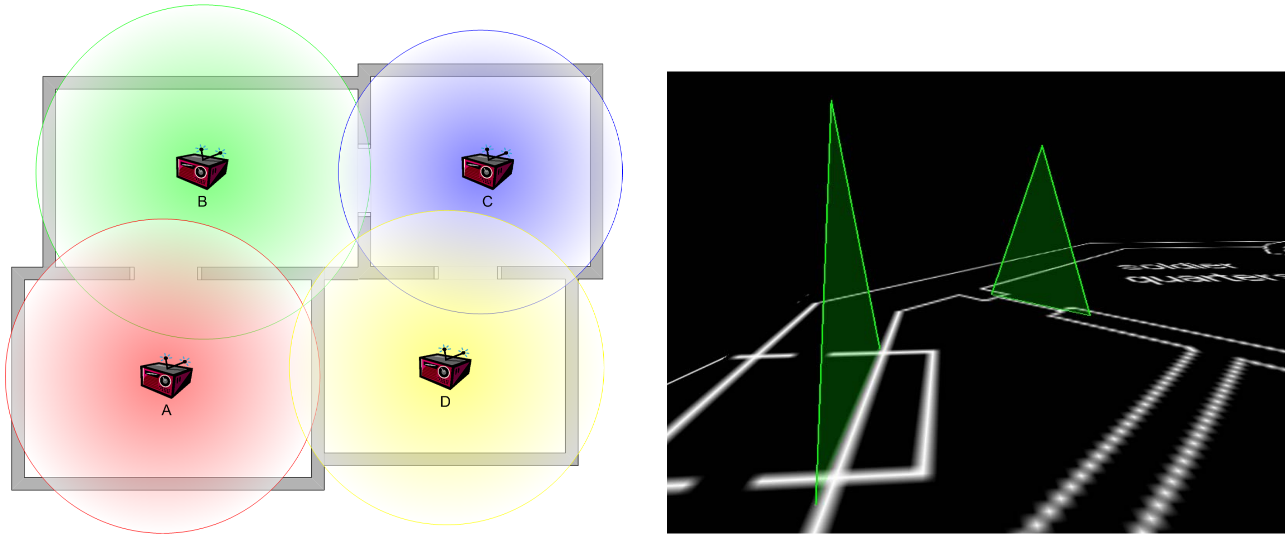
Other musical arrangement techniques — *abbreviations* and *jumps* — can help to overcome the **second problem:** *the smooth transition between musical elements.* Sometimes composers or editors include special marks into the score indicating that the performer can jump to other musical elements while omitting some segments (e. g., *da capo* or *dal segno*). A few game music use this method to ensure that the music is not cut at any position but only on these predefined ones (e. g., only on the barline like in Don Bluth's music for the game "Dragon's Lair 3D").

A non-compositional technique which is used quite often by disc jockeys for transitions between different pieces of music or sounds is the *cross-fade.* Cross-fading means, while the currently running music fades out the next piece is started and fades in. During this time both pieces of music are hearable. This bares a big problem: both pieces of music might not harmonize. In particular differing tempi, rhythmic overlays, and dissonant tones might be quite confusing to the listener. Hence, one cannot cross-fade arbitrary musical pieces ad libitum.

Computer games aim at immersing players into a **three dimensional** virtual environment. Interestingly, the *multi-choir music* of some Renaissance composers already integrated the three dimensionality of real world in some way into their compositions. The choirs (here this term also includes instrumental groups) were separated by open ground and placed e. g., to the left, right, front and/or back of the audience. One of the greatest and most famous representatives for this practice of composition and performance is the Venetian Giovanni Gabrieli (1556/57–1612). The listener can have quite different musical experiences by changing his own position in the room. He can hear the choirs playing alternately, communicating with and melting into each other bringing the whole room to sound. This can also be considered as *surround music.* Every choir has its own identity but all together build a bigger musical sound-scape.

In their analysis, Adorno and Eisler [1] already pointed out that traditional music structures do not work within the new medium film, where the music (i) once had to become formally more open and unsealed and where (ii) composers had to learn following rapid short-term scene structures. But while new compositional techniques and musical forms have been successfully established for film music, the development of compositional techniques for music in interactive media is still in the beginning.

In modern computer games, the development of a non-linear arborescent background story adds another dimension to the three dimensionality of virtual worlds. In contrast, music is only one dimensional with a fixed beginning and end where everything in-between is predefined or pre-composed. The musical techniques outlined above are able to add further dimensions to game music:



(a) Distributed Music

(b) Music Change Marks

Figure 1: **(a)** Sound sources and their radii in the distributed music concept.**(b)** Passing music change marks triggers musical changes.

instrumentation changes, building sets, and the melodic independence of interchangeable parts within a counterpoint score can vary the sound impression of a single musical element whereas musical dice games can even vary musical content; loops, abbreviations, and jumps can stretch and shorten the timely disposition. All these techniques have to be combined in order to tackle the problematic synchronization between musical and performance elements. Moreover, the multi-choir manner offers a way to integrate spatial dimension within the composition. Now we go a step further and introduce a way to gain actually four dimensions and consider user interactions.

3 A Music Engine as Real-Time Arranger

"Games may owe something to movies, but they are as different from them as movies are different from theater." This statement of Hal Barwood[2] also applies for the music of computer games: the player's integration in a three dimensional virtual environment, a non-linear arborescent background story, and unpredictable user interactions prevent the direct application of traditional techniques or film music composition techniques and sound elements designed for movies in computer games.

The previous section revealed the main problem of a music engine in interactive immersive applications, especially in computer games: the automatic adaptation of the score automatically according to non-predictable player interactions. Moreover, all game elements should be designed in a way that prevents losses of immersion. Hence, sound elements have to be integrated into the virtual world and all musical effects should be very subtle, i. e., any asynchronous hard cuts have to be avoided and multi-repetitions should be concealed.

This paper presents a new method to compose and arrange scores for interactive immersive applications. Composers can segment a score into rhythmic, melodic, or harmonic variations of basic themes, as known from musical dice games. The individual parts of these basic elements are assigned to characterize elements of the game play (e. g., objects, actors, locations, and actions) or narrative elements. Moreover, composers or game designers can specify how player interactions trigger the selection of appropriate parts from a given score and changes between musical elements.

The following subsections will describe the several aspects of music arrangement and composition that promote the adaptation of musical structure to interaction space structure.

3.1 Overview

The basic principle of our music engine is the integration of musical elements into the virtual world and the re-arrangement of pre-composed musical pieces in real-time.

We introduce the concept of *parallel* and *sequential* music distribution into different musical elements, which can be blended without dissonances (parallel and synchronously running elements), and meaningful self-contained musical entities, which can be re-arranged without interrupting the playback (sequential elements).

Inspired by multi-choir music, dedicated parallel parts of a score characterize elements of the virtual world and the game play. Therefore, the game designer can assign these parts to 3D locations. Fig. 1-a contains some game objects (four rooms in floor plan) with musical elements. Their hearability can interfere, when the player navigates from one location to the another.

Fig. 2 illustrates the subdivision of a holistic score ((a) in Fig. 2) into parallel tracks ((b) in Fig. 2) which characterize the four locations in Fig. 1-a. Since the player is free to navigate through all game objects the associated tracks should possess an independent musical power (e. g., with own melodies) and must harmonize with other synchronous tracks to do a proper cross-fading. Therefore, the composers have to apply the techniques of the building set manner and multiple counterpoint.

Furthermore, the score is segmented into sequential blocks ((c) in Fig. 2), which can be re-arranged in various ways in order to achieve articulated musical changes. *Music change marks* (see also Fig. 1-b) can trigger the re-arrangement, i. e., a edit the block sequence even during playback. Here different block classes (as illustrated in Fig. 2-d) are considered which denote special blocks. These are used for transitions and for music variance.

The following sections will describe these introduced concepts in more detail and also consider compositional matters and rela-

[2]Game designer, writer, and project leader for Lucas Arts's computer game adaptations of the Indiana Jones movies [2].

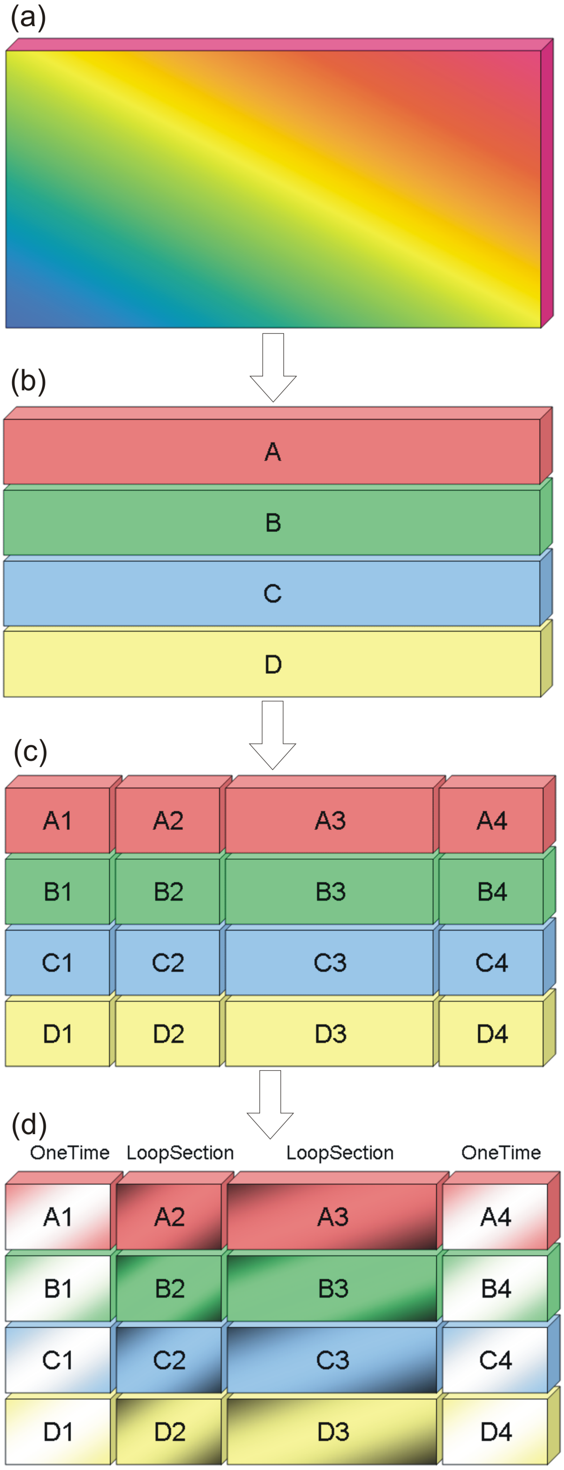


Figure 2: A parallel and sequential segmentation of a holistic score. Different block classes can be considered by the music engine.

tionships, which the composer considers to enable the adaptiveness of his music.

3.2 Distributed Music

The structure of music has to attend four dimensions: the three dimensional virtual world and the story dimension. Therefore, we describe an approach to distribute the music in these four dimensions.

Parallel Distribution. To locate music on several positions in the three dimensional environment we literally place it there by using punctiform sound sources as known from physically oriented 3D-audio modeling environments (e. g., OpenAL http://www.openal.org/). This can be considered as multi-choir music where the choirs are placed at particular positions in the room. As in the real world every source has a region of hearability. As Fig. 1-a illustrates it can be set according to the measures of its location. Thus, the musical accompaniment can cover the location it belongs to, completely. Depending on the position of the listener he can hear the sources at different volume levels, thus any movement can change the volume gain which corresponds to fading. Sec. 3.4 goes deeper into detail with this.

This concept means, multiple tracks which are associated to 3D locations run in parallel (and as loops) and are cross-faded when the player moves between the sound sources (i. e., the locations). As we discussed previously 2 one cannot cross-fade any pieces of music ad libitum. But to enable this, the music can be specially prepared: comparable to multi-choir music everything runs synchronously (by starting the playback at the same time 2-b), and the music of each sound source is composed having regard to sound in combination with the others.

If multiple parts need to sound together, they cannot sound as individual as the composer or the designer might want them to be. For the first, the music which is dedicated to the location the player currently visits, is the most important, and thus leading one. All other parts are adjusted variations, not the more individual original! If the player now leaves the location these variations can fade-in without any musical problems.

Sequential block distribution. Since, the music, that fades in, is only an adjusted variation to the one, that fades out, pure cross-fading is only half of the music transition. It can realize only a certain degree of musical change. The arrival at the new location, and the new music is still missing.

Therefore, all pieces of music are partitioned into blocks of self-contained musical phrases which should not be interrupted to ensure musical coherency. But to achieve a real music change, other blocks can be put into the sequence. The sequence can be adapted just in time even while the playback is running (cf. Fig. 2-c).

To perceive the necessity of such a music change, so called music change marks are placed at the connection points between the locations. These are triangle polygons as illustrated in Fig. 1-b. A collision detection perceives when the player moves through one of them. While the new music is loaded, the playback goes on till the end of the current musical block, where the block sequence of the next music is enqueued glueless. The playback goes through without any stops or breaks.

After such a music change the new location and its associated music is the most important and thus leading one. The remaining pieces are adjusted variations to this.

Up to now everything was triggered by position changes in the three dimensional virtual space. The fourth dimension, that is the story which can change independently from the players 3D-position, can also be an actuator for music changes. These are executed in the same way as the triggered music transitions, described here. But for this they are not caused by position changes of the player but by (story relevant) interactions.

3.3 Loop Variance

One basic principle of human communication is its economy. If a message is being repeated, i. e., if the communication contains a redundancy, it is interpreted purely on the level of pragmatics.

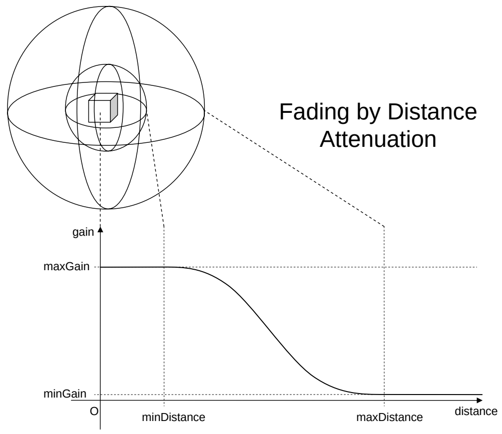


Figure 3: The distance of the listener to the source controls their perceived volume gain. For a smooth attenuation behavior a cosine function is used.

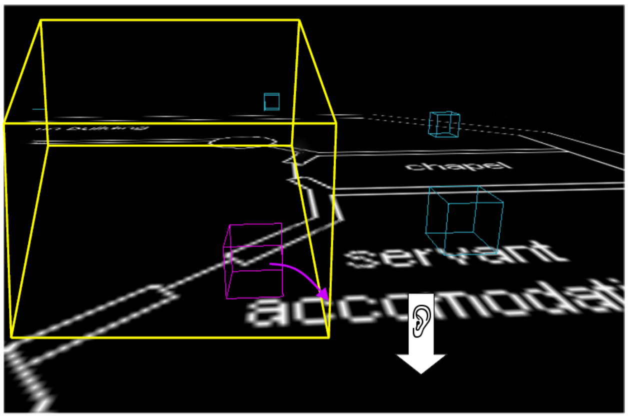


Figure 4: Moveable sources (pink, in contrast to static sound sources in blue) are positioned inside of their bounding volume (yellow) as near to the listener as possible.

Frequently, senders using this technique intend to convey the importance of this message to their audience. But if these messages are conveyed too often their inherent redundancy will cause the audience to be bored or bothered. This phenomena also applies to music: as soon as the player can recognize infinite loops within the background music of computer games it will sooner or later loose its unobtrusiveness and become flashy. Therefore, composers are urged to avoid readily identifiable motifs, themes, or melodic phrases which could be immediately be recognized at the first repetition. Hence, background music aims to be diffuse, nebulous, and less concrete. In practice game designers furthermore give composers an approximate time the user will presumably spend on each game element. In order to avoid that players recognize repetitions, the musical disposition is planned with regard to this length. But this does not work for all (especially the slow) playing behaviors.

To protract the effect of recognition, we introduce a way to vary the music in form and content: our system incorporates musical blocks called *one-times*, i. e., the music engine plays them only one time and removes them from the list of active blocks after the first cycle (cf. Fig. 2-d). Ideally, subsequent loop iterations appear like a continuation of the musical material or a re-arrangement of the first loop iteration and soonest the third iteration can be recognized as a real repetition.

This behavior was originally implemented for transitions between two pieces of music, which likewise have to be played only once. But, by using One-Times also in-between a current music, it turned out to be an effective instrument to adjust the musical length of game elements, as the second repetition acts as a buffer for very slow players.

Moreover, parallel musical themes of several game elements are cross-faded when the player moves, which activates the musical concept of timbre changes, instrumentation or harmonic variations.

3.4 A Music Distance Model

Our system places musical elements as punctiform sound sources in a virtual 3D environment. In a correct acoustic model the impact of a sound source — its gain — depends on the distance to the listener (the nearer the louder). But physically correct attenuation or distance models are not appropriate to maintain the details which characterize a piece of music as several important musical aspects such as its dynamic (e. g., *crescendi*: getting louder or fading in and *decrescendi*: fade-out) would be too quickly flattened or pop up too late after a very flat beginning phase. This behavior is not just unmusical; it catapults the music out of the subconscious and into the focus of the consciously perceived. In contrast, the music attenuation model of our system emulates how sound engineers mix several parts in a musical performance.

Therefore, often a linear function is used. But at the beginning and end there are points of undifferentiability, which cause abrupt volume changes at the begin and end. As in graphical animation this jerky behavior appears to be mechanical unnatural. In order to obtain those smooth fadings as sound engineers achieve manually, we make use of a scaled cosine-function in the interval from zero to Π. Fig. 3 illustrates that sound sources in our distance model are characterized by two circumferences of minimal and maximal perceivable gains. Therefore, we need only one source to cover a small room or a wide yard.

3.5 Moving Sources

The distance model presented in the previous section is well suited for compact and uniform locations. As background music is independent from sound effects and acoustic situations, it would be a fault to incorporate a physically correct sound rendering component which can consider sound barriers such as walls and reflections. This causes a problem with covering locations of a less compact shape (e. g., long, narrow, flat, or high rooms, corridors, or towers). Either several small sound sources have to be placed over the shape of the location or the maximal distance value of one centrally placed source is set very far. In this case one can hear this music through walls deep into neighboring rooms. For a more precise treatment we employ two strategies:

Moveable sources within a bounding volume. Fig. 4 presents an example of this strategy, which is specially suited for in-door scenes. Game designers can assign a three-dimensional bounding volume for each source. The bounding volume approximates the spatial extent and shape of the location. By placing the sound source inside of this volume and as near to the listener as possible it can now cover the location more precisely. If the listener is inside the bounding volume the source is on his position. If he leaves it, the sound source stops on the border and follows his movements along the border. This behavior also prevents jumps when the listener enters the volume. Otherwise source jumps would sound like sudden volume changes. By the automatic alignment towards the listener this can be avoided, thus the fading is always smooth and believable.

Bonded moveable sources. Music can also be applied to other moveable game elements like characters and objects. They do not have to be enchained to their predefined positions or locations in the virtual world. Non-player-characters in games can move as well as the player.

Music is attached to them by replacing sound sources at one go with the movement of the game object. This can be done by the game engine using a dedicated interface command offered by the music engine.

4 Results and Discussion

It is a challenging problem to develop methods which are able to evaluate the artistic quality of music — or any other kind of computer generated art. In our system, however, the quality of the background music accompanying interactive media heavily depends on the ability of an artist to compose multiple self-contained parts in the building set manner, so that the parts of the score can characterize game elements convincingly. Hence, the main objective of our music engine is to guarantee that all adaptation techniques do not interfere with inherent musical structures (e. g., prevent abrupt breaks of melodic units, conflicting tempi and rhythms, dissonances). The main challenges in this scenario are to (i) integrate the automatic arrangement of musical elements and the transitions between them and to (ii) conceal boring repetitions, so that the player gets the impression of consistency, coherency and seemingly pre-composed music that accidentally fits to the interactive events.

Except of a few standard cases, a classification of music transitions is not possible, because they eminently consider the specific musical contexts to which they attach. A music transition is usually as unique as the music it leads over. Therefore, a pure enumeration of supported music transitions does not reflect the quality of an adaptive music engine. In contrast, an evaluation has to consider the usability of compositional methods and techniques applied in music and music transitions for composers and game designers. In which way do they constrict the composer or enrich his possibilities? But as the first author of this paper is also the author of our system, the composer and the game designer, we cannot provide any proper results.

In the following, we will discuss some of our transition techniques in more detail: the most simple way to change from one musical idea or situation while preserving its unity is to finalize a musical block and append the next one. This corresponds to play the current music block over to the end and start the next. By partitioning the music into multiple short blocks the latency between interaction and music change can be reduced. But the composer has to be aware of the connectivity to the next music which can now follow after every block. For instance, the melodic connection should never possess any illogical ineligible jumps. Depending on the melodic mode this might entail a limitation for its evolvement.

In movies the so called *L-cut* denotes a consciously asynchronous transition of sound and pictures. That means, the sound (including music) can switch noticeably earlier to the next scene than the pictures. Carried over to interactive environments this means to do the music transition before the actuating interaction is done or the trigger is activated. Of course, this simple approach (wait until the end of a block then do the transition) does not work for this quite extreme example. But it can actually be achieved by cross-fading. The music transition is already in full activity when the end of the block is reached because the new musical material is already introduced by going nearer to the person, the object, or the location.

These special kind of scene transitions ans inner-musical ideas or processes often overlap or are interweaved in a way that this cannot be represented by a simple sequence of succeeding blocks. Modulation and tempo changes (*ritardando*, *accelerando*) are examples for this. Here the parallelism of multiple cross-fadeable parts can help, too. For modulation ambiguous chords can be used. In the same way it is possible to realize the evolution of a motif. Tempo changes can be achieved by changing the metrical conciseness. Here the composer is restricted in his possibilities and forced to use more complicated compositional tools to compensate this.

Nevertheless, these solutions, although they can achieve analog results, are not equivalent substitutions for common changes of harmony, tempo, motif, and so on. These usually happen in transitional blocks which lead over to the next music. Since these blocks are played only once those processes can run "pre-rendered" inside of them. So with the use of One-Times these ostensible limitations can be conquered, too.

Note, that the hard cut should still be available. It is used sometimes to mediate an abrupt change, a surprise and to shock. It may also still be useful for some types of measureless music.

The previous discussion reveals that the combination of all functionalities offers a rich and expressive pool of compositional techniques for adaptive music in interactive environments. But we are aware of the fact, that additional constraints can arise from specific musical styles. This raises the question, how different cross-fadeable parts can be? Can we integrate musical pieces which are not based on tonal music in order to extend the musical language used in interactive media? The poly-stylistic composition manner and the style-collages of composers like Bernd Alois Zimmermann (1918–1970) already affirm our hope that there are no restrictions to music for adaptable music in interactive media. Hence, composers are not forced into a specific musical style as the concept of parallelism and sequentiality are generally used in music. Furthermore, by including the *building set manner* already in the process of composition the results will always be faithful in style according to the composer's intention.

We developed two prototypes to demonstrate the capabilities of adaptive music in interactive applications: a 3D adventure game and a presentation presenting a picture sequence likewise an interactive comic strip. We believe that the techniques presented in this paper open up a number of new possibilities. Musical soundscapes, for example, can benefit from the fading concepts and with moveable sources they get a new powerful tool to establish a new never-before heard experience. It is even possible to let the music fly around the listener in all three dimensions. The three-dimensional arrangement of punctiform sound sources can furthermore be used for a positional audio effect and a surround output. Thereby the music can act as an auditive compass or an orientation guide.

5 Conclusion and Future Work

As already mentioned in Sec. 2, there is still a lack of compositional and arrangement techniques for music in new interactive media. This paper presents both (i) new compositional techniques for adaptive music in interaction media and (ii) an automatic real-time arrangement technique of pre-composed parallel and sequential musical elements. We have shown how they can be used to create a coherent musical accompaniment for interactive applications.

By abolishing the hard cut we could ensure an appropriate musical performance and — more importantly — we could raise the effect of immersion to a higher level. With this solution interactive environments can approach the immersiveness of movies. In spite of non-predictable user interactions the background music never seems to be taken by surprise of any scene transitions or user actions.

Our approach is able to integrate expressive scores from human artists. In oder to support their compositional style, traditional compositional techniques such as building set composition, multiple counterpoint, and multi-choir music which was up to now often just on the fringes grows up to new importance. All these aspects lead to a solution which includes technical and musical concerns as well. It actually opens up new musical spaces and possibilities.

The limitations of our work also mark some directions of future research: the integration of a random selection between alternative group members or more flexible transitions can prevent the direct recognition of looping parts, the player recognizes and gets bothered. Furthermore, the stripline between musical blocks should not be forced to be synchronous for every track or source. Musical blocks can overlap e. g., by an offbeat. An enhanced distance or attenuation model can improve the fading between parallel blocks. It ensures that the fading always sounds believable and without baring any points of undifferentiability. But if the listener stops his movement new such points appear again because the fading stops with the same abruptness as the listener. To avoid this the listener movement should be handled with some inertance. Thus an always continuous and differentiable distance model can be built.

References

[1] T. Adorno and H. Eisler. *Composing for the Films*. Oxford University Press, New York, 1947.

[2] H. Barwood. Cutting to the Chase: Cinematic Construction for Gamers. In *Game Developer Conference*, 2000.

[3] G. D. Birkhoff. *Aesthetic Measure*. Havard University Press, Cambridge, 1933.

[4] R. L. de Mantaras and J. L. Arcos. AI and Music from Composition to Expressive Performance. *AI Magazine*, 23(2):43–57, 2002.

[5] K. Ebcioglu. An Expert System for Harmonizing Four-Part Chorales. *Computer Music Journal*, 12(3):43–51, 1988.

[6] K. Ebcioglu. An Expert System for Harmonizing Chorales in the Style of J. S. Bach. *Journal of Logic Programing*, 8(1–2):145–185, 1990.

[7] A. Gartland-Jones and P. Copley. The Suitability of Genetic Algorithms for Musical Composition. *Contemporary Music Review*, 22(3):43–55, 2003.

[8] L. A. Hiller and L. M. Isaacsons. *Experimental Music: Composing with an Electronic Computer*. McGraw Hill, New York, 1959.

[9] J. P. Kirnberger. Der allezeit fertige Polonaisen und Menuetten Komponist, 1757. (trans.: The Ever Ready Composer of Polonaises and Minuets.

[10] R. Kungel. *Filmmusik für Filmemacher — Die richtige Musik zum besseren Film*. Mediabook-Verlag, Reil, 2004.

[11] B. Manaris, P. Machado, C. McCauley, J. Romero, and D. Krehbiel. Developing Fitness Functions for Pleasant Music: Zipf's Law and Interactive Evolution Systems. In *3rd European WS on Evolutionary Music and Art (EvoMUSART)*, pages 498–507, 2005.

[12] J. Manz and J. Winter, editors. *Baukastensätze zu Weisen des Evangelischen Kirchengesangbuches*. Evangelische Verlagsanstalt, Berlin, 1976.

[13] J. McCormack. Open Problems in Evolutionary Music and Art. In *3rd European WS on Evolutionary Music and Art (EvoMUSART)*, pages 428–436, 2005.

[14] W. A. Mozart. Musikalisches Würfelspiel: Anleitung so viel Walzer oder Schleifer mit zwei Würfeln zu componieren ohne musikalisch zu seyn noch von der Composition etwas zu verstehen. Köchel Catalog of Mozart's Work KV1 Appendix 294d or KV6 516f, 1787.

[15] J. Müller-Blattau, editor. *Die Kompositionslehre Heinrich Schützens in der Fassung seines Schülers Christoph Bernhard*. Bärenreiter, Kassel, 3. edition, 1999.

[16] G. Papadopoulos and G. Wiggins. AI Methods for Algorithmic Composition: A Survey, a Critical View and Future Prospects. In *AISB Symposium on Musical Creativity*, 1999.

[17] V. Rathgeber. *Missa Civilis, Opus 12, Nr. 8*. Johann Jakob Lotter Verlag, Augsburg, 1733.

[18] J. Ratia. Der Jazzwürfel — Ein harmonisches Würfelspiel. netzspannung.org; Fraunhofer Institut Medienkommunikation, 2005.

[19] N. J. Schneider. *Handbuch Filmmusik I — Musikdramaturgie im neuen Deutschen Film*. Verlag Ölschläger, München, 2. edition, 1990.

[20] M. J. Steedman. A Generative Grammar for Jazz Chord Sequences. *Music Perception*, 2(1):52–77, 1984.

[21] P. Todd and G. Loy, editors. *Music and Connectionism*. MIT Press, Cambridge, 1991.