# A Survey of Variation Techniques for Repetitive Games Music


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## ABSTRACT
How much time will a player spend in an interactive scene? For the majority of game scenarios this is impossible to predict. Therefore, their musical accompaniment is usually disposed to continuously loop until player interaction triggers a change. This approach involves an existential danger: Sooner or later the player becomes aware of the repetitive character of the ambience design; the game scenario emerges as a mere mechanical arrangement and loses much of its integrity.

In this survey paper we systematize and discuss the common approaches to conceal musical repetition. Furthermore, we complement them by a number of approaches that incorporate arrangement techniques, aspects of expressive music performance, and generative variation methods that work actively against repetitiveness.



## Categories and Subject Descriptors
D.5.5 [**Information Interfaces and Presentation**]: Sound and Music Computing—*Methodologies and techniques*

## Keywords
games music, generative music


## 1. INTRODUCTION: WHAT REPETITION MEANS
Music in audio-visual media can be located on two different layers, the diegesis and the extra-diegesis. Diegetic music is performed on-stage or within the scene, respectively. Its source is part of the scene, e.g., a radio, a music box, or a virtual musician. In music video games the whole diegesis can be constituted by music. A comprehensive discussion of diegetic music is given in [10]. Extra-diegetic music on the other side is external to the diegesis. It constitutes a separate layer comparable to the narrator's voice from the off. This music has a particular role within the interplay of the different auditive and visual media. It accompanies the scene, facilitates the effect of immersion, complements to visual information, and can even contradict the scene (the so-called audio-visual counterpoint) to annotate a deeper meaning or mediate a critical point of view to the scenic action. Comprehensive discussions on these narrative functions of music in audio-visual media can be found in [3, 35, 59].

An important basic principle of audio-visual media scoring is that musical change evokes (and therefore necessitates) a corresponding change in the scene, the narration, or the dramaturgy, even if it is not visible [35]. In interactive media, such as video and computer games, such changes are highly dependent on user interaction. But as this playing behavior in games is widely unpredictable it is also generally impossible to predict the amount of time a player will spend in a scene or for how long a certain situation lasts until the player makes that triggering interaction that causes the music to change. Thus, it is equally impossible to plan the length of the corresponding music in advance as film music composers can do. The endless loop is the most common means today to musically stay at a situation for an uncertain period.

But the exact repetition of a complete musical piece is a very specific means too that can become very conspicuous to the player and, therefore, desires a corresponding narrative reason. Most commonly, it indicates the recurrence of scenic content or action, déjà vu like. This is because of the symbolic power of melodic motifs, rhythm patterns, certain harmonic progressions, and timbral attributes. These are commonly used by composers of film music and autonomous music and are established in our listening habit. That means, we have learned to recognize such features in the music as they help us to comprehend the musical structure and understand what we hear (to a certain degree).

But recurrence is not the case in the typical gaming situation where the music is just waiting for the player. The player did not reenter a scene, nothing recurs, time passes on. Exact repetitions emit the unnatural aura of a time warp which usually contradicts the scene's actuality. Music becomes a foreign object to the scene, disturbing the dialectic unity of the multimedia. This effect is perceived even more intense since the player, when recognizing repetition, becomes consciously aware of the musical ambience and its structural contradiction to the scene. The player recognizes that one and the same piece of music is playing over and over again. Mapping this onto the scene leads to the insight that the whole world is in an idle loop, waiting for player interaction. The whole game degenerates into a simple machine doing nothing but waiting for input, which it ultimately is. But good game development conceals this from the player. At this point even the best musical compositions



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defeat their purpose. Collins reports that in this situation the players even interrupt the gameplay and switch off the music manually in the game settings menu [19].

Diversity is desired, but only to a certain amount. It should not go beyond the scope of a specific compositional architecture to meet the required character of expression and keep it for as long as necessary. Compositional decisions, the use of specific compositional means, must be well considered and planned in order to achieve the same aesthetic conclusiveness as we expect in human composed music. It is a balancing act between reproduction and innovation. Neither fully static compositions nor completely unrelated (random) music do an expedient job. This leads to the concepts of musical variation.

In the following we will introduce and discuss a variety of strategies to approach variance in repetitive games music. Section 2 discusses compositional means to conceal repetition. In Sections 3 and 4 we introduce and discuss automated arrangement techniques. Section 5 will focus on generative variation techniques. Section 6 will describe the potentials of expressive music performance as a means for variation followed by Section 7 which draws a conclusion to this paper.

## 2. STRUCTURAL DIFFUSION

Games music composers became aware of the problem very soon and were trying to conceal repetition by a more diffuse compositional structure which impeded to recognize specific features and, hence, also their recurrence [40].

This was achieved by avoiding memorable melodic features. A leading melodic part is one of the strongest catchers of attention. It is very often built of motivic figures that recur and vary over time. Even if not, the melody, due to its inherent formal principles, usually mediates a strong feeling of structure and form (see [4, 20]). A common way to conceal this is to abdicate motivic work and to split the melody into multiple preferably overlapping figures, i.e., into a polyphonic formation, and to diversify it over many different parts and instruments/timbres. This technique is also well known from composers of the romantic era, e.g., Gustav Mahler and Claude Debussy.

A further important means is to avoid clear structural borders that would give clues to the listener for orientation within the piece. Therefore, fluent structural borders work very well, i.e., overlapping structural layers in a complex interweaved polyphony and seamless connections of consecutive form elements. There is also a monophonic form of structural overlapping within only one part possible by "choking" the end of, say, a phrase with the beginning of the next one (see [53]). An example is shown in Figure 1.

Most effective is a clever timely disposition. Preliminary user studies during game development according to the playing behavior in each scene help to dispose the appropriate length of the accompanying pieces of music. Thus, the average player may not hear more than one repetition.

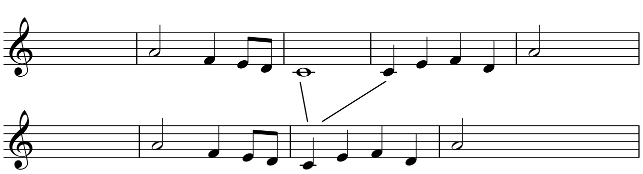

**Figure 1: An example for a "choked" phrase ending.**

Structural diffusion is a cheap and easy way to conceal the music's repetitiveness for possibly long enough, depending on the game scenario. But each iteration loop is still identical and after an admittedly slightly longer while the repetition still becomes recognizable.

## 3. SEQUENTIAL VARIANCE

A static musical form is inappropriate to accompany interactive media. It has to be opened up for nonlinearity, a necessity already mentioned to facilitate coherent musical transitions in the context of scene transitions [8]. However, the requirements for music that is accompanying scenes which are in an idle-like state differ in that as it does not change over to new musical material but has to treat the current one as flexible as possible.

A very coarse music-box-like approach can be observed in the *The Elder Scrolls* roll-playing games *Morrowind* [15] and *Oblivion* [16]. For each state of gameplay (explore, battle, dungeon etc.) there is a set of musical compositions with appropriate characters of expression from which one is randomly chosen. When the piece is over and the state did not change, another one is selected. Since each composition has a clear beginning and end, the impression of strictly separated episodes may emerge which is not the case in the actual gameplay, though.

A more fine-grained approach is to arrange on the level of inner-musical phrase and section structure as proposed within several research prototypes (see [12, 57]). Music is considered as a sequence of segments, i.e. musical snippets. Two types of segments can be distinguished, loop segments and *One Shot* segments. The One Shot segments are played back only during the first iteration of the musical loop and skipped later on. What remains is the sequence of loop segments. Thus, the first repetition appears to be a rearrangement instead of a repetition. Furthermore, by providing multiple alternatives for each segment a huge number of recombinations with big diversity become available (see [1]). That principle is well known from classic musical dice games [30, 45, 29, 56]. Computer games that implement the sequential arrangement are, e.g., *No One Lives Forever 2* [44], *Gothic II*, and *Gothic 3* [49, 50], although they do not use it for loop variance.

But still, after a while, when all the precomposed musical material in enough permutations and combinations was introduced to the listener, its recurrence can become conspicuous again. More variance and a less binding memorable structure can be approached by very short musical snippets that play single figures or even just single sound events (notes and chords) that fade in and out and may overlap with others. This *cue collage* may sound very diffuse but it features the possibility to be combined with (or triggered by) interactive events, creating a very reactive musical score. This leads to the concepts of electronic musical instruments and generative music which is further discussed in Section 5.

## 4. POLYPHONIC VARIANCE

The musical polyphony offers further potentials for variation beginning with the compositional technique of multiple counterpoint leading further to music that includes optional and alternative parts that can be combined in several ways up to orchestrational techniques that vary timbral attributes of music. Music engines that implement these techniques are mentioned. However, most of them are research prototypes. Polyphonic variance is not established in the games industry, yet.

## 4.1 Building Set Music

Music set in multiple counterpoint allows the transposition (and thereby interchange) of parts; a tenor part can serve as a soprano as well as the soprano can be transposed down and used as tenor. Examples can be found in J. S. Bach's "The Art of the Fugue" (BWV 1080). The technique itself, however, is much older and already described, for instance, by Heinrich Schütz [43].

Moreover, the building set principles of the baroque manner of the so-called rural compositions (see the foreword of [52]) experience a revival in a number of modern games, like *Monkey Island 2: LeChuck's Revenge* [37] and *Grim Fandango* [38][1], although never applied and discussed in the context of loop variance. The special feature of building set music is that it sounds complete even in the absence of several (optional) parts. One and the same composition can be performed in various combinations of parts (see [7, 39] for examples).

We implemented a music engine that uses location-based sound sources and fading techniques to add or remove musical material to or from the playback according to the position and movement of the player in a virtual environment (see [12]). As the player approaches a location in the virtual scene its music, its part of the music, fades in. And it fades away again as the player leaves the location. The audibility of the sound sources can overlap. Their mixdown reflects the player's position in the virtual world and adapts with each movement. These collage-like layerings offer a big potential for musical variance.

Not only the player can move in the virtual scene but also the sound sources that play the music. Thus, even when the player stands still the music is continuously varying, sound sources that approach the player fade in, those that go away fade out. These moving sound sources can also be connected to elements of the scene, e.g., to non-player characters that are important to the narration. In that way the music reflects their proximity to the player character, even if not visible yet, and mediates additional information about the scene.

## 4.2 Switching between Alternatives

Another way of utilizing polyphony is to prepare several alternatives for a melody. This may, for instance, comprize a very plain melody and several embellished versions. With each iteration of the musical piece another version can be selected. By switching between them even during playback (e.g., measure-wise) those different versions can be combined just in the way classic musical dice games work (see Section 3). The same can be done with the accompanying parts as well. These may, for instance, vary their rhythmic patterns. This opens up a wide range of possibilities.

## 4.3 Orchestrational Variance

Orchestration deals with the different timbres of instruments, their playing techniques and articulations in order to implement a certain aesthetic concept, emphasize structural properties of the composition, and promote a desired mood [2, 54]. Varying the instrumentation can shed different light on an otherwise unchanged musical material. Alteration between differently instrumentated versions can be implemented by fading techniques. They should, nonetheless, also be aligned with structural properties of the musical piece to integrate into the musical flow. An approach is described in [14].

[1]Both games apply the *Interactive Music Streaming Engine* (called *iMuse*) by Land & McConnell [32].

## 4.4 General Reflections on Polyphonic Variance

All polyphony based approaches to musical variance discussed so far demand precomposed musical material. Its vertical arrangement can create a big variety not just with respect to compositional structure but also sound and timbre. But the precomposed material remains static and, thus, the overall variance is limited to the number of possible combinations. Polyphonic variance, just like sequential variance, come along with additional effort in composition and production.

# 5. GENERATIVE VARIANCE

The variation, adaptation, and improvisation over a given musical material is a classical subject in computer music research. We have chosen representative prominent approaches from the last decade for discussion. But first we give a brief historical and theoretical introduction to musical variation.

## 5.1 Introduction to Musical Variation

Variation and its relative, improvisation, are probably the oldest concepts of music. We can find printed evidence for sophisticated variation techniques already in medieval music (e.g., in the collection *Codex Faenza*). For the transcription of vocal compositions to (keyboard) instruments several changes were necessary from reasons of a better playability. These changes were usually applied to accompanying or "improvisational" parts but only very carefully to the part that features the melody or Gregorian choral. An example is the motet *Aquila Altera* of Jacopo da Bologna (14th century); in the *Codex Faenza* transcription the melody leading lowest part was changed only very subtly while the ornate accompaniment varies quite free (for transcriptions see [5]).

Variation became a kind of a compositional aspect during music history. Performers had to learn how to vary a musical material correctly. Some of the early treatises come from Christoph Bernhard who wrote down the teachings of Heinrich Schütz (see [43]). He describes a type of singing, called *Cantar Passagiato*, that includes rules for good melody embellishment. The baroque was the era were variation and improvisation became a high art and necessary ability for the performer as the instrumental treatises of J. J. Quantz [51] and C. P. E. Bach [6] prove. Practical examples for the teachings of these treatises can be found in G. P. Telemann's *12 Methodische Sonaten*[2]. What is special about these sonatas is that Telemann notated both, the original melodies and their embellished version (see Figure 2).

Up to the extensive variation works of the classic era, especially of Beethoven, the development of a multitude of variation techniques can be posted. Today the musical morphology distinguishes variations by two aspects (following Altmann's systematization [4]):

**Subject of Variation:** The *direct variation* is applied to the theme or motif, whereas the *indirect variation* retains the theme or motif unchanged and varies its accompaniment.

[2]TWV 41:A3, a2, D3, E2, G4, g3, B5, C3, c3, d2, E5, h3

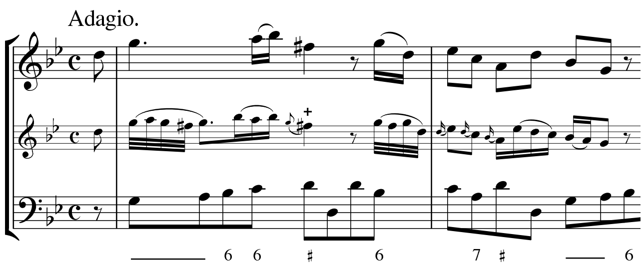


**Figure 2: An extract from the *Methodische Sonate* TWV 41:g3.**

**Type of Variation:** The *strict variation* saves the harmonic and architectural characteristics of the theme or motif. Its shape and gestalt quality remain unchanged. On the other hand, the *free variation* changes not just melodic and rhythmic aspects, but also harmonic and formal. Each one of such variation can afford new gestalt and quality.

## 5.2 Embellishment

A strict and direct type of variation is the melody embellishment. A given plain melody is enriched by various ornaments. Even modern musicology has only catalog-like embellishment theories like those for baroque music [23, 46, 48]. What is missing is a generative theory.

In this respect the systems *MeloNet* and *JazzNet* are very interesting. They utilize a neural network to learn melody ornamentations, i.e. ornamentation figures/patterns, and takes the melodic and harmonic context into account where they were applied (see [28]). This is demonstrated with melody variations in the style of J. Pachelbel [26] and Jazz improvisations imitating Charlie Parker [27]. The learning set directly influences the stylistic imprint of the network and should be homogeneous to a certain extent.

A generative music approach that utilizes genetic algorithms is described by Gartland-Jones, *MusicBlox* [24]. It combines several (predefined) input patterns to create variants. A fitness function measures the relational distance to the input patterns. Thus, it is possible to purposefully apply mutation and recombination operations and vary the result within the domain spanned by its input patterns. This is meant to be used as a combinatorial tool or toy for music composition. But it can also be used to combine, for instance, a plain melody and several embellished versions to create new embellished versions. This complements the approach described in Section 4.2 “Switching between Alternatives”.

## 5.3 Improvisation

The improvisation over a given musical material can be seen as a free variation. It can change all aspects of the original, its structure, melodic, rhythmic, and harmonic properties.

A genetic algorithm based approach is John Al Biles’ *GenJam* system (see [17, 42]). The musical input of a co-performing human musician is varied by mutation and crossover operations to generate an improvisational response. It is melody based; the chord progression scheme, the tempo, rhythmic pace, and overall arrangement structure of the piece to be performed are predefined. *GenJam*’s stylistic repertoire reaches from Jazz over Latin to New Age. The musical quality and variety of its improvisations strongly depends on the quality and variety of the human performer’s input. In the games scenario, where we have static precomposed music to be varied and limited input material, this may lead to over-fitness problems over time.

A very popular means in computer music, Markov models, was used by François Pachet in his system *Continuator* (see [47]). It builds a Markov model based structure from realtime musical input of a human co-performer. From this, new patterns are generated not just for the melody part but also its accompaniment. Since it directly analyses the realtime input the system is stylistically independent to a certain amount. The system can run in standalone mode like a music generator or as a collaborative improviser and composer that creates continuations to the musician’s input.

## 5.4 Reharmonization

The harmonization of a melody determines a sequence of chords and creates a polyphonic counterpoint. *Re*harmonization changes one or more of these chords and adapts the voice leadings, correspondingly. Well known is, for instance, the change from major to minor to achieve a darker more pessimistic mood. To “minorize” a major triad only one tone, the third, has to be transposed down by a semitone. Changes to completely different chords imply more and greater adaptations. This may also affect the melody part. Hence, reharmonization is not necessarily only an indirect variation.

Yoon & Lee describe a planning approach for affective reharmonizations [60]. Their intention is to change the tension curves of musical pieces based on measures by Krumhansl & Shepard [31], Lerdahl [33, 34], and Chew [18].

A system that implements reharmonization is described by Livingstone [36]. It implements the relatively unproblematic major-minor change. Changes to completely different chords are implemented in a system by Stenzel [55]. However, it also proves that such radical changes do harm to the musical coherence and conclusiveness quite quickly.

Naive adaptations may be implemented in the following way. Each note that belongs to the chord that is changed is tested. If its pitch is not contained by the demanded chord, it is shifted to the nearest fitting neighbor. These shiftings can cause jumps and tone repetitions within melodic lines, damp a jumpy melody movement, and disturb tone repetitions. Naive adaptations in voice leading tend to be unmelodious and disturbing to melodic structure. Furthermore, the gesture of the new harmonization can be opposed to the melodic gesture; a situation that is very hard to detect and to avoid but clearly to hear. Reharmonization can be seen as a non-trivial optimization problem that is not solved, yet.

# 6. PERFORMATIVE VARIANCE

The expressive performance introduces a series of transformations to the musical material. They affect its timing, dynamics (loudness), and articulation properties. By these means a piece of music can be performed very differently and feature a variety of characters of expression reaching from slow, soft, cantabile over harsh, marcato to fast-paced, and energetic. Usually it is not a good strategy to vary the expression over that whole spectrum, i.e., combine very distant types of performance, as this is detrimental to the musical coherence. Such changes require at least a corresponding narrative reason that is not given in the situations this paper discusses.

Hence, the macro features, to wit basic tempo and dynamics curves, may remain unchanged or vary only according to the characteristic of continuous transitions. That means for dynamics, distortions of

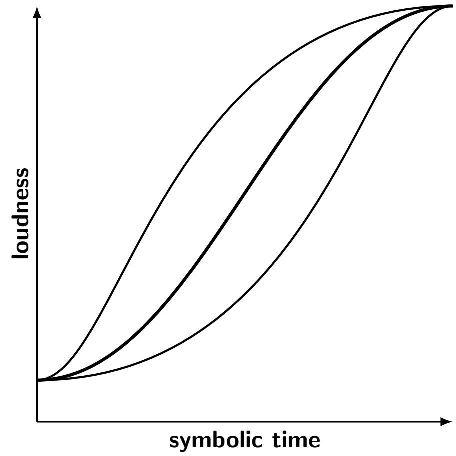


**Figure 3: An example for variation in continuous dynamics transitions. The symbolic time is also known as score time. Notice that the start and end values of the transitions are the same, only the transition varies.**

dynamics curves can cause a crescendo to grow very fast in the beginning and slowly in the end or slowly in the beginning and faster in the end, but its start and end values do not change (see Figure 3). Such variations can also be observed in human performances [13]. The same can be done with tempo transitions (rit. and accel.). The overall tempo and dynamics plan is kept and only its realization varies. Variations in final ritardandi have, for instance, been investigated by Friberg & Sundberg [22] and by Grachten & Widmer [25].

The use of micro features is not as restricted and allows more freedom. Such features are rubato (timing distortions that are self-compensating within a certain timeframe), metrical accentuations, and articulation. These features can be considered as additional details that enrich the macro plan but do not change it fundamentally. We can apply any shade of a swing timing. We can perform more neutral or very pronounced accentuations. One accentuation scheme may establish a fast-paced quarter meter whereas another may realize a more relaxed half meter. The overall articulation may be legato in one performance and portato in another, this creates either a tight or a brittle sound.

Most subtle differences can be achieved by random variations of note onset times and velocities, aspects that we know as random variation in human performance. Furthermore, the synchrony of the parts can be changed. A leading part may be ahead to mediate an active progressive mood or it can be behind creating a laid-back kind of feeling. However, these means may already be too subtle and not be sufficient to give enough variety to the music. Hence, they should be used in combination with the other features discussed so far.

Approaches to create such expressive performances are knowledge-based [21], machine learning-based [58], and derived from a mathematical music theory [41]. A detailed set of models to describe and render the phenomena of expressive performance has been developed in [11]. The performance engine described in [9] implements a technique to seamlessly transition and combine different performances and orchestrations.

# 7. CONCLUSION AND FUTURE WORK

This paper gave an introduction to the problems of repetitive music in interactive media like video and computer games. When listeners become aware of the ever-repeating unchanged music it is in great danger to become boring and annoying, but more important, it contradicts the situation to be scored and mediate repetition although nothing actually repeats. Todays composers try to delay this by compositional means.

But there are also substantial approaches to introduce variance into the musical playback. Sequences of musical segments and polyphonic combinations of parts can be automatically arranged. Approaches from the field of generative music can be applied (and in some cases adapted) to generate embellishments, improvisations, and changes in the harmonization. Finally, even the means of expressive performance reveal very strong potential for musical variance.

These manifold approaches are not mutually exclusive. They can be combined and open up a wide range of yet untapped possibilities. The approaches described in [1, 12, 57] combine sequential and polyphonic variance. The music engine in [9] combines orchestration and expressive performance. The potentials of the more advanced approaches are not fully discovered, yet. Beyond the development of algorithms that implement these functionalities it requires extensive compositional studies combined with user/listener studies. These have to explore the musical reactivity and variability as well as its conclusiveness and coherence in the listener's judgement.

We have to overcome the simplicity of todays music engines [19]. Most music engines that are currently used in interactive media are plain media players offering barely more than the play and stop functionality. Todays technology can do more!

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